Modeling Populations: Emphasizing the Importance of Mathematical Modeling in Undergraduate Ecology

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Introduction

Recent national reports on undergraduate biology education, such as "Vision and Change" (AAAS 2011) and "BIO2010" (NRC 2003), call for better integration into biology curricula of quantitative and mathematical modeling skills. Students need these skills to obtain a deep understanding of biological phenomena, to contribute effectively to future scientific inquiry, and to become science-literate citizens.

Strategies for integrating mathematics into undergraduate biology curricula (cited in biology education literature) include:

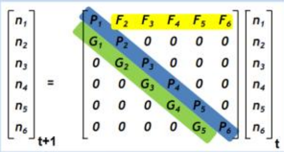
- Integrating quantitative concepts into biology courses
- Developing and using modules for integration into existing courses
- Including quantitative skills in undergraduate research
- Integrating biological examples into math courses
- Using evidence-based, learner-centered pedagogical strategies

We present and analyze a two-part lesson designed to help biology majors learn to develop and use mathematical models and appreciate their importance in ecology and conservation.

Description of Module

This computer inquiry module uses ecology research literature to introduce structured (matrix) population models and their use in conservation and management. Students:

- Participate in an interactive lecture introducing structured population models through a case study: "Lead Poisoning of Albatrosses at Midway Atoll: From Ecological Model to Conservation Action" (Figures 1-3, Finkelstein et al. 2009)
- Read research papers applying structured population models to a variety of taxa and conservation questions
- Work in small groups on computers using the Microsoft Excel add-on PopTools (Hood 2010) to model specific populations
- Present their model and their own research question to class



LEARNING GOALS: Students should be able to:

- Understand mathematics of structured population growth
- Apply structured population models to assessment of population viability and conservation strategies
- Appreciate the importance and uses of mathematical models in ecology and conservation

Setting

This module was evaluated in 2012 and 2013 in an upper-division ecology course at University of California, Santa Cruz: BIOE 163: "Ecology of Reefs, Mangroves, and Seagrasses," led by Dr. D.C. Potts and a teaching assistant. In 2012, the module included a 105 min lecture and a 2 hr lab for 61 students; in 2013, the module consisted of a 70 min lecture and a 3 hour lab for 26 students.

Study Design and Analysis

All students completed a lab worksheet, participated in poster and oral presentations, were observed during inquiry lab, and answered questions on the final exam.

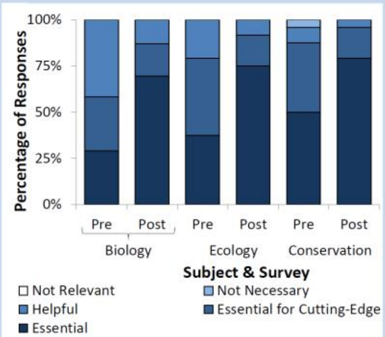
Combining years, 48 students responded to a voluntary online pre-survey, post-survey, or both. 5 male and 5 female students across both years volunteered for one-on-one interviews.

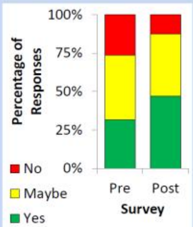
The surveys and interviews focused on students'

- Previous experiences and goals in biology and math
- Attitude toward math and its value in biology and conservation
- Understanding of the concepts and skills in the module

Results: Student Attitudes

Students had a significantly greater appreciation of the value of math to biology, ecology, and conservation in post-module surveys than in pre-module surveys (Figure 3 right, Pearson χ^2, $p < 0.05$ for all 3 tests).

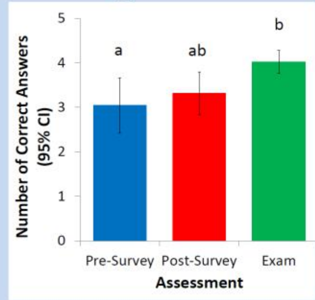




Although the percentage of students who would or might take a quantitative ecology course increased, the change was not statistically significant (Figure 4 left, Pearson χ^2, $p = 0.414$).

Results: Learning

Student scores on content questions increased from the pre-survey to the post-survey to the exam. In a two-way ANOVA (year x assessment), the only significant difference was the gain from pre-survey to exam (Figure 5 right, Tukey's HSD Posthoc test, $p = 0.035$, Cohen's d effect size = 0.83).



Students particularly liked the inquiry components of the lab, especially choosing their organisms, asking and answering their own questions, using the computer program to create their own models and calculate their own outcomes, and working in small groups.

Discussion

Students participating in the "Modeling Populations" module, gained a more positive toward math in biology and ecology and demonstrated that they learned to apply structured population models for conservation.

In the post-module survey, many students made comments such as "This module helped me understand why I was required to take math classes as a marine biology major" and "I assumed you would have to be a math wiz or statistical genius to be able to use models and equations in your research, but now I realize how easy it is to do it yourself."

Both our data and student comments are consistent with previous research indicating that learner-centered strategies increase student interest and motivation and help students learn biological concepts (Michael 2006, Derting and Ebert-May 2010). These strategies should also help the approximately one-third of college students who struggle with "math anxiety" (Betz, 1978).

Works Cited

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The UCSC Office of Research Compliance found this research exempt from IRB review (IRB protocol #HS1201814).

Poster & more information available at: kristinmccully.wordpress.com/