Lecture 5
Writing the results section of a paper

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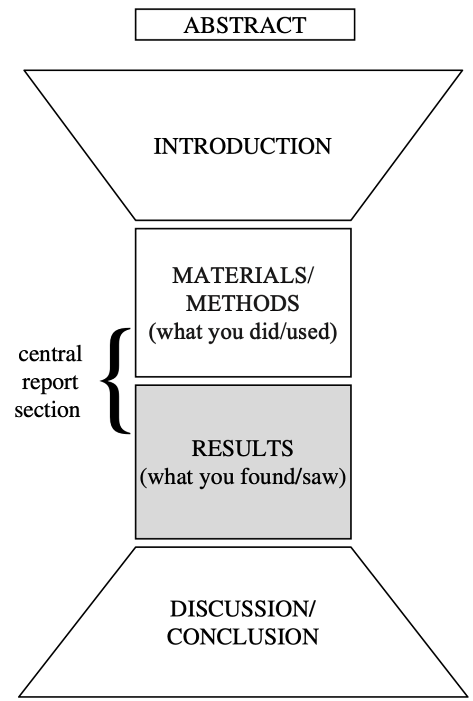
Purpose of the results section

- In the results section, the authors report what they found or observed with the help of figures and tables.
- Authors communicate their understanding of the data in the results section.



(Glasman-Deal 2010, Science Research Writing for Non-Native Speakers of English)

A model for the results section

- Because the results section describes the findings of the work, it can often be divided into individual subsections, each dedicated to a particular finding or a group of related findings.
- The results section often include the following elements:
  - Introductory context for understanding the results, i.e., research problems, summary of methods etc.;
  - Systematic descriptions of the results, highlighting for the readers findings that are most relevant to the topic under investigation;
  - Inclusion of non-textual elements, such as, figures, charts, photos, maps, tables, etc. to further illustrate the findings.

Examples of results section

To compare the differences in changes in phenology and growth rate of different functional groups over time, we standardized growth patterns for grass, forb and sedge functional groups by dividing them by their respective annual biomass production. We also used partial redundancy analyses to quantify the relative importance of the differential changes in phenology and growth rate of functional groups and the shifts in functional group composition for explaining variance in community growth patterns ('vegan' packages in R software). All statistical analyses were conducted using R 3.5.0 software (R Core Team, 2018).

RESULTS

Long-term changes in annual and seasonal biomass production

Over the past 35 years, annual biomass production ranged from 237.3 to 484.5 g m^{-2} year^{-1}, without exhibiting any significant overall trend (Fig. 2a; an increase of 14.7 g m^{-2} per decade; r^2 = 0.08, P = 0.10). However, seasonal biomass production showed strikingly different patterns: spring production (April–May) increased by 15.5 g m^{-2} per decade (Fig. 2b; r^2 = 0.39, P < 0.01), autumn production (August–September) decreased by 24.0 g m^{-2} per decade (Fig. 2d; r^2 = 0.32, P = 0.01), whereas summer production (June–July) did not exhibit any significant trend (Fig. 2c; an increase of 22.0 g m^{-2} per decade; r^2 = 0.17, P = 0.09).

Long-term changes in community phenology and growth rate

From 1980 to 2014, the start of the fast-growing phase advanced at a rate of 5 days per decade (Fig. 3a and b; r^2 = 0.31, P = 0.02), while the end of the fast-growing phase advanced at a rate of 12 days per decade (r^2 = 0.51, P < 0.001). The length of the fast-growing phase thus became shorter over time (7 days per decade; r^2 = 0.42, P < 0.01). Over the same period, the rate of maximum growth increased by 0.7 g m^{-2} day^{-1} per decade (Fig. 3c; r^2 = 0.41, P = 0.004), and the timing of maximum growth advanced at a rate of 9 days per decade (r^2 = 0.47, P = 0.002). These changes in growth patterns were observed in years that had more frequent measurements (Fig. S5; ≥7 times per year). Further analysis showed that the earlier phenology of the fast-growing phase was related to increased spring production and reduced

