

Exercise 13: Stream Ecology

Learning Goals

1. Know terminology associated with ecosystem and stream ecology.
2. Differentiate between ecosystems, communities, and populations.
3. Explain how minor changes in abiotic factors can influence community structure.
4. Use a dichotomous key to help classify organisms.
5. Master science process skills: inductive reasoning, generating hypotheses, generating predictions, running experiments, analyzing results with statistics, displaying results, deductive reasoning, drawing conclusions, evaluating experiments, and evidence-based argumentation.

Evolution Connections

Going with the Flow: Adaptations for Life in the Stream

Stream insects live in a constantly flowing world. This presents a suite of challenges including moving through water, breathing, and even staying in one place that, through natural selection, insects have solved on multiple occasions. Many different orders of insects, from flies to beetles to mayflies, have independently converged on similar solutions - a phenomenon known as convergent evolution.

Many insects have flattened bodies and cling to the surface of rocks where, due to friction, water currents are much slower (Fig. 1). For example, mayflies, stoneflies, and beetle larvae can be found crawling on rocks where they avoid faster moving water. Their low-profile bodies allow water to flow over them so they are not pulled into the current.

Other groups have evolved methods of physically securing themselves to the stream bottom. Black flies and caddisflies use silk to attach themselves to the substrate. Net-winged midge larvae live in fast flowing mountain streams and have evolved suction cups on the underside of each body segment.

Many aquatic insects are active swimmers and have rows of dense hairs along the ends of the pair of legs they use for swimming (fig. 2). These 'natatorial' legs act as oars, allowing the insects to swim quickly to escape from predators or to catch prey. Natatorial legs can be seen in several types of beetles (e.g., Dytiscidae) and true bugs (e.g., Corixidae), among others.

As you collect and identify aquatic insects for this lab, notice the various adaptations these species have evolved for life in a stream. What other challenges have they overcome to survive in the water and in their specific microhabitats?

By Tim Szewczyk

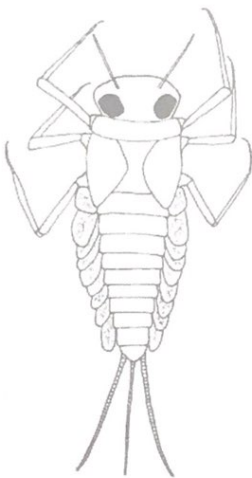


Figure 1. A mayfly of the family Heptageniidae showing a greatly flattened body and external gills.



Figure 2. The natatorial hind leg of a Corixid bug.

Introduction

Thus far in this class, you have carried out exercises inside the lab and have examined organisms at the level of the individual or the species. In today's exercise, you will examine life in the field at a level involving the interactions between both the biotic and abiotic environment. **Ecology** is the study of how organisms influence and are influenced by their biotic (living) and abiotic (non-living) environment. The abiotic and biotic parts of the environment are composed of numerous levels of organization.

1. **Species:** a group of organisms that are similar in appearance and are capable of interbreeding.
2. **Population:** a group of individuals of a single species living and interbreeding within a given area.
3. **Community:** a group comprised of all the populations of various species within a given area.
4. **Ecosystem:** a combination of the community and abiotic environment within a given area.

In lab today, you will investigate how minor changes in abiotic factors can influence a stream community.

Note: in this lab, you will be working in the field, so you may want to wear clothes appropriate for the field situation. Dress warmly if the weather is cold. You will be working in a stream so you may also get wet. Bring waders if you have them.

Factors Determining Where Organisms Live

Habitat and Niche

Habitat refers to a particular environment within an ecosystem in which the organism lives. Stream habitats can be divided into two general types, pools and riffles. **Pools** occur in sections where the water moves slowly and are usually associated with deeper sections of the stream. **Riffles** occur in sections where the water moves rapidly and are usually associated with shallower sections of the stream. A continuum of change from a pool to a riffle is always present in a stream and it is sometimes difficult to distinguish where a pool becomes a riffle. However, at the extremities (i.e. shallowest section of a stream with the fastest water, versus the deepest with the slowest water) pools and riffles are fairly easily distinguished. Within a larger habitat are **microhabitats** that are small pockets of unique environments. For example pools often have eddies where water swirls back from the main current and decomposing organic material aggregates. Pools also have sandy-bottomed areas where the smaller particles taken from the faster areas in the stream accumulate but current still removes the organic debris to collect in the eddies. Organisms that can live in a variety of different habitats are called **generalists** and organisms that are confined to limited habitats are called **specialists**.

