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Careers in ecology: a fine-scale investigation of national data from the U.S. Survey of Doctorate Recipients

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Abstract. For several decades, economists have been warning the academic community that graduate training has been too tightly focused on careers in higher education, using the apprenticeship model in which students are trained to become tenure-track faculty at research-focused institutions. These jobs are simply not growing at the same rate as graduate admissions. In biomedical research, the mismatch in supply and demand has now been widely recognized. Other disciplines have begun these discussions, but for smaller fields, employment trends are more difficult to identify because they are subsumed in aggregated national statistics. For non-biomedical biological fields in particular, such as ecology, using biology statistics may be inappropriate since trends within the field may be obscured by the strong signal from biomedical disciplines. Here, we use the 2013 Survey of Doctorate Recipients (SDR) to investigate career paths for ecology Ph.D. recipients in the United States, and present the first fine-scale national profile of careers in ecology. Our results demonstrate that while involuntary unemployment is low for ecology Ph.D. recipients (3.3%) and job satisfaction is high, the assumptions of the prevailing apprenticeship model are inappropriate: Less than 20% of employed recent ecology Ph.D. graduates are in tenure-track positions at a Ph.D.-granting university. Accordingly, proactive steps could be taken to create more realistic expectations about graduate training and preparation for diverse careers. Further, the SDR data provide demographic profiles for ecology. Ethnic diversity has remained low in ecology (7.5% non-Caucasian for Ph.D. recipients since 2000). Gender balance in career-track positions appears to have improved by multiple metrics. However, women are overrepresented in non-tenure-track academic positions, where access to resources that support professional advancement may be limited relative to tenure-track jobs, and salary disparities appear for women in private academic institutions. Thus, while there is much good news in these data, we suggest that ecology as a field would benefit from (1) a broad analysis of the training required to make Ph.D.s best prepared for jobs outside of the research-oriented tenure track and (2) continued attention to increasing diversity and equity.

Key words: academic apprenticeship model; career path; ecology; Survey of Doctorate Recipients; tenure.

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INTRODUCTION

Concerns have been raised across academia about the quality of training Ph.D. students receive relative to the job market. Specifically, a mismatch is suggested by the common practice of training Ph.D. students in an apprenticeship model—that is, faculty train their students to become faculty in a Ph.D.-granting institution—when tenure-track placement averages approximately 25% across all science, engineering, and health fields (NSB 2014). In spite of this statistic, a

recent survey of science graduate students (Woolston 2015) revealed a continued, strong cultural bias moving students toward pursuit of academic jobs. Approximately 78% of students anticipate pursuing academic careers; the students report that only half feel their advisors would support any non-academic career aspirations, and about one-third of advisors provide advice on non-academic job searches. Cautions against continuing academic support for this apprenticeship model are well founded, and they are not new (Stephan 1996). The discussion at last is garnering significant attention, including the National Science Foundation's (NSF) 2014 establishment of the NSF Research Traineeship program, which emphasizes broader training for diverse career paths.

At least two questions loom large with the recognition that an apprenticeship model is mismatched with the statistics of academic career placement. First, is science overproducing Ph.D.'s relative to overall demand, across academic and non-academic jobs? It is entirely possible that demand for scientists might be satisfied by Bachelors- and Masters-level candidates (Gould 2015, NSB 2015), which would argue for restructuring academic research groups with fewer Ph.D. students and postdoctoral trainees. Such reorganization would have important economic and structural implications for the research endeavor at universities (Stephan 2012). Second, how should Ph.D. training best prepare students for the Ph.D.-level work that is available outside of the tenure track? There already is strong suggestion that academic advisors may not all be prepared to help students gain non-academic employment (Woolston 2015) so such career counseling is a general area for improvement. Assuming that graduating students attain non-tenure-track positions—unemployment among science Ph.D.s is consistently low—their training may lack certain skills to function outside of the academic roles in which they apprenticed (NSB 2015).

