Bridging the Gender Gap: The Demographics of Scientists in the USDA Forest Service and Academia

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Past research has established that diverse scientific communities foster innovation and problem solving more effectively than communities with a narrow range of knowledge, skills, and experience. However, gender diversity among scientists is limited, particularly in natural-resource fields. We compared data on scientist gender and rank from the US Department of Agriculture Forest Service Research and Development (FSR&D, a hierarchical organization) with data on faculty gender and tenure status from universities (loosely coupled systems) with comparable areas of study. We found that the representation of women was greater among FSR&D scientists than among university faculty but declined with seniority in both institutions. Within FSR&D, data showed demographic inertia, suggesting that the representation of women in senior scientist positions will increase. Although many mechanisms affect gender representation, our findings suggest that organizational structure affects the diversity of the scientific workforce.

Keywords: workforce diversity, inclusivity, natural resources, promotion, tenure

Diversity of the scientific community is important to science

Diversity fosters innovation and leads to more effective problem solving (Østergaard et al. 2011, Rice 2011). In the scientific community, gender diversity has been skewed toward the underrepresentation of women (Taylor 2008), and masculine views set the framework in which scientific institutions work (Blickenstaff 2005). Gender bias creates barriers to scientists who might otherwise make important contributions to their field of study (Hanson 1996). The business sector has recognized this problem, and top firms manipulate the demographics of their workforce as a human-resources strategy (LBCWB 2007, Østergaard et al. 2011). Gender representation is also an important attribute of collaborative team productivity (Rice 2011). Scientific discovery, which was once perceived to be driven by individuals, is now driven by collaborative research teams (Wuchty et al. 2007). The addition of women to collaborative teams has a positive effect on group process (Bear and Woolley 2011). Specifically, teams with women in equal proportions to men have more collective intelligence and innovation than homogenous teams (LBCWB 2007, Woolley et al. 2010). Therefore, promoting equality in gender representation can have useful outcomes for science.

There has been some success overcoming gender bias in science (Ceci and Williams 2011). In ecology, women scientists have experienced dramatic improvements in representation and decreased perceptions of gender bias (McGuire et al. 2012). However, today, men continue to outnumber, receive more grant money, and author more articles than women ecologists (Martin 2012). The explanations for the continued underrepresentation of women in science are controversial and include ongoing bias (Martin 2012, Moss-Racusin et al. 2012), a lag effect of historical inequality (Shaw and Stanton 2012), different personal goals and lifestyle choices (e.g., family formation), innate differences (Ceci and Williams 2011), and the gendered nature of scientific institutions (Acker 1990, Maranto and Griffin 2011).

Science and institutions

Institutions influence the way scientists work (Holyoke et al. 2012). Using a pipeline model for scientific careers, institutions provide the demand side of the scientist talent pool (*sensu* Wolfinger et al. 2009). For example, institutions provide structure for research priorities, collaborative opportunities, reward systems, and the distribution of resources (Uriarte et al. 2007). These characteristics are social and organizational and can stimulate or stifle the creativity and innovation of scientific work (Fox 2001). As a result, the productivity of a scientist (e.g., time spent doing research and number of publications) in this culture varies for individual scientists and, notably, by gender (Fox and Mohapatra 2007).

Academia represents a major institution of science and plays a crucial role in training the next generation of

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scientists. Universities employ one-third of US biological/life scientists (NSF 2010) and are known for basic science and investigator-led research (Pouyat et al. 2010). Academia is recognized as a *loosely coupled system* (Root-Robins 2006), in which research is carried out through structurally decentralized networks of independent universities and academic units.

Faculty hiring and promotion decisions are made through the within-university hierarchy. Departmental peers provide recommendations about faculty hiring and tenure to administrators within the academic unit and at upper administration levels. Final decisions about personnel actions are informed by and usually—although not always—consistent with the recommendations of the peer committee. Scientists hired into tenure-track faculty positions (e.g., assistant professors) have an opportunity for tenure after a probationary period. Ideally, tenure is granted to faculty with outstanding productivity in research, education, and service. If a faculty member is not recommended for tenure, there are often opportunities for appeal. If an appeal is not made or unsuccessful, the faculty member is terminated or may resign in anticipation of termination.

