

Dramatic Improvements and Persistent Challenges for Women Ecologists

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The underrepresentation of women in science has received significant attention. However, there have been few studies in which longitudinal data were used to assess changes over time. Here, we surveyed the Organization for Tropical Studies graduate database, because this database was also surveyed in 1988, to determine the challenges still faced by women ecologists. Certain aspects of women's situations have shown substantial improvement since 1988, such as an increased number of female colleagues, more-equal sharing of childcare and household chores, and decreased perceptions of gender bias. However, women are still more likely to leave the field of science and have lower salaries, promotion rates, and productivity than do men. Women continue to have greater responsibility for childcare and housework and also experience challenges with childcare and safety while pursuing field-based research. These results indicate that although certain obstacles for women ecologists have substantially lessened, other issues of the family–work balance and of fieldwork still need to be addressed.

Keywords: women in science, gender bias, Organization for Tropical Studies, ecology, glass ceiling

The disadvantages that women face in the sciences have been well documented (Valian 1998, Rosser 2004, Holmes et al. 2008). Consequently, numerous programs have been implemented across various granting agencies and academic institutions to facilitate the advancement and representation of women (ESA 2006). In the biological sciences, there is evidence that gender equity is increasing (Sakai and Lane 1996, Luckenbill-Edds 2002). However, there is still notable attrition of women scientists at higher levels (Xie and Shauman 2003). For example, as of 2006, women received approximately half of all biology doctorate degrees, but they hold only 41% of postdoctoral positions and less than 20% of full professorships (NSF 2008). In ecology, women have a long history of participation and achievement (Schiebinger 1989, Langenheim 1996, Damschen et al. 2005), but, as in the other biological sciences, they are still underrepresented in top positions, are paid less than their male counterparts (Lawrence et al. 1993, Sakai and Lane 1996), and are less productive in terms of their number of publications (Primack and Stacy 1997). Assessing whether these gaps are a historical legacy and are closing over time has been challenging, in part because of a lack of longitudinal data.

The purpose of this study was to follow up on previous surveys of graduates from the Organization for Tropical

Studies (OTS; Primack and Oleary 1993, Primack and Stacy 1997). Specifically, we sought to determine whether the obstacles to the advancement and productivity of the older generation of women ecologists identified in the 1988 survey have diminished over time and whether women ecologists face special limitations in carrying out fieldwork.

The survey

Since 1963, OTS has held classes in the tropics, attended by more than 5000 graduate students from leading US and international universities; the organization offers a unique pool of participants with a wide range of ages, including those continuing in science and those leaving science. Using that database, e-mails were sent to 1450 alumni (all of those with current e-mail addresses), requesting participation in the survey. The online survey's Web address was also announced in the OTS electronic newsletter.

In addition to gathering demographic data, the survey consisted of questions to measure advancement, productivity, perceived barriers to productivity, career satisfaction, the influence of mentorships, and the effect of career on family (and vice versa). These were the same questions asked in the previous survey. Several questions were added related to the respondents' ability to carry out fieldwork—a special feature of the discipline of ecology—and their decisions related to

having children (see supplemental appendix S1, available online at <http://dx.doi.org/10.1525/bio.2012.62.2.12>).

We identified changes in factors affecting women and men by comparing the differences among age and gender cohorts within the 2010 survey, as well as differences between the 1988 and 2010 surveys. The data were analyzed in several ways. First, the respondents were grouped by gender. For most metrics, the data were further analyzed by age groupings in decadal increments from respondents in their 20s to those over 60 years old, in part to account for there being a majority of male respondents in the older age groups and a majority of female respondents in the younger groups (table S1). For questions pertaining only to respondents with PhD degrees, delineations were made between junior (birthdates after 1969; 40 years old and younger) and senior (birthdates before 1970; more than 40 years old) PhDs. Most statistical analyses were done using one-way ANOVAs (analyses of variance) or Pearson chi-squared tests, unless we report otherwise, with SPSS 17.0 (IBM, Armonk, New York). Interactions between age and gender and between gender and degree were explored for all of our analyses; however, we mostly report significant results, unless a nonsignificant difference was of interest.

