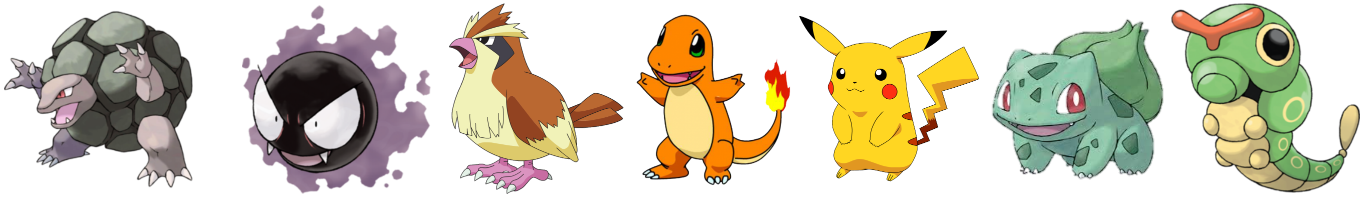
Origination, Extinction, Biodiversity

Paleobiology

February 17, 2016

Biodiversity and richness

- The total number of unique species is the richness



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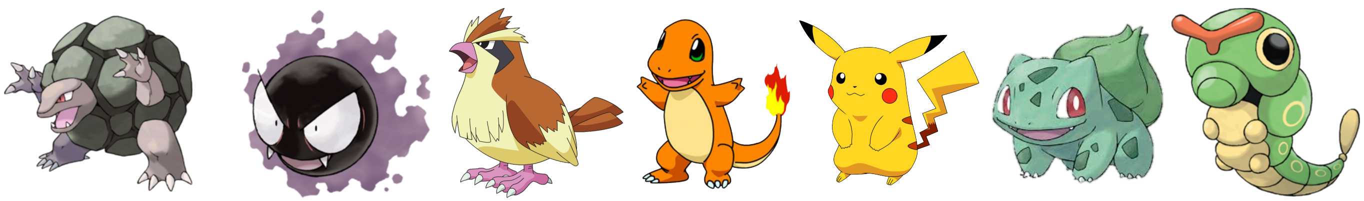
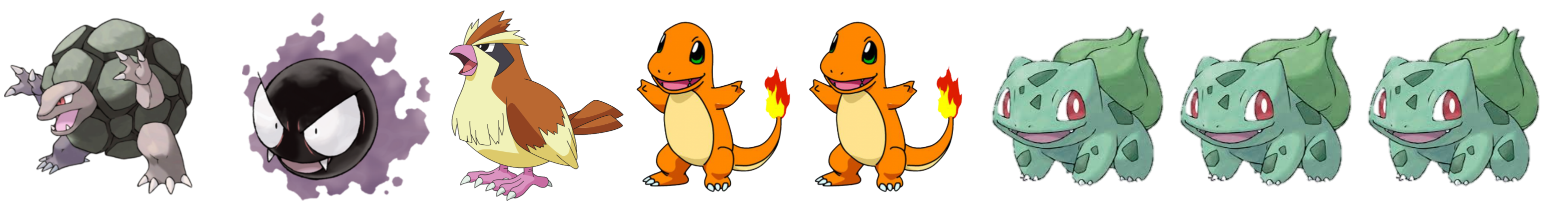
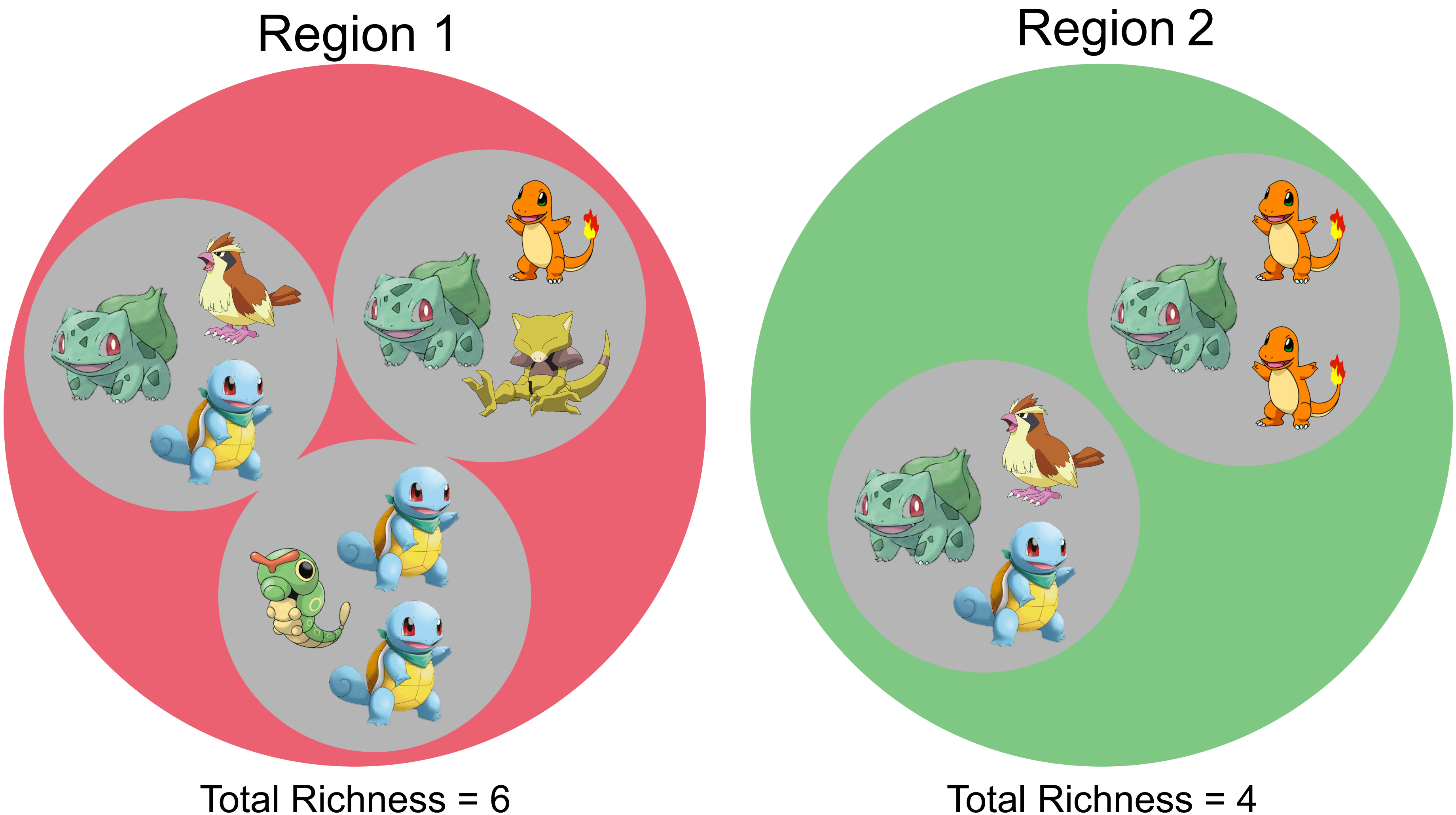
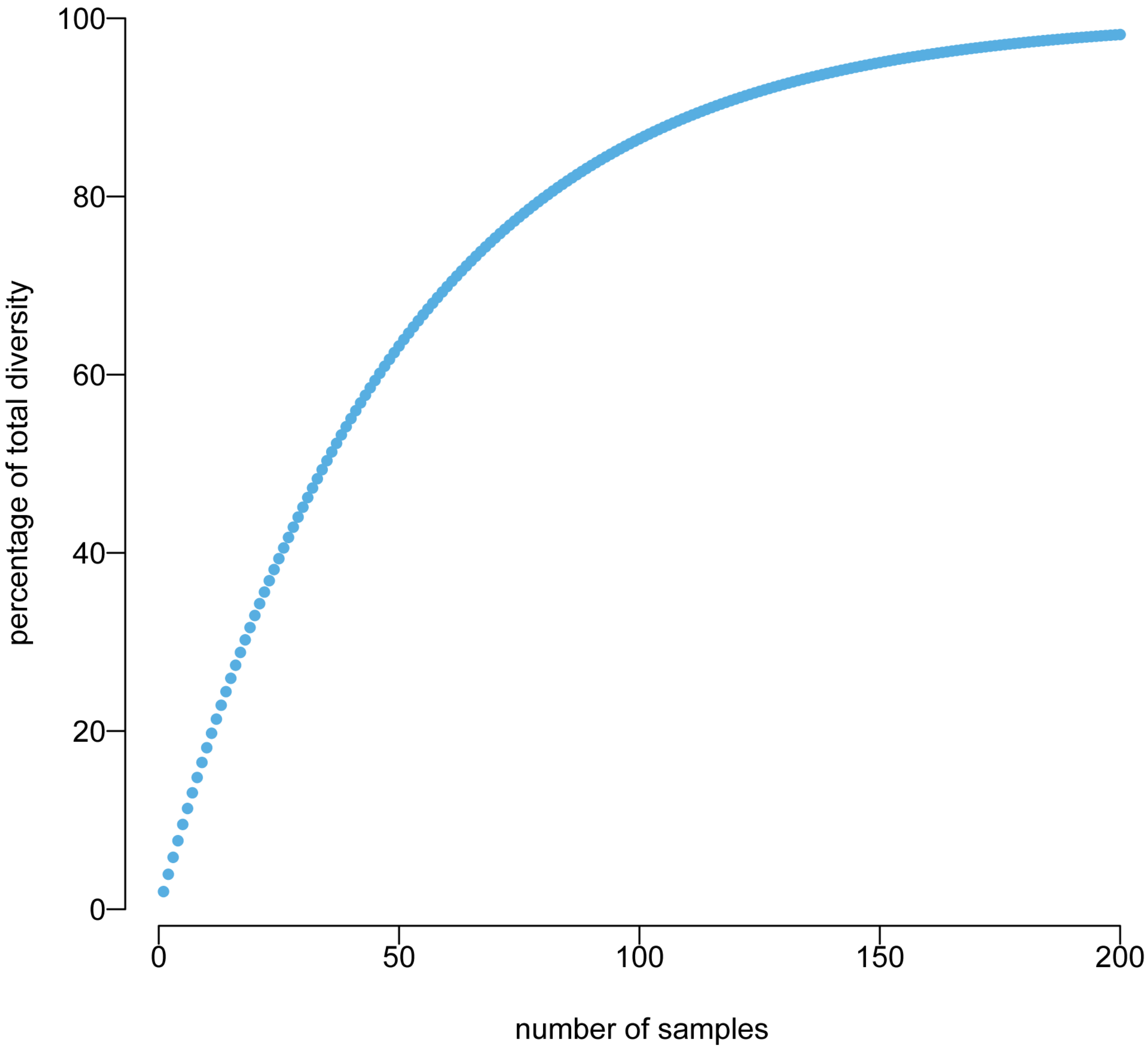




