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Authentic Ecology Field Investigation for Large (or Small) General Biology Lab Courses

Carolyn Schultz and Anna Strimaitis

Florida State University, Department of Biological Science, 1021 Atomic Way, Tallahassee, Florida 32306 USA
(**cschultz@bio.fsu.edu; anna@bio.fsu.edu**)

This is a two-part community ecology lab that engages students in an authentic field investigation. In part one, students plant pitfall traps for crawling invertebrates in three different habitats. On the day of the planting, students observe biotic and abiotic components of the habitats, discuss community interactions, and predict which organisms might fall into the traps. The following lab meeting, the catch is quantified and specific adaptations that may have benefitted the organism in its habitat are noted and related to natural selection and evolutionary change. Data is depicted in graph format and is compared over many semesters to reveal trends.

Keywords: community ecology, field investigation, sampling methods, biodiversity, fitness, adaptation, species accumulation curve, ecosystem diversity

Introduction

The objective of this lab is to provide non-science majors with an authentic field experience that is easily relatable to their everyday observations of the natural environment where they live and go to school and is coherent with recommendations for undergraduate biology education (AAAS, 2015). These recommendations aim to move biology education beyond a central focus on the content that students need to know and towards engaging students in authentic practices of science. Such science practices include asking questions, making observations and predictions in the field, and collecting and analyzing data (NRC, 2012). Just as biologists engage in these practices to generate new biological knowledge, students should also engage in such practices to develop a durable understanding of biological phenomena. In this general biology lab investigation, students go to the field site to make observations and predictions and the data collection and analysis to test those predictions involves unintimidating, low-tech equipment. Overall, this authentic field research experience encourages deeper biological consideration of common outdoor experiences than many students have experienced during prior schooling.

Prior knowledge required for this lab: Students complete a pre-lab assignment which provides an overview of the objectives of the field investigation. To inspire student predictions of arthropod adaptions they may observe, the pre-lab instructs them to explore and report on a science news article that makes a claim about an adaptation that enhances an arthropod's fitness. Students also read the lab manual instructions fully to understand their task is to collect evidence during the field investigation to answer the guiding question with a scientific argument. The argument includes a claim, the answer to the guiding question; evidence, an analysis of the data collected and interpretation of the analysis; and reasoning, an explanation of why the evidence supports the claim (Berland and McNeill, 2010). Throughout the semester and for this lab, students reflect on design elements of the investigation: What is the data collected? Is there an experimental variable? What is the control condition, treatment condition, number of replicates, controlled variables and sources of variation? This field investigation, a systematic observation investigation, rather than an experiment, further enhances student understanding of elements of investigation design. Additionally, students need to have had experience with calculating standard deviation and graphing data with error bars

Part One of this lab takes place in the field: students observe biotic and abiotic components of the habitats, discuss community interactions, predict which organisms might fall into small, pitfall traps and plant traps. Optimally, the field site consists of three different habitats within very close proximity to each

other and close proximity to campus. To prepare for the field experience, students read the lab manual which provides ecology background information and field trip protocol. They also will have completed the pre-lab assignment which develops understanding and interest in biological research and arthropod adaptations.

Part Two of the lab takes place one week after planting the traps; course staff retrieves the traps from the field site and students assess the catch while in the lab.

We conduct this highly successful field investigation and follow-up lab with 42 sections of 24 students, over 1,000 students per semester. Importantly, it can be implemented with modifications: smaller groups, varied environments, shorter sampling period, or emphasis on other ecological concepts. This proposed workshop is of general interest to the ABLE community because it will engage participants as learners in an investigation that is well-aligned with current recommendations for undergraduate biology education. Additionally, participants will have direct experience with the logistics involved in enacting this investigation in a large enrollment general biology lab course, and we will facilitate discussion of how to adapt this investigation to participants' unique instructional contexts.

Student Outline

Objectives for Part One and Part Two

- Describe how the environment influences populations of organisms over multiple generations.
- Explain how abiotic characteristics and biotic interactions influence organism distribution and abundance.
- Describe appropriate sampling methods for different types of communities.
- List the necessary components for natural selection to occur.
- Describe how genetic variation among organisms affects survival and reproduction.

Guiding Question for Part One and Part Two: How do biotic and abiotic environmental conditions structure the abundance and diversity of invertebrates in a community?

Background, Part One

The scientific study of the interactions between organisms and their environment is called **ecology** (from the Greek *oikos*, meaning home, and *ology*, meaning study). Community ecologists study an assemblage of directly or indirectly interacting populations living in a prescribed area or habitat and how those interactions affect the structure and organization of that community. A **population** is defined as a group of individuals of one species in an area. Biotic interactions include competition, predation, grazing, parasitism, mutualism, and detritivory. **Competition** is an interaction in which one organism deprives another of a resource, causing it to grow more slowly, leave fewer offspring, or die more quickly. **Predation** is broadly characterized as an interaction in which one organism kills another organism and eats it completely, whereas **grazing** is an interaction in which an organism takes only part of its prey. **Detritivory** is the consumption of dead organic matter and is a process essential to nutrient cycling. **Parasitism** has similarities to predation, but it differs in that it is a **symbiosis** (two organisms of different species living very closely together) in which one organism typically feeds on only one or a very few individuals of another species and rarely kills them immediately. A **mutualism** is another symbiosis, but in this interaction both organisms receive a net benefit that may allow them to grow faster, leave more progeny, or live longer. The ecology of parasitism and mutualism are often neglected in general biology curricula, yet more than half of the species on earth are parasites, and the greater part of the world's biomass is made up of mutualists.

