

Article

Mammalian Assemblage Differentiation Across the Anatolian Diagonal: Evidence Consistent with a Biogeographical Filtering Effect

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Abstract

The Anatolian Diagonal is a major mountain system in Türkiye, yet its community-level structuring effect on mammalian assemblages remains understudied. This study provides a comprehensive inventory of the mammal fauna in Ağrı Province and evaluates the biogeographical role of the Diagonal by comparing 14 provinces. Field surveys in Ağrı (2014–2015) across 228 localities identified 16 medium- and large-sized mammal species (705 individuals), including *Felis silvestris* as a new provincial record. Community structure followed a lognormal distribution (AIC: 95.29). Regional patterns were analysed using presence–absence data on medium- and large-sized mammals using alpha and beta diversity indices, PERMANOVA, and Partial Canonical Correspondence Analysis (PCCA). PERMANOVA revealed significant differences in mammal assemblages between the western and eastern sides of the Diagonal ($F = 3.08$, $R^2 = 0.19$, $p = 0.007$). Beta diversity was driven predominantly by species turnover (83.8%) rather than by nestedness (16.2%). Notably, PCCA confirmed that biogeographical position significantly influenced community variation independently of habitat, elevation, and slope. These findings support a biogeographical filtering effect associated with the Anatolian Diagonal, where species replacement drives diversity patterns. The results emphasize the necessity of trans-regional conservation strategies that account for the distinct faunal compositions across this evolutionary boundary.

Keywords: Anatolian Diagonal; beta diversity; conservation; mammal diversity; Türkiye

1. Introduction

Türkiye's unique position at the confluence of Europe, Asia, and Africa, characterized by diverse ecosystems and varied topography, establishes it as a primary center of mammalian biodiversity within the Palearctic [1,2]. Mammals in this region serve as vital indicators of environmental health and are central to national conservation strategies [3,4]. However, these populations increasingly face anthropogenic threats, including habitat fragmentation, illegal hunting, and land-use changes [5–7].

The foundation of Anatolian mammalogy was established by pioneering researchers who documented the region's initial species richness [8–13]. Although recent studies have expanded our understanding of Turkish fauna—now estimated at approximately 177 wild species—significant knowledge gaps regarding regional distributions persist [14–17], positioning areas like Ağrı Province as critical focal points for biodiversity assessments.

Ağrı Province, located in eastern Türkiye, represents a critical biogeographical focal point situated along the Anatolian Diagonal. It functions as a complex transition zone



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where Siberian and cold-steppe taxa from the Erzurum–Kars Plateau converge with desert-adapted species from the Iğdır–Aralık lowlands and the Van–Hakkari uplands [8–10]. This unique convergence makes the region an essential site for assessing beta diversity—the variation in species composition across space—which serves as a fundamental metric for modern ecosystem management and conservation planning [18–26]. Given that geographical distribution patterns underlie the context in which conservation actions are implemented, monitoring beta diversity at both site and species levels provides critical insights into environmental uniqueness. Consequently, integrating regional monitoring data with metrics of community differentiation is vital for developing trans-regional conservation strategies, particularly in high-priority protected areas [27,28].

The Anatolian Diagonal is a prominent mountain system extending from north-eastern to south-western Türkiye. It serves as a major floristic and faunal barrier, separating Mediterranean–European elements in the west from Irano-Turanian elements in the east. While its influence on the genetic structure and distribution of plants, insects, and herpetofauna is well documented [29–33], studies on its impact on mammal community composition are limited [34,35]. Despite its well-documented role in shaping endemism in plants and herpetofauna, the extent to which this barrier drives turnover in mammal assemblages remains a critical knowledge gap that this study aims to address.

Current research often focuses on individual species ranges rather than community-level beta diversity. It remains unclear whether mammal community differentiation across this boundary is driven by species turnover (species replacement) or by nestedness (where one community is a subset of another). Distinguishing between these patterns is vital; turnover suggests a hard biogeographical transition, whereas nestedness often reflects environmental gradients or habitat harshness.

This study aims to provide a systematic assessment of mammal diversity in Ağrı Province and contextualize it within a broader biogeographical framework. By harmonizing presence–absence data for medium- and large-sized mammals, we aim to (i) test whether mammal assemblages differ significantly between the western and eastern sides of the Anatolian Diagonal, (ii) quantify the relative contributions of turnover and nestedness to overall beta diversity, and (iii) disentangle the relative roles of habitat composition and biogeographical position in structuring mammal communities using constrained ordination and partial canonical correspondence analysis. We hypothesize that mammal assemblages will differ significantly across the Anatolian Diagonal, that beta diversity will be dominated by species turnover, and that biogeographical position will explain a significant portion of community variation independent of habitat composition.

2. Materials and Methods

2.1. Study Area and Biogeographical Context

The study was conducted across a broad longitudinal gradient in Türkiye, encompassing 15 provinces positioned on both the western and eastern sides of the Anatolian Diagonal (Figure 1, Table S1). This mountain system acts as a major biogeographical boundary, and sampling units were categorized into two groups (West and East) to test for compositional shifts in mammal assemblages.

Within this framework, intensive field studies were conducted in Ağrı Province (2014–2015), covering the high-altitude steppes of the eastern Diagonal. The environmental characteristics of the Ağrı study area were quantified using CORINE Land Cover data, revealing a landscape dominated by croplands (44%) and bare lands (31%), followed by shrub lands (22%) and water bodies (2%) (Table 1).

