Exploring Latitude and Bumblebee Diversity

Bombus BIN Richness Across the Northern Hemisphere

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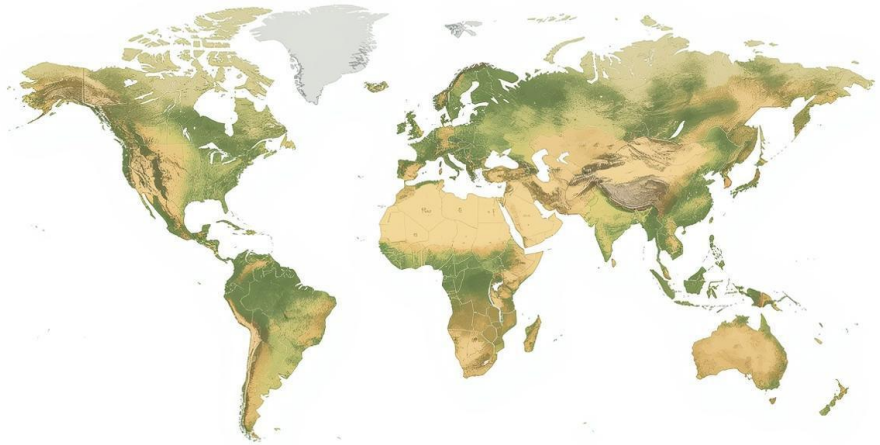
BINF 6210

Background: Global Biodiversity and Latitude

Exploring ecological patterns in Bombus species

- Biodiversity patterns often follow a latitudinal gradient (Latitude is a proxy for environmental factors such as temperature and day length), with species richness changing from equator to poles.
- This gradient reflects complex drivers; climate, productivity, and environmental variability (Hillebrand, 2004).
- Bumblebees (Bombus) are distributed across diverse climates, making them a powerful model to explore latitudinal patterns in genetic diversity.
- DNA barcoding (COI sequences) allows consistent comparisons of diversity using standardized BINs.



Exploratory Aim

How does Bombus (bumblebee) BIN richness vary across latitude in the Northern Hemisphere?

- The BOLD Systems database offers a large, standardized collection of Bombus barcode records across countries and climates.
- Exploring BIN richness vs. latitude can reveal large-scale biodiversity patterns and sampling biases in publicly available barcode data.
- This project focuses on visual, descriptive analysis, generating insights to guide future hypothesis-driven studies.
- Scope & Approach: Exploratory. not testing a hypothesis.
- visualizing and summarizing genetic diversity patterns geographically

Data Source & Taxon

Filtering Criteria and Justification

STEPS FOR DATA INTEGRITY

The dataset was filtered based on the following criteria:

- Geographic location relevance
- Taxonomic accuracy for Bombus
- Quality assurance for data reliability
- These steps ensure reproducibility and support the study's focus on latitudinal diversity in Bombus populations.

01 **DATA SOURCE**

The Barcode of Life Data Systems (BOLD) provides a comprehensive database of genetic data, enabling researchers to access diverse biological information essential for studying species like Bombus.

02 **STUDY TAXON**

Bombus, commonly known as bumblebees, are vital pollinators. Their ecological significance and sensitivity to climate change make them an ideal subject for investigating latitudinal diversity patterns.

03 **FILTERING**

Data filtering criteria ensure the accuracy and relevance of results. By focusing on specific environmental parameters, we enhance the reproducibility and reliability of the findings related to Bombus.

Methods Overview

1. **Data Import & Standardization**
   - Imported BOLD Bombus dataset (read_tsv)
   - Standardized key fields (BIN, coordinates, country)
2. **Quality Control & Filtering**
   - Removed invalid or missing coordinates
   - Focused on Northern Hemisphere (lat > 0)
   - Retained only entries with valid BINs
3. **Exploratory Analysis**
   - Generated latitude histogram (QC) for sampling bias
   - Mapped georeferenced records using sf + rnaturalearth
   - Calculated BIN richness by 5° latitude bands
4. **Visualization & Outputs**
   - Created 3 key figures with ggplot2
   - Optional coverage summary using iNEXT (sample completeness)
   - Saved results & session info for reproducibility

Tools and Packages Used:

- R, tidyverse (dplyr, tidyr, ggplot2, readr)
- sf + rnaturalearth: geographic data visualization
- iNEXT: biodiversity completeness (optional novelty)

