Notes On Writing Papers And Theses

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Many class papers and theses share a common set of problems in their early drafts. I began these notes because I found that I was making essentially the same comments on many student papers. I discovered that graduate students often find it difficult to identify problems in their writing and frequently lack tools to deal with them effectively. Few students, it seems, have received much instruction in the strategies and tactics for effective scientific writing. My notes grew into a document that I give to students as a part of course packages and to students whose theses I read. The suggestions I make here are based primarily on my written comments on major papers and theses over the last six years but also reflect common problems in manuscripts I receive for review.

1. Know your audience and write for that specific audience. Scientific and technical writing can almost never be "general purpose"; it must be written for a specific audience. For the kinds of writing I address here, that audience will generally be the community of ecologists who read a particular journal or study a particular subject. For class papers, this community is represented by your professor. In all cases, you must adopt the style and level of writing that is appropriate for your audience. Stylistic conventions and acceptable jargon can vary tremendously from one field to another, and to some extent, from one journal to another. If you are unfamiliar with the conventions of a field, study them as they are manifested in a selection of highly regarded papers and in the "Instructions for Authors" for key journals.

2. Your supervisor/professor is not here to teach you basic grammar and spelling. The more time and emotional energy she or he spends on correcting basic English usage, the less remains for issues of content or fine-tuning. You are responsible for mastering the basics of the language; save your supervisor's time for more substantive issues. A few glitches and non-parallel tenses will slip through your own careful editing, but there is no excuse for frequent ungrammatical sentences. Similarly, with word processors and spell-checkers having become standard writing tools, typos or other spelling errors should be very rare. Use a spelling checker before submitting anything for anyone else's reading.

If you find you are about to submit a paper which you know contains poor writing, consider why you are doing so. If there is a writing problem with which you are having a hard time (for instance organizing the structure of an argument in its most effective form), it is legitimate to submit this for someone else's review with the problem highlighted as a focused request for assistance. Otherwise, submitting a piece of writing with known errors or problems means either: 1) you do not consider your writing worth improving, 2) you do not respect the reader enough to present writing that is as good as you can make it, or 3) you are incapable of improving the writing. At some point, every thesis is as good as its writer can make it without outside review. That is the time to give it to your supervisor.

3. Do not turn in a first draft! Ever! Most people's first drafts are terrible. I wouldn't make anyone else suffer through mine. Don't make others suffer through yours. I've read early drafts of papers by eminent ecologists whose final products are jewels of English construction. Their first drafts are terrible too. "Good writing is rewriting" and you should make a serious effort at editing, rewriting, and fine-tuning before you give the manuscript to anyone else to read. There are few things more frustrating to read than a paper in which you know there are pearls of wisdom, but where those pearls are hidden by sloppy and ambiguous writing. The chapters of my Ph.D. thesis had been through 3-5 drafts before anyone on my advisory committee ever saw them. If you need to put a piece of writing away for a few days before you can approach it dispassionately enough to rework it, do so.

It takes much longer to read poor writing than good writing. It is a waste of an advisor's or editor's time to read material that is not yet ready to be presented - and it is disrespectful to expect them to do so. When an advisor receives a thesis in which the writing is poorly

Lertzman, K.P. 1995. Notes on writing papers and theses. Bulletin of the Ecological Society of America 76:86-90.

developed, expect them to go through enough of it to demonstrate the kinds of changes required, and then return it with the rest unread.

Consider forming a mutual editing team with other students to review each other's work. Publication quality scientific writing is usually a product of the research community rather than the sole efforts of the author(s): reviewers and editors make a big difference to the vast majority of published papers. You should become accustomed both to reviewing other people's work and to having your own reviewed.

4. Get and use style books. All aspiring ecologists should have a library of books which support their technical communication. Distinguish between those which are primarily manuals of accepted rules, those which address how to create a draft (e.g. disconnecting the creative from the critical voice, etc.), and those which focus on rewriting. I recommend Williams (1990) as a manual for rewriting. Williams focuses on how to turn a draft into a finished product.