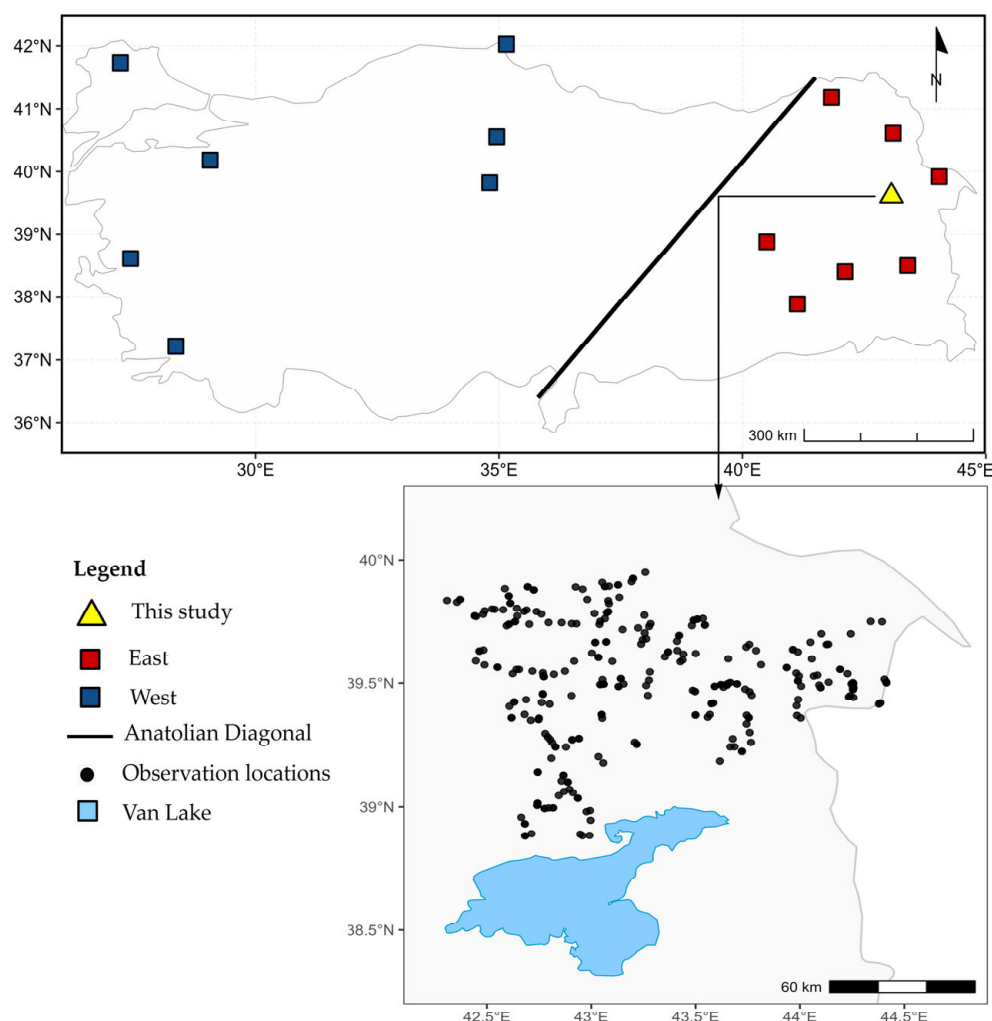


Figure 1. Spatial distribution of the study provinces across Türkiye in relation to the Anatolian Diagonal. Provinces included in the comparative analysis are grouped according to their position relative to the Diagonal (western group in blue; eastern group in red). The solid black line represents the approximate extent of the Anatolian Diagonal as described in previous biogeographical studies. Ağrı Province is highlighted as the focal field-survey area where intensive sampling was conducted during 2014–2015. The inset map shows the distribution of sampling localities within Ağrı Province. This spatial framework underpins the regional comparison of mammalian assemblage composition between the western and eastern sides of the Diagonal.

Table 1. Comparative habitat composition percentages and literature sources for the studied provinces and specific areas, organized by their location relative to the Anatolian Diagonal.

Province/Area ¹	Position	Crop Lands	Forest Land	Shrub Lands	Bare Land	Water Bodies	Data Source
Ağrı	East	43.53	0	22.02	31.20	2.02	This study
Bingöl	East	15.65	11.76	46.01	25.10	0.93	Karatay & Ulutürk (2026) [36]
Van	East	28.04	0.05	17.05	43.57	10.21	Ulutürk & Yürümez (2022) [37]
Batman	East	45.59	2.21	22.79	26.70	1.34	Oğuz (2019) [38]
Bitlis	East	25.24	9.20	22.94	19.91	22.11	Toyran (2016) [39], Toyran and Adızel (2018) [40]
Kars	East	60.38	2.82	19.98	13.95	1.27	Selçuk (2023) [41]
Iğdır	East	32.85	0.06	7.27	56.86	1.56	Selçuk (2023) [41]
Artvin	East	12.18	42.20	29.26	15.26	0.69	Göktürk et al. (2022) [42]

Table 1. *Cont.*

Province/Area ¹	Position	Crop Lands	Forest Land	Shrub Lands	Bare Land	Water Bodies	Data Source
Bursa	West	44.53	32.95	13.64	0.34	4.73	Gözütok (2017) [43]
Yozgat	West	65.21	9.68	15.03	8.01	0.47	Yorulmaz & Arslan (2020) [44]
Muğla	West	22.12	36.48	33.54	3.68	1.62	İlemin (2020) [45]
Sinop	West	29.33	50.37	16.98	1.78	0.92	Çam & Ölmez (2015) [46]
Çorum	West	51.59	16.73	20.78	8.99	0.79	Bulut et al. (2017) [47]
Manisa	West	53.78	16.02	25.28	1.45	1.04	İlemin (2022) [48]
Kırklareli	West	51.59	31.92	12.78	0.71	0.79	Ünal et al. (2023) [49]

¹ Habitat data were extracted from CORINE Land Cover (CLC) databases and processed using R programming software. Elevation and slope variables were integrated into the environmental matrix for multivariate analyses. All values represent the percentage (%) of the total area for each province or specific locality. NPA: Nature Protected Area. The reference numbers in brackets correspond to the citations in the Reference section. “This study” refers to the original field data collected in Ağrı Province.

2.2. Data Collection and Harmonization

2.2.1. Ağrı Province Inventory

The mammal fauna of Ağrı Province was compiled from three primary sources: (i) fieldwork, (ii) previous studies, and (iii) interviews with local residents. Mammal surveys were conducted at 251 localities across 92 map sheets (1:25,000 scale) in Ağrı Province, following the sampling framework of the Provincial Directorate of Nature Conservation and National Parks. During the 73-day field study, a minimum coverage of 10% per map sheet was achieved. Comprehensive data, such as geographic coordinates, timestamps, and abundance, were documented for each detection (Table S2). Mammal species were recorded through both direct and indirect observation methods. Direct observations were conducted using binoculars (Travel 10 × 40; Levenhuk, Tampa, FL, USA), digital video cameras (HDR-CX190E; Sony, Tokyo, Japan), and DSLR cameras (D7100; Nikon, Tokyo, Japan). Indirect evidence, such as footprints, scats, feeding remains, and scratch marks, was systematically identified and documented. To maximize sampling efficiency across diverse habitats, surveys were conducted at sunrise and sunset. The study area encompassed a broad ecological gradient, including mountains, forests, moorlands, wetlands, and agricultural zones, as well as anthropogenic environments ranging from urban centers to rural settlements. The spatial distribution of the recorded observations is presented in Figure 1.