To determine what interactions may be taking place in a community, ecologists must know what organisms are present that could possibly be interacting. Communities are often described and compared through patterns of **diversity** (the variety of different organisms) or **abundance** (the amount of organisms, often in terms of number of individuals or total biomass). Patterns of diversity and abundance can be quantified as the number of different species (**species richness**), the relative abundance of each species, or a diversity index that takes into account both measures. Quantifying the abundance of organisms requires a decision about whether the most biologically meaningful measure is the number of individuals of a species or its **total biomass.** For example, 100 tiny insects may be grazing a single plant, but because of their small biomass, those 100 may graze the same amount of plant tissue as 10 large insects. Whether the number of grazing insects or the biomass of grazing insects is most important depends on the research question.

Inevitable limitations, such as time and resources, prevent ecologists from counting and identifying every single organism living in a habitat. Instead, biologists have developed different **sampling methods** that allow them to estimate, with a certain level of confidence, the number of species and their relative abundances. A researcher primarily interested in **sessile** (nonmoving) organisms may lay **transect lines** of a specified length in a carefully designed array and catalog the abundance of organisms either directly under the transect line or within the area of a **quadrat** (plot of a specified area such as 0.5 m^2, 1 m^2, 10 m^2) that is placed along the transect line. This method is popular for quantifying community characteristics in both terrestrial and marine environments. To sample mobile organisms in **aquatic environments**, scientists can pull a seine net through the water, either on foot or behind a boat; use bait traps; or swim in a specified area for a specified amount of time recording the organisms they come across. In **terrestrial environments**, scientists can sample small mobile organisms by means of **pitfall traps,** containers of appropriate size placed in the ground so that the lip of the container is flush with the surface. Sometimes bait is added to the container, but even without bait, organisms moving through the habitat will walk into the pitfall trap, providing a sample of that community. To sample a community effectively, ecologists must consider the **number** of traps that will be sufficient, the best **spatial arrangement** of traps,

and how to avoid biasing the sample. Ecologists plot **species-accumulation curves** to visualize the accumulation rate of newly discovered species over the sampled area. The number of samples may represent subsequently quantified transect lines, 1-m^2 quadrats, or pitfall traps, depending on the method used to sample the community. For each sample accumulated, the total number of species represented up to and including that sample is plotted on the y-axis, and the cumulative number of samples is plotted on the x-axis (Figure 1). Many species are found in initial samples, so the accumulation curve will rise steeply at first and then more slowly as the increasingly rare species are added. When the curve levels off and adding more samples does not result in additional species, ecologists can be pretty confident that they have collected enough samples to describe the diversity of the community accurately.

In addition to the diversity and abundance of species needed for determination of what biotic interactions may structure a community, **abiotic factors** are important for understanding why different habitats may be more suitable for different species. Besides climatic factors such as temperature and rainfall, **soil characteristics** and **light intensity** can structure the community by influencing which plants can live in a habitat. Plants may shade out competitors or provide camouflage for both predator and prey, and their production as primary producers depends in part on the soil. Soils are of three main types: sandy, clay, and loam. Sandy soils dry out quickly and do not hold mineral nutrients necessary for plant growth. Clay soils have plenty of nutrients, but they can become compacted and hold water, restricting oxygen availability. The best soil for most plants is **loam** (composed of sand, clay, and silt) because it drains at a moderate rate, holds nutrients, and has a lot of organic matter to support detritivores, creating a rich microbial community to recycle nutrients. **Soil pH** and **moisture** are also important to plant community structure because they affect how minerals and nutrients dissolve in the soil. Soils that are slightly acidic or neutral (pH of 6 or 7) are best for dissolving nutrients. In addition, acidic and basic soils reduce the activity of detritivores that break down organic matter to release nutrients and make nutrient uptake by plants difficult.

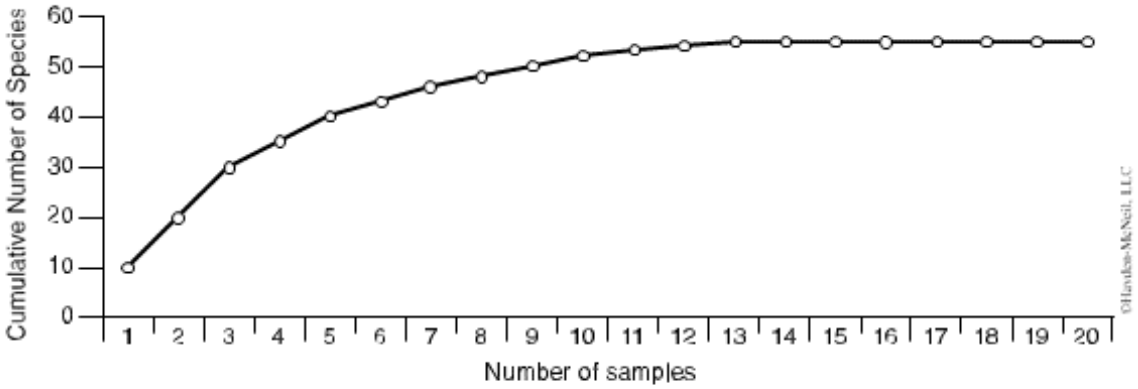


Figure 1. A species accumulation curve depicting the accumulation rate of new species as more area is sampled.

Your Task, Part One

This week you will work in groups of four to set pitfall traps and sample the invertebrate community in three different habitats. You will measure abiotic variables in the three habitats as well as make visual observations of the similarities and differences of these habitats that will help you interpret your data and draw conclusions about the interactions structuring the diversity and abundance of invertebrates.

Materials list for students, Part One

You will use the following materials during your field investigation (Figure 2).

- Plastic vial and lid. The vial is used as the trap. Don't touch the inner lip, as the fluon (slippery substance) will rub off.
- Drill.
- Propylene glycol (low-toxicity antifreeze to preserve the invertebrates) in wash bottles.
- Clear plastic plate pierced on the edges with three nails to serve as a roof against rain.