In biology, alarms have been raised about this issue by the biomedical community, which arguably may have experienced the greatest extremes in funding, Ph.D. production, and poor career prospects for its graduates (Alberts et al. 2014, Finneran 2014, Daniels 2015). A rapid doubling of the National Institute of Health (NIH) budget in the 1990s increased demand for graduate students, and some say created an unrealistic expectation of unlimited growth in this field (Alberts et al. 2014). After the NIH budget leveled around 2003, the problems became more evident; postdoctoral appointments became increasingly lengthy holding patterns for newly minted Ph.D.s and hypercompetitive conditions have reduced funding probability (Alberts et al. 2014, Daniels 2015). The calls for reform that rally around these statistics are motivational for all scientists to examine trends within our specializations.

Among biologists, teasing apart trends for specific fields is particularly difficult because of the strong signals in the comparatively large subdisciplines involved in biomedical research. Many or most ecologists, evolutionary biologists, systematists, and other biologists have never had access to NIH funding that drove the biomedical trends, and the numbers of Ph.D. recipients in these fields are dwarfed by those in biomedical research. Partly due to their smaller numbers, these fields of biology are typically subsumed in the national statistics for biology, which protects individual identities of survey respondents. Thus, interpreting trends for biology without parsing disciplines more finely may create either too much or too little alarm (Xue and Larson 2015) about prospects for our biology workforce outside of the biomedical endeavor.

Of biology's subdisciplines, ecology typifies a field for which (1) its statistics are swamped by those of biomedicine, and therefore unknown, and (2) career prospects differ from those of biomedical research, not necessarily for better or for worse. Indeed, Martin (2012) highlights ecology's need to disentangle its statistics for targeted analysis of employment trends. There is no a priori reason to expect that placement of ecologists in tenure-track academic positions is higher than that of biomedical researchers, and there are some suggestions that this placement is similarly low (Hansen et al. 2014). However, jobs outside of academia probably fit a different profile for ecologists in ways that could substantially alter their trends in placement and career profiles. For example, there may be less private sector investment in ecological research than is apparent in the biomedical research endeavor, but potentially more demand for ecologists in non-profit environmental organizations.

Having recognized that we may have a problem with matching academic preparation with available careers for Ph.D. recipients, the next logical step is to learn about the extent and

nature of that potential mismatch. In the United States, NSF houses the National Center for Science and Engineering Statistics (NCSES), which collects fine-scale data appropriate for these analyses in the form of the Survey of Doctorate Recipients (SDR). Much of the publicly available data is aggregated to the level of biological/agricultural/environmental life sciences, and specific information about career paths is necessarily broad. This obfuscation is especially true for ecology, which is grouped into the subgroup "other biological sciences" with disciplines from neuroscience to botany to bioinformatics.

National Center for Science and Engineering Statistics can provide raw data for researchers to analyze trends within subdisciplines that are normally aggregated in the public data and reports (NCSES 2014). Previous surveys of ecology career trends that did not use these fine-scale data (Martin 2012, Hansen et al. 2014) have revealed suggestive trends. Use of the NCSES raw data, which is collected through a stratified random sampling design, allows broader inference as well as a wealth of contextual information. Here, we present the first analysis of the SDR data at scales both broad and fine enough to profile contemporary ecology careers.

Methods

We used the 2013 SDR raw data to assess career paths and profiles of ecology Ph.D. recipients. Upon receipt of these data, strict confidentiality protocols were followed to protect identity of survey respondents (although names were not included in the data to which we had access). Detailed methodology regarding the 2013 SDR sampling design is available in NORC (2014). In brief, the design integrates the National SDR (U.S. doctorate recipients still in the United States) and the International SDR (U.S. doctorate recipients located internationally during survey period) and samples existing doctorate recipients (degree prior to 1 July 2009) as well as the new cohort of recipients since the last survey (degree between 1 July 2009 and 20 June 2011). Within these sample frames, 194 strata, including sex, ethnicity, citizenship-at-birth, disability status, and field of degree, are used to allocate sampling (NORC 2014). After all survey responses were collected, those executing the survey assigned each respondent a final survey weight, to correct for oversampling of underrepresented groups and nonresponse and allow extrapolation to population statistics. In addition to survey weights, 104 replicate weights were created for each respondent using the successive difference replication method (NCSES 2015, and references therein) and supplied in conjunction with the SDR raw data by NCSES.

