Statistics Writing

How to write more gooder

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Outline

- Types of scientific writing
  - IMRaD manuscripts
  - Figures and tables
- Writing about statistics
  - Translating model results
- How peer review works

Part 1: Types of scientific writing

Where do I start?

- You've finished fitting your models, and the results make sense to you, but...
- How do I translate all these numbers into "real" English?
- Where do I put all these numbers in the paper?
- Do I need figures and tables?

Answer: “It depends”

What is your story? Who is your audience?

- How do these numbers serve the questions I’m asking?
- Do these numbers help my audience to understand what I found?
- Would figures or tables help to prove my point more concisely or easily?
- How do these numbers relate to the rest of the literature?

A bit of history

- (European) Universities are largely offshoots of the Christian monastic tradition
- What we now call science started in about the 1600s, largely as offshoots of astrology and alchemy
  - Biology began slightly later (1700s-1800s), as offshoots of medicine and natural history
- "Natural philosophers" (scientists) would write letters to each other about what they were up to
- Eventually, organizations of scientists began publishing research results publicly (e.g. *Philosophical Transactions of the Royal Society*, 1665)
- Peer review was sparse, and was usually done by the editor or a board. External peer review wasn't widespread until 1950-1970
- Early science writing is *extremely* varied, and is much different from modern science writing

What is science writing for?

- "Recording secret knowledge" (Newton)
- "Describing *exactly* how an experiment proceeded" (Bacon)
- Modern science writing does mostly the latter:
  - Text should be understood by your peers, not obscured
  - Not *all* details are needed, only those that help make your arguments (e.g. I don't need to know the brand of pipette tips)
- More recent push for *replicability*, with data and code being stored in online repositories

How does this relate to statistics?

- Early use of statistics in science was fairly "vibes-based", at least until computers became more readily available (1950s onward)
  - Not necessarily a bad thing!
- More complex and extensive data collection requires more complex modeling approaches
  - Trade-off between realism and "explainability"
- Pushback from some quarters: One aspect of the ongoing replication crisis
  - *Statistics are political*

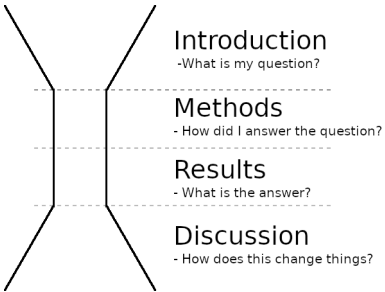
"I have heard from graduate students opting out of academia, assistant professors afraid to come up for tenure, mid-career people wondering how to protect their labs, and senior faculty retiring early, all because of methodological terrorism" - Susan Fiske, APS Past President

"[Fiske is] seeing her professional world collapsing... her work and the work of her friends and colleagues is being questioned in a way that no one could've imagined ten years ago. It's scary, and it's gotta be a lot easier for her to blame some unnamed"terrorists" than to confront the gaps in her own understanding of research methods." - Andrew Gelman

Common types of scientific writing

1. IMRaD papers: "standard" scientific papers
   - Introduction, Methods, Results, and Discussion
2. Meta-analyses
3. Review papers
4. Perspective/opinion pieces
5. Theses
6. Proposals
7. Data papers
8. Books/book chapters
9. "Grey" or "white" papers
10. Blogs

IMRaD Paper Structure



- Most scientific papers follow the IMRaD canon
- Allows the reader to quickly assess whether this paper is useful and skip to important sections only
- Generally, statistics are discussed in the *Methods* and *Results* sections only

Group exercise: pick apart a paper

- We're going to go through the IMRaD paper you read this week
  - You did read it... didn't you?
- In each of the sections, we'll identify how the author follows (or doesn't follow) the form described below
- I recommend highlighting, underline, or otherwise annotate the paper for later reference

