Forest Policy and Economics 154 (2023) 103022

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

Attracting and retaining women in forest entomology and forest pathology

Jessica A. Hartshorn [a,*], Eckehard G. Brockerhoff [b,**], Maartje J. Klapwijk [c], Mariella Marzano [d], Rebecca J. Ganley [e], Molly N. Darr [f]

[a] Department of Forestry and Environmental Conservation, Clemson University, Clemson, SC 29634, USA
[b] Swiss Federal Research Institute WSL, Zürcherstrasse 111, 8903 Birmensdorf, Switzerland
[c] Department of Ecology, Swedish University of Agricultural Science, Ullsväg 16, Uppsala SE-75651, Sweden
[d] Forest Research, Northern Research Station, Roslin, Midlothian, Scotland EH25 9SY, United Kingdom
[e] New Zealand Institute of Plant and Food Research Ltd., Te Puke, New Zealand
[f] Department of Agricultural and Natural Resources, Washington State University, Mount Vernon, WA 98273, USA

ARTICLE INFO

Keywords:
Diversity
Forest entomology
Forest pathology
Gender equality
Inclusion

ABSTRACT

Inclusion of women in the forest entomology and forest pathology workforce has been a difficult journey. While policies and resources exist for organizations and departments to increase diversity and retain women, there still exist large gaps in gender parity at forest research institutions globally. It is imperative that we better understand the barriers that exist for women in forest entomology and pathology so that more inclusive environments can be created that are welcoming towards women and other underrepresented groups. To assess these barriers and subsequent opportunities for improvement, we surveyed forest entomology and pathology professionals globally to ask about their experiences in the workforce. We also provide examples of trends in gender representation at relevant institutions. Barriers to success for women and men were very different; women experienced more barriers related to family caretaking while men experienced more barriers related to funding opportunities. These differences show where opportunities lie to better attract, support, and retain women in forest entomology and forest pathology. Although some trends in gender representation are promising, large gaps continue to exist which need to be addressed.

1. Introduction

The under-representation of women in science, technology, engineering and mathematics (STEM) is a persistent issue that deserves attention (Carr et al., 2018). The number of women entering and graduating from STEM fields has increased substantially over the last few decades (Rivers, 2017), but the gender ratio across STEM subjects still remains skewed in most fields, especially in senior roles. In fact, the "leaky pipeline" is a common analogy in STEM and expresses the tendency for women to make up less of the workforce in more senior positions (Gasser and Shaffer, 2014). However, there are many issues with the pipeline analogy. Instead, a pathway analogy, whereby academics move along a pathway with multiple options rather than a singular pipeline, appears to be better suited for issues women face in STEM (Cannady et al., 2014). The pipeline analogy is oversimplified and generalizes the experiences of those in different STEM fields, emphasizes an unrealistic universal experience of a linear career pathway in terms of education and necessary benchmarks, and fails to address complex causes for the lack of diversity in STEM fields, including academic gatekeepers. The pathway analogy illuminates multiple trajectories towards STEM degrees and careers, informed by individual paths taken by STEM graduates and career entrants (Cannady et al., 2014).

In the U.S., gender disparities from the bachelor's to the PhD level have essentially disappeared (Miller and Wai, 2015). However, in the professional academic setting, women are often still viewed as less competent and less likeable as compared to their male counterparts (e.g., Eaton et al., 2020). In addition, although the share of women in the work force is improving in some fields like higher education in agriculture and forestry, women in these fields still face significant challenges in the form of pay inequality (Xu, 2015), overt and covert sexism (Leaper and Starr, 2019), as well as institutional issues like departmental culture (e.g. "good old boys club"; De Welde and Laursen, 2011). While

* Corresponding author at: Forestry and Environmental Conservation, Clemson University, Lehotsky 256, Clemson, SC 29634, USA.
** Corresponding author at: Swiss Federal Research Institute WSL, Zürcherstrasse 111, 8903 Birmensdorf, Switzerland.
E-mail addresses: jhartsh@clemson.edu (J.A. Hartshorn), eckehard.brockerhoff@wsl.ch (E.G. Brockerhoff), maartje.klapwijk@slu.se (M.J. Klapwijk), mariella.marzano@forestresearch.gov.uk (M. Marzano), beccy.ganley@plantandfood.co.nz (R.J. Ganley), molly.darr@wsu.edu (M.N. Darr).

https://doi.org/10.1016/j.forpol.2023.103022
Received 25 October 2022; Received in revised form 12 April 2023; Accepted 5 June 2023
Available online 24 June 2023

the intersection of gender, race, religion, ethnicity, accessibility, sexual orientation, and other factors has a direct and often compounded impact on the experiences of people in academia, this paper focuses on those experiences related solely to gender.

Forest entomology is the study of insects and other arthropods (e.g., spiders, mites) and the issues they cause in, or benefits they provide to, natural and managed forest ecosystems, timber production and non-timber forest products. As an interdisciplinary field combining forestry and entomology, traditional forest entomology focuses on the interactions among insects, their symbiotic fungi, and their host trees (Berisford, 1992). Forest pathology is the study of pathogens (e.g., fungi, oomycetes, bacteria, viruses, nematodes) and the diseases they cause in tree species that occur in natural or managed forest ecosystems. With roots in plant pathology, forest pathology is distinguished from other related disciplines by the long time scales, diversity and heterogeneity in relation to biological, socio-cultural and socio-economic dimensions (Merrill and Shigo, 1979; Desprez-Loustau et al., 2016).

Many theories have been proposed to explain the gender disparity in some scientific fields; some are helpful (e.g., Gendered Socialization; Reinking and Martin, 2018), and some are sexist and damaging (e.g., Biological Determinism; Miller and Costello, 2001). For example, Summers (2005) implied that women avoid STEM majors due to an inherent ineptitude in these fields. While this has been debunked several times (Ceci et al., 2014), the idea that women are simply uninterested, or incapable, persists. In reality, all genders perform similarly in STEM-related subjects in early childhood (Association for Women in the Sciences, 2011) and are equally interested in STEM (O'Dea et al., 2018; Robinson and Lubienski, 2011), even if they do not complete a degree in a STEM field.

