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Research paper

Incipient biotic homogenization of desert rodents driven by a late response to precipitation

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Abstract

Incipient biotic homogenization of desert rodents driven by a late response to precipitation. Climate variability can drive biotic homogenization in arid ecosystems. Using 15 years of rodent monitoring in a grassland and a shrubland in the Chihuahuan Desert, we 1) evaluated the change in temporal β-diversity, and 2) analyzed the relationship between β-diversity of rodent communities and climatic conditions. The β-diversity was calculated using the total dissimilarity partitioning method and we performed multiple regression on distance matrices. The results showed a slight decrease in the temporal beta diversity of rodents in the grassland, this could indicate the beginning of biotic homogenization. Changes in rodent β-diversity were related to changes in the difference in precipitation. Long-term temporal studies are therefore required to fully understand the relationships between climate and community dynamics in arid zones.

Key words: β-diversity, Long-term, Climate change, Temporal scale, Communities, Abundance

Introduction

In the face of the evident global crisis of biodiversity loss (Butchart et al 2010, Cowie et al 2022), the study of how diversity changes at different spatial and temporal scales is paramount (Olden and Rooney 2006). In recent decades, long-term studies increasingly show that biodiversity declines are associated with multiple global drivers, among which climate change plays an important role (Díaz and Malhi 2022, Moura et al 2023). Alterations in precipitation and increased temperatures could alter local colonization-extinction dynamics by disproportionately affecting species with narrow environmental tolerances, while favoring widespread, climatically tolerant or generalist species (Clavel at al 2011, Waldock et al 2018). As sensitive species are lost and resilient species persist, biological communities may become similar over time (Rolls et al 2023); i.e., a decrease in beta diversity. This process known as biotic homogenization, may act to alter ecosystem functioning and biological conservation (Clavel et al 2011, Olden and Rooney 2006).

Biotic homogenization can be studied through the analysis of beta diversity (β). Beta diversity quantifies the change in species composition in space (Whittaker 1960), but it also provides a powerful framework for evaluating compositional change within a single community through time (Lindholm et al 2021). Temporal beta diversity can be assessed using dissimilarity metrics, Baselga (2010, 2013) proposes partitioning the total dissimilarity into two additive components. If we consider presence-absence data, the nestedness component occurs when species at a site are a subset of the species at the site with the highest species richness while, in the turnover component, some species are replaced by others. When abundance data are used, there are two patterns derived from dissimilarity partitioning: (1) balanced variation abundance, which consists of individuals of some species at one site being replaced by the same number of individuals

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of different species at another site; and (2) abundance gradients, when species abundance changes from one site to another (Baselga 2013).

In recent years, emphasis has been placed on integrating both properties of diversity (Baselga 2013, Socolar et al 2016). Since, changes in ecological communities may be noticed in the composition rather than in species richness (Dornelas et al 2014), including both properties of beta diversity in the study of communities could improve our understanding of ecological processes (Hillebrand et al 2018, Mori et al 2018), making it possible to disentangle the mechanisms driving homogenization. As a result, beta diversity has become a widely used tool to evaluate biotic homogenization across ecosystems and temporal scales, particularly in long-term studies assessing the ecological consequences of environmental change (Pool and Olden 2012, Finderup Nielsen et al 2019, Paraskevopoulos et al 2024).