Introduction

- Set up your research question, using the literature
  - Moves from general ("Animals need food") to specific premises ("Bats need bugs")
  - Explain why we should care ("Bats are really cute! Don't you like cute things?")
- Establish the *knowledge gap* or *question* that your research will address
  - "Forest have lots of bugs, but nobody has checked whether there are bats there too!"
- Last paragraph: strong statement that sums up what you're expecting to see
  - Hypothesis: "Bats eat bugs, and forests have lots of bugs. Therefore, . . . "
  - Prediction: ". . . we should see more bat foraging activity in forests"

Methods

- Establish how you collected the data, and how you analyzed it
  - This defends against criticism of your model or your data, and makes your results more believable
- The detail you use depends how "unusual" your model is, which depends on your audience
- Clarify what the dependent, independent variables, and random effects in your models are
- Sometimes you can just use the actual R model formula:
  - "I fit the model using `lm` in R using the following model structure for bat counts (while accounting for unicorns):"

```
lm(batCounts ~ forest + unicorns)
```

Results

- Brief summary of what you collected[1]
  - "I caught 420 bats at my 69 sampling sites."
- Present your results as an answer to the questions that you posed in the Introduction.
  - "Forest cover caused an increase of 3 bats for each 10% of forest ($p<0.001$), while unicorns had no effect ($p=0.19$)"
  - Try to keep the language as normal and direct as possible
  - Having tons of p-values and other numbers can make the text hard to read
- If something weird happened, just say it and move on. Speculate on *why* in the Discussion.
  - "Surprisingly, frogs had a negative effect on bat counts."

[1] Can sometimes go at the end of the Methods

Discussion

- Relate your results to your research question. Did your results match your expectations?
- Move from specific ("Bats need bugs") to general ("Animals need food"); opposite of the Introduction
- Put the Results you found into the context of the rest of the literature. If your results contradict other studies, why do you think that occurred?
  - "Barclay et al. (2017) showed that bats don't like forests, but our results may differ because..."
- **So what?** What new things have we learned? How might this affect theory or practice? Should non-bat people pay attention to this paper?

Figures and Tables

- Figures can be excellent tools for telling your story, but...
  - Figures take up lots of room, cost $ in publications, and can overwhelm the reader if there are too many
  - Many resources for good figure design: aim to minimize extra information
- Tables are kind of boring, but are great for conveying lots of numbers at once
  - Useful for showing information on large numbers of coefficients
  - If you have lots of models, `library(broom)` provides summaries of all of them at once
- Tables and figures (+ captions) should be readable without knowing the rest of the text

Suggestions:

1. Choose 2 or 3 figures and tables to be the **Main Characters** in your Results section.
2. Use them to illustrate what your models show and move the rest into a supplemental or appendix.

Title and Abstract

- Title: "Advertisement" of your study topic and results
  - *Why should the reader read any further?*
- Abstract: quickly and effectively tells the reader what the paper is about
  - Usually follows the IMRaD format order
  - Not a movie trailer: spoilers are expected!
- Keywords: extra words that could help search engine results

Part 2: Writing about statistics

Models as evidence for arguments

- Scientific discourse can be thought of as a series of logical arguments
- When making an argument, you bring evidence to support your claims
- We use experiments/observations, mathematics, and previous literature to support our claims
  - None of these are assumption-free: The reader must be convinced that these are appropriate!
- Models also act as a *piece of evidence*, translating raw data into "ammunition" for your claim
  - Model structure and performance checks (residual plots, etc.) should *also* convince the reader that this is believable

Show the *bare minimum* number of statistics needed to convince people. If it's not relevant to your story, move it somewhere else.

