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Adaptations of Aquatic Insects to Habitat and Food Resources in Streams

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Abstract: This exercise is a field study of the ecology of aquatic insects in a small stream. By using the inquiry technique, students discover how different animals have unique adaptations for being successful in particular habitats, especially at small spatial scales. Students also learn how these specializations establish essential ecological roles for the aquatic insects in stream ecosystems. Thus, students gain an appreciation of how biodiversity is not just a list of species in a particular environment; it also includes what they do in that environment.

Keywords: field ecology, benthic macroinvertebrates, inquiry, ecosystems, biodiversity

Contents:

Introduction

A field trip to a shallow stream is ideal for using inquiry to teach how animals have special adaptations for success in particular environments. This exercise can be done entirely in the field, or it can include follow up studies in the laboratory. In the field, students are directed to several small-scale habitats (microhabitats) that differ in aspects of current velocity, substrate composition, and food resources. Students initially make written descriptions of each microhabitat and address questions such as: why would an aquatic insect want to live here, and what would be difficult about living here? Then students collect some of the aquatic insects that live in each microhabitat, observe and identify them with a field guide, and make original sketches. Students write answers to further questions about the ecology of their aquatic insects, and then the instructor leads an inquiry discussion with the entire class. Discussions lead to conclusions about how ecological specializations, such as the ones exhibited by aquatic insects, contribute to biodiversity, and about the importance of biodiversity.

This exercise could be used in an upper-division course such as ecology, or in an introductory biology course. Assuming that travel and logistics will require a bit of time, it is likely that this exercise will require at least two 3-hour laboratory periods. The best option is probably to complete all of the field observations and insect collections (Part I) in one laboratory period, then use one or two laboratory periods for identification, speculation, and discussion (Part II).

Student Outline

Introduction

Although the majority of insect species live in terrestrial environments, an appreciable number of species live in freshwater environments, such as swamps, ponds, lakes, springs, streams, and rivers. These underwater species are often inconspicuous and relatively unknown to most people. Freshwater habitats are challenging places for small-bodied animals to live, but various species of aquatic insects have a wide assortment of adaptations that enable them to be successful. Nowhere is this more evident than in small streams that alternately have swift, rocky segments (called riffles), and slow, sandy segments (called pools). Streams offer some advantages for the insects that live there, but not all insects are capable of existing in the harsh physical conditions of a stream, or at least not everywhere in a stream. Watersheds (drainage basins), which contain freshwater as it flows in channels from high to low elevation, are important ecosystems that provide valuable services to humans. Aquatic insects play ecological roles that are essential for these ecosystems to function properly. Thus, aquatic insects are an important component of biodiversity. The purpose of this exercise is to study some of the special adaptations that aquatic insects have for successful existence in running waters, and to relate that information to the concept of biodiversity.

The objectives of this investigation are to:

1. Examine the characteristics of the major habitats and microhabitats in a stream;
2. Discuss the advantages and disadvantages of living in those places;
3. Determine the different kinds of aquatic insects that live in specific stream microhabitats;
4. Observe some of the special adaptations that aquatic insects have for successfully dwelling in streams;

5. Discuss the roles of aquatic insects in stream ecosystems and why aquatic insects are an important component of biodiversity.

Part I. Field Investigation

Getting Started In the Field

The entire class will assemble at the edge of the stream, and divide up into teams of 3 people. The instructor will show the boundaries of the stream segment being investigated. No one should go beyond those boundaries. The instructor will show examples of riffle and pool habitats within the study area, and then point out five different microhabitats within the stream segment:

1. Surfaces of large stones (boulders, cobbles) in fast current within riffles;
2. Accumulations of leaves (leaf packs) wedged against large stones or large woody debris in moderate to fast current within riffles;
3. Spaces within large, loose stones (cobbles, pebbles) in moderate to fast current within riffles;
4. Accumulations of leaves, twigs, and other coarse particulate organic matter lying on the bottom in slow to no current within pools;
5. Sand and fine sediment deposits in slow to no current within pools.