In the study of beta diversity and biotic homogenization, we found a gap in the knowledge relating to the study of mammal communities, particularly those found in arid regions of the world. Arid zones are characterized by high precipitation variability with prolonged dry periods, and extreme temperatures coupled with low relative humidity (Berdugo et al 2022, Noy-Meir 1973). Among the fauna occurring in arid zones, rodents are one of the most diverse groups of mammals. There are numerous publications on the study of rodents in arid zones, mainly focused on understanding population and community responses to precipitation events (Dickman et al 1999, Ernest et al 2000). Rodent populations respond to climatic conditions from three months to two years following a precipitation event (Meserve et al 1995, Hernández et al 2011, Ventura-Rojas et al 2024). Differences in response can sometimes be related to the difference between habitat types (Hernández et al 2005) or to species-specific biological traits (for example, *Octodon degus*; Meserve et al 1995). In contrast, the study of rodent diversity in arid areas has not been as extensive. Communities of small mammals present low alpha diversity and are composed of few common species, with a high incidence of rare species (Supp et al 2015) and a high beta taxonomic diversity among arid regions (Kelt et al 1996, O'Connell and Hallett 2019). To date, some studies have analyzed rodent diversity among sites (Ojeda et al 2000, Hernández et al 2005, Stevens and Tello 2011, Riojas-López et al 2011, Cárdenas et al 2021), as well as components of spatial beta diversity (Maestri and Patterson 2016, Novillo and Ojeda 2021, Novillo et al 2024). However, the study of beta diversity over time and its relationship to climatic conditions in arid zones is a topic that has not been addressed, despite its great importance since these are the ecosystems most vulnerable to climate change and experience considerable environmental fluctuations (Mori et al 2018).

Climatic conditions in drylands are changing, there has been an increase in temperature, greater variation in annual precipitation, and a greater intensity of extreme precipitation events as a consequence of global disturbances over the last two centuries (Zhao et al 2023). These changes may alter biodiversity in these ecosystems, potentially promoting biotic homogenization. In this study, we evaluate the process of biotic homogenization over the last 15 years in rodent communities of the Mapimí Biosphere Reserve (MBR), one of the first protected areas in Latin America, created and recognized by UNESCO's Man and Biosphere program and featuring characteristic ecosystems of the Chihuahuan Desert. We used a long-term dataset of rodent presence and abundance, derived from sampling twice a year (dry season and after rain) in the two main vegetation types present (shrubland and grassland), to i) analyze changes in beta diversity to determine whether dissimilarity has decreased (biotic homogenization), increased, or remained unchanged, and ii) analyze the relationship between climatic variables and beta diversity components between years. We ask how taxonomic beta diversity changes over time in each vegetation type, and whether the changes in temporal beta diversity are related to precipitation and temperature. Grasslands and shrublands differ markedly in soil properties and vegetation structure. Grasslands have clay-rich soils with slow infiltration, which retain moisture near the surface and favor the growth of annual grasses. In contrast, shrublands have sandy or saline soils with rapid infiltration, promoting deep-rooted perennial species (e.g., shrubs and cacti). These contrasts lead to distinct patterns of primary productivity: grassland productivity –and thus seed availability for small mammals– depends strongly on annual rainfall, producing a highly variable resource system. Shrubland, however, maintain a stable baseline of perennial vegetation, with fruits and new growth produced at different times of the year, resulting in more stable resource availability (Hernández et al 2005). Although both habitats experience similar temperatures and total rainfall, their contrasting water dynamics and vegetation responses may lead to distinct community responses to climatic variability. Because the grassland is more sensitive to climatic conditions, we hypothesized that rodent beta diversity will decrease over time more evidently in the grassland than in the shrubland, as a consequence of climatic variability. Furthermore, given the close relationship between rodent population fluctuations and precipitation, we expect there to be a relationship between beta diversity and precipitation. This study contributes to the understanding of how climate affects the structure of ecological communities and the dynamics of arid ecosystems and provides evidence of conservation challenges derived from global climate change.

Material and methods

Study area

The study was conducted in the MBR (26 °32' 07" N - 26 °47' 20" N, 103 °33' 58" W - 104 °00' 04" W; Arriaga et al 2000), located in the central part of the Chihuahuan Desert, between the states of Chihuahua, Durango, and Coahuila, in northern Mexico (fig. 1). Elevation ranges from 1000 to 1800 m a.s.l. (Arias-Del Razo et al 2011). The average temperature is 11.8 °C in winter and 28 °C in summer (Durán-Antonio et al 2020). The average annual precipitation is 264 mm, around 75 % of which occurs during the summer, although precipitation may occur outside of this season in some years (Cornet 1988).