The US federal government is another institution of science. Federal agencies employ approximately 20% of the biological/life scientists in the United States (NSF 2010) and are known for their role in applied science and mission-led research (Pouyat et al. 2010). Government research is carried out in a hierarchically structured system. In the US Department of Agriculture Forest Service Research and Development (FSR&D), for example, the staff of the Chief of the Forest Service in Washington, DC, set strategic program areas for the six FSR&D research stations and one Forest Products Laboratory, geographically spread across the United States. Research stations address the strategic program areas, with programs or research work units composed of a line officer and scientists of various disciplines. Hiring recommendations are made by line officers to meet strategic program area goals, and decisions are made by leaders such as station directors. The Forest Service has a line of authority for decisionmaking and communications that is similar to the military chain of command (Conrad 1997).

Scientists employed by the federal government are not eligible for tenure. Instead, research scientist positions are administered following the Research Grade Evaluation Guide (RGEG; OPM 2006). RGEG positions are reviewed every 2–5 years by panels composed of peer scientists. The panels review recent and career-long contributions to determine scientific impact, stature, and recognition and decide on the appropriate classification of a scientist's position or grade series ("grade" or "GS") within a range from GS-11 to GS-15+. Based on supervisory controls and research assignments, grades 13+ are equivalent to tenured faculty (Glenn 1996), and obtaining GS-13 classification from a panel review is difficult (Campbell and Dix 1990)—that is, similar to obtaining tenure. Therefore, a recent PhD graduate recruited into an FSR&D scientist position is initially classified as a GS-11 scientist (OPM 2012) and must develop their research program in ways similar to a tenure-track faculty member (i.e., obtain grants, publish, etc.) over two panel cycles (approximately 5–7 years) to obtain a GS-13 classification. Panel recommendations may result in an increase in grade (a promotion) but may also result in a decrease or no change in grade. The panel system only classifies the scientist's position. Unlike the tenure process in academia, panels do not grant tenure. In the event of an unfavorable panel outcome, other performance processes are used for evaluation, and, if necessary, managers or leaders specify an improvement plan that must be met to preclude termination.

The personnel processes in federal government institutions and academia are similar, but they differ in terms of the degree of centralization in hiring. In both cases, institutional leaders make final hiring decisions and therefore have important effects on the composition of scientists. However, candidate recommendations are made by committees of departmental peers in academia and by line officers in federal agencies such as FSR&D. Each model has inherent weaknesses with respect to creating a diverse workforce. In academia, studies have associated unconscious bias in peer searches and hiring decisions with the low representation of women scientists in university faculty (Glass and Minnotte 2010). In the Forest Service, the workplace culture has favored leaders who make decisions on recruitment and promotion that foster "acculturation" (Robinson 1975), or compliance with the organization norms (Chojnacky 2012), such that women continue to be underrepresented in leadership positions and within the workforce in general (Brown et al. 2010a).

Hiring and promotion processes in both academia and the federal government adhere to national policies that prohibit sexual discrimination (e.g., the Civil Rights Act of 1964, Title IX of the Education Amendments of 1972, and the Equal Employment Opportunity Act of 1972), which have greatly diminished blatant gender bias in the sciences as a whole (Ceci and Williams 2011). In addition, after a 1981 consent decree resulting from a lawsuit that charged gender discrimination against the Forest Service (Winokur 1986), the agency enacted programs aimed to match the gender representation of the federal workforce, including FSR&D scientists, to the civilian workforce (Kennedy 1991, Brown and Harris 1993).

Within academia, diversity initiatives vary with individual universities. However, in 2001, the National Science Foundation initiated a nationwide awards program, ADVANCE, to encourage institutional solutions to allow women scientists to fully participate in the sciences across academia (NSF 2001). At that same time, prestigious universities suggested a national effort to make changes academia-wide to accommodate women scientists and match the gender representation of faculty to that of the student body (Rosser 2004).

Academia and the federal government represent two institutions of science with different organizational structures.

On one hand, federal agencies are hierarchically structured, gendered organizations (Newman 1995); feminist theory suggests that such organizations are based on and preserve patriarchal models that maintain male dominance (Acker 1990). Academia, on the other hand, consists of loosely coupled systems (Weick 1976), in which adaptability is greater but influence spreads slowly and coordination is weak (Root-Robins 2006). Each type of organization integrates the varying mechanisms of gender representation differently.

