The future of ecology: a collision of expectations and desires?

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When developing recommendations for sustaining a biotic community, it would be reasonable to ask: (1) what is the present structure of the community, (2) what are the likely changes in the structure of the community, and (3) what management practices align with these changes? These questions also apply to the human community comprising the field of ecology. Two of this community's most pressing dynamics are potential changes in generational and gender perspectives (race and ethnicity are also important but beyond the scope of our study).

Younger scientists may find satisfaction in different ways than the old guard; we have moved from silent springs to warming winters. At present, a 25-year-old PhD student has never known a time without the US Endangered Species Act, was a year old during the massive fires in Yellowstone National Park, and was a toddler when the Exxon Valdez ran aground. This ecologist has experienced a world dramatically different than that of her 60-year-old mentor.

Along with a new generation comes change in the gender composition. In 1966, women represented about 12% of the PhDs in the biological sciences; by 2006, they earned nearly 50% of these doctorates (Hill et al. 2010). In 2003, women made up 20% of the scientific and technical workforce in the US as compared with just 3% 40 years ago (Groop 2006). However, more than half (52%) of women scientists quit by mid-career (Hewlett et al. 2008), a rate that is markedly higher than that for men (Groop 2006; AWIS 2012a), so gender imbalances persist.

Although specific beliefs about age and gender patterns in ecology may be based on the personal experiences of different individuals, our concern pertains to developing rigorous, objective data from which to infer potential and ongoing changes in the social structure of ecology. Previous studies have found that the relatively poor retention of women in science may be partially explained by social factors, such as their bearing disproportionate responsibilities for child care and the challenges of balancing “life and career” (Baker 2011). Another important and largely overlooked consideration is the effect of individual perspectives and preferences among scientists in generating dissonance among institutional missions, disciplinary goals, and personal fulfillment. Our survey of the Ecological Society of America’s (ESA’s) membership examines whether young/old, female/male ecologists work and derive professional satisfaction in the same ways. We then consider what needs to be done in the coming years to advance ecological science, assuming that diversity contributes to this goal.

Methods

Although ESA has more than 9000 members, our sample frame was restricted to 6083 non-student, US-addressed ecologists, of which 1283 individuals, or 21%, responded. From 14 to 25 April 2011, we administered an online survey – consisting of 56 questions organized into five sets – to this group. Only the first set is addressed in this paper; analyses of the other responses are forthcoming. The first set of questions addressed who we are and what provides professional satisfaction:

(1) Age
Response options: decadal intervals.

(2) Gender
Response options: male, female, other.

(3) Highest academic degree
Response options: BS/BA, MS/MA, PhD/MD/or equivalent.

(4) Nature of your employment
Response options: self-employed; corporate, private; government; not-for-profit; academic; other.

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(5) Primary domain(s) of your ecological inquiry (choose up to 2)
Response options: organisms; populations; communities; ecosystems; landscape (aquatic or marine systems); biosphere; other (two choices permitted).
(6) Primary method(s) you use to perform your research (choose up to 2)
Response options: field observations; field experiments; laboratory experiments; modeling; meta-analysis/data mining; other.
(7) Professional activity(-ies) that provide(s) the most personal satisfaction (choose up to 2)
Response options: field work; design and implementation of experiments; data analysis and synthesis; written communication of findings; oral communication of findings; classroom teaching; working with individual students; program management; other.

As with any survey of this nature, there is potential for bias resulting from systematic differences between those who elected to respond and those who did not. However, we believe that the relatively high response rate offers confidence in the generalizability of our results. Moreover, in cases where we were able to match the distributions of variables of our sample with those reported by ESA, we found no significant differences. For example, our sample contains 32.6% females, while ESA reports 32.1% females within the sampled population.

