How to Do Ecology

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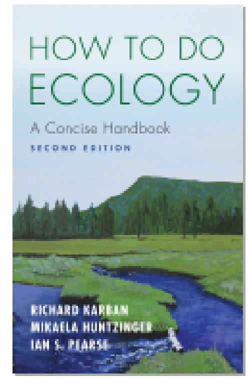

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CHAPTER 8

Communicating What You Find

Communicating is an essential part of doing field biology, although it requires very different skills than scientific investigation. Learning about nature is fun, but the field of ecology only advances when you communicate what you have learned. We have never been able to make a lick of sense of the argument that a tree that falls in the forest hasn't really made a sound if nobody is there to hear it. However, if you don't make other interested people aware of what you have learned, then from society's point of view, essentially nothing has been learned.

Not all attempts to communicate are successful, and this aspect of ecology has an enormous effect on whether your findings and ideas will have an impact. In the sixth and final edition of *The Origin of Species,* Charles Darwin (1889) included "an historical sketch of the progress of opinion on the origin of species." Essentially, Darwin explained why his ideas really were different from those of numerous predecessors who, by 1889, wanted some of the credit and fame for the theory that Darwin had expounded. Most of the authors were easy to deal with; they had simply missed the main points of the theory of natural selection.

However, one author was more troublesome for Darwin, and he wrote,

> In 1831 Mr. Patrick Matthew published his work on "Naval Timber and Arboriculture," in which he gives precisely the same view on the origin of species as that (presently to be alluded to) propounded by Mr. Wallace and myself in the "Linnean Journal," and as that enlarged in the present volume. Unfortunately the view was given by Mr. Matthew very briefly in scattered passages in an Appendix to a work on a different subject, so that it remained unnoticed. . . .

Matthew understood the principles and their significance, but he didn't effectively communicate what he had grasped. He had the same impact as if he had never had the ideas in the first place.

This wasn't a one-time event. For example, MacArthur and Wilson (1963, 1967) revolutionized the field with their theory of island biogeography. Years before MacArthur and Wilson, Eugene Monroe proposed the same equilibrium theory, along with empirical support for the species-area relationship for butterflies in the West Indies, and detailed models to explain it (Monroe 1948 [his thesis], 1953 [an obscure proceedings]). Unfortunately, Monroe did little to communicate what he had found, and the scientific community remained unaware of his insights (Brown and Lomolino 1989). These examples illustrate that it matters where you publish. Make sure that you are reaching the largest and most appropriate audience. Both Matthew and Monroe are forgotten footnotes in the history of ecology because better communicators independently came to similar conclusions. How many Matthews and Monroes have there been, whose potentially revolutionary advances have never been repeated or communicated?

Publications are the currency of our field. Some journals are more influential than others and reach a much wider audience. Rating systems for journals have been developed to measure this influence. These ratings fluctuate and are available at several websites, including http://www.scimagojr.com/journalrank.php?category=2303. The best way to get a sense of the respected journals in your subdiscipline is to ask several experienced ecologists and to read (skim) a lot yourself.

Writing and talking about your work communicates your ideas and findings. In addition, the act of organizing your work by presenting talks and writing papers helps you figure out what you know, what you don't know, and how the various pieces fit together. Almost all seasoned ecologists will tell you that they often think that they have a pretty good grasp on a subject they are about to lecture or write about; however, once they sit down and look for the actual words they are going to use, they realize that they haven't thought through the ideas. The act of writing or speaking clarifies your thoughts and will probably be valuable for you, independent of the value of communication.

Many ecologists who communicate their work successfully use an outline to organize talks and papers. The outline can be either hierarchical, with roman numerals (Rick's preference), or informal, in a bulleted list (Mikaela's preference). When we're organizing our work, we use a list when we aren't sure about how to order the various ideas. Then we give each of the things we've written down a number or color code that helps to group the ideas that are similar or related. Next, we figure out which of these should go first and how to connect them to make a logical argument. If you think you don't like outlines, but you haven't actually used them to write a professional paper, we recommend you give them another try. It may seem like you're wasting time, but they make you more efficient in the long run and help you write a more organized paper.

If you took our advice from chapter 6, you will write up your results after each field season. The preliminary literature review that this requires will help give you a sense for how your work fits into the bigger picture. Writing up your results will also make it clear what you have nailed down conclusively and what parts of your argument are weak and need further testing. Coming to grips with what you have will also help you design the next steps. Doing this may seem like extra work. It's not. You wind up using a lot of this preliminary draft when you write up the paper for real. It also makes writing the final paper much less overwhelming. Finally, it is easier for colleagues or committee members to provide helpful feedback if they can read a manuscript rather than just listen to something vague about what you think you found. In the sections that follow, we offer some suggestions for organizing your work into (1) a journal article, (2) an oral presentation, (3) a poster, and (4) a grant proposal.

Journal Articles

Journal articles are the bread and butter of biologists. Writing papers can seem daunting at first, but as you begin to recognize the formula for writing them, they will become easier. Journal articles serve the important function of archiving what you have learned and making it available to the rest of the ecological community.

Expect to revise your manuscript. Rick sometimes likes to think of his first draft as a place to get his ideas organized and out of his head. He tries to approach his second draft much more critically, from a reader's perspective. Is the story clear? Does the logic follow? Does his writing express exactly what he was thinking? Sometimes he tries to imagine that his father is reading the manuscript. His father had no formal training and therefore didn't have the jargon and preconceptions of a trained ecologist. Rick asks: Would he follow what I am saying? How would I change my paper so that he would understand it?

Inexperienced writers sometimes imagine that they should sit down and write a polished version. Instead, it may be helpful to think of the writing process as four distinct steps (Lertzman 1995). The first step is figuring out what you have to say. Don't worry about grammar or organization during this stage—your goal is to get your thoughts on paper, as we described above. The second step is organizing your thoughts (with an outline or other technique that works for you) so that you can present a logical argument. The third step is putting down the words that make your argument. Read this draft critically, imagining how it will sound to your audience. Then, as a fourth step, carefully craft your writing so that it makes your points concisely and convincingly. Separating these tasks may help you get started. Including all four, if you don't already, should improve your writing and make the process less difficult. If your native language is not English, it may be a good idea to get a native speaker to help you with this last step.

