Latitudinal Diversity Gradients in Freshwater

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History

- **20 Oct 2016** created document
- **25 Oct 2016** added spatial scale, biome, and curve plots
- **26 Oct 2016** added Hillebrand's data

Introduction/Methods

I did a literature search using Web of Science, trying to find as many studies of latitudinal diversity gradients (LDG) in freshwater as possible. The search term was *latitud* diversity freshwater*. That search found 228 articles of which I saved 50 after reading the abstracts. Laura added several articles as well. I compiled the results in a table, for those studies that had valid tests of the LDG, and classified them by taxon, type of waterbody, type of gradient, response variable, and continent. I also roughly classified the study by spatial scale/extent: regional, continental, or global. Finally, I tried to classify them by biome but it was difficult because so many studies spanned biomes; the classification was just into tropical, temperate, boreal, or many. I also found a few elevational gradient studies, which I've ignored for the moment. Almost all the studies looked at richness, but there were 2 or 3 studies that looked at some other diversity metric (which incorporated richness), 1 study that looked at functional diversity, and 2 or 3 studies that looked at intraspecific genetic diversity. I have lumped those together for the moment. A study could have multiple rows in the table if it reported gradients for different taxa. I just classified the LDG results by whether it declined with latitude, increased, had a peaked/unimodal pattern, had a trough/U-shaped pattern, or no pattern, rather than reporting the slope.

Results

Overall, the majority (58%) of the studies found a "standard" LDG, which I define as richness declining with latitude as you go away from the equator. This is probably pretty close to what meta-analyses that encompass terrestrial and aquatic systems have found, but might be a little less than expected.

Table by number of gradients

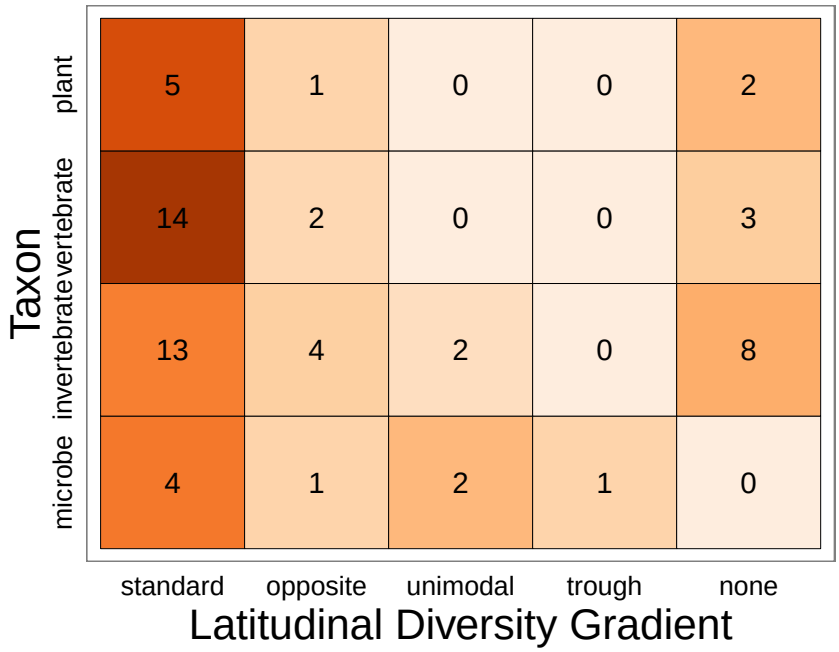
```
##
## standard opposite unimodal   trough     none
##       36        8        4        1       13
```

Table by proportion

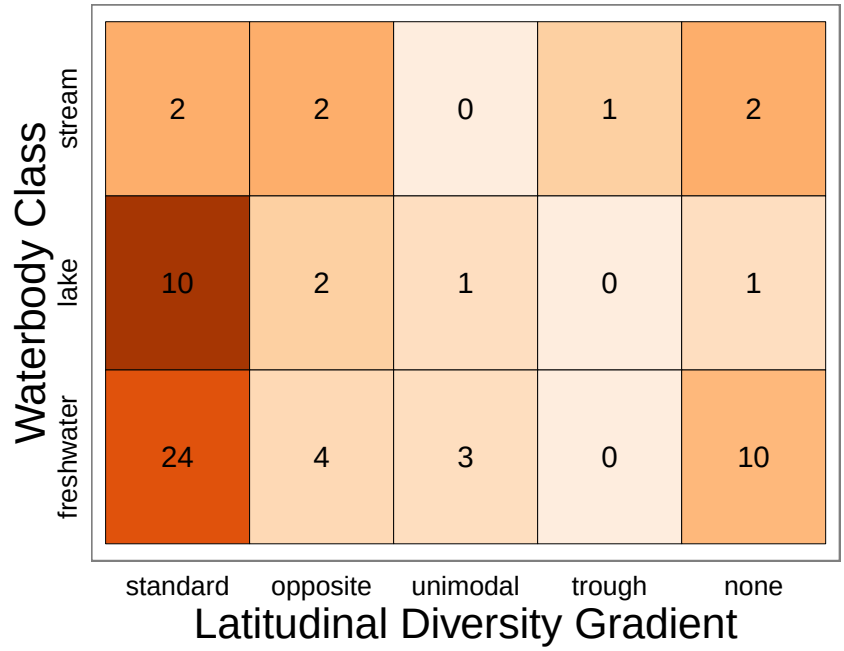
```
##
## standard opposite unimodal   trough     none
##    0.581    0.129    0.065    0.016    0.210
```

