Writing a scientific paper in Ecology

Taken from materials in Bio 16: Introduction to Ecology

Data Analyses and Interpretation of Results

The data you collected can now be compiled, processed, summarized with descriptive statistics and analyzed for patterns. The potential patterns, as defined by your original research hypotheses, can be investigated graphically and with inferential statistics. Your TA is available in lab and in office hours to help you with figure production and inferential statistics. If you and your TA perform statistical analyses, be sure that you understand, in a general sense, what was done and what it means. Work together with your research mates to interpret the results of your study. Draw conclusions about what your data revealed with respect to your hypotheses. You should also discuss with each other the broader ecological significance of your findings. Then, you will individually report on your study in writing following a scientific primary literature format.

Scientific Writing

Your final report will take the form of a journal article and will answer the questions of "why did we do it?", what did we do?", "what did we find?" and "what does it mean?". Your TA will discuss the process and the product of good scientific writing. See **Scientific Writing Format** for details on the content, organization, and style of scientific research papers. See any issue of *Ecology* (the scientific journal) for examples. We suggest the following sequence for efficient preparation of quality research papers:

1. Prepare 1-3 figures and/or tables (with legends) that efficiently summarize your results. Perform analyses as needed. Formal statistical analyses are not required.
2. Outline the main results (as indicated by your figures and tables) in 3 or 4 sentences.
3. Outline the main conclusions (especially the fate of your hypothesis) in 3 or 4 sentences.
4. Write a draft of the report. Firstly, use steps 1-2 above to provide the backbone of your Results. Secondly, use step 3 to formulate the backbone of your Discussion. Thirdly, write your Introduction. And fourthly, write your Methods.
5. Edit the draft as needed to improve clarity, organization, and overall efficiency of communication.
6. Prepare the Title and Literature Cited (Include at least 3 appropriate primary literature references).
7. Write and carefully edit your abstract.

The Results section has two components: figures and/or tables, and text. The figures and tables must possess captions with enough detail to enable the reader to understand patterns in the data by looking only at those tables and figures. The text of the Results section describes the significant patterns and trends in the data. Be careful not to include Introduction, Methods or Discussion items in your Results section. The Discussion section has four main components: relating the findings to the hypothesis, interpreting the patterns found (ecological significance), relating the patterns and interpretations to other research, and concluding (adding to the body of knowledge for the field). It may be appropriate to include a paragraph in the Discussion that addresses deficiencies in the study and suggests remedies. The Introduction section will have three primary components: background information pertaining to the area of ecology in question, a link between your work and the research area, and a statement of your question, hypothesis, and/or prediction. The Methods section will have a description of your field and analytical procedures with enough information (generally what was done, not detailed instructions) for someone to repeat your study.

Scientific writing places a huge premium on efficiency of communication. If your paper is well written, you should be surprised (perhaps even dismayed) at how brief it is. However, audiences will reward you for your brevity by reading and considering what is there. In your editing, ruthlessly eliminate surplus words, extraneous details, vacuous sentences and repetition of ideas. When in doubt, delete it.

SCIENTIFIC WRITING FORMAT

A formal laboratory report usually includes the following 8 sections, presented in the order shown.

1. Title and Authors
2. Abstract
3. Introduction
4. Methods
5. Results
6. Discussion
7. Literature Cited
8. Tables and/or figures

2. ***Abstract***

A brief section in which you describe the study, state the important results and summarize the general conclusions. Hint: Write the abstract last and include the key points from each section of the paper.

3. ***Introduction***

Describe why the objective is relevant to the general field of study. The introduction of a scientific paper generally includes a brief review of the relevant literature. State the specific objective of the research and hypotheses to be tested.

4. ***Methods***

Describe the methods and materials employed in enough detail to enable the reader to duplicate the entire study. Be sure to include any changes you made to standard procedures.

5. ***Results***

The text of the results section should merely highlight the main features of the data. Do not give a complete description of the details of tables and figures; the reader is free to look at any details that interest her/him. Review your handout on statistical analyses to determine the correct presentation of statistical results. These results should be included either in the legends of the tables and figures or, parenthetically, in the text of the results section, or both.

6. ***Discussion***

Interpret and critically evaluate the results. Compare the results to your expectations, and to the results of previous studies with which you are familiar. Be sure to respond to the hypothesis(es) and objectives stated in the introduction. Draw conclusions.