An organism's niche is a little more complex than the habitat it lives in. The specific environmental requirements of an organism that allow it to live in a certain area determine the **niche** of that organism. The habitat the organism lives in and interactions with other organisms within the habitat define the niche of an organism.

Abiotic Factors

Dissolved Oxygen (DO)

Dissolved oxygen is required for aerobic respiration and is an important factor influencing diversity in aquatic ecosystems. In areas with slow moving water, if too much organic debris builds up, light is reduced and thus photosynthesis by algae is also reduced. There are plenty of nutrients for heterotrophic organisms, however, through time oxygen is removed from the site and organism diversity is reduced. This is typical of streams and ponds in disturbed areas such as in cities where nutrients enter the stream through run-off.

DO is measured in parts per million. Stream ecosystems with DO levels greater than 5 ppm are healthy, with DO levels from 3 - 5 are moderate, and with DO levels less than 3 are not healthy.

pH

Various organisms have different pH requirements. Many factors in the stream result in changes in pH. Some of the more important factors are: the types of soils surrounding the stream, how much water is flowing through, and the amount of debris and nutrients in the stream. Healthy streams have a pH range typically from 6.5 to 8.2, above and below which water quality is considered poor.

Nitrate

Nitrogen is a vital compound for growth of organisms. When nitrogen is abundant in an aquatic ecosystem, it increases the growth of aquatic plants and algae. When the growth of plants and algae increase, more nutrients are available to aquatic organisms which increases

numbers of heterotrophic organisms which favors high numbers of decomposers. Thus, changes in Nitrogen can have dramatic effects on community structure of a stream ecosystem.

The three forms of Nitrogen in water are Nitrate (NO_3), Nitrite (NO_2), and Ammonia (NH_3). Nitrates are easy to test for and give a good indication of stream pollution. Nitrogen enters the water from several pollutant sources: human wastes (via sewage treatment facilities), animal wastes, lawn and crop fertilizers (via run off with rain), and decomposing organic matter. Streams typically have very low concentrations of Nitrogen (below 4 ppm). Nitrate levels between 5 and 15 ppm are considered moderate in quality and above 15 ppm are considered poor in quality. Water is unsafe to drink when Nitrate levels exceed 40 ppm.

Phosphate

The function of phosphates as pollutants is similar to that of nitrates — they increase growth of aquatic plants and algae. The primary pollutant source of phosphates in streams and rivers is through detergents that wash into the stream. Streams typically have very low phosphate levels. Phosphate levels of 1 - 2 ppm are considered healthy and those from 2 - 5 ppm are considered moderate.

Temperature

Temperature has an effect on where organisms can live and it directly influences DO, pH, and rates of photosynthesis of aquatic plants, algae and bacteria. Streams should typically have low temperatures. Streams with temperatures below 5°C are considered healthy, those between 5 and 10°C are considered moderate, and those exceeding 10°C are considered to be in poor condition.

Sunlight

Sunlight is critical for photosynthesis that supplies food and oxygen to animals in a stream ecosystem. Many factors influence the amount of sunlight that can penetrate the water. For example a stream may be in a deep canyon or in a heavily forested area that blocks the sun. A stream may be murky or clear depending on the quantity of dissolved minerals and/or pollutants in the water.

Flow Rate

Flow rate is the quantity of water that moves through a given area in a given amount of time (liters per second).

Substrate

Materials on the bottom of the stream comprise the substrate. These may vary from organic debris from decomposing material, to fine sand, to medium-size rocks, to large rocks.

Biotic Factors

There are many biotic factors that may help determine what organisms are present in a riffle and a pool. Again the canopy around a pool influences sunlight which in turn influences the photosynthetic organisms present. The abiotic components of depth, clarity, and temperature of the water also influence the photosynthetic organisms present. In the rapidly moving water, algae attach to rocks and logs to avoid being swept down stream. Plants on the surrounding banks also supply food to the stream ecosystem by dropping leaves, stems, and even insects living on their leaves into the water.

Various organisms live directly off of the food supplied by photosynthetic organisms. Some stream organisms are called “scrapers” that eat green

algae attached to rocks and logs. Other organisms are called “shredders” that feed on leaves, needles and wood in the water. Still other organisms are called collectors that eat small particles of organic matter that pass by in the stream.

Beyond the primary consumers are predators that feed on the other animals. Trout feeding on aquatic insects are a good example of predators.