The main vegetation types are shrubland and grassland (García-Arévalo 2002). The shrubland is predominantly composed of: creosote bush *Larrea tridentata*, mezquite

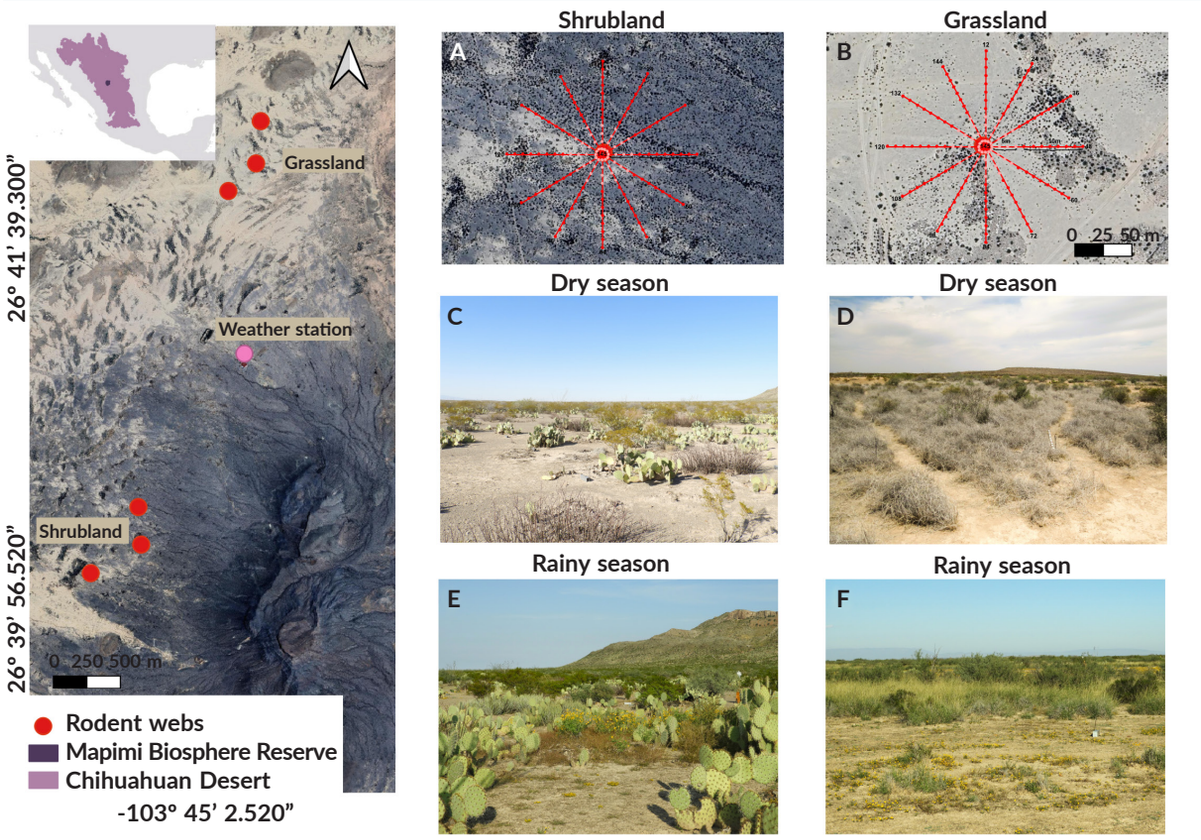

Fig. 1. Location map of the study area and sampling sites in the Mapimí Biosphere Reserve, in the Chihuahuan Desert, Mexico. A, and B, show the radial design of the rodent monitoring webs; C, and D, show images of the shrubland and grassland during the dry season; E, and F, show images of the shrubland and grassland after the rainy season.