Observe Microhabitats

Students will break up into their teams and spread out over the stream segment (but not beyond the previously determined boundaries). Each team will find examples of all microhabitats and study each one. Team members should confer and propose answers to the following questions that address several different advantages and disadvantages of each microhabitat for aquatic insects. Approach these questions from the perspective of an aquatic insect, i.e., "think like a bug." Use Table 1 to compile the team's thoughts.

1) What advantage would an aquatic insect gain by living in this microhabitat? Think about things that all animals must have to survive. Thinking about what humans need to survive might help you get started.
2) What aspects of this microhabitat would make it difficult for an aquatic insect to live there? If you could fit in this microhabitat, what would be a challenge for you to deal with?

Collect and Observe Aquatic Insects

Each team will make observations of the aquatic insects living in each microhabitat, with as little disturbance to the organisms as possible. (The collecting and observing techniques for the different microhabitats are explained below.) The idea is to observe them in their natural surrounding. Notice how they move or resist being moved. Are they easy to see? What do you suppose they are doing while they "hang out" in this place? After making your observations, use forceps to place the organisms from each microhabitat into a separate, labeled jar of alcohol. It is not necessary to kill all of the organisms you find. Just collect and preserve a few representatives (no more than 10) of each kind, and make some notes about the relative abundance of each kind in the microhabitat. Use Table 2 to record the team's observations and notes; some simple sketches will be helpful. Follow the techniques listed below for each microhabitat:

1. Surfaces of large stones (boulders, cobbles) in fast current within riffles: Pick up a stone the size of your head or larger and examine all sides carefully. Some aquatic insects remain motionless, so you need to poke around with your forceps. Pay particular attention to the cracks and

crevices. Also look to see if anything is dropping or crawling off of the stone. Repeat with a few other stones until you stop seeing different aquatic insects.

2. Accumulations of leaves (leaf packs) wedged against large stones or large woody debris in moderate to fast current within riffles: Quickly grab a handful of soft, decomposing leaves and place them in the sorting pan without any water. Dig through the leaves with the forceps for a while, then add a little stream water and see if anything comes out. Repeat until you stop seeing different aquatic insects.
3. Spaces within large, loose stones (cobbles, pebbles) in moderate to fast current within riffles: This microhabitat will have to be sampled with a dip net. Place the net on the stream bottom, downstream of the cobbles and pebbles you want to sample. Disturb the rocks with your hands. Move all of the rocks that are larger than golf balls in the area immediately in front of the net. Place the material captured in the net into the sorting pan. Don't put more than one handful of the material into the pan at one time. Repeat until you stop seeing different aquatic insects.
4. Accumulations of leaves, twigs, and other coarse particulate organic matter lying on the bottom in slow to no current within pools. – Pick up a handful of this material and put it into the sorting pan. Dig through the material with the forceps as you did in #2. Repeat until you stop seeing different aquatic insects.
5. Sand and fine sediment deposits in slow to no current within pools. – Jab the dip net into the soft bottom a few times, then wash out as much of the fine sediment as possible by swishing the net in the stream. When cloudy material stops washing out of the net, place a handful of the remaining material into the sorting pan and add a little stream water. Wiggle the forceps through this material, gently stirring as you go. Repeat until you stop seeing different aquatic insects.

Discuss Field Observations

All teams will assemble together with the instructor to discuss the microhabitats. One at a time, each team should contribute what they think is an advantage or a disadvantage for aquatic insects living in one of the microhabitats. Proceed through the microhabitats and teams until there are no more new ideas. The instructor will facilitate an inquiry discussion that leads to some conclusions about the most important "pros and cons" for each microhabitat. Students should record the class conclusions about microhabitats in Table 1. If a portable flip chart is available, the conclusions can be recorded in the field and posted in the laboratory for the second part of the activity.