- One copy per four-person group of the lab manual Field Work Observation Form (Table 2)
- 3 liters of tap water, one at each site, for rinsing the soil sampling tube and hands
- 3 liters of distilled water for testing soil sample pH.
- Plastic 50 mL tube for soil sample.
- Light meter, pH meter, psychrometer (measures humidity), soil thermometer.

Safety Precautions: If you spill propylene glycol, the low-toxicity antifreeze, on yourself when in the field, rinse with the tap water at the site. After returning to campus, wash with soap and water.

Figure 2. Sampling tools.

Data Collection, Part One

Use the following procedure to collect the data you will need to answer the guiding question.

1. Record the different habitats you observe at the site on the Field Work Observation Form. What characteristics are you using to distinguish habitats? Which characteristics are biotic, and which are abiotic?
2. Make predictions on the data sheet about the characteristics that would allow an invertebrate to thrive in each habitat. Do you think the habitats will differ in abundance of invertebrates?
3. The class will divide into three groups to plant pitfall traps and rotate through the three specified habitats. At each habitat, your group will make detailed observations about the site and measure soil pH, soil moisture, and soil type. Groups will be assigned to measure light intensity, soil temperature, or humidity at the three sites and share their readings with the rest of the class upon return to the lab.
    - Light intensity: The light meter measures light intensity. Hold it so the sensor points directly at the sun. Full sun (summer at noon) is about 2000 microEinsteins per meter squared per second. Allow time for the reading to stabilize.
    - Soil temperature: Insert the thermometer into the ground to the indicated mark to record soil temperature at each site.
    - Humidity: The psychrometer measures the humidity at each site. Allow time for the reading to stabilize.
    - Soil pH: Put about 25 mL of soil in a 50 mL tube and add 25 mL distilled water. Shake to thoroughly mix the contents and test pH with a pH meter. Allow time for the reading to stabilize
    - Soil moisture and type: Use the “feel and appearance test” to estimate soil moisture and type. Squeeze soil and evaluate using Table 1.

Table 1. Soil moisture and type.

More Moist ↓ Less Moist	Wet—soil forms ball with visible wetness	
	Moist—forms a weak ball	
	Slightly moist—forms a very weak ball and may show finger marks	
	Dry—loose, may form a very weak ball, soil grains break away easily from the ball	
Soil Type	Sandy	Mostly sand
	Clay	Mostly clay
	Loam	Lots of ground-up bits of organic matter (leaves, etc.)

4. Deploy the traps as follows to facilitate easy trap collection by course staff after one week.
   a. Before planting your trap, write the number of the trap you'll be planting (each trap has a number #1–6), on the Field Work Observation Form. Each group of four or five students plants one trap at each habitat.
   b. Plant your trap in the area designated for your lab section. Each lab section will plant traps 30 cm (12 inches) away from all other lab sections. The location is designated by a flag marked with the lab section number.
   c. Plant your trap close to the other traps in your lab section so all six traps from your section fit underneath the same plastic plate roof. The plastic plate roof is marked with the lab section number.
5. Steps for planting a trap:
   a. Put approximately 2 cm (3/4 inch) of low-toxicity antifreeze in a numbered trap.
   b. Cap the trap without touching its inner lip.
   c. Drill (or otherwise make) the hole in the ground and place the trap in the hole so that the top of the trap is level with the surface of the soil. Push any loose soil up against the vial to complete the plant.
   d. Remove the caps from all six traps in the lab section *after* the sixth is planted to help keep dirt from falling into the vials during the planting process.
6. Once the traps for a lab section are planted and the lids are removed, place the clear plate, suspended on three nails, over the group of six traps, making sure the section number is on the top of the plate.

Field Work Observation Form, Part One

Use this form to record your group's observations. Describe the various communities that you see at the field site. List the biotic and abiotic components of each site.

Table 2. Field work observation form.

Habitat (pond, grass, woods)	Abiotic Characteristics (What makes it unique in the eyes of an invertebrate?)	Biotic Characteristics (What makes it unique in the eyes of an invertebrate?)	Predictions about the Abundance and Characteristics of Invertebrates in This Community (What might an invertebrate need to thrive in this habitat?)
Habitat: Trap #:	Light intensity: Humidity: Soil temperature: Soil moisture: Soil type: Soil pH: Other:		
Habitat: Trap #:	Light intensity: Humidity: Soil temperature: Soil moisture: Soil type: Soil pH: Other:		
Habitat: Trap #:	Light intensity: Humidity: Soil temperature: Soil moisture: Soil type: Soil pH: Other:		

Conclusion, Part One

Once you have finished setting your traps, answer the following question to wrap up Part One of this two-week investigation: How do community ecologists effectively sample mobile invertebrates in terrestrial habitats? Be sure to describe all of the considerations that must be taken into account.

Discussion, Part One

Answer the following questions about your investigation.

1. How would you know when you have collected enough samples to describe the community? What would you need to consider about the spatial arrangement of your samples?

2. On the basis of your observations at the site, how do the three sites differ in their abiotic characteristics? Why must the abiotic characteristics of a habitat be measured, as well as the biotic community?

3. What is the difference between a predator, a grazer, and a detritivore? Do you think the abundances of these three groups will differ among the invertebrate communities in the three habitats? Why or why not?

4. Suppose you mix up the traps after collecting them and you do not know which sample represents which habitat. Describe a characteristic that you might look for to associate one of the traps with one of the habitats. (Hint: What characteristics did you predict might help an invertebrate thrive in each habitat?)

