Zombies, Foxes and Murder

Experiences in learning and teaching quantitative biology using technology

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Overview

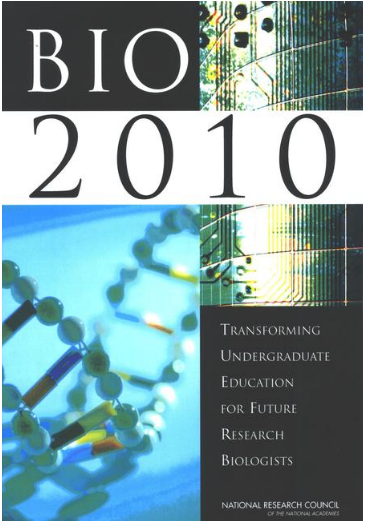
Motivation

Preliminaries

- School System Definitions
  - **Primary school**: K-6 education (ages 5-12)
  - **Secondary school**: 7-12 education (ages 12-18)
  - **Undergraduate**: University education for an Associate or Bachelor's Degree (18+)
- **Bioinformatics**: Research, development, or application of computational tools and approaches for expanding the use of biological, medical, behavioral, or health data, including those to acquire, store, organize, archive, analyze, or visualize such data.
- **Computational Biology**: The development and application of data, analytical and theoretical methods, mathematical modeling, and computational simulation techniques to the study of biological, behavioral, and social systems.
- **Mathematical Modeling**: Aims to describe the different aspects of the real world, their interaction, and their dynamics through mathematics.
- **Quantitative Biology**: Includes bioinformatics, computational biology, and mathematical modeling.

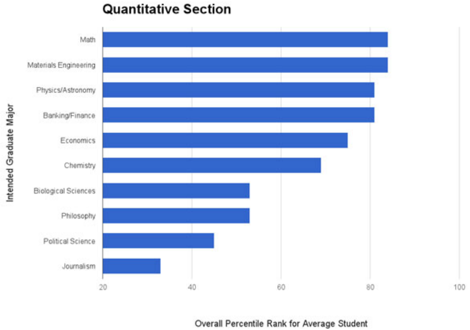
Quantitative Biology Education in the United States

- At the secondary level:
  - Common Core
  - AP/IB programs
  - Other education groups
- At the undergraduate level:
  - *BIO2010*
  - Degree programs
  - Courses
  - Research opportunities



Why Secondary Quantitative Biology Education Matters

- Reduction in math anxiety
- Improved understanding of the natural world
- Preparation for undergraduate study
- Quantitative requirements of careers in biology
- Quantitative requirements of careers in other fields



Resources

- Distance Education and Research

zoom

- Software and Applications

- Repositories

QUBES
The Power of Biology × Math × Community

Distance Education and Research

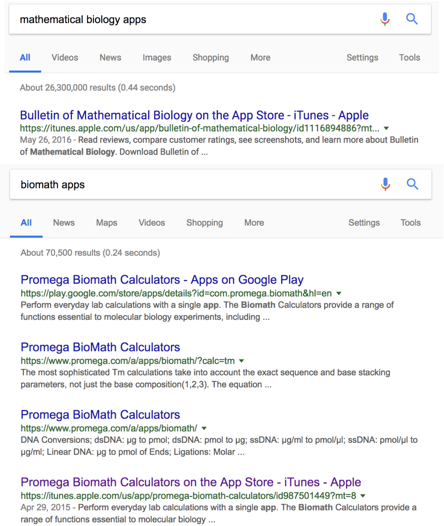
- Web-based courses
- Tele-conferencing
  - Remote research meetings
  - Guest lectures
- Blended or hybrid courses
  - Computer Assisted Instruction (CAI)
  - Online activities or modules
- File sharing, storage, and collaboration
  - Google Drive
  - Dropbox
  - OneDrive
  - ShareLaTeX

Software and Applications

Software

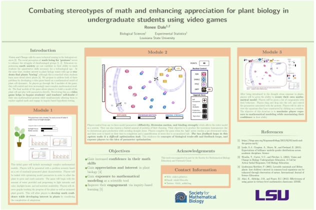
- Netlogo*
  - Agent-Based Modeling
  - Exploring changing parameters
- Mathematica
  - Documented demonstrations
  - Combining text, code, and figures for lessons
- Matlab
  - GUI-based exploration
  - Playing with matrices and statistics
- R
  - Introduction to coding
  - Free, open-source*