Education, employment, and advancement

A total of 549 surveys (approximately a 38% response rate) were collected; 48% of the respondents were female, and 52% were male (table 1). Most of the respondents were US citizens of European descent (86%). A total of 334 respondents held PhD degrees (61%), and significantly more men held both master's (51%; $F(1, 544) = 7.8, p = .005$) and PhD degrees (73%; $F(1, 547) = 30.4, p < .001$) compared with women (44% and 51%, respectively). Junior female respondents constituted 60% of all of the female respondents (57 women), and junior male respondents constituted 32% of the male respondents (78 men).

Significantly more women (15%) indicated that they had left science than did men (figure 1; 7%; $F(1, 547) = 8.5, p = .004$). The top three reasons cited by the women for leaving science were that they had more interest in other fields, that they had family responsibilities, and that there were no scientific positions available. For men, the top three reasons were a loss of interest in research, more interest in other fields, and better income elsewhere.

Of the respondents with PhDs working in academia, the percentage of full professors was significantly higher for men (23%) than for women (13%; $F(1, 270) = 12.6, p < .001$) (see figures 1 and 2). The distribution of salary rankings between men and women was significantly different ($\chi^2(5, 486) = 57.8, p < .001$), with men occupying more of the higher-salary brackets (figure 3).

Productivity

According to the metrics of self-reported productivity included in the survey, men listing themselves as *academics* or *researchers* were consistently more productive than were

Table 1. Demographic data for all respondents.

Demographic variable	Proportion of the female respondents (n = 259)	Proportion of the male respondents (n = 282)
Age		
20s	.34	.09
30s	.29	.22
40s	.10	.24
50s	.19	.17
Over 60	.08	.28
Ethnicity		
White	.84	.89
African American or Black	.03	.00
Hispanic	.06	.05
American Indian	.01	.00
Asian American	.02	.01
Mixed	.02	.02
Other	.01	.03
Education		
Bachelor's	.87	.86
Master's	.44	.51
PhD	.51	.73
Marital and familial status		
Married with children	.23	.37
Married, no children	.20	.17
Single	.57	.46
Married with children	.21	.46
Married, no children	.19	.13
Single with children	.04	.07
Single, no children	.44	.22

female academics and researchers (table 2). Both junior and senior men published more papers, wrote more books, received more grants, and were awarded more grant money ($p < .05$) than their female counterparts. When all of the men were compared with all of the women (i.e., no junior or senior categories), during the past 5 years, 41% of the men but only 22% of the women had over \$200,000 worth of grant support. Furthermore, 55% of the men but only 25% of the women had published more than five scientific articles.

Married women spent significantly less time on research than did single women ($\chi^2(6, 154) = 35.5, p < .001$), but marriage had no effect on the time that the men devoted to research ($\chi^2(6, 205) = 10.5, p = .104$) (table 3). Both women ($\chi^2(6, 153) = 32.3, p < .001$) and men ($\chi^2(6, 199) = 19.5, p = .002$) with children (table 3) spent significantly