To analyze the relationship between age and gender, we used a chi-square test and Pearson’s correlation. For the analyses of academic degree and employment (one response permitted) as a function of age and gender, we used a chi-square test. Analyses of the primary domain(s), method(s), and satisfaction(s) (two responses permitted) as a function of age and gender were conducted through the use of binary logistic regression. We conducted the analysis of age by the various factors, using the 30–69 year cohort (93% of respondents) because younger (<30 years) and older (>70 years) age categories had extremely lopsided gender distributions (eg 3 of 47 ecologists in their 70s were female, whereas 22 of 28 ecologists in their 20s were female). In the analyses of the role of gender by the various factors, we used both the entire dataset and only the academic respondents (64%). Analyses were performed with IBM SPSS 19; differences were considered significant at P < 0.05. There are an enormous number of analytical possibilities with survey data such as these, and individuals interested in conducting further analyses can access the data through coauthor DSR.

Who are ecologists?

Assuming that ESA membership is representative, ecology is a graying field. Most respondents (54%) are >40 years of age, with the largest proportion (32%) within the 50–59 age range. In 1992, 50.2% were <40, with 41% being in their 30s (Lawrence et al. 1993a). Today, less than one-quarter (24%) are younger than 40. The modal age of ecologists is now 55 years (average 44.2), as compared with a mode of 35 years (average 42.3) in 1992. If one randomly picked an ecologist from a gathering today, that individual would be 3.4-times as likely to be over the age of 60 as would have been the case in 1992. In sum, professional ecologists have become middle-aged (Figure 1).

Ecology is also a feminizing field. One-third of ecologists are female (Figure 1), as compared with less than one-quarter (23%) in 1992 (Lawrence et al. 1993a). In spite of that trend, ecology today has a lower proportion of women than the biological sciences in general (53%). Our gender profile is similar to that of chemistry and material sciences (33% women) and the environmental and geological sciences (29%; Hill et al. 2010).

The other demographic features of ecologists are unsurprising. Ecologists are highly educated, with 84% having doctorates. Most are employed in academia (64%), followed by government (17%), with all other categories of employment representing <10% each. In short, most ecologists are among the ranks of the professoriate (Figure 1).

Among the domains of ecological inquiry, communities (26% of responses) and ecosystems (25%) are most frequently studied. With half of all ecologists engaged in these two subdisciplines, no other domain exceeded 20%. Organismal, population, and landscape ecology ranged from 12–18% of responses, and just 2–3% of ecologists study the biosphere or some other domain. As such, the core of contemporary ecology is the community and ecosystem (Figure 1).

Despite the preponderance of analytic instrumentation and computer models, field observation remains our primary method, as identified by 65% of respondents. Field experimentation was the next most common approach (50%). Modeling, laboratory experiments, and meta-analysis each accounted for 14–25%. So, ecology remains primarily a field science (Figure 1).

In terms of professional satisfaction, field work is the leading source (50% of responses). The next most satisfying activity is data analysis and synthesis (38%). Other research-based activities (design and implementation of experiments and written/oral communication of findings) were chosen by 12–23% of respondents. Classroom teaching and individual mentoring of students provide satisfaction to only 15% and 22% of ecologists, respectively. Program management comes in at just 8%. In sum, we derive satisfaction primarily from research, with teaching a distant second, and administration far behind (Figure 1).

On the basis of this survey, we can describe today’s “typical” ecologist as a 55-year-old male professor who studies communities and ecosystems using field observations and experiments, and who finds professional satisfaction in his research. Twenty years ago, the description would have been a 38-year-old male professor studying aquatic communities (Lawrence et al. 1993a,b,c). However, not all individuals who define themselves as ecologists are members of ESA, and if we included limnologists,
Who are ecologists becoming?

As might be expected, there is a significant relationship between age and gender, with the proportion of females decreasing as the age class increases ($\chi^2 = 101.3$, $P < 0.001$; Pearson’s correlation $\tau = 0.280$, $P < 0.001$). With this interaction, we must keep in mind that differences about age (or gender) may reflect the influence of the other variable (eg if young ecologists frequently engage in some practice, this may also be a function of gender). However, there were also significant differences in domains, methods, and satisfactions that tracked age but not gender and vice versa when the effects of age and gender were used to control for each other (Table 1).