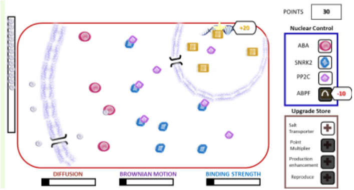
Applications



Application in Development

- The game is intended to:
  - Give players exposure to math, decreasing math-phobia and improving math confidence through progressively difficult modeling scenarios.
  - Expose players to mathematical modeling, preparing them for techniques they will encounter in later educational efforts. Players will also be exposed to programming and parameter optimization concepts.
  - Provide players with a medium to develop testable hypotheses in an electronic lab setting on a scale that isn't otherwise physically feasible.
  - Interest students in plant biology, including differences between species and "invisible" adaptations.
- Recently funded through the SMB Education and Outreach Grant (recipient Renee Dale, LSU, USA)

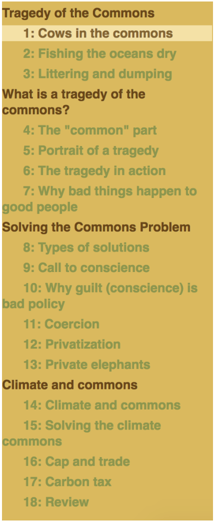


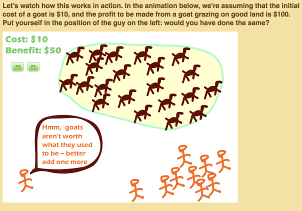


Repositories

- MathBench
- Data Nuggets
- BioQuest
- QUBES

MathBench





- "Introduces students to the mathematical underpinnings of what they learn in introductory biology"
- Modules are interactive and use everyday situations to explain the mathematics
- Appropriate for most learning levels

Data Nuggets

- "Give students practice interpreting quantitative information and making claims based on evidence."
- Activities are broken down by education level
  - **Level 1:** Elementary school and above
  - **Level 2:** Middle school and above
  - **Level 3:** High school and above
  - **Level 4:** Advanced high school and undergraduate

DATA Nugget

Finding Mr. Right

Featured scientist: Carrie Branch from University of Nevada Reno

Research Background:

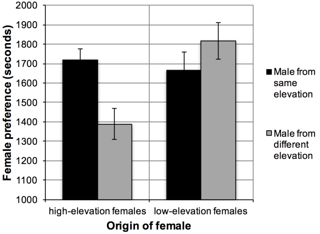
Mountain chickadee, photo by Vladimir Pravosudov

Depending on where they live, animals can face a variety of challenges from the environment. For example, animal species that live in cold environments may have adaptive traits that help them survive and reproduce under those conditions, such as thick fur or a layer of blubber. Animals may also have **adaptive behaviors** that help them deal with the environment, such as storing food for periods when it is scarce or hibernating during times of the year when living conditions are most unfavorable. These adaptations are usually consistently seen in all individuals within a species. However, sometimes populations of the same species may be exposed to different conditions depending on where they live. The idea that populations of the same species have evolved as a result of certain aspects of their environment is called **local adaptation**.

Scientific Question: How does mate choice by high- and low- elevation female mountain chickadees contribute to local adaptation?

What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

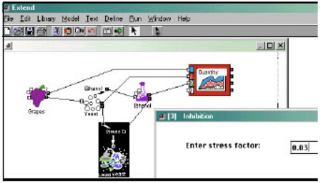
Below is a graph of the data: Identify any changes, trends, or differences you see in your graph. Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.



BioQuest

- “A community of scientists, educators, and learners of all ages who are interested in supporting biology education that reflects realistic scientific practices.”
- Three P’s Approach: Problem Posing, Problem Solving, and Peer Persuasion

The Search for the Hereditary Molecule	This research lab simulation gives students control of the classic investigations that supported that DNA is the hereditary molecule.... More Details 3 User Resources	Donald Buckley William Coleman
Virtual Laboratory	Virtual Laboratory is based on the Nobel Prize winning Hodgkin-Huxley model for excitation of the squid axon.... More Details 1 User Resource	Robert Macey Tim Zahnley
Visual Datasets	The Visual Datasets text module discusses the concept of visual learning and presents some suggestions for ways to design learning ... More Details 5 User Resources	Ethel Stanley
Wine Modeling	The Wine simulation allows you to model the fermentation process and explore variables and their effects on winemaking.... More Details 5 User Resources	Ethel Stanley Elisabeth C Odum H. T. Odum Virginia Vaughan
Winter Twig Key	An interactive visual key to dichotomous trees using winter twigs.... More Details 1 User Resource	Ethel Stanley Joseph Armstrong Dent Rhodes