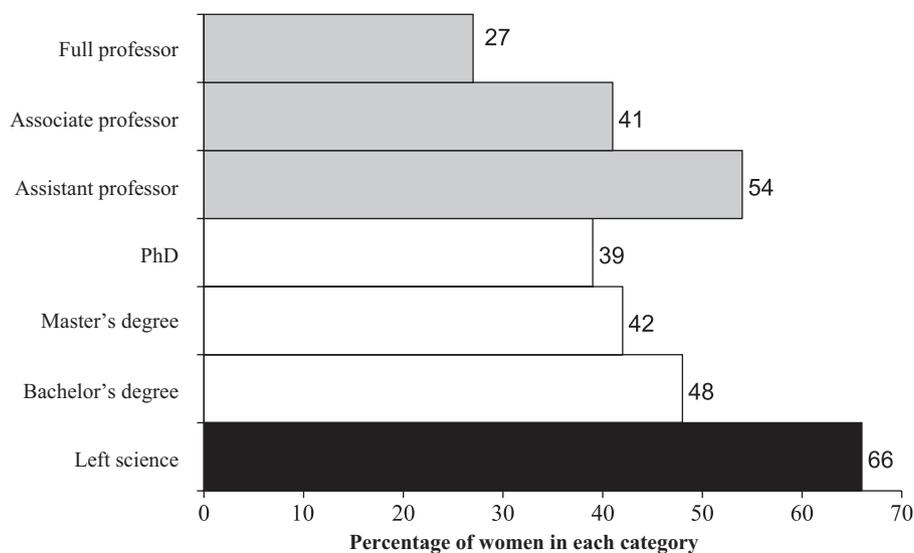


Figure 1. The percentage of women within each category of education and academic advancement, including those who left science. The low percentage of female full professors is partially accounted for by the lower percentage in courses at the Organization for Tropical Studies in the 1960s and 1970s.

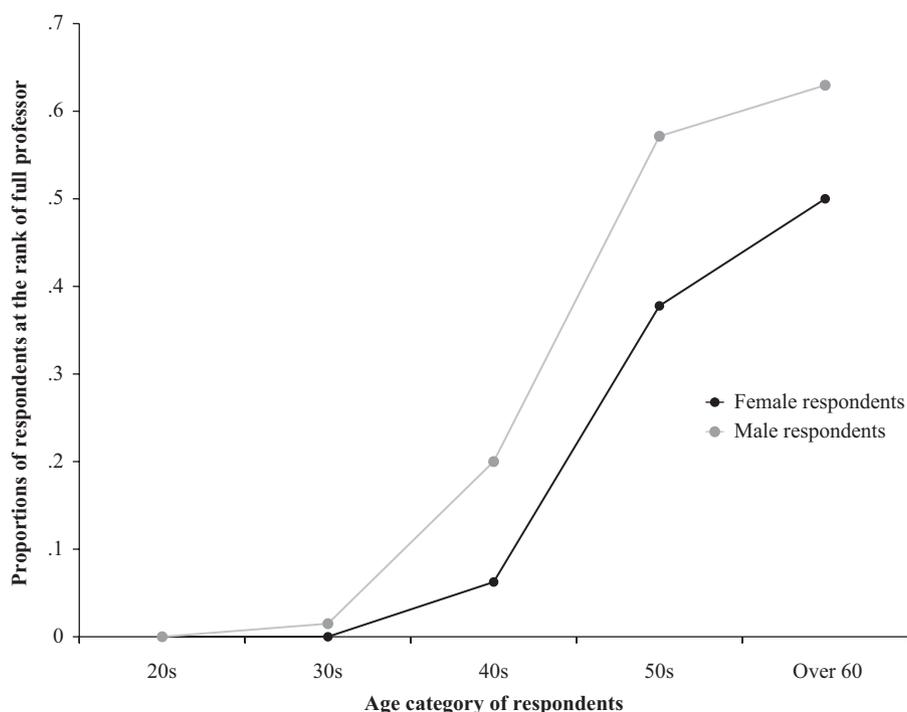


Figure 2. The proportion of the respondents from the present (2010) survey with PhDs who are at the rank of full professor as a function of age group.

less time on research than did the people without children. When broken down according to junior and senior academic ages, the married women reported spending less time on research at both the junior ($\chi^2(6, 43) = 18.4, p = .005$) and the senior ($\chi^2(5, 65) = 12.3, p = .03$) rankings than their single-women counterparts. Similarly, the female respondents with children reported less time devoted to research at both the junior ($\chi^2(6, 43) = 14.8, p = .02$) and the senior

($\chi^2(5, 65) = 17.1, p = .004$) level than the women without children. When the respondents were separately analyzed by age, being married and having children had no effect on the time devoted to research for either the junior or the senior men, possibly because of the smaller sample sizes.