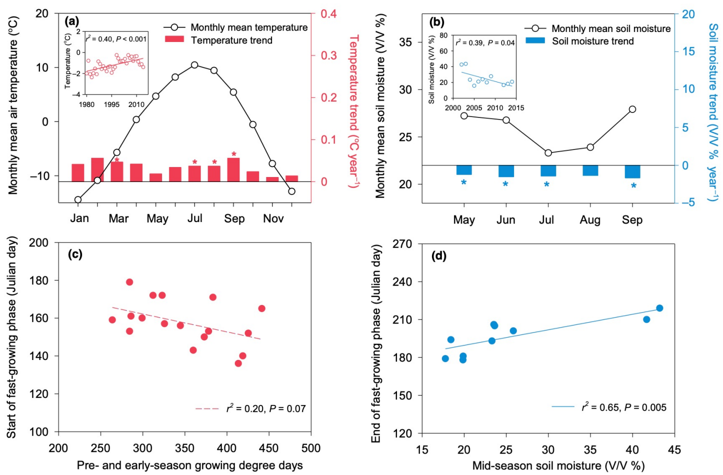


Figure 4 Controls of air temperature on the start of the fast-growing phase and soil moisture on the end of the fast-growing phase. Seasonal dynamics in monthly mean air temperature (a) and soil moisture at the 5 cm depth (b) and their changing trends. Lines with circles indicate monthly mean values; bars indicate their changing rates, as expressed by the slopes of linear regressions between years and monthly averages, and * indicates statistically significant at P < 0.05. The insets in (a) and (b) indicate the interannual trends in annual mean air temperature and soil moisture, respectively. Relationships between pre- and early-season growing degree days (January–May) and the start of the fast-growing phase (c) and between mid-season soil moisture (June–August) and the end of the fast-growing phase (d). Solid and dashed regression lines indicate statistically significant and non-significant trends at the 0.05 level, respectively.

autumn production, whereas the shorter fast-growing phase and the enhanced maximum growth jointly led to no change in summer production (Fig. S6).

Effects of climate change on community phenology and growth rate

Over 35 years, annual mean air temperature at the study site increased by 0.4 °C per decade (Fig. 4a; r^2 = 0.40, P < 0.001), and the warming trend was statistically significant (P < 0.05) for both March and from July to September. Annual precipitation did not vary systematically (Fig. S7a; r^2 = 0.06, P = 0.16); precipitation in July, however, decreased by 11.0 mm per decade (r^2 = 0.13, P = 0.04). In contrast, the annual humidity index tended to decline (Fig. S7b; r^2 = 0.11, P = 0.06), with a significant decline in July (P = 0.02). In addition, soil moisture at the 5 cm depth decreased from 2002 to 2014 (Fig. 4b; r^2 = 0.39, P = 0.04). Overall, the site became both warmer and drier over our study period.

Increased pre- and early-season growing degree days (January–May) and warmer March temperatures were associated with an earlier start of the fast-growing phase (Fig. 4c and Fig. S8), while a reduction in both soil moisture and precipitation during mid-growing season (June–August) was related to an earlier end of the fast-growing phase (Fig. 4d and Fig. S8). At the same time, increased temperatures and reduced precipitation in July were related to a higher rate of maximum growth (Fig. S8).

Changes in abundance, phenology and growth rate of different functional groups

Between the two periods, 1980–1983 and 2007–2010, the abundance of grasses increased and the abundance of forbs and sedges decreased (Fig. 5). Over the same period, grasses and forbs were more sensitive to climate change than sedges (Fig. S9). Specifically, grasses and forbs started and ended growth earlier, had a higher growth rate, but had a shorter fast-growing phase (Fig. S10). In contrast, sedges did not exhibit any significant trends. Partial redundancy analysis further showed that the changes in growth patterns of grasses and forbs, rather than the shifts in plant functional group composition, were mainly responsible for the observed changes in community phenology and growth rate (Fig. S11).