Identifying Stream Organisms

Today, you will use animal phyla and insect orders to examine how local changes in stream dynamics influence diversity. Before beginning background information is needed.

Insects develop through the process of **metamorphosis**. Two types of metamorphosis are incomplete and complete metamorphosis. In **incomplete metamorphosis**, young individuals resemble the adults, and young individuals are called **nymphs**. In **complete metamorphosis**, young individuals do not resemble adults and young are called **larvae**. In many species, nymphs and larvae are aquatic, but once they change into adults they leave the stream ecosystem and become terrestrial. An overview of the insect orders you will examine follows.

1. Ephemeroptera. This order is comprised of mayflies. Mayflies occur in both streams and lakes throughout Colorado. Nymphs are aquatic and adults are terrestrial. Most nymphs of mayflies live on the undersides of medium sized rocks and debris.
2. Plecoptera. This order is comprised of stoneflies. Stoneflies also occur in streams and some lakes in Colorado. Nymphs are aquatic and adults are terrestrial. Nymphs are mainly found among rocks in streams.

3. Hemiptera. This order is comprised of true bugs. The two primary groups of hemiptera are water boatmen and water striders. These will be seen swimming in the water. Bugs are characterized by a diamond shape located in upper middle part of the abdomen on the back. Only a few species of bugs are aquatic, most are terrestrial.
 4. Odonata. This order is comprised of dragonflies and damselflies. Nymphs are aquatic and adults are terrestrial. Nymphs are common in ponds, lakes, and streams.
 5. Diptera. This order is comprised of true flies such as the crane fly, mosquito, black fly, and midge. Different Dipterans are present in streams and lakes. Larvae are often aquatic while adults are terrestrial.
 6. Trichoptera. This order is represented by caddisflies. The larvae of caddisflies are abundant in nearly all ponds, lakes, and streams. Some larvae encase themselves inside structures made of small stones or sticks. Adults are terrestrial.
 7. Coleoptera. This order is comprised of beetles and is represented by the whirligig beetle. Coleopterans are often found in slow moving water.
- c. Dig down approximately 10 cm (a little deeper than the length of your finger) into the substrate.
 - d. Sift through the substrate with your hands. For boulders, rub off the bottom with a vegetable brush. Make sure that all debris flows into the net and is collected.
 - e. Sift through the total substrate within the area outlined inside the frame of the Surber net or the area defined for the dip net.
 - f. Dump the contents of the net into a jar with stream water to be taken back to the lab for analysis.
5. Once you are finished, wait for the other groups to finish. As a class, return to your lab room. Make sure you have all the equipment you started with.

Procedure 1

1. Divide into assigned groups.
2. In lab today, you will examine the diversity of insect orders and other animal phyla in pools vs. riffles in a stream ecosystem.
3. Choose a representative pool and riffle to investigate.
4. You will use a D-frame net for sampling. Three people are required for each sample.
 - a. Place the net firmly on the bottom of the stream with the net down stream.
 - b. Approximate an area double the size of the net for your sample.

Procedure 2

1. Once in your lab room, label enamel trays according to the location your sample was taken (pool or riffle) and empty the stream samples into the appropriate trays.
2. Sift through creek samples. At the lab desk are small culture dishes with labels of various phyla of animals or orders of insects. Use the dichotomous key to identify each animal you find and transfer the animal to the appropriate culture dish. You should be able to recognize the phyla in which animals are classified. For insects, use the dichotomous key to categorize them into orders. Tally the number of individuals in each order and phylum for the particular sample in Table 13.5. Tabulate final numbers of organisms and compare differences between the two samples taken.
3. Write your results on the board and run a X^2 test with the results of the total class. Procedure 3 gives directions to run the X^2 test.

X² test (chi (ki) square)

1. The X² test is used to determine if an expected series of values is different than those observed (values obtained from the study) and uses the following equation:

$$\frac{(O - E)^2}{E}$$

where O = observed and E = expected. The X² equation is simple to use. The tough part of the X² test is figuring out the expected values. Expected values depend upon the research hypothesis. For this lab the expected values will be based on the null that there is no difference in insect group composition between the meadow and the forest. Table 10.1 shows a fictitious data set.

Table 10.1. A fictitious example of the number of different insects found in a meadow (A) or a forest (B).