2.2.2. Comparative Dataset

To minimize sampling bias in constructing the dataset for regional comparisons, a selective protocol was implemented. In this context, published literature data from different regions of Türkiye were reviewed; however, only provinces ($n = 15$) that were systematically surveyed using camera trapping and direct observation methods in accordance with the standards of the ‘National Biodiversity Inventory and Monitoring Project’ of the General Directorate of Nature Conservation and National Parks (DKMP), Ministry of Agriculture and Forestry, were included in the analyses. This standardization minimized differences in data quality among provinces, ensuring a more reliable biodiversity signal.

2.2.3. Taxonomic and Temporal Scope

The scope of the analysis was limited to medium- and large-bodied mammals to ensure higher detectability and more robust inventory data. Small mammals (Rodentia and Soricomorpha) were omitted from the dataset due to significant methodological heterogeneity and elevated ‘betajac’ values observed between studies. Finally, all faunistic records

were transformed into a binary presence–absence matrix to mitigate potential biases in taxonomic resolution.

2.3. Statistical Analyses

Statistical analyses were performed using R v. 4.5.2 (R Foundation for Statistical Computing, Vienna, Austria) and categorized into two scales: local (Ağrı) and regional (Diagonal comparison).

2.3.1. Local Diversity

For the Ağrı dataset, where individual counts were available, alpha diversity was quantified using Shannon (H') and Richness (S) indices. Gamma diversity was calculated by pooling abundance data across all localities. Sampling completeness was evaluated using the Chao1 richness estimator. The Rank–Abundance Distribution (RAD) was modeled to assess niche partitioning, and community structure was visualized using the *vegan* package.

2.3.2. Regional Biogeographical Comparisons

To explore the potential structuring effect of the Anatolian Diagonal, beta diversity was quantified using Jaccard dissimilarity and partitioned into turnover and nestedness components [50]. Because the analyses rely on incidence-based data derived from heterogeneous literature sources, the resulting estimates reflect patterns of compositional differentiation at a regional scale and should be interpreted cautiously.

Multivariate ordination techniques (NMDS and PCoA) were applied to visualize similarities among provinces. Differences between western and eastern groups were evaluated using PERMANOVA (adonis2, 999 permutations). Given the non-standardized sampling effort among provinces, PERMANOVA results indicate statistically detectable differences in species composition but do not imply fully standardized ecological equivalence among sites.

2.3.3. Environmental and Habitat Modeling

Environmental variables, including habitat composition, elevation, and slope, were extracted and standardized in R. Five major CORINE land-cover categories—agriculture, forest, grassland, rocky areas, and wetlands—were used as environmental predictors. To evaluate the relationship between mammalian community composition and these environmental factors, community comparisons, ordination, partitioning, and partial CCA (PCCA) were employed.

A Permutational Multivariate Analysis of Variance (PERMANOVA) was performed using the *vegan* package to test for significant differences in species assemblages between the eastern and western sides of the Anatolian Diagonal. Canonical Correspondence Analysis (CCA) was also used to examine the influence of habitat structure and biogeographical position on community divergence. To isolate the unique contribution of the Anatolian Diagonal, PCCA models were fitted by conditioning on specific variables: (i) Habitat/Biogeography: Assessing the effect of habitat while controlling for biogeographical position. (ii) Biogeography/Habitat: Assessing the independent effect of the Anatolian Diagonal while controlling for contemporary habitat composition, elevation, and slope.

The complete analytical workflow is archived on Zenodo: <https://doi.org/10.5281/zenodo.18921210>. All statistical analyses were conducted in R, with significance levels set at $\alpha = 0.05$.

3. Results

3.1. Ağrı Mammalian Fauna

3.1.1. Mammalian Species Richness and Abundance

This comprehensive study of mammalian diversity in Ağrı Province identified 32 species across six orders and seventeen families, spanning 251 localities. According to the IUCN (Mediterranean assessment), *Capra aegagrus* and *Ursus arctos* are classified as Vulnerable (VU), while *Lutra lutra*, *Lynx lynx*, *Spermophilus xanthoprimum*, *Scarturus williamsi*, *Mesocricetus brandti*, *Rhinolophus hipposideros*, *Rhinolophus ferrumequinum*, and *Myotis blythii* are listed as Near Threatened (NT). Additionally, *Nannospalax xanthodon* is categorized as Data Deficient (DD), and the remaining 21 species are listed as Least Concern (LC). Notably, this survey recorded *Dryomys nitedula* and *Felis silvestris* as new findings not included in previous preliminary reports. Representative images of some of the species identified in the study are provided in Figure 2.

