Leaf cutter ant foraging - Instructor Guidance*[[1]](#footnote-1)*

Module description and purpose:

This module was created as a way to give students a realistic, open-inquiry research experience, even when lab or field research is not possible. Students are introduced to leaf-cutter ants and how they forage, provided with images and videos taken in a rainforest in Panama, and are asked to develop a hypothesis, plan a study, collect real primary data, and analyze the data. Minimally the experience can take a couple of hours of class time and some report writing as homework. On the other end, full research papers or posters could be the product of a more rigorous research experience.

**Setting:** The context for study is examining leaf-cutter ants from the lowland tropical rainforest in Gamboa, Panama, very near the canal. There are paired images (of individual "focal" ants") and videos of those individual ants, and others, walking a known distance. Given these images/videos, there are a variety of topics students could ask questions about:

* **movement**
	+ numbers of ants moving in each direction (not terribly meaningful scientifically in its own right, but ok)
	+ speed of ants moving in each direction
	+ speed of laden ants vs. unladen ants
	+ speed vs. body size
	+ speed vs. traffic intensity
	+ speed vs. load size, with body size as a covariate
* **energetics**
	+ relationship of body size to leaf size (directly related to published research questions, and does not have a simple answer)
* **morphometrics/allometry**
	+ relationships between body parts as ants increase in size

**Focal quantitative concepts**: This module can be used to teach data visualization, frequency histograms, scatterplots, linear equations, linear regression, and image analysis concepts per se. More advanced courses could open up the analytical options, and therefore the hypothesis generation options, to include more than just regression. The regression focus here was chosen in large part to make the support materials and preparation students would need to do the analysis manageable for the instructor. However, if students already know regression, ANOVA, 2, etc., then the analysis won't need to be so prescriptive. In this regard, this activity could be a great "capstone" experience for the end of a biostatistics course - can your students put all the pieces together to choose, perform, and interpret the appropriate analysis for a novel study? :-)

## Alignment:

 **AP Biology:**

Learning objective 4.14: The student is able to apply mathematical routines to quantities that describe interactions among living systems and their environment, which result in the movement of matter and energy. [See SP 2.2; Essential knowledge 4.A.6]

[**Next Generation Science Standards**](http://www.nextgenscience.org/hsls-ivt-inheritance-variation-traits)**:**

|  |  |
| --- | --- |
|  |  |

Science and Engineering Practices: Using Mathematics and Computational Thinking: Use mathematical representations of phenomena or design solutions to support claims. (HS-LS2-4)

Science and Engineering Practices: Constructing Explanations and Designing Solutions: Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future . (HS-LS1-6), HS-LS2-3)

Science and Engineering Practices: Asking questions and defining problems: Ask questions that arise from examining models or a theory to clarify relationships. (HS-LS3-1)

Science and Engineering Practices: Developing and using models: Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS3-3)

HS-LS2-8. Evaluate the evidence for the role of group behavior on individual and species’ chances to survive and reproduce. [Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.]

HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. [Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.]

[**Common Core ELA Standards for Science and Technical Subjects**](http://www.corestandards.org/ELA-Literacy/RST/11-12/)**:**

[CCSS.ELA-LITERACY.RST.11-12.3](http://www.corestandards.org/ELA-Literacy/RST/11-12/3/)
Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

[CCSS.ELA-LITERACY.RST.11-12.7](http://www.corestandards.org/ELA-Literacy/RST/11-12/7/)
Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

[CCSS.ELA-LITERACY.RST.11-12.8](http://www.corestandards.org/ELA-Literacy/RST/11-12/8/)
Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

[CCSS.ELA-LITERACY.RST.11-12.9](http://www.corestandards.org/ELA-Literacy/RST/11-12/9/)
Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

[**Common Core Mathematics Standards for Statistics and Probability**](http://www.corestandards.org/Math/Content/HSS/introduction/)**:**

[CCSS.MATH.CONTENT.HSS.ID.A.1](http://www.corestandards.org/Math/Content/HSS/ID/A/1/)
Represent data with plots on the real number line (dot plots, histograms, and box plots).

[CCSS.MATH.CONTENT.HSN.Q.A.1](http://www.corestandards.org/Math/Content/HSN/Q/A/1/)
Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

[CCSS.MATH.CONTENT.HSN.Q.A.2](http://www.corestandards.org/Math/Content/HSN/Q/A/2/)
Define appropriate quantities for the purpose of descriptive modeling.