Common issues recognized as reasons why women leave STEM include the traditionally masculine culture, a lack of role models, a lack of encouragement, and difficulties with re-entering the workforce after having children (Else, 2019; Hunt, 2016). While parenting is an issue for all people who choose to have children, it can manifest in different ways for different genders. For example, women often take on more of the burden of childcare, even when working full time, while men feel they may be professionally penalized for prioritizing childcare (Hsain et al., 2020; Sallee et al., 2016). This leads to more new mothers than new fathers leaving STEM fields or full-time employment, or totally exiting the workforce to raise children (Cech and Blair-Loy, 2019). Similarly, women are more likely than men to take care of ailing family members (Viglione, 2020). Many women feel that they have to work harder to meet a double standard in their jobs (Kmec, 2013), or simply take on extra domestic work in addition to their jobs (Rothstein, 2012). The masculine culture of STEM is often referred to as the "good ol' boys club" or "bro culture" where social behaviors, language and expectations can be alienating to women (De Welde and Laursen, 2011; Ruder et al., 2018). In the U.S., higher rates of tenure for men (Baker, 2011) and higher rates of men acting as department heads and chairs (McCullough, 2011; Moedas, 2015) indicate the lack of role models for young women looking to enter scientific fields. The lack of representation can make women feel isolated or scrutinized in the workplace, particularly if they have children during their career (Blau and Kahn, 2013; Cech and Blair-Loy, 2019; White, 1970). Additionally, the low numbers of women in STEM fields, especially in leadership roles, can contribute to negative effects on motivation and self-efficacy in qualified individuals, causing them to question their ability to achieve certain goals. This may lead some women to choose other career paths where the apparent gender disparity is not so severe (Carrell et al., 2010; Stout et al., 2011). It should also be noted that this issue is not simply men discriminating against women; women also tend to hold these same views due to internalized misogyny and a feeling of competition (e.g., Savigny, 2019).

The gatekeeping of scientific fields which denies women and minorities the chance at an equal contribution hinders scientific advancement and negatively impacts experimental design, data collection and analysis, and interpretation and communication of results (McGee, 2021). Additionally, the culture of an institution or society influences employee/member retention more strongly than any other exogenous or demographic factor (Sheridan, 1992) and the ability of these organizations to retain women directly impacts their ability to meet diversity and inclusion goals. Therefore, scientific institutions, agencies, and professional societies have an obligation to implement policies which promote gender equity and inclusivity. However, the values espoused by those who advocate for gender equity, such as providing additional resources for those from disadvantaged backgrounds, may conflict with those of the meritocracy frequently encountered in scientific fields, especially in academia (Powell, 2016).

While some scientific societies are beginning to create codes of conduct for meetings, sign resolutions, and provide training or workshops to promote diversity and inclusion (Entomological Society of America, 2020), interviews conducted by the authors indicate that there are still significant issues (e.g., benevolent sexism, excessive service burdens) with regards to women's experiences in science. While there are myriad papers proposing solutions to these problems (e.g., mentorship programs, implicit bias training), there is still a significant gap in knowledge as to how scientific institutions, agencies, and societies can attract, promote, and retain more women, especially in leadership positions (Kloxin, 2019; Liu et al., 2019). While many areas of biological science have made significant leaps in addressing the issue of gender parity, the fields of forest entomology and forest pathology appear to be lagging and deserve specific attention.

There are still significant gaps in forest entomology and forest pathology with regards to attraction and retention of women in faculty positions and other leadership roles. In this paper, we aim to identify areas for improvement that may help women specifically in these fields. Even with concentrated efforts to attract and retain women to STEM fields, there is still a significant lack of women in faculty and other senior roles, as well as leadership positions, in forest entomology and forest pathology. Our objectives with this study were to 1) identify the major issues women face as professionals in forest entomology and forest pathology, 2) assess the views and attitudes towards women in professional roles in these fields, 3) describe how the roles of women, and attitudes towards them, have changed in forest entomology and forest pathology, and finally, 4) provide suggestions for organizations and institutions to better support women in these fields.

2. Materials and methods

2.1. Interviews and survey

To accomplish these objectives, we used a sequential mixed model design. In the first phase of our study, JH and MD conducted semi-structured interviews with female ($n = 8$) and male ($n = 1$) forest entomologists in 2017. Interviews took place during scientific meetings (Entomological Society of America meeting, Interagency Forum on Invasive Species meeting) and by phone. Prior to these meetings, JH and MD distributed an email via meeting listservs requesting that interested parties contact either JH or MD to set up a time for an interview. Interviews were open to all interested persons. JH and MD conducted interviews individually and all interviews were recorded with the subjects' permission. JH and MD took notes during each interview.

Questions were asked to identify demographics (i.e., age, gender identity, education, professional position) and to identify specific issues often faced by professionals in scientific fields (e.g., *have you ever been asked about your marital status during an interview?*). Open-ended questions to assess these experiences included: *What is the greatest or most consistent obstacle you've experienced in your career? What has been the most rewarding experience of choosing a career in the sciences? Was there ever a point in your career that you wanted to abandon science for another discipline? How has your experience as a professional in the sciences evolved over the years?* Notes from interviews were compiled and examined to

identify themes among responses.

In the second phase, the authors created a 53-question mixed methods survey in June of 2020 (Supplementary Material 1) which consisted of quantitative questions using a Likert scale, and qualitative questions which were open-ended and examined for themes. We distributed this survey to forest entomologists and forest pathologists in August and September 2020 using mailing lists, including regional groups in the United States (e.g., Southern Forest Insect Work Conference), and the 'forent' and 'forpath' lists of the International Union of Forest Research Organizations (IUFRO), a global, non-profit, non-governmental and non-discriminatory organization with about 650 member organizations in >120 countries representing over 15,000 scientists (www.iufro.org).

The survey was divided into seven sections, each intended to reveal different aspects of the participants' professional and personal lives that were relevant to the study, as well as their perceptions of gender issues in forest entomology and forest pathology. Specifically, these sections were designed to:

1. Identify professional information about the survey participant (e.g., education level, position title),
2. Characterize the professional activities and roles of participants at, as well as their perceived support from, their home institution and scientific societies,
3. Understand the positive aspects of the participants' career in forest entomology and forest pathology (e.g., professional accomplishments, job satisfaction, career goals),
4. Understand challenges faced by participants, focusing on those related to the participant's gender,
5. Identify areas for growth and improvement for professional institutions and organizations,
6. Perceptions of gender roles (e.g., parental responsibilities vs. career) as well as contributions and abilities of women in forest entomology and forest pathology professions (e.g., conducting field work),
7. Personal information (e.g., marital status, region of the world).

Active survey consent forms were presented in a virtual format and all participants were asked whether they consented to taking the survey before beginning. All human subject protections were adhered to and reviewed by the Clemson University Institutional Review Board. All participants took the survey online anonymously through Qualtrics (Qualtrics, Provo, UT). Partial responses were removed so that surveys could be compared across all questions. Questions were presented to all genders and the experiences of respondents were assessed either through quantitative responses on a seven-point Likert scale (1 = strongly disagree to 7 = strongly agree) or qualitative responses which were examined for themes (Table 1). Quantitative responses were summed and then divided by the total responses ($n = 139$) to obtain an average for each response. We also read individual text responses and identified major themes (e.g., childcare access) across each question by categorizing responses based on keywords (e.g., childcare). (See Table 2.)

