

Analysis of Anuran Biodiversity Across Latitude Bands

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Assignment 1 - BINF 6210: Software Tools



Anurans, a key indicator taxon, are experiencing species loss worldwide



Amphibians are one of the most threatened classes of organisms in the animal kingdom, with the list of species at risk of extinction continuing to grow (Stuart et al., 2004, IUCN, 2004, IUCN, 2023).

- As habitat loss and climate change continue to alter ecosystems, amphibians are increasingly exposed to suboptimal conditions, including drier environments that push species to their physiological limits across the globe (Wu et al., 2024)
- Anurans are the largest amphibian order, comprising approximately 88% of all recorded amphibian species (IUCN, 2023).
- As indicator species, frogs serve as markers for ecosystem health, making their distribution patterns of particular interest (Simon et al., 2011)



What is the relationship between anuran biodiversity and latitude?

- To assess biodiversity patterns of anurans, the current analysis primarily aims to determine whether anuran species follow the latitudinal diversity gradient (LDG).
 - To explore this question, barcode index numbers (BIN) from BOLD are used as a proxy for species
 - Prior to determining BIN richness, an important prerequisite analysis explores sampling completeness of anurans across different latitude bands



It is hypothesized that species richness of anurans will be highest at the equator

- The latitudinal diversity gradient describes a widespread pattern in global species richness, where biodiversity peaks in the tropics and declines with increasing distance from the equator (Hawkins, 2001).
- This pattern has been observed in anurans as well, supporting the prediction that if species richness is highest at the equator, there will be a negative relationship between species richness and distance from the equator (Wiens et al., 2009).
- If this pattern is not observed, it may be due to incomplete sampling data reported in BOLD, or an indication of a change in typical diversity patterns for anuran species that warrants further investigation.



The workflow for the analysis moves from data extraction through statistical analysis to visualization

Data Extraction

Data Investigation

Data Cleaning

Statistical Analysis

Visualization

Use the BOLD API to retrieve data points on specimens of order Anura

Packages used:

- readr

Explore data types and distributions and counts for latitude, unique BINs, BINs per country

Packages used:

- dplyr
- stringr

Filter NA values for latitude, longitude, BIN and country, then create latitude bands

Packages used:

- dplyr
- stringr
- janitor

Explore sampling completeness and extrapolate for asymptotic richness, then look at statistical differences

Packages used:

- dplyr
- vegan
- iNEXT

Visualize specimens, sampling completeness, and estimated asymptotic richness

Packages used:

- maps
- vegan
- ggplot2

Figure 1. Anuran records span the globe and a broad range of latitudes

Distribution of Anura Specimens Collected

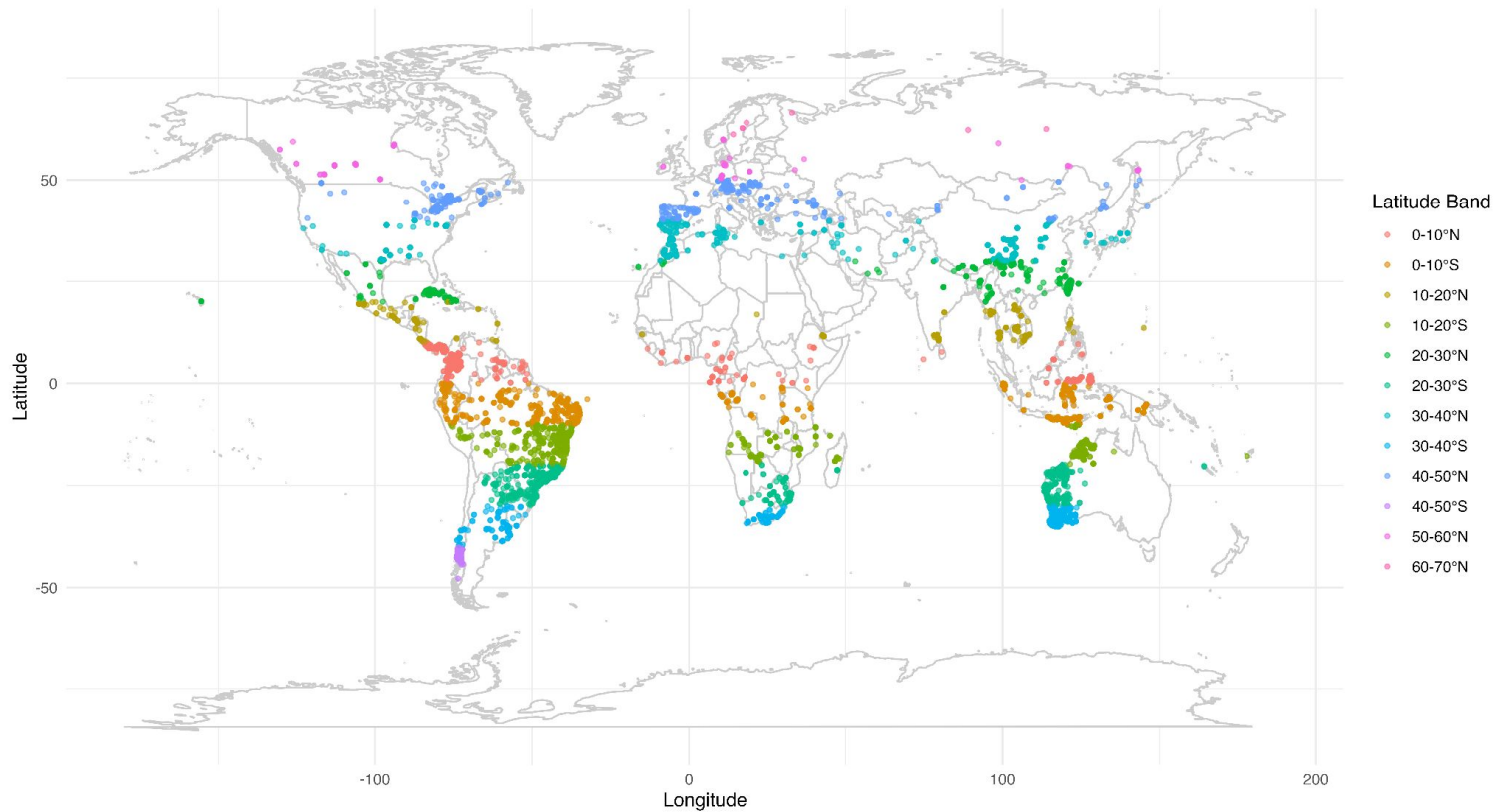