Most journal articles are expected to follow a standard format: abstract, introduction, methods, results, discussion, and conclusion. (Even articles in *Science* and *Nature* are written in this format, although it is less easy to spot.) Most of your paper should be written in the past tense. You are describing what you did, what you found when you did it, and how you interpreted those findings. Some authors write the introduction in the present tense, describing the current state of knowledge.

In the following sections, we give you some information that will help you with each of the components of a journal article.

Title and Abstract

The paper starts with a title and an abstract (although we find it is easier to write these later, when we have a good sense of the main points and their significance). The title tells what the paper is going to be about. Don Strong, the editor of *Ecology*, says it should present the main result rather than just including the key words. For example, "Fire increases butterfly diversity in riparian and woodland habitats" is a more informative title than "A study of the effects of fire on butterfly diversity in two habitats."

The abstract provides a summary of the paper. It should include a couple of sentences each of rationale, main results, and interpretation. Throughout, be concrete; in other words, don't tell us that results are presented—tell us instead exactly what they are. The abstract has to be concise and clear. Far more people will read your abstract than other parts of your paper. Even if they do read the entire paper, reviewers and critics of all kinds will make their decisions about the paper and your story based largely on the title and abstract.

Introduction

Your introduction should present your question and explain why it is interesting. Your first paragraph or first few sentences should set the stage for your question. How do we (other ecologists) think about this subject? One effective way to begin your paper is by stating a problem or observation that everyone agrees is important and grabs our attention. If it is not obvious why your problem is important, then you must make a case for why we should care enough to read your paper. Could solving your problem shed light on a bigger issue, for instance? Think about what matters to your audience (e.g., conservation, basic physiology, theory) and frame your question so that they find it interesting.

We find an introduction that poses a big-picture question to be much more effective than one that starts with a description of an organism, study system, or topic (although the latter is how many students are tempted to begin). So for instance, don't tell us that you are interested in wooly bear caterpillars. Instead, lead with your general question: How do herbivores choose food? Then tell them how the study will add to this knowledge by considering the food choices of wooly bears. If your audience won't immediately find this question highly relevant to their interests, explain why choice of host plants is critical to understanding other ecological and evolutionary questions. In other words, make sure that you have explained why we as ecologists need the information you are providing. Don't just assert that it is critical to know the rates of parasitism of lemmings. Instead, explain why knowing about parasitism could help us understand why populations cycle. Wait until later in the introduction, or even the methods section, to tell us the natural history of your system. Beginning with a general "hook" will catch the attention of a larger audience.

You test the general question you led with by looking at a specific example. In your introduction, you may want to reference other research that informs your big-picture question, such as prior work on this question that has been conducted in other systems. But do not include references in your intro (or anywhere in your paper) just to show that you are familiar with the literature. You may want to explain why research in your system will contribute to answering the more general question.

We like to end our introduction by giving either a formal listing of the questions that we will answer (for a paper) or a brief answer to the question that we posed at the beginning (for a talk, see next section). What specific hypothesis or hypotheses are you testing? They don't have to be stated as null hypotheses (which have a bit more statistical precision but can be confusing to follow). These questions let the audience see where we are going to go in our methods and results. Also, because this formula is relatively standard, some readers will skip to the last paragraph of your introduction to decide whether the questions you plan to answer are interesting enough to keep them reading.

Methods

Methods sections often begin with a brief description of the natural history of the system. (This can also go near the end of the introduction, preceding the list of questions that the paper addresses.) Tell us enough, but only enough, natural history so that we can follow the important points of your experiments and interpretation.

The core of your methods section is the description of what you did to gather data. Your methods must be described clearly enough that the work could be repeated by someone else. This should include a description of where, when, and how you applied your treatments and took your measurements, as well as the statistical methods you applied. Make sure that the reader understands the motivation for each experimental procedure: instead of just launching into the details, start the description of each experiment with something on the order of "To test the hypothesis that wooly bear caterpillars choose the most common host plants, we did the following experiment."

Your methods section should be kept brief because methods are often boring to read and because reviewers and editors look unfavorably on papers with lengthy methods. Graduate students often assume that they need to explain every detail of their projects, but this is not true. Only include information that is directly relevant to the story that you want to tell. For example, perhaps you kept detailed data each day on temperature, percentage of sunlight, or precipitation because you thought that these might help explain variation in crawdad feeding events. However, you didn't find any such relationship, and your story evolved in other directions. Readers don't need to hear about these details even though you may be tempted to show them how thorough you have been. Information that isn't immediately relevant will only clutter up your presentation and obscure your main story.

Results

The results section tells what you have found—your data and statistical analyses. In general you will not be permitted to make a statement if you don't have statistical analyses to support it. Results should be described in a way that tells your story logically. Often students describe their results chronologically, in the order in which the experiments were conducted. But a topical organization that answers your main questions in a logical progression is generally more effective. We like to organize our methods and results sections by questions or experiments. We use subheadings as titles for each question; and we use these subheadings in the same order in both sections so that the reader can easily connect a method with the corresponding result.

Results should be reported in the text or summarized as figures or as tables (generally use only one of these three for any given result). Text is the default choice; if a result can be conveyed effectively by describing what you found, do so. Figures are particularly good at conveying relationships between factors, although actual values are generally obscured. Tables show exact values but are not good at presenting relationships between factors. Often the most informative way to present your results is to illustrate the data in a figure and then describe the effect size in the text. For example, if you are describing the effects of selenium on salmon fecundity, you might use a bar graph to show that female salmon produced approximately 60 eggs in low selenium streams and 20 eggs in high selenium streams. Then, in the text, “High selenium levels dramatically reduced salmon egg production. Female salmon produced only about one-third as many eggs in high-selenium streams as in low-selenium streams” (followed by a statistical test comparing these means).