2.2. Institutional gender distributions

Based on themes identified in survey results, we then examined the history of gender distributions in leadership roles in forest entomology and pathology at the global scale and within the U.S. (where data was most readily available). To quantify changes in gender distributions at the global scale, we examined office holder positions within research groups and working parties of IUFRO. We obtained gender data of office holders (i.e., research group and working party coordinators and deputies) in the Entomology and Pathology research groups of IUFRO Division 7 (Forest Health) from IUFRO's headquarters from 1987 until 2020. For each office term (typically five years), the total number of office holders was divided by the number of female office holders to

Table 1
Total number (#) and percentage (%) of females and males at different academic levels in forestry and natural resource institutions in the U.S. Undergraduate students (UG), Master's students (MS), PhD students (PhD), and postdocs (Post) data were obtained via a voluntary survey sent to forestry and natural resource institutions. Pre-tenure assistant professors (Pre-T), and tenured and full professors (Post-T) data were obtained by examining faculty data on institutional websites.

	Male		Female	
	#	%	#	%
UG	140	69	64	31
	315	57	237	43
	163	37	283	63
	85	45	103	55
	185	45	228	55
	117	73	44	27
MS	178	57	132	43
	28	65	15	35
	65	51	63	49
	22	59	15	41
	23	35	42	65
PhD	46	46	55	54
	13	41	19	59
	63	49	65	51
	19	51	18	49
Post	3	50	3	50
	8	67	4	33
	4	44	5	56
Pre-T	1	100	0	0
	4	40	6	60
	5	83	1	17
	6	46	7	54
	1	25	3	75
	1	50	1	50
Post-T	1	33	2	67
	8	67	4	33
	7	67	4	33
	8	89	1	11
	5	63	3	37

Table 2
Responses to survey assessing the roles and contributions of women in forest entomology and forest pathology.

		# Women (%)	# Men (%)
Institution Type	Academia	29 (39)	20 (38)
	National/Federal Gov't	22 (30)	21 (40)
	State/Provincial Gov't	20 (27)	9 (17)
	Private Industry	3 (4)	3 (6)
Length of Time in Career	<5 years	15 (20)	2 (4)
	6–10 years	17 (22)	7 (13)
	11–15 years	15 (20)	3 (6)
	16–20 years	8 (11)	6 (11)
	>20 years	21 (28)	35 (66)
Highest Education Obtained	B.S./B.A.	7 (9)	2 (4)
	M.S./M.B.A./Masters	25 (33)	12 (23)
	Ph.D./J.D./ Doctorate	44 (58)	39 (74)
# Conferences/Year	2 or fewer	47 (62)	29 (55)
	3–5 per year	26 (34)	20 (38)
	6 or more	3 (4)	4 (8)
# Organizations/Societies	2 or fewer	55 (72)	30 (58)
	3–5 organizations	18 (24)	22 (42)
	6 or more	3 (4)	0 (0)
How often do you present at conferences?	Less than every other year	11 (14)	5 (9)
	Every other year	8 (11)	9 (17)
	Once per year	16 (21)	12 (23)
	Multiple times per year	41 (54)	27 (51)

obtain the percentage of female office holders in each research group (i.e., entomology and pathology). If office holders changed within a term, both were counted for our assessment, therefore, not all terms consisted of the same number of office holders. To assess these changes over time, we performed a Chi square test of independence.

We also examined gender distributions within forestry and natural resources institutions in the U.S. This was limited to the U.S. partly because this was the most represented country/region based on survey responses and also because regions like Europe and Oceania do not have one unifying body, such as the SAF (Society of American Foresters) in the U.S., which provides accreditation to forestry and natural resources schools. To quantify changes in gender distribution within the U.S., we examined the proportions of tenured and untenured women in forestry and natural resource departments. Forest entomology and forest pathology positions may be housed in a variety of departments (e.g., biological sciences, forestry, entomology), so we limited our examinations to forestry institutions accredited by the SAF to ensure consistency across departments. First, we identified SAF-accredited institutions (e.g., departments, colleges; $n = 52$) that had a focus of forestry and/or natural resources (including forestry). We then excluded programs that did not include enough information to determine gender for all faculty of all ranks, resulting in 46 institutions included in analyses. For each program, we then tallied the number of untenured men, untenured women, tenured men, and tenured women. Faculty with special ranks (e.g., adjunct faculty, research faculty) were not included in these data as each institution has its own standards and titles for non-tenure track positions. Similarly, only the difference between pre-tenure and post-tenure was considered in these data because institutions have different standards and titles for positions beyond tenure (e.g., university professor, distinguished professor). We then converted the raw numbers of men and women in each category to a proportion. Faculty data were not normally distributed; therefore, we compared the proportion of untenured women to tenured women using a paired Wilcoxon Sign-Rank test. We performed a Kruskal-Wallis test comparing proportions of women with and without tenure using 'region' (i.e., Northeast, Midwest, South, West) as a fixed effect. All statistics were conducted using R (R Core Team, 2020).

Following analyses of faculty data, we then distributed a survey to the department chair/head of all 52 forestry and natural resource institutions in the U.S. We requested that the chair/head report the number of females and males at different levels in the program (i.e., undergraduate, master's, Ph.D., post-doctoral) as well as the regional location (i.e., southeast) of the program. Because not all institutions had individuals at all levels (e.g., some institutions do not offer a PhD), sample sizes were different and not statistically comparable.

We integrated the combined qualitative and quantitative results from all our methods to make inferences about the 1) the major issues women face as professionals in forest entomology and forest pathology, 2) the views and attitudes towards women in professional roles in these fields, 3) how the roles of women, and attitudes towards them, have changed in forest entomology and forest pathology, and finally, 4) suggestions for organizations and institutions to better support women in these fields.

3. Results

3.1. Interviews and surveys

A total of nine people (eight women, one man) were interviewed for the first part of the study. Most interview participants ($n = 5$) worked for a government agency with the remainder working either in academia ($n = 3$) or the private sector ($n = 1$). Female interviewees ranged in age from 36 to 59 and all but one self-reporting as heterosexual and the remainder as lesbian. All female participants self-reported as cis-gendered and all were either married or in a long-term domestic partnership. Female interviewees self-reported as Black (1), Latina/o (1), Caucasian only (4), or a mix of Caucasian and Native American (2). All female participants had reported experiencing some form of discrimination relating to their gender during their career in forest entomology or forest pathology. One half reported at least one incident to a supervisor while the other half never reported any incidents. Those that did report incidents felt that the situation was handled well and experienced fewer instances of discrimination after reporting.

The only male participant was 37 years old and worked in academia. He reported that he was cis-gendered, heterosexual, married, Caucasian, and had children. He reported never having experienced discrimination based on his gender (or any other characteristic). He had, however, experienced threats (unrelated to his gender) during graduate school (from another graduate student), which were not reported out of a fear of jeopardizing his career.

