Testing drivers of allopatric speciation in Amazonian plants

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ABSTRACT

The origins of biodiversity in Amazonia are poorly understood. Uncovering patterns of speciation within clades of Amazonian plants may provide insight into the origins of biodiversity in Amazonia. Following modern synthesis, it has been thought that the predominant mode of speciation is allopatric, where populations are separated by large environmental barriers such as mountain ranges, habitat or climate barriers, etc. In Amazonia, large environmental barriers are located along the perimeter of the "core Amazon". The core Amazon has presumably strong river barriers; however, no strong evidence has been found to indicate that river barriers are necessarily isolating mechanisms for plant taxa. We tested whether there was a signal of more allopatric speciation along the periphery of the core Amazon, and more sympatric or parapatric speciation within the core by investigating the spatial distributions of 68 sister species pairs from the *Miconeae*, *Lecythidaceae*, and *Bignoniacaeae* clades as they relate to major environmental barriers in Amazonia. We developed approximate ranges for each species and calculated the area of range overlap for each pair to determine which pairs exhibited complete, or nearly complete, allopatry. We then analyzed the spatial relationship between each pair of ranges and their location relative to the core Amazon.

BACKGROUND

- Home to 10% of the world's species, the Amazon rainforest is the most biodiverse region on the planet (Wade, 2016). The origins of this biodiversity, however, are still poorly understood.
- Major hypotheses attempting to explain the origins of biodiversity in Amazonia involve physical barriers which separate populations, causing the differentiation of species (Haffer, 2008).
- In Amazonia, major barriers tend to be distributed along the perimeter of the "core Amazon". These barriers include the Andes mountain range, the Cerrado and Los Llanos grassland/savanna ecoregions, and the Venezuela Tepuis.
- By investigating the spatial distributions of 68 sister species pairs across 3 clades of Amazonian plants, we tested whether there was a higher proportion of allopatric pairs associated with perimeter barriers than in the core.
- A study of diversification in Amazonia is important to the field of ecology because it provides information about drivers of biodiversity. Understanding factors influencing biodiversity is necessary for biodiversity conservation.

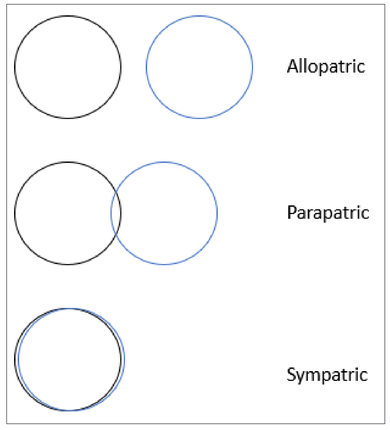

Figure 1. A conceptual model of different modes of speciation. Circles represent the spatial distributions of sister species following a speciation event.

METHODS

- Using a phylogenetic tree, we selected 68 sister species pairs from the *Miconeae*, *Lecythidaceae*, and *Bignoniacaeae* clades.
- Using Quantum GIS, we created range maps for each species based on geographic data from FLMNH, NYBG, and iDigBio databases.
- We used calculations of mean range overlap (MRO) to classify each pair as being allopatric or not allopatric. We defined allopatric as having MRO < 0.05.
- We classified each pair as being associated with perimeter barriers or not associated with perimeter barriers.
- We ran a chi-squared test to determine whether there was a significantly higher proportion of allopatric pairs associated with perimeter barriers than not associated with perimeter barriers.

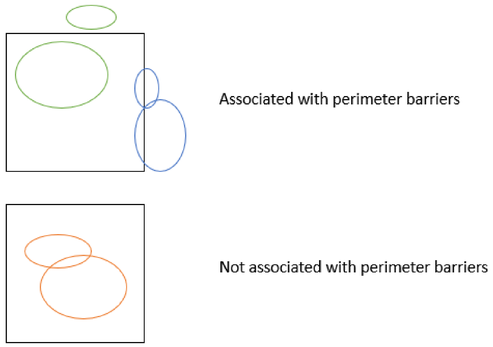

Figure 2. A conceptual model showing our method of classifying pairs. The black square represents the core Amazon, its edges represent perimeter barriers surrounding the core. Circles represent the spatial distributions of range pairs.