Obstacles to and facilitation of productivity or career success

When they were asked about the factors facilitating productivity, the female respondents cited the importance of family ($F(1, 364) = 10.8, p = .001$) and a positive or supportive work environment ($F(1, 360) = 4.1, p = .043$) significantly more than did the men. The women also reported that mentorship was more important for facilitating their productivity than the men did ($F(1, 366) = 3.86, p = .05$). The only difference between the male and female respondents' responses in the factors holding back their productivity was that the female respondents identified gender discrimination significantly more often than did the men ($F(1, 239) = 36.1, p < .001$). The time spent on teaching was identified as a factor inhibiting productivity for both the men and the women, but there was no significant difference between them in their estimations of how much time they devoted to teaching.

When they were asked about their perceptions of whether maternity leave affected a woman's career, the women (60%) were more likely to perceive a negative effect of maternity leave than were the men (38%) ($F(1, 386) = 17.5, p < .001$). The women (24%) were also more likely than the men (5%) to perceive that their current places of employment

preferentially hired and gave tenure to men ($F(1, 373) = 45.4, p < .001$).

The respondents were asked to identify which of their colleagues—male or female—were more helpful in their workplace. The female and male respondents responded very differently to this question ($F(1, 363) = 16.5, p < .001$): About half of the female respondents claimed that their female colleagues were more helpful in their current

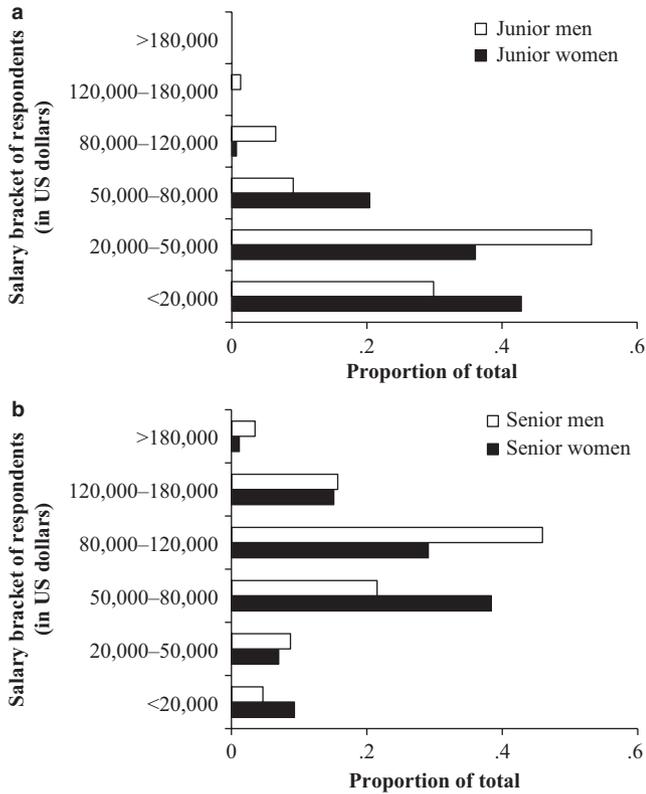


Figure 3. The proportion of male and female respondents in different salary brackets for the current survey ($p < .001$). (a) Junior respondents. (b) Senior respondents.

position, whereas about 70% of the male respondents identified male colleagues as the most helpful (figure 4).

When the responses from our present survey were compared with those from the 1988 survey, there were notable decreases in the perceived gender bias against women (figure 5). For example, both the male and the female respondents now perceive less bias in salary practices, hiring, and the granting of tenure than did those in the 1988 survey. By comparing the percentage changes across the surveys, we found that 23% fewer women now (59%) perceive that maternity leave has a negative impact on a woman’s career than did those responding to the 1988 survey (82%). Survey responses among men are also changing over time with regard to maternity leave, with 38% now saying that maternity leave has a negative impact in comparison with 53% in 1988. Moreover, in this present survey, 26% more women (50%) identified other women as their most helpful colleagues than did those responding to the 1988 survey (24%). Male respondents are also changing over time in being more likely to perceive helpful female colleagues and in their perception of maternity leave.