Our analyses included individuals who selected ecology as the field of their first U.S. science Ph.D. To avoid confounding patterns, analyses excluded the <2.5% of ecology Ph.D. recipients who subsequently earned another degree. Summary statistics (e.g., percent unemployment, average years since receipt of Ph.D.) were calculated for these ecology doctorate recipients. As career paths of ecology doctorate holders in the past decade are of more pressing concern than trends in more established graduates, we then focused the majority of analyses on the recent ecology Ph.D. recipients, that is, those who received their doctorate between 2000 and 2011. We chose to exclude postdocs from analyses focused on recent graduates, as they occupy a unique and temporary position within academic institutions and we are most interested in those graduates employed in less inherently transitory positions. More detailed analyses focused on those employed in academia, defined here as educational institutions excluding pre-college institutions, medical schools, or other educational institutions not classified as postsecondary education. Within academia, we further split the data by 2005 Carnegie classification, an indication of the overall emphasis on research activity for respondents' institutions. Where possible, we examined gender and ethnic diversity, salary, and job satisfaction across varying career pathways.

Summary statistics were calculated, and general linear models were conducted using the survey package (Lumley 2004, 2016) in R (R Core Team, 2016). This package incorporates both survey and replicate weights for the most accurate point and error estimates. Figures were created using the R package ggplot2 (Wickham 2009, 2016).

Results

Overview summary statistics

On the whole, ecology doctorate recipients have been finding jobs. Accounting for all the

ecology Ph.D. recipients in the 2013 SDR (population estimate of 9984 individuals who received their Ph.D. between 1968 and 2011), only 3.3% were involuntarily unemployed. Only 5.6% of all employed ecology Ph.D. recipients reported that their job is not related to ecology. Educational institutions were the primary employers of working graduates (66.1%), followed by government (14.8%), non-profit organizations (7.5%), and self-employed/non-incorporated or for-profit business and industry (11.7%). The gender breakdown for all ecology Ph.D. graduates since 1968 was 37.2% female and 62.8% male. This gender gap retreated for those who received their doctorate since 2000 (population estimate of 4826 individuals, or approximately half of total ecology Ph.D. recipients), with 52.3% female and 47.7% male. For these recent graduates, involuntary unemployment was equivalent (3.5%) and employment sector breakdown was similar (69.3% educational institution, 16.4% government, 8.4% non-profit organizations, and 6.0% self-employed/non-incorporated or for-profit business and industry) to the full 1968–2011 population.

Postdocs comprised 10.8% of employed recent graduates. Postdocs were 46.2% women, and together averaged 4.3 yr since degree (i.e., received doctorate degree ~4 yr before 2013, when survey was conducted). Most postdocs were employed in a higher education institution (69.5%), with nearly 20% in government positions, and the remainder in non-profits or other private sector positions. No further analyses on postdocs were conducted; all subsequent analyses exclude postdocs, in order to focus on career-track positions. An estimated population of almost 4000 individuals comprised the main subset of interest—recent (2000–2011) and employed non-postdoc ecology Ph.D. recipients—upon which all subsequent analyses were based.

Exclusion of postdocs did not alter overall employment patterns, with the majority of recent graduates working at an educational institution (Fig. 1). The nearly 70% of recent ecology Ph.D. recipients working at an educational institution were employed by the following: 52.4% at four-year universities (excluding medical schools), 11.3% at university-affiliated research institutions, 4.7% at two-year/community colleges, and the remainder at pre-college institutions, medical schools, or other educational institutions not categorized above. These trends are explored further below (see *How do career paths differ within academia?*).