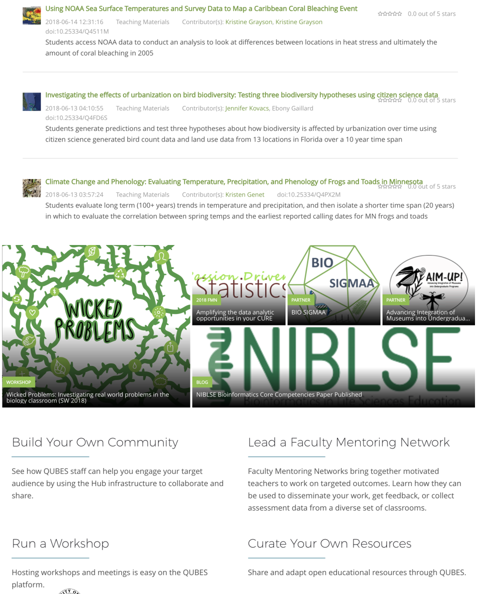
The Wine simulation allows you to model the fermentation process and explore variables and their effects on winemaking.

Students can probe the basic fermentation process. Enhancements such increased alcohol tolerance in cultivated yeasts used in modern wine making can be explored as well.

- Getting_Started_with...nd_BQLIBOnLine.pdf
- Install Info - WineFerment.pdf
- Wine.mox
- WineWork.mox
- WineYeasts.mox

QUBES

- "Provides logistical, intellectual, and community support for innovative quantitative biology education projects and the extended community of instructors seeking resources."
- Composed of three main areas:
  - Resources
  - Community
  - Services



Application

Introductory Course in Mathematical Modeling

- Uses discrete mathematical models to analyze problems arising in the biological sciences, without using calculus
- Types of models used:
  - Difference equations
  - Matrix models
  - Agent-based models
- MATLAB
- Materials provided:
  - Course Readings
  - Problem sets with some solutions
  - Labs

Discrete Math Modeling with Biological Applications (Course Materials)

By Erin N. Bodine

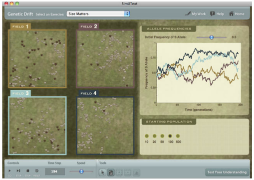
Rhodes College

In Lab 11 we developed a simple model for the ferret-skink-rabbit food web. In this final project, you will expand on that project to develop a more sophisticated and accurate ABM. Additionally, you will use data generated from the ABM to build a matrix model of landscape dynamics

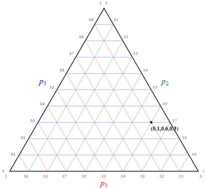
1 Methods

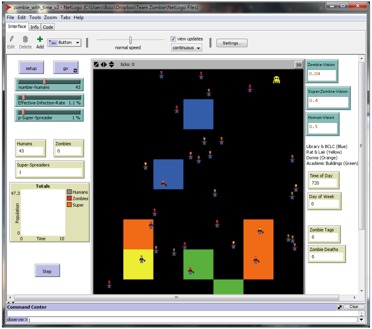
In this experiment, we ran a predator-prey model of lynxes and hares. In order to test this model, we both used a Leslie Matrix Model of the population, as well applying an agent-based model to the data, allowing us to observe the differences between the two forms of mathematical modeling with biological models. We tested the model under differing initial conditions. These included beginning with 20 lynx and a random-normal number of hares with a mean of 1.1 and a standard deviation of 0.36 (scenario A), 20 lynx and the number of hares depending on a mean of 1.15 and a standard deviation of 0.36 (scenario B), 50 lynx and hare populations with a mean of 1.1 and 0.36 (scenario C), and 50 lynx with the number of hares depending on a mean of 1.15 and a standard deviation of 0.36 (scenario D).

Technology-Based Learning in Other Courses




```
%Filename: LSR.m
%This m-file:
%   computes equations for least squares regression line
%   plots a least squares regression line on a graph with data
%   computes the correlation coefficient
%   computes the coefficient of determination
%LSR=Least Squares Regression

%Enter the data
x=[2 5 2 4 6];
y=[4 7 5 8 11];

%Find eqn for YSR line
C=polyfit(x,y,1);

%display eqn
fprintf('Eqn for LSR: yhat=%fx+%f\n',C(1),C(2))

%Find the yhat value for each x value
yhat=polyval(C,x);

%Plot data and YSR line
plot(x,y,'k.',x,yhat,'k-')
xlabel('x')
ylabel('y')
xlim([min(x)-1 max(x)+1]) %set x-axis a little wider than data

%Find the correlation coefficient
rho=corrcoef(x,y);
%display correlation coefficient
fprintf('rho=%f\n',rho(1,2))
%Display coefficient of determination
fprintf('The regression line accounts for %5.2f%%',(rho(1,2)^2)*100)
fprintf(' of the variance in the data. \n')
```






```
(*Super Awesome Jacobian Matrix Fun Time*)

SEIRModel = {Ω - B S I - μ S, B S I - (μ + k) E, k E - (γ + μ) I, γ I - μ R};
SEIRStates = {S, E, I, R};
SEIRJ = D[SEIRModel, {SEIRStates}] // MatrixForm
```

$$\begin{pmatrix} -BI-\mu & 0 & -SB & 0 \\ BI & -k-\mu & SB & 0 \\ 0 & k & -\gamma-\mu & 0 \\ 0 & 0 & \gamma & -\mu \end{pmatrix}$$

```
SEIRJ /. {S → Ω/μ, I → 0, E → 0, R → 0} // MatrixForm
```

