

### Basic Guidelines for Writing

Writing a paper on your observations, experiments, and conclusions is a critical part of a laboratory course in ecology. You should set aside whatever notions you may have about "scientific writing" and prepare reports that are composed of straightforward English-language sentences. Remember that the point of the report is to effectively convey a message to the reader. Decide what you want to say and then translate your mental notions into symbols that will have specific meaning for the reader. In this context, writing sentences that sound right is not merely a matter of aesthetics, but a way of promoting effective communication. Follow the organization suggestions below, and use the guidelines for each section to organize your paper.

1. Prepare your summary tables and figures. **Identify the key points that you wish to make and structure your paper around them.**
2. Prepare an outline on a computer. The outline is the design of your paper. The more time you take to construct it carefully, the more logical your paper will be and the easier it will be to turn the outline into text. Save your outline and first draft on disk, and save any early hardcopies you prepare. Be sure to save your work on more than one disk.
3. Prepare at least two drafts of text. First, prepare a rough draft that can be checked, read aloud, altered, and rewritten. The second draft may be ready for your instructor.
4. Avoid jargon as much as possible. State your meaning in a simple and concise manner. When possible, remove unnecessary words from your sentences. Reading aloud helps identify unnecessary words and awkward phrases. Unnecessarily long sentences are ineffective; they dilute the writer's meaning. Economical sentences drive their messages home forcefully.
5. Use the "spell check" feature of your word processor! Use the "grammar check" too, if you feel inclined. By removing errors, you help the reader focus on your message, rather than by distracting them with your errors.

### The Form of a Scientific Report

Both tradition and common sense support the fundamental structure of scientific report consisting of an introduction, materials and methods, results, discussion, and references. In preparing your reports, you may work together to compare and compute results, but each individual must write their own report. See below to help you prepare tables and graphs.

#### 1. **Abstract:**

Here you summarize the problem, why the problem was addressed, your experimental approach, and the major conclusions. Begin with one sentence on each of these to make a concise first draft. This is probably the most difficult part of the report to write well; it summarizes the entire report, so save it for last.

## 2. Introduction:

This is a statement of the purpose of the study. Introduce the problems and questions you addressed in your experiment (i.e., why did you do it?). You must also make a statement of your hypothesis or question. In a formal scientific paper, the author will usually review previous publications related to the hypothesis or question, in order to put their work in a larger context. For our purposes, an introduction of 1-2 paragraphs should be sufficient. Use information from lectures, text, and a literature review to provide background.

## 3. Methods and Materials:

The purpose of this section is to allow the reader to critique or repeat the experiment performed. Usually you would address the following questions: What did we do? How did we do it? Where did we do it? What organisms did we study? What equipment did we use? How did we analyze the data? How did you set up your experiment? How many experimental groups did you have? How did you measure the effect you studied?

## 4. Results:

This section presents the key findings of the study, the results of experiments and field observation, and/or the data gathered during the project. Here you want to show data, in tables or graphs, that relate to your stated hypotheses and questions and **make specific points**. Each finding should be briefly discussed and perhaps related to other results, although you should save discussion of truly significant conclusions for the next section. The object here is to describe in a clear and logical way what you discovered.

Whenever we perform experiments with multiple replicates, condense your data into averages and standard deviations across replicates. Do not show all raw data in this section unless I specifically ask you to.

### Presenting Your Data

Numerical results are useful because they help answer a question or test a hypothesis. The task of scientists is to make certain that their readers understand why certain data do or do not answer a given question. Presenting data in tabular or graphic form are two methods that scientists use to assist their readers (and themselves) in the interpretation of their results. Presentation of results, for maximum effectiveness, requires condensation and summarization of raw data. There are very rare occasions when it is desirable to present raw data, and those occasions are exceptions to the rule. The processing of raw data usually leads to presentation of average values for treatments, estimated from replicates of each treatment, along with a measure of the variability around those estimates, either standard deviation or standard error of the mean.

In a laboratory report, tables and figures should **always** be labeled with a table or figure number, such as "Table 1" or "Figure 3." Always refer to the table or figure in the text, either to point out a trend in the data or to discuss the significance of the data. Never put tables or figures into a report without discussing them or referring to them in the text!

Tables are generally used to show the relationships between treatments and controls when it is necessary to present information on several different dependent variables for each treatment or subject. However, this method can become cumbersome when large data sets are

displayed or when there are many dependent variables. Alternatively, graphs are often used to demonstrate relationships without burdening the reader with large quantities of numbers. There are advantages and disadvantages to both styles of presentation.