DISCUSSION

Our results support the first two hypotheses that long-term climate warming enhanced plant maximum growth and shortened the fast-growing phase, in addition to shifting phenology earlier. These changes in growth patterns led to altered seasonal biomass production: spring production increased, summer production remained relatively constant and autumn production decreased over time in this alpine grassland (Fig. 6). Inconsistent with our third hypothesis, the observed changes in growth patterns were largely attributed to changes in phenology and growth rate of grasses and forbs, rather than effects of shifting functional group composition. Altogether, this study, to our knowledge, provides the first *in situ* evidence that the growth patterns of alpine grassland plants

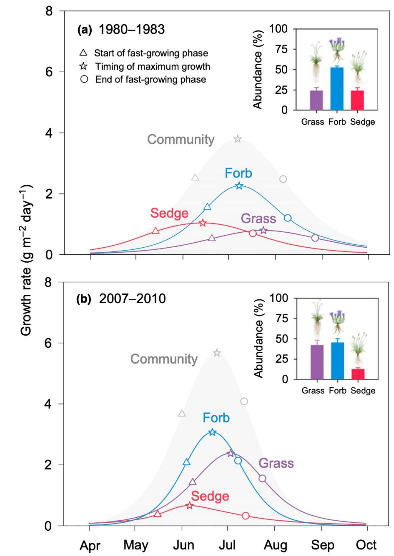


Figure 5 Comparisons of growth patterns of different plant functional groups. Data are mean values during 1980–1983 (a) and 2007–2010 (b). The insets in (a) and (b) indicate relative abundance of different functional groups.

have strongly responded to long-term climate change, despite the lack of systematic change in annual biomass production.

Earlier phenology and faster growth jointly contributed to changes in growth patterns

Results from 35 years of monitoring show an earlier start of the fast-growing phase and enhancement in maximum growth in the alpine grassland we studied. These changes indicate that earlier phenology and enhanced growth in spring jointly contributed to the advancement in the start of the growing season detected by satellite-derived NDVI data (see Fig. S4a). The earlier start of the fast-growing phase was associated with increases in spring temperatures and growing degree days, which may accelerate ecodormancy break and spring snow thaw (Chen *et al.* 2015; Suonan *et al.* 2017; Bibi *et al.* 2018).

In contrast, enhanced maximum growth during the mid-growing season may be attributable to three factors. First, climate change led to increased synchronization in the timing of maximum growth of different functional groups (see

(Wang et al. 2020, Ecology Letters)

Writing strategies: LD structure

- Lead/Development structure is an effective way to guide readers through technical or detailed text.
- First give an overview or summary of the findings, and then flesh out the details.

Simultaneous additions of N and P produce higher responses than single nutrient additions across all systems ($P < 0.001$; Table 2) but, across systems, overall responses to P or to N added separately are broadly equivalent ($P = 0.222$). N enrichment or P enrichment result in growth responses (Fig. 1) that are statistically indistinguishable in freshwater ($P = 0.637$) and terrestrial systems ($P = 0.999$) when systems are analysed separately (Table 2). N enrichment in marine environments produces significantly greater growth response than P enrichment ($P = 0.002$, Table 2), although, as noted above, average marine $\mathrm{RR_P}$ is significantly greater than zero, indicating a positive response to P enrichment.

(Elser et al. 2007, Ecology Letters)

Writing strategies: LD structure

- This example here directly goes into details of the results.

The steady-state pH of cultures continuously exposed to 380 and 700 ppm CO_2 was 7.29 and 7.20 respectively. This difference in pH is less than the 0.2–0.4 unit change predicted by Caldeira and Wickett (2003) due to the buffering capacity of growth medium…Total DIC concentrations under 380 and 700 ppm CO_2 were 135.94 and 208.63 µmol L^{-1}, respectively.

(Song et al. 2014, Biogeochemistry)

- Adding a lead sentence could make this paragraph much easier to follow for the readers.