[CCSS.MATH.CONTENT.HSA.CED.A.1](http://www.corestandards.org/Math/Content/HSA/CED/A/1/)
Create equations and inequalities in one variable and use them to solve problems.

[CCSS.MATH.CONTENT.HSA.CED.A.2](http://www.corestandards.org/Math/Content/HSA/CED/A/2/)
Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

[CCSS.MATH.CONTENT.HSG.MG.A.1](http://www.corestandards.org/Math/Content/HSG/MG/A/1/)
Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).\*

**Instruction level**: Introductory or advanced undergraduate biology courses, high school, AP biology

**Prerequisite knowledge:** This module is designed to fit into a study of ecology, evolution, animal behavior, or the like. Alternatively, it could be used in a biostatistics course as an interesting context for analysis. Previous experience with image analysis is not required for either the instructor or the students.

**Keywords**: data visualization, graphing, linear regression, body size, allometry, foraging, leaf-cutter ants

# Instructional approaches:

These materials are constructed to allow some instructors to just pick up the lab and go, and to allow others to construct their own customized lab from the pieces. As indicated above, the experience could be pared down to two hours, or extended to a capstone research experience.

The class could cooperate to all study one question, or each group could ask and answer their own. In testing of this module, some really interesting things happened when different group asked their own questions. For example, several groups independently decided to investigate the relationship between leaf size and ant body size (it is one of the most obvious questions to ask). However, different groups decided to measure leaf and ant size by different metrics, and got DIFFERENT answers depending on their definitions of size. Specifically, a group that looked for a relationship between leaf area and ant length did not find a relationship, while one that looked at leaf area versus ant cross-sectional area DID! This led to a great impromptu discussion of what that means more generally about definitions and vocabulary, scientific results, and how much we should generalize from any particular study.

# Quantitative concepts:

**Basic**

* Basic graphing
	+ Scatterplots (e.g., leaf size vs. body size, body size vs. walking speed)
* Linear regression
	+ R2, p-values, hypothesis testing, slopes/y-intercepts

**Advanced / Extensions**

* Frequency histograms (not emphasized, but could do histograms of body sizes, leaf sizes, walking speeds, etc.)
* ANOVA, t-tests, etc. for categorical variables
* ANCOVA (e.g., accounting for body size when comparing laden and unladen workers walking speed)

# Potential learning objectives:

**Basic**

* Students will be able to generate meaningful scientific hypotheses given a context for study.
* Students will use image analysis software to generate data from an image set.
* Students will be able to conduct and interpret linear regression analyses (including R2, p-values, hypothesis testing, slopes/y-intercepts), given data they've collected.
* Students will write a results section in typical scientific literature format.

**Advanced/ Extensions**

* Students will be able to construct and interpret frequency histograms. Students will apply programming concepts to automate a series of procedures.
* Students will be able to conduct appropriate statistical analysis for a categorical independent and numerical dependent variable.

# Details on the Main Lab Activity:

Overall, students usually can follow along with the image analysis instructions pretty well. The instructions for conducting the regression analysis are likewise pretty straightforward. The sticking points are really three-fold:

1. Identifying an interesting research hypothesis
2. Planning a study that takes enough samples, collects the right information to address the research hypothesis
3. Interpreting the regression analysis in a meaningful way.

Stopping each group at each of those three points in the process for a 2-3 minute discussion is probably a good idea.

Having students read one or more research papers about ant foraging can really help prepare them to generate meaningful hypotheses in this lab. Moreover, seeing that the scope and scale of what they can accomplish in this lab is not too far off what professional scientists publish should reinforce that what they are doing is realistic science and meaningful.

**Dividing up the work:** There are too many images and videos for one student to do everything. How many samples to do is therefore a function of class/group size, available time, and instructor preference. Having each student group choose their own question does provide more student "ownership", though it requires a bit of work on the instructor's part to talk with each group about their proposed work to make sure it is a viable plan.

# Credits

Module content and writing: Jeremy Wojdak

Field photography and videography: Jeremy Wojdak, Justin Touchon, Myra Hughey

Review and formative suggestions:

1. This lab was created by JM Wojdak at Radford University. [↑](#footnote-ref-1)