

Essay on *Biodiversity and Biogeography* by Luís Borda de Águas

Lucas C. Monteiro - fc52849@alunos.fc.ul.pt

Abstract - *Biodiversity and biogeography vary over time, creating the global biological patterns that we observe. But how can we create reliable theoretical models that reproduce our observations? Professor Luís Águas approaches this question with Extreme Value Theory's Block Minima procedure, trying to establish a relationship with the species accumulation curve of a 50ha plot in Panama. He discusses that the data doesn't meet the theorem's assumptions and recognizes the limitations of EVT in this case study.*

INTRODUCTION

The Earth is endowed with an enormous variety of life forms, each performing an incredible array of ecological roles. This biological variety and variability at all levels of life is broadly referred as *Biodiversity*. On the other hand, *Biogeography* attempts to understand the patterns of biodiversity in space. Both biodiversity and biogeography vary considerably over large timescales, as we see for example in the evolution of Earth's number of genera (Figure 1) or tectonic plates (Figure 2).

We can then ask, can we observe patterns associated with the diversity of life, and if so, what drives them? On the planetary scale, it is easily observable that a large percentage of vascular plant biodiversity is located at the equatorial regions, ever decreasing towards the poles, as in Figure 3. A deeper analysis, quantifying the number of mammal species per area, reveals that this is also the case for this Class of life, with a high number of species at the equator that abruptly decreases at higher latitudes^[1].

So we observe patterns associated with biodiversity, but can they be quantified or recreated with reliable theoretical models? In other words can we get several *universal* rules to describe *how* life organizes itself and, in particular, *what* patterns of biodiversity emerge, be it here on Earth or on any other life bearing planet?

THE SPECIES-AREA RELATIONSHIP

Several empirical laws can be deduced from observations in nature, e.g. Taylor's law. The *species-area relationship*, or species-area curve, is an interesting result obtained from the relationship between a sampling area A and the number of species found within that area S . When sampling a single type of organism, the measurements plotted in a Log-log scale resemble a straight line, indicating a *power law*, i.e. a function of the form $S = cA^z$, as seen in Figure 4.

So, following the question in the introduction, is there a theorem that we can apply to real data, recovering our observed patterns, more concretely the species-area curve? That's where professor Luís Águas ventures into the branch of probability *Extreme Value Theory* or **EVT**. This branch approaches the problem by dividing the data in blocks and analysing only the extremes, be it the local minima or maxima. By treating the data using EVT, he hopes to find a correlation between the theory's theorems and a type of species-area curve, called *species accumulation curve* or **SAC**. With this, he intends to describe this curve in a quantitative way^[2].

The SAC is constructed by determining a initial point and plotting the number of different species in the circle area with the radius of the last found new species (Figure 5). So for that, he uses the data collected in a 50 ha plot in Barro Colorado Island, Panama, which comprises $\sim 300\,000$ specimens with stems larger than 1cm dbh. It contains the frequency of each one of ~ 315 species as a function of the distance from that predetermined initial point, as we can see in Figure 6 in histogram form.

To obtain the SAC of vascular plants he analysed each species frequency curve as a block of data, focusing on the minimum distance of each block, since this is the extreme of interest in finding the *first* individual of each species. That is where we find the paralelism with EVT because by plotting the cumulative density function of the distribution of the minima, we should obtain a SAC with a well-understood distribution, given by EVT's Block Minima Approach. This distribution is known as *Generalized Extreme Value* distribution, or **GEV_m**, a function with three parameters.

However, when best fitting the **GEV_m**'s parameters to the SAC obtained from the observational data of Barro Colorado Island, professor Luís found limitations to the implementation of EVT in this case study, since the fit wasn't statistically significant.

DISCUSSION

He then discusses EVT's Block Minima Approach assumptions. More concretely, this approach requires the use of *independent* random variables having a *common cumulative distribution*, i.e. each species' frequency curve being similar. However each species curve is different, simply by the different behaviour that each species presents, e.g. reproduction. So the curves are not identical as the theorem requires, so this SAC disobeys the conditions of classical statistics of extremes.