The “problem” with richness



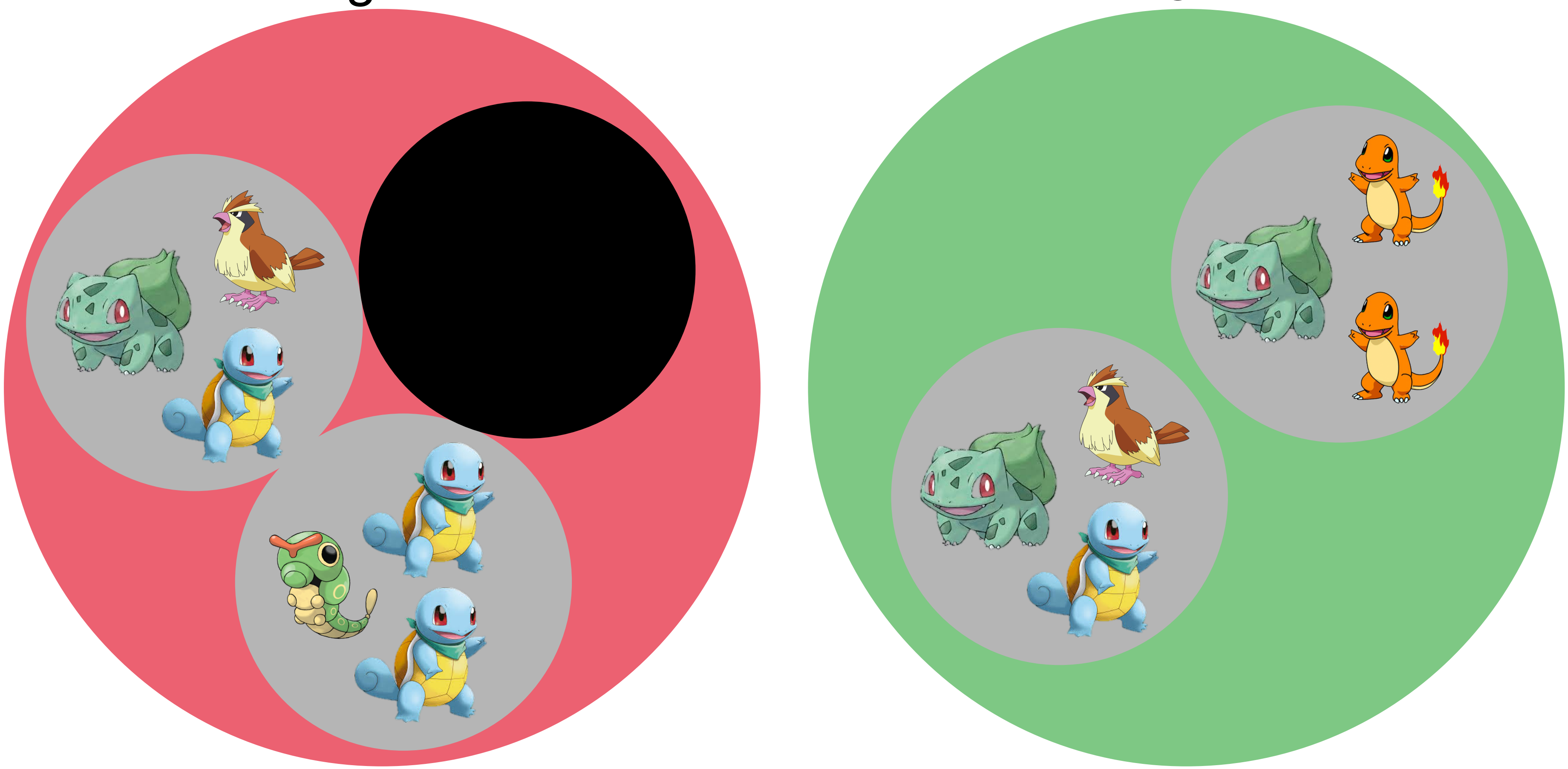
The species-area effect



Sample standardization

Region 1

Region 2



Total Richness = 4

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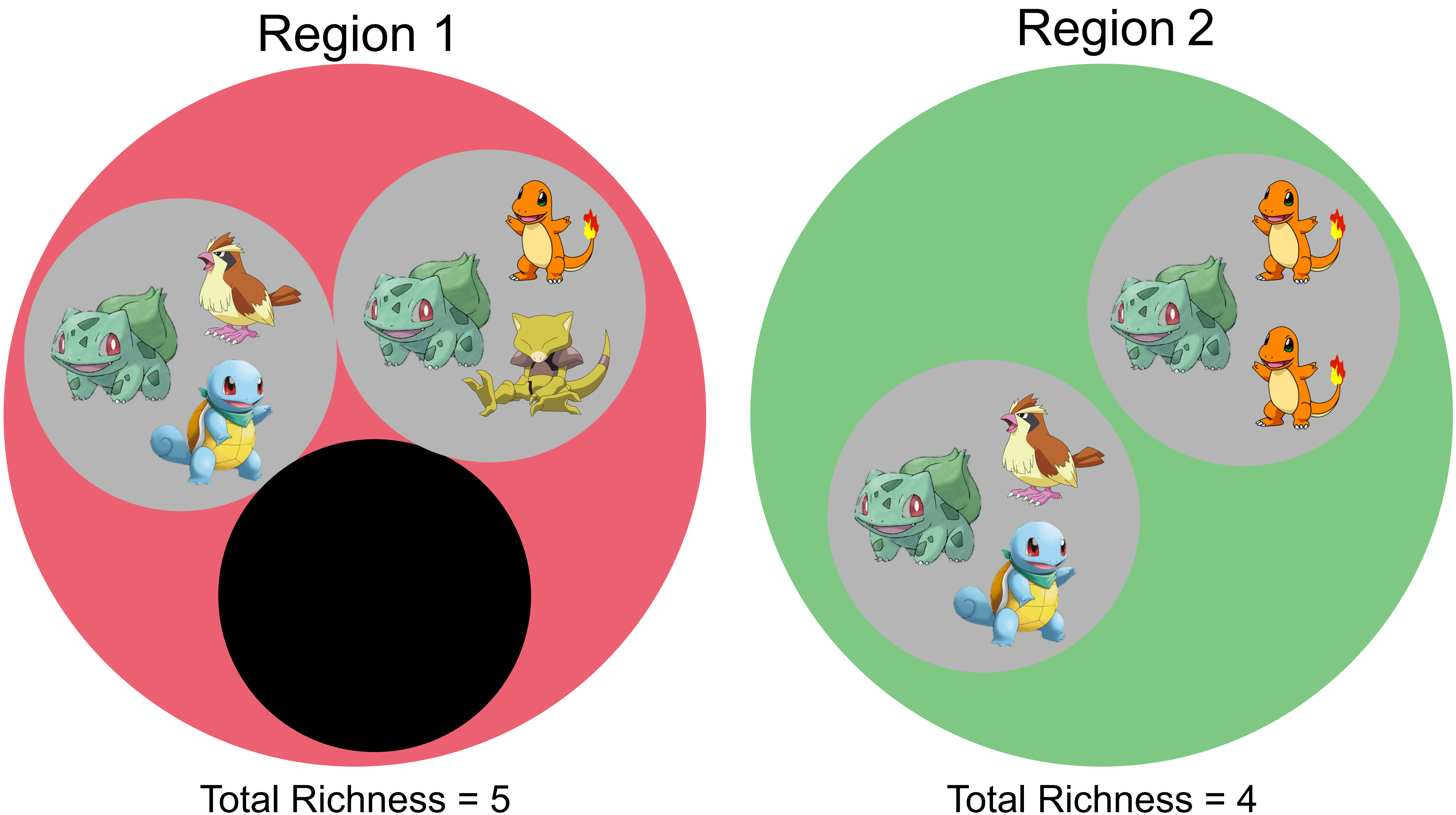
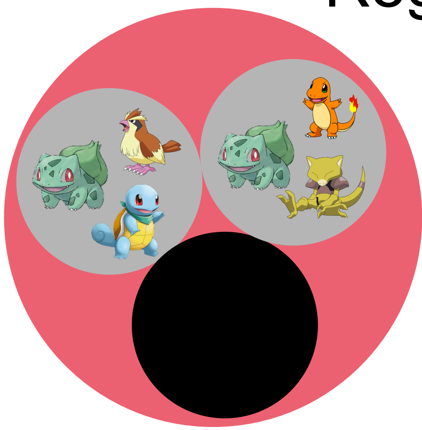
Sample standardization (resampling)