Background, Part Two

The variety of living organisms is referred to as **biodiversity** (Figure 3). Diversity is important at many levels of the biological hierarchy, from **genetic diversity** (the number of different alleles in a population) to **species diversity** (the number of different species in a community) to **ecosystem diversity** (the number of different ecological functions performed by a community that maintain ecosystem stability). Maintaining biodiversity is important because a diverse ecosystem is more resistant to natural disturbances (e.g., hurricanes) or human-caused disturbances (e.g., pollution). Diverse ecosystems have this property because they include multiple species that perform the same functions, such as decomposition or filtering food particles from the water column. Some species play a much larger role in supporting communities than their abundance might indicate, because they are ecologically connected to numerous other species. These are called **keystone species,** because if they disappear from the community, the structure of the community is likely to collapse. The gopher tortoise, native to North Florida, is a keystone species that excavates large burrows that also support approximately 350 other species, including the indigo snake, burrowing owl, gopher frog, and opossum. Gopher tortoise habitat is protected by Florida law, and suitable habitats can be restocked with the tortoises as necessary to preserve these ecological relationships.

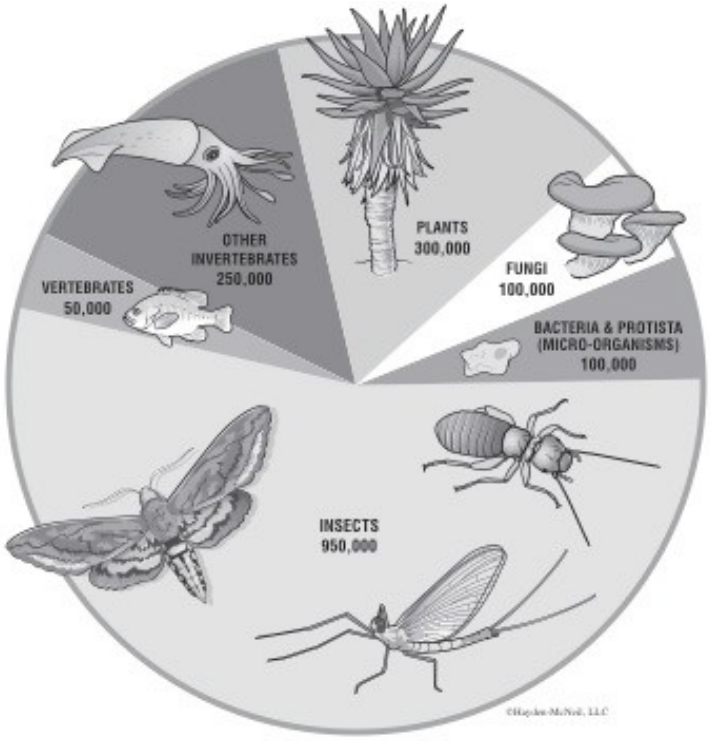


Figure 3. Estimated number of species on earth.

Loss of species diversity and genetic diversity also has negative consequences. Roughly 50,000 species become extinct each year, and most are lost as a result of human actions such as **habitat destruction,** introduction of **invasive species, overexploitation,** and **pollution**. When species become extinct, their roles in community interactions (e.g., trophic or symbiotic relationships) are unfulfilled. When many individuals of a species are lost, the genetic diversity of that population is reduced. Fewer unique genetic combinations are therefore available to code for different phenotypes that could increase survival and reproduction (**an organism's fitness**). The fittest individuals are those that pass the most genes on to the next generation. An **adaptation** is a trait that is common in a population because it increases fitness.

When a population harbors variation in heritable traits of individuals and its individuals undergo differential survival and reproduction, **evolution by natural selection** will take place, and the traits that confer the highest fitness advantage will increase in frequency. Evolutionary change is essential for maintaining life in the face of a changing environment. Different species have adapted to use unique combinations of biotic and abiotic resources in their environment (i.e., have developed different ecological niches), and the diversity of life that has evolved over millions of years is staggering. Biologists organize this diversity by grouping related organisms according to a hierarchical classification system. Species that are closely related are grouped in the same genus, closely related genera are placed in the same family, families are grouped into orders, orders into classes, classes into phyla, phyla into kingdoms, and kingdoms into domains. Insects, a class of organisms, are the largest and most successful group of animals on earth. They have adapted to almost every terrestrial and freshwater habitat, as well as to the atmosphere through the evolution of flight!

Your Task, Part Two

Work in groups of four, two students per dissecting microscope. Quantify the samples in your pitfall traps from each habitat by identifying your catch, counting the individuals, and calculating the biomass of each individual.

Materials list for students, Part Two

You will use the following materials during your investigation.

- Pitfall traps retrieved from the field site after one week of sampling
- 70% ethanol, 50 mL squeeze bottle
- Small strainer
- Plastic beaker
- Small paintbrush
- Dissecting microscope
- Tweezers
- Petri plates labeled W, G, P
- Rulers and graduated tubes calibrated for biomass measurement
- Conversion chart for height of biomass to volume of biomass conversion
- Invertebrate identification sheets on the bench
- Three large collection jars for samples from each site after analysis
- Propylene glycol containers for collection of strained propylene glycol

Safety Precautions: Wash hands with soap and water if you touch the propylene glycol. Predict how the samples from the woods, pond, and grass will compare in terms of:

Number of individuals:
Diversity of organisms:
Biomass of organisms:

Data Collection Part Two

Use the following procedure to collect the data you will need to answer the guiding question.