Example arguments:

- Premise 1: Bats eat bugs
- Premise 2: Forests have lots of bugs
- Claim: Therefore, bats should prefer forests [2]

Example 1:

- Evidence: The model of my data **supports this claim**
- Conclusion: This means that our understanding of bugs, bats, and forests is pretty good

Example 2:

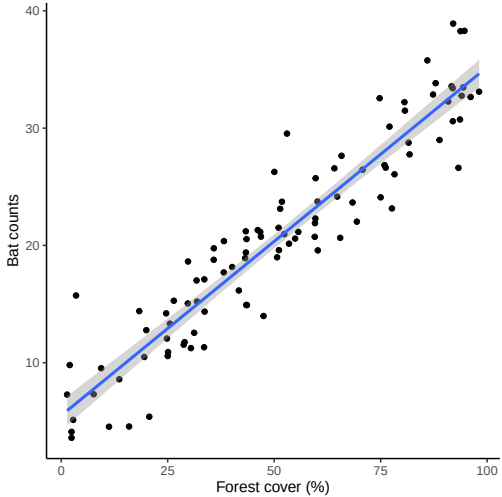
- Evidence: The model of my data **does not support this claim**
- Conclusion: One of these premises is wrong, or we left out an important premise

[1] Inductive reasoning

Models as reflections of reality

- Models are meant to reflect an *underlying biological process*
- Things like effect size (mean/SE) reflect the relative strength of the factors involved
- Things like R^2 reflect how well the model fits the data *overall*
- Causality is implied, but has to be justified

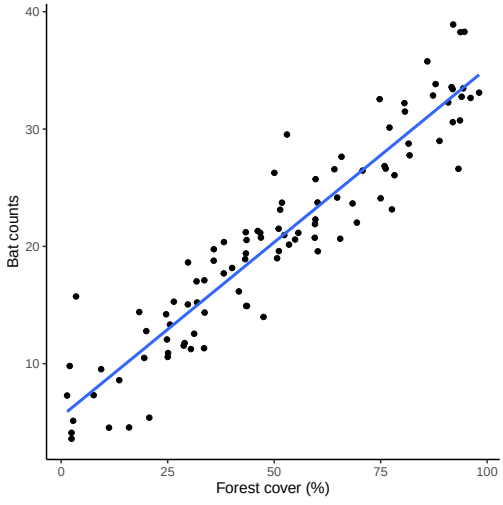
"Keep your eye on the biology!"



What might the underlying physical process be here?

Evidence type 1: coefficients

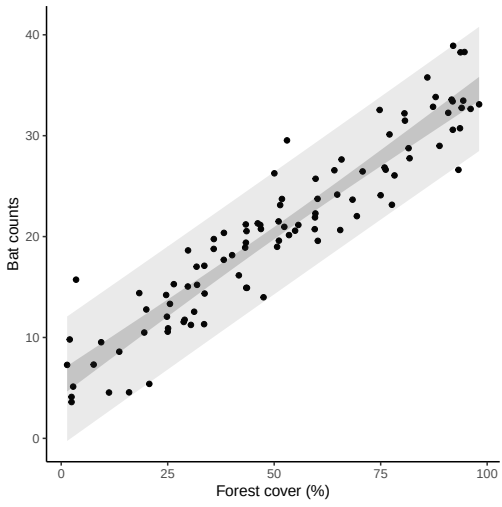
- Slopes and intercepts have physical interpretations
  - Intercept: How many bats at 0 % forest?
  - Slope[3]: $+$ 1 % forest $=+$ 1 bat
- Interpretation can be:
  - Yes/no: "Is there any relationship?"
  - Directional: "Is the relationship positive?"
  - Magnitude: "How big is the slope?"