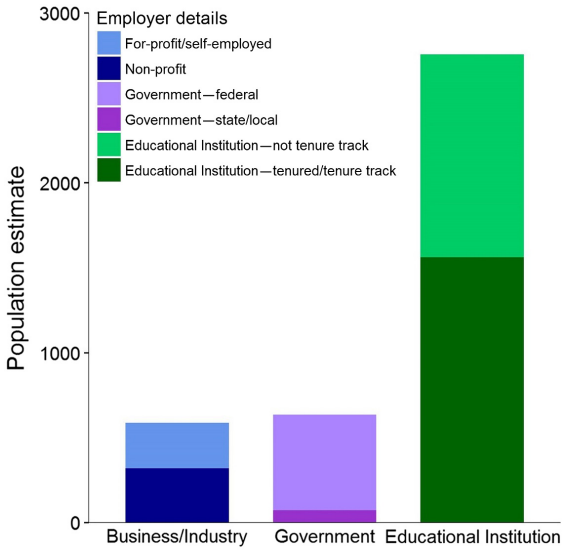

Fig. 1. Employment sectors for recent ecology Ph.D. recipients (received doctorate between 2000 and 2011) excluding postdocs. For educational institutions, note that this group includes instances where tenure is not necessarily applicable (e.g., pre-college institutions); all instances of such are included in the Educational Institution—not tenure-track subcategory.

How do employment sector cohorts differ?

As may be expected, a suite of demographics varied with employment sector. For instance, those employed in for-profit business were, on average, further along in their careers, as measured by years since Ph.D. received (Table 1). Gender balance was roughly equivalent in academia (defined here to exclude pre-college institutions, medical schools, or other educational institutions not classified as post-secondary education), and the greatest proportion of women was found in non-profit organizations. Average salary was highest in government positions and lowest in academia. Overall, no employment sector displayed gender differences in mean salary (Appendix S1), although some differences emerge with finer scale analysis (see *How do career paths differ within academia?*).

Primary work activity also varied by employment sector (Table 2). For nearly half those in academia (47.7%), teaching constituted the primary work activity. Research and development was the

Table 1. Summary statistics across employment sectors for employed ecology Ph.D. recipients who received their doctorate between 2000 and 2011 (population estimate of ~3800 individuals).

Employment sector	Of total (%)	Women (%)	Years since Ph.D. (mean)	Salary (mean)
Academia	68.2	51.4	7.9	$62,530
Tenured/tenure track	40.6	43.0	7.9	$67,567
Not tenure track	27.6	63.8	7.9	$55,115
Government	16.5	43.8	7.0	$84,900
Non-profit	8.3	68.0	7.9	$74,722
For-profit/self-employed	7.0	66.5	8.8	$82,873

Notes: Academia is defined here to exclude pre-college institutions, medical schools, or other educational institutions not classified as post-secondary education. Postdocs and those employed in non-academia educational institutions are excluded from these totals.

top primary work activity for government employees (81.8%) as well as for those in non-profits (65.3%). All sectors reported some level of management and administration, with the highest percentage of such activities in non-profits (Table 2).

Despite variation in primary work activity and salaries, job satisfaction was generally high across employment sectors. In academia, about 90% of both men and women reported being somewhat or very satisfied with their jobs. In government work, this figure approaches 100% for both men and women. The individuals most dissatisfied with their positions were those working in non-profit organizations, with 32.5% of women and 10.7% of men responding they were somewhat dissatisfied with their job.

How do career paths differ within academia?

The survey design allows the finest scale investigations within academia, at least partly because the promotion and tenure structures are consistent enough for comparisons to be made across institutions. Accordingly, trends are further broken down within academia below.

Ecologists are not evenly distributed within academia (Fig. 2). Nearly half of recent Ph.D. recipients (49.5% of academic job holders) are at Ph.D.-granting institutions (Fig. 2), which support a smaller proportion of tenure-track jobs than non-Ph.D.-granting universities (Table 3). Overall, only 19.6% of recent employed, non-postdoc ecology Ph.D. recipients (781 of estimated population of 3978) are following the path assumed by the apprenticeship model, that is, as tenure-track faculty at a Ph.D.-granting university.

Gender ratios differed across types of academic institutions. Over 60% of those at Ph.D.-granting institutions were women, compared to about 42.4% at non-Ph.D.-granting institutions. The proportion of men who had already received tenure or were on the tenure track at both types of institution was much higher than that of women (Table 3). The gender difference in tenure status at non-Ph.D.-granting institutions is potentially confounded by years since degree, with men at these institutions having more years of experience (Appendix S1; $P = 0.046$) than women (2.0 yr on average). However, years of experience did not differ between men and women at Ph.D.-granting institutions (Appendix S1; $P = 0.91$), such that experience could not reasonably account for the much higher proportion of men tenured or in tenure-track jobs at Ph.D.-granting universities.