1. Your TA will give you the specific traps you recorded and planted last week. To prevent mix up, put the trap from the appropriate habitat near or in the appropriate Petri dish (one labeled for woods, W; one for grassy area, G; and one for pondside, P).
2. Use a strainer to separate the solid and liquid contents of each trap. Pour the liquid through the strainer into a plastic beaker and transfer the solid contents from the strainer into the appropriate Petri dish. Use the small paintbrush and/or a small amount of ethanol to clean out the vial and the strainer as needed.
3. Discard the liquid from the trap in the appropriate container at the front of the room.
4. Examine the Petri dish under the dissecting microscope to identify and count your catch.
    a. Use an Invertebrate Identification Guide to find the common name of each organism. If you think you have multiple kinds of a specific group (e.g., ants) you can further separate them and give them unique names (e.g., "fuzzy ant," "crazy antennae ant"). Write the name of each different group of organisms on a separate line under "Organism ID" on the Observation and Measurement Summary Table (Table 3).
    b. Count the number of individuals from each group of organisms you identify and record the data on the Observation and Measurement Summary Table (Table 3).
    c. In Table 4, sketch and identify at least three different organisms from the pond, grass, and woods habitats. Label characteristics that may allow each group of organisms to thrive in that habitat. If your pitfall trap does not have at least 3 different organisms, make observations from another group's sample. Do not collect quantitative data on the other group's catch.

       Do these organisms have any of the adaptations you predicted? Remember to pay special attention to modified appendages and mouthparts.

    d. After identifying the different groups and counting all of the individuals in each group, carefully put all of the organisms in the tube to measure the total biomass. Be sure to exclude any non-animal debris. Gently tap the tube to shake all of the organisms to the bottom and read the height of the volume off of the side of the tube. If the markings have rubbed off, use the ruler to measure the height. Refer to the biomass calculation chart (Table 5) to determine the total biomass of your catch based on the height.
    e. Once you have identified and quantified your vial from each habitat, complete the Observation and Measurement Summary chart (Table 3) and add these values to the class data sheet. Add the organisms from your vials to the appropriate storage container at the front of the room. Rinse, clean, and dry all materials and organize them at your station.

Use Table 3 to keep a record of the observations and measurements you make during your investigation.

Table 3. Observation and Measurement Summary.
Record your observations and measurements for each habitat in this table.

Habitat: WOODS				Habitat: PONDSIDE		
Organism ID	Number of Individuals (n)	Biomass (cm^3)		Organism ID	Number of Individuals (n)	Biomass (cm^3)
1.				1.		
2.				2.		
3.				3.		
4.				4.		
5.				5.		
6.				6.		
Totals for Trap:				Totals for Trap:		

Habitat: GRASS				Summary of Totals for Each Trap			
Organism ID	Number of Individuals (n)	Biomass (cm^3)		Site	Number of Different Types of Organisms (n)	Total Number of Individuals (n)	Total Biomass (cm^3)
1.				WOODS			
2.				GRASS			
3.				POND			
4.							
5.							
6.							
Totals for Trap:							

Observations, Part Two

Table 4a. Sketch and identify organisms from the woods.

Habitat: Woods

If the organisms from the woods have any of the adaptations you predicted last week, list them here.

Table 4b. Sketch and identify organisms from the pond.

*Habitat:*Pond

If the organisms from the pond have any of the adaptations you predicted last week, list them here.

Table 4c. Sketch and identify organisms from the grass.

*Habitat:*Grass

If the organisms from the grass have any of the adaptations you predicted last week, list them here.

Observations and Measurements, Part Two

Table 5. Use the table to estimate the biomass in each habitat based on the height of the organisms in the tube.

Height of biomass in graduated tube (cm)	Volume of biomass from pitfall trap (cm)
0.5	1.9
1.0	3.8
1.5	5.7
2.0	7.6
2.5	9.5
3.0	11.4
3.5	13.3
4.0	15.2
4.5	17.1
5.0	19.0
5.5	20.9
6.0	22.8
6.5	24.7
7.0	26.6
7.5	28.5
8.0	30.4
8.5	32.3
9.0	34.2
9.5	36.1
10.0	38.0
10.5	39.9
11.0	41.8
11.5	43.7
12.0	45.6
12.5	47.5
13.0	49.4
13.5	51.3
14.0	53.2
14.5	55.1
15.0	57.0
15.5	58.9
16.0	60.8

Data Analysis, Part Two

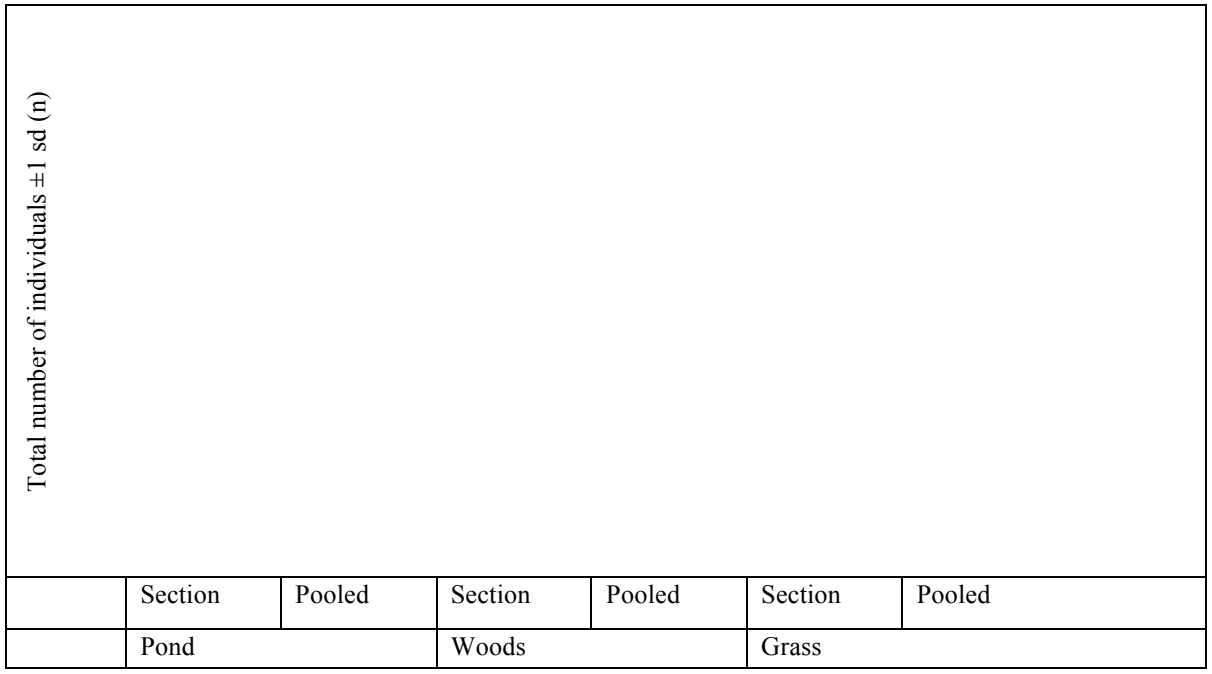
Use the following steps to create graphs in Figure 4 that illustrate the relationships between habitat and each of three variables: number of different groups of organisms, total number of individuals, and biomass of organisms.