[3]For GLMs, slopes are in log or log-odds (logit) units

Evidence type 2: variance

- Variance has a physical interpretation
  - What is the variation in bat counts at a given level of forest?
- R^2 relates actual to modeled variance: what % of variance does your model explain?
- GLMs: different distributions model variance differently
- Hierarchical models deal with many levels of variance
  - Tells you where the variance in your system is coming from



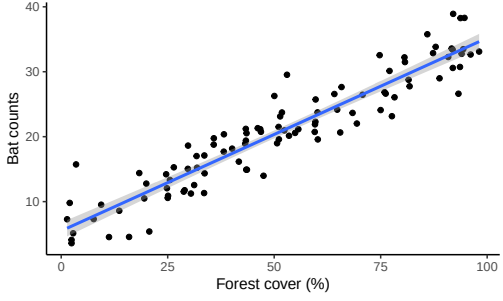
Example write-up

Say we fit a model of bat counts that looks like this

```
##
## Call:
## lm(formula = batAbund ~ forest + unicorns, data = d1)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -6.5929 -2.1272 -0.1578  2.0274  9.2034
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  5.5277071  0.8915895   6.200 1.38e-08 ***
## forest       0.2969644  0.0111925  26.532  < 2e-16 ***
## unicorns    -0.0001879  0.0035452  -0.053    0.958
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.06 on 97 degrees of freedom
## Multiple R-squared:  0.8794, Adjusted R-squared:  0.8769
## F-statistic: 353.5 on 2 and 97 DF,  p-value: < 2.2e-16
```

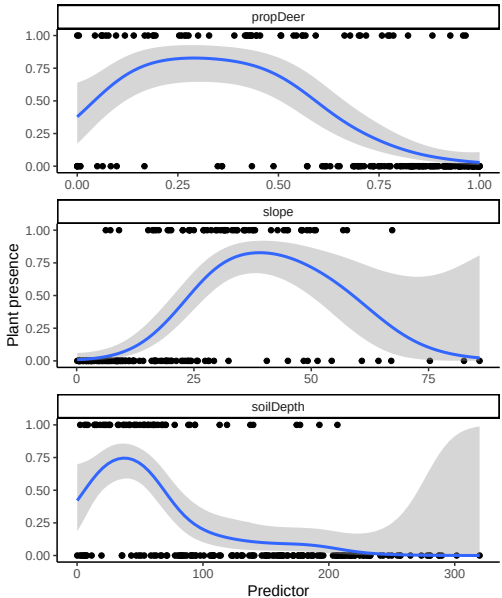
Methods:
"I collected data from 100 sites around Calgary, and recorded..."
"I used a linear model to estimate the effect of forest cover and unicorns on bat abundance. Models were fit using `lm()` in R and were checked for..."

Results:
"My model identified a strong, positive effect of forest cover, with each additional 10% of forest cover adding an additional 3 bats (Figure 1, $p < 0.0001$), while the effect of unicorns was weak ($p = 0.19$). The model also explained $\sim$ 88% of the variance in bat abundance, further highlighting the importance of forest cover to bats..."



Challenge: analyse and explain

- I have a dataset of plant abundance `plantDat.csv` (see here) containing records of plant presence/absence, deer browsing, soil depth, and slope
- Come up with a reasonable set of hypotheses about plant presence/absence (given the available data)
- Fit a model that tests those hypotheses, verify the model, and explain the model approach in plain English
- Explain the model results, and make an accompanying "Figure 1" to go with the results



My (personal) order of writing a paper

1. Methods: I usually write this section first, as it gets me "warmed up" for the rest of it[4]
2. Results: I write this section after I write the Methods section
3. Discussion: I write this after my model Results. Here you can name-drop all the relevant papers you've read (make sure they're setup in the Introduction first)
4. Introduction: I find this section the trickiest to write, so I usually write it last
5. Title and Abstract: After everything else is done, you can *advertise and summarize*!

[4] You can even write it before you collect your data!

Part 3: Peer review

How do journals work?

- Journals are usually society publications (BES, ESA, IEEE) run out of academic publishing companies (Wiley, Elsevier, Taylor & Francis)
- Most journals have a *lead editor* and an *editorial board*. These will be the people who will first see your submitted manuscript
  - Peer review is done for free by working scientists
- Traditional publishing: costs you nothing, costs the U of C library $ (depending on subscription)
- Open-access publishing: costs you $1000-5000 depending on the journal, but then anyone can read it
  - Keep an eye out for predatory or "papermill" journals! Some sets of open-access journals (MDPI) have a *suspiciously fast* peer review process

OK, you've got a paper written! Now what?

