Visibility matters: increasing knowledge of women's contributions to ecology

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Recent scholarship about women and science is a good source of material for addressing the under-representation of women in science. This review is the result of an interdisciplinary fusion of science and women's studies to critically assess teaching tools in undergraduate ecology education. We examine: (1) the representation of women and the coverage of social and cultural context in introductory ecology textbooks, and (2) student learning about women's contributions to ecology. Discipline demographics reveal that women are presented in textbooks less often than expected, and that explicit discussions of the social and cultural context of science are rare. When course content is enriched with material about women's contributions, student's awareness of women scientists improves. Such knowledge can play a critical role in proactively challenging students' perceptions of ecology and ecologists, creating a more positive classroom climate for all students, and introducing novel avenues of questioning and discovery.

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The attrition of women scientists from undergraduate classes through tenure-track faculty positions has recently attracted attention and controversy (eg Bhattacharjee 2004; Goodman 2003; Lawler 2003; Muller *et al*. 2005; Nadis 2001; Nelson 2005). Contemporary theory resulting from studies on women in science has advanced our understanding of the relationships between gender and the production of scientific knowledge (eg Bleier 1988; Harding 1991; Keller 1985; Longino 1990; Rosser 1991, 1997). While it is logical that these disciplines should gain insights from one another, collaborations between practitioners in the sciences and in women's studies are rare. This review is a product of one such collaboration, in which theoretical insights from women's studies were applied to the practice and teaching of ecology. We focus specifically on the undergraduate classroom and show how the incorporation of information about women's contributions to science into course content affects student knowledge.

In a nutshell:

- Undergraduate learning environments can affect women's decisions about scientific careers
- Textbooks often fail to portray women scientists and rarely include explicit discussions of the cultural and social context of science
- Small changes to course content affect students' awareness of the participation of women in science and ecology

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Women now account for 58.4% of undergraduates and 44.7% of doctoral students in the biological sciences at US research universities (Nelson 2005). Classroom climate, defined as encouraging or discouraging explicit and implicit messages from textbooks, educators, and peers about an individual's intellectual and interpersonal potential, capabilities, and interests, is a major contributory factor in student success (Hall and Sandler 1982; Pascarella *et al.* 1997; Whitt *et al.* 1999). The perceived fairness and equality of learning environments has been directly linked to aspirations towards high degrees and career achievement (Pascarella *et al.* 1997; Whitt *et al.* 1999; Wyer 2003a, b). Women's studies scholars have argued that the absence of women in course content serves as an invisible curriculum, discouraging women from developing their interests and abilities in science (Harding 1991; Mayberry *et al.* 2001; Rosser 1991, 1997).

There are many reasons why women do not advance into faculty positions. Parental influences, lack of self-confidence, negative perceptions of the life of scientists, limited access to role models and mentors, course selection, student attitudes, concerns about balancing career with family, and career aspirations have all been found to influence the retention of women in scientific careers (Frieze and Hanusa 1984; Oakes 1990; Rosser 1991, 1997; Sax 1994, 2001; Seymour and Hewitt 1997; Sonnert and Holton 1995). A woman's decision regarding whether to continue in a scientific career probably results from the integration of many of these factors acting in concert over her lifetime. The undergraduate classroom is an important arena for these accumulating influences, so it is the responsibility of academic educators and researchers to critically assess the teaching tools used in classrooms, and their impact on students, with this in mind.

Here, we review introductory ecology textbooks, one of the most ubiquitous teaching tools in undergraduate ecology education, for their coverage of women's contributions to ecology as well as their thematic integration of science and society, a central tenet of theory about gender in science. We then ask if instructors can increase students' awareness of women scientists in an introductory ecology course by enriching course content with women's contributions. We conclude with a discussion of strategies for incorporating more content about women into introductory courses and the possible educational effects that could result.