Work–life balance

Women with PhDs reported that they were more likely to do most of the childcare than did the male PhDs ($\chi^2(10, 122) = 47.8, p < .001$). However, this difference was only statistically

Table 2. Proportion of respondents for each age and gender category for different metrics of productivity.

Productivity metric	Senior women	Senior men	Junior women	Junior men
Number of scientific papers written				
0	.10***	.04	.05***	.00
1–5	.48***	.24	.67***	.56
6–10	.23***	.24	.26***	.21
11–20	.11***	.25	.02***	.18
21–50	.08***	.20	.00***	.06
51–100	.00***	.01	.00***	.00
>100	.00***	.02	.00***	.00
Number of books written				
0	.70	.60	.94	.93
1–5	.27	.38	.03	.07
6–10	.04	.01	.03	.00
21–50	.00	.01	.00	.00
Percentage of time to research				
<5	.11*	.08	.12	.06
6–15	.35*	.16	.09	.09
16–30	.26*	.19	.09	.06
31–50	.18*	.27	.12	.15
51–75	.08*	.22	.19	.15
76–95	.02*	.08	.19	.29
>95	.00*	.01	.21	.21
Total amount (in US dollars) of grant awards between 2005 and 2010				
<10,000	.27*	.21	.31	.25
10,000–50,000	.18*	.13	.21	.41
50,000–99,999	.06*	.04	.14	.06
100,000–199,999	.09*	.10	.19	.13
200,000–499,999	.17*	.24	.02	.13
>500,000	.23*	.29	.12	.03

* $p < .05$, *** $p < .001$.

significant between the senior male and senior female PhDs ($\chi^2(10, 82) = 32.7, p < .001$). The female respondents with PhDs also reported spending more time on household chores than did the male PhDs ($\chi^2(10, 130) = 34.1, p < .001$), but this difference was again only significant between the senior

male and senior female respondents ($\chi^2(10, 97) = 41.3, p < .001$). The junior women reported spending a smaller percentage of their time on childcare (50%) than did the junior female respondents to the 1988 survey (62%). However, the responses for the senior women were identical to those in the 1988 survey (59%). The junior male respondents reported doing an average of 34% of the childcare, which was an increase from the 28% reported in the previous survey. The

senior men also reported an increase in childcare contributions (45%) relative to those in the 1988 survey (32%). As in the past study, the women (61%) were significantly more likely to have a spouse or partner employed in a full-time, demanding career than were the male (44%) respondents (table 4; $F(1, 358) = 9.7, p = .002$); this was true for both the junior and the senior groups and among the respondents with PhDs.

Table 3. Proportion of respondents in each marriage- and family-status category as a function of the percentage of their time allocated to research.

Respondents' gender	Percentage of time allocated to research	Marriage status		Family status	
		Married	Unmarried	Children	No children
Female	<5	.05	.29	.04	.25
	6–15	.28	.13	.35	.12
	16–30	.23	.15	.20	.18
	31–50	.19	.13	.26	.10
	51–75	.15	.03	.09	.08
	76–95	.07	.10	.04	.11
	>95	.03	.19	.02	.15
Male	<5	.10	.09	.11	.07
	6–15	.14	.16	.14	.16
	16–30	.14	.19	.17	.11
	31–50	.25	.16	.24	.23
	51–75	.23	.13	.25	.12
	76–95	.10	.15	.06	.22
	>95	.03	.10	.03	.09

Note: All of the values for the female group were significantly different from those for the male group in the Married category ($p \leq .001$) and in the Children category ($p \leq .05$).