In both academic and federal government institutions, leaders influence the demographic composition of scientists, and peers influence the promotion (i.e., vertical segregation) of scientists. However, we suggest that the leadership influence on the demographic composition of scientists is greater in federal government institutions (e.g, line officer recommendations), such as the Forest Service, than in academia (e.g, peer committee recommendations), because Forest Service leadership (a) has a top-down chain of command that can influence the implementation of gender initiatives more effectively than the decentralized network of independent universities of academia and (b) has had more time, since the 1981 consent decree, to implement agency-wide diversity initiatives than academia, which initiated nationwide diversity efforts (ADVANCE) in 2001. Therefore, we hypothesized that a greater proportion of women scientists would be affiliated with the Forest Service than with universities with similar programs of study.

Research approach

As researchers employed by FSR&D, we have a particular interest in quantifying and understanding gender representation within our agency. The Forest Service is a leading employer of natural-resource professionals, and its R&D branch includes close to 500 biological, physical, and social scientists at multiple locations across the United States (USDA Forest Service 2014). Despite long-standing diversification initiatives, the Forest Service remains male dominated (Lee 2012); this is also true for forestry as a broader field of study (UNECE–FAO 2006). Social constructs that have historically favored the view that science, and particularly applied fields such as forestry, are more suitable for men than women (Brandth and Haugen 1998) and the close affiliation of forestry research with the male-dominated utilization and logging industries create obstacles to inclusivity. To test the influence of institution on gender representation, we compared the demographics of FSR&D to those of the subset of US universities most closely affiliated with forestry and related natural-resource fields—that is, those accredited by the professional forestry society the Society of American Foresters (SAF) or with membership in the National Association of University Forest Resources Programs (NAUFRP).

We compiled 2009 FSR&D scientist data on gender and grade and compared them with 2008 university faculty data on gender and tenure status queried from the US Department of Agriculture (USDA) Food and Agriculture Education Information System (FAEIS 2008) database (table 1). The FAEIS database is a compilation of faculty and student information from 1862, 1890, 1994, and non-land-grant institutions with programs related to food, agriculture, life, human, veterinary, and natural-resource sciences (FAEIS 2008). Our faculty query of the database was constrained to universities with advanced degree programs and forestry and natural-resource affiliations (i.e., by SAF accreditation or NAUFRP membership), to tenured and tenure-track faculty only, and to disciplines (e.g., atmospheric, environmental, biological, geological, molecular, chemical sciences…) in any department that might be used in the study of forests and natural resources. See supplemental appendix S1 for a complete list of the 37 universities and 66 disciplines used in the query.

Because we focused on two specific sample populations (FSR&D and SAF/NAUFRP universities), we were not able to estimate confidence intervals and other statistical metrics. Instead, we evaluated our data for a *meaningful difference*, a dissimilarity defined by similar reference populations with widely accepted gender representation differences. Our widely accepted gender-representation difference was based on national trends in science occupations (NSF 2010). It is widely accepted that the life sciences have a greater representation of women scientists than the physical sciences do (Ginther and Kahn 2006, Shaw and Stanton 2012). To determine whether the representation in our sample populations was as meaningfully different as the representation in life and physical sciences, we created an evaluation metric, or *dissimilarity criterion* (DC). The DC equates to the absolute difference in percentages between occupations with known disparities of high (life sciences) and low (physical sciences) representation of women: DC = |(the high-disparity percentage of women scientists) – (the low-disparity percentage of women scientists)| = 7% (table 2). Therefore, we used 7% as the DC to denote meaningfully different gender representations among institution types. For instance, the absolute difference in the percentage of women scientists between FSR&D and SAF/NAUFRP university faculty had to be more than or equal to 7% to be considered meaningfully different for the purposes of our assessment (table 2). To be sure that one population did not have a greater emphasis on certain disciplines (i.e., more life or more physical sciences), we compared representation from the life sciences alone in addition to all disciplines. Life-science disciplines represented 71% of all FSR&D scientists and 69% of all SAF/NAUFRP faculty.