Tables are useful when one wants the reader to see the actual numbers (the processed, condensed numbers, rarely the raw data) or when there are several different variables with varying scales (Table 1). They are also useful to show frequency counts of categorical variables or results of statistical tests (Table 2). As previously mentioned, tables can be a disadvantage when one has to present large data sets, because it forces the reader to visualize the relationships among many numbers and the complex interactions between many variables.

**Table 1.** An example of a table with several different variables from a stream study. Note that the title of the table is the same as the legend, and goes **above** the table.

	<b>Stream 1</b>	<b>Stream 2</b>
<b>Abundance of Sediment</b>	None	High
<b>% Cobble</b>	35	0
<b>% Erosion (Left Bank)</b>	0	68.8

**Table 2.** An example of a table with results of statistical tests. Note how the table is laid out, with titles in bold text and values in the body of the table are centered within the cells, to make the table easier to read.

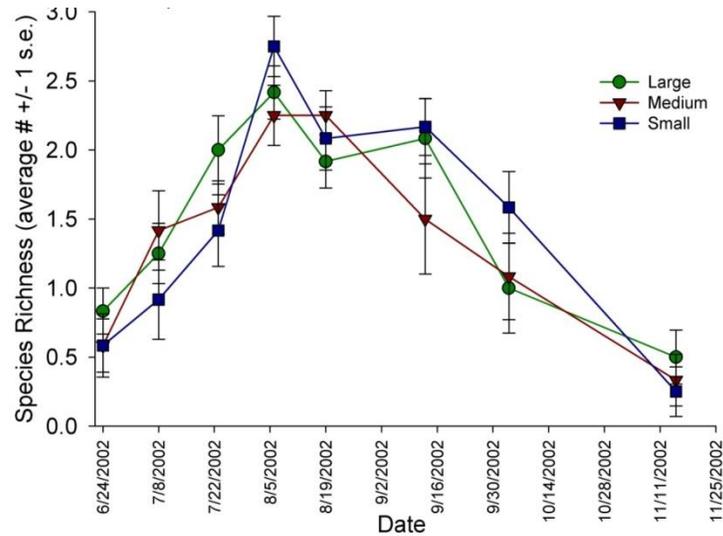
	<b>t</b>	<b>degrees of freedom</b>	<b>P</b>
<b>t-test #1: A vs. B</b>	4.55	23	0.00018
<b>t-test #2: A vs. C</b>	1.56	23	0.12
<b>t-test #3: B vs. C</b>	3.67	23	0.0016

That's where graphs come in. When a reader looks at a graph, they should be able to quickly grasp the point being made. The graph should effectively show a trend (e.g., an increase in the dependent variable over time) or a relationship (e.g., the difference between a control and treatments). However, if there are many variables on which one needs to present data, it could overwhelm the reader, and to present different variables for each treatment on the same graph may require special graphing programs.

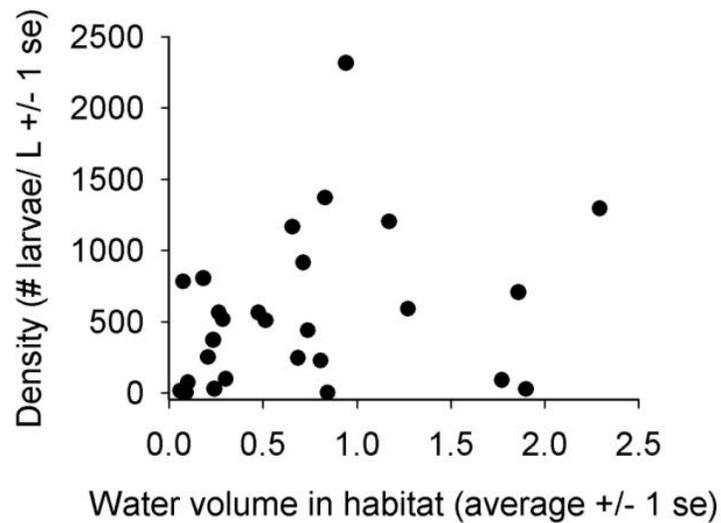
Graphs generally consist of an independent and a dependent variable. The independent variable is generally displayed on the abscissa (the x-axis) and can be a measured quantity, such as time, or a category, and may be set by the investigator. This variable should be unaffected, or as the name implies, **independent**, of the factor being studied. The **dependent** variable is affected by the factor under investigation (or at least one hypothesizes that it is before the experiment is conducted). The dependent variable is graphed against the independent variable so that one can see how the dependent variable changes with changes in the independent variable.