Make your results, not your tables and figures, the star of the show. The tables and figures merely illustrate what you are describing in the text. For instance, “Adults consumed 40% more than juveniles (table 1)” is preferable to “Table 1 shows the consumption rates of adults and juveniles.” Similarly, when citing published work, focus on the results, not the authors: “Males were bigger than females (Brown 2000)” rather than “Brown (2000) reported that the sexes differed in size.”

Simple figures and tables are better than more complicated ones. Figures and tables should be described clearly with titles and captions, so that someone looking at them can make sense of the results without necessarily reading the whole paper. Your audience must be able to discern what you actually measured. This is often achieved by clearly labeling the axes of your figures. The fewer the number of treatments presented in one figure, the easier it is to grasp. Don't combine figures unless viewing all the information at one time adds meaning. If possible, identify the treatments in a legend rather than in the figure caption. Letters, numbers, and lines must be readable when they are reduced for publication, which means you often have to make them larger and thicker than the defaults on your software program.

The most commonly used figures are bar graphs and scatterplots. When you use bar graphs, it is easier for a reader to grasp the meaning if you use fewer bars. Under most circumstances, error bars should be presented with all bar graphs. These are important because they give the reader a sense of the noise around the signal. Usually you will use standard errors to show the noise or precision around your estimate of the mean. Standard deviations are used only when you want to show the amount of variation *per se*. Occasionally error bars make a figure so busy so that the signal becomes unrecognizable, and only under these circumstances should error bars be omitted. Scatterplot figures are also commonly used by ecologists. The line that describes the best fitting model can be added to the scatterplot when the model is found to be significant.

We find that diagrams, cartoons, and other graphic representations of ecological hypotheses are often informative, although they are less commonly used and generally belong in the introduction or discussion rather than in the results. These can be simple path diagrams that describe hypothesized causal schemes, or more complex figures that provide a visual representation of an ecological model. Many readers grasp concepts more readily through figures than through verbal or mathematical representations.

Tables should be used only when repetitive data are essential to tell your story. For many arguments, fewer data are more effective than more. Only include those variables that are relevant. Don't use tables (or any part of the results section) as a core dump for your field notebook. One common application for tables is to summarize statistical tests. For example, in an analysis of variance, the sums of squares, F ratio, degrees of freedom, and *p*-values all provide unique information. If this information is not required to make a convincing case, then include just the F ratio, degrees of freedom, and p-value in parentheses in the text.

To communicate effectively to a biological audience, your results should be presented in biology-speak rather than statistics-speak, and you should highlight the biological results and not the statistical tests. For instance, tell us "Males were twice the size of females (Student's $t = x$, $df = y$, $p = 0.0z$)" rather than "The Student's t-test with y degrees of freedom showed a statistically significant effect at the $0.0z$ level of gender on body size." Further, always present the effect size, not just the level of statistical significance—"Males were twice as big as females" rather than "Males were significantly bigger." The effect size tells us about the biological relevance of the result (see box 4 in chapter 4), whereas the statistical significance tells us how likely it is that the result was caused by chance.

As we mentioned in the section on methods, it may be tempting to include all of the experiments and observations that you performed. Don't do it. Include only those results that are connected logically—that tell one coherent story. Variables and effects that are not relevant to the story should be omitted, or the audience will be distracted from the main points. Many authors make the mistake of trying to include all the data they have instead of thinking about what pieces are needed to tell the best single story. If you feel compelled to include data for archival purposes, stick them in an appendix or online supplement rather than bloating your results.

Discussion

Use this section to explain what your work means. To do this, it is often a good idea to restate concisely the most important result before you interpret it. How do you make sense of what you found? Do your results resolve the question that you posed in the introduction? What evidence have other studies brought to bear on the question? Then as they become relevant to your story, add in the other results of your study and interpret them. Often the results of experiments will suggest subsequent hypotheses, which can be integrated into your discussion. You may be able to generalize from your results in conjunction with those of others. Do any useful models or paradigms result from this work?

Believe your results and interpret them as such. If you didn't find what you were expecting, don't excuse your results and talk about how they might have been different with a larger sample size, or if you had controlled for other factors, or if you had done the work in a different place. If you don't believe your results yourself, don't take our time telling us about them. If the evidence supports your hypothesis but you still don't believe your results because you feel unconfident and doubtful about everything, talk about this with a therapist, but don't let these doubts pervade your presentation. Also remember that most discoveries are surprises. If you already know the answer, then the question isn't particularly interesting.

Throughout your paper you should tell a cohesive story. Don't wander from your central point. Rather, your writing should present a tightly reasoned argument that is evident from start to finish.

Conclusion

Papers should end with conclusions (although these are often missing). The conclusion, like the abstract, is a concise summary of your results and their significance. End with a sentence or two that states the important consequences of the findings. Leave us with the take-home message—and don't have too many take-home messages. Most papers have only a single real lesson. Make sure that it doesn't get lost but instead is painfully obvious for those people who will read only the conclusion.

It may be useful to once again state and answer the question that you posed at the start. Don't trail off with some weak non-conclusion like "this is a good system" or "more work should be done." Of course more work should be done following every study. Instead, leave us with what you have learned. If we remember anything from this work, what should it be?

Box 6 provides a summary and checklist of our suggestions for writing journal articles.

The publication process can be emotionally brutal and requires a thick skin. All ecologists get their manuscripts rejected. Ecologists who succeed at publishing the most also experience the greatest number of rejections (Cassey and Blackburn 2004). Even established professors experience a rejection rate of 22%. In a careful statistical analysis across multiple journals in ecology, papers that were rejected and resubmitted were ultimately more often cited than those that were published without resubmission (Calcagno et al. 2012). Papers published without resubmission probably don't contain any ground-breaking ideas or data and were assimilated without question.

Although it's painful, the review process does make your papers better. Reviews from journals indicate how two or three readers perceived your paper. If they missed important points, other readers are likely to miss the same points. Take the comments of reviewers seriously; they almost always have useful ideas for improving the manuscript. When a paper gets rejected, put it aside for a day or two, and then make changes that will address the concerns of the reviewers whenever possible. If you are being given the opportunity to resubmit your manuscript, address every point that the editor and reviewers raised both in your cover letter and in the text. Letters from editors generally

Box 6. *Journal article checklist*

Title

☐ Does the title summarize the main result?