Similarities and differences between institutions

We found that gender representation varied by institution type. The overall representation of women was 7% higher among FSR&D scientists than among SAF/NAUFRP faculty (figures 1 and 2). The representation of women was also higher in FSR&D than among SAF/NAUFRP faculty within rank and within life-science fields alone (table 1). The disparity among these institutions meets or exceeds

Table 1. The total number of scientists and the percentage of those scientists who are female for USDA Forest Service Research and Development (FSR&D) and the Society of American Foresters/National Association of University Forest Resources Programs (SAF/NAUFRP) universities and the difference in the percentage of female representation between institutions in all disciplines and in only the life sciences.

	All disciplines					Life sciences only				
	FSR&D		SAF/ NAUFRP			FSR&D		SAF/ NAUFRP		
Tenure status and grade series (GS)	Total	Percentage female	Total	Percentage female	Representation difference (percentage)	Total	Percentage female	Total	Percentage female	Representation difference (percentage)
All/GS-11+	471	26	2,225	19	7 [a]	388	26	1,533	17	9[a]
Tenure track/ GS-11/12	81	41	494	30	11[a]	60	40	351	28	12[a]
Tenured/GS-13+	390	23	1,731	16	7[a]	278	23	182	14	9

Note: Life-science disciplines represented 71% of all FSR&D scientists and 69% of all SAF/NAUFRP faculty. [a]The absolute difference in the representation of women is more than or equal to 7% or meets the dissimilarity criterion (based on table 2).

Table 2. The calculation of the dissimilarity criterion.

	Life sciences		Physical sciences		
Tenure status	Total	Percentage female	Total	Percentage female	Representation difference (percentage)
All	35,600	27	23,100	20	7
Tenure track	10,900	36	5600	29	7

Note: The representation of women scientists as a function of select occupations and tenure status (*Source:* NSF 2010 , Table 9-24) and the difference in percentage representation between occupations. The difference was calculated by taking the absolute value of the difference between the percentage of female scientists in the physical sciences and the percentage in the life sciences.

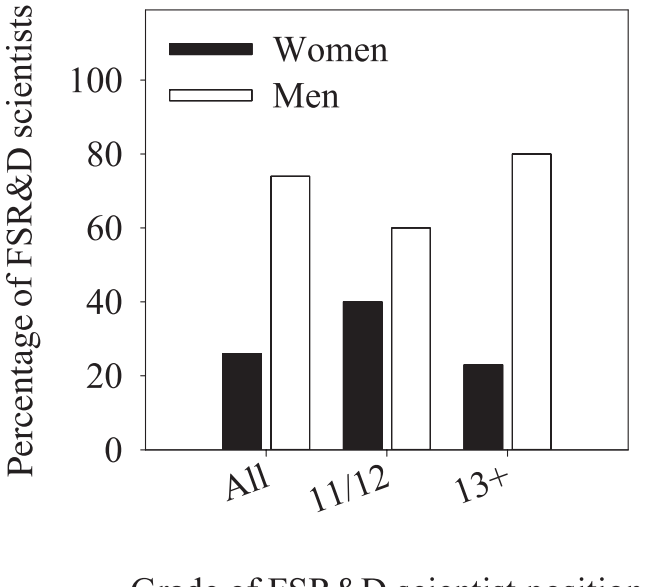

Figure 1. The gender representation in 2009 of 471 USDA Forest Service (FSR&D) scientists in life-science disciplines overall and as a function of the grade of position (under the Research Grade Evaluation Guide; OPM 2006).

our dissimilarity criterion (tables 1 and 2), suggesting a meaningful difference in representation among institution types.

Our data also highlighted that the proportion of women scientists declined with seniority (figures 1 and 2). We explored this pattern first by comparing the representation of women at the junior-scientist level to those with recently awarded doctoral degrees. Ideally, at the junior-scientist level, the representation of women should approximate the proportion of women receiving doctoral degrees such that there is no attrition. Using the same database (FAEIS 2008) and subset of universities and programs, we found PhD students (n = 12,013) were 44% women (6% unknown gender). This finding is comparable to 2008 estimates of women (44%) and women with US citizenship and permanent residency (40%—i.e., those eligible for federal employment) graduate students in science and engineering fields (the National Science Foundation's Survey of Graduate Students and Postdoctorates in Science and Engineering; Hill and Einaudi 2010). On the basis of these estimates, the representation of women in graduate programs is closer to the representation of women scientists in FSR&D (41%) than that in universities (30%) in our sample (table 1). This suggests that, at the junior-scientist level, the representation of women scientists in FSR&D approximates the proportion of women receiving doctoral degrees in relevant fields. It also highlights the meaningful disparity (DC = 11%) in gender composition at the junior rank between FSR&D and SAF/NAUFRP universities (table 1).