There are many different ways to graph data. **Line graphs, scatter plots, and histograms** are probably the most popular and will be the types that you will use most frequently. Line graphs show the relationship of a dependent variable to an independent variable when the independent variable is a continuous measurement, such as time (Figure 1). A scatter plot would be simply a plot of Y vs. X, with no lines connecting the points (Figure 2). Finally, a histogram is a bar graph,

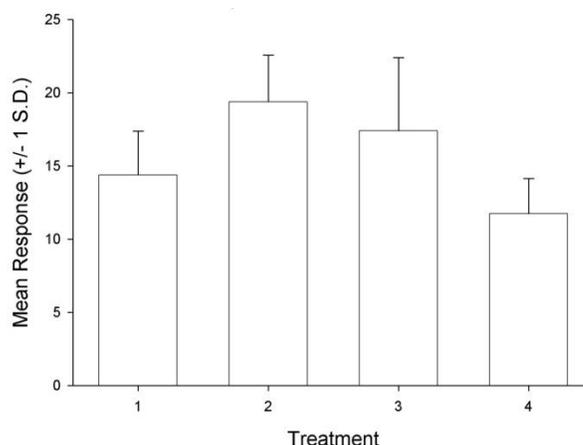
and is the best way to show **averages ( $\pm$  standard deviations)** and **frequency distributions** of either **categorical or continuous variables** (Figures 3 and 4). The frequency is the number or proportion and is the dependent variable, while the various categories or scale on the x-axis make up the independent variable.



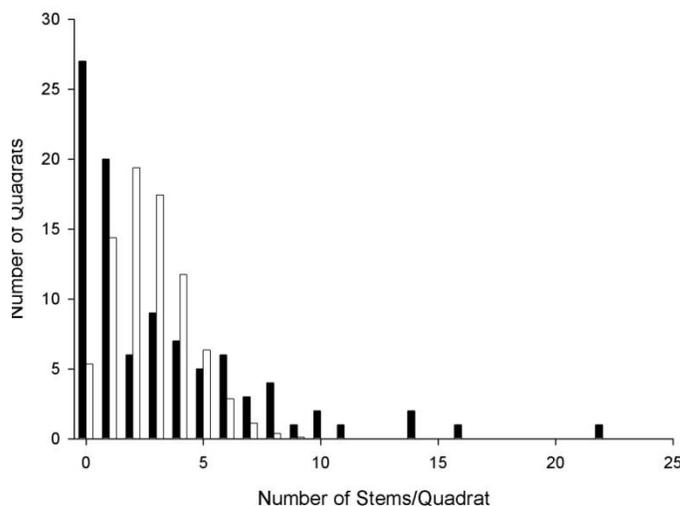
**Figure 1.** Example of a line graph, with time as the independent variable.



**Figure 2.** Example of a scatterplot. Note there is no title above the figure. This figure legend serves as the title of the figure and is placed **below** the figure.



**Figure 3.** Example of a histogram with error bars added. Here the error bars are calculated standard deviations.



**Figure 4.** Example of a frequency distribution. There are no error bars because each point represents a frequency, not an average.

## 5. Discussion:

This section should contain a detailed examination for the few (usually two to three) major issues illustrated by the study. You should point out why the research was significant, what general conclusions can be drawn, and the relation between your findings and basic scientific principles and concepts. Consider the following questions: How do your results support your hypotheses? Or do they? What sources of error and/or bias were present? How would you perform the experiment differently to help eliminate error? What new questions come to mind after examining the results? How do your results and conclusions add to the body of scientific knowledge in ecology?

**6. References:** Include complete citations of any works you cite. Use a standard format, as always. The choice of format is yours.

Sample laboratory reportName  
Lab Report #XBiology 114  
Date**A Comparison of Water Chemistry and Macroinvertebrate Life in Dye Creek and Jacob's Fork****Introduction**

Basic sampling techniques can be used to determine the health of aquatic environments (Paradise 2004). Monitoring the water chemistry, macroinvertebrate life, and physical appearance of streams can frequently be a helpful assessment of human impact on aquatic environments. The two streams sampled in this study are located in North Carolina. Dye Creek runs through a housing development past a horse farm and was once used by a textile company as a depository for their waste products. Jacob's Fork is located in South Mountains State Park, drains a forested watershed, and is further from human development than Dye Creek. Dye Creek was sampled approximately 1000 feet from the horse farm, while Jacob's Fork was sampled within the state park.