5. Avoid passive constructions wherever possible. The rule that you must avoid personal pronouns is antiquated and has been rejected by most scientific journals. If *you* collected the data using Smerdyakoff's Bicranial Olfactory Apparatus, then there is nothing wrong with saying "I collected the data using Smerdyakoff's Bicranial Olfactory Apparatus." Where it would be repetitive to use personal pronouns ("I did this. I did that. I did the other thing."), or where it makes the sentence more awkward to use the active voice, you may occasionally, cautiously use the passive voice.

6. Avoid abusing word forms. Use words in the form which conveys your meaning as clearly and simply as possible. A variety of writing problems arise from using verbs and adjectives as nouns. Such word forms are called *nominalizations* (Williams 1990). Consider the sentence "The low rate of encounters was a reflection of the reduction in population density." The verbs "to reflect" and "to reduce" are used as nouns and the sentence is more turgid and less direct than when they are used as verbs: "The low rate of encounters reflects a reduced population density.". Some nominalizations are both useful and effective, as in "taxation without representation." Williams (1990) has an excellent discussion of useless and useful nominalizations.

Creating awkward phrases where nouns and verbs are used as adjectives or adverbs is another common problem leading to awkward and wooden writing. In his delightful critique, Hildebrand (1981) called nouns used this way "adjectival nouns." Such constructions are almost invariably clumsy and unclear. For instance, though shorter, "the Chilko Lake park proposal" is not as good as "the proposal for a park at Chilko Lake". The first form illustrates both a nominalization ("proposal" as noun versus verb) and adjectival nouns ("Chilko Lake" and "park" as adjectives modifying "proposal" rather than nouns). Table 1 provides examples of adjectival nouns culled from papers and theses I read during one month. It is distressingly easy to find awkward strings of adjectival nouns in published papers, where they are common in titles. Phrases built with one adjectival noun or verb are often useful (e.g. "hair pin", "gut contents", "sampling unit"), but those with more are usually awkward, rarely necessary, and generally replaced easily (e.g. "beaver gut contents", "researcher defined sampling units").

7. Do not use more words where fewer will do. Do not use long words where short ones will do. Do not use jargon where regular language will do. Do not use special words to make your writing seem more technical, scientific, or academic when the message is more clearly presented otherwise.

8. Use an outline to organize your ideas and writing. When you first start a writing project, make an outline of the major headings. List the key ideas to be covered under each heading. Organize your thinking and the logic of your arguments at this level, not when you are trying to write complete, grammatical, and elegant sentences. Separate out the three tasks of: 1) figuring out *what* you want to say, 2) planning the *order* and *logic* of your arguments, and 3) *crafting* the exact language in which you will express your ideas.

Many people find it useful when making an outline to attach page lengths and time lines to each sub-section. For instance, section 2.4 may be "Evidence for differential use of canopy gaps by *Clethrionomys*." To this you might append: "3 more days analysis, 4 days writing; 10 pages." Such time estimates are usually inaccurate, but the process of establishing them is quite useful.

It is very easy to write and expand outlines with word processors. When starting a writing project, I create a file in which I first develop an outline as described above. I save a copy of the outline separately and then commence the writing by expanding the outline section-by-section. I usually get ideas for later sections while writing earlier ones and can easily page down and write myself notes under later section headings. This is especially useful for filling out the structure of a Discussion while writing the Results (for instance, "When discussing the removal experiment, don't forget to contrast Karamozov's 1982 paper - his Table 3 - with the astonishing results in Figure 7.") By the time I get to writing the Discussion, the outline has usually been fleshed out substantially and most of the topic sentences are present in note form.

9. Think about the structure of paragraphs. Poorly structured paragraphs are one of the most common problems I find in graduate student writing. Though most graduate students can write reasonable sentences, a surprising number have difficulty organizing sentences into effective paragraphs. A paragraph should begin with a topic sentence that sets the stage clearly for what will follow. One of my most frequent comments on student papers is that the contents of a paragraph do not reflect the topic sentence. Make topic sentences short and direct. Build the paragraph from the ideas introduced in your topic sentence and make the flow of individual sentences follow a logical sequence.