1. Add appropriate scales to the y-axis of the graph below.
3. Graph the mean of your section's data from the three habitats for the three different variables.
4. Review the data pooled from all lab sections that is posted on the course website at the end of the week. Graph the mean and standard deviation for the pooled data for each habitat and each variable next to the graph from your section.

Mean number of different groups of organisms ±1 sd (s)

	Section	Pooled	Section	Pooled	Section	Pooled
	Pondside		Woods		Grass	

Habitat



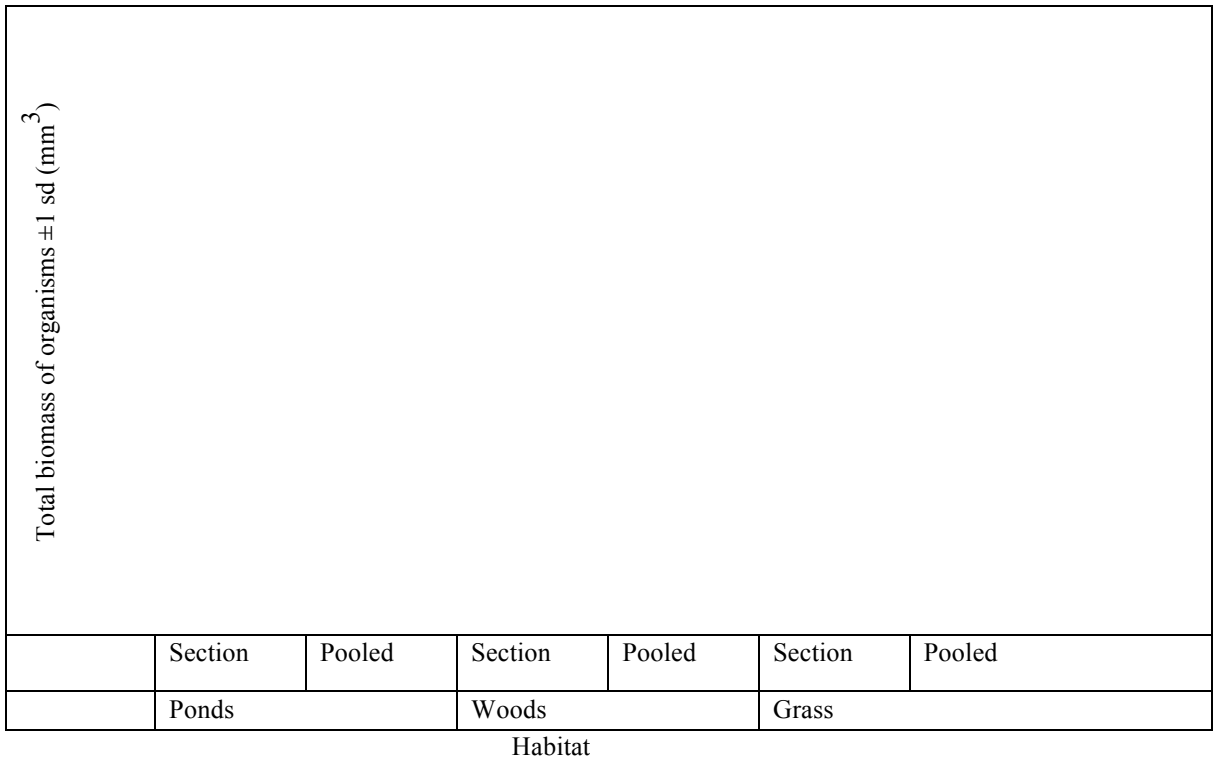


Figure 4. Graph the relationship between the site and each of three variables: number of different organisms, total number of individuals, and biomass of organisms.

Conclusion, Part Two

Once you have finished collecting and analyzing your data, provide an answer to the guiding question: How do biotic and abiotic environmental components structure the abundance and diversity of organisms in a community? In the space below, discuss the results from your data and from the pooled data posted on the course website.

Claim:

What evidence did you collect to support your claim?

Why do you think this evidence is appropriate and sufficient to support your claim?

Discussion, Part Two

Answer the following questions about your investigation.

1. Is your answer to the guiding question consistent with what you thought previously, before this lab, about how communities are structured? Be sure to explain why or why not.

2. Choose an organism that you found in one area and not another. Develop a justified explanation for this distribution pattern, supported by evidence involving both abiotic and biotic factors.

3. What specific types of diversity are encompassed by the concept of biodiversity, and why is maintaining each important?

4. Explain how one individual can have a higher fitness than another individual in a population and how fitness relates to the adaptation of a population to a specific environment.