Exposure to high atmospheric CO_2 led to increases in concentration of all inorganic carbon species in the culture. The steady-state pH of cultures continuously exposed to 380 and 700 ppm CO_2 was 7.29 and 7.20 respectively. This difference in pH is less than the 0.2–0.4 unit change predicted by Caldeira and Wickett (2003) due to the buffering capacity of growth medium…Total DIC concentrations under 380 and 700 ppm CO_2 were 135.94 and 208.63 µmol L^{-1}, respectively.

Writing strategies: LD structure

- The lead can be a brief mention of the method that led to the result you are presenting;
- This strategy helps the reader follow where the results come from and is particularly useful when methods are long or complex.

To examine the PtrCLE20 peptide localization, specific antibodies against PtrCLE20 peptide were raised as well as antibodies against phloem expressed PtrCLE41 peptide (Figure S5a–d). Both antibodies were able to detect a single band, respectively, in total proteins isolated from *Populus* young stem without bark (Figure 5e). It was noted that...

(Zhu et al. 2020, Plant Biotechnology Journal)

Writing strategies: LD structure

- The lead can be a statement about the purpose of the results. This help guide the readers understand what was done and why it was done.

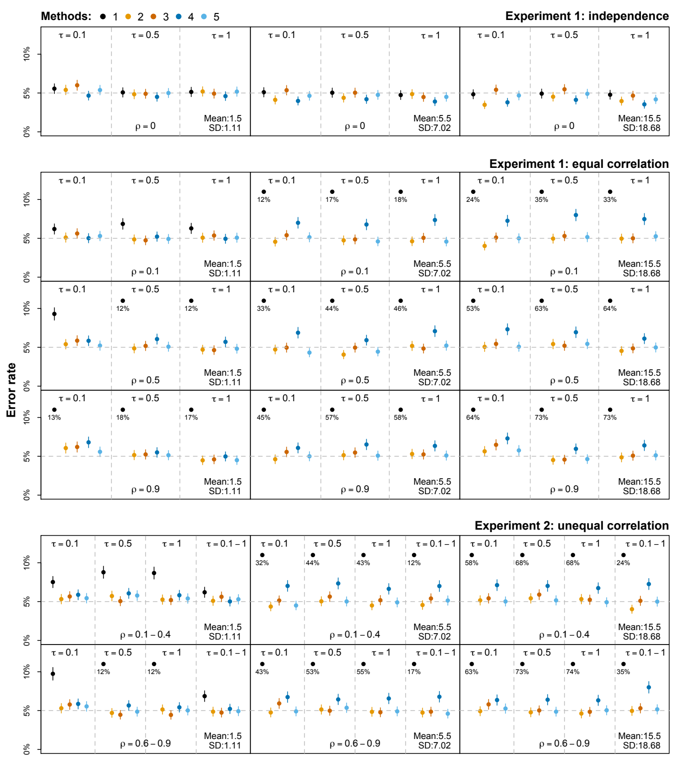
Next, we examined whether our Ribo-Seq experiments efficiently captured the translational signals of uORFs. We focused on the 35,735 uORFs that were annotated in the modENCODE mRNA-Seq and CAGE-Seq data and also expressed in at least 1 of the 12 samples we examined (mRNA-Seq RPKM $\geqslant 1$). We found...

(Zhang et al. 2018, PLOS Biology)

