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  + Hello everyone, I’m John
  + This afternoon I will answer the question of whether the accuracy of elevational range shift models in a Neotropical cloud forest can be improved through the addition of biotic variables.
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  + We know that climate change is occurring at an unprecedented rate, causing an increase in temperature, changes in precipitation regime, and an increase in the frequency of extreme weather events.
  + Populations of plants can adapt to these changes in climate by changing their morphology (i.e. their average leaf thickness), their phenology (the timing of life events like flowering and seeding), or their physiology (i.e. changing their photochemistry).
  + If species fail to adapt to climate change fast enough, this will result in higher mortality in some areas, and higher recruitment in others. Causing range shifts, either to higher elevations or higher latitudes.
  + A key area of ecological research is in predicting how species will move, whether their ranges will contract or expand, and whether ecosystem functioning may change as a result.
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  + The majority of studies that have aimed to do this in the past have used bioclimatic envelope models.
  + These models use current species distributions, which are then correlated with climate variables to build a bioclimatic envelope. This envelope is then compared to future climate predictions to anticipate how the envelope will change, either getting larger, smaller, or moving across space.
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  + But bioclimatic envelope models don’t always produce accurate results, especially when tracking range shifts across elevation.
  + These graphs show that models predicting latitudinal range shifts are doing a good job at explaining observed range shifts, but models over elevation predict a lot of upslope movement that we aren’t seeing in real life.
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  + A potential reason for the models not matching up with observed range shifts is because they fail to include non-climatic variables which also vary with elevation.
  + Nutrient availability normally increases with elevation due to increased erosion and landslide frequency, while competitive interactions and herbivory generally decrease with elevation.
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  + Additionally, these models often assume that species are equally sensitive to changes in climate, but as we can see here, using data from the same study sites that I used, different genera found in the same area are moving both upslope and downslope at very different rates.
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  + In this study I focused specifically on whether competition interactions should be included in these predictive models to improve their accuracy, by seeing if they can explain variation in plant stress measurements.
  + Additionally, I looked at whether species ranges vary in their sensitivity to climate change by measuring stress responses to elevation.
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  + To answer these questions I went to the Peruvian Andes, to the Kosñipata valley, where previous studies have shown that tree species are moving upslope in response to temperature increases.
  + Along this valley, from around 400 m above sea level right up to the tree line at about 3200 m, a series of 1 ha forest plots have been set up by the Andes Biodiversity and Ecosystem Research Group.
  + I chose 10 of these plots in which to sample the seedlings of nine locally common tree species.
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  + The nine species were chosen because they have contrasting ranges, some lowland, some found only in the cloud forest zone, and some spanning the two ecosystems.
  + For each of these species I sampled individuals at the top, middle, and bottom of their range.
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  + I used measures of chlorophyll fluorescence and chlorophyll content to quantify whether a plant was experiencing stress.
  + Chlorophyll fluorescence can be explained like this. When light hits a chloroplast, the majority is absorbed by Photosystem 2 in the thylakoid membrane. From there the energy can take three pathways, it can by used to drive the light reactions of photosynthesis, or it can be dissipated as heat, or fluorescence.
  + Fluorescence measurements are normally presented as a ratio, where a healthy plant has a value of about 0.8.
  + In a healthy plant we expect most of the energy to be used in photosynthesis…
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  + But in a stressed plant, where some of the photosynthetic machinery has been shut down, we would expect less to be used in photosynthesis, and therefore more to be dissipated as fluorescence, causing a reduction in the ratio value.
  + Plants with an efficiency less than 0.7 are considered to be stressed.
  + Chlorophyll content is somewhat easier to explain. A decrease in chlorophyll content is associated with various forms of plant stress including temperature and nutrient stress, and a decrease in chlorophyll content limits overall photosynthetic capacity.
  + Both of these measures can be used to infer whether a plant will be successful over its lifetime in terms of fitness.
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  + Around each seedling, I also measured three proxies for competition interactions.
  + I measured canopy competition, which was represented by Leaf Area Index, calculated from a hemispherical photograph taken above the seedling
  + And adult-seedling root competition, which was measured using an index that I designed myself and took into account the distance and trunk diameters of competitor trees.
  + Seedling-seedling competition was measured simply by counting the number of seedlings around the seedling I was measuring.
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  + To determine whether either of the stress variables were affected by competition interactions, I conducted linear mixed effects models, each using one competition variable.