We also considered the distribution of women in junior and senior ranks. We hypothesized that the ratio of women in senior to junior ranks in our populations would be similar to general trends in science. A ratio of 1 results from equal numbers of women in junior and senior ranks, a ratio of more than 1 results from more senior women, and a ratio of

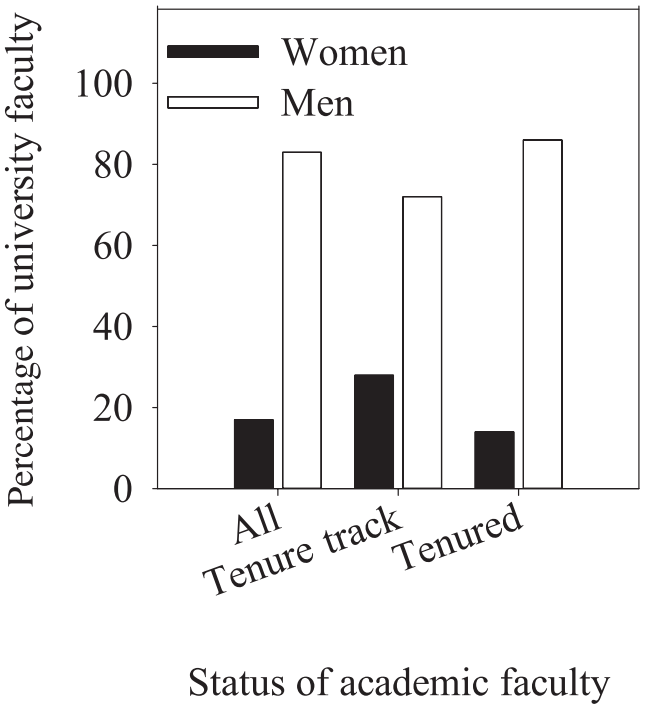

Figure 2. The gender representation in 2008 of 2215 tenure-track and tenured university faculty in life-science disciplines from institutions with programs similar to the disciplines of US Department of Agriculture Forest Service (FSR&D) scientists and with Society of American Foresters accreditation or National Association of University Forest Resources Programs membership, overall and as a function of tenure status.

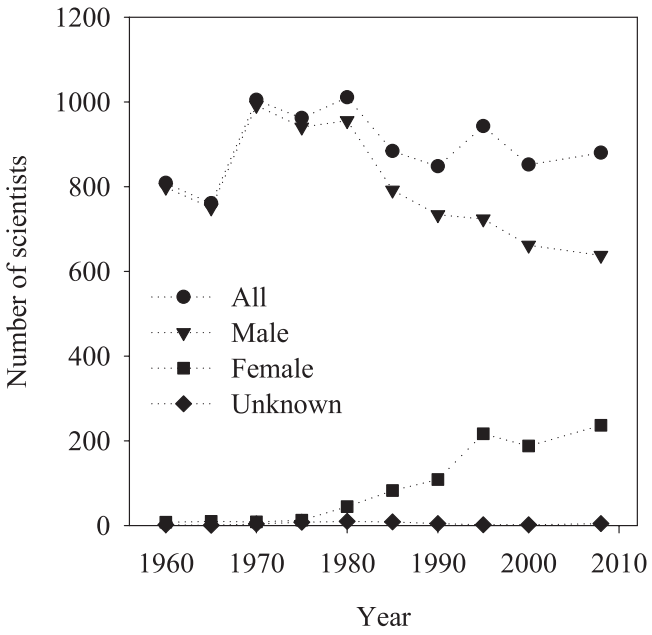

Figure 3. The number of US Department of Agriculture Forest Service (FSR&D) scientists as a function of gender between 1960 and 2008.

less than 1 results from more junior women. Using National Science Foundation data, the overall ratio of women in junior to senior ranks was 0.64 in the life sciences and 0.59 in the physical sciences (table 2). In our sample populations, the ratio was 0.56 for FSR&D and 0.53 for SAF/NAUFRP universities (table 1). This suggests that the reduction in the representation of women scientists from junior to senior positions (figures 1 and 2) is relatively similar among sample institutions. It also highlights that this reduction is similar to—or greater than—national trends in the life and physical sciences.