Review of introductory ecology textbooks

Background

Theory about women in science has suggested that textbooks have important impacts in terms of attracting or deterring people from science, because they are instrumental in the teaching of introductory science courses (Rosser 1991). While most blatant forms of sexism, such as the use of gendered pronouns and terminology, have been removed from modern science texts, more subtle forms, such as omitting contributions by women scientists or issues of central interest to women, still frequently occur (Phillips and Hausbeck 2000; Rosser 1991). Rosser (1991) argues that before women can be fully integrated into science, the scientific community must recognize both women's absence and presence as scientists. Theorists in women's studies further contend that it is critical to present the practice of science within its social and cultural context. They disagree with the portrayal of science as "pure", "objective", and "value free" because this denies that science is shaped by what questions society deems important to ask or what tools are chosen to answer them. Thus, they suggest, science is established as an elite and exclusionary practice (Harding 1991; Longino 1990). When science is seen as a social process, this encourages active and inclusive scientific discovery and creates more balanced and complete scientific knowledge by examining distorted and latent gender biases (Wyer *et al*. 2001). Textbooks that integrate science and society therefore encourage a diverse community to participate in the scientific process by encouraging scrutiny of biases.

Methods

Seven of the most frequently used introductory ecology textbooks in the US were critically assessed for their coverage of women's contributions to ecology (Table 1). Methods for content analysis came from similar studies in other fields (Phillips and Hausbeck 2000; Rosser 1991). Two layers of analysis were used: (1) a quantitative determination of the proportion of scientific contributions by men and women, and (2) a qualitative assessment of the coverage of the social and cultural context of science. Texts were examined with the assumption that the reader had no prior knowledge about the people and topics included, since our goal was to assess the impact of course materials on undergraduate learning experiences. While some students may initially be exposed to the field of ecology in a general biology course, most students receive their first in-depth exposure to people and topics in ecology in introductory ecology courses.

For the first layer of analysis, we counted the number of women and men presented in six major categories. Individuals were classified as female, male, or of an undeterminable sex, by applying cultural conventions to the first names and images used in the books. "Undeterminable sex" was used when initials were given for a first name, only a last name was given, a first name could be either male or female, and there was no other gender reference provided (eg no corresponding image or gendered pronoun). We did not research the gender of those named, since our goal was to analyze the representations by gender and not the accuracy of those representations per se. The six categories examined in each text were the: (1) authors, (2) scientific reviewers (data from acknowledgments), (3) editors and publishers (data from acknowledgments), (4) photographs and drawings, (5) written text, and (6) textbook indices.

To analyze the written text, we used a subset of six chapters from each textbook. Chapters were chosen for two reasons: to standardize topics across textbooks, and to include many levels of ecological organization (ie individuals, populations, and communities) in an attempt to eliminate bias due to differing proportions of women and men in specific ecological subdisciplines. At this time, there are no data describing the representation of women and men in ecological subdisciplines to provide guidance

Table 1. Introductory ecology textbooks analyzed

Author(s)	*Title*	*Edition*	*Edition Year (Original year of publication)*
Krebs, Charles	*Ecology*	5th	2001 (1972)
Krohne, David T	*General Ecology*	2nd	2001 (1998)
Molles, Manuel C	*Ecology: Concepts and Applications*	3rd	2005 (1999)
Ricklefs, Robert E	*The Economy of Nature*	5th	2001 (1976)
Smith, Robert L Smith, Thomas M	*Elements of Ecology*	4th	2000 (1977)
Stiling, Peter	*Ecology: Theories and Applications*	4th	2002 (1992)
Townsend, Colin R Begon, Michael Harper, John L	*Essentials of Ecology*	2nd	2003 (2000)

Texts were chosen by searching the Ecological Society of America's Ecology Course Syllabus Exchange website (ESA 2004) and then using an internet search engine (Google 2004) with the keywords "general", "ecology", "syllabus", and "text", reviewing the first 30 sites with syllabi for an undergraduate introductory course. Seven texts matched our search criteria, each used by three or more universities, and together used by 76% of the reviewed courses. Above are the author(s), title, edition number, the year of the edition, and original publication date (in parentheses) for each textbook.