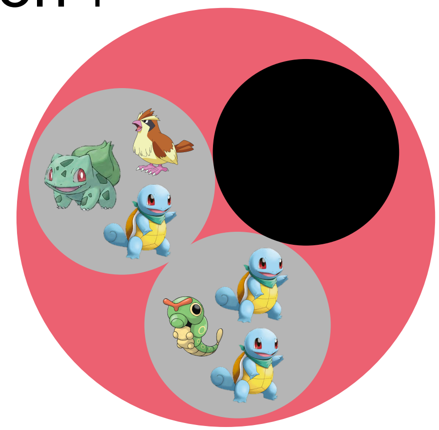


Sample standardization (resampling)

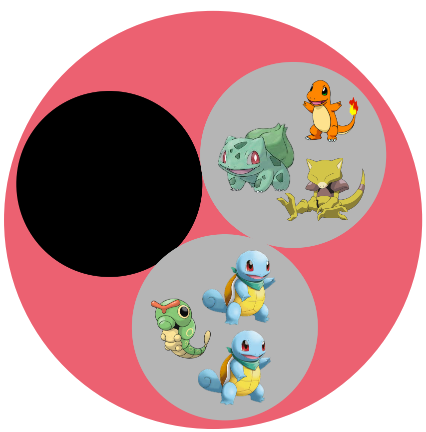
Region 1



Total Richness = 5



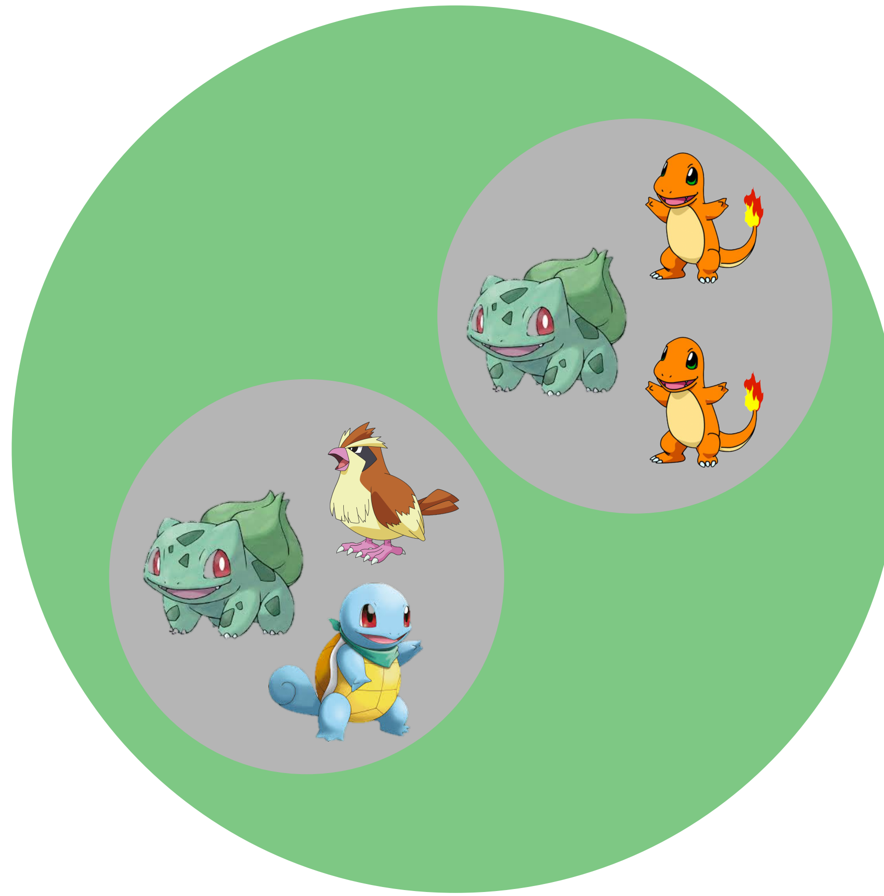
Total Richness = 4



Total Richness = 5

Average Richness = 4.66

Region 2

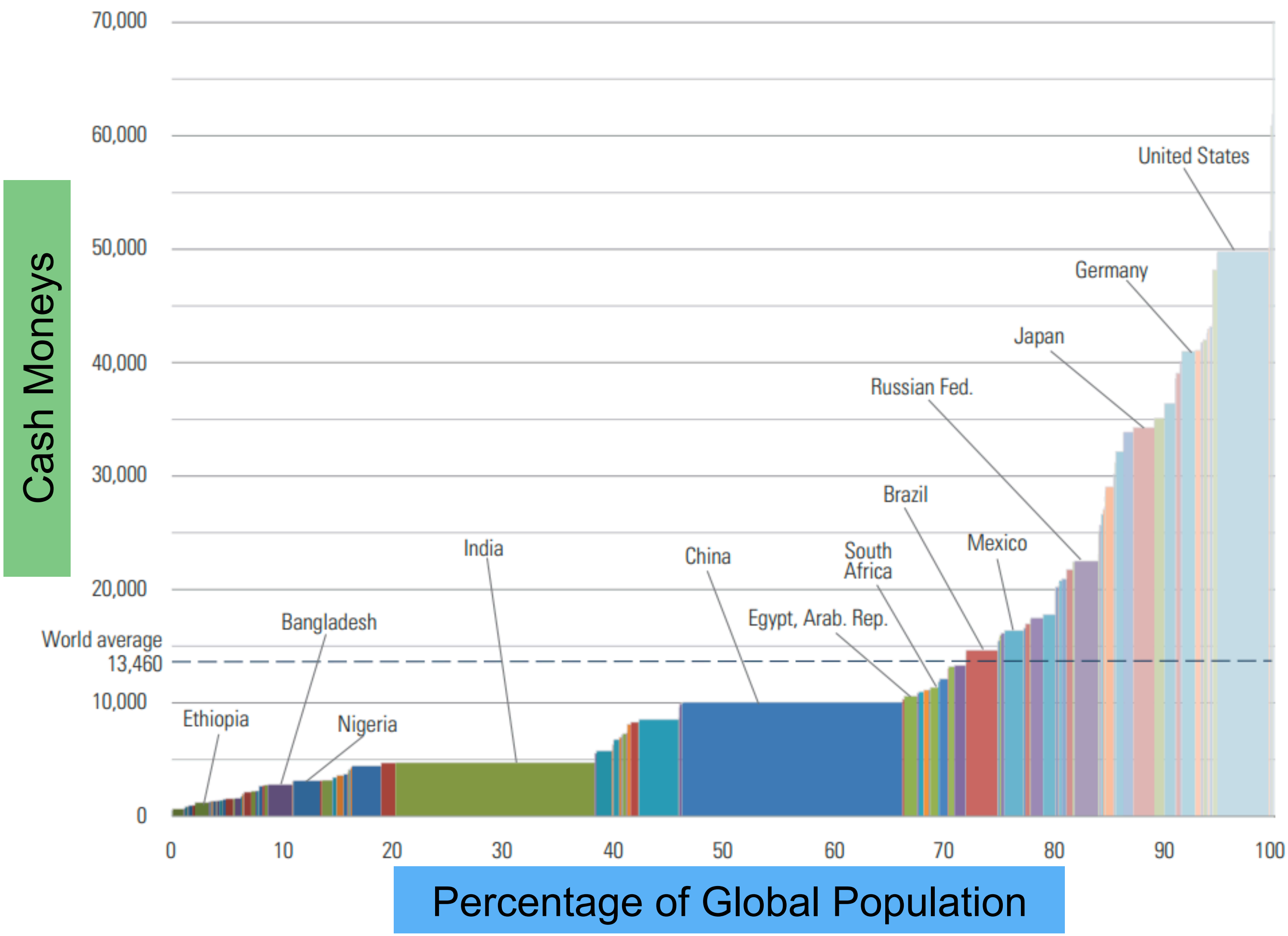


Total Richness = 4

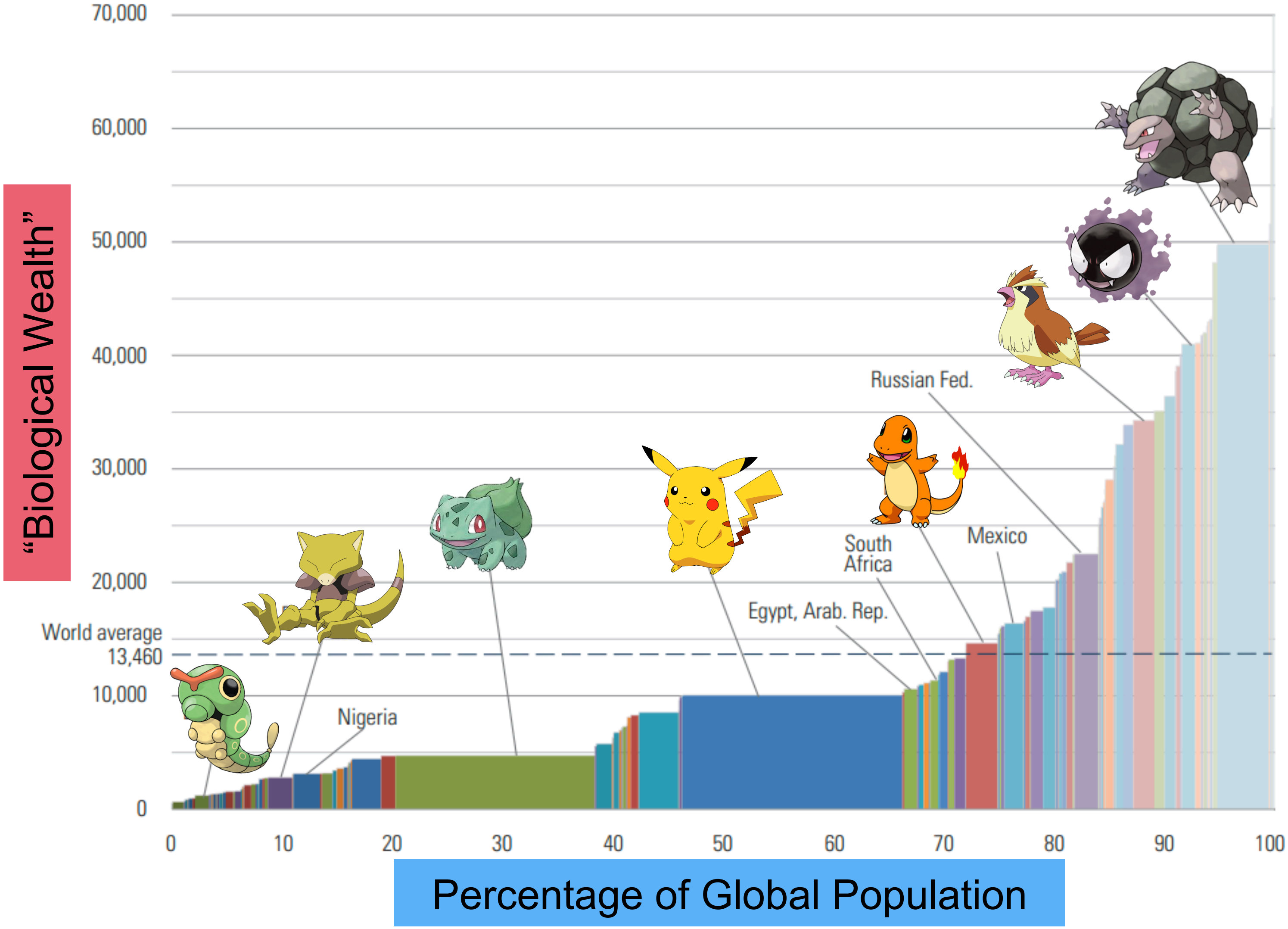
The drawbacks and best solution

- You have to standardize down to the smallest sample, which means you may have to throw out a huge percentage of your data.