The young and the restless

Although a significantly larger proportion of older ecologists have their doctorates (32% of those < 30 years versus 83% of those ≥ 30), we assume that the upcoming cohort will soon earn doctorates. And if hiring reflects the shifting demography (younger ecologists can be hired at lower salaries than more experienced scientists in a time of tightening university budgets), we can anticipate that academia in particular will become younger. We already see that for the entire 30–69-year cohort: those in academia are significantly younger than are those who are self-employed or engaged in “other” employment.

With regard to domains of inquiry, younger ecologists are significantly more prevalent in community and ecosystem ecology, suggesting a shift away from such endeavors as organismal and population ecology (Table 1). The responses to the primary method being used by ecologists indicate that laboratory experiments and modeling are significantly more common among young scientists, while field studies are significantly more often carried out by older ecologists (Table 1). Thus we can expect a shift from “outdoor” to “indoor” ecology, although longitudinal studies will be needed to see whether this change persists.

Perhaps most tellingly, the upcoming generation of ecologists seems headed toward professional dissatisfaction (Table 1; Figure 2). Although younger ecologists do not report a significantly greater use of field observations and experiments, they derive markedly greater professional satisfaction from such work than do older ecologists. In other words, there is an emerging gap between what ecologists do and what provides satisfaction.

In numbers too big to ignore

With the significantly negative relationship between age and gender in ecology (Figure 2), if gender-based retention rates equalize, ecologists can expect a shift in gender composition given a substantially greater proportion of females in the younger age classes (70% of those 20–29 years of age and 49% of those 30–39, as compared with just 35% in their 40s and 27% in their 50s). As such, parity or even a predominance of women in ecology is plausible in the foreseeable future. If so, we should analyze how women are employed, what methods they use, and how they find professional satisfaction.

Significantly more males than females are in corporate/private positions, while the situation is reversed for “other” forms of employment. Therefore, as the proportion of women increases, we might expect a diversification, by preference or necessity, of how ecologists make a living.

Perhaps the most dramatic change will be manifest in methodology (Table 1). Women show a significantly higher composition given a substantially greater proportion of females in the younger age classes (70% of those 20–29 years of age and 49% of those 30–39, as compared with just 35% in their 40s and 27% in their 50s). As such, parity or even a predominance of women in ecology is plausible in the foreseeable future. If so, we should analyze how women are employed, what methods they use, and how they find professional satisfaction.

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Figure 1. The current status of ecologists who are non-student ESA members (note that, for “Domain”, “Method”, and “Primary Satisfaction”, subjects could select up to two responses).
while males report a markedly greater use of modeling and meta-analysis. The shift from outdoor ecology may reflect the challenges of conducting fieldwork by female ecologists with child-care responsibilities (McGuire et al. 2012). If these practices persist, the future of ecology would move indoors, with women pursuing experiments and men developing models.

The sources of satisfaction for men and women are notably different. Women report that they obtain substantially greater satisfaction from classroom teaching (20% of females listed this as a source of satisfaction, as compared to 13% of males), while men derive significantly greater satisfaction from data analysis and written communication (Table 1; Figure 2).

In sum, a substantial difference in how male and female ecologists perceive quantification is exemplified by men reporting both significantly greater use of quantitative approaches and greater satisfaction from data analysis.

**Table 1. Differences in the domain of study, method of investigation, and professional satisfaction as a function of age (30–69 years) and gender with each variable used to control for the other**

<table>
<thead>
<tr>
<th>Factor</th>
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**Notes:** Highlighted categories showed significant differences at \( P < 0.05 \), according to binary logistic regression ("ns" indicates non-significance). The raw data used for these analyses are available in WebTables 1–6.

### What do these changes mean for ecology?

As scientists who are younger than 40 years of age replace the older cohort, substantial shifts in ecology can be expected (Figure 2). If the sorts of investigations pursued by younger ecologists and the sources of their professional satisfaction persist with time, then the gap between what is primarily done by ecologists (ie laboratory experiments and modeling) and what provides fulfillment (ie field observations and experiments) might well contribute to a gradual exodus from the discipline or perhaps lower productivity. It seems reasonable to assume that ecologists will not pursue lines of research that are internally less satisfying without some external motivations, such as funding or professional rewards (eg peer recognition and promotion). We cannot predict that funding and hiring institutions would shift resources to field-based inquiry, in order to align external reward structures with personal desires. Likewise, we cannot say whether institutions would or should attempt to shift the interests of young ecologists toward laboratory and modeling investigations (eg through stimulating collaborations or fulfilling professional development). Possibly, through continued engagement with indoor science, the younger ecologists will come to derive personal satisfaction from such endeavors, but such changes are not at all certain.