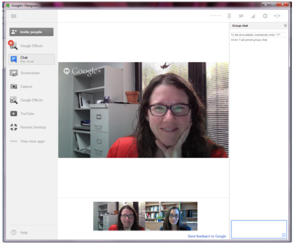
$$\begin{pmatrix} -\mu & 0 & -\frac{B\Omega}{\mu} & 0 \\ 0 & -k-\mu & \frac{B\Omega}{\mu} & 0 \\ 0 & k & -\gamma-\mu & 0 \\ 0 & 0 & \gamma & -\mu \end{pmatrix}$$

```
Eigenvalues[%]
```

$$\left\{-\mu,\ -\mu,\ \frac{-k\mu-\gamma\mu-2\mu^2-\sqrt{\mu}\sqrt{k^2\mu-2k\gamma\mu+\gamma^2\mu+4kB\Omega}}{2\mu},\ \frac{-k\mu-\gamma\mu-2\mu^2+\sqrt{\mu}\sqrt{k^2\mu-2k\gamma\mu+\gamma^2\mu+4kB\Omega}}{2\mu}\right\}$$

Independent and Collaborative Research Using Technology

- File Sharing and Storage
  - Dropbox
  - Google Drive
- Collaborative Writing
  - ShareLatex
  - Google Docs
- Communication: Google Hangouts
  - Google Hangouts
  - Slack



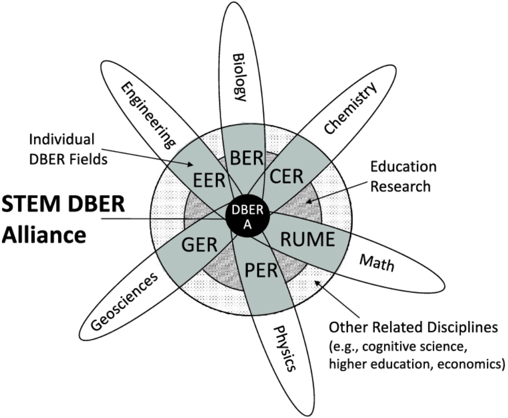
Overleaf + ShareLaTeX

Calculations and Crime: Teaching with Tech

- Five days, 9am-12pm each day
- Maximum class size: 20 Minimum class size: 6
- Objective: Use topics from high school level mathematics to explore concepts related to forensic science and criminology
- Activities
  - Footprint and Blood Spatter Analysis - Linear Regression
  - Fingerprint Analysis - Geometry
  - DNA Extraction - Probability
  - Body Decomposition - Algebra (Pre-Calculus)
- Resources Used
  - Google Slides - Collaborative Presentations
  - Math Bench - Punnett Squares
  - Matlab - Fingerprint Analysis
  - Desmos - Plotting Data
  - Youtube - Crime Show and Informational Clips
- Difficulties
  - Skill Mismatch
  - Math anxieties
  - Time management
  - Assessment/Feedback

Barriers to Teaching with Technology

- Assessment
- Professional Development Opportunities
- Student Pushback
- Monetary Constraints
- Curriculum Inflexibility
- Instructor Math Anxiety
- Institutional Pushback
- Course Development



Conclusions and Future Directions

- There is a need for:
  - Improved publicity for these resources
  - Communication about quantitative biology expectations and education across all education levels
  - Grants specifically aimed at supporting educators who want to introduce more quantitative biology in their classrooms
  - Workshops in course and module development
- Exposure to quantitative biology for younger students is necessary, but it will not happen if it is not accessible to our educators
- New resources and opportunities in the field:
  - Plant growth modeling application
  - Math Modeling Hub
  - Faculty Mentoring Networks (open for application)
  - Upcoming conferences and workshops

Acknowledgments

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NDSEG
NATIONAL DEFENSE SCIENCE & ENGINEERING GRADUATE FELLOWSHIP

THE UNIVERSITY OF TENNESSEE KNOXVILLE

DEPARTMENT OF ECOLOGY & EVOLUTIONARY BIOLOGY

Questions?

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