Figure 2. Rarefaction curves indicate incomplete sampling for some

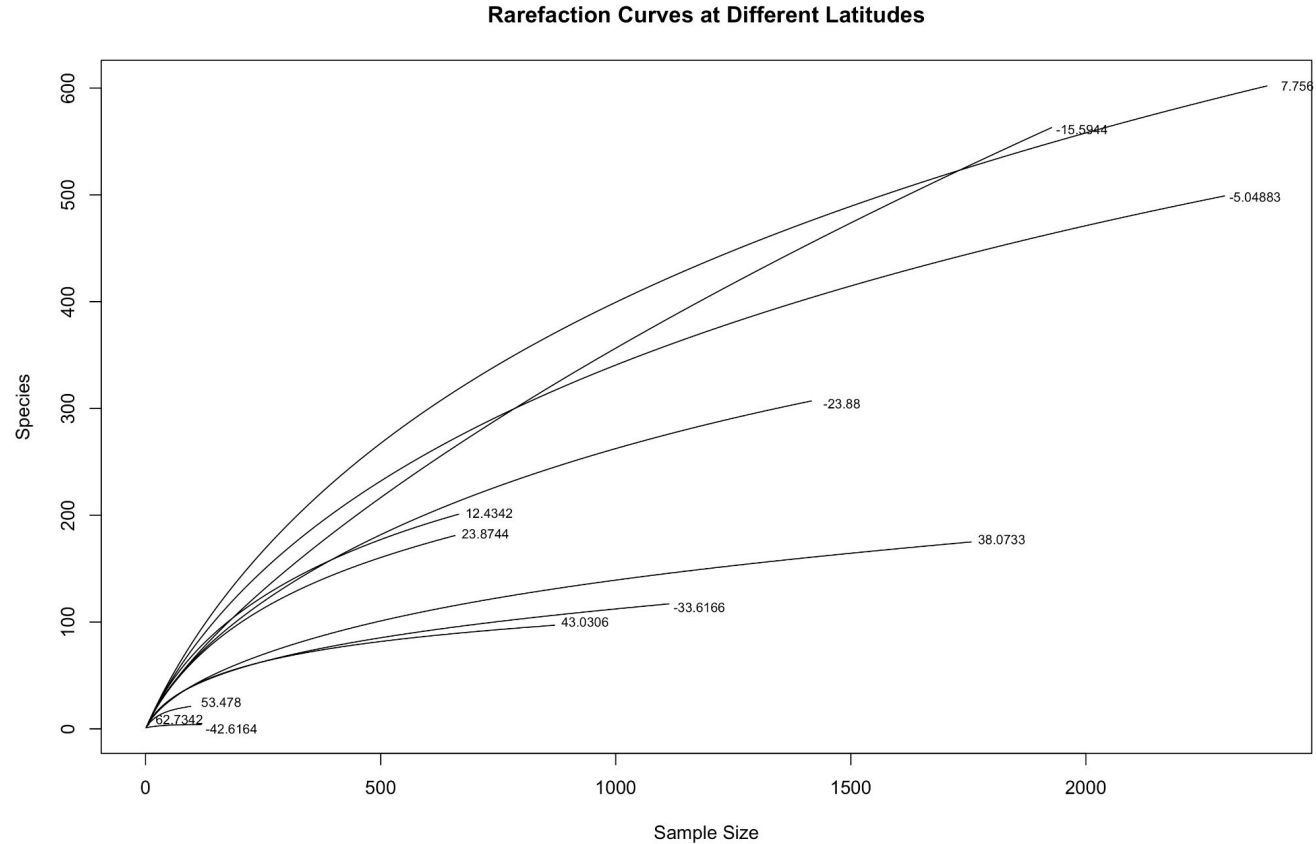
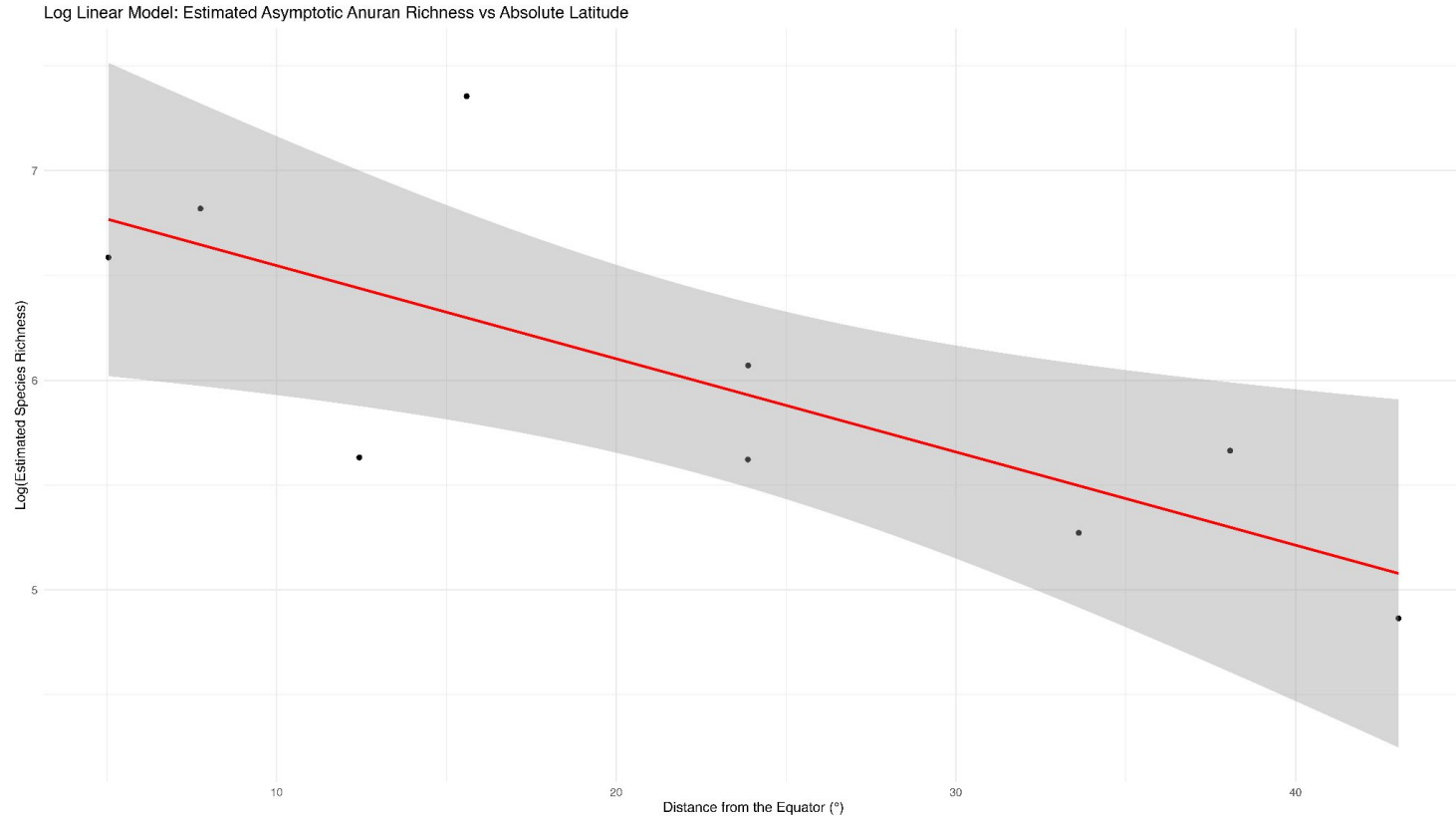