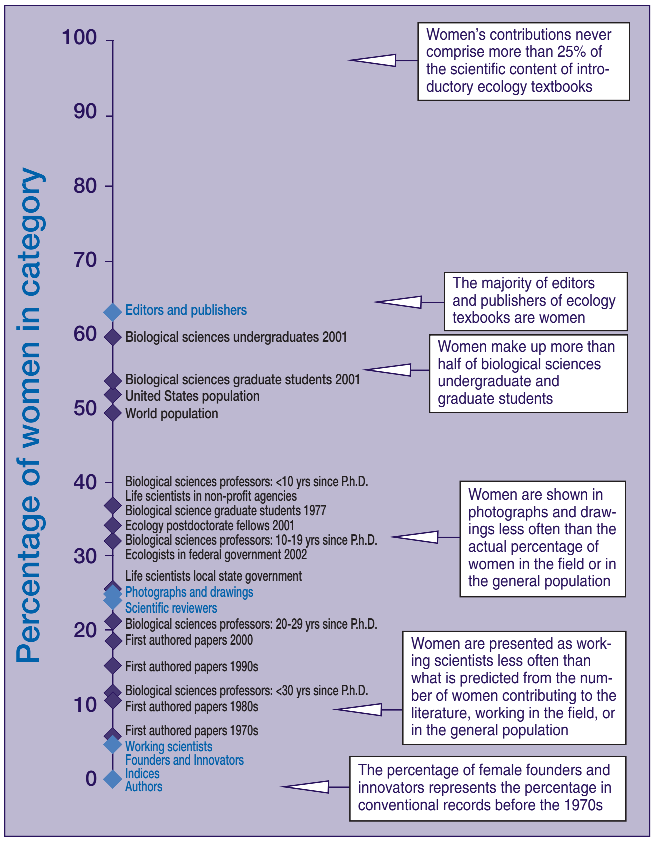

Figure 1. *Benchmarks for representation. The percentage of women contributing to ecology (dark blue) in comparison to the percentage of women portrayed in introductory ecology textbooks (light blue). Data for the number of women come from the National Science Foundation (2004) and the US Census Bureau (2000). Data for the number of publications came from a literature review of The* American Naturalist, Ecology, Ecological Monographs, *and* Oikos. *All papers in a year were reviewed in 5-year increments from 1970–2000 (ie 1970, 1975, 1980, etc) and the numbers of male, female, or undeterminable first author names were recorded.*

on this issue, so chapters covering wide-ranging topics from many levels of ecological organization were instead selected for analysis. Chapters included were: (1) an introduction to ecology, (2) population growth, (3) natural selection, adaptation, and population genetics, (4) life histories, sex roles, and mating systems, (5) competition, and (6) species diversity. All names found in the written text were classified in one of two categories, based on the context from each textbook, either as "founders or innovators" or "working scientists" to distinguish historical figures from current ones. Founders or innovators were defined as individuals who were portrayed as establishing a major line of thinking, a theory, or an idea; working scientists were individuals who were described as recently completing ecological work or advancing the progression of ecological ideas.

To assess the adequacy of textbooks' coverage of women scientists, we established three expectations, based on the presumption that there was no gender bias in textbooks' representation of women scientists. Data for establishing these expectations came from the National Science Foundation (NSF) (2004), the US Census Bureau (2000), and from a primary literature review of the sex of first author names (as male, female, or undeterminable) in all papers in a year in 5-year increments from 1970–2000 (ie 1970, 1975, 1980, etc.) in *The American Naturalist*, *Ecology*, *Ecological Monographs*, and *Oikos*. The percentage of women documented by NSF in the biological sciences compares to that found in a 1992 survey of the ESA (9–38%; ESA 1992). The three expectations were that the coverage of women scientists should be equivalent to: (1) the percentage of the primary ecological literature produced by women (6–18% from 1970–2000; Figure 1), (2) the percentage of women in the biological sciences and ecology (11–37%; Figure 1), and (3) the percentage of women in the general population, since educators might expect classrooms to contain equal contributions of men and women (~50%; Figure 1). An analysis of variance was used to determine if men and women are equally represented in the textbooks and how the the percentage of women compared with our expectations.

For the second layer of analysis, the same six chapters selected for the analysis described above were examined for descriptions of social and cultural impacts on science in their written text, study questions, recommended readings and websites, online quiz questions, and online exercises and case studies. We then determined the percentage of material in each category that explicitly considered how society and culture influence scientific research and knowledge, as well as the degree and consistency of this integration across topics and material types.