Although shifts to a younger age structure may be important, the most dramatic change is that ecology is rapidly becoming gender-balanced. Assuming that gender diversity is desirable and that social engineering is a valid enterprise of a scientific discipline (Musante and Potter 2012), substantial change is on the horizon. A core question – given our conditional premises – is how to sustain diversity in the context of the challenges facing women (Baker 2011; Martin 2012).

Various explanations have been offered for why women are less likely to study science (and ecology in particular; Damschen et al. 2005) and to stay or advance in the sciences (Lawrence et al. 1993b; Sonnet and Holton 1995; Groop 2006; Xu 2008; Hill et al. 2010; AWIS 2012b). However, little attention has been paid to whether what scientists do (which presumably reflects social, institutional, and disciplinary expectations and rewards) accords with what provides professional satisfaction for women. Our study suggests a problematical act–satisfaction mismatch in ecology, from which we infer the need for changes if women are to thrive.

The classic notion is that men excel in mathematics and women excel in linguistic fields, although Hill et al. (2010) provided an opposing perspective. Although women undoubtedly can master mathematical skills (AWIS 2012c), they are more likely to pursue humanities, life sciences, and social sciences than more quantitative fields.
One explanation is that women find mathematical work less satisfying, and our results would support this interpretation. Indeed, this might account, in part, for the declining interest in population ecology, a mathematically intense subdiscipline.

Interestingly, although girls outperform boys in terms of verbal skills, and especially in writing (AWIS 2012a), male ecologists reported greater satisfaction from writing. If women are reluctant to write extensively, this might contribute to lower rates of advancement and retention. Publishing papers and obtaining grants are the conventional criteria of academic performance, and the success of female ecologists in these realms lags behind that of males (Martin 2012). Teaching is typically a less valued endeavor (Xu 2008), and this source of satisfaction strongly distinguishes women from men in ecology; this might also contribute to heavier teaching loads among female faculty (Sonnert and Holton 1995).

Women are more likely than men to favor work with a clear social purpose (Hill et al. 2010), and most people do not view science, technology, engineering, and mathematics (STEM) fields as directly benefiting humanity (NAE 2008; Hill et al. 2010). Alternatively, women may perceive classroom teaching as having a positive effect on society, and this could account for gender differences in professional satisfaction. Perhaps the disparities in rewards of male and female scientists and the fact that research-intensive universities average fewer women on the STEM faculty than other academic institutions (AWIS 2012d) reflect women’s predilection for teaching as a source of fulfillment. With regard to social purpose, our survey revealed that more women than men (8% versus 5%) are employed in non-profit endeavors, although the difference was not significant.

While there have been substantial improvements in the past 25 years with regard to workplace and household equitability for female ecologists, women still have markedly lower retention and promotion rates (McGuire et al. 2012). Our study suggests that this persistent problem may be rooted in a mismatch between what prestigious universities expect and what women find professionally enriching, instead of a specific and intentional bias against women per se. This raises a very difficult question for ecology: should we attempt to change what women find meaningful so that their interests align with the research-intensive agenda of major institutions, or should these institutions change their systems of advancement to reflect the interests of female faculty? Perhaps it is time to stop asking women if they “fit in” with their male colleagues (Hill et al. 2010) and begin asking whether our universities are prepared to reward what women have to offer and what they find professionally satisfying.

Many of the implications of our study will require further research to be fully understood. Of particular interest would be longitudinal studies to track changes in practices and satisfaction over time, follow-up studies to explore why women derive less satisfaction from writing despite their evident skill in this realm, and focused investigations looking at how women’s perception of social purpose shapes their decisions with regard to teaching. Understanding and reforming the relationship between ecologists’ desires and institutional structures will require the collaborative expertise of social psychology, cultural anthropology, educational theory, and management science.

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References