Many writers try to finish each paragraph with a sentence that forms a bridge to the next paragraph. Paying attention to continuity between paragraphs is a good idea. However, such sentences are often better as a topic sentence for the following paragraph than a concluding sentence of the current one. It is nice to conclude a paragraph by recapitulating its main points and anticipating what follows, but you should avoid statements of conclusion or introduction which contain no new information or ideas.

Strive for parallelism in structure at all times. When you present a list of ideas that you will then explore further ("Three hypotheses may account for these results: hypothesis 1, hypothesis 2, hypothesis 3."), make sure that you then address the ideas in the same sequence and format in which you have presented them initially. It is both confusing and frustrating to read a list presented as "1, 2, 3, 4" and then find the topics dealt with "1, 4, 3, 2."

Think about how the structure of your paragraphs will appear to the reader who is reading them for the first time. She should not have to read the text more than once to understand it. Carefully lead the reader along so that the structure of your argument as a whole is clear, as well as where the current text fits in it.

Paragraphs containing only one or two sentences are rarely good paragraphs because they can't develop ideas adequately. Two-sentence paragraphs usually represent either misplaced pieces of other paragraphs or fragments of ideas which should be removed or expanded.

Choppiness both within and among paragraphs often results from the ease with which we can cut and paste text on the computer. Ideas which were written separately but belong together can be moved easily. Unfortunately, they often still read as if they were written separately. This is a great way to restructure a draft. However, you *must* read over such text for continuity before submitting it to others for review.

It is difficult to read for continuity on the computer screen because you can see so little text in front of you at any given moment. It is also more difficult to flip over several pages to scan for repetition, parallel structure, etc. To do a really good job of proofing a paper, most writers find it necessary to read hard copy at some point during the writing/rewriting process. Print all but final drafts on paper which has been used previously on one side.

10. Pay attention to tenses. Problems of inappropriate or inconsistent tenses are common in student writing. What you, or others, did in the past should be stated in the past tense (e.g. "I *collected* these data ..."). Events or objects which continue to happen or exist can be described in the present tense (e.g. "In this paper I *examine* ..."; "The data *reject* the hypothesis that ..."). Events which will take place in the future can be in the future tense. Whatever tense you choose, be consistent. Be careful in using "might", "may", and "would" (as in "this might indicate that ..."). They are frequently used as ways of weaseling out of making a clear statement.

11. Captions shouldn't merely name a table or figure, they should explain how to read it. A caption should contain sufficient information that a reader can understand a table or figure, in most cases, without reference to the text. While very simple tables and figures may require only a title for clarity, and exceptionally complex ones may require reference to the text for explanation, these circumstances should be rare. Captions are often most effective when they *briefly* summarize the main result presented in the table or figure (for example see the caption for Table 1). Don't leave caption writing to the end of the project; write captions when you organize your Results section and it will help you write the text.

12. When citing a reference, focus on the ideas not the authors. Unless the person who reported a result is an important point in a statement, literature citations should be parenthetical, rather than in the body of the sentence. For instance, in most cases, it is preferable to write a sentence of the form "Though mean growth rates in Idaho were < 10 cm per year (Table 2), growth rates of > 80 cm are common in populations in Alberta (Marx 1982)." rather than "Though mean growth rates in Idaho were < 10 cm per year (Table 2), Marx (1982) found growth rates of > 80 cm to be common in populations in Alberta." Sometimes the identity of the writer is important to the meaning of a statement, in which case emphasis on the citation is appropriate (e.g. "While Jones (1986) rejected this hypothesis, Meany's (1990) reanalysis of his data failed to do so.").

13. Show us don't tell us. Rather than telling the reader that a result is interesting or significant, *show them how* it is interesting or significant. For instance, rather than "The large difference in mean size between population C and population D is particularly interesting.", write "While the mean size generally varies among populations by only a few cm, the mean size in populations C and D differed by 25 cm. Two hypotheses could account for this, ..." Rather than describing a result, show the reader what they need to know to come to their own conclusion about the result.