APPENDIX

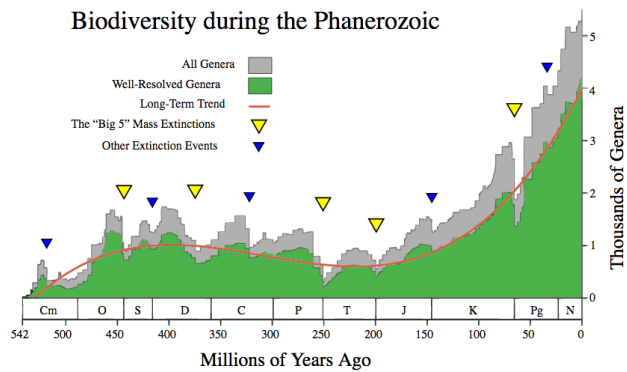


Figure 1. Evolution of Earth’s biodiversity in regard to number of genera over the last 542 million years.

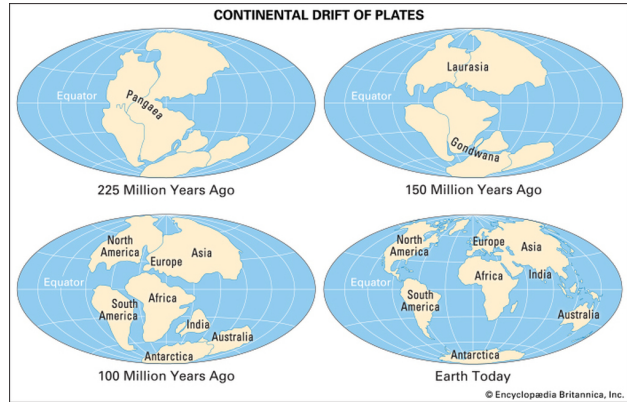


Figure 2. Evolution of Earth’s tectonic plates configuration from Pangea to present, roughly 225 million years.

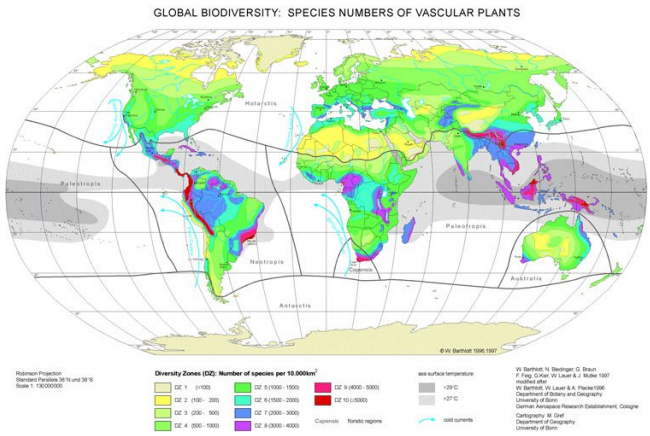


Figure 3. Number of vascular plant species by area. It is easily observed that most biodiversity is at equatorial regions.

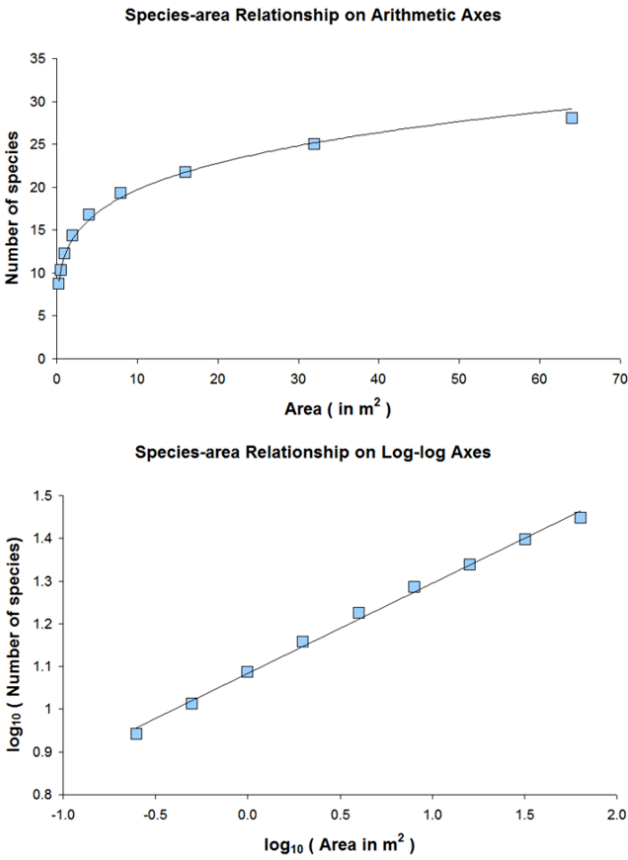


Figure 4. The species-area relationship for a contiguous habitat in arithmetic (top) and Log-log (bottom) scales.