Type	A	B
Ants	20	30
Aphids	10	15
Grasshoppers	30	35
Crickets	60	80
Lady Bugs	45	65

2. In this case we are interested in the relative numbers of insect types in the two locations. Not the overall abundance of the insect types in the two locations. In other words: Is the ratio of ants to aphids to grasshoppers, etc. different between the meadow (A) and the forest (B)? Notice that in the table B has more insects than A. The estimate of expected must account for the larger number of insects in B than A. The following is how the expected can be calculated.

3. Begin by adding a row on the bottom of your table for column totals and a row to the side of your table for row totals.

Type	A	B	Row Total
Ants	20	30	50
Aphids	10	15	25
Grasshoppers	30	35	65
Crickets	60	80	140
Lady Bugs	45	65	110
Column Total	165	225	390

4. For each observed value in the table calculated the expected with the following equation and write the number in parentheses next to the observed value in the table.

$$\frac{(\text{Row Total} \times \text{Column Total})}{\text{Grand Total}}$$

Grand Total

For example, the expected number of Ants in sample A would be $(50 \times 165) / 390 = 21$. Expected values should be calculated for all observed values and are indicated in the table below in parentheses.

Type	A	B	Row Total
Ants	20 (21)	30 (29)	50
Aphids	10 (11)	15 (14)	25
Grasshoppers	30 (28)	35 (38)	65
Crickets	60 (59)	80 (81)	140
Lady Bugs	45 (47)	65 (63)	110
Column Total	165	225	390

5. The next step is to use the X^2 equation for each of the observed values $((O-E)^2/E)$. In the box below the X^2 values associated with each observation are indicated in the second set of parentheses.

Type	A	B	
Ants	20 (21) (0.05)	30 (29) (0.03)	50
Aphids	10 (11) (0.09)	15 (14) (0.07)	25
Grasshoppers	30 (28) (0.14)	35 (38) (0.24)	65
Crickets	60 (59) (0.02)	80 (81) (0.01)	140
Lady Bugs	45 (47) (0.09)	65 (63) (0.06)	110
Column Total	165	225	390

6. Add all of the X^2 values together to get a value we will call X^2_{calc} . From the table the value of X^2_{calc} is 0.80.
7. To determine whether observed values are significantly different than those expected, search on line for a chi-square table to determine what we will denote as X^2_{tab} . On the table, notice the column signified as df . This stands for degrees of freedom. Use the following equation to calculate degrees of freedom from the data table.

$$df = (\# \text{ of observed rows} - 1)(\# \text{ of columns} - 1)$$

In the table the number of columns is 2 and the number of observed rows is 5. So the df is calculated by $1 \times 4 = 4$.

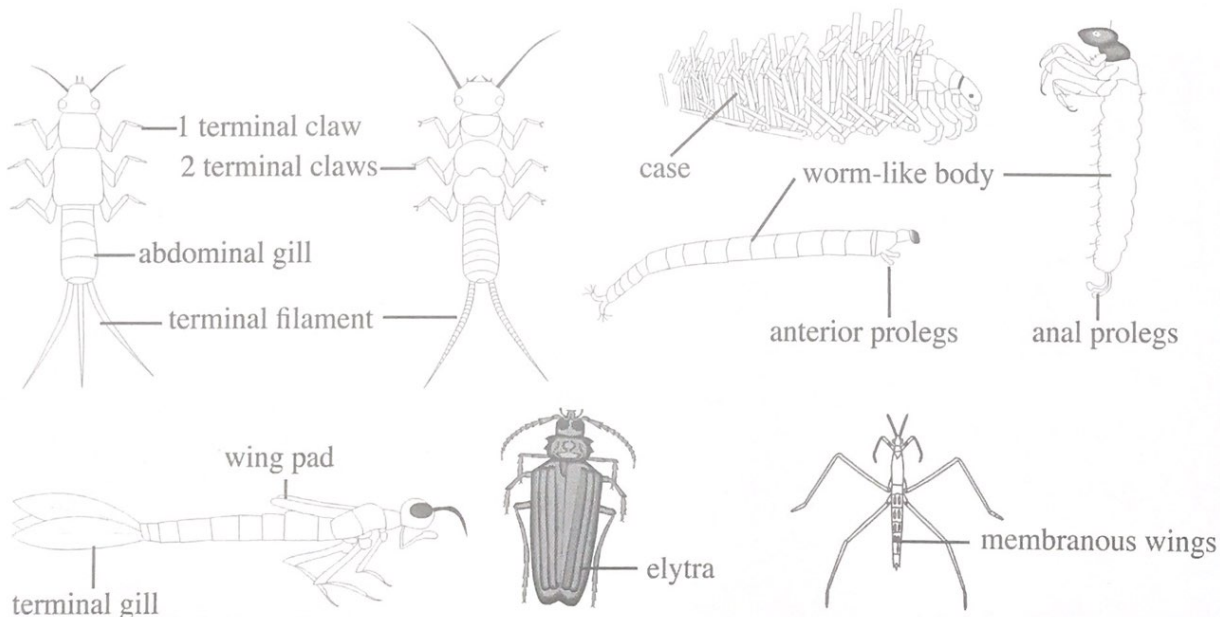
8. On the table, go down to the appropriate degrees of freedom and go over to the column for $P = 0.05$. For this example the value is 9.49. Thus the value of $X^2_{tab} = 9.49$.
9. If X^2_{calc} is greater than X^2_{tab} then there is a significant difference between expected and observed values. In this case X^2_{calc} is 0.8 and $X^2_{tab} = 9.49$; thus, there is not a significant difference between the expected and observed. It can be concluded that the meadow does not have a significantly different distribution of these insects groups than the forest ($P < 0.05$).