Women were more likely to report that their career influenced their decision to have children than were the men (table 5; $F(1, 463) = 33.9, p < .001$). This difference was significant across all age groups except for the men and women in their 20s. When they were asked about their willingness to relocate, the junior men and women were significantly more willing to relocate to advance their careers than were the senior men and women ($\chi^2(4, 341) = 14.3, p = .006$). When they were asked about the adverse impact of relocating for the purpose of advancing their career (in term of the relationship with a partner or effects on their children), adverse impacts were reported more often by the women (43%) than by the men (27%) ($F(1, 256) = 7.0, p = .009$).

Fieldwork

Women were significantly more likely to state they did not have an active tropical field research program (43%) than were the men (32%)

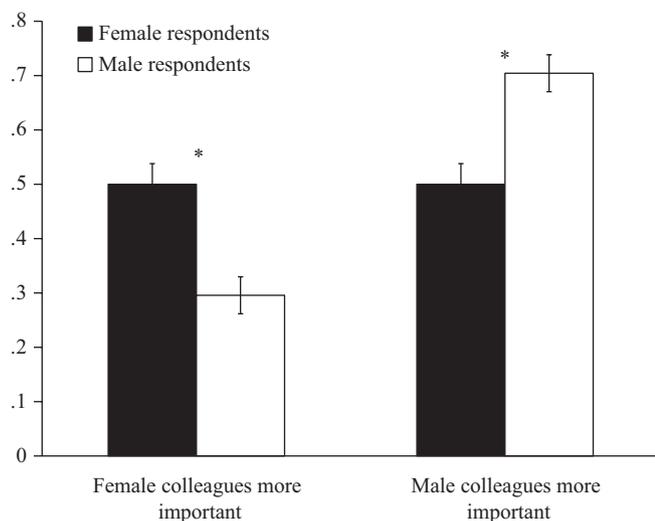


Figure 4. The reported helpfulness of male and female colleagues for female and male respondents in the present (2010) survey. * $p < .05$.

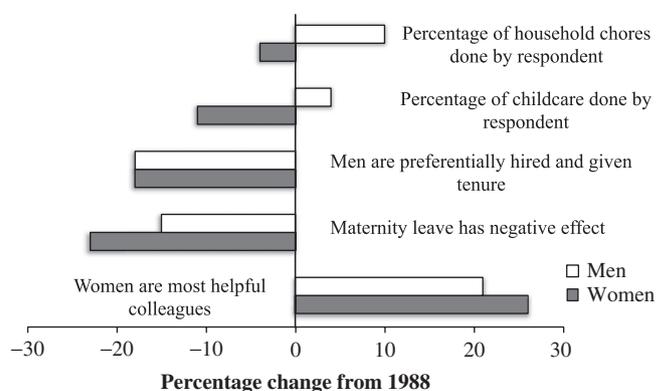


Figure 5. Percentage change in responses from the 1988 Organization for Tropical Studies survey (Primack and Oleary 1993) to the present (2010) survey for specific responses related to perceived gender discrimination and collegial support. For example, 25% more women in the present survey said that their most-helpful colleagues were other women than did those in the 1988 survey.

Table 4. Proportion of the responses of the male and female PhD-holding respondents as a function of the employment status of their spouse or partner.

Spouse or partner's employment status	Female respondents	Male respondents
Employed in full-time, demanding career	.68***	.42
Employed full-time, but not in demanding career	.11	.10
Employed part-time	.12*	.24
Not employed	.10**	.24

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 5. The probability that the careers of the respondents influenced their decisions to have children as a function of age group.

Age group	Female respondents	Male respondents
20s	.27	.08
30s	.49*	.30
40s	.52*	.26
50s	.42**	.13
Over 60	.45***	.08

* $p < .05$, ** $p < .01$, *** $p < .001$.

($F(1, 351) = 5.14, p = .02$). This pattern was present across all of the age groups but was not affected by marital status or children. Across all of the age groups, the women (45%) were significantly more likely than the men (23%) to identify personal safety as a primary factor for bringing a field assistant with them ($F(1, 368) = 21.8, p < .001$).