Because Dye Creek is located near a horse farm as well as human habitation, two large sources of fertilizers, we hypothesized that the amount of nitrates and phosphates would be much higher in this stream than in Jacob's Fork. An increased concentration of these compounds would lead to decreased abundance and diversity of insects in Dye Creek as compared to Jacob's Fork. In addition, macroinvertebrates known to be sensitive to organic pollutants are predicted to be absent from Dye Creek, including some families of mayflies (Ephemeroptera) and stoneflies (Plecoptera).

**Brief Methods (in this example, students only needed to write an abridged methods)**

Water chemistry was measured using a combined dissolved oxygen and conductivity meter, as well as sampling kits for acidity, alkalinity, nitrates, and phosphates. Abundance and diversity of macroinvertebrates were determined using kicknet samples of rocky areas, gravel areas, and areas of high leaf litter. Samples were preserved in ethanol, and macroinvertebrates were enumerated in the laboratory. General characteristics of the two streams were noted, such as amount of riparian vegetation, amount of erosion, and abundance of sediment in the water. See Paradise (2004) for full description of methods (the lab manual has the full methods; not the case for you).

**Results**

The physical habitat of the two streams showed a marked difference (Table 1). Jacob's Fork had a greater percentage of cobble on the stream bed, compared to the sandy bottom of Dye Creek. There was no sediment and no erosion in Jacob's Fork, while Dye Creek had a high abundance of sediment and much erosion between the two banks.

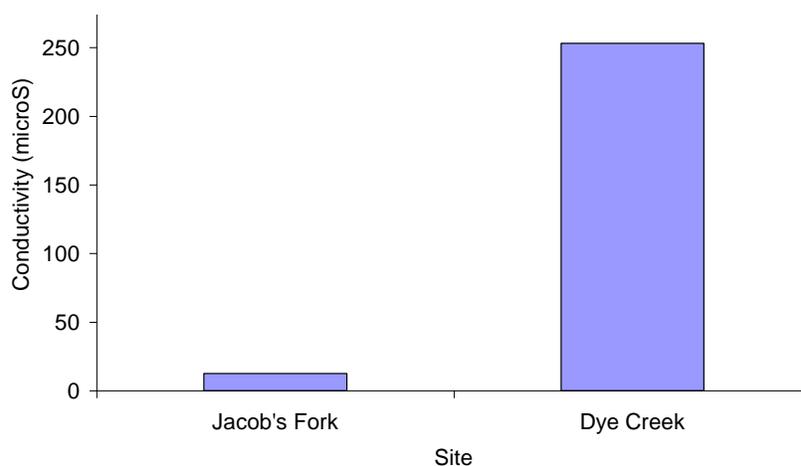
**Table 1. Some physical features of Jacob's Fork and Dye Creek.**

	Jacob's Fork (10/11)	Dye Creek (Ave. for 10/13 & 14)
Abundance of Sediment	None	High
% Cobble	35	0
% Erosion (Left Bank)	0	68.8

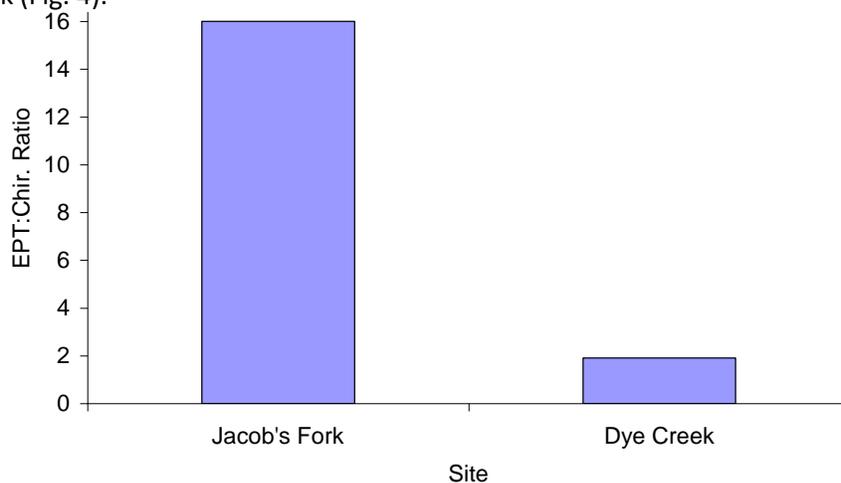
The pH was slightly lower in Jacob's Fork than Dye Creek, although both were circumneutral (Table 2). Nitrates were higher in Dye Creek than Jacob's Fork, and phosphates were slightly higher in the latter. Hardness was almost three times as high in Jacob's Fork than Dye Creek, while conductivity was nearly twenty times higher in Dye Creek (Fig. 1). Temperature was 6°C higher in Dye Creek than Jacob's Fork, and dissolved oxygen levels were slightly lower in Dye Creek than Jacob's Fork (Table 2).