Note: If there is no observed in a row eliminate that row from the overall analysis.

Dichotomous Key to Common Orders of Aquatic Insects

A **dichotomous key** is a key in which you have to decide between two choices. After you decide, then you are directed to another set of two choices, until finally you reach the point where you can categorize the individual. The following is a dichotomous key which you should use to classify insects from the stream to order.

- 1a. Has more than 3 pairs of jointed legs. ----- **arthropods other than insects**
- 1b. Has 0 - 3 pairs of jointed legs. ----- **insects** ----- 2
- 2a. Does not have fully developed wings or a hard covering over the wings. ----- 3
- 2b. Has fully developed wings or has a hard covering over wings. ----- 8
- 3a. Body not worm-like. ----- 4
- 3b. Body worm-like, body may be enclosed in a case ----- 6
- 4a. Has no terminal filaments, but may have terminal gills ----- **Odonata**
- 4b. Has terminal filaments ----- 5
- 5a. Has 1 terminal claw per leg, usually has lateral abdominal gills;
usually 3 terminal filaments ----- **Ephemeroptera (nymph)**
- 5b. Has 2 terminal claws per leg, lacks lateral abdominal gills,
has 2 terminal filaments. ----- **Plecoptera (nymph)**
- 6a. Has 3 pairs of jointed legs. ----- 7
- 6b. Has no jointed legs, may have anterior prolegs,
may be large and look like a caterpillar ----- **Diptera (larva)**
- 7a. Has anal prolegs, may have hair-like abdominal gills,
may be enclosed in a case of sticks or sand. ----- **Trichoptera (larva)**
- 7b. Does not have anal prolegs. ----- **Coleoptera (larva)**
- 8a. Has a hard covering (elytra) over the wings. ----- **Coleoptera (adult)**
- 8b. Has membranous wings, and a beak-like piercing mouth ----- **Hemiptera (adult)**



Name _____
 TA _____
 Day/time _____
 Date _____

Lab Report Check

1. State the problem you are examining in this lab.

2. Write your hypothesis and predict the results.

Table 13.5. The number of individuals of various phyla of animals and orders of insects found in the pool versus the riffle for your group and the total class.

Group of Organisms	Your Group		Class Total		Row Total
	Pool	Riffle	Pool	Riffle	
Ephemeroptera			() ()	() ()	
Plecoptera			() ()	() ()	
Hemiptera			() ()	() ()	
Odonata			() ()	() ()	
Diptera			() ()	() ()	
Trichoptera			() ()	() ()	
Coleoptera			() ()	() ()	
Cnidaria			() ()	() ()	
Platyhelminthes			() ()	() ()	
Nematoda			() ()	() ()	
Mollusca			() ()	() ()	
Annelida			() ()	() ()	
Non-Insect Arthropods			() ()	() ()	
Chordata			() ()	() ()	
Column Total					

_____ Record the value of X^2_{calc} for these data

_____ Record the value of X^2_{tab}

_____ Is there a significant difference between your expected and observed?

3. Discussion:

a. Explain what your results indicate. Also, if there was a difference between the pool and riffle, why was there a difference? If there was no difference, why was there no difference? Think about both biotic and abiotic factors that lead to diversity in your explanation and use actual observations to support your contentions.

b. Were there problems with the data analysis and/or data collection? Explain!