Abstract

☐ Does the abstract tell your story, very concisely?

Introduction

☐ Does the beginning of your introduction "hook" the reader by setting the stage for the question(s) your paper answers?
☐ Do you explain and justify your question(s) instead of just extolling the virtues of your study organism?
☐ Do you briefly summarize previous work that informs your current question(s)?
☐ Do you end your introduction by clearly listing the question(s) your manuscript addresses?

Methods

☐ Do you briefly explain the relevant natural history of your organisms or study system, if you haven't already included it in your introduction?
☐ Do you describe your methods thoroughly enough that another ecologist could repeat your experiment, but briefly enough that space-pressured journals won't send your manuscript back?
☐ Do you start the description of each experimental method with a phrase justifying why it was done?
☐ Do you include a brief explanation of each statistical procedure you used?

Box 6. Continued

- ☐ Do you include only the methods relevant to your overall story?

Results

- ☐ Are your results presented in a logical order to help your reader follow your story (not in the order in which you did your experiments, if that is different)?
- ☐ Have each of your results been presented once, and only once (in the text, a figure, or a table)?
- ☐ Does your text inform your readers of your results as much as possible, instead of simply referring them to your figures or tables?
- ☐ Do you describe your results in biological rather than statistical terms?
- ☐ Do you present effect sizes for each of your results?
- ☐ Do you present each of your results in terms of your overall story?

Discussion

- ☐ Do you restate your main results very briefly and interpret them?
- ☐ Do you generalize to larger ecological concepts where appropriate?
- ☐ Does the information in your discussion relate to your initial question(s)? Does your story seem cohesive?

Conclusion

- ☐ Do you hit your reader over the head one last time with your take-home message?

Figures and Tables

- ☐ Are your figures and tables as simple as possible?
- ☐ Do the titles and captions convey enough information that your reader can understand the meaning without referring to the text?
- ☐ Do your figures show error bars, if appropriate?
- ☐ Do your scatterplots include a line that describes the best fit, if appropriate?
- ☐ Do your figures have a legend identifying the treatments, if appropriate?
- ☐ Are your figures print-ready according to the web page of the journal to which you plan to submit?
- ☐ Have you trimmed your figures and tables to the lowest number possible to tell your story clearly?

English as a Second Language

- ☐ If you are not a native English speaker, have you gotten someone confident with English to review your writing?

sound more negative to the uninitiated than they were intended to. Few manuscripts are actually accepted on their first submission. Having your submitted paper 'rejected with the opportunity to resubmit' is the new 'accepted' (if you can address the reviewers' concerns). As a grad student, you can learn a lot about the review process by getting involved yourself, either formally or informally. Offer to review papers for other grad students, for your major professor, or for journals if your professors are handling editors.

Oral Presentations

Hearing a talk is a very different experience from reading a journal article. As a speaker, you should be aware of the differences so that you can use them to your advantage. Interacting with a person is far more compelling than reading a book. Think about how likely you are to put down a book without finishing it compared to how likely you are to walk out of a play or movie.

General Organization and Presentation

The more you involve your audience, the more successful you will be at holding their attention and having them remember what you say. As a result, you definitely do not want to read your talk; it's far more difficult to listen to someone who is reading aloud than to someone who is speaking. A conversational tone is easier to absorb than a speech. If possible, you should give your talk without notes, but this is less critical than not reading it. If you are worried about forgetting your talk, use an outline or let your slides lead you. If there are specific essential concepts or points that you are prone to forget, link them to a particular slide. When you get to that slide (usually an image rather than text), it is your cue to remember to provide a particular piece of your story.

If you are not a native speaker of the language you are presenting in, giving a talk can be even more daunting. If absolutely necessary, read your talk, but practice making it sound as conversational as possible to keep your audience's attention. Practice pronouncing key terms until you have made them as clear as you can. It also helps to put those words into your slides in case people still don't catch them. It can be tempting to speak quietly or very quickly, but resist the urge—your audience will enjoy your talk more if you speak loudly and enunciate.

When you are giving a talk, look at the people in the audience; eye contact will help to involve them. A common mistake is facing the screen and talking to your slides; instead, talk to your audience. If you must see your slides, glance at your computer rather than turning your back on the audience. Leave the room as bright as you can so that you can see the faces of the audience and they can see yours. It is a biological fact that dark rooms and slides with dark backgrounds put people to sleep; don't use them. A lot of light is much more important than having photographs that show up really well on the screen. Which would you prefer, having some large fraction of the audience dozing while really sharp pictures go up on the screen or having the audience alert and attentive at the expense of some photographic quality?

Stay close to your audience. This lets you relate to them more effectively. If the podium is too far away, move it closer or don't use it. Come out from behind it and address the audience directly. Walk around a bit in the space you are given as well. It is amazing how much walking from one side of the screen across to the other helps keep your audience alert and focused. Speak to the audience in the corner farthest from where you are standing—it will help you remember to project your attention throughout the room instead of just to the first few rows.

Tailor your talk to your particular audience and keep the information clear. Tell people things that they have the background to relate to. Imagine what the interests of your audience are likely to be and prepare your talk with that bias in mind. Avoid jargon (abbreviations, specialized words, measures, techniques) that is not familiar to most of your audience. Once people tune out or get lost, it is hard to get them back. You cannot expect people to grasp equations or complicated theory that they have not come to grips with previously. When readers come upon new or complicated material in an article, they can slow down, digest it, and reread it until they understand it. There is little chance for this to happen in a talk, so don't lose your audience by including this kind of material. It is fine to include a theoretical motivation for your work or to develop a new theoretical argument, but use words rather than equations if you are presenting a talk, and be especially careful that you are clear and the material is accessible. If you are presenting a talk that is mostly theory, you may have no choice but to include an equation or two. Spend a lot of time with any equation, explaining in words and perhaps simple graphs what each of the clusters of terms means to a biologist. It may help to circle relevant terms in the equation and then explain in plain English what they mean.