Results

Texts were relatively consistent in the proportion of women depicted in each category examined, although there was some variation between texts in the total amount of material presented for each category (Table 2). Overall, 10 authors, 336 founders and innovators, 727 working scientists, 163 photographs and drawings, 448 scientific reviewers, 57 editors and publishers, and 1245 names in text indices were examined. Women were depicted less often than men in all categories examined except for publishers and editors (Table 2). Out of 18 possible comparisons, our expectations were met only six times (Figure 1). The proportion of women founders and innovators (5%) nearly matches the percentage of women who were first authors on publications in the 1970s. The proportion of women scientific reviewers and women in photographs and drawings (25%) exceeds the percentage of women first authors of papers (6–18%) and of women in the field for over 20 years (22%; Figure 1, 2). Editors and publishers were the only category to meet and exceed all three of our expectations with women listed three times as often as men (Figures 1, 2).

Our second level of analysis suggests that the social and cultural context of science is rarely explicitly considered (Figure 3). Including the connections between humans and ecosystems was common in chapters focusing on higher levels of ecological organization (eg the impacts of human pollution on nutrient cycling), but there was no further extension of how societal values or cultural views influence scientific questions or knowledge. Furthermore, texts most often integrated science and society by relying on concluding paragraphs or additional discussion questions, rather than establishing connections throughout the narrative. Five percent of the discussion questions and online exercises and case studies included the social and cultural context of science, but summary chapter outlines and online quiz questions never did (Figure 3).

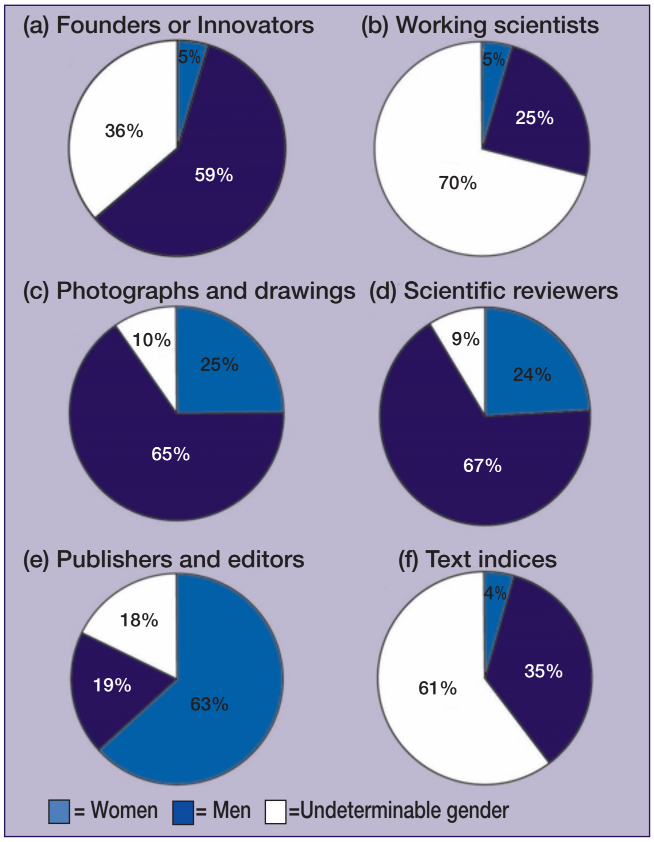

Figure 2. *Quantitative content analysis for introductory ecology textbooks. The percentage of men and women (determined from images and cultural conventions for first names) in all textbooks, who were (a) depicted as founders or innovators of ecological ideas, (b) highlighted as current working scientists, (c) shown in photographs or drawings, (d) acknowledged as scientific reviewers, (e) acknowledged as publishers or editors, or (f) listed in text indices.*

■ Enriching course content

Background

Students are seldom exposed to information about women's contributions to science in the undergraduate science curriculum, so the importance of this information to students is unknown. Educators generally expect that students will retain material covered in course content, but knowledge about women's contributions to science may challenge closely held attitudes and preconceptions about gender, leading to the marginalization of the material by students during course preparation and performance. Moreover, the prospect of making extensive revisions to course content hinders the incorporation of new material. Empirical evidence is needed to assess if increasing the coverage of women's contributions to ecology leads to greater student knowledge about women scientists, as this would inform efforts to improve the visibility of women in the sciences. Here, we provide a rudimentary assessment of students' awareness of women's participation in science as a first step towards understanding the impact of such material.