Table 2. Sector-specific summarized work activities of employed ecologists (excluding postdocs and those employed by pre-college institutions, medical schools, or other educational institutions not classified as post-secondary education), who received their doctorate between 2000 and 2011.

Employment sector	Research and Development	Teaching	Management/Administration	Other
Academia	39.6	47.7	11.1	1.54
Government	81.8	0	5.3	13.0
Non-profit	65.3	0	26.3	8.5
For-profit/self-employed	43.3	0	11.5	45.2

Note: Values are percent of total within employment sector.

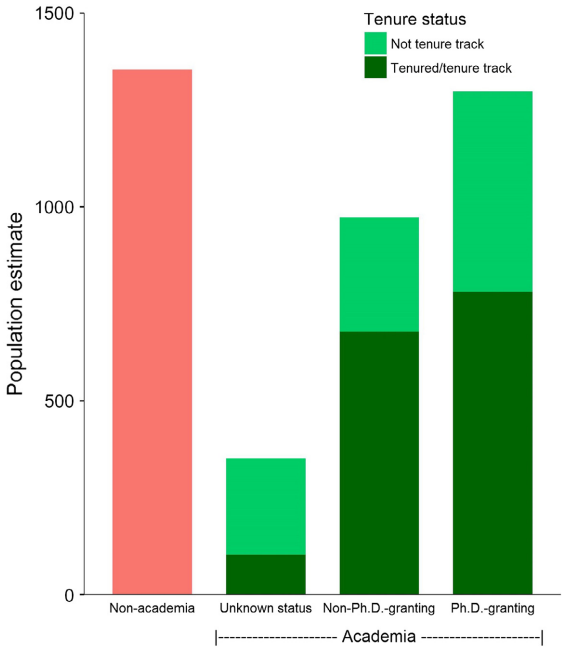

Fig. 2. Tenure status for recent ecology Ph.D. recipients (received doctorate between 2000 and 2011) employed in academia (defined here to exclude pre-college institutions, medical schools, or other educational institutions not classified as post-secondary education). Ph.D. granting status of academic institution was determined by 2005 Carnegie classification as specified in the 2013 Survey of Doctorate Recipient data. Non-academia individuals are displayed for comparison.

What about differences in daily work activity? Nearly 90% of those at non-Ph.D.-granting institutions reported teaching as their primary work activity, compared to about 15% at Ph.D.-granting institutions. At Ph.D.-granting institutions, research and development was by far the top primary work activity (approximately 70%). This difference in work activity between academic institutions did not differ by tenure status, such that both tenure-track and non-tenure-track individuals at Ph.D.-granting institutions reported research and development as their main work responsibility, while teaching was the main responsibility for both tenure-track and non-tenure-track individuals at non-Ph.D.-granting institutions.

Also of interest from a career path standpoint were differences between public and private academic institutions. Across all academic institutions (Ph.D.-granting, non-Ph.D.-granting, and unknown), 75.4% were public. Ratio of public to private varied by institution type, from 65.8% public in non-Ph.D.-granting institutions to 82.2% in Ph.D.-granting institutions. Average salary did not differ between public and private institutions (Appendix S1; $P = 0.37$). However, there was a gender difference in average salary at private institutions (Appendix S1; $P = 0.04$), with men earning over $12,000 more than women. This gendered pay differential was not found in public institutions (Appendix S1; $P = 0.69$).

Discussion

These fine-scale, national survey data offer important insights into the life history of ecologists under changing conditions and can inform decisions about the training and advancement of young ecologists.

Mentors and students will be encouraged to see that ecologists have been getting jobs and largely express satisfaction. Concordant with overall trends for science, unemployment for Ph.D.-level ecologists was very low, at 3.3% in 2013. This level compares favorably to the national averages of unemployment in the United States in 2013 (7.4%; Bureau of Labor Statistics, U.S.

Table 3. Tenure and gender breakdown for ecology Ph.D. recipients who earned their doctorate between 2000 and 2011 and were working in academia during the 2013 Survey of Doctorate Recipients reference week.