Materials

Part One

- Plastic vials and lids used for traps: Thornton Plastics, 745 Pacific Ave, Salt Lake City, UT 84104 http://www.thorntonplastics.com/ 15 dram, sku: 15c. Traps measure: ~3 cm x 8 cm. Alternative: 50 ml (conical) tubes. Sets of pre-numbered vials for each lab section are prepared to save time at the site and to ensure students quantify the contents of their exact vial during Part Two. Students in each lab section are divided into three groups (one group for each of the three habitats) and rotate through each of the 3 habitats in 10 minute intervals. A lab section of 25 students would have one group of nine students and two groups of eight students. The prepared re-closable vial bag at each habitat (for each lab section) has six vials numbered 1 through 6; six tubes for each of three vial bags = 18 vials needed per lab section.
- Clear, plastic, approximately 26 cm plates, large enough to serve as a roof over each lab section's 6 vials to protect from rain and debris. Plates are pre-labeled with the section number and pre-pierced with 3 nails approximately 7.5 cm long to support the plate above the traps. One plate per habitat for each lab section = three plates needed per lab section. http://www.partycity.com/product/clear%20plastic%20dinner%20plates%2010%201-4in%2050ct.do?kwid=clear%20plastic%20dinner%20plates%2050ct&qcid&ref=ci&extcmp=pla|Google
  Alternative: set up a canopy tent over the planting area http://www.dickssportinggoods.com/product/index.jsp?productId=2935027
- Survey flags: Label the area where each lab section plants with a survey flag pre-numbered with the lab section number.
- Fluon: Insect-a-Slip Insect Barrier-Fluon BioQuip Products, Inc., 2321 E. Chadwick St., Rancho Dominguez, CA 90220 www.boiquip.com Item #2871A. Prior to the field trip, coat inner lip of vial/tube with a small paintbrush to prevent invertebrate escape.
- Drill: Have a tool at each habitat to make a hole for each vial that is the depth of the vial and slightly larger than the diameter of the vial. DeWalt DC970 ½" VSR cordless drill (with battery charger) and DeWalt Ship Auger Bit 1-1/4" x 6" DW1674 works well in many soil types. Alternative: a galvanized pipe approximately 3.8 cm in diameter and long enough to hold comfortably while standing and hammered into the ground to the depth of the vial. Mark the pipe with tape to the correct depth. Hammer into ground with a short-handled sledge. Remove dirt from pipe by poking with a dowel.
- Propylene glycol (low-toxicity antifreeze to preserve the invertebrates) in wash bottles, one/habitat. Available at auto parts supply stores. MSDS information: https://fscimage.fishersci.com/msds/19870.htm
- Sharpie pen for labeling replacement vials, plates or flags at the site, one per habitat.
- One copy per four or five-student group: Field Work Observation Form from the lab manual.
- Tap water for hand washing and distilled water for soil PH testing: one 2 liter jug per habitat.
- Plastic 50 mL tube for soil sample, one per habitat. Alternative: any small container with a lid.
- pH meter: one at each habitat. Hanna Instruments, HI98100 Checker Plus pH Tester http://shop.hannainst.com/products/testers/parameter/ph.html
- Light meter: only one needed. Students in charge of collecting light data at each habitat carry the meter with them and share data with the rest of the class after returning from the field trip. MQ-100 Quantum Integral Sensor with Handheld Meter, Apogee Instruments, 721 W 1800 N, Logan, UT 84321, http://www.apogeeinstruments.com/ works well. Alternative: measure other abiotic features, as you wish.
- Psychrometer: only one needed. Students in charge of collecting humidity data at each habitat carry the psychrometer with them and share data with the rest of the class after returning from the field trip. Alternative: measure other abiotic features, as you wish. (http://www.coleparmer.com/Product/Extech_RH300_Digital_Psychrometer_0_to_100_RH_4_to_122F/UX-37803-10?referred_id=778&gclid=CPnv3MvsksgCFQgXHwodCU0AvA
- Soil thermometer: only one needed. Students in charge of collecting soil temperature data at each habitat carry the thermometer with them

and share data with the rest of the class after returning from the field trip. Alternative: measure other abiotic features, as you wish.

- Digital Pocket Thermometer, LCD, Item 4LY14 from Grainger http://www.grainger.com/product/TAYLOR-Digital-Pocket-Thermometer-4LY14?nls=3&nlsit=0.8&ssf=3&searchQuery=4LY14

Part Two

- Pitfall traps retrieved from the field site after one week of sampling
- Pliers for removing traps from the ground
- Vial pick up tray to organize vials by habitat and section. One option is to drill holes the diameter of the vials in sheet-type Styrofoam insulation, then glue a sheet of plastic to the bottom so vials don't fall through. See Figure 6.

Figure 6. Vial pick-up tray. Vials are kept organized using a tray.

Arrange the items listed below on a tray for student use in the lab. See Figure 7.

- 70% ethanol in 50 mL wash bottles, two/group of four
- Small strainer to separate invertebrates from propylene glycol
- Small plastic beaker (or other container) to collect used propylene glycol during the straining process.
- Small paintbrush to move invertebrates, as needed
- Dissecting microscope
- Tweezers to move invertebrates, as needed
- Three ~8 cm plastic petri plates labeled W, G, P for each group of 4 students.
- Rulers and graduated tubes (~2cm diameter glass vials with cm labeled) for biomass measurement
- Conversion chart for height of biomass to volume of biomass conversion, See Table 5.
- Invertebrate Identification Guide, specific to the locale and a variety of other resources for identification.
- Three large collection jars for invertebrate samples from each student group; labeled W, G, P, one per lab room
- Propylene glycol containers for collection of strained propylene glycol. Propylene glycol not diluted by rainwater, ethanol or dirt can be reused. Waste propylene glycol is collected into hazardous waste containers and disposed of according to US EPA guidelines. MSDS information: https://fscimage.fishersci.com/msds/19870.htm
- TAs add section data to a tally sheet that is later used to generate pooled data for the semester with mean and standard deviation. Students view this data on the course website, add it to Figure 4 and discuss it in the Conclusion and Discussion sections of Part Two.