- The best solution is sample evenly in the first place. This means that proper experimental design and forethought is extremely important for biodiversity analyses.
- The species-area effect doesn’t matter as much if you collect enough data such that you are close to the asymptote.

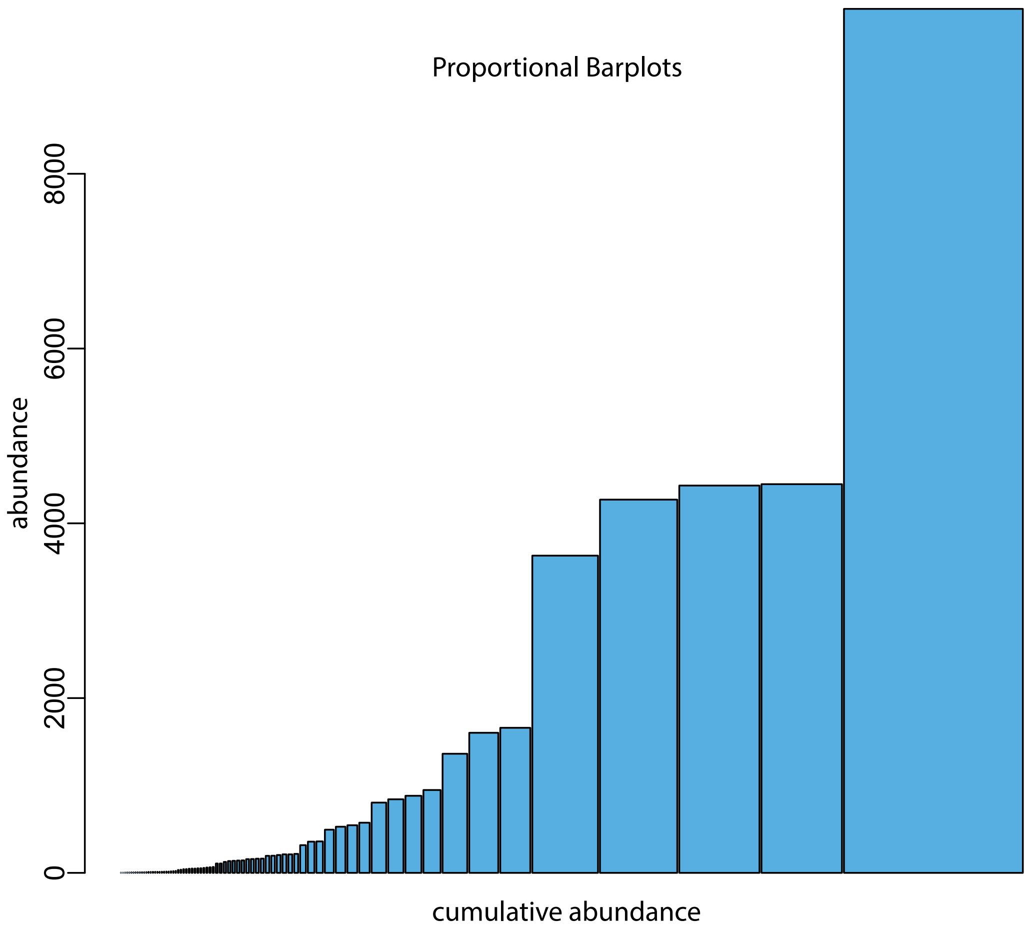
Income inequality



Income inequality



Biological inequality



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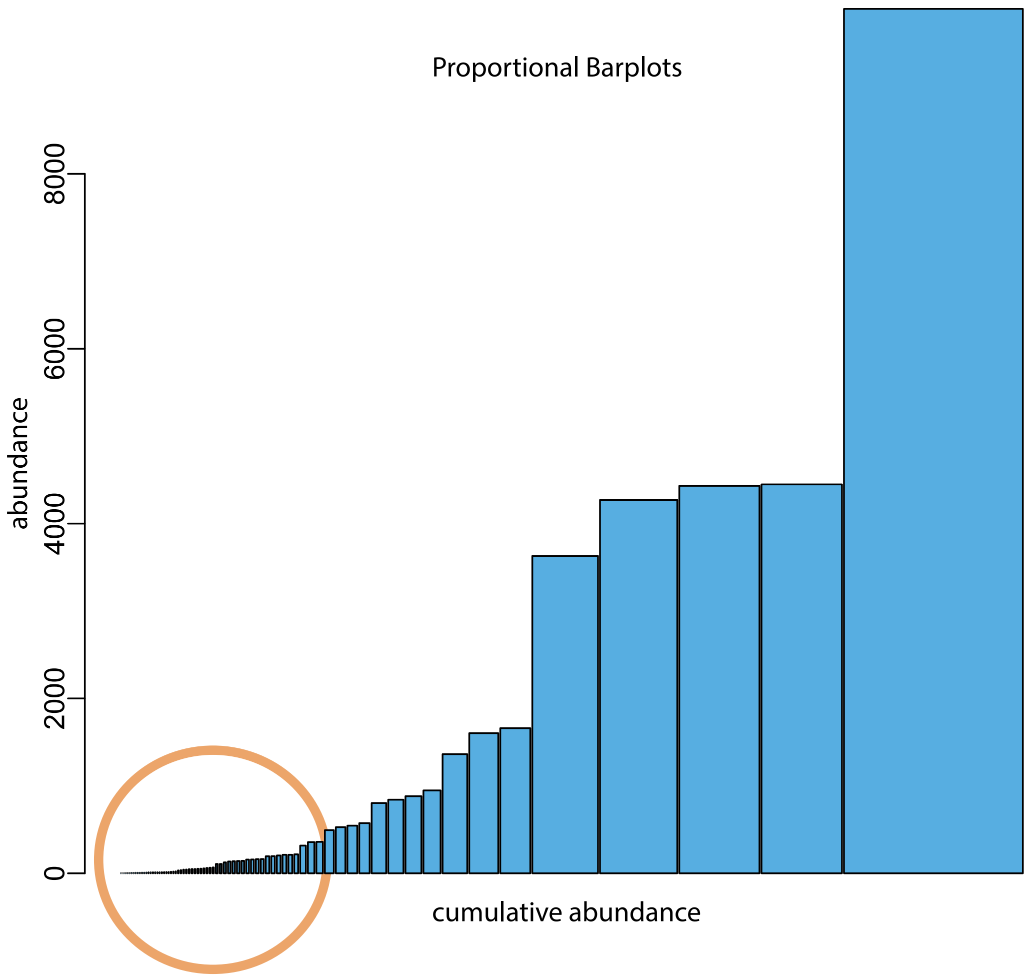