Structure

Good talks require as much structure and planning as good papers. Don't imagine that you can just wing your talk off the top. When you are organizing your talk, build it around your take-home message. Figure out what your punch line is, set it up right from the start, tell the audience what it is going to be, deliver it, and then remind the audience what it was during the conclusion. Someone, supposedly either Aristotle, Dale Carnegie, or Winston Churchill, came up with a pithy way to remember this strategy: "Tell them what you're going to tell them, tell them, and then tell them what you just told them." Those listening to your talk should be able to grasp your take-home message even if their thoughts have drifted away at some point or they came into the room after the talk began.

A paper requires elaborate documentation of the existing literature, of your detailed methods, of the statistical analyses, and so on. These are generally boring to listen to and should be minimized in a talk (though you should be ready to talk about them if anyone asks about them at the end). Your talk must have one, single coherent story to tell. Don't be tempted to include all the loose ends—just your best single story. This is true for a paper but even more so for a talk. Stress the concepts and not the details. Try not to switch gears and tell two stories during your talk; your audience won't take much away from such a mixture. If you feel that you don't have enough material for one coherent story, then spend some time thinking about how to organize it so that it seems like a single story, and then more time smoothing the transition between the pieces. One way to do this is to present a single question (or short series of interrelated questions) in the introduction and one punch line that integrates all of the parts of your story in the conclusion.

We like to use signposts to let the audience see the structure of the talk and how each piece fits into the bigger picture. When you're reading a paper, you rely on the subheadings and paragraph indentations to recognize transitions. The audience listening to a talk needs similar signposts. Rick often likes to make an outline slide of his talk or have it up on the whiteboard if one is available. Then he refers to the outline at various times during the talk. It helps people follow his train of thought if they can see where he is going throughout the presentation. (Remember, though, that the whiteboard will not be visible if the light is dim.) Mikaela uses a higher tech approach. She puts up an outline slide early in her talk and repeats it at various times throughout her talk, highlighting where she is in the outline at each point.

Let the questions dictate the outline. Don't use the traditional methods, results, and discussion that you would in a paper. Instead, integrate these three for each question or sub-question that you address. For each experiment, tell the audience in a sentence the question that was asked. Describe the approach you used in a sentence or two, and then describe the result. What does this result mean? If it stimulated the next question, explain how. Then repeat this sequence for the next experiment. Make sure that the audience follows your logical path.

Methods

The description of your methods should be very abbreviated and contain only what is absolutely essential for you to tell your story. A talk should not attempt to provide the listener with the ability to repeat the experiment; unfortunately, many speakers make the mistake of including far more methods than are necessary or interesting. If you need to include a method in your talk, illustrate it with a photo rather than text. Very abbreviated methods are often effectively integrated with results in talks.

Results

When presenting your results, aim for simplicity. Simplicity is important for a paper, but critical for a talk. Pictures are better than words or tables. Make sure that you explain the axes of graphs. The audience isn't already familiar with the variables you put on each axis and needs to identify these before the data you are presenting can be appreciated. Keep the graphics simple. Three dimensions and a bunch of colors rarely help tell the story. In general, tables are much less effective in talks than in papers and should be used sparingly, if at all. Any tables you do use must be simple, with large, easily read characters.

Similarly, each slide should make only a single point. Never put more on a slide than can be presented easily. Don't put up slides with text that you merely read. Text slides should be as abbreviated as possible—a few words or phrases. We don't like full sentences. Put no more than ten or fifteen words up at a time, and use a font size of at least 24.

Let your slides guide your story, but don't make them your focus. Plan to give your talk as if you didn't have slides. (In case there is a technical failure, you should always be able to give your talk without using slides at all.) Slides should be the background that illustrates what you are saying. Don't structure your talk so that it is a progression of

"This slide shows this and this next slide shows that." You'll give a better talk if your slides illustrate the story rather than if they are the whole story. Instead of reading the exact words from a slide, share the spontaneity of putting the words together to express your thoughts. Focus on connecting with your audience, not with your slides. If you must use a pointer, a physical pointer, your arm, or a meter stick can be better than a laser pointer; if for some unknown reason you feel obliged to use a laser pointer, don't wiggle it about, circle the object repeatedly, or let it wander annoyingly across the screen.

Preparing Your Talk

Spend extra time preparing your introduction and conclusion. These are the only parts that some of the audience will hear. Everyone is most alert at the start, so tell them what questions you are going to ask and what you found. Even if you lose some of them at some point, they will have heard your punch line. Similarly, if they haven't followed all of the talk, the conclusion should provide the take-home message. Students are often impressed by several established scientists at UC Davis who nod off conspicuously during talks but always seem to ask good questions afterwards. When this occurs, a lot of the credit should go to the speaker for highlighting the important points before the lights went out and then again after they came back on.

Practice your talk before you give it for real. The more you practice it (especially in front of an audience), the better it will be and the more confident you will feel when it's time to give it for real. If a rehearsal audience is not available, saying the actual words out loud is much better than thinking them. Mikaela used to think it was too embarrassing to practice a talk out loud with her housemates overhearing her. Then she learned it was more embarrassing to give a poorly practiced talk. Recording a practice (or actual) talk will help you learn your talk quickly and will also help you improve it if you give it repeatedly. If Rick has to give a talk that he really cares about or if he is strapped for time, he records a practice and then listens to it (or at least has the recording on) several times while he's doing other things. It is amazing how much this helps. If you're really brave, videotape your talk and review it to learn what aspects need improvement.

Editing Your Talk and Getting Ready

Show only as many slides as your audience can digest. As a rule of thumb, use about one slide per minute of talk. Many speakers make the mistake of including far too many slides and then needing to rush at the end or annoy the audience by going overtime. To avoid this, time yourself each time you practice.

We like to pause after we have made an important point. This provides emphasis and gives listeners a chance to make sure they absorb the last message. When you first begin giving oral presentations, your nervousness is likely to cause you to speak faster than you practiced. Practice making well-timed pauses to help you to pace your talk. Stopping to take a deep, slow breath helps your audience digest what you just said and can help you stay focused.