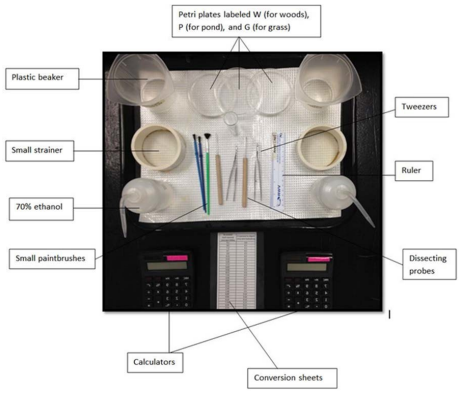


Figure 7. Items for Part Two are arranged on a tray for student use.

Notes for the Instructor

Part One

Critical steps to ensuring success on this field trip concern advance preparation. Locate a permissible site that will remain undisturbed during the sampling period. Gather and organize all investigation materials so there is no confusion at the site. Familiarize staff with idiosyncrasies of each habitat and ensure they are trained in their tasks. Orient students to what they are expected to do and why they are doing it. Make arrangements for student transportation to the field site in advance so that movement between the classroom and field site is

seamless. The level of detail in scheduling will depend on the lab/course enrollment, where you'll be going, how students will get there and how long it will take to get there. It is ideal to keep the trip during the regular lab day and time to avoid conflicts with other scheduled activities and to allow students to work with classmates and a teaching assistant who can call them by name.

Part Two

At the start of the lab meeting, have students confer with their groups to recall predictions, observations and measurements from the field trip. Groups then examine contents from traps. Invertebrates are identified and drawn, counted, measured and biomass is calculated. Students also use the dissecting microscope to observe the bodies and structures of the invertebrates and look for evidence of the adaptations they predicted. TAs prompt student thinking about components of natural selection:

- What do you think causes "x" trait to occur in high frequencies in this habitat?
- What would happen if this trait did not provide an advantage? Would it still be prevalent?
- Why is increasing survival and reproduction important?
- What might be going on here that we cannot see?
- What do you think causes variation in this trait?

Following clean-up, students share group information (can compile on a white board first) and compile a class list. Data is entered into the TA spreadsheet; class findings are graphed. Students graph this section data in the Data Analysis figure (Figure 3). TAs prompt student thinking:

- Do the communities seem to be made up of different organisms?
- Were any of your predictions supported?
- Were there any organisms found in multiple habitats?
- How did the number of individuals, diversity and biomass vary across habitats?

Course data from the previous semester is projected and discussed. (Figure 5)

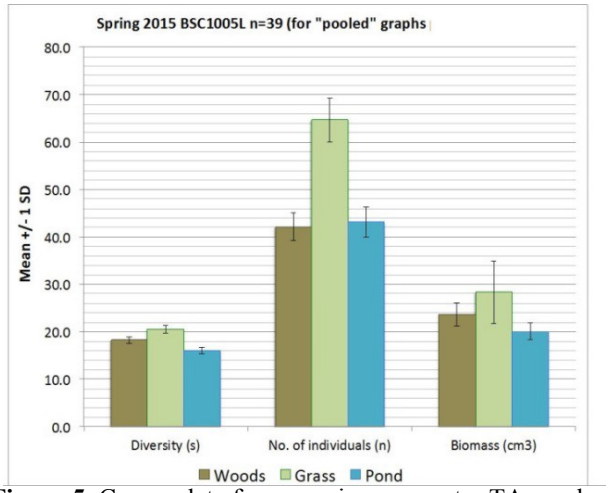


Figure 5. Course data from previous semester TAs probe student thinking:

What claims can be made?
What evidence supports those claims?
What might differ between semesters?
What follow-up studies do students want to do?

The remaining class time is spent formalizing ideas of adaptation and natural selection through discussion enhanced with power point slides. Students will complete the Data Analysis (Figure 4) figure using pooled data from the current semester that is posted at the end of the week on the course website.

Acknowledgements

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About the Authors

Carolyn Schultz received her B.S. in Biology from Florida State University and her M.A. in Child Development from Michigan State University. She has been heavily involved in curriculum development and is interested in the effective teaching of introductory biology using innovative curriculum and active learning. She has 21 years of experience in science teaching and is enthusiastic about increasing scientific proficiency in the general population. In her current position as faculty coordinator of the general biology courses for non-science majors (BSC1005 and BSC1005L) at Florida State University, she supervises and facilitates instruction of more than 2,000 students each semester.

Anna Strimaitis is a 3rd-year doctoral candidate in the Curriculum and Instruction program in Science Education at Florida State University. She is also the curriculum coordinator for the General Biology laboratory program for non-science majors at FSU. In this role, she is responsible for iteratively evaluating and refining the laboratory course curriculum and designing and implementing weekly professional development for 21 undergraduate teaching assistants. Prior to this, she earned her M.S. in Ecology and Evolution at Florida State University, examining the trophic ecology of Caribbean coral reef sponges.

Anna's research interests center on science teaching assistant professional development. Her dissertation examines how 21 teaching assistants use Ambitious Science Teaching practices, a framework of core practices intended to guide novice teachers to develop a strong teaching foundation (Windschitl et al., 2012), while enacting an undergraduate biology laboratory curriculum for non-science majors. The core practices include selecting big ideas, eliciting student ideas to inform instruction, engaging students in science practices and discourses to inform initial ideas, and pressing for evidence-based explanations of the big ideas. Anna is specifically interested in how teaching assistants enact the practices of eliciting and responding to student ideas and pressing for evidence based explanations. Anna was selected to attend the 2015 Sandra K. Abell Institute for Doctoral Students, was a finalist for the Robert M. Gagne Research Award from the College of Education at FSU, and has presented her educational research at the annual meetings for the National Association of Research in Science Teaching, the American Education Research Association, and the Ecological Society of America.

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