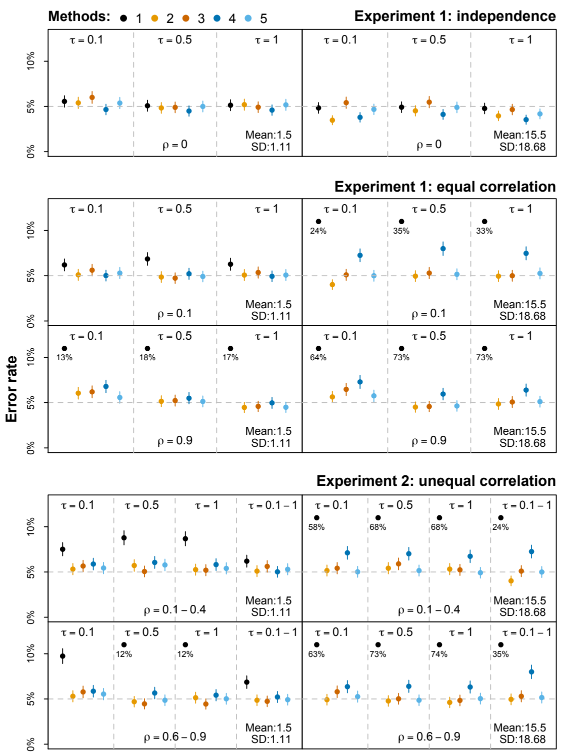
Choose what to present

- Present representative data rather than endlessly repetitive data;
- Because patterns under many simulation scenarios are similar, only a subset are shown in the figure.

Draft figure



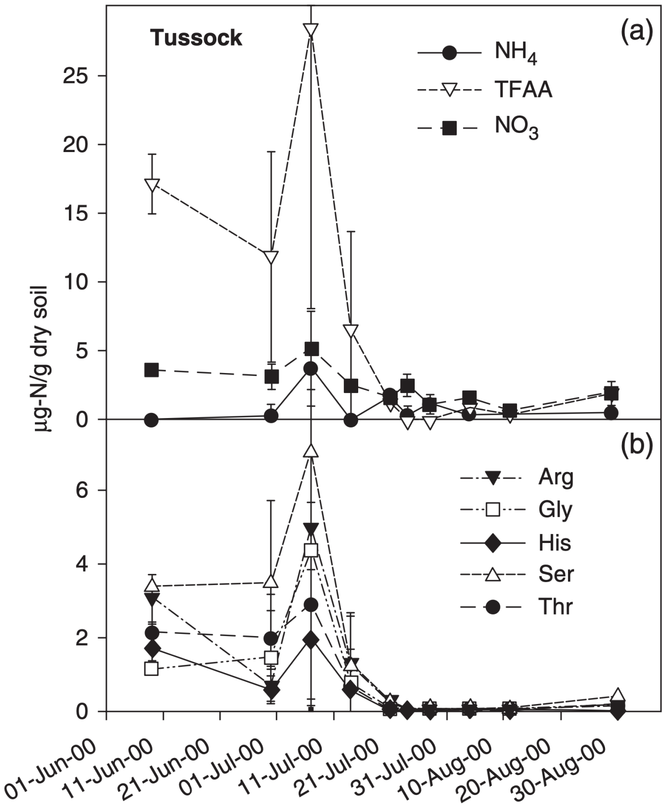
Final figure



(Song et al. 2020, Ecology)

Choose what to present

- State the findings that matters to your story. No need to describe every datum or pattern you show in the figures or tables.
- In this example, the overall trend is what matters. There is thus no need to state how each amino acid changes seasonally.