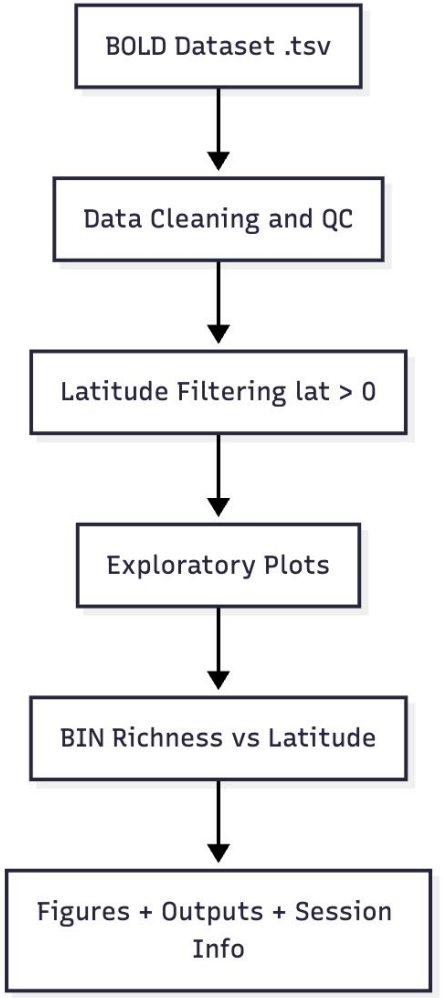


Figure 1: Latitude Distribution

- Most Bombus barcode records are concentrated between 40°N and 60°N, with few records in tropical or Arctic regions. This pattern reflects sampling bias toward temperate zones; especially North America and Europe.
- The histogram confirms that geographic coverage is uneven, which must be considered when interpreting richness patterns.
- Data filtered to include only valid BINs and latitudes > 0. Histogram created with ggplot2 using 40 bins.

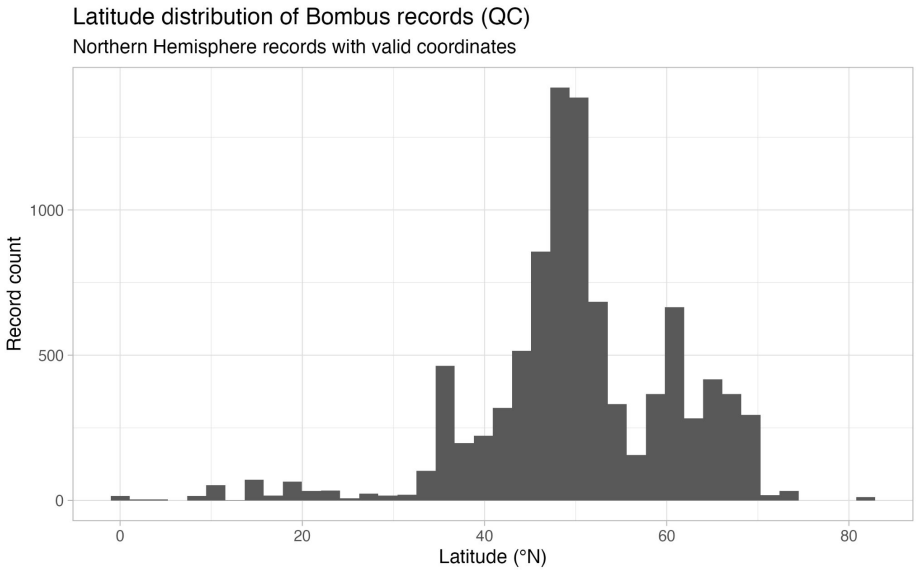


Figure 1: Latitude distribution of geo-referenced Bombus barcode records. Sampling density is highest in temperate regions (40°–60°N).

Figure 2: Spatial Map of Records

- Bombus records are densely clustered in North America and Europe, with few from Asia or Arctic regions. Sparse coverage in central Asia and high-latitude zones indicates uneven global sampling effort.
- Despite gaps, records span a broad latitudinal range (~10°N–75°N), suitable for exploring diversity patterns.

Map plotted using sf + rnaturalearth

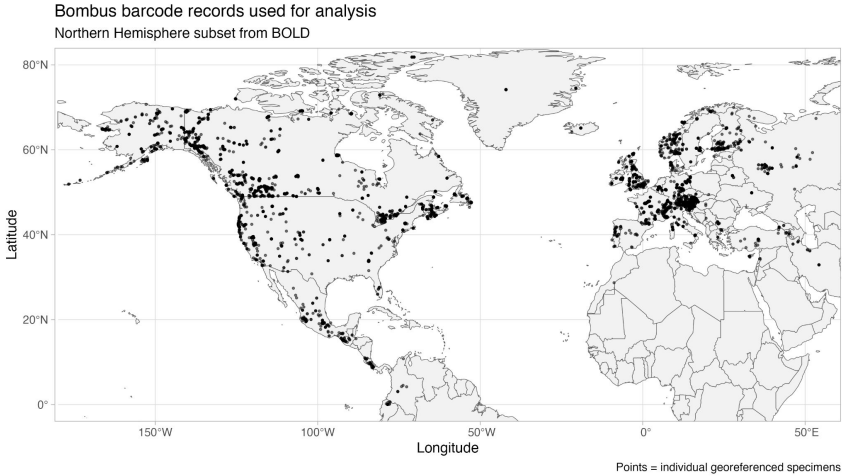


Figure 2: Spatial distribution of Bombus COI barcode records (Northern Hemisphere). Darker clusters represent regions with intensive sampling effort.