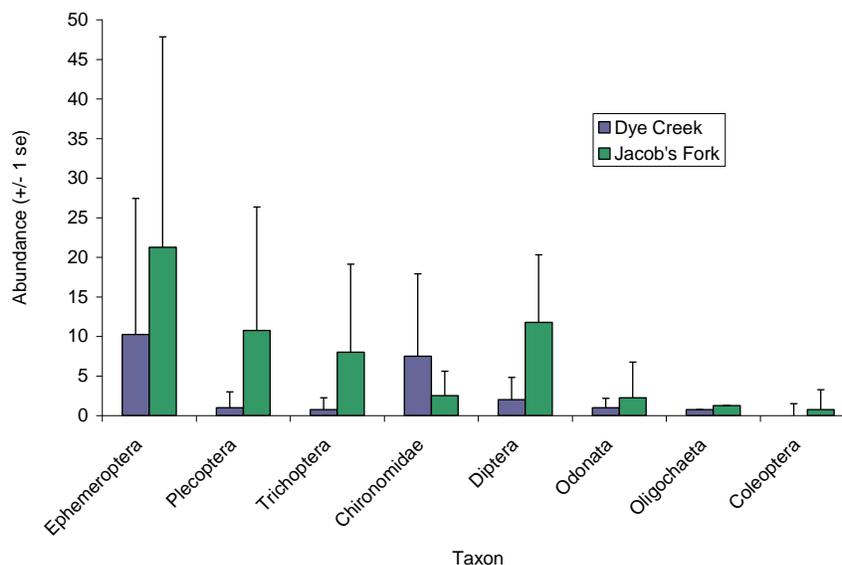
**Table 2. Water Chemistry of Jacob's Fork and Dye Creek.**

Parameter	Jacob's Fork	Dye Creek
pH	6.0	7.3
Hardness (mg/L CaCO <sub>3</sub> )	156	56
Conductivity (Avg. fast & slow; $\mu$ S)	12.5	253.1
Dissolved Oxygen (Avg. fast and slow; mg/L)	11.6	9.9
Nitrate (ppm)	0	6.4
Phosphate (ppm)	0.1	0.4
Temperature ( $^{\circ}$ C)	11.0	17.2

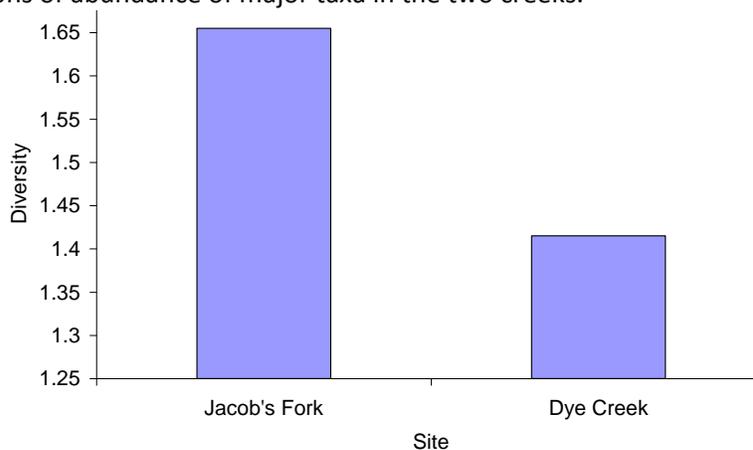
**Figure 1.** Conductivity in the two creeks.