Status	Percentage of academia	Overall % tenured or tenure track	Overall % Women	Women % tenured or tenure track	Men % tenured or tenure track
Non-Ph.D.-granting	37.1	69.6	42.4	53.5	81.6
Ph.D.-granting	49.5	60.2	62.6	52.2	73.4

Notes: Responses are summarized for those employed in Ph.D.-granting institutions (population estimate of 1300) and those employed in non-Ph.D.-granting institutions (population estimate of ~1000). Note that percent of academia totals <100%; the remaining 13.4% of institutions had unknown Ph.D.-granting status and are not included in this table.

Department of Labor 2016) and similarly to other Ph.D. recipients in science and engineering (2.1%; NCSES 2014). Further, the percentage of recent, non-postdoc ecologists who reported being satisfied was so high that quantitatively evaluating the reasons for unhappiness was not possible without compromising respondent confidentiality. However, it should be noted that job dissatisfaction can reduce the probability of survey response (Rogelberg et al. 2000) and even the most comprehensive survey designs may be challenged by such unpredictable factors.

Our results suggest that in recent years, most ecologists have not followed their advisors' paths into tenure-track jobs at Ph.D.-granting institutions, the destination career assumed by the apprenticeship model. Only 19.6% of the recent graduates in ecology are employed in such positions. The finding that the majority of ecology Ph.D.s are not on the tenure track is consistent with other studies and essays (Hansen et al. 2014). Based on raw data from a rigorously designed stratified random sampling effort of Ph.D. recipients across the Nation, analysis of the SDR data represents the most robust characterization of science career trends currently possible. Our aim is that publication of this result will reduce, if not remove, uncertainty that may still exist among academic mentors and administrators, as well as their current or prospective graduate students, such that proactive steps will be taken to create more realistic expectations about graduate training.

Positive actions include altering dialog with students about careers, addressing unconstructive sociocultural attitudes about careers outside of the research-oriented tenure track, and modifying tenure and promotion standards to reward mentors' commitment to student success. The lack of transparency about career options for science Ph.D. students has been identified as a major shortcoming in American graduate education (Council of Graduate Schools and Educational Testing Service 2012). National scientific leaders see a serious conundrum in that academic mentors steer students toward academic jobs that do not necessarily exist, while the United States continues to anticipate that higher education in the sciences will be increasingly critical to national prosperity and international competitiveness (Xue and Larson 2015). Without a clear understanding of careers with future demand that are well matched for specific fields, the most generalizable recommendations (e.g., Schillebeeckx et al. 2013, Gould 2015) are for faculty to (1) discuss careers early and often with students, (2) help students to network with non-academic colleagues who can provide both role models and valuable insights into competing successfully for non-academic jobs, (3) encourage students to do internships with non-academic organizations, which provides both experience and a credential, and (4) cultivate entrepreneurship, through formal or informal training. Such actions will help send the message that landing a job outside of the tenure-track research university is both expected and valued. While it should go without saying that it is unacceptable for our trainees to have any sense of failure when they are not employed on the research-oriented tenure track, unfortunately there is evidence that this attitude still exists (Patton 2014, Woolston 2015). Such attitudes may not be caused by—but are probably perpetuated by—institutional systems in academia that reward high production of Ph.D.s (e.g., Association of American Universities standards focused on number of Ph.D.s produced) and penalize faculty mentors whose graduates do not go into tenure-track research university jobs (e.g., tenure and promotion standards that articulate this preference). Revision of such standards would signal that student success, whether that takes the form of an academic career or not, is a central aspiration for universities.