7. ***Literature Cited***

When referring to published literature or other information in the text of the report do not use footnotes. Instead, follow these examples:

a. Jones (1977) found that germination was enhanced...
b. Light is commonly required for the germination of small seeds (Keeton 1976, Salisbury & Ross 1983, Miller 1984).
c. Other studies (Hall 1977, Alexander 1981) have found...
d. For example, Mueller (1979) found that...
e. This handout (Schulze et al. 1989) is so full of detail that I'm getting ill. When a work has 3 or more authors use this format in the text but list all of the authors in the Literature Cited section.

The Literature Cited section includes all of the references, listed alphabetically. Refer to the following examples for appropriate, specific formats.

a. Journal articles:
Lewontin, R.C. and L.C. Birch. 1966. Hybridization as a source of variation for adaptation to new environments. *Evolution* 20:315-336.

b. Books:
Harper, J.L. 1977. Population Biology of Plants. Academic Press, New York.

c. Book chapters (from an edited volume or symposium proceedings):
Cook, R.E. 1979. Patterns of juvenile mortality and recruitment in plants. pp. 207-231. In O.T. Solbrig, S. Jain, G.B. Johnson and P.H. Raven (eds.), Topics in Plant Population Biology. Columbia University Press, New York.

d. Unpublished articles:
Schulze, P., G. Peartree, and A. Smith. 1989. Excessive detail in laboratory report guidelines. Unpublished manuscript.

8. ***Tables and Figures***

Do not repeat the same information in tables and figures. Give careful thought to the most easily interpretable format for presenting the data. The preferred format will vary with the characteristics of the data. Each table and figure should have a detailed caption. The data should be presented in either "raw" or "reduced" form. "Reduced" data is data described by summary variables such as means, percentages, frequencies, etc. Reduced data is generally preferable, but occasionally may be inappropriate. Number tables and figures sequentially (use the order in which they are referred to in the text). The first table referenced in the text should be Table 1. The first figure referenced in the text should be Figure 1. Refer to tables and figures by number in the text. For example:

a. The barnacle Balanus balanoides was particularly common in the upper intertidal zone (Figure 1). (underline or italicize genus and species names)

b. During the day Bosmina longirostris was more abundant than Daphnia pulex in the epilimnion of Post Pond (Table 1).

GENERAL SUGGESTIONS

Scientific writing has much in common with good writing of any kind. However, some qualities are especially important in scientific reports. You must have something very specific to say, and say it very clearly. The messages, ideas and points should be concisely and logically written. There should be little or no room for misinterpretation.

A scientific paper is not the place for rhetoric, nuance or metaphor. For example, it is better to use the same word over and over for the same concept, rather than introducing alternative words for variety and richness of expression, as you might in a novel or literature review. A well-written scientific paper is a pleasure to read because of its clear informative message and succinct presentation.

Reread, rework and edit the first draft. Usually you will shorten the report, deleting wordy, redundant or irrelevant sentences and ideas. Shortening the report typically makes it clearer. Proofread the final copy to remove distracting and potentially confusing typographical errors.

<u>Some specific points</u>

1. Decide on the conclusions and outline the main points before you begin writing.
2. Develop your reasoning with clearly stated data, assumptions, hypotheses or predictions. (Make sure you understand these terms).
3. Develop logical, clear paragraphs supporting your statements. Make sure you write down everything that is necessary to make your points, but use the minimum number of words necessary to make those points clear.
4. Don't ignore part of the data set.
5. Avoid stating something was "proved". Hypotheses can be supported, but not proved.
6. Be sure to explain associations. Example: "Red maples grow better in sunlight". Better than what? where? Another example: "it" or "this" used without clear indication of what is being referenced.
7. Include tables and figures when appropriate. Usually tables and figures are easier to read and understand, or use less space on the page than lists of results in the text.
8. Cite references when referring to information not presented in your data. Cite sources when referring to verbally communicated information.
9. If we have provided questions and/or directions, make sure you understand them and respond to them.
10. Use active voice, e.g., "I predicted", not, "it would be predicted".
11. Underline or italicize Latin names, and capitalize genus name only, e.g. *Sterna hirundo* or <u>Quercus</u> <u>rubra</u>.
12. Type the report on a word processor. It will be much easier to revise.
13. Proofread.
14. Ask your TA questions!