In Dye Creek, many chironomids were found, while only a few Ephemeropterans, Plecopterans, and Trichopterans were found (the sum of these three equals "EPT," which are considered taxa sensitive to, and used as bioindicators of, polluted waters). The ratio of EPT to chironomids should be high in unpolluted streams. In Jacob's Fork, the EPT to Chironomid ratio was much higher than in Dye Creek (Fig. 2). In addition, a greater abundance and diversity of macroinvertebrates was found in Jacob's Fork (Fig. 3), and macroinvertebrate diversity, as measured by the Shannon index, was higher in Jacob's Fork than in Dye Creek (Fig. 4).

**Figure 2.** The EPT:Chironomid ratio in the two creeks.



**Figure 3.** Comparisons of abundance of major taxa in the two creeks.



**Figure 4.** Overall diversity in the two creeks.

### Discussion

Most of the physical and chemical measures indicated that Jacob's Fork was more suitable for a high diversity of macroinvertebrates than Dye Creek. The high amount of sediment, the low amount of cobble and the high percentage of bank erosion indicate that sedimentation is likely a source of pollution in Dye Creek. Sedimentation pollutes by introducing high quantities of small particles into a body of water, clogging gills and reducing visibility for aquatic animals (Kalff 2001). High conductivity is also generally correlated with high sediment loads, and indicates high levels of ions dissolved in water.

In a healthy stream, we would expect to also find low levels of phosphates and nitrates, and high levels of dissolved oxygen (Kalff 2001; Paradise 2004). Jacob's Fork showed low phosphate levels, no detectable nitrates, and near-saturation levels of DO. Conversely, Dye Creek had higher phosphate and nitrate levels, and in fact, had nitrate levels considered to be detrimental to aquatic animals (Roy et al. 2003). Dissolved oxygen in Dye Creek was also near saturation, at least in the high flow zone. It's not surprising to have high levels of DO in polluted creeks that have turbulent flows (Kalff 2001). Possible causes of the high phosphate and nitrate levels in Dye Creek include sewage contamination, runoff from agricultural fertilizers, animal waste, and industrial wastes. With a horse farm, agriculture, and a housing development nearby, there are many sources of these nutrients. While some phosphate and

nitrate is required by living organisms, an excess may result in eutrophication. The abundance and diversity of macroinvertebrates decrease as a result of eutrophication (Ometo et al. 2000). Buildup of organic wastes as a result of eutrophication can cause DO levels to decrease as oxygen is consumed.

One chemical measure that might indicate impairment of Jacob's Fork was pH, and our measurements indicated a slightly lower pH in Jacob's Fork than Dye Creek. This may mean that Jacob's Fork is subject to more acid rainfall than Dye Creek. Most aquatic animals are adapted to live in pH ranges from 6.5 to 8.2 (Kalff 2001). However, pH of 6.0 is probably not too much of a detriment to the organisms we found, and the high water hardness in Jacob's Fork indicates a high buffering capacity.

The macroinvertebrate community may be the best measure of the health of streams, since macroinvertebrates are exposed to long-term changes and the dynamics of water chemistry over the length of their larval life. Water chemistry may change on an hourly basis in streams. The measurements we took can be improved by measuring in different parts of the stream and after rainfalls. This could show whether pollutants are leaching in through groundwater, which might result in different conductivity readings in different parts of the stream, or whether the pollutants enter the stream through rainfall. Analysis of the macroinvertebrate community gives us a long-term view of the stream ecosystem, and those data support our short-term measurements of water chemistry and physical habitat – that Jacob's Fork is a more hospitable stream habitat for a wider diversity and greater abundance of macroinvertebrates than Dye Creek. This is consistent with previous studies that show that watershed urbanization has a negative effect on water quality, decreased macroinvertebrate diversity, and increased abundance of tolerant organisms (Ometo et al. 2000; Roy et al. 2003).

## References

- Kalff J (2001) Limnology: Inland Water Systems. Prentice Hall, NJ
- Ometo JP, Martinelli LA, Ballestei MV, Gessner A, Krusche AV, Victoria RL, and Williams M (2000) Effects of land use on water chemistry and macroinvertebrates in two streams of the Piracicaba river basin, south-east Brazil. *Freshwater Biology* **44**: 327-37.
- Paradise CJ (2004) Exercise 4: Diversity of Stream Insect Communities. Biology 321 Laboratory and Field Manual. <http://www.bio.davidson.edu/courses/ecology/lab/ex6.pdf>.
- Roy AH, Rosemond AD, Paul MJ, Leigh DS, and Wallace JB (2003) Stream macroinvertebrate response to catchment urbanization (Georgia, USA). *Freshwater Biology* **48**: 329-46.