Figure 3. Log-linear model indicates slight negative relationship between anuran species richness and latitude





Analysis results reveal insights about sampling and species richness patterns at different latitudes

- Figure 1 displays the distribution pattern of all recorded anuran specimens in BOLD, by latitude band.
 - The figure indicates global sampling of anurans
 - Interestingly, specimen counts are higher near the equator and in the southern hemisphere, particularly in South America
 - Specimens seem to decline moving away from the equator, especially in the northern hemisphere
- Figure 2 shows rarefaction curves for the median of each latitude band.
 - The number of samples per latitude band is uneven, shown by the extreme differences in the curves
 - Latitudes 62.7°, 53.4°, and 42.6° have very little sampling coverage, while 38.0°, 33.3°, and 43.0° seem to reach almost complete coverage
- Figure 3 displays the results of a linear regression where estimated species richness was log-transformed.
 - A non-significant ($p = 0.279$) negative relationship between estimated asymptotic species richness and distance from the equator

Low sampling coverage and latitude band widths may explain the weak association

- Although the trend was not significant, the relationship between estimated asymptotic richness and distance from the equator followed the negative relationship that was predicted.
 - A limitation of the analysis was the incomplete sampling in many of the latitude bands, which may have led to an unreliable estimate of asymptotic species richness.
 - Of the 42,000 records in the original data, many records were missing geographical data. If latitude and longitude data were imputed, it may be sufficient for rarefaction, or estimating asymptotic richness.
 - Additionally, the latitude band of 10° was arbitrarily chosen for this analysis. An interesting subsequent analysis may look at the ideal latitude band-width to use in a similar study.



Geographic range shifts of anurans due to habitat loss and climate change may explain the weak association

- As habitat fragmentation and climate change continue to threaten anuran species' existence, it may be the case that the weak association between latitude and anuran species richness is due to expanding geographic ranges.
 - Colletta and Vasconcelos (2025) describe possible changes in geographic range that may occur for some Brachycephalidae anurans. They predict that while many species will likely go extinct due to ecosystem changes, some may have the capacity to expand into other regions.
- An investigation of ranges leveraging predictive models could be used to explore whether anuran species-richness patterns are deviating from the expected LDG, and determine whether species are more likely to expand their ranges or go extinct.



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- https://www.youtube.com/watch?v=bUFdei_zl88
- <https://www.youtube.com/watch?v=h3MLWK9IJ4A&t=43s>
- https://www.youtube.com/watch?v=_OEdFjc1D9I&t=334s
- <https://www.datacamp.com/tutorial/gg-pLOT>
- <https://condor.depaul.edu/sjost/it223/documents/normal-plot.htm>
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- <https://www.statology.org/how-to-choose-between-mean-median-or-mode-for-imputation/>
- <https://academicweb.nd.edu/~rwilliam/stats3/OrdinalIndependent.pdf>
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