Part II. Laboratory Investigation

Getting Started In the Laboratory

The laboratory portion of this activity consists mostly of examining specimens with stereomicroscopes. If possible, each student should have a stereomicrosope and an illuminator. Team members should choose workstations that are close together to facilitate sharing observations and ideas. If there are not enough microscopes for all students, an acceptable alternative is for team members to share a microscope. The instructor will begin by teaching the fundamentals of using a stereomicroscope.

Identify Aquatic Insects

Team members should identify all of the different kinds of aquatic insects they found in each microhabitat. The guide by Voshell (2002) is designed for use by persons with no previous experience with freshwater invertebrates. Students should use only Section 2 on identification (pages 79-189). The instructor will outline how to identify organisms with this book. Begin with the QuickGuide on page 81. The QuickGuide will determine the major group that an organism belongs to and refer you to a group of color plates for identifying the organism to a lower taxonomic level, usually family. Make a list of these organisms, using the common names given in the guide. Use Table 3 to compile the team's list of aquatic insects in each microhabitat.

Examine Specimens and Speculate on Adaptations

With the help of the instructor, each team should choose one aquatic insect they collected from each microhabitat. Choose one that has a distinctive body shape or unique structures on its body. The instructor will steer teams to a variety of aquatic insects. Then, the team members should confer and propose answers to the following questions. Again, approach these questions by "thinking like a bug." Use Table 4 to compile the team's ideas.

1) How is this aquatic insect adapted for the conditions of the particular microhabitat where you found it? In other words, how does it deal with the disadvantages of living in the microhabitat that you described during the field investigation? Make sketches to illustrate your ideas.
2) How do you think this aquatic insect obtains its food? Does it have special structures or mechanisms for getting its food? What type of food do you think it eats? Did you notice any particular food that was available in the microhabitat where it lived? Make sketches to illustrate your ideas.
3) How do you think this aquatic insect avoids being eaten by larger animals?
4) What important contribution do you think this organism makes to the stream ecosystem? In other words, what is its role or job in the ecosystem? (Hint: the roles of aquatic insects are often related to their feeding.)
5) If this species disappeared, and was not replaced by another one, what would happen in the ecosystem? Would this species be missed?

Discuss Ecosystems Roles and Biodiversity

The instructor will facilitate an inquiry discussion, beginning with the meaning of the term biodiversity. Each team will be expected to contribute their ideas about the 5 questions above. Discussions will lead to conclusions about how ecological specializations such as those observed in this activity are an important component of biodiversity in streams and the ecosystem services that humans lose when biodiversity in streams is reduced. Use Table 4 to compile the conclusions of this discussion.

Materials and Equipment

- Dip nets (1 per group)
- Sorting pans (1 per person)
- Forceps (1 pair per person)
- Probes (1 per person)
- Vials (4 dram) and small jars (2 oz)
- Alcohol – 60% isopropyl or 70% ethyl (about 500 ml per group)
- Preprinted labels for microhabitats
- Portable flip chart (optional)
- Plastic petri dishes (several per group)
- Stereomicroscopes with at least 10X magnification (1 per group)
- Illuminators for microscopes (1 per group)
- Identification guide (Voshell 2002) (1 per group)
- Pencils (1 per person)

Notes for the Instructor

Reconnaissance of Study Site and Fauna

It is essential for the instructor to scout the local area well before the field activity to find a site on a stream that is suitable for this exercise. The stream should be large enough to accommodate the numbers of students but not too deep or swift for safe wading and observing. Become familiar with the microhabitats and the aquatic insect fauna before the field activity. This exercise is designed to examine only aquatic insects, which are the dominant macrofauna (large enough to see with your naked eye) in most small streams; however, in some streams other invertebrates, such as worms, crustaceans, and snails, may also be common. The instructor can include all invertebrates in the exercise, if desired. Finally, decide beforehand which aquatic insects in the stream would be the best examples for demonstrating special adaptations to microhabitats and for obtaining food. These should be organisms with conspicuous body shapes and specialized external structures.