Show Time

A talk from a person who is slightly nervous is often better than a talk from someone who lacks sufficient adrenaline. However, excessive nerves can make a talk difficult to follow. Convert your nervous energy into larger, more flowing motions rather than small, repetitive jitters. Remind yourself that the more times you give talks, the easier they become. A mistake many beginning speakers make is to be self-deprecating and apologetic. Replace this with enthusiasm; your feelings become contagious.

One of the best parts of a talk is the question session at the end, although this can be the most intimidating. We like to leave a lot of time at the end for questions (10–15 minutes for an hour-long talk and 2–5 minutes for one that's 12–15 minutes). We already know what we have to say, but we're excited to hear the spins that other people will place on our results. Often new and exciting ideas come up in the questions after a talk. We sometimes ask a friend to take notes during the questions so that we don't have to remember all the suggestions. If the room is large or the questioner soft-spoken, repeat the question for the audience before answering it. Make sure you understand a question before responding to it. It is fine to paraphrase the question and ask the questioner if you have it right. If you don't know the answer to a question, it's fine to say so. If you think the point raised is an interesting one, you can say you will think more about it and design an experiment in the future to test it. You might ask if the questioner can think of a way to test the notion that he or she is bringing up. Especially if the talk you are giving is your oral exam, try not to be defensive when people question you about your talk. Students who fail oral exams are generally not ones who are the least prepared but rather the ones who become defensive and argue with their committees. If an audience member is aggressive about asking questions and won't give up the floor, you can say that you would like to move on but you would be happy to talk more after the session is over. By the way, remember not to be that person when you are in the audience.

Box 7 presents a summary and checklist of our suggestions about talks.

Posters

Posters have become the most common medium at some academic conferences. They should be much more like talks than papers in their structure. However, most posters suffer from being prepared like manuscripts. Remember that people at meetings are burnt out. Do you enjoy reading a lot of fine print when you are viewing posters? We don't. Instead, we want the take-home message in a simple, readily available package. Posters are to scientific communication what *USA Today* is to journalism. You should present only the headlines and the briefest explanation to make your point. Your poster should present a short summary of your take-home message and should encourage conversation if you happen to be present. Everyone who walks by your poster should immediately know your question and

Box 7. *Oral presentation checklist*

See also box 6, "Journal article checklist," for reminders of good communication habits in ecology.

General Structure and Presentation

- ☐ Are you able to give your talk (from the slides or an outline) without reading it?
- ☐ Have you practiced making eye contact with your audience (instead of with your slides), moving about the room enough to keep your audience engaged, etc.?
- ☐ Have you carefully examined your talk for jargon you might not even realize you are using?
- ☐ If your talk includes an equation, have you planned how you will make it readily accessible to your audience?
- ☐ Do you present your information as one single, coherent story to help your audience follow you?
- ☐ Does your talk includes signposts so that your audience follows the structure you have created?
- ☐ Do you use a large font size (24 point or larger) and include very few words (10–15 maximum) at a time per slide?

Introduction

- ☐ Do you structure your introduction around your take-home message?
- ☐ Do you eliminate most of the citations and other details you would include in a manuscript to help keep your audience's attention focused?
- ☐ Do you end your introduction by showing an outline slide that clearly indicates the questions you will address?

Methods, Results, and Discussion

- ☐ Have you integrated your methods, results, and discussion in a way that makes your story easy to follow (even if that means doing a separate series of methods, results, and discussion for each question)?
- ☐ Have you minimized (that is, practically eliminated) your methods?
- ☐ Do you explain how the results of your first experiment generated your next question and experiment, so that your audience understands the relationship between the parts as the story develops?

Conclusion

- ☐ Do you leave your audience with one take-home message?

Figures and Tables

- ☐ Do you show your results in pictures and figures instead of just describing them?
- ☐ Do you minimize or eliminate the use of tables, since they are hard to grasp during a talk?
- ☐ When presenting your figures, have you planned to indicate to your audience what the *x* and *y* axes are?
- ☐ Are your graphics simple, so that each makes only one single point?

Preparing your Talk

- ☐ Have you practiced your talk (especially the introduction and conclusion) until you are absolutely comfortable with the information in it?

Box 7. Continued

- ☐ Have you created roughly one slide for each minute of your talk?
- ☐ Have you timed yourself to make sure your talk does not go overtime?
- ☐ Are you prepared to give your talk without any slides at all in case of a technical problem?

the answer. Those people who are interested can ask you to explain in more detail and can read the paper when it comes out.

The title is the only thing that many people will see. It should summarize your results in one phrase. Like the title of a paper or talk, it should give the main message rather than a list of the characters or the question. For example, "Interactions between student protestors and campus authorities" is less effective than "Chancellor defends pepper spraying of peacefully protesting students." Since most conferences have many posters, you need to compete for an audience. Your title and the visual layout of your poster must be compelling. A poster is analogous to an elevator speech, in which you have ten seconds or so to sell your work or convince someone that what you do is valuable (Erren and Bourne 2007).

Structure

Your introduction should be no more than a few sentences stating the conventional wisdom or explaining the justification for your question. Next, present your results as pictures (figures and photographs) that tell your story. Move logically from one result to the next, making sure not to include more information than your viewer can easily and quickly digest. You should either skip the methods completely or include only enough to make your results meaningful. The details of your experimental design, sample sizes, and so on should not be included. After each result, you can include one sentence of "discussion" that makes each result more general or relates it to your big question. At the end of your poster you might want to include a sentence or two that explicitly answers the question that you posed at the start. Another useful way to conclude is with a sentence or two (but no more) explaining the significance of your results and how they fit into the big picture. This can be labeled as your conclusion. Usually the conclusion will be the section of your poster that will be most noticed after the title and abstract.

After you have worked out the pithy content of your poster, spend some time figuring out how to present it so that exhausted conference attendees can follow you. Again, images can illustrate your points and help you cut down on text. Use large or color type to draw attention to your organization and main points. As a rule of thumb, sans-serif fonts are better for titles and headings and serif fonts are better for full sentences; it's fine to mix both font types in a single poster. Keeping a lot of white space can help focus the viewer's gaze. Variation in font sizes and colors can help the viewer grasp your organizational structure. Finally, get feedback before printing it.