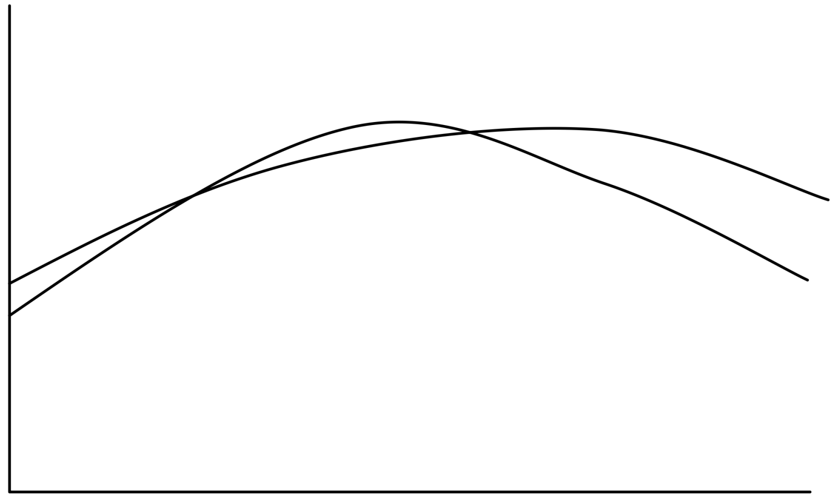


The five highest overall individual amino acids were serine, arginine, glycine, threonine, and histidine. They all closely tracked one another, and DIN, for the most part. At the beginning of June, immediately after snowmelt, amino acid concentrations in tussock soil were among the highest we measured that summer, in any soil, while NH_4^+ was below detection and NO_3^- was below 5 µg N/g soil. The highest TFAA concentration we observed during the growing season, 28 µg N/g soil, was on July 7, 2000, when there was a large peak in amino acids and smaller peaks in NH_4^+ and NO_3^-. After this, the declines in concentrations were rapid, and none went above 2 µg N/g soil after July 14. On July 24 and 28 no amino acids were detected whatsoever .

(Weintraub et al. 2005, Biogeochemistry)

Tell the story

- Results do not speak for themselves! Readers' interpretation may not always be what you want them to see. You need to tell what the data say.
- The readers will focus on the similarities if you say "the two curves are very similar". They will focus on the differences if you say "the two curves are noticeably different".



(Glasman-Deal 2010, Science Research Writing for Non-Native Speakers of English)

Tell the story

- The language you use to describe your results has as much power as the tables and figures, perhaps even more.
- Compare the following two writings about the finding that a statistical method might inflate type I error rate from 5% to 8%.

The highest Type I error rate of multilevel meta-analysis models achieved across all scenarios was about 8.2% (mean (median) error rates: 6.42% (6.42%)), which seems marginal in absolute terms, but relative to the nominal rate of 5% constitutes an increase of 64%.

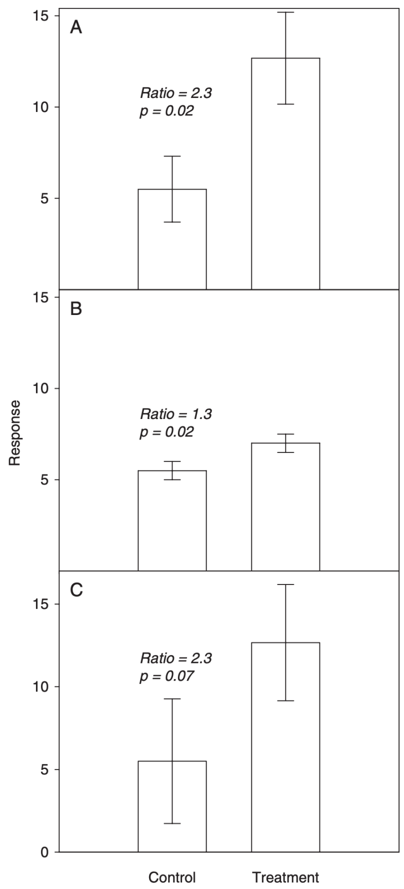
(Nakagawa et al. 2022, Ecology)

Although one might be tempted to dismiss this inflation as minor, error rates were as much as 1.6 times the nominal rate of 0.05, which, in certain contexts, might be unacceptable.

(Song et al. 2022, Ecology)

Statistics and stories

- A common mistake is too much focus on the statistics；
- Focus on the data, be concrete, and show the whole story.



Only focus on statistics:

A: Treatment significantly increased the response ($P = 0.02$).
B: Treatment significantly increased the response ($P = 0.02$).
C: There was no significant treatment effect ($P \geqslant 0.05$).