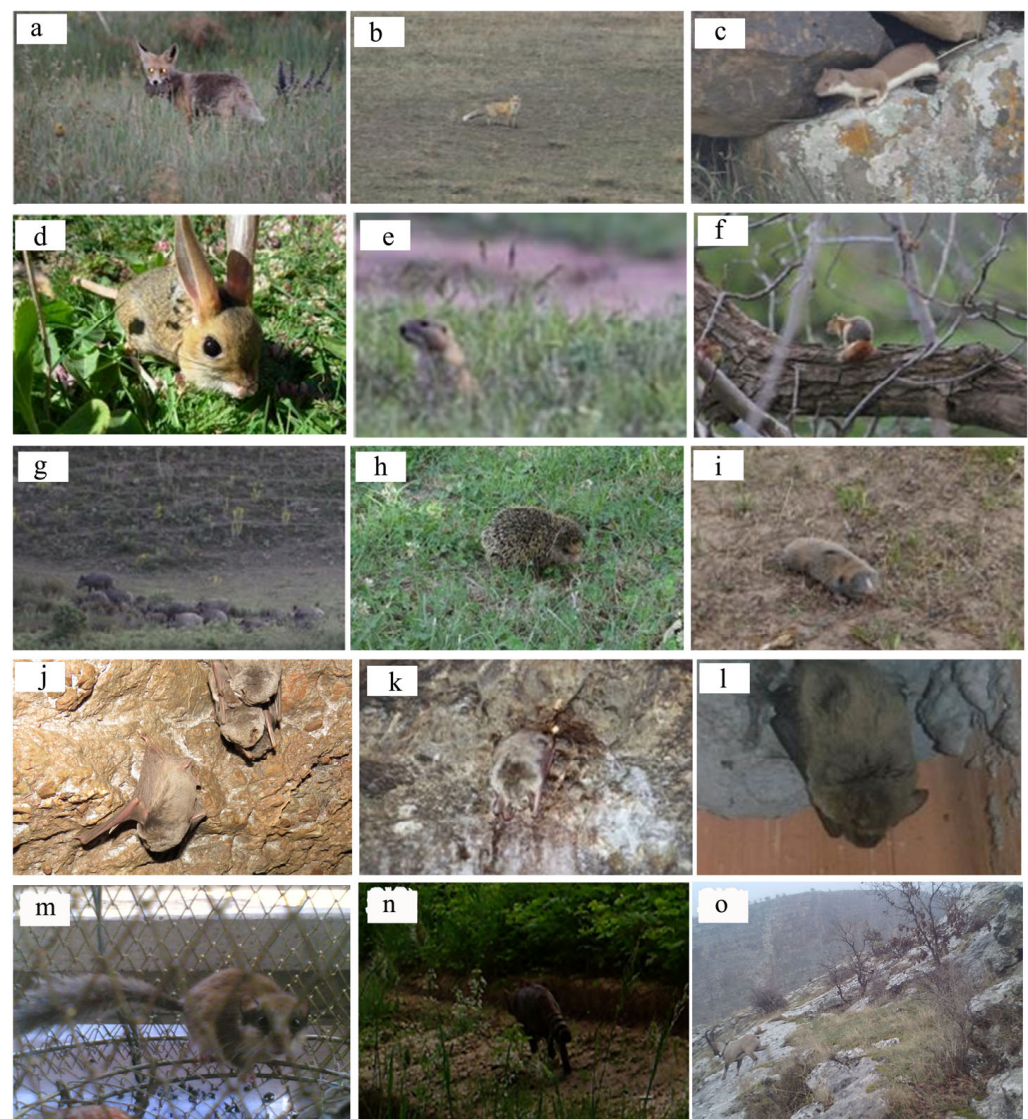


Figure 2. Photographs of wild mammal species recorded in the Ağrı region (a) *Canis aureus*, (b) *Vulpes vulpes*, (c) *Mustela nivalis*, (d) *Scarturus williamsi*, (e) *Spermophilus xanthoprimum*, (f) *Sciurus anomalus*, (g) *Sus scrofa*, (h) *Erinaceus concolor*, (i) *Nannospalax xanthodon*, (j) *Myotis blythii*, (k) *Myotis myotis*, (l) *Pipistrellus pipistrellus*, (m) *Dryomys nitedula*, (n) *Felis silvestris*, and (o) *Capra aegagrus*.

While the overall inventory includes a broad range of taxa, the core analysis focused on 16 medium- and large-sized mammals recorded across 228 localities, comprising 705 individuals. The community composition within this group was dominated by a few highly abundant species; *Sus scrofa* was the most prevalent, accounting for 33.0% of total observations ($n = 233$), followed by *Capra aegagrus* (21.0%, $n = 148$) and *Vulpes vulpes* (13.0%, $n = 92$). Conversely, *Felis silvestris* and *Martes martes* were the rarest species, representing less than 1% of the total community (Figure 3). Ecological observations indicated that the high density of *C. aegagrus* was notably associated with rocky terrains (CORINE Class 332), while *S. scrofa* occurrences were concentrated in the ecotones between agricultural areas (Class 211) and shrublands (Class 324).

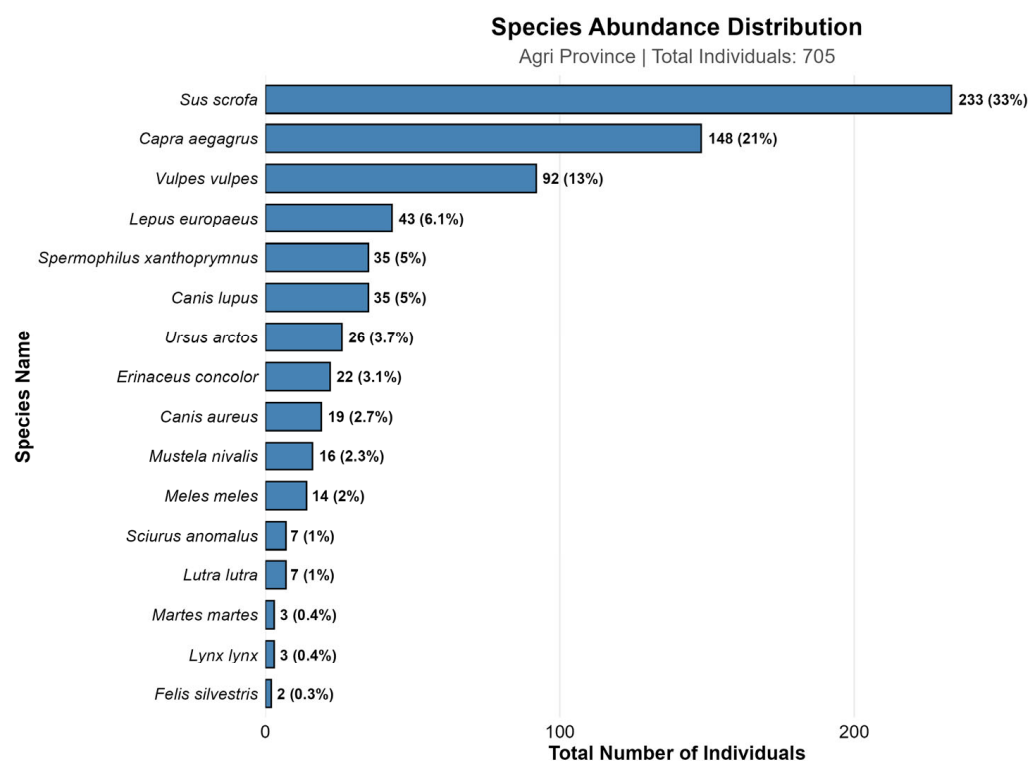


Figure 3. Species abundance distribution (SAD) of the mammalian assemblage in Ağrı Province. Bars represent the total number of individuals recorded for each species, with their respective percentages shown in parentheses. The distribution follows a characteristic log-normal pattern, dominated by *Sus scrofa* and *Capra aegagrus*.