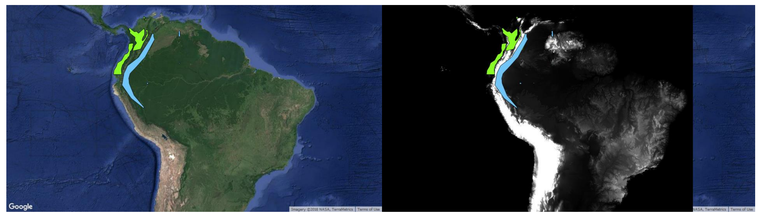

Figure 3. Range maps for sister species pair *G. macarenensis* and *G. speciosa*. This is an example of an allopatric pair that was judged to be associated with a perimeter barrier, the Andes in this case. The map on the right shows elevation, with higher elevations represented by lighter shading.

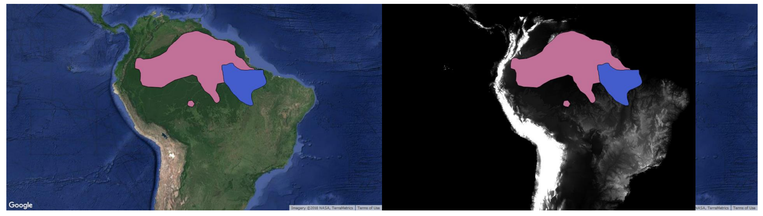

Figure 4. Range maps for sister species pair *A. magnificum* and *A. schomburgkii*. This is an example of a non-allopatric pair that was judged not to be associated with any perimeter barriers. The map on the right shows elevation, with higher elevations represented by lighter shading.

RESULTS

- Out of the 40 total pairs that were judged to be associated with perimeter barriers, 13 were allopatric.
- Out of the 28 total pairs that were judged not to be associated with any perimeter barriers, 3 were allopatric.
- The results of the chi-squared test gave a p-value of 0.03712705 . This is less than out alpha-value of 0.05, thus we failed to retain our null hypothesis that there is no significant difference between the proportion of allopatric pairs associated with perimeter barriers and the proportion of allopatric pairs not associated with perimeter barriers.
- This result indicates that the proportion of allopatric pairs associated with perimeter barriers is greater than the proportion of allopatric pairs in the core Amazon by an amount larger than would be expected due to random chance.

CONCLUSIONS

- The results of our analysis provide evidence that large physical barriers, including the Andes mountain range, the Cerrado and Los Llanos grassland/savanna ecoregions, and the Venezuela Tepuis, may be drivers of allopatric speciation in Amazonian plants.
- Some limitations of this study include:
  - The subjective nature of classifying species pairs as being associated with, or not associated with, perimeter barriers.
  - Potential bias in data collection. Some areas of the Amazon are more easily accessible for sampling, for example along major rivers.
  - Analysis of ecology at a single scale. Other ecological patterns may be present at different spatiotemporal scales.

FUTURE DIRECTIONS

- Continued studies of diversification in the tropics will strengthen our understanding of drivers of biodiversity. Future studies should aim to include a wide breadth of taxonomic groups across many ecosystems and many spatial scales.
- Future studies should attempt to reduce subjectivity, bias, and uncertainty to the greatest extent possible.

REFERENCES

Haffer, Jürgen. "Hypotheses to explain the origin of species in Amazonia." *Brazilian Journal of Biology* 68.4 (2008): 917-947.

Wade, Lizzie. "Cradle of life." (2015): 496-501.

Figure 5. From left to right, *Miconia pachyphylla* (Howard, R. A.), *Gustavia longifolia, Dolichandra unguis-cati (*Acevedo-Rodríguez, P.). US National Herbarium, Department of Botany, NMNH, Smithsonian Institution.