We further explored the reduction in the representation of women with increasing seniority using longitudinal FSR&D data; data of this type were not available for the subset of academic institutions we examined here. We hypothesized that the lower representation of women in senior positions is a consequence of demographic inertia, or fewer women scientists in the past—that is, fewer women available for promotion to senior levels. FSR&D data available from 1960 confirm that the representation of women was lower in the past (figure 3). The percentage of women FSR&D scientists has increased from 1% to 26% over 50 years. The increase in women scientists has largely occurred since 1980 such that over the last 30 years, the proportion of women scientists has increased about 1% per year.

To provide context for the increase in women FSR&D scientists over time, we used temporal trends in PhD recipients from the National Science Foundation's longitudinal Survey of Doctoral Recipients (NSF SDR; NSF 2010), because the women available for FSR&D positions is limited to the number of women with PhDs. Female recipients of PhDs have increased about 25% between 1974 and 2004, and PhDs granted in the life sciences made substantial gains: about 30% over the same time period, or approximately 0.8 to 1.0% per year. This suggests that the temporal change in FSR&D scientists is consistent with broader trends in the changing pool of available talent and confirms that fewer women were available for scientist positions in the past.

In addition, a 2009 companion study of the Northern Research Station of FSR&D (n = 96) highlighted that in 2009, *time in*, or the number of years in a FSR&D scientist position (Wald $\chi^{2(1)} = 33.2$, $p < .01$; $\alpha = .05$), was associated with grade, but there were less distinct associations between gender (Wald $\chi^{2(1)} = 2.6$, $p = .11$) and the interaction of gender and time in (Wald $\chi^2 = 1.6$, $p = .21$). For FSR&D, this and the temporal demographic data suggest that the observed reduction in the representation of women in senior rankings is a time-lag consequence: There were fewer women in the past and fewer available for promotion. Although this is undoubtedly true in academia as well, the current proportion of women faculty remains lower than that in FSR&D. Overall, our data suggest that FSR&D has been relatively more successful at reducing gender disparity than SAF/NAUFRP universities.

Institutions and demographics

Our data highlight the potential influence of institution on scientist demographics. Data also support our hypothesis that the representation of women in natural resources is higher in a hierarchical federal government agency than in loosely coupled, academic institutions. We did not test mechanisms of demographic representation in each institution, but we suggest that organizational structure may explain, in part, our findings. Although implementation success likely varies among research stations, the top-down structure of centralized government facilitates agency goals to create a diverse workforce within the broader government institution in a relatively even way across regional research stations. This effect may mitigate the gendered nature of hierarchical institutions (i.e., Acker 1990). In contrast, as an institution, academia is decentralized and operates as a loosely connected network of independent universities such that the enforcement and implementation of diversity initiatives are uneven (Morimoto et al. 2013). This finding is similar to that of Sullins (2000), who observed gender inequality among clergy in loosely coupled (congregational) but not hierarchical (denominational) positions, suggesting that policies of diversification may be more consistently realized in hierarchical organizations than in those driven by more local cultural values.

Another possible explanation of a greater proportion of women scientists in FSR&D is the long history of workforce diversification efforts. Since the 1981 consent decree, the Forest Service has established a number of agency-wide programs in response to these mandates including "Work Force 1995," established in 1987 (USDA Forest Service 1987), and the "National Work Force Diversity Task Force," commissioned in 1990 (USDA Forest Service 1991). In addition, FSR&D has implemented initiatives, including specialized recruitment programs (Cooperative Education in 1971, then the Scientist Recruitment Initiative in 2001, and now Pathways in 2012), to diversify the scientific workforce. The influence of these initiatives on RGEG positions has not been studied, but studies of the larger FS workforce have suggested marginal change in demographics initially between 1983 and 1992 (Mohai and Thomas 1995). However, in recent years, changes in gender representation have made significant changes in employee perceptions of the organization (Brown et al. 2010a, 2010b). The effectiveness of these top-down initiatives may be attributable, in part, to the agency's hierarchical structure, in which line officers are responsible for implementing policies at all levels of the organization (Conrad 1997).