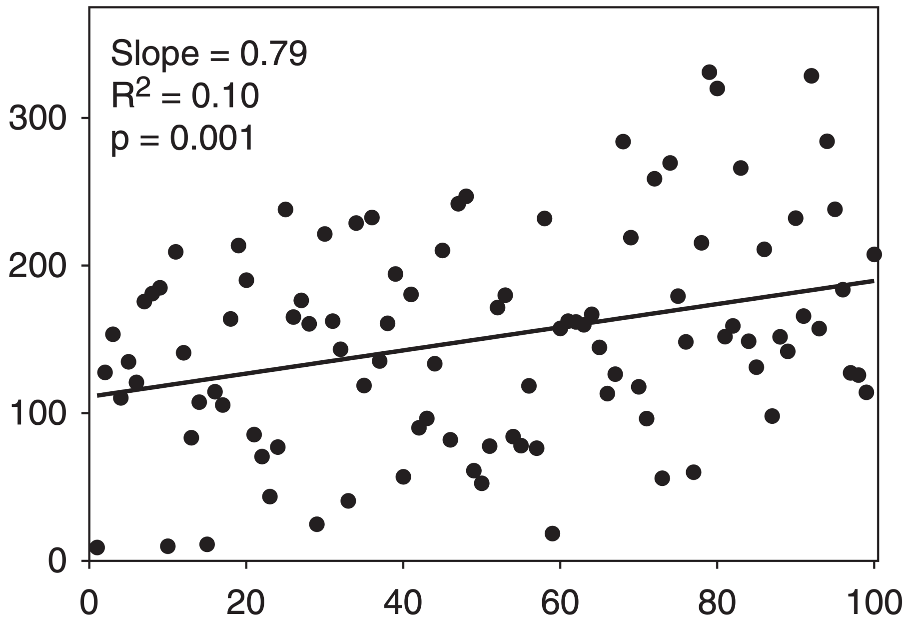
Concrete and tell the whole story:

A: The treatment increased the response by a factor of 2.3 ($P = 0.02$).
B: The treatment increased the response by only 30 percent, but this increase was statistically significant ($P = 0.02$).
C: The response in the treatment was 2.3 times higher than in the control, but the difference was only significant at $P = 0.07$.

(Schimel 2012, Writing Science: How to Write Papers That Get Cited and Proposals That Get Funded)

Statistics and stories

- Is this a strong relationship? Through the lens of statistics, you may describe it as a strong relationship because P = 0.001.
- If you look at the data, you see "the relationship between *x* and *y* is weak (R^2 = 0.1) but statistically significant (P = 0.001).



(Schimel 2012, Writing Science: How to Write Papers That Get Cited and Proposals That Get Funded)

Writing style: tense

- Because results section details what you found at the time of your experiments/analyses, and your new findings have not become established knowledge yet, **past tense is often** used in the results section in primary research papers;
- If results can be regarded as established knowledge, for example, results from a synthesis, **present tense can** be used, but this is very rare.

Writing style: avoid redundancy

- Avoid being verbose in citing figures and tables.
- The writing in the example is very redundant. You do not need to explain in words what the figure is. Instead, inform the readers what the figure tells us and refer to the figures in the parenthesis.

Figure 5 lets you compare the amount of CO_2 emitted from the Northern and Southern Hemispheres. CO_2 emissions from the Northern Hemisphere were twice those of Sothern Hemisphere – 40.5 Pg C y^{-1} *cf* 18.0 Pg C y^{-1} respectively.

(Pollard 2022, Frontiers in Environmental Sciences)

- The example can be revised to be more concise.

CO_2 emissions from the Northern Hemisphere were twice those of Sothern Hemisphere – 40.5 Pg C y^{-1} *cf* 18.0 Pg C y^{-1} respectively (Figure 5).

Writing style: present numbers

- Sentence does not start with a number in Arabic. If it is necessary to start a sentence with a number, write it out in letters;
- Journal requirements may vary. But in general, there should be a space between a number and its unit except unit symbols for degree (º), minute (’), and second (”) for plane angle;
- Symbols representing variables are italic, but symbols representing unit are not.

Twenty liters of water were collected from the stream.

Total DIC concentration was 208.63 µmol L^{-1}.

The mean effect size, θ, was estimated using the weighted average.

This study was performed at XXX Research Station (101°12’E, 37°30’N).