Figure 3: BIN Richness vs. Latitude

- BIN richness shows a clear mid-latitude peak around 35°- 45° N, tapering toward tropical and Arctic regions.
- The trend suggests a hump-shaped diversity pattern, consistent with many macroecological studies. Because record counts also peak in this range, part of the pattern may reflect sampling intensity, not purely biology.

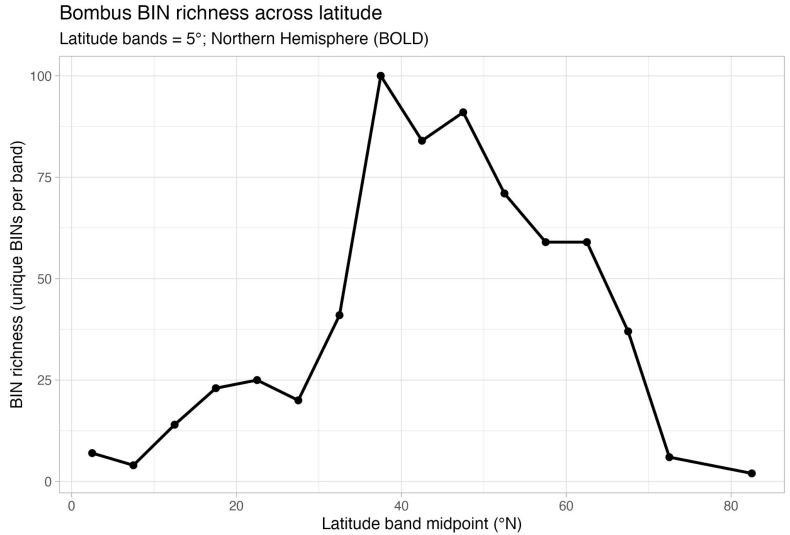


Figure 3: BIN richness of Bombus across 5° latitude bands (Northern Hemisphere). A mid-latitude maximum is evident, though influenced by uneven sampling.

Findings

01 **Ecological Diversity**

Bombus BIN richness peaks at mid-latitudes (35°–45° N), suggesting temperate zones host greater genetic and species diversity.

02 **Climate Impact**

This pattern mirrors the classical latitudinal diversity gradient, though not perfectly monotonic; possibly reflecting complex climatic effects.

03 **Sampling Bias**

The mid-latitude richness maximum likely reflects a blend of ecological reality and sampling intensity, as most barcode records come from North America and Europe.

Limitations

01 **Sampling Bias**

Sampling across regions is uneven (underrepresentation of Asia and Arctic zones).

02 **Ecological Gradient**

BINs are genetic proxies, not exact species; over- or under-splitting may affect richness estimates.

Exploratory trends align with known ecological gradients but highlight the influence of sampling bias in barcode datasets.

Conclusions & Next Steps

Richness Insights

BIN richness in Bombus shows a mid-latitude diversity peak, roughly between 35°N–45°N. This pattern is consistent with ecological expectations that temperate zones harbor higher diversity but also highlights the role of sampling bias in open databases like BOLD. Exploratory results demonstrate that barcode data can reveal large-scale biodiversity patterns, even with simple visualization-based methods.

Next Steps

1. Incorporate environmental variables (e.g., mean annual temperature, habitat type) to test ecological drivers statistically.
2. Apply sampling-standardization methods (e.g., rarefaction or iNEXT coverage estimates) for fair richness comparison.
3. Expand analyses to other pollinator groups (e.g., Apis, Megachile) to evaluate whether similar latitudinal trends occur.

References

1) Ratnasingham, S., & Hebert, P. D. N. (2013). *BOLD: The Barcode of Life Data System (v4).* Molecular Ecology Resources, 13(5), 969–977. https://doi.org/10.1111/1755-0998.12194
2) Hillebrand, H. (2004). *Latitudinal diversity gradients are pervasive across taxa.* Global Ecology and Biogeography, 13(6), 471–478. https://doi.org/10.1111/j.1466-822X.2004.00114.x
3) Barcode of Life Data System (BOLD). (2025). *Bombus* Taxonomy Browser. Retrieved from https://bench.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxon=bombus&searchTax=Search+Taxonomy