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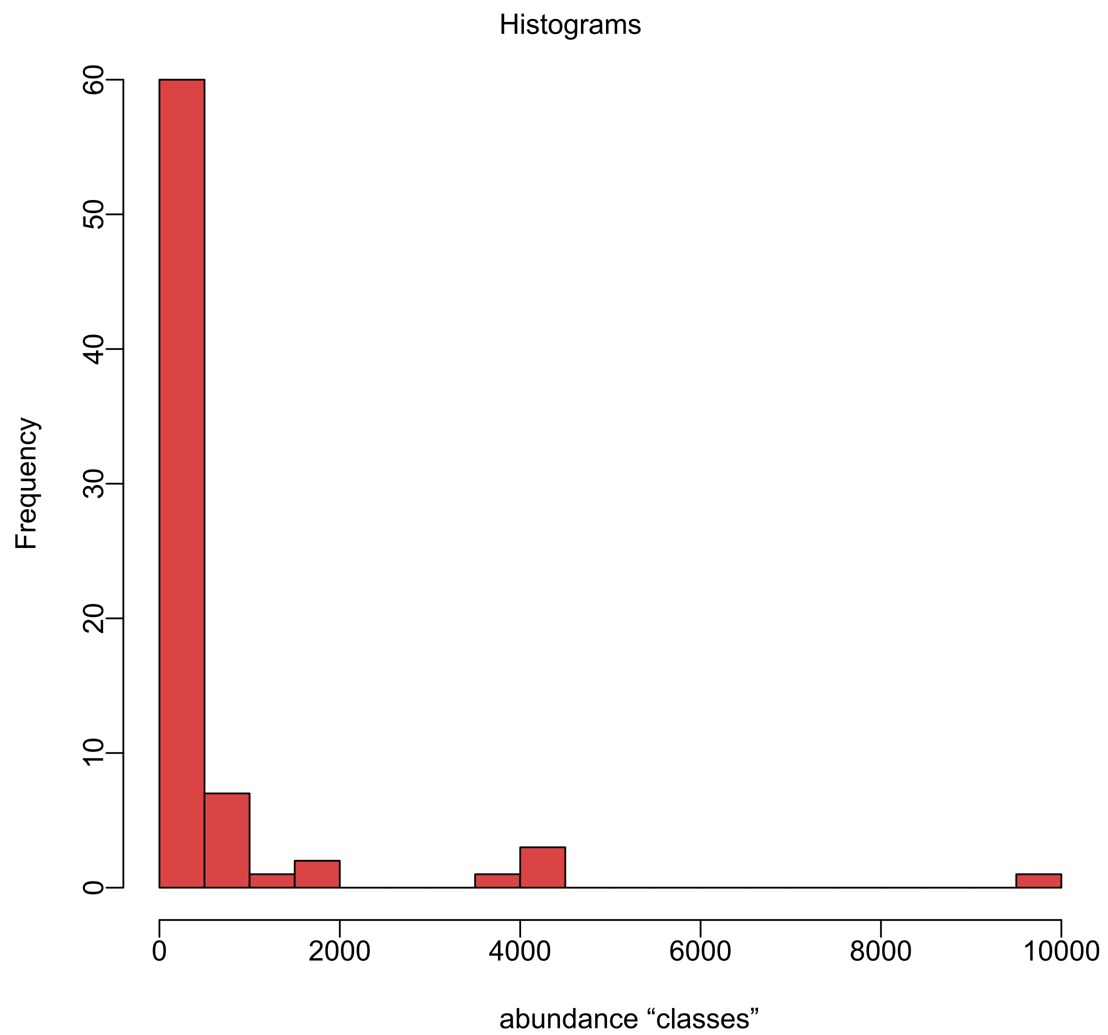

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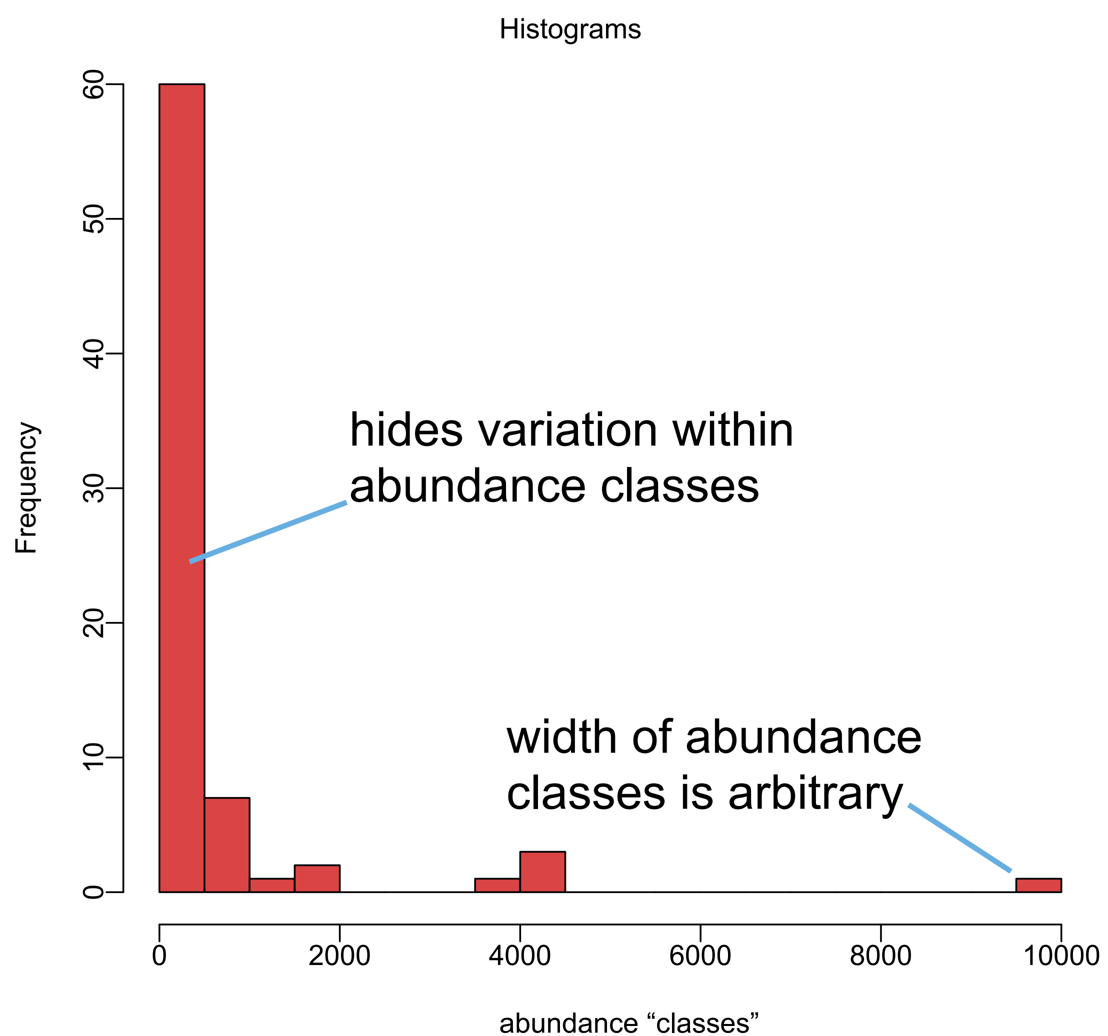