3.1.2. Alpha Diversity and Sampling Efficiency

The alpha diversity analysis revealed a Shannon–Wiener index (H') of 2.08 indicating a moderate level of diversity with a clear dominance structure. Pielou's evenness index ($J' = 0.73$) further confirmed that individuals were not perfectly evenly distributed among species, reflecting the high abundance of *Sus scrofa* and *Capra aegagrus*. Sampling completeness was validated using the Chao1 richness estimator; the observed richness (Sobs = 17) and the estimated richness (Schao1 = 17.0 ± 0.24) converged perfectly. This statistical alignment, supported by the ACE estimator (17.5 ± 1.93), demonstrates that the sampling effort across 228 localities was exhaustive and sufficient to capture the regional mammalian biodiversity (Figure 4).

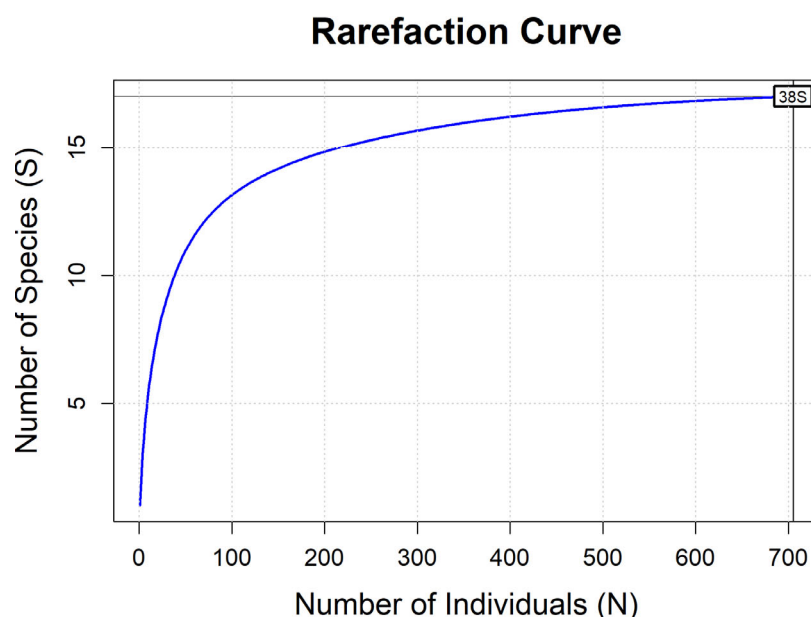


Figure 4. Individual-based rarefaction curve (with 95% confidence intervals) for the mammalian fauna of Ağrı Province. The flattening of the curve indicates that the sampling effort across 228 localities was sufficient to capture the majority of the expected medium- and large-sized terrestrial mammal richness in the region.

3.1.3. Community Structure and Trophic Guilds

The Rank–Abundance Distribution (RAD) was best explained by the Lognormal model (AIC: 95.29), outperforming the Preemption and Zipf models. This fit indicates a well-structured community in which niche partitioning is governed by multiple environmental factors rather than by a single dominant resource (Supplementary Figure S1).

Trophic analysis showed that the community is primarily composed of omnivores, largely driven by the high density of *Sus scrofa*. However, a significant presence of carnivores ($n = 167$ individuals across 6 species), including apex predators such as *Canis lupus* and *Ursus arctos*, indicates a functional and relatively intact food web. Herbivores were represented by three species, with *Capra aegagrus* being the primary contributor to this guild.

3.2. Comparison Sites

3.2.1. Differences in Mammal Assemblages Between West and East of the Anatolian Diagonal

Permutational multivariate analysis of variance (PERMANOVA) based on Jaccard dissimilarity revealed significant differences in mammal assemblage composition between the western ($n = 7$) and eastern ($n = 8$) sides of the Anatolian Diagonal ($F = 3.08$, $R^2 = 0.19$, $p = 0.007$). Biogeographical position accounted for 19.2% of the total variation in community composition.

To verify that the significant PERMANOVA result was not driven by differences in multivariate dispersion among groups, a test for homogeneity of multivariate dispersions (betadisper) was conducted. The analysis revealed no significant difference in dispersion between the western and eastern groups ($F = 0.051$, $p = 0.825$), indicating that the observed compositional differentiation reflects genuine shifts in community structure rather than unequal within-group variability.

Non-metric multidimensional scaling (NMDS) ordination based on Jaccard dissimilarity (Stress = 0.142) effectively visualized the compositional differentiation between western and eastern assemblages (Figure 5). The ordination plot showed clear spatial segregation

of provinces by their position relative to the Anatolian Diagonal. Although some overlap exists between the 95% confidence ellipses, the centroids of the two groups are distinctly separated, reflecting a significant shift in community structure.

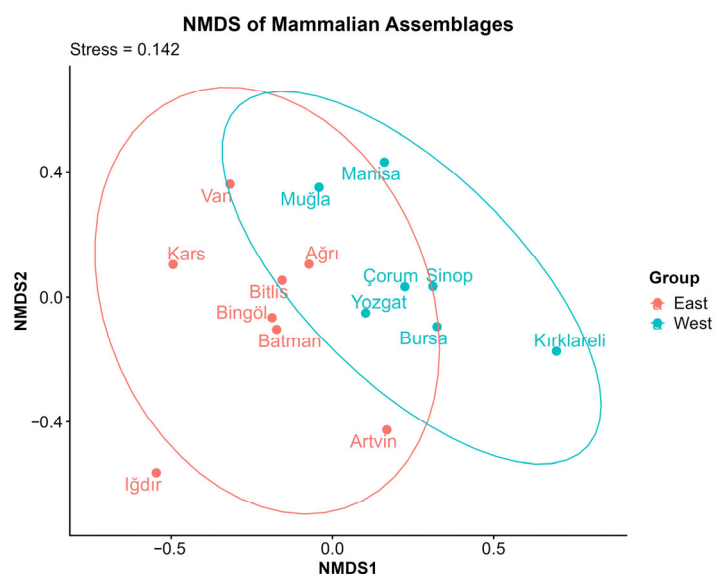


Figure 5. Non-metric Multidimensional Scaling (NMDS) ordination based on Jaccard dissimilarity, showing the differentiation of medium- and large-sized mammalian assemblages between the western (blue) and eastern (red) sides of the Anatolian Diagonal. Each point represents a province or study area. The separation between the two groups reflects the significant turnover in species composition ($p = 0.007$, PERMANOVA). The stress value (0.142) indicates a high level of reliability for the two-dimensional representation of the community distances.

