Lack of quantitative training among early-career ecologists: a survey of the problem and potential solutions

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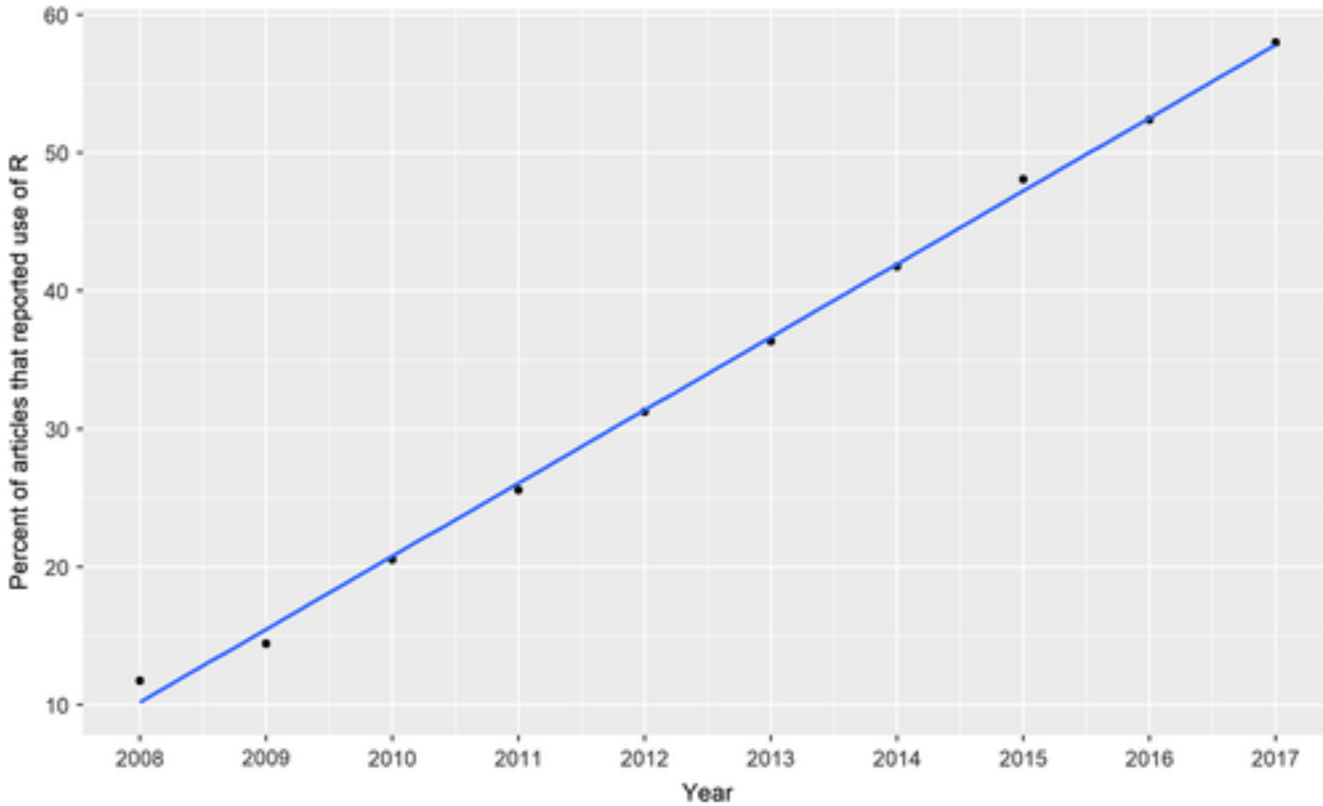
ABSTRACT

Proficiency in mathematics and statistics is essential to modern ecological science, yet few studies have assessed the level of quantitative training received by ecologists. To do so, we conducted an online survey. The 937 respondents were mostly early-career scientists who studied biology as undergraduates. We found a clear self-perceived lack of quantitative training: 75% were not satisfied with their understanding of mathematical models; 75% felt that the level of mathematics was “too low” in their ecology classes; 90% wanted more mathematics classes for ecologists; and 95% more statistics classes. Respondents thought that 30% of classes in ecology-related degrees should be focused on quantitative disciplines, which is likely higher than for most existing programs. The main suggestion to improve quantitative training was to relate theoretical and statistical modeling to applied ecological problems. Improving quantitative training will require dedicated, quantitative classes for ecology-related degrees that contain good mathematical and statistical practice.