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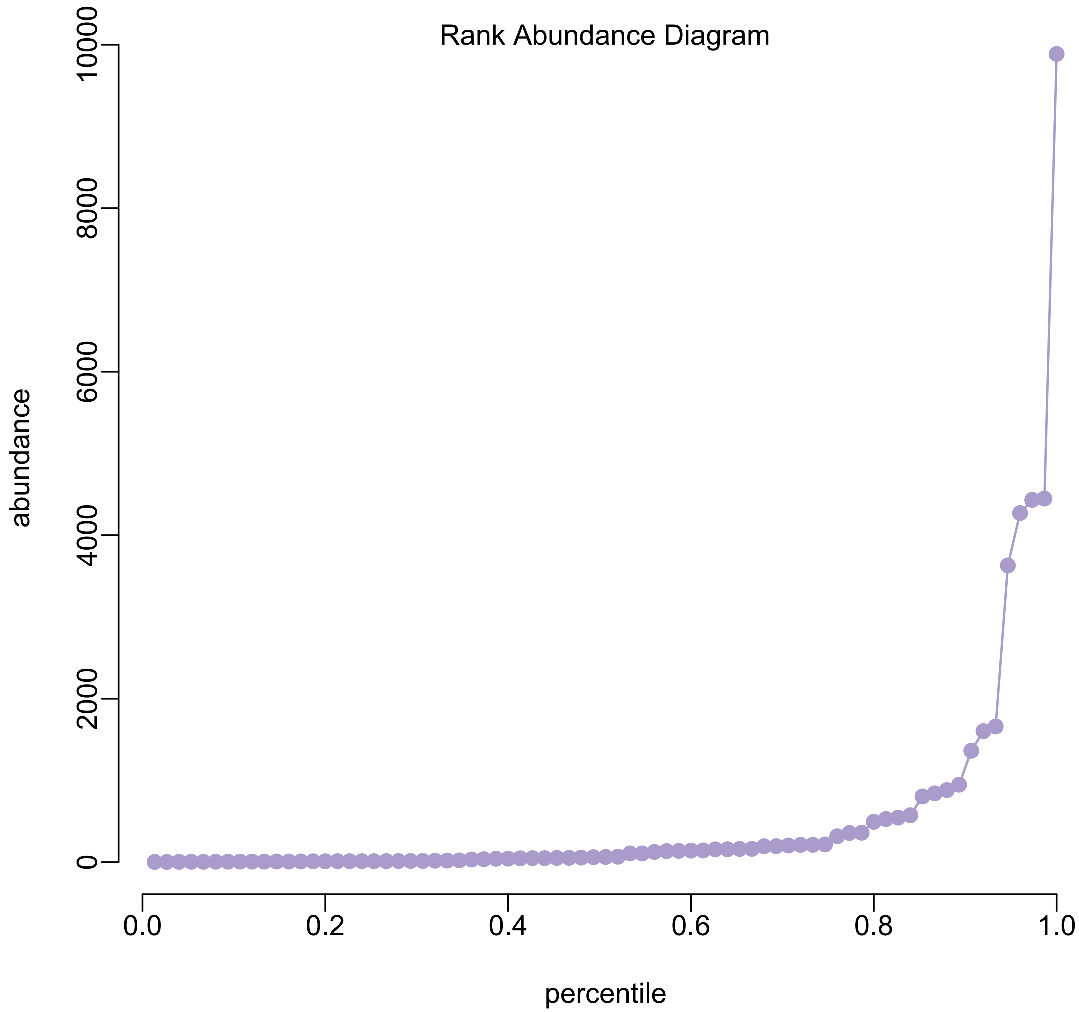
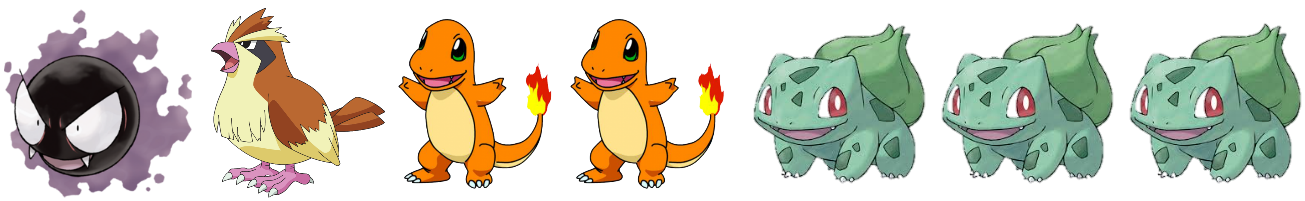
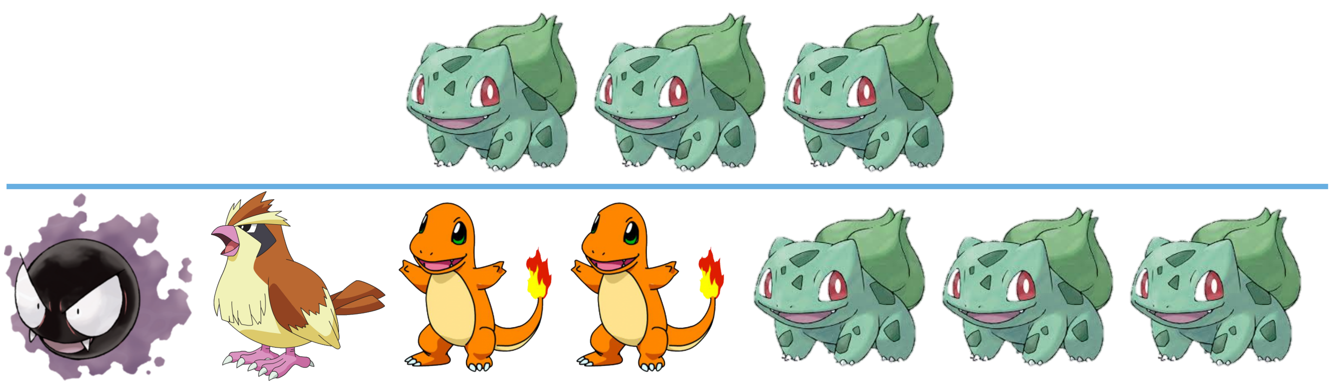


Evenness metrics

- Berger-Parker Index
  - The abundance of the most common species divided by the total abundance of all species.

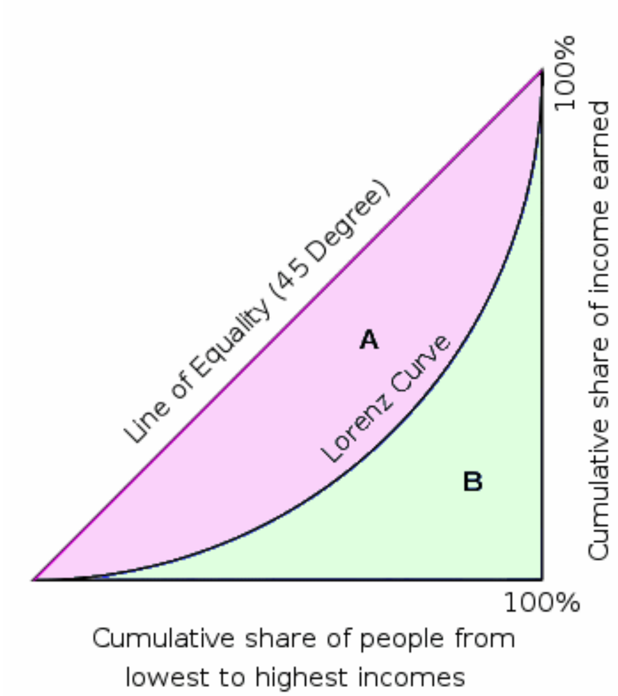




$$= \frac{3}{7}$$

Evenness metrics

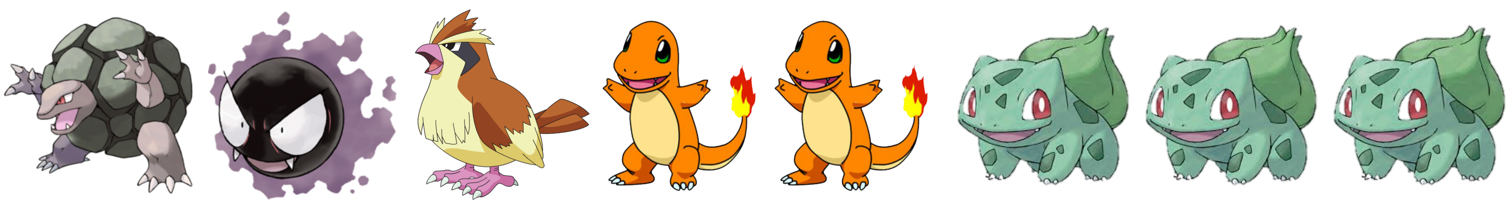
- Gini Coefficient
  - How economists measure income inequality.
  - Ranges form zero (perfect inequality) to one (perfect equality)
  - Called Simpson's Index in ecology
  - It's inverse is PIE (probability of interspecies encounter)