Background Information

If the instructor does not have expertise in aquatic entomology or freshwater ecology, there are several books that will provide the necessary background information for this exercise. Voshell (2002) has information about the organisms and their biology: Section 1 contains fundamental information on movements, habitats, and feeding mechanisms; section 2 is used to identify the organisms; and section 3 has biological information about the specific kinds of invertebrates. Students will only use Section 2 of the guide, because the other sections would provide answers that they should figure out for themselves by inquiry. The book on stream ecology by Allan (1995) will provide the necessary background information on the roles of invertebrates in stream ecosystems. This exercise deals mostly with their role in trophic dynamics, which is covered in Chapter 6.

The capstone of this exercise is the inquiry discussion on biodiversity. The following background information will help the instructor to get the discussion started.

What is biodiversity?

Biodiversity is the variety of life forms, i.e., the number of species, and the natural processes of which these living things are a part. The natural processes include the ecological roles that livings things perform in ecosystems. Thus, biodiversity is not just the number of species living somewhere; it is also what they do there.

Why do we care about biodiversity?

We care about biodiversity because of the services that we derive from ecosystems. Ecosystem services are the essential roles played by organisms in creating a healthful environment for humans. Ecosystems (both natural and managed) can be thought of as factories or businesses, both of which produce goods and services. In this analogy, the roles of living organisms in ecosystems are like the jobs of people in a factory or business. Without workers doing their jobs effectively, no goods or services are produced in a factory or business. If biodiversity is not maintained, ecosystems will not be able to provide the services that the existence of human society depends upon. Examples of services from terrestrial ecosystems are regulation of atmospheric gases (oxygen versus carbon dioxide) and creation of soil. Examples of services from stream ecosystems are:

- drinking water
- recreation (swimming, fishing)
- food (commercial fisheries in large rivers)
- habitat for species that we value and want to conserve
- aesthetics
- delivering water of appropriate quality and composition to estuaries.

What essential roles do aquatic insects play in maintaining the ecological services from stream ecosystems?

Some of the major roles that participants in this exercise should be able to understand and relate to their field and laboratory observations are:

- Breaking down large pieces of detritus from surrounding terrestrial vegetation (shredders)
- Scraping excess algae from the rocks and other solid substrates (scrapers)
- Filtering particles out of suspension in the water (collector-filterers)
- Mixing the bottom sediments (burrowers)
- Keeping the populations numbers of other invertebrates under control (predators)
- Serving as essential food for water birds, fish, and other animals that we value (prey)

Details about these ecological roles of aquatic insects can be found in Allan (1995) and Voshell (2002).

Conducting the Exercise

The following are minimum times that should be allowed for each part of the activity listed in the Student Outline.

Part I. Field Investigation

Getting Started In the Field - 15 minutes
Observe Microhabitats - 30 minutes.
Collect and Observe Aquatic Insects - 90 minutes
Discussion of Field Observations - 30 minutes

Part II. Laboratory Investigation

Getting Started In the Laboratory - 15 minutes
Identify Aquatic Insects - 90 minutes
Examine Specimens and Speculate on Adaptations - 45 minutes
Discussion of Roles in Ecosystems and Biodiversity - 30 minutes

The instructor will need to be familiar with the use of stereomicroscopes. The major features of these microscopes that need to be explained to students are: adjusting the distance between the eye tubes, choosing the magnification level, focusing the image, and adjusting the light from the illuminator.

Literature Cited

Allan, J. D. 1995. Stream ecology, structure and function of running waters. Chapman and Hall, London. 388 pages.

Voshell, J. R., Jr. 2002. A guide to common freshwater invertebrates of North America. McDonald & Woodward Publishing Company, Blacksburg, Virginia. 442 pages.