Sexual discrimination was consistently cited by female interviewees regardless of race, sexual orientation, ethnicity, and career status as a significant impediment in their career advancement. While the only male participant stated that he had never considered leaving science, every female participant reported at least some past or present desire to leave their institution, field, or science altogether. A common theme among female interviewees with regards to obstacles faced during their professional careers was sexism from superiors. Several women interviewed described supervisors who would offer opportunities only to male colleagues, refuse to write letters of recommendation, or even demean and degrade their female students and technicians. Because of the pervasive nature of these complaints, we identified gender discrimination as a focus of the survey.

After survey termination in October 2020, we removed partial responses resulting in a total of 129 complete responses from 76 women and 53 men. Most respondents had PhDs in their fields or related fields, both for women (57.9%) and men (73.5%). Most women (61.8%) had been working in their field for <15 years with the average being 11.7 years while most men (66%) had been working in their field for >20 years with the average being 16.6 years. Women were less likely (63.2%) to be married than men (75.4%) and were less likely to have children (55.3% of women compared to 71.7% of men). At the time of the survey, most respondents were based in North America (73.7% of women and 73.6% of men) with the second highest percentage (15.8% of women and 18.9% of men) in Europe.

While 28% of women belonged to three or more scientific societies compared to 42% of men, only (some) women responded as belonging to six or more societies (4%). Thirty-eight percent of women reported attending three or more conferences per year compared to 45% of men. Despite these differences, women and men responded similarly regarding presenting at conferences multiple times per year (54% of women and 51% of men), implying that women are likely presenting multiple times at some conferences they attend. And despite belonging to fewer societies, women only served in slightly fewer roles compared to men ($\mu = 1.66 \pm 0.01$ and $\mu = 1.79 \pm 0.02$ respectively). Women also served in slightly fewer conference roles compared to men ($\mu = 0.55 \pm 0.01$ and $\mu = 0.62 \pm 0.02$ respectively). This trend was noticeably reversed within institutions, however, with women serving in significantly more roles than men ($\mu = 1.66 \pm 0.01$ and $\mu = 0.96 \pm 0.02$ respectively).

Both women and men, on average, felt moderate to high support (e.g., emotional support, monetary support) from their supervisors and institutions, but men and women with children often felt less supported, found it more difficult to achieve a satisfactory work/life balance compared to respondents without children. While both women and men experienced challenges during their career, women were more likely (51%) to report challenges related to their gender compared to men (2%). Women were also more likely to report a lack of institutional support when facing these challenges. Women with and without children were also less satisfied than men with their professional progress.

Women with (83%) and without (79%) children overall agreed that women are more likely to put their career on hold to have children while

there was a significant shift from men without children (46%) to men with children (61%) agreeing with this statement. Similarly, men with children tended to agree that women prioritize raising children over their careers more than men without children, while women both with and without children tended to agree with this statement. Both men and women with children were more likely to rate their work/life balance as more difficult and to have less satisfaction with their work/life balance compared to men and women without children.

A majority of both men and women agreed that women add valuable contributions to forest entomology and forest pathology and that both fields are better with women contributing to them. A majority of respondents (88%), both men (85%) and women (89%), did not believe that work conditions (e.g., strenuous fieldwork) was something women were unable to handle. Survey themes identified from assessing responses to open-ended questions fell into three main categories: attributes that make forest entomology or forest pathology attractive career options, gender-based challenges faced by respondents, and career-development challenges faced as a parent. Both women and men identified a love of nature and the outdoors, as well as a concern for the environment, as a major reason for their career choice. Men, more than women, identified an opportune open position as the reason for them working in forest entomology or forest pathology. Both men and women identified major publications and grants, student mentorship, and promotions or awards as their biggest professional accomplishments thus far.

Women frequently identified overt and covert sexism as a significant professional challenge facing them. Significant challenges described by female survey respondents included "getting no credit, whereas men having the same accomplishment time and again garner support. Women were criticized, men coddled" and being "…isolated and pushed out of groups and having to constantly prove myself." None of these issues were mentioned by male respondents. Covert sexism consisted of feelings of not being taken seriously or their opinions being valued less than those of male colleagues. By comparison, men more frequently identified factors not related to sexism such as competition within their field, administration, and obtaining research funding as the most challenging aspect of their professional careers. Both men and women believed recent changes to flexible work hours and an acceptance of talking about personal issues helped mitigate these professional challenges. Specifically, both men and women felt it was more acceptable to discuss workplace and work/life balance challenges than it was in the past.

Survey respondents suggested several action items for work institutions, agencies, and scientific societies to address in the context of issues women face in science, and to attract and retain more women to the fields of forest entomology and forest pathology. These suggestions included 1) organizations should highlight issues of sexism through official statements and provide resources like mandatory training and "how tos" if women find themself in a difficult situation (e.g., experiencing sexual harassment or discrimination), 2) organizations should work to promote women to leadership positions, being cognizant of the extra service burden (e.g., serving on committees; Pederson and Minnotte, 2018) that women already face in science, 3) work institutions should rework and clearly define expectations for promotion and tenure, keeping in mind the extra challenges women face in terms of acquiring grant funding, publishing, and being invited to speak at conferences and seminars, 4) organizations could include childcare and family activities when organizing meetings, and 5) organizations should create mentorship programs for women and minorities to achieve leadership roles in their respective fields.

Survey results also indicated several action items for societies and institutions to take in order to attract and retain more women in the fields of forest entomology and forest pathology. Specific actions identified were to 1) create leadership roles for women, 2) create committees dedicated to diversity, equity, and inclusion, 3) write and publish statements demonstrating a commitment to diversity, equity, and inclusion, 4) ask women who occupy leadership positions who else should be included but aren't, and 5) distribute surveys about diversity, equity, and inclusion following meetings and conferences.

3.2. Institutional gender distributions

There was a total of 666 office holders (Research Group and Working Party coordinators and deputies) in IUFRO's Entomology (Division 7.03) and Pathology (Division 7.02) research groups between 1987 and 2020. Entomology groups had a total of 378 office holders over the assessed period while pathology groups had a total of 288 office holders. However, many individuals were represented more than once by serving in multiple working parties or over multiple time periods, so the total number of unique individuals was 168 in the entomology groups and 99 in the pathology groups.

Overall, the percentage of female office holders increased significantly ($\chi^2 = 44.652$, df = 7, p-value <0.001) from 4% in 1987–1990 to 38% by the 2019–2024 session (Fig. 1). Except for two time periods (1996–2000, 2010–2014), pathology groups had consistently higher proportions of female office holders compared to entomology groups. The percent of female office holders ranged from 0% (1987–1991) to 40% (2019–2024) for entomology groups and 6% (1991–1995) to 36% (2019–2024) for pathology groups.

Europe was the most represented region for both entomology (44%) and pathology (38%) office holders. Despite the high proportion of office holders from Europe, the average percent of European office holders that were female across all time periods was only 16% for entomology groups and 21% for pathology groups. In comparison, Western Asia (Turkey to Iran) was the least represented for both entomology (1.5%) and pathology (0.7%) groups, but 100% of the office holders have been female. Conversely, nearly 40% of female office holders in entomology groups were from Latin America while pathology groups had no female Latin American representatives (Fig. 2).