Evenness metrics

$$\sum\left(\frac{n}{N}\right)^2$$

- Gini-Simpson Coefficient



N = total number of individuals = 8

 $n = 3$

 $n = 1$

 $n = 2$

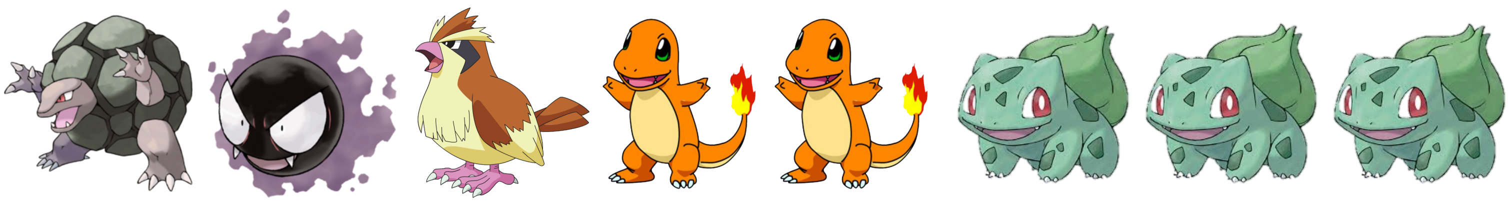
 $n = 1$

 $n = 1$

Evenness metrics

$$1-\sum\left(\frac{n}{N}\right)^2$$

- Gini-Simpson Coefficient



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```
Abundances<-c(3,2,1,1,1)
1 - sum( (Abundances/8) ^2)
[1] 0.75
```

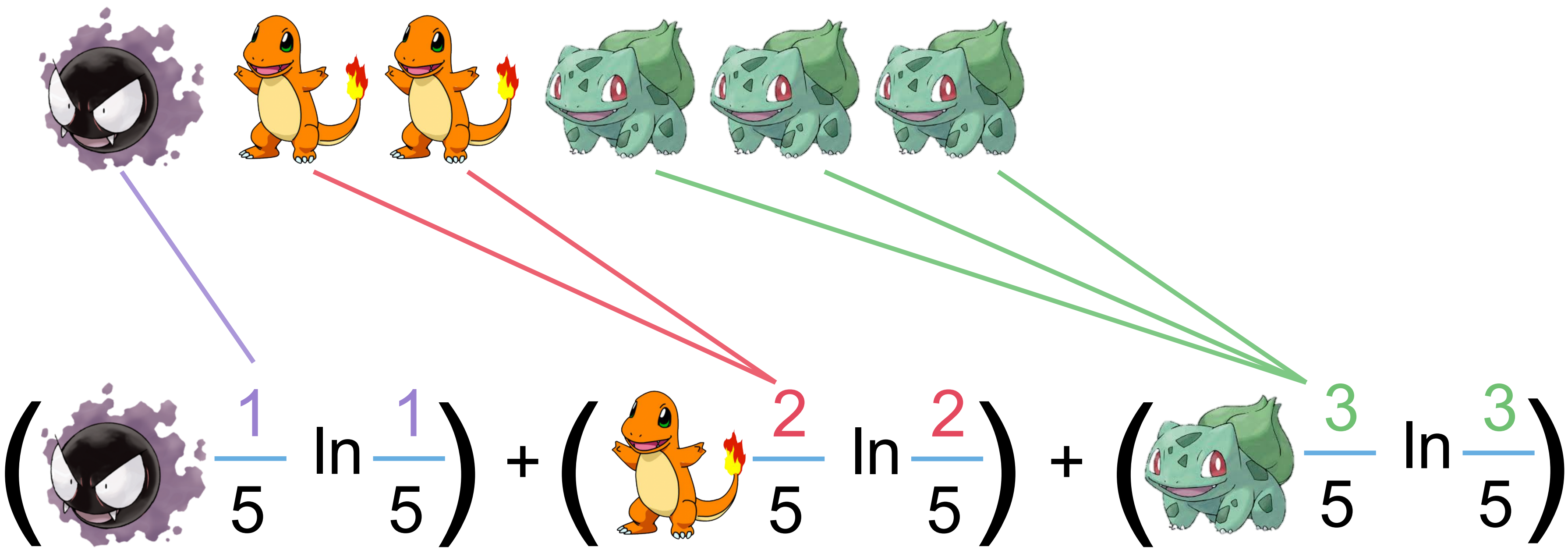
The dual-concept view of biodiversity

- Biodiversity is a mixture of richness and evenness.
  - People dislike richness because of the species area-effect issue.
  - Gini-Simpson is a biodiversity measure under this paradigm, rather than a measure of evenness/inequality.
  - The dual-concept measure views biodiversity as a measure of biological complexity (potential number of ecological interactions).

The most common metric

$$-\sum \frac{n}{N} \ln \frac{n}{N}$$

- Shannon’s entropy, Shannon’s Information Index
  - Sometimes called Shannon-Wiener, Shannon-Weiner, or Shannon-Weaver… all of those are wrong.



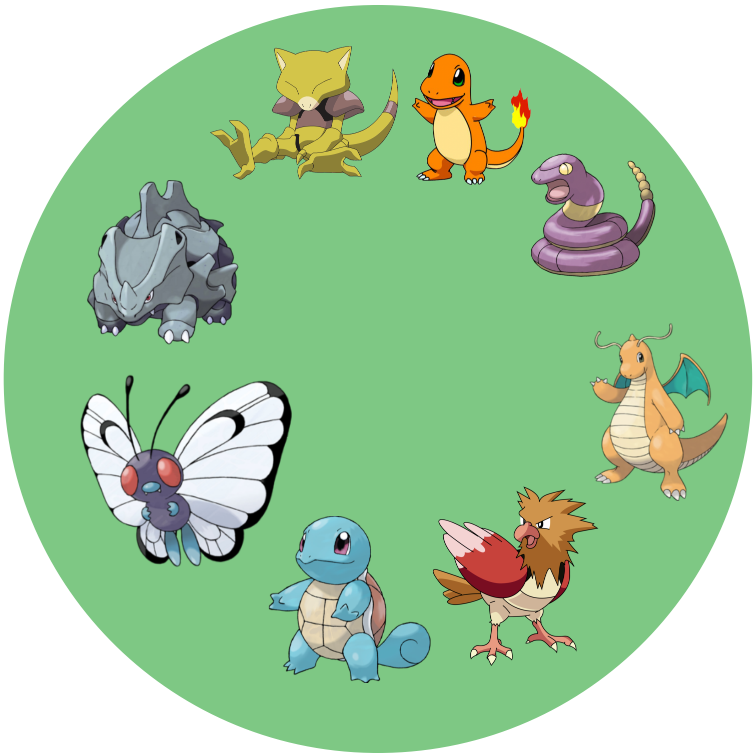
Why dual-concept makes no sense

1. No shared species between regions
2. All species are equally abundant

Region 1

Regional Richness = 1,000,000

Region 2



Regional Richness = 1,000,000

Why dual-concept makes no sense

Shannon's Index = 14.5

Region 1

Regional Richness = 1,000,000

Region 2

Regional Richness = 1,000,000

Why dual-concept makes no sense

Old Index = 14.5
New Index = 13.8
= <5% drop

Region 1

Regional Richness = 1,000,000

Regional Richness = ☠

Doubling property

- We can convert these entropy/information/pseudo-evenness metrics such that they have Hill's (1973) doubling property.
- If region A is twice as diverse as region B, then we would need to to double the diversity of region B to equal A.

DIVERSITY AND EVENNESS: A UNIFYING NOTATION AND ITS CONSEQUENCES[1]