14. Write about your results, not your tables, figures, and statistics. Confusing and disjointed Results sections often arise from the writer not having a clear idea of the story they intend to tell. The frequent consequence of this is a Results section consisting of a long, seemingly unrelated sequence of tables and figures. We often go through a lengthy and convoluted process in understanding the content of a data set; your paper needn't document all the twists and turns of that process. Expect that you will produce many more figures and perform many more statistical tests than will be included in the final written product. When preparing to write your results, decide on the elements of the story you wish to tell, then choose the subset of tests, figures, and tables that most effectively and concisely conveys your message. Organize this subset of tables and figures in a logical sequence, then write your story around them.

Novice writers of scientific papers frequently pay too little attention to discussing the content of tables and figures. They sometimes merely present a list of references to them (e.g. "Table 1 shows this result, Table 2 shows that result, Figure 1 shows the other result."). When writing Results sections you should use the tables and figures to illustrate points in the text, rather than making them the subject of your text. Rather than writing "Figure 4 shows the relationship between the numbers of species A and species B", write "The abundances of species A and B were inversely related (Figure 4)." Distinguish between your scientific results and the methodological tools used to support and present those results.

15. Focus on ecological hypotheses, not statistical hypotheses. Most graduate students have learned the importance of having and testing clear hypotheses. Unfortunately, many focus their writing on statistical hypotheses, not ecological hypotheses. Statistical hypotheses are generally a trivial consequence of standard statistical inference, such as the null hypothesis of no difference between two populations. They rarely have inherent ecological significance and are meaningful only in the context of the specific test being performed. Focus your writing on the ecological hypotheses underlying your research (e.g. that species A is influenced by processes X and Y in a specific way, resulting in different growth rates in habitats S and T), not the statistical null hypotheses required to test specific predictions of those ecological hypotheses (e.g. there is no difference in growth rates among populations of species A in habitats S and T).

16. Develop a strategy for your Discussion. Many novice paper writers begin their Discussion section with a statement about problems with their methods or the items in their results about which they feel most insecure. Unless these really are the most important thing about your research (in which case you have problems), save them for later. Begin a Discussion with a short restatement of the most important points from your Results. Start with what you can say clearly based on what you did, not what you can't say or what you didn't do. Use this statement to set up the ideas you want to focus on in interpreting your results and relating them to the literature. Use sub-headings which structure the discussion around these ideas.

17. Introductions and conclusions are the hardest parts -- plan on spending a lot of time on them. Many technical writers prefer to write their introductions last because it is so difficult to craft that balance of general context and specific focus which a good introduction requires. Often it is easier to achieve this after you have already worked through writing the entire paper or thesis. If you need to write the introduction first to set the stage for your own thinking, resist the temptation to perfect it. By the time you have finished the rest of the paper it will likely need substantial modification. The same concerns apply to conclusions, abstracts, and summaries. These components of the paper are all that many people will read and you must get your message across in as direct, crisp, and enticing a manner as possible. Plan on taking your time and giving these components several more drafts than the rest of the paper.

18. Break up large projects into small pieces and work on the pieces. Don't write a thesis; write chapters or papers. Many thesis writers have a hard time starting to write because they are intimidated by the huge project looming ahead of them. As a result, their first few month's efforts are often awkward and disjointed, as well as sparse. The thesis should be separated into small discrete sections, ideally distinct publishable papers. The overall organization of ideas should be done during the planning stage so that when you work on individual sections you can concentrate on them.

Don't wait until you think you've completed all your analyses to start writing. "Parallel processing" of writing one chapter while you complete the analyses for others and make presentation quality figures is a good strategy for avoiding writer's burn-out. Writing and analysis for any given chapter or paper is often an iterative process. Writing the results section of a paper is often the best way to discover the analyses and figures that still need to be done.