At the highest levels of leadership within IUFRO Research Groups, the gender ratio was even higher (50% female out of a total of six coordinators and deputies). Out of 52 total SAF accredited forestry programs in the U.S., a total of 46 institutions in the U.S. met the stated criteria to be included in analysis. Programs were mostly evenly distributed with the northeastern U.S. having the fewest number of programs (9), the Midwest and the western U.S. having equal numbers of programs (11), and the southeastern U.S. having the most programs (15).

All faculty members identified as either male ($n = 799$; 72%) or female ($n = 308$; 28%) based on language included on departmental or lab websites. There were significant differences between untenured and tenured women across programs (V = 823.5, $p = 0.0001$). The average proportion (± SE) of untenured women was 0.407 (± 0.04) while the average proportion of tenured women was 0.204 (± 0.02). There were no significant differences among proportions of tenured and untenured women based on 'region' ($X^2 = 2.208$, $p = 0.5304$).

A total of 11 department representatives filled out the voluntary survey regarding gender parity at different program levels. No departmental respondent provided numbers of non-binary individuals. It was not clear whether this was because it was not recorded or if no members identify as non-binary. Not all programs were represented at all institutions and sample sizes differed between programs, so statistical analysis was not possible. However, it should be noted that half or more of the programs reported were near, or above, 50% female for undergraduate, graduate, and post-doctoral programs (Table 1, Fig. 3).

4. Discussion

While many aspects of our results point towards the need for more effort in gender equality, some positive trends can be seen. For example, based on our survey results, women respondents have been working in their respective fields for 15 years or less while men respondents have

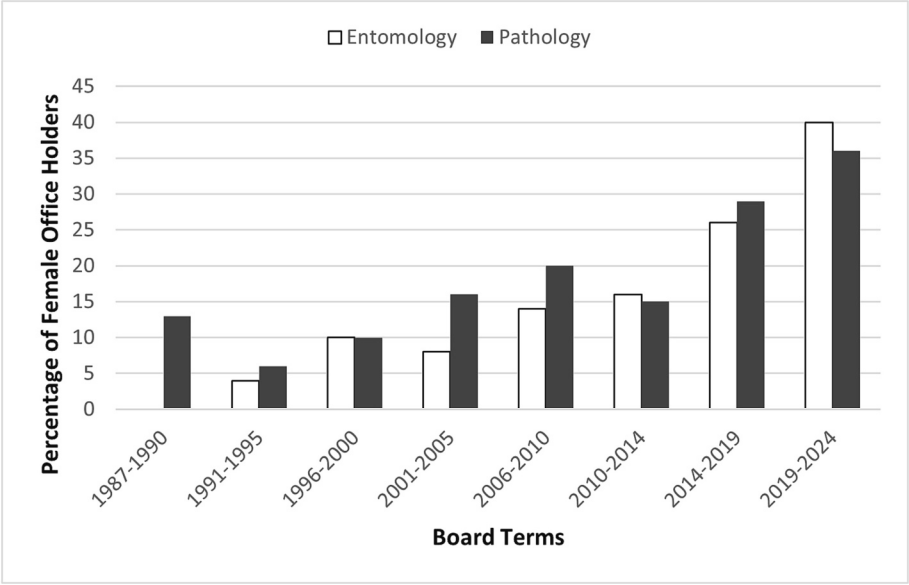

Fig. 1. Percentage of female office holders (coordinators and deputies) in International Union of Forest Research Organization's Pathology and Entomology research groups across the eight board terms from 1987 to 1990 to 2019–2024 (until 2020).

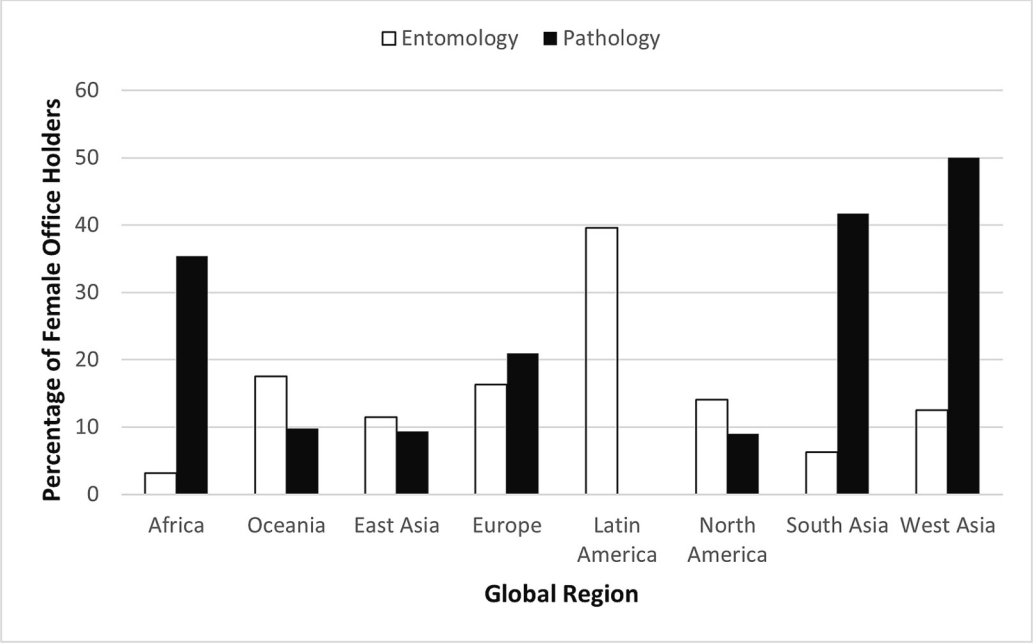

Fig. 2. Percentage of female office holders within International Union of Forest Research Organization's Pathology and Entomology research groups split by global region (1987–2020).

been working in their respective fields for 20 years or more. While this could be due to women leaving these fields earlier than men, it may also indicate that women occupy a considerably greater proportion of the forest entomology and forest pathology workforce as compared to 20+ years ago, which suggests that institutions are working towards parity and equity. In addition, many survey respondents felt that institutions and scientific societies had become more flexible in terms of work/life balance and had been supportive of issues such as difficulties in accessing childcare facilities faced by women specifically and parents in general.

Access to grant money was identified by both men and women as a significant obstacle in their careers. Despite this concern applying to both genders, men are awarded significantly more grants than women (Bornmann et al., 2007; Burns et al., 2019; Witteman et al., 2019). Similar situations exist in the U.S. and Europe, with respect to granting agencies and funding awards (Roper, 2019). Suggestions to advance women in this area include anonymizing grant proposal or providing unconscious bias training for reviewers.