Study overview

Through an interdisciplinary collaboration between the Departments of Botany, Psychology, and Zoology at North Carolina State University in Raleigh, NC, we assessed the impact of highlighting women's contributions to ecology on student knowledge of women scientists.

Our study focused on a large introductory undergraduate ecology course, during three weekly lectures and one weekly laboratory section for three consecutive semesters (Table 3). All students attended the same lectures, but registered for separate laboratory sections of 11–24 students each. During the first two semesters, half of the laboratory sections received 5–10 minutes of enriched material each week (see "Course content" below), while the other half served as controls, receiving unaltered course material. During the third semester, students' exposure time to the enriched material was increased by also supplementing 5–10 minutes of course lectures each week. Responses of students receiving the enriched material during both lectures and laboratories during the third semester (enrichment level 2) were compared to students in the previous two semesters who received material during laboratories only (enrichment level 1) or no additional material (control).

Table 2. Text analysis ANOVA table

Response Variable	*Textbook* *F*	*P-value*	*Gender* *F*	*P-value*
Founders or innovators	$1.96_{6,6}$	0.2275	$150.87_{1,6}$	0.0001*
Working scientists	$11.68_{6,6}$	0.0007*	$107.92_{1,6}$	0.0001*
Scientific reviewers	$15.72_{6,6}$	0.0002*	$19.13_{1,6}$	0.0047*
Publishers or editors	$0.51_{6,6}$	0.7819	$12.35_{1,6}$	0.0126
Names in text indices	$18.0_{6,6}$	0.0013*	$51.90_{1,6}$	0.0004*
People in photographs or drawings	$6.96_{6,6}$	0.0163	$16.18_{1,6}$	0.0069*

Separate ANOVAs were conducted for each of six log-transformed response variables (the number of founders or innovators, working scientists, scientific reviewers, publishers or editors, names in the text indices, and people in photographs or drawings) using textbook (seven textbooks) and gender (female or male) as independent variables. Because we used separate analyses for each response variable, we corrected for multiple comparisons using the Dunnsidák procedure. Since this did not substantially alter our results, uncorrected P-values are reported with asterisks indicating those analyses that remain significant after using the Dunnsidák correction.

Course content

Material was enriched with: (1) biographical sketches, photographs, and stories of women

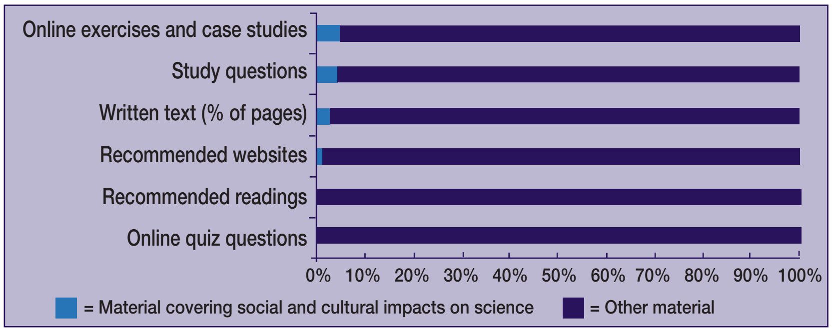

Figure 3. *Qualitative content analysis for introductory ecology textbooks. A ranking of the approximate percentage of material dedicated to incorporating the social and cultural context of science in the online exercises and case studies, study questions, written text (defined as the percentage of pages in each chapter that consider social and cultural impacts on science), recommended websites, recommended readings, and online quiz questions.*

ecologists who were not discussed in the students' textbooks, but who had made contributions to ecology (see Figure 4a–b and Langenheim 1996 for examples), and (2) discussions of the social and cultural context of scientific knowledge (see Figure 4c–d for examples). The supplementary material was fully integrated into the course content and was not emphasized or given special attention.

Survey design and analyses

At the beginning and end of each semester, students were asked to complete a voluntary survey during their laboratory section. They were told the survey was part of an NSF study and their answers were strictly confidential. Surveys were distributed, conducted, and collected by an independent researcher and not by the instructors for the laboratory sections. Students did not know ahead of time that surveys would be given and incomplete surveys were mainly due to student absences.

