# Plastic Tadpoles: Can predators change the phenotypes of prey?

# Instructor Guidance

**Module description and purpose:** This module is intended to teach introductory statistical concepts in the context of predator-prey ecology. The hope is that the drama of predation among charismatic organisms, the colorful images, and the personal story of the original investigator will engage students' attention and motivate their interest in analysis. Moreover, the module is designed to leave the lines of inquiry open and investigative, promoting student ownership of the ideas and process. Students collect real data, and can make meaningful discoveries, even while in a computer lab or at home; ideally all our students could visit amazing field sites to do independent research, but this kind of module can be a substitute when that isn't possible.

**Setting:** The setting comes from the work of [Dr. Justin Touchon](https://biology.vassar.edu/bios/jutouchon.html) while he was at the [Smithsonian Tropical Research Institute](http://www.stri.si.edu/) in Gamboa, Panama. Photographs of tadpoles were taken from an experiment in which tadpoles were raised in different predator treatments (e.g., control, fish, insect predation) ([Touchon and Warkentin 2008](http://onlinelibrary.wiley.com/doi/10.1111/j.0030-1299.2008.16354.x/abstract)). The tadpoles developed different phenotypes depending on their larval predation risk environment. Students may or may not find treatment differences depending on what traits they choose to measure, how they define those traits (i.e. "color" of tail spots could be defined in many different ways), and of course how accurately they measure those traits.

**Focal concepts**: This module can be used to teach very elementary statistical concepts, but features enough real-world complexity to allow for much more sophisticated analyses, depending on the course and preparation of the students. See below for example statistical concepts that can be approached.

The variation among individual tadpoles within the same treatment is substantial and of primary interest - many times phenotypic plasticity is described in textbooks (or viewed by students) as a light switch, yes or no, affair, whereas professional biologists are much more keenly aware and interested in the variation among individuals. This provides a nice opportunity for students to literally see, measure, and describe variation, a concept that many find opaque.

Because the context for study comes from a published research article, we have a great opportunity to have students practice reading the primary literature. Whenever possible, we encourage the use of the primary text (e.g., the experimental setting/rational/methods are described in Appendices I and II, excerpted from the methods section of the paper).

## Alignment:

 [**AP Biology**](https://secure-media.collegeboard.org/digitalServices/pdf/ap/ap-biology-course-and-exam-description.pdf)**:** Essential knowledge 1.A.2.c; 3.C.1; 2.D.1.b; 4.A.5

Learning objectives 1.26; 2.21; 2.42; 4.11; 4.23; 4.26

[**Next Generation Science Standards**](http://www.nextgenscience.org/hsls-ivt-inheritance-variation-traits)**:** HS-LS3-3, with Science and Engineering

practice "Analyzing and interpreting data", and Disciplinary Core Idea "variation of traits" LS-3-B, and Connection to Nature of Science "science as a human endeavor"

[**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/) ; [CCSS.ELA-LITERACY.RST.11-12.7](http://www.corestandards.org/ELA-Literacy/RST/11-12/7/); [CCSS.ELA-LITERACY.RST.11-12.9](http://www.corestandards.org/ELA-Literacy/RST/11-12/9/)

[**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/); [CCSS.MATH.CONTENT.HSS.ID.A.2](http://www.corestandards.org/Math/Content/HSS/ID/A/2/); [CCSS.MATH.CONTENT.HSS.IC.A.1](http://www.corestandards.org/Math/Content/HSS/IC/A/1/); [CCSS.MATH.CONTENT.HSS.IC.B.5](http://www.corestandards.org/Math/Content/HSS/IC/B/5/)

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

**Prerequisite knowledge:** This module is designed to fit into a study of population or community ecology, or evolution and natural selection. Previous knowledge about predator-prey ecology, and working with data in spreadsheets and constructing basic graphs, is helpful but not required.

**Keywords**: hypothesis formulation, data visualization, graphing, predator-prey interactions, phenotypic plasticity, image analysis, ANOVA, t-test, frequency histogram, R, Excel

# Instructional approaches:

These materials are constructed for two avenues - 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. Most instructors will find the complete lab to contain too many concepts, take too much time, and provide too much background. Just delete what you don't need.

More importantly, there are several different pedagogical/logistical approaches one could use with these materials:

1. **Complete research experience** - students read context for the study, define hypotheses, collect data, analyze data, and write a report
	1. **Completely open inquiry** - let students define their own hypotheses, collect their own data, and turn in a report in the style of scientific paper.
		1. probably the gold standard, in terms of mimicking real science and providing an authentic research experience
		2. probably the most engaging and interesting from the student's perspective
	2. **Constrained inquiry** - give students some direction about the research hypotheses, or discuss as a large group to come to a whole-class decision, then student groups work independently.
		1. might work best for newer students without much experience defining research hypotheses, or with the ecological concepts at hand
		2. probably reduces the ownership students feel towards the research
2. **More supported research** - as a class, discuss the issues, define a research hypothesis, then collaborate to collect data, students analyze and report individually or in small groups
	1. might work best with limited time (e.g., dividing image set by number of students), such as over two periods of a lecture setting
3. **Isolate part of the process** - Depending on the learning objectives, an instructor could:
	1. start with the data already collected and just have students read the context for study and do the statistical analysis
	2. just learn the image analysis skills
	3. just quantify variation among individuals within one treatment and plot frequency histograms

# Statistical concepts:

**Basic**

* ANOVA/ t-test
	+ pairwise comparisons among multiple treatments
* Basic graphing
	+ Bar chart with error bars (means and variation within treatments)
	+ Frequency histograms (distribution of trait values within and across treatments, distribution of color values in images)
* **Advanced**
* Principal Components Analysis
* Standardizing responses by index of animal size
* Multivariate ANOVA

# Learning objectives:

**Basic**

1. Students will be able to define phenotypic plasticity.
2. Students will practice extracting meaning from published methods section.
3. Students will generate meaningful hypotheses, given a context for investigation.
4. Students will use image analysis software to generate data from an image set.
5. Students will be able to measure, describe, and interpret variation among individuals within and across treatments.
6. Students will be able to construct bar charts with standard error bars and frequency histograms.
7. Students will calculate and interpret significance tests with categorical treatments.

**Advanced**

1. Students will interpret covariation among correlated traits (e.g., body size and tail depth).

**Credits**

Original research setting: Justin Touchon and Karen Warkentin

Help adapting research to module: Justin Touchon

Module content and writing: Jeremy Wojdak

Review and formative suggestions: