

## 1. Introduction

Ecological research involves designing a study, collecting samples, measuring variables, analyzing data, and presenting the results in a formal report. The process of writing, evaluating, and rewriting research findings makes the author think more deeply about the study. The principal objectives of a research report are to present a record of one's work and to communicate the ecological ideas inherent in that work. Accurate, clear, and concise writing is essential to effective communication among researchers, teachers, and students. A scientific research report provides a writing experience different from that associated with a library term paper, for a research report is based on one's own data and personal involvement in an organized investigation.

## 2. Format and style

Generally, a biological paper has a title and byline (the later identifying the authors and their institutional affiliations), followed by such sections as Introduction, Materials and Methods, Results, Discussion, Summary, and Literature Cited (or References). Often an abstract at the beginning of the report will appear in place of or in addition to the summary. This format serves as a framework for preparing a more detailed working outline, which is a necessary first step in constructing a research paper.

Manuscripts are typed double spaced and with margins of one to one and one-half inches, and each page is numbered. Avoid the use of footnotes. Follow the conventions of section 8 below for referencing. A heading is customarily typed for each of the major sections of the report. Indented subheadings in a section may also be included for clarity. These subheadings generally are a product of the detailed working outline.

The style of a scientific paper varies, depending on the writer and his or her audience. The writing style of scientific papers often is poor, largely because the authors lack experience and training in writing. For the preparation of biological papers, the *CBE Style Manual* (Council of Biological Editors, 1983) is a standard reference for form and style; it is a book with which every serious biological scientist should become familiar. A good summary of report writing fundamentals, with an ecological emphasis, is provided by Scott and Ayars (1980). The following general guidelines gleaned from these sources should be helpful:

1. Wherever possible, use the first person (I or we) instead of awkward indirect statements (this author, these researchers).
2. Avoid long involved sentences and overuse of polysyllabic words. Long, run-on sentences often obscure your meaning, and frequent use of cumbersome words

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reduces the readability of the paper. Check for excessive use of commas and conjunctions (and, but, or). These often connect clauses that can be more clearly separated into two or more sentences.

3. Use the active voice instead of the passive voice. For example, "I measured the water temperature" is preferable to "The water temperature was measured by the author," as it uses fewer words and is unambiguous (i.e., it is clear who measured the temperature). And "I measured forty-four trees" is preferable to "forty-four trees were measured," because the latter statement does not tell us who performed the measurement.
4. Avoid excessive use of nouns as adjectives. Such use of nouns often is acceptable (*temperature stratification* or *tree height*), but it frequently is overused (e.g., *morning lake water temperature profile record sheet* format).
5. Be positive in your writing. Don't hide your findings in noncommittal statements. For example, "the data could possibly suggest" implies that the data actually may show nothing; simply state "the data show."
6. Avoid noninformative abbreviations such as "etc." and phrases such as "and so on" or "and the like."
7. Keep specialized jargon to a minimum. If (but only if) vernacular terminology is just as accurate, use it. Similarly, excessive use of Latin nomenclature should be avoided. If acceptable common names exist for organisms, introduce them together with the Latin names, and thereafter use the former. Otherwise, identify the Latin names. Whenever Latin genus or species names are written they are to be either italicized or underscored; higher taxonomic ranks—e.g., family, order, class, phylum—are not italicized or underlined.
8. Avoid repeating facts and thoughts. Decide in which portion of the report different statements are best placed, and do not repeat them elsewhere.

9. Be concise and succinct. Avoid verbosity in writing. For example, say "many species" rather than "a large number of species," and say "because" rather than "due to the fact that." Include all that is necessary, but don't pad the report with data irrelevant to the purpose or conclusions of the study.

### 3. Introduction section

In the introduction of the paper state the nature of the problem, objectives of the study and any hypotheses to be tested. Also, give a brief background for the study, which would typically include a brief review of the literature. Relate the problem and its significance to the general discipline of study. This part of the paper presents the background, justification, and relevance of your study.

### 4. Materials and methods section

Procedures in research reports are usually detailed enough for the reader to have an accurate idea of what was done in the study or to be guided to appropriate literature for this information. A good description of materials and methods used is one that would enable a reader to duplicate your investigative procedure. Keep to a minimum the details of standard and generally known procedures (such as how an item was weighed). Detailed published accounts, such as chemical formulations for reagents, may be omitted but should be referenced. In a field study, a general description of the study site is called for. If this description needs to be lengthy, then it may comprise a separate subsection (or a new section).

### 5. Results section

This portion of a report gives the facts found, even if they are contrary to hypothesis or expectation. Listings of raw data are rarely presented, except occasionally in a class activity or as an appendix to the report. Instead, data typically are summarized using means, frequency tables, percentages, or other descriptive statistics for presentation and analysis in some appropriate statistical manner (see section 1B). These data summaries may be incorporated into figures or tables if this results in additional clarity or helps illustrate a pattern or trend.

In general, the number of data collected should be indicated, and some measure of variability of the data should accompany statements of means (see section 1B). Statistics used, type of data analysis performed, and mode of presentation depend on the study and type of data collected. Statistical comparisons of different groups of data are often called for, as explained in section 1B.

The Results section is not just a data summarization or a collection of tables and figures; it should contain an explanation and description of the data. Tell the reader exactly what you found, what patterns, trends, or rela-

tionships were observed. For example, do not just say "The species-area curve is shown in figure 1." Tell the reader what is being presented, as "Figure 1 shows that the number of species in the habitat increases and then levels off as the area of the habitat increases."

Illustrations in the Results section may consist of graphs, photographs, or diagrams that visually depict your results. All such illustrations are individually numbered and cited in the text and referred to as a figure (e.g., "Dominance of sugar maple is shown in figure 4."). Labeling and citing tables of data in the text is done in the same manner as for graphs. If a graph will summarize the data as well or better than a table, then the graphical presentation typically is preferable. Each figure and table should contain an explanatory legend. In standard thesis and publication manuscripts the figure number, figure title, and legend are generally on a separate page from the illustration. Be sure the axes of all graphs are fully and correctly labeled with a scale marked off and the units of measurements given; units of measurement (preferably metric) must also be given for tabular data. (Appendix B provides conversion factors for common measurement scales.) Avoid the tendency to cram too much information into one graph or table, thus losing readability.

You may benefit from examining various portions of this book (e.g., section 2A) to observe how figures and tables are titled and are referred to in the text.

### 6. Discussion section

In the previous section of the paper the results are summarized and described. In this section they should be interpreted, critically evaluated, and compared to other research reports; and conclusions should then be drawn based on the study and its findings. Whereas the Results section presents the "news," the Discussion section contains the "editorial." Some research reports have a combined Results and Discussion section, and in some the conclusions are placed in a separate section or are included in a Summary and Conclusions section.

In the discussion, examine the amount and possible sources of variability in your data. Examine your results for bias and evaluate its consequences in data interpretation. Develop arguments for and against your hypotheses and interpretations. Do not make generalized statements that are not based on your data, known facts, or reason. Be sure to relate your findings to other studies and cite those studies. Draw positive conclusions from your study whenever possible.

### 7. Summary section

The end of your paper should contain a summary, which is a concise but exact statement of the problem, your general procedure, basic findings, and conclusions. It should not be just a vague hint of the topic covered, an amplified

table of contents, or a shortened version of the report. In many scientific journals, an abstract of the paper at the beginning of the paper replaces a summary. Some research papers include a separate Conclusions section between the Discussion and Summary sections.

*Example of a poor summary:*

The food habits of various amphibians were studied in detail by the authors. The data were analyzed statistically and the findings were discussed at length. Certain similarities and differences were found between the species studied and the habitats in which they were found. Conclusions about feeding habits, habitat relationships, and niches were made for these species.

This summary or abstract is merely an expanded table of contents with verbs added to make complete sentences. Notice that no specific information is given to the reader.

*Example of an acceptable summary:*

Stomach contents of the red eft, red-backed salamander, and dusky salamander were identified. Analysis of overlap of food taxa shows that the feeding habits of only the latter two species were similar. As an example of niche segregation, the salamanders show less feeding overlap in habitats where they are living together.

## 8. Literature cited section

No comprehensive literature survey is required for a class research report; however, you are expected to use some sources other than a textbook (such as technical journals and reference works). These sources should be cited in the body of your report. Useful references are given at the end of each section in this manual, in textbooks, and in the Literature Cited or References sections of scientific papers. It is up to you to select the most useful references. All references given in your paper must appear in the Literature Cited section. Rarely (e.g., in an instructional report), it may be desirable to list references in addition to those cited in the paper. In this case the heading Literature Cited should be replaced by Bibliography, or Suggested References, or Selected References.