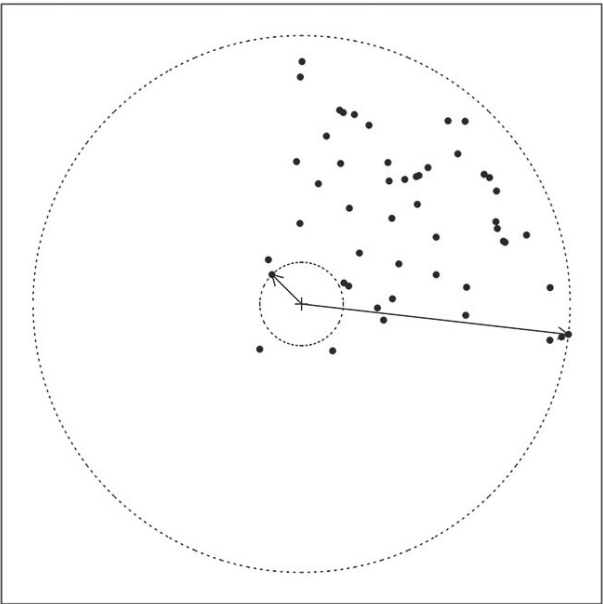


Figure 5. SAC construction where each point represents a specimen and the areas are circles with radius equal to the minimal distance to a certain species specimen.

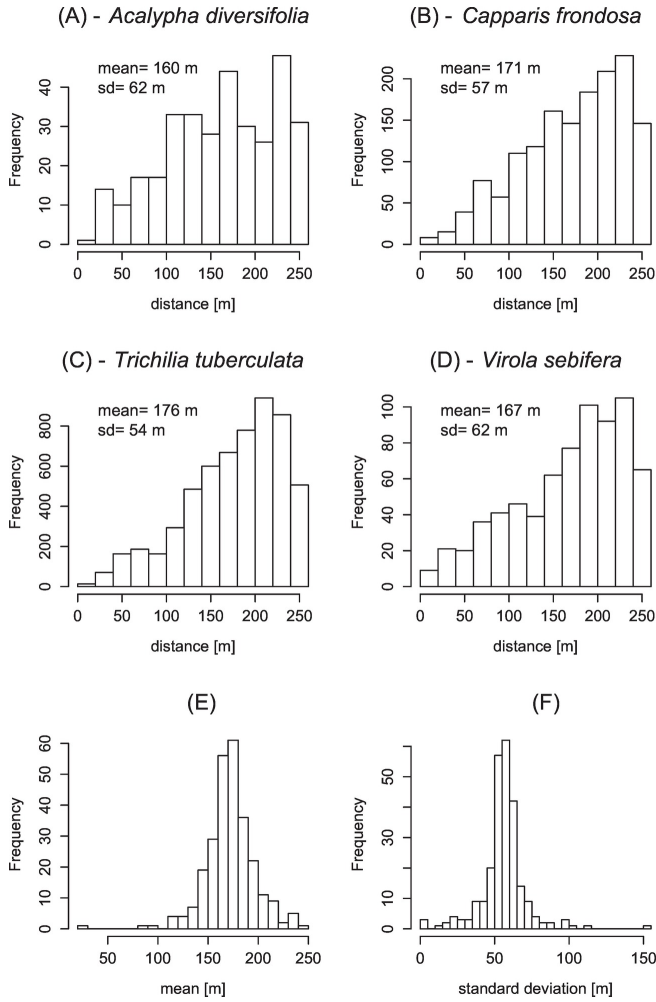


Figure 6. Different species frequency-distance histogram, from data collected in Barro Colorado Island, Panama

REFERENCES

- [1] Mark D. Pagel , Robert M. May, and Annie R.Collie, "Ecological Aspect of the Geographical Distribution and Diversity of Mammalian Species, "The American Naturalist 137, no. 6 (Jun.,1991): 791-815.
- [2] Borda-de-Água, L., Alirezazadeh, S., Neves, M., Hubbell, S., Borges, P., Cardoso, P., . . . Pereira, H. (2021). "Species Accumulation Curves and Extreme Value Theory". In T. Matthews, K. Triantis, R. Whittaker (Eds.), The Species–Area Relationship: Theory and Application (Ecology, Biodiversity and Conservation, pp. 211-226). Cambridge: Cambridge University Press. DOI:10.1017/9781108569422.014