Relative to the men, the women with both children and a field-based tropical research program reported more often that they brought or hired someone in the field to take care of the children at the field site (table 6; $F(1, 169) = 7.8, p = .006$), that they hired someone to take care of the children at home or at a location other than the field site ($F(1, 169) = 13.9, p < .001$), or that they sent the children to a family friend or relative ($F(1, 169) = 4.08, p = .045$). By contrast, the men reported more often than the women that their partner or spouse took care of the children at home ($F(1, 169) = 6.03, p = .015$). These patterns were the same for the junior and the senior researchers.

We also compared the effect of fieldwork on the various productivity measures among all of the respondents and within each gender group. For all of the respondents, those still involved in tropical fieldwork were more productive than those respondents not involved in fieldwork in terms of the number of papers written ($\chi^2(7, 352) = 26.2, p < .001$), the number of grants received ($\chi^2(6, 352) = 36.5, p < .001$), and the total amount of grant money awarded ($\chi^2(6, 352) = 38.5, p < .001$). When these statistics were broken down by gender, the female respondents involved

Table 6. Reported childcare arrangements that the respondents with active tropical fieldwork programs use while conducting fieldwork.

Childcare arrangement	Female respondents	Male respondents
Someone is brought to or hired at the field site	.31**	.13
Someone is hired at home or in a place other than the field site	.39***	.14
The children are sent to a family member or friend	.29*	.16
The respondent's partner provides childcare at home	.69*	.85

Note: The proportions in each column add up to more than 1 because some of the respondents use more than one type of arrangement.

* $p < .05$, ** $p < .01$, *** $p < .001$.

in tropical fieldwork wrote as many papers as those female respondents who were not involved in tropical fieldwork. However, we did find that the women involved in tropical fieldwork were awarded more grants (in terms of the total numbers of grants; $\chi^2(5, 143) = 9, p = .04$), but they received less total grant money than did the female respondents not involved in fieldwork ($\chi^2(6, 143) = 16.3, p = .01$). The men doing tropical fieldwork showed the opposite pattern: They received fewer grants ($\chi^2(5, 209) = 23.7, p < .001$) but were awarded more grant money than the men not involved in tropical fieldwork ($\chi^2(6, 209) = 24.2, p < .001$).

The improving situation

The longitudinal data provided by this survey indicate that the situation for female ecologists has improved significantly in several key areas. Most notably, the percentage of women who have helpful women colleagues is now much higher than in the past. Women now more commonly hold academic and research positions, can provide mutual support to one another, and can serve as mentors and role models. The differences between men and women in terms of how their career affected their decision to have children and the percentage of childcare that they carry out are more pronounced among older ecologists than younger ecologists. As a further indicator of change, the percentage of childcare is now more equally divided between women ecologists and their spouses than it was in the 1988 survey. These findings suggest that among the younger age groupings, there is more recognition of the need to share childcare and the other responsibilities of family life. Another important finding is that both men and women now perceive much less gender bias in the workplace in terms of hiring, tenure, and salaries, and perceive fewer effects of maternity leave on female scientists than did those in the previous survey. Although gender bias has not been eliminated, there is strong evidence from this study indicating that the climate for women has dramatically improved since the 1988 survey.

It has been suggested that time will gradually resolve the leaky science pipeline for women and that many of the disparities between men and women are due to the historically low numbers of women in science (Luckenbill-Edds 2002, Holmes et al. 2008); our data provide partial support for this viewpoint. However, many of the key obstacles to women's retention and advancement may now pertain to the choices that women make in relation to the work–family balance (Ceci and Williams 2011). A higher percentage of women than men have spouses with demanding careers, and women still do the majority of the childcare and housework. The great professional demands placed on academic researchers appear to disproportionately affect women in terms of their decisions about whether to have children. These obstacles were present in the earlier study more than 20 years ago, and they are still present today, although their magnitude appears to be more pronounced in older generations of ecologists. Although numerous government and university policies have been implemented to alleviate gender discrepancies, in the end, the realities of family and personal life still place a greater burden on women in our society (Ceci and Williams 2011). The consequences of these personal choices can contribute to the observed higher rates of women leaving the field of science and their lower productivity, rates of promotion, and salaries in comparison with those of men.