3.2.2. Beta Diversity Partitioning

The overall beta diversity (β_{jac}) across the entire study area was 0.431. Partitioning this diversity into its core components revealed that species turnover ($\beta_{jtu} = 0.361$) is the overwhelming driver of community differentiation, accounting for 83.8% of the total beta diversity. In contrast, nestedness-resultant dissimilarity ($\beta_{jne} = 0.070$) contributed only 16.2% (Figure 6).

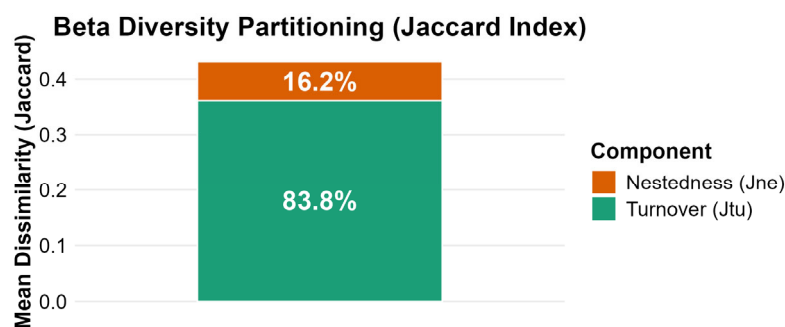


Figure 6. Partitioning of beta diversity (β_{jac}) for mammalian assemblages using the Jaccard dissimilarity index. The total beta diversity is decomposed into its two components: species turnover (β_{jtu}) and nestedness (β_{jne}). The dominance of the turnover component (83.8%) indicates a high degree of species replacement between the studied sites.

The beta diversity partitioning analysis revealed that taxonomic differentiation of wild mammal assemblages across the Anatolian Diagonal is primarily driven by species turnover rather than nestedness. Total dissimilarity was highest in the inter-regional comparison (0.46), exceeding the intra-regional variation observed within the Eastern

(0.41) and Western (0.39) sectors (Figure 7). In all comparisons, the turnover component (blue) accounted for the vast majority of the total beta diversity, particularly in the Western region where it contributed 0.35 to the total dissimilarity of 0.39. This suggests that mammalian community structure on the western side of the Diagonal is characterized by high species replacement between localities, likely reflecting fine-scale environmental filtering or habitat heterogeneity. Conversely, the nestedness-derived component (pink) remained consistently low, although it was slightly more pronounced in the Eastern region (0.1) compared to the Western region (0.03). The marginal increase in nestedness in the East may indicate a subsetting effect, where certain high-altitude or climatically harsh sites harbor impoverished versions of more diverse regional species pools. However, the overall dominance of the turnover component (0.39 for 'Between_Groups') underscores the role of the Anatolian Diagonal as a significant biogeographic barrier, facilitating distinct species compositions on either side through replacement rather than non-random species loss.

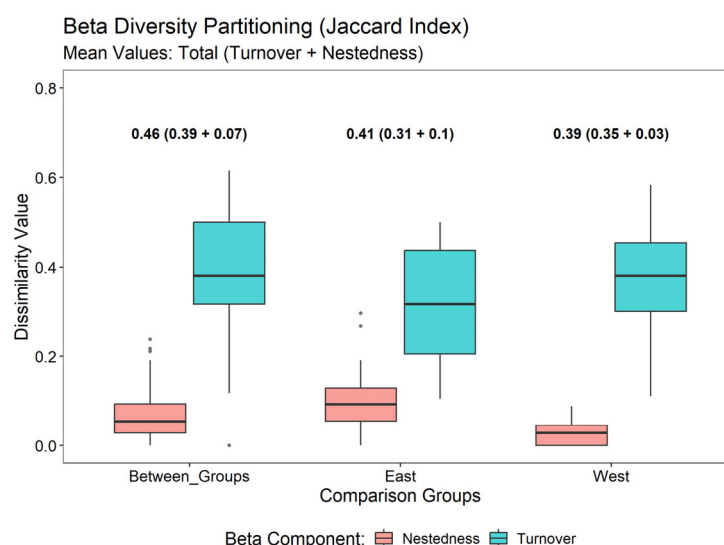


Figure 7. Partitioning of beta diversity (Jaccard dissimilarity) for wild mammal assemblages across the Anatolian Diagonal. The total beta diversity is decomposed into its two additive components: species turnover (replacement) and nestedness-derived loss. Boxplots illustrate the distribution of dissimilarity values; mean values for total dissimilarity are provided above each category, with the relative contributions of turnover and nestedness indicated in parentheses. The individual dots represent outliers, defined as values exceeding 1.5 times the interquartile range from the edge of the box. “Between_Groups” represents the comparison across the Diagonal, while “East” and “West” denote intra-regional comparisons.

The dominance of the turnover component (species replacement) over the nestedness component (richness differences) provides conclusive evidence that the observed community differences are not due to unequal sampling efforts or species loss. Instead, these results confirm that the Anatolian Diagonal acts as a significant dispersal barrier, facilitating a high degree of species replacement between the two regions.

3.2.3. Canonical Correspondence Analysis

To further disentangle the effects of topography and geography, a Canonical Correspondence Analysis (CCA) was performed. The full model, including biogeographical position, elevation, and slope, was highly significant ($p = 0.005$) (Figure 8). Even after controlling for topographic variables, the partial CCA revealed that biogeographical position had a strong independent effect on mammal community composition ($p = 0.005$). In contrast, topographic variables such as elevation ($p = 0.204$) and slope ($p = 0.054$) did not have a significant independent influence on community structure after accounting for

geographical position. These findings indicate that the Anatolian Diagonal functions as an independent biogeographical barrier that influences mammal assemblages, beyond simple habitat or elevation differences (Figure 8).