Based on our interviews and survey results, women respondents in forest entomology and forest pathology regularly experience sexual harassment in the workplace, in the field, and at conferences. Our results are in line with other studies and a recent review (Bondestam and Lundqvist, 2020) which show that most women, and many men, are exposed to sexual harassment in higher education. Often times, women are afraid to speak up due to possible retaliation or are unaware of the proper routes to take for reporting, and the perpetrator avoids

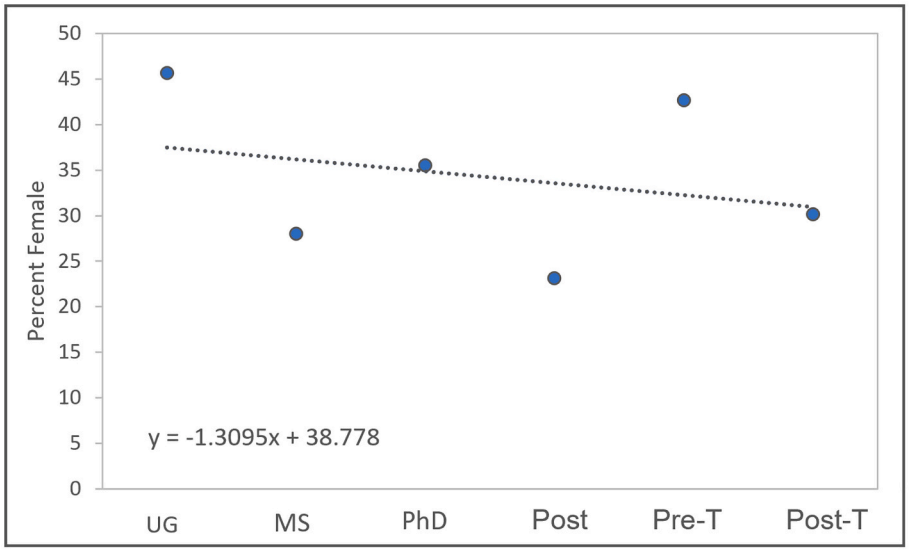

Fig. 3. Means of percent females at different academic rank across U.S. forestry and natural resource institutions showing trendline and linear regression equation.

accountability (Clancy et al., 2014). It is also recommended that granting agencies treat sexual misconduct in the same way as scientific misconduct and require that any involvement in sexual misconduct be disclosed on grant applications (Greider et al., 2019).

Childcare and family care were repeating themes throughout the survey for both women and men. Many people mentioned that conferences should have family-oriented support such as 1) availability of childcare services, 2) events for children and spouses, and 3) "crying rooms" for attendees to watch talks while caring for a child or breastfeeding. With the recent increase of virtual conferences due to COVID-19, accessibility may have improved for many women and people with families. Accommodations like these can break down certain financial and geographic barriers to attending professional meetings, however, family-friendly options at in-person conferences are still a necessity. However, it is important to ensure that virtual meetings do not inadvertently widen the gap in participation with women being expected to participate virtually due to family obligations.

Several action items were identified by survey respondents to attract and retain more women to societies and institutions:

- **Create leadership roles for women in committees**. Women hold disproportionately high service burdens in professional positions (Pederson and Minnotte, 2018). Meanwhile, the roles women serve on committees and other professional positions are complicated; equal gender splits on committees do not indicate equity, as fewer women occupy faculty positions and, therefore, are expected to serve more roles to meet gender proportion requirements (Guarino and Borden, 2017). Additionally, while women make up a large percentage of these service groups, they typically do not hold leadership positions on committees (Beeler et al., 2019). Creating leadership roles for women involved in heavy service increases their visibility in their respective institution and rewards them with demonstrated leadership experience.
- **Create diversity and inclusion committees**. Similar to the above action item, committees can be beneficial when certain issues are considered. One consideration is that, for these types of initiatives to be effective, the committee should be a part of a larger structure for oversight of departments, institutions, and organizations (Roberson et al., 2020). When committees, or individuals, are responsible for holding these institutions accountable for actions that directly promote diversity, research indicates that representation of minorities increases (Hegewish and Mefferd, 2021). Along these same lines, the lower numbers of women and minorities in STEM, especially in higher positions, means that they are more frequently asked to participate in service to meet diversity and inclusion standards, thus potentially resulting in an increased workload imbalance (Harris, 2012). Therefore, this disproportionate service load should be considered when forming these committees. To mitigate these concerns, committees should consider ways in which women and minorities are most benefitted by joining these committees (e.g., through the creation of leadership roles on committees).
- **Write statements/resolutions to show commitment to diversity, equity, and inclusion**. If carefully crafted, diversity statements have the ability to increase individuals' commitment to their work institution or scientific organization (Purdie-Vaughns et al., 2008). Conversely, poorly written statements can backfire and cause feelings of isolation and resentment among employees. To ensure that diversity and inclusion statements have a positive effect on employees, they should include messages that 1) promote autonomy, 2) describe the value of differences (e.g., cultural values), and 3) are aspirational (Carnes et al., 2019).
- **Ask women already occupying leadership positions "who isn't here that should be?"**."Gatekeeping" involves leadership identifying and promoting individuals who meet their standards for certain individual traits and performance measures and often utilizes exclusionary language. Women and minorities have fewer opportunities and more barriers to overcome, and thus they often fail to meet these standards and are often not noticed by those in leadership. Conversely, involving women and other underrepresented groups in identifying missing individuals shifts the leadership model from "gatekeeping" to "groundskeeping" which has been shown to increase diversity (Montgomery, 2020).
- **Send out a diversity and inclusion survey after conferences to find areas that could be improved upon**. Conference and meeting evaluation is necessary to ensure that goals and objectives are being met. While statements and policies regarding harassment and inclusion at meetings can set the tone for the duration of the conference, assessing their effectiveness can be done through post-hoc surveys of meeting participants (Tulloch, 2020). These surveys can then be used to address gaps and refine goals and initiatives of the organization.

Our analysis of gender make-up of forestry institutions in the U.S. showed two times as many untenured women compared to tenured women. This indicates a significant increase in hiring women at the assistant professor level compared to previous decades. In the U.S.,