One advantage of presenting a poster is that you can "walk" interested people through your story. This is more effective than asking them to read the thing. In addition, they have the opportunity to ask you questions about things they don't understand or suggest other experiments and directions. As such, it seems like a good use of your time at the conference to hang out with your poster and interact with viewers as much as you can. Practice explaining the content of your poster beforehand so that you are ready when someone stops to ask about it.

It is often helpful to include a photo of yourself and coauthors on your poster so that interested people can find you during the meeting. Contact information including your address and email should also be included. Some presenters like to have handouts of the poster on 8.5 × 11-inch or A4 paper, or copies of related journal articles.

The poster that we have described contains less than one tenth the number of words of most posters at ecology meetings. It tells only a single story and does this using only headlines. It contains no or few references, and no methodological details. It has figures and photographs but rarely tables. Details and statistical analyses are not included. It is much more effective at conveying information than the poster that is essentially a manuscript pasted on a board.

Box 8 presents a summary and checklist of our suggestions about posters.

Box 8. *Poster checklist*

Refer also to box 6, "Journal article checklist," for reminders of good communication habits in ecology. Because your poster will rely much more on pictures and figures than on words, you may especially want to refer to the section labeled "Figures and Tables" in box 6.

Title

- ☐ Does the title summarize the main result?

Introduction

- ☐ Do you limit the introduction of your question(s) to one or two sentences?
- ☐ Do you clearly present the question(s) your poster will answer?

Methods

- ☐ Is your methods section extremely brief?

Results and Discussion

- ☐ Are your results presented mainly as graphics (bar graphs, scatterplots, etc.)? Do you show the differences in treatments with photographs where appropriate?
- ☐ Do you briefly explain the significance of each result?
- ☐ Do you present each of your results in terms of your overall story?

Conclusion

- ☐ Do you include a sentence or two briefly answering the question(s) you posed at the start?

Box 8. Continued

General

- ☐ Does your poster contain only the headlines?
- ☐ Does your poster use variation in font sizes, font styles, and colors to help the viewer grasp your organization?

Grant and Research Proposals: Selling Your Research Ideas

The purpose of grants and research proposals is to sell your plans about work you want to do. You want your committee to agree to give you a degree if you fulfill the objectives in your research proposal, and you want people to give you money in response to your grant proposal. In addition, your proposal provides two less obvious functions; it forces you to develop a research plan, and it forces other people to consider your ideas more carefully than they might otherwise so they can give you better feedback. Nonetheless, grant and research proposals involve more salesmanship than research talks or papers. Therefore, a slightly different emphasis is required. As you prepare a proposal, focus on three things: (1) novelty and justification, (2) clarity, and (3) feasibility.

Your proposal outlines what you want to do. First, it must be exciting and original. You must convince the reader that your work will forward your subdiscipline or the way in which people apply science to solve problems. Obviously not every proposal is going to change the way all scientists think, but those people who work on your question or on your system should be influenced by your work. If it is not clear to you how this will happen, think hard about how to justify your work in these terms. Emphasize this justification throughout your proposal. If justifying your proposal sounds too vague, think about answering questions such as: What makes your proposed work significant? What is the value of the work? How might other people use your results? How will other people inside and outside of your field view the contribution of your work? The biggest mistake that students make when writing proposals is not including enough justification.

Second, your proposal must be simple and clear, even more so than a scientific paper. Reviewers often get many proposals to read at one time, and all reviewers have better things to do than read them. Unlike scientific papers, these proposals may not be about subjects that the reviewers are already interested in or knowledgeable about. From the reviewer's first glance at your proposal, you have only a few seconds to convince him or her to pay attention and read further. Then you have only a few minutes to convince the reviewer that your proposal is worthy of funding from a budget that can in many cases fund fewer than 10% of the proposals in the stack. If your writing is not clear and concise, the reviewer may not do the work required to figure out what you are trying to say. The proposal must be convincing to both the meticulous reader and the rapid skimmer. A well-known colleague who serves on many NSF panels calls this the "two glasses of wine problem." He does all of his reviewing at the end of the day after two glasses of wine at dinner. Successful proposals must be clear enough to make sense to him under those conditions.

Third, you must convince readers that your proposal is feasible. Nobody is going to give you money or assurances of a degree unless they are convinced that you can complete the work you propose and that your work will answer the interesting questions that you have posed. There is an inherent contradiction in this process, since your proposal must appear both feasible and novel. You must convince people simultaneously that your ideas are important and ground-breaking, and that the experiments you propose can be accomplished. The best way to convince people that you can pull off your experiments is to use techniques that have been used before and include citations for those techniques. It is even better to be able to say that the techniques are old hat for you or people in your lab. An excellent way to show that your plan is feasible is to present preliminary data. For a research proposal this often involves doing a first year of fieldwork that addresses the main question. This heavy emphasis on preliminary results frequently means that researchers propose work that they have largely completed and use the money to generate the next set of preliminary data.

Organizing Your Proposal

The organization of a proposal differs slightly from that used for talks and papers and is generally less canalized into a specific style. Different universities and granting agencies require different organization, and it is important to know these requirements and to fulfill them. Below we consider the form and content of a proposal that would apply generally for many graduate groups and funding agencies. Many proposals include (1) an abstract or project summary, (2) an introduction, (3) explicit objectives, (4) experiments, justification, and interpretation that correspond to each objective, and (5) a budget. Other sections that are often helpful include separate discussions of the significance of the experiments, the potential pitfalls associated with the experiments and your solutions, a timetable for completion of each experiment, and a justification of the budget. You can get more detailed advice about preparing proposals in a recent book by Friedland and Folt (2009).

The abstract or project summary shares many similarities with those for scientific papers. It comes first, though we write it last. It needs to be crystal clear and capture the excitement and rigor of the proposal. In it, describe the big-picture problem that you are addressing. Next, emphasize a justification for your work and explain its significance. Describe what you expect to find and explain why your results will be influential in your field. The project summary generally presents fewer results than an abstract for a paper, but can contain a few sentences about your approach.