  + I also conducted a similar model using just elevation in order to compare the effects of competition to that of the other environmental variables which change across the species ranges.
  + I included the random effect of plot to account for non-independence of data collected at each plot and
  + I included the random effect of species to account for baseline differences in the physiology of each species I sampled.
  + These random effects give each species and each plot it’s own intercept, but identical slopes
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  + To determine whether a combination of competition effects and elevation best explained the variation in each stress variable. I compared the quality of models using various combinations of fixed effects using AIC and pseudo-r-squared estimates.
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  + And finally, to determine whether species differ in their sensitivity to climate variation I used mixed models using the fixed effect of elevation as before, but this time I allowed each species in the model to have its own slope as well as intercept, so we could see whether these slopes differed.
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  + The graph on the left shows the model quality of each of the single fixed effect models, and the graph on the right shows how much of the variance in the stress variables is explained by the fixed effects.
  + For photosynthetic efficiency, elevation produced a model of higher quality than any of the competition variables, seedling abundance didn’t produce a model any better than a random effects model including no fixed effects.
  + Only the seedling abundance model for chlorophyll content was any better than a random effects model and this still only explained a very small amount of the variation in chlorophyll content.
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  + This graph shows the slopes produced by the fixed effects of each of these models. It shows that photosynthetic efficiency increases with elevation and with increased canopy density.
  + An increase in efficiency with canopy density might be because as the canopy density increases so does the stability of the micro-climate, reducing temperature stress.
  + A decrease in efficiency with root competition might be because adult trees poach nutrients from the seedlings, preventing them from synthesising the necessary photosynthetic machinery.
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  + The best model for photosynthetic efficiency included elevation and both of the adult-seedling competition interactions, but not seedling-seedling competition.
  + While chlorophyll content was best explained by a model including only the random effects of site and species
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  + These graphs show whether species are different in their sensitivity to environmental variation across their ranges.
  + The graphs on the left are scatterplots showing how the stress levels of individuals change across species’ elevational range. At the top is photosynthetic efficiency and at the bottom is chlorophyll content.
  + The graphs on the right show the slopes of these species.
  + Photosynthetic efficiency increases in the majority of species, though the steepness of this slope does vary somewhat.
  + For chlorophyll content, there is so much variation between individuals at a given elevation that these slope estimates aren’t powerful enough to say whether species actually vary considerably.
  + From this we can conclude that species exhibit different sensitivities to climate change though none except Alzatea verticillata (the most abundant species sampled) need to be treated individually in bioclimatic envelope models.
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  + This study is limited in that it only investigated seedlings. Therefore, we can’t reliably infer that adult trees will respond in the same way to competition interactions.
  + I only sampled 9 species from a possible 1655 that have been identified within the plots. There is evidence that rare species react differently and be more sensitive to changes in environment.
  + Because this was an observational study, there are many other environmental variables that may have co-varied with those that I measured, meaning that we cannot definitively say that canopy density, for example, is the cause of an increase in photosynthetic efficiency.
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  + I suggest that in the future, experimental studies transplant seedlings to elevations outside of their current range, to see whether the stress effects I found in this study can be extrapolated.
  + I would like to investigate how the stress measurements seen in this study can be translated into mortality and recruitment variation.
  + I suggest that studies similar to this one are carried out in other biomes to see if the relationship is specific to cloud forests or not.
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  + In summary,
  + This study found that the adult-seedling competition interactions do have an effect on seedling stress levels, and that their inclusion will likely improve the accuracy of range-shift models.
  + However, elevationally dependent climatic variables play the greatest role in driving range shifts.
  + Chlorophyll content doesn’t vary meaningfully with any of the variables we measured and so is not a reliable measure of plant stress in this case.
  + Of these common species, only Alzatea verticillata, the most abundant tree species in the plots, is considerably more sensitive to elevation than any of the others, suggesting that the majority of tree species could be modelled identically, without considerable loss of accuracy.

**Questions:**

Questions that might be asked:

* What are some other options for interactions
  + Herbivory
  + Insect-tree mutualisms
* How did you deal with the effects of competition potentially being confounded with elevation?
* Why do you think chlorophyll content varied so much within each site? //
  + Maybe because SPAD value is confounded by leaf thickness, but we didn’t measure that.
* Why did you choose the Neotropical biome to do this research in?
  + F
* How did you calculate the index for root competition? //
  + **Slide**
* Why did you choose seedlings if you said adult trees are better? //