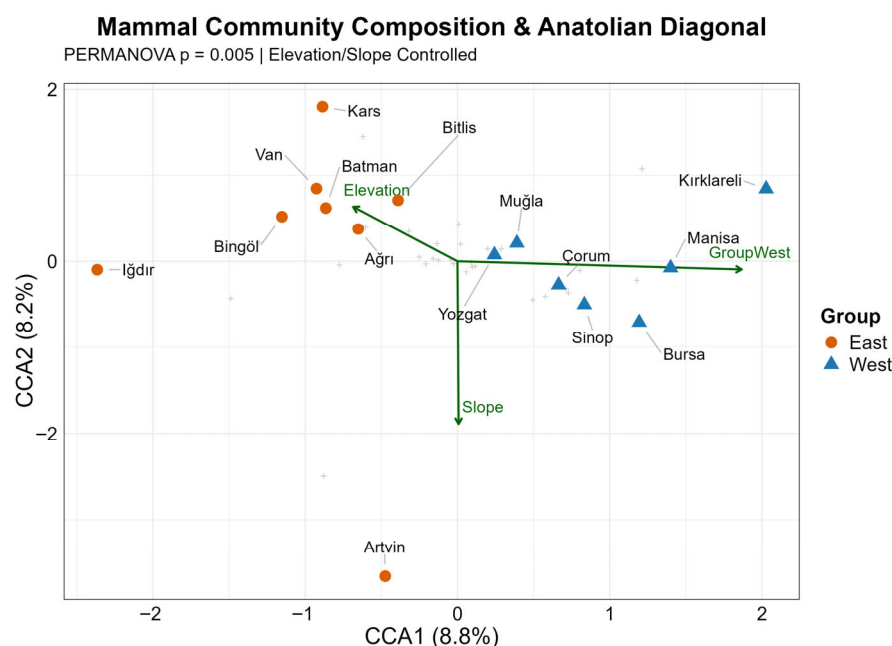


Figure 8. Canonical Correspondence Analysis (CCA) biplot illustrating the relationship between mammal assemblages, biogeographical groups (West vs. East), and environmental vectors (elevation and slope). The “+” symbols represent the distribution of species. CCA1 and CCA2 explain 8.8% and 8.2% of the total inertia, respectively. Significant differentiation is observed along the first axis ($p = 0.005$), with key indicator species such as *Sciurus anomalus* and *Spermophilus xanthoprimum* characterizing their respective regions.

3.2.4. Nestedness Patterns (NODF)

Nestedness analysis based on the NODF metric revealed a moderate nested structure across all sites (NODF = 53.34). When analysed separately, nestedness values were considerably lower and highly similar for the eastern (NODF = 38.00) and western (NODF = 37.30) subsets. The higher nestedness observed when all sites were considered together suggests that the nested structure largely emerges from differences in species composition between regions rather than from a pronounced nested ordering of communities within each region.

These findings are consistent with the results of beta diversity partitioning based on the Jaccard index, which indicated that most of the compositional dissimilarity among sites was explained by species turnover ($j_{tu} = 0.361$), whereas the contribution of nestedness ($j_{ne} = 0.070$) was comparatively small (total β -diversity, $j_{ac} = 0.431$). Together, these results indicate that regional differences in mammal communities are primarily driven by species replacement rather than by nested species loss across sites.

4. Discussion

4.1. Effects of Habitat Composition and Biogeographical Position

The Anatolian Diagonal has long been recognized as a major biogeographical boundary structuring patterns of species distributions and endemism [51–54]. Our results provide quantitative, community-level evidence that this mountain system significantly structures assemblages of medium- and large-sized mammals. The significant differences in mammal community composition detected by PERMANOVA ($F = 3.08$, $R^2 = 0.19$, $p = 0.007$)

between the western and eastern sides of the Diagonal indicate that this region functions not only as a historical barrier but also as a contemporary biogeographical filter. Notably, biogeographical position alone explains 19.2% of the total variation in community structure [2].

Partitioning of Jaccard-based beta diversity revealed that assemblage dissimilarity was heavily dominated by species turnover (83.8%) rather than nestedness (16.2%). This suggests that differences between western and eastern mammal assemblages primarily reflect species replacement across the Anatolian Diagonal, rather than simple species loss or gain [29–35]. Historically, Anatolia served as a critical corridor for faunal dispersal during the Early Miocene and subsequently functioned as a vast, non-homogeneous refuge area during the climatic fluctuations of the Pleistocene [9,51]. In this context, the Anatolian Diagonal likely acted as a refugial boundary where isolation by barrier facilitated the divergence of lineages by helping different taxa escape the analogous effects of both glacial and interglacial cycles [33,34,51,55,56]. The high turnover observed suggests that the Diagonal limited post-glacial expansions, effectively ‘trapping’ certain lineages on either side and reinforcing long-term spatial isolation that persists in contemporary assemblage structures [35]. Furthermore, the fact that inter-regional dissimilarity across the Diagonal (0.46) was higher than the intra-regional means (East: 0.41; West: 0.39) underscores its role as a primary filter, exceeding the influence of internal environmental gradients. Such turnover-dominated beta diversity is consistent with the interpretation of the Anatolian Diagonal as a biogeographical transition zone, where faunal elements of European–Mediterranean origin in western Anatolia are progressively replaced by Irano-Turanian and eastern Anatolian elements [29–35,51–53].

4.2. Disentangling Habitat and Biogeography: Legacy Effects

A critical finding of this study, derived from Partial Canonical Correspondence Analysis (PCCA), is that biogeographical position (west vs. east) retained a highly significant independent effect on mammal community composition ($p = 0.005$) even after controlling for contemporary habitat composition. Conversely, habitat variables alone were not significant when the effect of biogeographical position was accounted for. This indicates that historical and biogeographical processes associated with the Anatolian Diagonal play a more important role than present-day land-cover composition in structuring mammalian assemblages [29–35,51–54]. While current CORINE habitat classes are ecologically important for species occupancy, they do not fully explain the observed community divergence. Instead, legacy effects of past climatic and geological processes continue to shape the contemporary mammalian distribution patterns in Anatolia [56–58]. The potency of biogeographical position over contemporary land cover suggests that the filtering mechanism is driven by deeper environmental gradients, such as the sharp transition between the humid Mediterranean climate and the semi-arid, continental Irano-Turanian climate. These climatic gradients likely act as physiological filters, limiting the westward expansion of cold-adapted eastern species and the eastward dispersal of thermophilic western elements. Thus, the Diagonal represents a complex interaction between topographic obstruction and climatic constraints [56–58].