During each survey, students were asked to list the names of as many women scientists or minority scientists as they could remember. Names were verified using primary literature searches, the "Marquis Who's Who in Science and Engineering", a local university directory, and an internet search engine (Google 2004). While this question asked students about both women and minority (men or women) scientists, less than 5% of responses were names of male minority scientists and this percentage did not differ between time periods, indicating our results were not confounded with the names of male minority scientists. The total number of names was used as the response variable in a repeated measures ANOVA analysis (Table 4).

Results

At the end of the semester, students who had received the enriched materials listed significantly more female or minority scientists' names than students in control sections (Table 4; Figure 5) and the magnitude of this effect increased relative to exposure time (Table 4; Figure 5). Women students could remember more names in general (Table 4), regardless of whether they were in a control or enriched section (Table 4). The results were not biased by students' course grades, laboratory section times, or teacher effects.

■ Discussion

Introductory textbooks

In our study, women were consistently under-represented in ecology textbooks when compared to the most appropriate prior assumptions of no bias. For example, the coverage of women as working scientists in textbooks should have reflected their presence in the recent primary literature, yet texts included women's contributions 2–3 times less often than expected. Similarly, photographs and drawings should have reflected the proportion of women working in the field of ecology and in the general population, yet textbooks portrayed women less than these measures. Photographs and diagrams rarely included people at all, but when they did, scientists were often portrayed through the use of headshots or as small human figures against the backdrop of an entire landscape. These types of images fail to challenge the common and flawed assumption that science and scientists are asocial and removed from society.

There was just one exception, in which a woman was shown actively engaged in science; Molles (2005) included a photograph of Dr Nalini Nadkarni working in the Costa Rican rainforest canopy and explained that she helped establish a field of research examining nutrient sources in rainforest canopies. Even when the percentage of women founders and innovators did meet expectations, contemporary texts perpetuated the lack of coverage of women's contributions by omit-

Table 3. Study design summary

Condition	*Percent of weekly material*	*Semesters*	*Laboratory sections*	*Women*	*Men*	*Total students*
Control	0%	1st , 2nd	9	83 (60%)	55 (40%)	138
Enrichment level 1 (laboratory only)	2–5%	1st, 2nd	8	76 (60%)	50 (40%)	126
Enrichment level 2 (laboratory and lecture)	5–10%	3rd	8	84 (68%)	40 (32%)	124
Total	0–10%	3	25	243 (63%)	145 (37%)	388

The approximate percentage of total course material students received each week, the distribution of control and enrichment sections across semesters and laboratory sections, and the number and percentage of undergraduate women and men in the control and enriched laboratory sections.

Figure 4. *Examples of material highlighting women scientists and cultural bias in science. (a) Ellen Swallow Richards, a founder of ecology, used during an introduction to ecology. (b) E Lucy Braun, a pioneer in understanding eastern deciduous forests, used during a forest gradients laboratory. (c) Anthropomorphism and cultural bias in biological terms discussed after foraging theory game where students "foraged" and were "predated". (d) Discussion generated by news headlines on impact of cultural origins of language on research directions used while studying invasive species.*

(a)

**Founder of ecology:
Ellen Swallow Richards (1842–1911)**

- American chemist and biologist
- First women to earn Bachelor of Chemistry
- Master's at MIT
- PhD at Smith College
- Isolated new metal: vanadium
- Established the *Science Laboratory for Women* at MIT (upper right)
- Created and taught the the first ecology curriculum
- Established *Summer Seaside Laboratory* where women could study marine biology
- Asked audience in 1889 to, "stand witness ... to the christening of a new science... ecology"

Taken from Clark 1973

Courtesy of the MIT Museum

Courtesy of the MIT Museum

(b)

Eastern deciduous forests: E Lucy Braun

- Classic book: *Deciduous Forests of Eastern North America*
- American botanist, ecologist
- Published over 180 works
- Pioneer in plant research
- First female president of Ecological Society of America (1950)

Courtesy of the Cincinnati Museum Center–Cincinnati Historical Society Library

(c)

Cultural bias and behavioral terms

"[There is a] pervasive sense of the investigator's perception of their own self as a universal reference point, as equivalent to humanity, viewing all others – the other sex, other classes, races, cultures and civilizations, species, and epochs – in the light and language of their own experiences, values, and beliefs"
– Ruth Bleier, Neurobiologist –

Applying human terms to animals

- Uses faulty logic and unsupported assumptions and premises
  Exp: If animal and a human behavior look alike, they may not be the same (eg purpose, function, etc is different)
- Uses poor definitions of the behavior being explained
  Exp: Words like "aggressivity", "entrepeneurship", and "materialism" are not quantitative. Meaning of words depends on context and personal experiences.