About the Authors

Amy Braccia completed her Ph.D. in Entomology at Virginia Tech shortly after the 2005 ABLE conference. She was awarded a USDA National Needs Fellowship for her graduate studies, which involved quantifying the effects of cattle grazing on stream macroinvertebrate assemblages. She served as a graduate teaching assistant for laboratories in two courses, Aquatic Entomology and Freshwater Biomonitoring. In addition, she presented a number of guest lectures in several courses and was involved with a variety of outreach activities. Her research interests involve the ecology of aquatic insects, and she will be conducting post-doctoral research at Virginia Tech on the effectiveness of stream restoration.

Reese Voshell is a Professor of Entomology and has been a member of the faculty at Virginia Tech since 1976. He teaches two upper-division undergraduate/graduate courses, Aquatic Entomology and Freshwater Biomonitoring, and a university core curriculum course on Insects and Human Society. He has also been involved with a variety of outreach activities, including workshops and short courses for state and federal agencies and K-12 teachers. He has won several teaching awards and is a member of the university's Academy of Teaching Excellence. His research interests involve using aquatic insects in the assessment and restoration of biological integrity in streams.

Appendix A. Names and addresses of suppliers

BioQuip Products
2321 Gladwick Street
Rancho Dominguez, CA 90220
Phone: (310) 667-8800
URL: www.bioquip.com

Carolina Biological Supply Company
2700 York Road
Burlington, NC 27215
Phone: 800-227-1150
URL: www.carolina.com

Forestry Suppliers Inc.
205 West Rankin Street
P.O. Box 8397
Jackson, MS 39284-8397
Phone: 800-430-5566
URL: www.forestry-suppliers.com

Ward's Natural Science
5100 West Henrietta Road
P.O. Box 92912
Rochester, NY 14692-9012
Phone: 800-962-2660
URL: www.wardsci.com

Appendix B: Data Tables

Table 1. Microhabitat observations.

Microhabitats	Advantages of Living There	Disadvantages of Living There
1) Surfaces of large stones (boulders, cobbles) in fast current within riffles		
2) Accumulations of leaves (leaf packs) wedged against large stones or large woody debris in moderate to fast current within riffles		
3) Spaces within large, loose stones (cobbles, pebbles) in moderate to fast current within riffles		
4) Accumulations of leaves, twigs, and other coarse particulate organic matter lying on the bottom in slow to no current within pools		
5) Sand and fine sediment deposits in slow to no current within pools		

Table 2. Aquatic insect observations.

Microhabitats	Notes About Aquatic Insects Found There
1) Surfaces of large stones (boulders, cobbles) in fast current within riffles	
2) Accumulations of leaves (leaf packs) wedged against large stones or large woody debris in moderate to fast current within riffles	
3) Spaces within large, loose stones (cobbles, pebbles) in moderate to fast current within riffles	
4) Accumulations of leaves, twigs, and other coarse particulate organic matter lying on the bottom in slow to no current within pools	
5) Sand and fine sediment deposits in slow to no current within pools	

Table 3. List of aquatic insects.

Microhabitats	Names of Aquatic Insects Found There
1) Surfaces of large stones in fast current	
2) Leaf packs in moderate to fast current	
3) Spaces within large, loose stones in moderate to fast current	
4) Coarse particulate organic matter on the bottom in slow or no current	
5) Sand and fine sediment in slow to no current	

Table 4. Adaptations and ecological roles of aquatic insects.

Microhabitats	Adaptations, Ecological Roles of Aquatic Insects Found There
1) Surfaces of large stones (boulders, cobbles) in fast current within riffles	
2) Accumulations of leaves (leaf packs) wedged against large stones or large woody debris in moderate to fast current within riffles	
3) Spaces within large, loose stones (cobbles, pebbles) in moderate to fast current within riffles	

Table 4. (Continued).

4) Accumulations of leaves, twigs, and other coarse particulate organic matter lying on the bottom in slow to no current within pools	
5) Sand and fine sediment deposits in slow to no current within pools	
Conclusions about biodiversity and the ecosystem services that humans lose when biodiversity in streams is reduced.	