With the myth of tenure-track research-focused apprenticeship thus soundly dismissed, where are ecology Ph.D.s? Many are in non-tenure-track (non-postdoc) academic positions, as well as tenure-track positions at non-Ph.D.-granting universities. Ecologists outside academia are roughly evenly divided between government, non-profit organizations, and the private sector. Those in non-tenure-track academic positions may have positions with wide diversity in duties, stability, and salary, especially dependent upon the university's Ph.D.-granting status. The degree to which these positions can be considered stable or career track is unclear. Universities struggling to adapt to new financial models are increasingly hiring non-tenure-track faculty to provide teaching, with varying levels of university commitment—some may have longer term contracts and clear

opportunities for advancement and institutional leadership while at the other end of the spectrum, the status of contingent or adjunct faculty can be far less attractive (Baldwin and Chronister 2002, Feldman and Turnley 2004, Kezar and Sam 2013). An equivalent proportion of ecologists in non-tenure-track academic jobs report research (42.0%) rather than teaching (41.3%), as a primary activity. These positions may be those of project scientists employed as research faculty or program managers employed as academic professionals. Again, a diversity of employment conditions (e.g., contract duration and professional advancement) can apply to such positions, and stability may vary a great deal, with potential for some to be dependent on soft money or to be at least partially funded by university coffers. To the extent that the apprenticeship model prepares students to do research and teaching in a university, these ecologists may or may not feel well prepared for the positions they occupy. Whether on the tenure track or not, for those in non-Ph.D.-granting institutions, teaching is clearly the primary work activity. Graduate programs in ecology likely vary in the extent to which they have prepared trainees in teaching, project management, and the entrepreneurial pursuit of external funding. Programs such as Faculty Institutes for Reforming Science Teaching (FIRST IV), which prepares postdocs to be top-notch educators (Ebert-May et al. 2015), are national resources for such training and might be usefully emulated to address this need.

Lurking in these numbers is a necessary discussion about access to resources. Unless they are employed full-time to teach or run a specific program, non-tenure-track academics likely have some expectation of pursuing external funding. Thus, it is a pool of colleagues that cannot grow indefinitely without substantially reducing everyone's access to external funding. Environmental funding at the National Science Foundation remains flat, and funding rates now hover at 5–8% in NSF's Division of Environmental Biology and Integrative Organismal Systems (Watanabe 2014). As universities encourage the growth of non-tenure-track positions, it must be acknowledged that the universities are increasing competition for a limited resource among all their scholars—whether on the tenure track or not.

Outside of universities, 81.8% ecologists working in government report primary effort in research, and those working in non-profit organizations report 65.3% effort in research. Salaries for these jobs tend to be higher than those of academics. Traditionally, government jobs have been viewed as relatively stable, with clear paths for advancement; however, the use of contractors in preference to permanent employees has greatly increased since the 1980s (AAP 2007) and it is difficult to discover information about the nature of their positions. Similarly, stability and advancement may vary to an unknown degree across non-profit organizations. The extent to which training has prepared these ecologists for government or non-profit jobs is also not clear from the SDR data. However, a recent survey of non-academic jobs related to conservation (Blickley et al. 2013) highlights some of the needs for additional skills beyond those normally provided by an apprenticeship model.

Blickley et al. (2013) reviewed job advertisements and interviewed conservation professionals with experience hiring Ph.D.-level scientists in the U.S. government, non-profit, and private sectors. All sectors called for not only disciplinary expertise but also interpersonal and project management skills. Other desired skills varied by sector but included outreach, communication, program leadership, and fundraising. Professionals interviewed indicated that a highly qualified candidate who is missing one of the top skills would not be disqualified; rather, they would immediately begin formal or informal training. However, they also emphasized that it is a competitive marketplace such that one missing skill may be where the bar is set. These professionals considered activities outside of dissertation work to be the best signals for most of these non-disciplinary skills. Although the SDR data do not contain a large number of individuals in the non-profit or private sector, Blickley et al.'s (2013) study certainly highlights the availability of such jobs, at least for conservation-oriented ecologists. A potentially important difference for the private sector was that evidence of technical and information technology skills was explicitly valued, and coursework was not sufficient to signal proficiency in these skills to these employers. Overall, the variation among sectors suggested that graduate students should

start working on gaining specific skillsets relevant to the desired sector of work, well before Ph.D. completion.