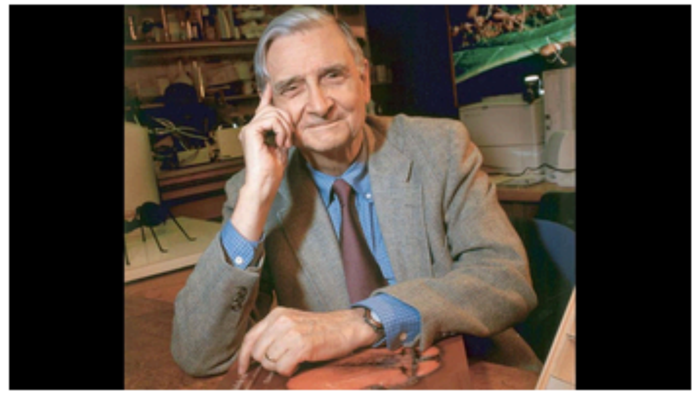
Evaluating the popularity of R in ecology



Lai et al. Evaluating the population of R in ecology. Ecosphere, Volume: 10, Issue: 1, First published: 11 January 2019, DOI: (10.1002/ecs2.2567)

Researchers Challenge E. O. Wilson Over Evolutionary Theory

By **Elizabeth Pennisi** | Mar. 23, 2011 , 2:00 PM



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Online today in *Nature*, nearly 150 evolutionary biologists challenge Harvard University's **Edward O. Wilson**, one of the world's most preeminent scientists, and two colleagues. At issue is the usefulness of a 50-year-old theory about the role of relatedness in the evolution of complex social systems like those of ants, bees, and humans. Wilson, along with Harvard mathematicians Martin Nowak and Corina Tarnita **argue** that the theory, called inclusive fitness, does not explain how these complex societies arose; in a **rebuttal** today in *Nature* and in an upcoming issue of the ***Journal of Evolutionary Biology***, their critics say that the Harvard trio have misrepresented the literature and are simply wrong.

"They are wrong both empirically and theoretically," says critic Edward Allen Herre of the Smithsonian Tropical Research Institute (STRI) in Balboa, Panama.

"I think it's so wrong I don't think it will have any effect on what people in the field are doing," adds University of Oxford evolutionary biologist Stuart West, who orchestrated one letter to *Nature* with more than 130 signees. West said he and his colleagues reacted so strongly because they worried that, given Wilson and Nowak's fame and *Nature*'s prestige, others will take notice. "[Our] letter is written in the hope that it will keep nonspecialists from wasting time on it."

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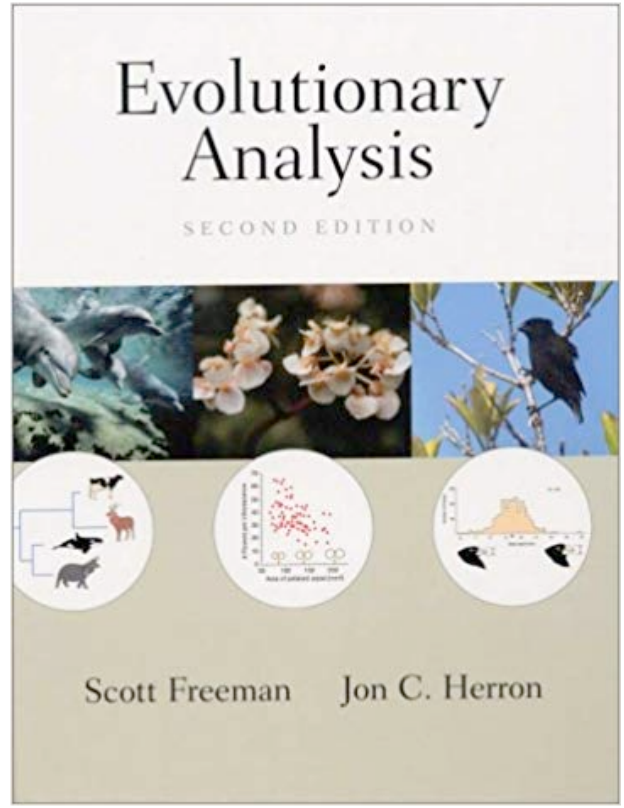