Few studies have addressed issues related to gender and fieldwork (Henson 2002, Burek and Kölbl-Ebert 2007), and we found that women ecologists carrying out tropical fieldwork face greater challenges than do men. Fieldwork was correlated with increased productivity for the men, but not for the women. When we evaluated only respondents with active field research programs, we found that the lower quantity of grant money awarded to women with tropical field research programs was in stark contrast to the higher numbers of grants received by women. This observation suggests that women in tropical fieldwork may spend more time writing grants than their male counterparts, but the payoff is smaller. An alternative explanation is that women request less money in their grant proposals than do men, although we could not deduce the causal factors for this pattern from our data set. It is interesting to note the high proportion of single respondents in our survey, which is a phenomenon that has been found in other disciplines of academia (Fox et al. 2011). We expected that the respondents engaging in tropical field research would be less likely to be married and to have children and that the rigors of fieldwork would affect the female more than the male respondents. Surprisingly, tropical fieldwork did not correlate with marital or family status.

Women more often feel the need to hire a field assistant for reasons of personal safety and are consequently less likely to continue carrying out field research in remote locations. Women are also more likely to bring children with them during field research and to hire someone to take care of their children while they perform fieldwork. In contrast, men are

more likely to have their spouse take care of their children at home while they are away carrying out field research, which gives them more flexibility to carry out the fieldwork and to work longer hours once they are in the field. Given these issues, it is not surprising that women are less likely than men to pursue field research in tropical ecology, and the issues highlight the need for childcare, field assistants, and other support programs to promote fieldwork at both field stations and remote locations. As a starting point, funding agencies should encourage field stations to make childcare and field assistants more readily accessible, and information about these services should be listed on the field stations' Web sites.

In summary, the results of this study show substantial improvements in the suitability of the work environment for female ecologists, most notably in terms of an increased number of female colleagues, less perceived gender bias, and less-negative attitudes concerning maternity leave. Although significant differences between men and women still persist for some of these issues, the longitudinal data suggest that the gaps are lessening over time. The unique aspects of ecological fieldwork in remote areas has been neglected in discussions of women in science; our study draws attention to the challenges that women face when carrying out fieldwork and the need for greater support for childcare and field assistants. Although some of the barriers that women face in their advancement and retention have not been eliminated, our data indicate that dramatic progress has been made over the past two decades, which suggests that these obstacles are not insurmountable.

Future directions and recommendations

Over the last three decades, governments, private foundations, professional societies, and institutions of higher learning have made substantial efforts to remove barriers to women's advancement in the sciences (e.g., ESA 2006). Consequently, it is not surprising that many positive changes were identified in this survey of OTS alumni. Many legal and regulatory safeguards are now in place to stop gender discrimination; programs such as the National Science Foundation's (NSF) ADVANCE program and the Ecological Society of America's SEEDS (www.esa.org/seeds) program have created opportunities and incentives for women working in ecology. However, the present survey also shows that, although the barriers to the advancement of women in science may be less institutionalized now than they were several decades ago, women still do not advance at the same rate that men do, and parity has not been achieved. Some claims have been made that women's personal lifestyle choices are the ultimate cause of the differences in women's advancement and that continued discussions about historical forms of sex discrimination are misplaced (Ceci and Williams 2011). Although our data support the perception that overt discrimination is lessening, the underlying subtle forms of discrimination still need to be addressed (Cortina 2008).

The good news is that many of these funding agencies, universities, and foundations continue in their efforts to reform academic policies and culture, including a focus on issues that affect lifestyle choices. The NSF, for example, just adopted a series of changes to their grant-application-review process to encourage women to stay in the science pipeline, including allowing one-year grant postponement because of childbirth or adoption and permitting virtual participation in review panels to reduce the childcare burden (www.nsf.gov/career-life-balance). These types of structural support systems within the various scientific institutions should be continued, acknowledged, and enhanced.

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