The introduction to the proposal must get the reviewer excited about your questions. Justify why this work is important. This is difficult. Even after giving this advice to grad students, we find that more often than not their proposals could use more justification. How does your work relate to the big questions in ecology and why should we care? Frame your work in terms of the questions that you will address rather than systems that you will use. This advice holds even if you chose your project because you were interested in the system. In fact, it holds especially if you chose your project because of your system. Rather than saying "This question is transformational," explain why it is transformational. For example, if you are studying chytrid fungus population dynamics, say, "Chytrid fungal infections threaten amphibians worldwide. To better conserve amphibians, we must understand the factors that affect fungal transmission and population dynamics," and so on.

It is often best to first present the general question and then describe how your specific research on a particular system will address that broader question. Start general and get specific. Your introduction should explain what has been done to date to motivate your question. Here you can also tell us about the natural history of your system, but only if this information is immediately useful in understanding how you will answer your question.

Next present your objectives. These can be long term (more than you can accomplish now to address a big-picture question) and short term (the actual goals of experiments in this proposal). The objectives should be presented explicitly and should be numbered. With each objective, you can include the hypothesis that is tested and a rationale for that objective. Using Christopher Columbus as an example, van Kammen (1987) differentiates objectives, justification, and hypotheses. If Columbus submitted a proposal to Queen Isabella and King Ferdinand, his *objective* would be to establish a new trade route to India to bring back three ships full of spices. He would *justify* his proposal by explaining that a water route to the west could be faster and less expensive than currently used routes and that such a route would increase their wealth and international power. By fulfilling these objectives he would test the scientific *hypothesis* that the earth was round. He would further justify his proposal by attempting to convince Isabella and Ferdinand that it was feasible to accomplish these objectives and that he, Columbus, had the necessary know-how and experience.

Each objective should be addressed by specific experiments. It is often useful to number these experiments exactly as you have numbered the objectives. A rationale and an experimental design should be presented for each experiment. Describe how you would do each experiment with sample sizes included, and demonstrate that you can accomplish each procedure by presenting preliminary results or citing similar methods. Finally, describe how you plan to analyze the data from each experiment.

Tell us how your results will be interpreted: “If experiment 1 gives this result, I will conclude the following.” Interpretation of the results may or may not be its own section in the proposal. Remember that although hypotheses in ecology must be testable, they are not necessarily falsifiable or mutually exclusive. At this point you might want to include another section or paragraph entitled “Significance” if the importance of your work has not been extensively discussed and stressed.

We like to include a small section detailing potential pitfalls. This section provides damage control. Anticipate questions that the reviewers are likely to have and address them here. Try to explain how you will turn apparent misfortune into a situation in which the field will learn a lot. Describe here how you will interpret experimental outcomes that differ from those you anticipate. The best projects are those that give interesting results no matter what the outcome. If you have designed a research program that will let you gain new and useful perspectives about nature no matter what the outcome, make certain that you stress this feature.

We also like to include a timetable for our objectives and experiments. This helps establish that we have thought about how and when we will get everything done. A timetable helps make the work appear feasible and is useful to refer to when doing the work.

If you are applying for money, include a realistic budget that will enable you to complete your project. This is an itemized list of your expected costs. Explain why you need each piece of equipment, supplies, field assistants, travel money, and so on.

Box 9 summarizes our suggestions about grants and research proposals.

Three things about the granting process should be kept in mind. First, grants are competitive, and it often takes several attempts before a grant gets funded. Don't get discouraged. At the same time, take the comments to heart. We find it helps us get our emotions under control if we put the comments down for a few days after getting painful criticism. It can also be frustrating to get comments that seem to miss the point. If a reviewer missed our point, it indicates that we need to rewrite the proposal so that two

Box 9. *Grant and research proposal checklist*

Refer also to box 6, "Journal article checklist," for reminders of good communication habits in ecology.

General

- ☐ Is your proposal novel and exciting, and have you explained why to your reader?
- ☐ Do you explain the value to the larger ecological community of your proposed work?
- ☐ Is your proposal simple and clear, easy enough for an exhausted non-ecologist to understand at the end of a long day?
- ☐ Is your proposal feasible, and have you explained this in a way that will be convincing to your readers? When possible, have you proposed to use established techniques and presented preliminary results?

Project Summary/Abstract

- ☐ Does your project summary capture the excitement of your proposed research?

Introduction

- ☐ Do you take extreme pains to justify your proposed work?

Objectives

- ☐ Do you state each of your objectives explicitly?
- ☐ Do you justify each of your objectives?
- ☐ Do you articulate hypotheses that address your objectives?
- ☐ Have you designed and described experiments that address your hypotheses and objectives?

Box 9. Continued

Interpretation, Significance, and Budget

- ☐ Do you describe how you will analyze your findings and evaluate each hypothesis?
- ☐ Do you highlight the significance of your potential findings?
- ☐ Do you include a budget, if appropriate?
- ☐ Are you truly excited to do the work if it gets approved?

glasses of wine won't keep the next reviewer from following our logic. Almost invariably, the comments will contain extremely useful suggestions as well as some misconceptions. If you are resubmitting a proposal, make sure to address all of the comments that you received from reviewers.

Finally, don't let the granting process dictate what your questions are. Of course we like funded grants for the way they signify the approval of our peers. In addition, some projects require money to pursue. But there are plenty of ecological questions you can address for relatively little money. The granting process is a very conservative one; only ideas everyone is already comfortable with get funded. This retards innovation. We have seen over and over again how a few dollars can get graduate students and senior faculty alike to change their research priorities and pursue projects that were not necessarily burning questions for them. Our advice is to follow your own intuition. Proposals are approved by a committee. Why give up something that is as personally important to you as your research direction to an anonymous committee? Would you let a committee approve your choice of a partner over the next three to five years?

Hard work often determines productivity, and productivity often determines success. Pick the questions that are most exciting to you whether you get funding or not and you are more likely to work hard enough to be successful.