19. Make your writing flow and resonate. Probably the most frustrating and useful review I have received was from my masters advisor Lee Gass on a draft of a paper from my M.Sc. thesis . He said that all the key points were there and that the writing was clear, but it didn't "flow and resonate." He sent me back to rework it and, eventually, the published product did "flow and resonate" (at least we thought so). Once or twice a year I come across a paper that is written so well it is a joy to read. If the content is as good as the writing, the experience of reading it can shape my thinking for some time thereafter. Papers which are written so well they "flow and resonate" are much more likely to influence your readers than the equivalent message presented in a form which is merely clear. When you find a paper that succeeds in this, study carefully how

the authors constructed their arguments and used language; try to identify what makes the paper work so well.

20. Use word processors effectively and back up your work religiously. Computers have improved tremendously the ease with which we can edit, shuffle, rewrite, and spell-check a paper. To do this efficiently requires investing time in learning about your tools. You needn't learn how to use all the more exotic features of your word processor, but learn the options that are available and how to find out the details when you need them. Minimally, be familiar with basic requirements for document formatting (character and paragraph formatting, how to make lists with hanging indents, page organization, etc.) and basic operating system requirements (copying and saving files, doing directory searches). The same comments apply to the use of statistical packages, graphics programs, and spreadsheets: it is often possible to get the job done with little finesse in manipulating your software, but you will usually do a better job more efficiently after some investment in technical skills.

Almost everyone seems to require their own personal disaster to convince them of the need for backing up important files regularly. The frequency of "lost file" based excuses for late papers is remarkable. I save files to my hard drive frequently during working sessions and at the end of *each* session I make a back-up copy of any file that I would mind losing. The working memory of your computer is transitory and easily purged of its contents. Individual hard drives, CD's, and flash memory sticks are little better as permanent storage forms. Redundant copies dispersed in space and time are your main hope for avoiding disasters. When you have invested a lot in a writing project (such as a thesis that is nearing completion), keep *at least* one recent backup copy at home and one at school at all times - in addition to your working copy on a hard drive. Keep sample hard copies of recent drafts until you complete the project.

21. Take editorial comments seriously. It may be clear from an editor's comments that they didn't understand the point you were making. If so, that is a clear indication that you need to improve your writing. Here is an example of my comments on an early draft of a thesis. These are among the most frequent recommendations I make.

"This section offers enormous opportunities for improvement. The text is choppy, both at the sentence-to-sentence level and the paragraph-to-paragraph level. Many different points are mixed together in a sequence that often follows no logical flow.
You should:

1. Create a list of the main points that you want to make here.
2. Organize them in point form in a logical sequence in which each one builds on what comes previously. Then restructure your text so it follows this sequence.
3. Write topic sentences that state the key issue for each point succinctly and without jargon.
4. Flesh out each paragraph with a carefully constructed sequence of sentences that builds the argument you want to make.
5. Make sure there is adequate conceptual "glue" between paragraphs and major sections. Lead the reader along so there are no surprising jumps in subject. The reader should anticipate your next subject before you get there."

Acknowledgements
I would like to thank the many students who inspired and gave feedback on these notes. I hope their pleasure in good writing justifies the pain of getting there. Thanks also to Lee Gass for his continuing inspiration in the use of language.

Literature Cited

Williams, J.M. 1990. Style: toward clarity and grace. University of Chicago Press, Chicago. pp. 208
Hildebrand, M. 1983. Noun use criticism. Science 221:698

Table 1. Examples of adjectival nouns and verbs from graduate student papers read in December 1994. Each can be changed easily to a form which is clearer and more active (e.g. "suspended sediment increases" ------> "increases in suspended sediments"). Rewriting these is a useful exercise for students.

suspended sediment increases
maximum three-week nitrogen concentrations
water supply concern
streamwater DOC concentrations
DOC soil solution concentrations
appropriate waterbody buffering system
maximum floodplain extent
fire severity gradient
fisher habitat use
the most energy favorable den location
researcher defined stands
above ground coarse woody debris
previously designated special habitats for particular species
time and information constraints
the first construction attempt
different width linkages
riparian linkage boundaries
biogeoclimatic subzone and watershed forest interior objectives
old growth retention and forest interior Forest Ecosystem Network objectives
the compositional dynamics focused perspective of traditional gap studies

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