gender parity has largely been reached in many STEM fields for the bachelor's to the Ph.D. level (Miller and Wai, 2015), including forest entomology and forest pathology (Table 1). Despite these achievements in reducing gender discrimination in academia, there still exist many obstacles facing women in academic positions including overt and covert sexism as well as difficulties re-entering the workforce after having children. This is important because many of the policies that organizations adopt to improve the work-life balance for employees are perceived differently by men and women in the workplace. For example, flexible scheduling of work hours is viewed as a positive by women and contributes positively to their commitment to the organization regardless of their personal use of the policy while men only view this type of accommodation in a positive light when they personally use it (Casper and Harris, 2008). Women also shoulder much of the burden of service at their institutions due to their low numbers; the few women present are often asked to serve on committees and other roles to increase the representation of women (ignoring the fact that this puts additional strain on them) (Social Sciences Feminist Network Research Interest Group, 2017). Creating leadership roles on these committees which lead to increased recognition for members, is one way to alleviate some of these issues.While this study reports on gender issues in forest entomology and forest pathology, the challenges and issues faced by women scientists are often shared by minorities and gender diverse scientists who can face additional barriers in the workplace. The benefits of diverse workplaces, societies, groups and teams are well documented, including in academic settings (Cheruvelil et al., 2014; Fine and Handelsman, 2010; Roberson, 2019). This diversity can lead to increased productivity, innovation, creativity and profit through the exposure and inclusion of a wider array of ideas and knowledge than could be gained in a more homogenous setting, and, in addition, this can lead to improved cultural insight. Conscious changes to the inclusion and support of females in science, as recommended above, are likely to have other benefits across the diversity spectrum and in the process may help identify and challenge other forms of institutional bias. These changes should be considered in further examination of theories created to approach the issue of gender inclusion in STEM fields (e.g., "pathway metaphor"; Cannady et al., 2014). These theories tend to focus on attributes of those entering STEM fields as determinants of their future success in those fields. Our result suggest that the institutional environment and culture of the field are large influences on whether women continue to work in the field or not. Future research should focus on updating analogies such as these to put the emphasis on organizations to make these intentional changes.

This study has several limitations: first, interviews were only conducted with nine individuals, eight of which were female. This small sample size is likely attributed to the interviews being long and requiring in-person discussions, removing a layer of anonymity. Second, themes from those interviews were possibly skewed because people who responded positively to being interviewed about gender issues and sexual discrimination were likely those who had a story they wanted to tell. Systematic surveys would help form a bigger picture relating to the experiences of individuals of all genders in these fields. In the future, conference organizers could include a section in a post-conference survey about experiences of participants related to gender issues which may help broaden the scope of this work. While there are issues inherent in this study, and those like it, we believe our results shed light on these issues and ways for organizations and institutions to to improve gender diversity and inclusion.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Jessica A. Hartshorn: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration. **Eckehard G. Brockerhoff:** Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Maartje J. Klapwijk:** Methodology, Data curation, Writing – original draft, Writing – review & editing. **Mariella Marzano:** Methodology, Data curation, Writing – original draft, Writing – review & editing. **Rebecca J. Ganley:** Methodology, Data curation, Writing – original draft, Writing – review & editing. **Molly N. Darr:** Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

Association for Women in the Sciences, 2011. Women in Science: A 2011 Snapshot. Association for Women in the Sciences, New Zealand.
Baker, B., 2011. Women face more hurdles in science careers, survey shows. Bioscience 61, 88.
Beeler, W.H., Smith-Doody, K.A., Ha, R., Aiyar, R.S., Schawrzbach, E., Solomon, S.L., Jagsi, R., 2019. Institutional report cards for gender equality: lessons learned from benchmarking. Cell Stem Cell 25, 306–310.
Berisford, C.W., 1992. Andrew Delmar Hopkins–A West Virginia Pioneer in Entomology, Circular-West Virginia University Agricultural and Forestry Experiment Station.
Blau, F.D., Kahn, L.M., 2013. Female labor supply: why is the United States falling behind? Am. Econ. Rev. 103, 251–256.
Bondestam, F., Lundqvist, M., 2020. Sexual harassment in higher education - a systematic review. Eur. J. High. Educ. 10, 397–419.
Bornmann, L., Mutz, R., Daniel, H., 2007. Gender differences in grant peer review: a meta-analysis. J. Informetr. 1, 226–238.
Burns, K.E., Straus, S.E., Liu, K., Rizvi, L., Guyatt, G., 2019. Gender differences in grant and personnel award funding rates at the Canadian Institutes of Health Research based on research content area: A retrospective analysis. PLoS Med. 16 (10), e1002935.
Cannady, M.A., Greenwald, E., Harris, K.N., 2014. Problematizing the STEM pipeline metaphor: is the STEM pipeline metaphor serving our students and the STEM workforce? Sci. Educ. 98, 443–460.
Carnes, M., Fine, E., Sheridan, J., 2019. Promises and pitfalls of diversity statements: proceed with caution. Acad. Med. J. Assoc. Am. Med. Coll. 94, 20.
Carr, P.L., Raj, A., Kaplan, S.E., Terrin, N., Breeze, J.L., Freund, K.M., 2018. Gender differences in academic medicine: retention, rank, and leadership comparisons from the national faculty survey. Acad. Med. 93, 1694.
Carrell, S.E., Page, M.E., West, J.E., 2010. Sex and science: how professor gender perpetuates the gender gap. Q. J. Econ. 125, 1101–1144.
Casper, W.J., Harris, C.M., 2008. Work-life benefits and organizational attachment: self-interest utility and signaling theory models. J. Vocat. Behav. 72, 95–109.
Cech, E.A., Blair-Loy, M., 2019. The changing career trajectories of new parents in STEM. Proc. Natl. Acad. Sci. 116, 4182–4187.
Ceci, S.J., Ginther, D.K., Kahn, S., Williams, W.M., 2014. Women in academic science: a changing landscape. Psychol. Sci. Public Interest 15, 75–141.
Cheruvelil, K.S., Soranno, P.A., Weathers, K.C., Hanson, P.C., Goring, S.J., Filstrup, C.T., Read, E.K., 2014. Creating and maintaining high-performing collaborative research teams: the importance of diversity and interpersonal skills. Front. Ecol. Environ. 12, 31–38.
Clancy, K.B., Nelson, R.G., Rutherford, J.N., Hinde, K., 2014. Survey of academic field experiences (SAFE): trainees report harassment and assault. PLoS One 9, e102172.
De Welde, K., Laursen, S.L., 2011. The glass obstacle course: informal and formal barriers for women Ph.D. students in STEM fields. Int. J. Gend. Sci. Technol. 3, 571–595.
Desprez-Loustau, M., Aguayo, J., Dutech, C., Hayden, K.J., Husson, C., Jakushkin, B., Marçais, B., Piou, D., Robin, C., Vacher, C., 2016. An evolutionary ecology perspective to address forest pathology challenges of today and tomorrow. Ann. For. Sci. 73, 45–67.
Eaton, A.A., Saunders, J.F., Jacobson, R.K., West, K., 2020. How gender and race stereotypes impact the advancement of scholars in STEM: professors' biased evaluations of physics and biology post-doctoral candidates. Sex Roles 82, 127–141.
Else, H., 2019. Nearly Half of US Female Scientists Leave Full-Time Science After First Child. Nature News.