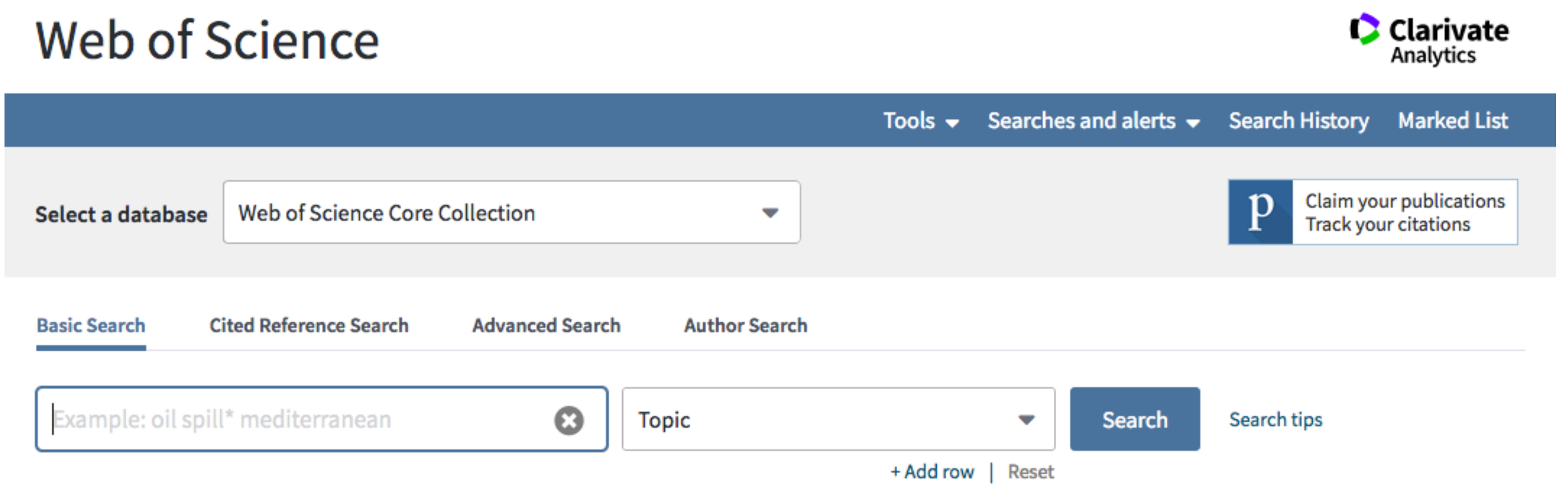

Systems biology provides rich opportunities for all students to learn about scientific inquiry and, because of the complex nature of the research involved, to practice in a multidisciplinary context. For example, early applications of systems biology to ecosystem processes resulted in useful simulation models.

Core Competencies and Disciplinary Practice

Knowledge of *concepts* and the development of *competencies* form the bases for the practice of any discipline, but particularly in the sciences. All students need to develop the following competencies:

1. ABILITY TO APPLY THE PROCESS OF SCIENCE:
Biology is evidence based and grounded in the formal practices of observation, experimentation, and hypothesis testing.
All students need to understand the process of science and how biologists construct new knowledge by formulating hypotheses and then testing them against experimental and observational data about the living world. Studying biology means practicing the skills of posing problems, generating hypotheses, designing experiments, observing nature, testing hypotheses, interpreting and evaluating data, and determining how to follow up on the findings. In effect, learning science means learning to *do* science. For example, authentic research experiences in undergraduate biology through course-based projects, independent or summer research, community-based student research, or other mechanisms can be a powerful means of providing students with opportunities to learn science by doing it (Mulnix, 2003; Sadler and McKinney, 2010).

2. ABILITY TO USE QUANTITATIVE REASONING:
Biology relies on applications of quantitative analysis and mathematical reasoning.
The application of quantitative approaches (statistics, quantitative analysis of dynamic systems, and mathematical modeling) is an increasingly important basic skill utilized in describing biological systems (Jungck, 1997; Brewer and Gross, 2003). Advances in several fields of the biological sciences provide opportunities for students to appreciate the impact of mathematical approaches in biology and the importance of using them. For example, the dynamic modeling of neural networks helps biologists understand emergent properties in neural systems. Systems approaches to examining population dynamics in ecology also require sophisticated modeling. Advances in understanding the nonlinear dynamics of immune system development have aided scientists' understanding of the transmission of communicable diseases.

All students should understand that biology is often analyzed through quantitative approaches. Developing the ability to apply basic quantitative skills to biological problems should be required of all undergraduates, as they will be called on throughout their lives to interpret and act on quantitative data from a variety of sources.

3. ABILITY TO USE MODELING AND SIMULATION:
Biology focuses on the study of complex systems.
All students should understand how mathematical and computational tools describe living systems. Whether at the molecular, cellular, organismal, or ecosystem level, biological systems are dynamic, interactive, and complex. As new computational approaches improve our ability to study the dynamics of complex systems, mathematical modeling and statistical approaches are becoming an important part of the biologist's tool kit. Biologists must understand both the advantages and the limitations of reductionist and systems approaches to studying living systems. Also important is the advantage of qualitative analyses, including steady-state behaviors (e.g., homeostasis) and associated stability analyses (e.g., responses to perturbations). A combination of these approaches is essential to teasing apart the complexities of biological systems.