- Identify a journal you'd like to submit it to
  - Which journals do you cite the most in the paper? Maybe one of those? Check their Aims and Scope
  - Helps to start thinking about it earlier, and have a tier-list
  - **Ask your supervisor!** They will have good experience with this
- Assemble the document in the way that the journal wants. Check their Guidelines for Authors
  - Check that the document conforms to the types of papers they publish
  - Some journals are more lenient about the first submissions (e.g. just a pdf with simple formatting)
  - Double-blind journals require you to remove all identifying info (separate title page that the reviewer never sees)
- Submit the article and wait for a response!
  - Think about who you might recommend as a reviewer. Who would you want to read your paper?
  - A *cover letter* helps convince the editor they should give your paper a chance

Peer Review Process

What the editor will do

- An editor will skim the paper and make sure that the topic is relevant. If not, your paper gets a *desk reject*
- If it looks generally OK, the editor will contact peer reviewers and ask them to review the paper
- Once they've gotten the comments back, the editor will assemble the comments, and read the paper a bit more to see if they agree with them
- They will contact you with their decision based on the reviewer's comments: *reject*, *accept with major revisions*, or *accept with minor revisions*
  - They may use *reject and resubmit*, depending on the journal
  - They may temper the claims from *bad or rude peer reviewers*, or may remove them entirely!

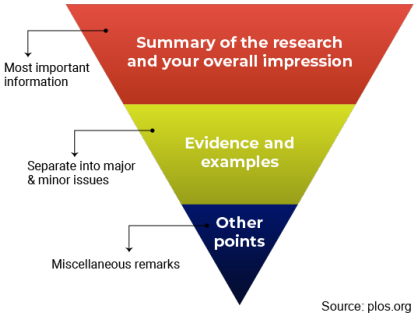
My (personal) style of peer review

- Read the paper once through without writing anything down
- Go back through each section and write general "overall" comments
  - e.g. "Intro needs to be trimmed down", "Results section is disorganized", "I don't understand the relevance of X"
- Write line-by-line comments where needed
  - e.g. "L40: change `insect` to `arthropod`", "L89: How does this test work, and is it commonly used?", "L112: Citation needed, perhaps Smith et al. 2020?"
- Think about what could improve the paper, and provide a suggested way forward where possible! (e.g. "I suggest moving this paragraph to here...")

My (personal) style of peer review (cont.)

- Put all the comments together in a single document, split into overall and line-by-line, and re-read your comments.
  - *Do you need to tone things down a bit?* (or tone them up)
- Make a reject/accept decision on the paper. Try to be as objective as possible:
  - "This person didn't do exactly what I would have, but does it matter to the results or overall story?"
  - "Maybe I don't think these results are very interesting, but are they believable given the evidence?"
- If the paper is accepted, how much time will it take to do revisions? (Major vs Minor)

There are many other appproaches to doing peer review: see here, here, or here)



Final remarks

- Good writing is re-writing
  - What is obvious to you may not be obvious to your readers. Revision is annoying and painful, but it **will** help!
  - "[Good writing is:] Telepathy, of course" (Stephen King)
- Use the literature
  - There are tons of poorly-written papers out there, but was there a paper that you found easy to understand? Re-read it, and figure out why!
  - Check out how other scientists display their statistics, and imitate/avoid their style
- Use your supervisor and committee members
  - They have a much wider picture of the field, and have lots of writing and editing experience
  - This means that they can be a good stand-in for your audience

Remember: Good writing is good storytelling

Here are some examples from my work

- I'm usually not allowed to publicly share peer reviews that I've done on other papers...
- But here are some of the reviews I've received!