Taken from Sociobiology, Biological Determinism, and Human Behaviour by Ruth Bleier (1988)

(d)

Cultural rhetoric and research

"Aliens among us"
– New York Times –
"Alien invaders: Costly uninvited guest in Virginia"
– Associated Press –
"Invaders taking over countryside – and it will get worse"
– The Independent (London) –

Traditional approaches

- Prevention of introduction
- Use of control methods (eg chemical, mechanical, biological)

New approach – Banu Subramanium, University of Mass, Amhurst:

- Critiques "invasive species" rhetoric and draws parallels to nationalistic/xenophobic language
- Suggests this language directs and limits the focus of our research questions
- Suggest a more proactive (vs reactive) research approach: focus on effects of environmental quality and sustainability rather than individual species

Take-home message

- Historical influences and etymologies can define appropriate research questions
- Critique your work and make attempts to recognize these influences
- Collaborate with other disciplines and with scientists with diverse backgrounds

Taken from Subramaniam (2001)

ting references to women pioneers (see Figure 4a–b for examples).

Many citations in the textbooks use only last names or first initials, making it impossible to assign gender. While it is plausible that textbook authors are attempting to represent science as egalitarian by making contributors' gender invisible to students, research shows that if the gender of "a scientist" is not specified, students assume that the scientist is male (Hughes 2002; Rosser 1991). Theorists in women's studies believe that the lack of challenges to these kinds of assumptions may reinforce undergraduate perceptions about the absence of women in science. Making the contributions of women and other underrepresented groups visible in course content may motivate and encourage a more diverse population of students. Providing students with vivid images of women as scientists may be a necessary step in recasting science as a fully inclusive human activity.

The social and cultural context of science is rarely explicitly considered in undergraduate ecology texts. Authors presented material in some chapters highlighting human impacts on natural systems, but they almost never extended these discussions to examine how culture influences the practice of science or scientific outcomes. We did find a few exceptions to this general trend. For example, one online case study asked students to read several papers highlighting the depletion of the world's fisheries and to answer questions about how the methodological differences could impact study conclusions and the valuation of the work by different user groups (eg the fishing community, ecologists, law makers). In their first chapters introducing students to ecology, Krebs (2001) included a thorough one-page discussion of cultural impacts on ecology and Ricklefs (2001) had one paragraph on the social context of ecology. Integrations like these effectively link

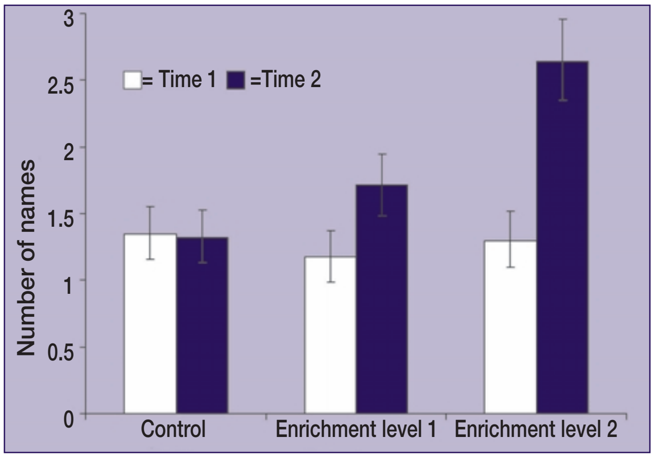

Figure 5. *Student's knowledge of names. Mean number of women and minority scientists students could name in control, enrichment level 1 (laboratory only), and enrichment level 2 (laboratory and lecture) sections at the beginning (time 1) and the end (time 2) of the semester in an introductory ecology course. Error bars indicate 95% confidence limits.*

social processes and scientific discovery, but they are very rare and in most cases only accessible to students motivated enough to take advantage of supplemental materials. Failure to explicitly discuss the social and cultural context of ecology, or to integrate these discussions across chapters, sends an implicit message to students that either connections between society and science do not exist or that these connections are unimportant.