In addition, I classified the results by taxon, by type of waterbody, by spatial extent, and by biome. The first figure below shows that the breakdown is pretty consistent across taxa, though invertebrates seem disproportionately likely to show a non-standard pattern. The second figure shows that streams (including all running waterbodies) may be more likely to show a non-standard pattern than lakes (including ponds, etc.) though there are few studies done only on streams. I had to lump a lot of studies together as "freshwater" because it either included both streams and lakes or it was not adequately clear if it focused on one or the other. The spatial extent table might be interesting, as it shows that a disproportionate number of studies at the global scale fail to detect a pattern. That is maybe the opposite of what I would have thought, but perhaps too many confounding variables are thrown together at that scale. Finally, the biome table does not seem to have huge differences among biomes.

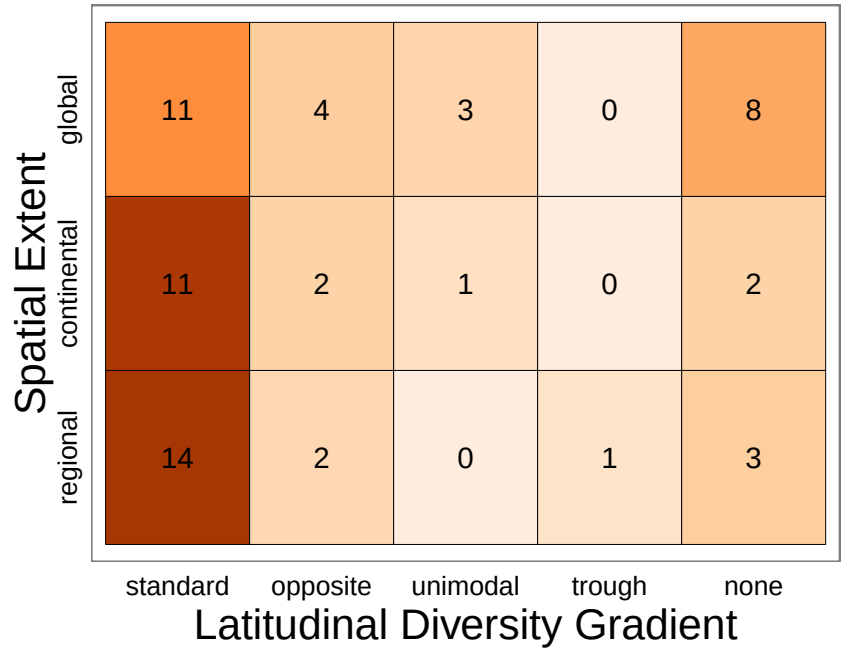
Contingency table by taxon



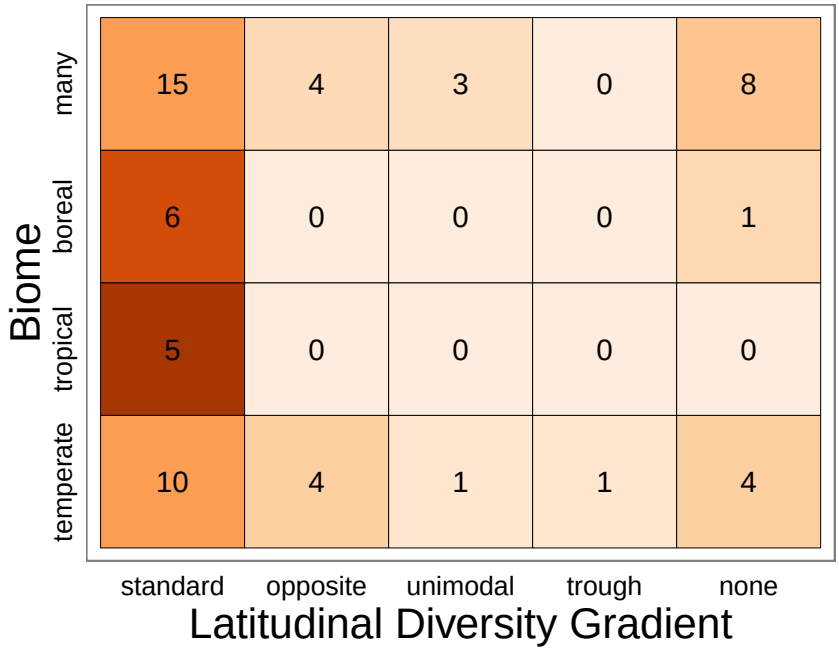
Contingency table by waterbody class



Contingency table by spatial extent

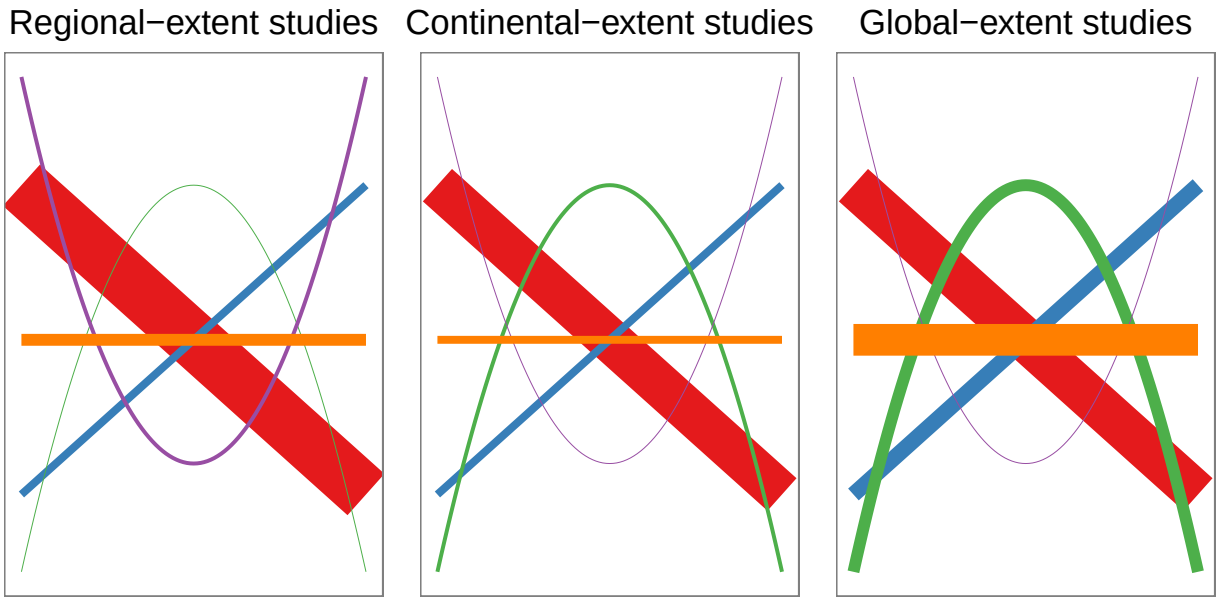


Contingency table by biome



Here is another fun way of visualizing the trends. I drew a little line for each type of gradient (obviously the slopes are completely made up). The thickness of the line corresponds to the proportion of studies with that type of latitudinal diversity gradient. I represented zeroes with really thin dotted lines. The below figure, for example, might be nice for visualizing that the non-standard gradients become more common at the global extent.