References may be cited in the text of your paper in one (but not both) of two forms: (1) by author and year or (2) by number. Citation by author and year is more common in biological writing; for example:

Smith (1980) stated that eastern grasslands are either tame or seral.

or

Eastern grasslands are either tame or seral (Smith, 1980).

If there are two authors of the reference, then they are referred to as "Smith and Jones"; if there are more than

two, then "Smith et al." is written (although all authors will be listed in the Literature Cited section). All references are then listed in the Literature Cited section in alphabetical order of the first author's surname. (If there are more than one reference for an author, they are listed chronologically for that author.)

If the reference numbering system is used, then the text citation would be of the following form:

Eastern grasslands are either tame or seral (21).

and the Literature Cited section would consist of a listing of references in numerical instead of alphabetical order.

For a book in a list of references, the general form is:

Smith, R. L. 1980. Ecology and field biology. 3rd ed. Harper & Row, New York.

where the author (all authors if more than one) is followed by the year of publication, the title, and the name and location of the publisher. Sometimes the number of pages is also indicated at the end of the citation (e.g., ". . . 835p.").

For a journal article, the general form of citation is:

Greenwald, G. S. 1956. The reproductive cycle of the field mouse, *Microtus californicus*. J. Mammal. 37: 213-222.

where the author (all authors if more than one) is followed by the year of publication, the title, and the journal name, volume, and page numbers. In journal citations it has been customary to use standard abbreviations for the name of the journal (as above), but it is an increasing practice to spell out the entire name, especially if the audience is a general one that might not recognize the abbreviations.

You may benefit from observing the various chapters in this book to see how literature may be cited.

## 9. Some common problems

1. Use, evaluate, and interpret your data. Failure to do so is the most common problem students have in report writing. Many will calculate their results and make figures and tables, thereafter leaving these data to sit idly in the paper without any explanation or elaboration.
2. Do not ignore results because they differ from textbook generalizations. Your data are not incorrect just because they do not agree with some general principle or a conclusion in another report.
3. Use reference material only if pertinent to your data. Often, much irrelevant information is brought into reports.
4. Be careful about making small differences seem important. Different values are not necessarily significantly different. If you have not used statistical testing

- (see Section 1B), you should at least consider in your subjective evaluation the amount of variability in your data.
5. Do not discard data because of variability and biases. There are some errors in nearly all scientific data. If recognized and accounted for in interpretation of results, errors of reasonable size need not discredit your data.
  6. Round off final quantitative results to no more digits than can be reasonably justified. What sense does it make to compare two numbers such as 17.289761 and 19.82946? Do the last several digits have any special meaning? Reporting 17.3 and 19.8 may suffice in your case.
  7. Label figures and tables properly and thoroughly and cite them in your text. Too often figures and tables are inserted in a report without identifying their contents or explaining their purpose to the reader.
  8. Play around with your data before preparing the final graphs and tables. Get your mind working over the data, in order to seek patterns and trends. Try to organize the data in various ways, as different presentations may elucidate different patterns or trends. But be careful not to force a preconceived conclusion on the data.
  9. Do not select or reject data in order to make desired results apparent. Any "fudging" of data is dishonest and unacceptable.
  10. Do not perform calculations on data just for the sake of calculating. Have a reason for and draw conclusions from the calculations performed. Padding your report with excessive though honest numbers serves no useful function.
  11. Document ideas, conclusions, and hypotheses with data, facts from the literature, and sound reasoning. Do not leave your ideas up in the air without support or they will fall with the first touch of the instructor's red pencil.
  12. Relate your results and conclusions to accepted principles and concepts. Explain any discrepancies.
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#### 10. Selected references

- Baker, S. 1984. *The complete stylist and handbook*. 3d ed. Harper and Row Publishers, New York.
- Council of Biological Editors, Committee on Form and Style. 5th ed. 1983. *CBE Style Manual*. American Institute of Biological Sciences, Washington, D.C.
- Rathbone, R. R. 1972. *Communicating Technical Information in Scientific and Engineering Writing*. Addison-Wesley Publishing Co., Reading, Mass.
- Scott, T. G., and J. S. Ayars. 1980. Writing the scientific report, 55-60. In S. D. Schemnitz (ed.), *Wildlife management techniques manual*. 4th ed. Wildlife Society, Washington, D.C.
- University of Chicago Press. 1982. *The Chicago manual of style*. 13th ed. University of Chicago, Chicago.