4.3. Mammalian Diversity in Ağrı and Regional Comparisons

The 16 species identified in Ağrı province represent approximately 40% of the medium- and large-sized terrestrial mammals found in Türkiye [14]. Our findings show that the community is dominated by *Sus scrofa* (33%) and *Capra aegagrus* (21%), which together account for more than half of the recorded individuals. The dominance of plastic species such as *S. scrofa*, *Vulpes vulpes*, and *Canis lupus* across both sides of the Diagonal reflects

their high ecological adaptability [5]. However, the presence of *C. aegagrus* and its strong association with high-altitude rocky areas (CORINE Class 332), combined with the absence of Mediterranean-adapted species, confirms that regional distribution is governed by the interplay of climate and the Diagonal's filtering effect [29–35]. Beyond taxonomic turnover, our results point toward functional shifts in assemblage structure. For instance, the high abundance of *C. aegagrus* in the East reflects a specialization toward vertical, high-altitude niches, whereas western assemblages are characterized by species associated with temperate forest mosaics. This suggests that the Anatolian Diagonal filters species based on functional traits related to habitat specialization and climatic tolerance, leading to ecologically distinct communities that fulfill similar trophic roles but via different taxonomic representatives [29–35,51–54].

4.4. Taxonomic Considerations and Sampling Consistency

The exclusion of small mammals (Rodentia and Soricomorpha) was a strategic decision to minimize sampling bias. High betajac values in small mammals across all regions, along with high NMDS stress values, indicated inconsistencies in survey efforts among literature sources. By focusing on medium and large mammals—and specifically utilizing standardized data from provinces with high-quality inventory records—we ensured a more reliable signal for biogeographical analysis. From a conservation perspective, the predominance of turnover suggests that both sides of the Diagonal host distinct communities. Protecting representative habitats on both sides—specifically, the high-altitude rocky areas in the east and the forest mosaics in the west—is crucial for preserving Anatolia's evolutionary processes [51–54].

4.5. Methodological Limitations and Interpretative Scope

Although this study applies standardized multivariate approaches, some limitations remain. First, while we focused on provinces with standardized survey data to reduce resolution bias, differences in sampling duration and detection techniques may still exist. Second, the use of incidence-based indices assumes equal detectability, which can vary with habitat structure. Third, environmental variables were derived from coarse-grained CORINE classes; fine-scale microclimatic factors might further contribute to differentiation. Despite these limitations, the robust significance of the PERMANOVA and PCCA results, alongside the high turnover rates, provides strong evidence consistent with a structuring role of the Anatolian Diagonal at the community level. Future research incorporating molecular phylogeography and high-resolution climatic modeling would be instrumental in further disentangling the relative contributions of historical vicariance versus contemporary environmental filtering in shaping these mammalian assemblages.

5. Conclusions

This study provides a comprehensive assessment of the diversity of medium- and large-sized mammals in Ağrı Province within a broader biogeographical framework. Although Ağrı represents a relatively small proportion of Türkiye's total land area, the documented assemblage underscores its ecological significance within the Eastern Anatolian highland ecosystem and provides essential baseline data for regional monitoring and conservation planning.

At the regional scale, our comparative analyses reveal that mammal assemblages differ significantly between the western and eastern sides of the Anatolian Diagonal. The overwhelming predominance of species turnover (83.8%) over nestedness indicates that compositional differences are primarily driven by species replacement across this transition zone. This striking turnover rate suggests that the Anatolian Diagonal does not

merely act as a filter that reduces species richness in one direction; rather, it functions as a genuine biogeographical barrier where distinct species assemblages replace one another. Such a high replacement rate supports the hypothesis that the Diagonal has historically promoted allopatric speciation or restricted the post-glacial expansion of divergent lineages. Furthermore, partial constrained ordination (PCCA) results support the interpretation that biogeographical position contributes to community differentiation independently of contemporary habitat composition.

However, given the inherent heterogeneity in sampling designs, temporal coverage, and data sources across provinces, these findings should be interpreted with caution. While the results are strongly consistent with a biogeographical filtering effect associated with the Anatolian Diagonal, they do not constitute definitive proof of a strict, impermeable barrier. Future research incorporating standardized, detection-corrected, and abundance-based surveys across multiple regions will be required to rigorously test the underlying mechanisms of mammalian assemblage differentiation in Anatolia.

The observed divergence in mammalian communities also reflects broader biogeographic patterns, including latitudinal and longitudinal gradients of biodiversity. In the complex topography of Anatolia, these gradients often interact with the peninsula effect, where species richness and turnover are influenced by the narrowing of landmasses and increasing isolation from source populations. Such patterns have been well-documented in the region's herpetofauna [59] and are here corroborated by our mammalian dataset, suggesting a consistent biogeographic response across different taxonomic groups.

Recognizing these gradients is essential for applied biogeographical solutions [60]. From a conservation standpoint, the high beta diversity observed along longitudinal transitions requires the implementation of ecological networks that maintain connectivity between the Mediterranean, Iranian, and European faunal elements. By integrating these spatial trends into a historical applied ecology framework [61], practitioners can better understand how past climatic shifts have shaped current gradients. This dataset thus serves as a critical tool for 'situation and context analysis' [62], allowing for the development of logical frameworks [63] that prioritize habitat heterogeneity along these environmental axes. Incorporating such multi-dimensional biogeographic data into the IUCN project cycle ensures that conservation efforts are aligned with the fundamental ecological rules governing the region's biodiversity.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/conservation6020058/s1>. Table S1: The wild mammals of Ağrı Province and the fourteen comparison areas, IUCN—International Union for Conservation of Nature, DD—Data Deficient, LC—Least Concern, NT—Near Threatened, VU—Vulnerable; Table S2: The sampling locations and wild mammal records of Ağrı Province with their conservation statuses. IUCN—International Union for Conservation of Nature, BERN—Biological and Industry Reporting Network, CITES—Convention on International Trade in Endangered Species of Wild Fauna and Flora, MAKK—Central Hunting Commission Decisions, DD—Data Deficient, LC—Least Concern, NT—Near Threatened, VU—Vulnerable, and N—number of individuals; Figure S1. Rank–abundance distribution of species recorded in the study area. Black points represent the observed species abundances, while colored lines indicate the fitted species–abundance distribution models: Null (black), Preemption (red), Lognormal (green), Zipf (blue), and Mandelbrot (cyan). Species are ordered by rank on the x-axis, and abundance is presented on a logarithmic scale on the y-axis. The comparison of observed and predicted curves illustrates differences in model performance in describing the community structure.

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