Entomological Society of America, 2020. ESA's Code of Conduct, 2020.
Fine, E., Handelsman, J., 2010. Benefits and challenges of diversity in academic settings. In: Brochure Prepared for the Women in Science & Engineering Leadership Institute (WISELI).
Gasser, C.E., Shaffer, K.S., 2014. Career development of women in academia: traversing the leaky pipeline. Prof. Couns. 4, 332–352.
Greider, C.W., Sheltzer, J.M., Cantalupo, N.C., Copeland, W.B., Dasgupta, N., Hopkins, N., Jansen, J.M., Joshua-Tor, L., McDowell, G.S., Metcalf, J.L., 2019. Increasing gender diversity in the STEM research workforce. Science 366, 692–695.
Guarino, C.M., Borden, V.M., 2017. Faculty service loads and gender: are women taking care of the academic family? Res. High. Educ. 58, 672–694.
Harris, G.L.A., 2012. Multiple marginality: how the disproportionate assignment of women and minorities to manage diversity programs reinforces and multiples their marginality. Adm. Soc. 45, 775–808.
Hegewish, A., Mefferd, E., 2021. The Gender Wage Gap by Occupation, Race, and Ethnicity 2020. Institute for Women's Policy Research Policy Brief #C497.
Hsain, H.A., Tam, R., Kamboj, I., Berman, H., Dudek, R., 2020. Paid family leave to strengthen the STEM workforce. J. Sci. Policy Gov. 17, 1–8.
Hunt, J., 2016. Why do women leave science and engineering? ILR Rev. 69, 199–226.
Kloxin, A.M., 2019. Addressing the leaky pipeline through mentoring and support: a personal perspective. Nat. Rev. Mater. 4, 287–289.
Kmec, J.A., 2013. Why academic STEM mothers feel they have to work harder than others on the job. Int. J. Gend. Sci. Technol. 5, 79–101.
Leaper, C., Starr, C.R., 2019. Helping and hindering undergraduate women's STEM motivation: experiences with STEM encouragement, STEM-related gender bias, and sexual harassment. Psychol. Women Q. 43, 165–183.
Liu, S.C., Brown, S.E., Sabat, I.E., 2019. Patching the "leaky pipeline": interventions for women of color faculty in STEM academia. Arch. Sci. Psychol. 7, 32.
McCullough, L., 2011. Women's leadership in science, technology, engineering and mathematics: barriers to participation. Forum Public Policy Online 2011 (2).
McGee, E.O., 2021. Black, Brown, Bruised: How Racialized STEM Education Stifles Innovation. Harvard Education Press, p. 208.
Merrill, W., Shigo, A.L., 1979. An expanded concept of tree decay. Phytopathology 69, 1158–1159.
Miller, E.M., Costello, C.Y., 2001. The limits of biological determinism. Am. Sociol. Rev. 66, 592–598.
Miller, D.I., Wai, J., 2015. The bachelor's to Ph. D. STEM pipeline no longer leaks more women than men: a 30-year analysis. Front. Psychol. 6, 37.
Moedas, C., 2015. She Figures 2015. European Commission.
Montgomery, B.L., 2020. Academic leadership: gatekeeping or groundskeeping? J. Values-Based Leadersh. 13, 16.
O'Dea, R.E., Lagisz, M., Jennions, M.D., Nakagawa, S., 2018. Gender differences in individual variation in academic grades fail to fit expected patterns for STEM. Nat. Commun. 9, 1–8.
Pederson, D.E., Minnotte, K.L., 2018. University service work in STEM departments: gender, perceived injustice, and consequences for faculty. Sociol. Focus 51, 217–237.
Powell, S., 2016. Gender equality and meritocracy: contradictory discourses in the academy. In: Swedish University of Agricultural Sciences, Faculty of Natural Resources and Agricultural Sciences Department of Urban and Rural Development. Uppsala, Sweden, p. 131.
Purdie-Vaughns, V., Steele, C.M., Davies, P.G., Ditlman, R., 2008. Social identity contingencies: how diversity cues signal threat or safety for African Americans in mainstream institutions. J. Pers. Soc. Psychol. 94, 615–630.
R Core Team, 2020. R Core Team R: a language and environment for statistical computing. Foundation for Statistical Computing. Vienna, Austria. https://www.R-project.org/.
Reinking, A., Martin, B., 2018. The gender gap in STEM: theories, movements, and ideas to engage girls in STEM. J. New Approaches Educ. Res. 7, 148–153.
Rivers, E., 2017. Women, Minorities, and Persons with Disabilities in Science and Engineering. National Science Foundation.
Roberson, Q.M., 2019. Diversity in the workplace: a review, synthesis, and future research agenda. Annu. Rev. Organ. Psych. Organ. Behav. 6, 69–88.
Roberson, Q., King, E., Hebl, M., 2020. Designing more effective practices for reducing workplace inequalities. Behav. Sci. Policy 6, 39–49.
Robinson, J.P., Lubienski, S.T., 2011. The development of gender achievement gaps in mathematics and reading during elementary and middle school: examining direct cognitive assessments and teacher ratings. Am. Educ. Res. J. 48, 268–302.
Roper, R.L., 2019. Does gender bias still affect women in science? Microbiol. Mol. Biol. Rev. 83, 18.
Rothstein, B., 2012. The reproduction of gender inequality in Sweden: a causal mechanism approach. Gend. Work. Organ. 19, 324–344.
Ruder, B., Plaza, D., Warner, R., Bothwell, M., 2018. STEM women faculty struggling for recognition and advancement in a "men's club" culture. In: Anonymous Exploring the Toxicity of Lateral Violence and Microaggressions. Springer, pp. 121–149.
Sallee, M., Ward, K., Wolf-Wendel, L., 2016. Can anyone have it all? Gendered views on parenting and academic careers. Innov. High. Educ. 41, 187–202.
Savigny, H., 2019. Cultural sexism and the UK Higher Education sector. J. Gend. Stud. 28 (6), 661–673.
Sheridan, J.E., 1992. Organizational culture and employee retention. Acad. Manag. J. 35, 1036–1056.
Social Sciences Feminist Network Research Interest Group, 2017. The burden of invisible work in academia: social inequalities and time use in five university departments. Humboldt J. Social Relat. 39, 228–245.
Stout, J.G., Dasgupta, N., Hunsinger, M., McManus, M.A., 2011. STEMing the tide: using ingroup experts to inoculate women's self-concept in science, technology, engineering, and mathematics (STEM). J. Pers. Soc. Psychol. 100, 255.
Tulloch, A.I.T., 2020. Improving sex and gender identity equity and inclusion at conservation and ecology conferences. Nat. Ecol. Evol. 4, 1311–1320.
Viglione, G., 2020. Are women publishing less during the pandemic? Here's what the data say. Nature 581 (7809), 365–367.
White, M.S., 1970. Psychological and social barriers to women in science: limited opportunities for colleague interaction may hamper the scientifically trained woman. Science 170, 413–416.
Witteman, H.O., Hendricks, M., Straus, S., Tannenbaum, C., 2019. Are gender gaps due to evaluations of the applicant or the science? A natural experiment at a national funding agency. Lancet 393 (10171), 531–540.
Xu, Y., 2015. Focusing on women in STEM: a longitudinal examination of gender-based earning gap of college graduates. J. High. Educ. 86, 489–523.