Course enrichment

Student knowledge of women scientists increased after alterations were made to a very small amount of material (2–10%) in an introductory course and increased relative to exposure time. While the average number of names students in enriched sections could remember was still small, approximately half of all students entered the course without being able to name a single woman or minority scientist; but only 10% of students who received enriched material in both laboratory and lecture were still unable to do so.

This increased knowledge about women scientists can play a critical role in proactively challenging students' perceptions of ecology and ecologists. When faculty talk about ecologists in the classroom, using biographies and stories, they both explicitly teach students about ecology and ecologists and also implicitly communicate by challenging (or not challenging) the images and assumptions students bring to the classroom about ecology and ecologists. For example, the names of ecologists are often used in course examinations as a way to determine if students are familiar with a body of knowledge. When names of entire groups of individuals are under-represented, this supports an implicit message about who can create ecological knowledge. Emphasizing the importance of societal and cultural influences on scientific processes humanizes the profession, calls attention to how individual experiences and cultures influence research questions and methods, reveals biases in our work, and provides novel avenues of inquiry and discovery.

This study provides rudimentary evidence that "content matters", in that relatively small changes in course content can affect students' awareness of the participation of women in science. This could be expanded upon in several important ways. Since we only asked about women scientists, we do not know if the retention of names differs for male and female scientists. We only know that, after one semester, students who received the material could name more women scientists relative to a control group. Because our study measured effects over only one semester, we do not know how long this effect lasted. Moreover, our study does not link students' exposure to enriched course materials with students' perceptions of the classroom climate or to educational outcomes such as retention in their major subject area or career plans. Other studies have found that more positive evaluations of classroom climate have led to positive benefits for student learning and career outcomes (Hall and Sandler 1982; Pascarella *et al.* 1997; Whitt *et al.* 1999; Wyer 2003a, b). So if the enrichment material indeed created a more positive classroom climate, similar results could be expected. Data collected by our colleagues in women's studies indicate that this may be the case, because students receiving the enrichment material reported more positive evaluations of their classroom climate than those who did not (M Wyer, under review). Further work is needed before making a direct link.

Table 4. Enrichment material ANOVA table

Variable	*F*	*P-value*
Gender	$6.18_{1,382}$	0.0134
Condition	$8.90_{2,382}$	0.0002
Time	$86.54_{1,382}$	< 0.0001
Condition x Time	$32.70_{2,382}$	< 0.0001
Condition x Gender	$0.39_{2,382}$	0.6760
Condition x Time x Gender	$1.16_{3,382}$	0.3253

Repeated measures ANOVA for the number of women and minority scientists named by time (pre-semester and post-semester surveys) and condition (control, enrichment level 1, and enrichment level 2). The total number of names (square-root transformed) was used as the response variable in a quasi-experimental non-equivalent control group design (Shadish et al. 2001), commonly used in the social sciences when the assignment of treatment and control groups cannot be random (eg students self-selected course and laboratory sections).

Recommendations

This review provides a rationale for developing initiatives that will increase the representation of women in ecology in a number of ways. As courses and textbooks are revised they should ensure the visibility of women as contributors to the production of ecological knowledge. Documenting women founders and innovators should go beyond traditional accounts of history, and a repository should be established to collect such material and facilitate its inclusion in textbooks and courses. Women currently working as scientists should be included in texts and their gender specified, at least at levels that match available information from the primary literature. Texts should also include discussions of social and cultural impacts on research questions, language, and methodologies across topics and material types. Scientific organizations and societies should engage in regular assessment activities that determine the representation of women in specific ecological subdisciplines, in order to provide benchmarks against which to compare studies such as this one. Assessing the impact of science courses that more fully integrate new scholarship on gender in science, as well as implementing longitudinal studies at multiple research universities, will be crucial for understanding the widespread and long-term impacts of these efforts on attitudes and the retention of women.

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