A variety of computational educational tools is readily available to examine complexity as it arises in biological systems. These tools can simulate many interacting components and illustrate emergent properties that allow students to generate and test their own ideas about the spatiotemporal complexity in biology. Today, modeling is a standard tool for biologists, so basic skills in implementing computational algorithms for models are increasingly being incorporated into the undergraduate curriculum (Rowland-Godsmith, 2009; NetLogo, n.d.).

4. ABILITY TO TAP INTO THE INTERDISCIPLINARY NATURE OF SCIENCE:
Biology is an interdisciplinary science.
Integration among subfields in biology, as well as integration between biology and other disciplines, has advanced our fundamental understanding of living systems and raised a number of new questions. As exciting new areas of study emerge from the interstices, solid grounding in the sciences, including computer science and social science, can advance the practice and comprehension of biology. Accordingly, all students should have experience applying concepts and subdisciplinary knowledge from within and outside of biology in order to interpret biological phenomena.

Interdisciplinary science practice may be achieved in several ways. For future biologists, one way is through developing expertise not just in an area of biology, but also in a related discipline. That way, students will develop the vocabulary of both disciplines and an ability to think independently and creatively in each as well. A second, less intensive approach is to develop deep expertise in one area and fluency in related disciplines. A third option is to serve as a biologist on a multidisciplinary team. All of these routes develop a student's facility to apply concepts and knowledge across traditional boundaries. For those not majoring in biology, the inherent interdisciplinary nature of biology practice lends itself to forming connections between biology and other sciences and, in so doing, can help all students understand the way science disciplines inform and reinforce each other.

5. ABILITY TO COMMUNICATE AND COLLABORATE WITH OTHER DISCIPLINES:
Biology is a collaborative scientific discipline.
Biological research increasingly involves teams of scientists who contribute diverse skills to tackling large and complex biological problems; therefore, all students should have experience communicating biological concepts and interpretations. As the science of biology becomes more interdisciplinary in practice and global in scope, biologists and other scientists need to develop skills to participate in diverse working communities, as well as the ability to take full advantage of their collaborators' multiple perspectives and skills.

Effective communication is a basic skill required for participating in inclusive and diverse scientific communities. Communicating scientific concepts through peer mentoring helps students solidify their comprehension and develop the ability to communicate ideas not only to other biology students, but also to students in other disciplines. Practicing the communication of science through a variety of formal and informal written, visual, and oral methods should be a standard part of undergraduate biology education.

6. ABILITY TO UNDERSTAND THE RELATIONSHIP BETWEEN SCIENCE AND SOCIETY:
Biology is conducted in a societal context.
Biologists have an increasing opportunity to address critical issues affecting human society by advocating for the growing value of science in society, by educating all students about the need for biology to address pressing global problems, and by preparing the future workforce. Biologists need to evaluate the impact of scientific discoveries on society, as well as the ethical implications of biological research. Cross-disciplinary opportunities for students to explore science in a social context may be generated through real-life case studies embedded in biology courses, or in social science courses designed specifically to explore the effect of science and technology on human beings (e.g., Fluck, 2001; Pai, 2008).

Trends in Ecology & Evolution

CellPress REVIEWS

Scientific Life

Lamarck, the Father of Evolutionary Ecology?

Mats Björklund[1,*]

Lamarck realized life had evolved from simple to more complex forms, due to adaptation to a changing environment over time. Though he was wrong in many details, he got the overall picture right. Thus, he can be seen as the first evolutionary ecologist, connecting evolutionary change in organisms to their environment.

it would work mechanistically, which was equally rejected when appropriate data became available [4]. The fact that Lamarck did believe in the inheritance of acquired characters is not strange at all, as it was the predominant theory of inheritance at this time, decades before the work of Mendel became more widely known.

However, it is important to remember that if we are to judge scientists, we need to understand the historical context in which they worked. Lamarck was active at a time when the idea of common ancestry started to gain interest, not least by his mentor Buffon. These ideas were by no means obvious at the time [5] and were strongly contested by, for example, changes imposed on the organisms as a result of changing environments and that these changes were gradual over long periods of time.

Lamarck was strongly of the opinion that the accommodation to a specific change in environment gained during the life-time of an individual was transmitted to the next generation. Today this has been phrased in terms of epigenetics, even though this is not correct historically [3] or biologically [7,8]. In modern terms, the change in Lamarck's view was due to a cross-generational transmittance of a plastic response of individuals to the environment. His ideas were revolutionary at the time, not for the inheritance of acquired characters, but for the proposals that indi-