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Abstract. Three commonly used measures of diversity, Simpson's index, Shannon's entropy, and the total number of species, are related to Rényi's definition of a generalized entropy. A unified concept of diversity is presented, according to which there is a continuum of possible diversity measures. In a sense which becomes apparent, these measures provide estimates of the effective number of species present, and differ only in their tendency to include or to ignore the relatively rarer species. The notion of the diversity of a community as opposed to that of a sample is examined, and is related to the asymptotic form of the species-abundance curve. A new and plausible definition of evenness is derived.

Hill numbers

- Hill showed that Richness, Simpson's D, and Shannon's H are actually all variations of a single equation!

$$\left(\sum\left(\frac{n}{N}\right)^{q}\right)^{\frac{1}{(1-q)}}$$

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$q = 0 =$ Richness

$q = 1 = e^{\text{Shannon's Entropy}}$

$q = 2 = \dfrac{1}{\text{Gini-Simpson}}$

$q = \infty =$ Berger-Parker Evenness Index

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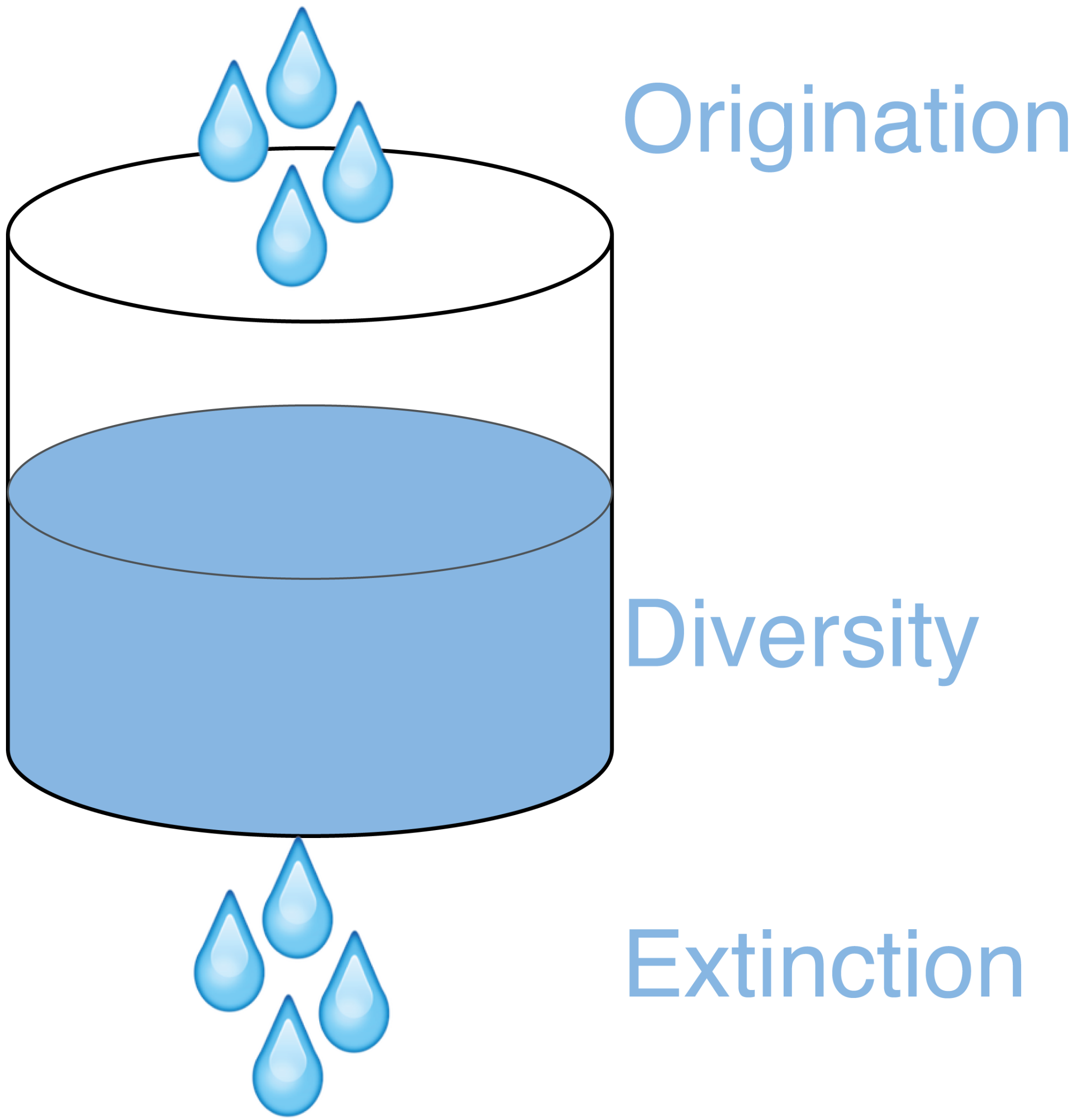
Extinction and origination rate



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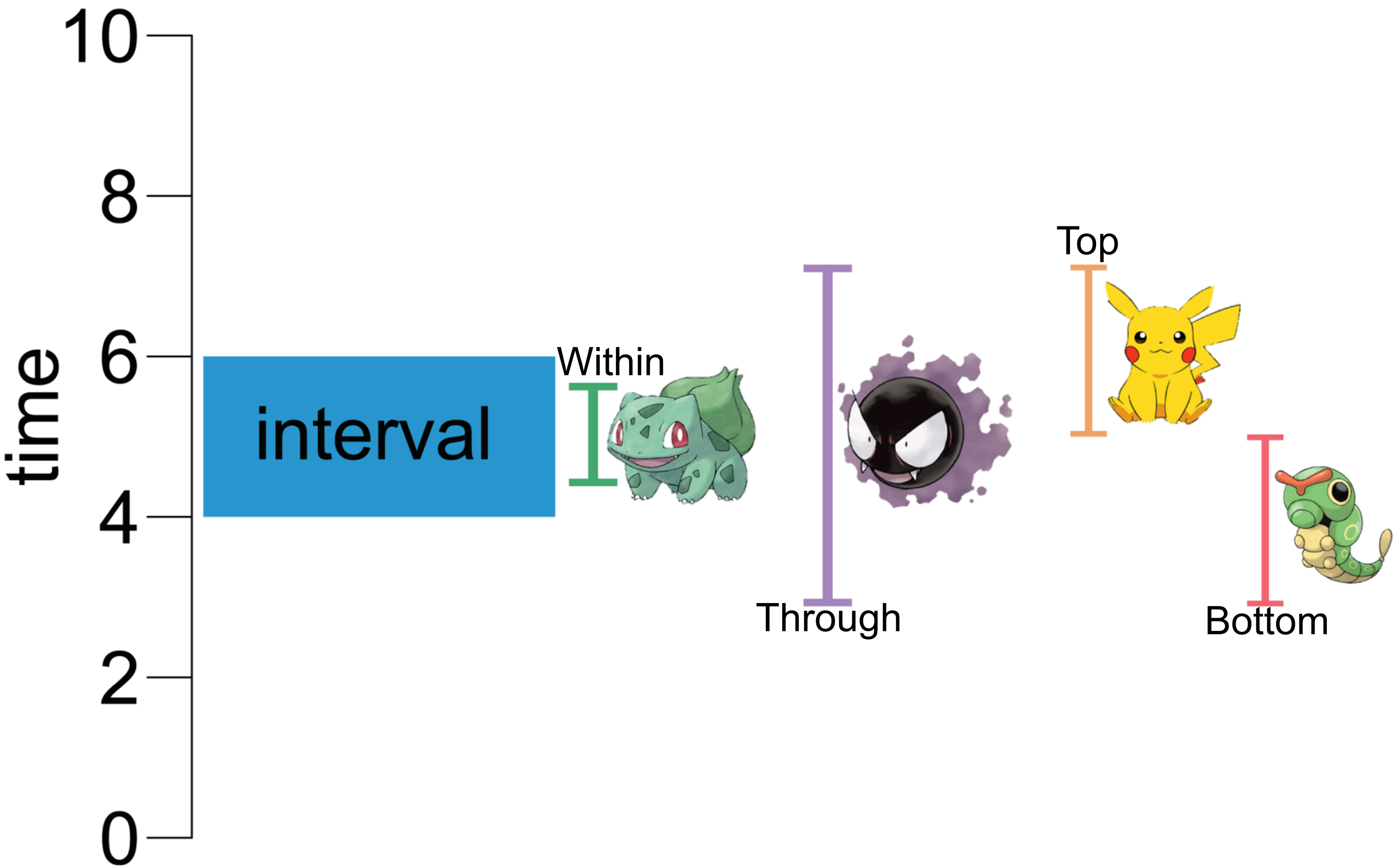
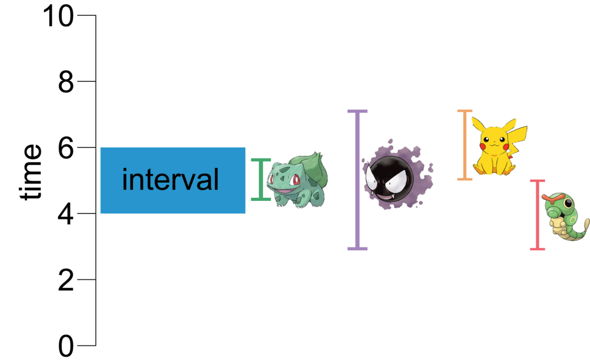


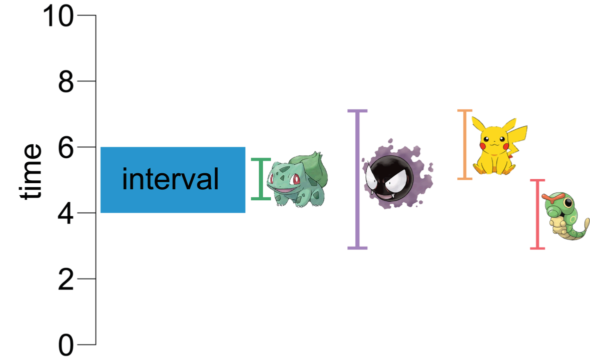
Basic definition



$$\text{Percent origination per year} = \frac{\dfrac{\text{within} + \text{top}}{\text{within} + \text{top} + \text{bottom} + \text{through}}}{\text{Interval start} - \text{interval end}}$$

$$\text{Percent extinction per year} = \frac{\dfrac{\text{within} + \text{bottom}}{\text{within} + \text{top} + \text{bottom} + \text{through}}}{\text{Interval start} - \text{interval end}}$$

Fancy definition



$$\text{estimated per-capita origination rate} = \frac{-\ln\left(\frac{\text{through}}{\text{top}}\right)}{\text{interval start} - \text{interval end}}$$

$$\text{estimated per-capita extinction rate} = \frac{-\ln\left(\frac{\text{through}}{\text{bottom}}\right)}{\text{interval start} - \text{interval end}}$$