Proportion of gradients, grouped by spatial extent



Comparison with Hillebrand's meta-analysis

In my reading, I noticed that a lot of authors stated that the LDG is ubiquitous across systems: terrestrial, marine, and freshwater. The 2004 meta-analysis by Hillebrand in Am Nat is a highly cited work on the subject. Hillebrand did find that the slope of the LDG is significantly negative for terrestrial, marine, and freshwater systems, when he ran a meta-analysis on the slopes from a lot of different studies. However, the effect size for freshwater is a lot lower than for the other realms, indicating that there are a lot more individual systems that don't play by the LDG rules. To look at this more closely, I pulled the raw data from appendix A of that manuscript, and "dumbed down" the dataset to make it comparable with our dataset. I did this by converting the slopes and standard errors he provided to a simple significance value. I multiplied the standard error by 1.96 to construct a confidence interval for the slope and checked whether each slope was significantly < 0 (standard), significantly > 0 (opposite), or overlapping 0 (no LDG). There were about 600 studies; Hillebrand really covered his bases. Only 60 of them are freshwater but that is still a sizable amount. You can see from the table below that the freshwater gradients are way more likely to be non-standard: only 35% are standard, compared to 58% for terrestrial and 87% for marine. This could be an important thing to highlight.

Contingency table by realm, data taken from Hillebrand 2004