In 2001, a similar unified mission to diversify the scientific workforce of academia was proposed through the ADVANCE program. However, these initiatives are associated with individual-, department-, and university-level changes at a subset of universities. Change in academia varies because universities have different gender inequalities to address (e.g., Morimoto et al. 2013). Only 28% of the universities in our study received ADVANCE grants. As such, the potential effects of ADVANCE awards on gender representation in SAF/NAUFRP universities may be muddled by the irregular distribution of resources or the short timeframe (our data query was from 2008).

Another interesting finding from our study was the similar reduction in the representation of women from junior to senior ranks in both institution types, despite dissimilarities in the representation of women in junior positions. Attrition among ranks (vertical segregation) can result from demographic inertia (Shaw and Stanton 2012), free or constrained choice (Ceci and Williams 2011), and bias (Martin 2012, Moss-Racusin et al. 2012). Within FSR&D, for which historical data were available, our data support demographic inertia as a possible explanation of the lower proportion of women on senior positions, whereas gender bias was not supported. Demographic inertia is likely an explanation of the lower proportion of women in faculty positions of SAF/NAUFRP universities and academia at large, as was suggested by the NSF SDR data (Shaw and Stanton 2012) and the similar ratios of women in junior to senior positions that we observed in academia and FSR&D.

The effect of free or constrained choices of women on decisions to leave scientist positions is not known for either of our study populations. A recent study highlighted the significant effect of lifestyle preferences (e.g., child rearing) on the underrepresentation of women in science (Ceci and Williams 2011). For example, in academia, a challenging career phase is the time between obtaining a tenure-track position and building a portfolio worthy of tenure. This phase overlaps the biological phase of decreasing fertility and creates choices for women faculty who would like to have children, a choice that men do not face (Williams and Ceci 2012). Consequently, it is possible that the attrition of women from the junior to senior ranks in our data is explained by women making choices to leave positions while in the junior rank. However, we speculate that rank attrition due to lifestyle choice may be more important in SAF/NAUFRP universities than in FSR&D, because FSR&D does not use the tenure system; the panel system may be more accommodating to alternative career paths. For example, a scientist could maintain status in a junior rank longer in the federal government than in an academic position to attain personal and professional goals. As such, the promotion process of the federal government may attract more women to FSR&D than to SAF/NAUFRP universities, which may, in part, explain the overall higher representation of women in FSR&D than in SAF/NAUFRP universities.

Conclusions

The values, practices, and norms of scientists from the most represented groups set the pace, depth, and breadth of science. Science is known for its gender bias, and understanding the obstacles to women is important to allowing all scientists to fully participate in the advancement of science (Uriarte et al. 2007). Institutions are important to creating an inclusive, diverse science community and overcoming

barriers to women and other underrepresented groups. The institutional differences in gender representation observed in the present study align with some aspects of theory regarding the processes of differently structured organizations (Weick 1976, Sullins 2000, Root-Robins 2006) but run counter to the feminist theory that hierarchal institutions are more gendered (Acker 1990).

Our goal was to explore gender representation in federal government (FSR&D) and academic institutions. Overall, we found that women remain underrepresented in scientist positions, regardless of institution. However, our results emphasize that the gender gap is not the same at all institutions; we found that the gender gap is smaller in FSR&D, at both junior and senior levels, relative to academic institutions in comparable disciplines. Although many mechanisms affect the gender representation of scientists, our findings suggest that institutions play a role in creating a diverse scientific workforce.

Moving forward, institutions can play an important role in moving science ahead by supporting diversification programs and allowing time for them to flourish. We suggest that future research on gender representation include longitudinal measures to better assess change from the past and change anticipated in the future. Finally, to our knowledge, this is the first data-based study of gender representation among institutions with different organizational structures in the natural-resource field. Therefore, additional research on institutions not examined here (e.g., industry and nongovernmental organizations) and the mechanisms of effective implementation of diversification policies in loosely and tightly coupled systems would provide more insight into the role of institutional mechanisms in gender representation.

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Supplemental material

The supplemental material is available online at *http://bioscience.oxfordjournals.org/lookup/suppl/doi:10.1093/biosci/biv144/-/DC1*.

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