For over two decades, ecology has worked toward greater gender balance and inclusion of underrepresented groups, as represented by the 1993 formation of the Ecological Society of America's (ESA) committee on Women and Minorities in Ecology (WAMIE). The 2006 report (Ortega et al. 2006) portrayed a male-dominated Caucasian community of professional ecologists, with women constituting only 26% of ESA membership, unchanged over a decade since the establishment of WAMIE. Similarly, ethnic minorities had changed little over time, comprising 8.8% of ESA membership. Lockwood et al. (2013) found some improvement in ESA membership diversity in 2011, with women comprising one-third of members. While the 2013 SDR data we analyzed do not allow a rigorous analysis of trends over time, such an analysis is possible with additional data requests to NCSES for previous years' raw data. Without these prior years of SDR data, we still can compare composition of ecologists in the 2013 SDR survey to that of the 2006 WAMIE report.

Our results suggest substantial progress in balancing gender among gainfully employed Ph.D.-level ecologists, although with some specific areas of gender disparity remaining, and far less evidence of progress in other measures of diversity. Non-Caucasian ecologists are so rare (7.5% of recent ecology Ph.D. recipients) that data cannot be parsed at finer scale (e.g., by sector) without potentially compromising confidentiality of SDR respondents. In contrast, women now comprise 53.4% of recent graduates working in non-postdoctoral professional appointments and vary from 44% to 68% depending on sector. Given this gender balance, it is somewhat surprising that women only account for 37% of the current ESA membership (Beck et al. 2014). A high proportion of younger ESA members are women (55% of members under 30; ESA Education and Human Resources Committee 2006), indicating the potential for greater gender balance of ESA in the future if retention can be maintained. While gender balance is good overall, disparities do emerge, however, consistent with some trends identified in earlier reports for ecology (Ortega et al. 2006). For instance, men held a higher proportion (57%) of tenure-track positions across institutional type. Although the gender disparity in holding a tenure-track position at non-Ph.D.-granting universities is potentially confounded by years of experience, no such trend explains the difference at Ph.D.-granting universities. In addition, there is a striking salary gap between men and women (over $12,000) at private academic institutions. This difference was not apparent at public universities.

The reasons that women may be treated differently in academia have been explored in great detail elsewhere (reviewed in Hill et al. 2010). Here, we briefly discuss a non-exhaustive list of potential factors. Women's contributions may be differently valued by colleagues, due to unconscious bias expressed by both men and women (Budden et al. 2008, Moss-Racusin et al. 2012, Boring et al. 2016). Women's performance measures may also differ because they operate differently than men on average. For example, they may be more collaborative (Zeng et al. 2016), or more likely to promote junior colleagues' first-authored publications (Pezzoni et al. 2016), which can be penalized where reviewers are looking for single- and first-author contributions by faculty (Sarsons 2017). Finally, women frequently report spending more time on undergraduate instruction than men, at the detriment to research (Carrigan et al. 2011) where tenure and promotion reviews typically focus. While Ceci and Williams (2011) rejected many of these claims of discrimination, they do advance a non-mutually exclusive argument that women's occupation of non-tenure-track positions in academia constrains their access to resources that support professional activities, which undermines future success.

Our results underline the need to examine aspects of professional practices in ecology at several levels, as has been suggested for science more broadly. Currently, recent ecology Ph.D.s are largely satisfied and gainfully employed in ecology. However, there is little reason to anticipate that markets will indefinitely expand to employ emerging Ph.D.-level ecologists. The idea of limiting recruitment of Ph.D. students has been treated as blasphemy in academia, in spite of decades of research on the structure of science that have emphasized the inherent instability of current practices (Stephan 1996, 2012). Leaders in the biomedical research community, where these

instabilities are now evident (Alberts et al. 2014, Finneran 2014, Daniels 2015), have suggested that some of the reliance on graduate student labor for productivity in the university laboratory might usefully shift toward permanent staff scientists. Increasing the ratio of staff to students would require changes within laboratories, universities, and also funding agencies. Whether or not ecology makes this shift over time, this study makes clear that ecology Ph.D. recipients currently occupy a wide range of career-track positions, and an assessment of training needs to best support these careers is in order. Information about these training needs could be gained from surveys of established ecologists across the full range of prospective careers, building on the surveys executed already for conservation careers (Blickley et al. 2013). As a relatively small community of researchers who now have fine-grained data on our Ph.D. recipients in hand, ecologists may be well poised to invigorate this conversation, and make constructive changes in our culture and practices.

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