Neltuma glandulosa, ocotillo *Fouquieria splendens*, and prickly pear *Opuntia rastrera*, among others. The soil of the shrubland presents rapid water filtration, which promotes the establishment of deep-rooted vegetation, including trees and shrubs (Hernández et al 2005). The grassland is dominated by an association of toboso grass *Pleuraphis mutica* and *N. glandulosa* (Montaña 1988). This plant formation is known locally as mogote. The grasslands have clay soils with slow infiltration rates that maintain moisture in the root zone (Hernández et al 2005).

There are 23 species of rodents recorded in the MBR, including geomyids (*Cratogeomys castanops* and *Thomomys umbrinus*), heteromids (*Dipodomys merriami*, *D. nelsoni*, *D. ordii*, *Chaetodipus collis*, *C. eremicus*, *Perognathus flavus*), cricetids (*Neotoma leucodon*, *N. goldmani*, *Sigmodon hispidus*, *Peromyscus eremicus*, *P. labecula*, *Reithrodontomys fulvescens*, *R. megalotis*, *Onychomys torridus*), murids (*Mus musculus* and *Rattus norvegicus*), an erethizontid (*Erethizon dorsatum*), and sciurids (*Xerospermophilus spilosoma*, *Ictidomys parvidens*, *Otospermophilus variegatus*, *Ammospermophilus interpres*) (Aragón and Garza 1999, CONANP 2006, Montero-Bagatella et al 2020). The identities of the species have been updated by consulting the Mammal Diversity Database of the American Society of Mammalogists (Upham et al 2024).

Rodent sampling

The data analyzed here are derived from the project 'Long-Term Ecological Research – Mapimí' (LTER – Mapimí) and correspond to sampling conducted from 2008 to 2023. The sampling design consists of three permanent sampling webs of 145 Sherman traps established in each vegetation type (shrubland and grassland). These webs originate from a point in the center and are arranged in 12 radii of 100 meters in length (fig. 1A and B). Twelve traps are placed in each radius, the first four spaced five meters apart and the remaining eight spaced 10 meters apart (fig. S3). Each sampling web is 200 meters in diameter (3.1 ha). The traps were baited with oat flakes. Rodents were monitored for three consecutive nights, twice a year, in both vegetation types: during the dry season (March-April) and after the rainy season (October-November). Each new individual was temporarily marked on the belly to determine if it was recaptured. Animals were released at the capture site after identification. It was not possible to sample during the 2013 and 2014 rainy seasons due to weather conditions, nor the 2021 dry season due to the COVID-19 pandemic. Figure 1 shows the conditions during some sampling of the shrubland and grassland in

the dry season (fig. 1C and D) and after the rainy season (fig. 1E and F).

Climatic data

Precipitation and temperature data were measured daily at the weather station of the Laboratorio del Desierto, located 1 km from the rodent sampling networks. The data we obtained from the station included: ambient, maximum, minimum, and average temperatures (°C) and daily precipitation (mm). Prior to analysis, we evaluated the multicollinearity of the temperature and precipitation variables, pairwise, using a correlation analysis. When the variables had a correlation value of > 0.7, one of them was eliminated. Analyses were performed with monthly average temperature and cumulative precipitation as predictor variables. The precipitation data were summed annually. The annual precipitation value was obtained by summing the monthly precipitation values for the 12 months prior to rodent monitoring. For example, for the November sampling, the period considered was from November of the preceding year to October just prior to the sampling date (Hernández et al 2011).

Data analysis

To analyze the rodent communities for each vegetation type, the data from the captures of the three sampling webs of each vegetation type were summed. For the analysis of the presence data, we employed Sorensen's index (β_{sor}), using the formula (Baselga and Orme 2012):

$$\beta_{sor} = \beta_{sim} + \beta_{sne} \equiv \frac{b + c}{2a + b + c} = \frac{b}{b + a} + \left(\frac{c - b}{2a + b + c}\right)\left(\frac{a}{b + a}\right)$$

Where β_{sor} is the Sorensen dissimilarity, β_{sim} is the turnover component, β_{sne} is the nestedness component, *a* is the number of species shared between years, *b* is the number of unique species in the year with the lowest species richness, and *c* is the number of unique species in the year with the greatest species richness.

To analyze the abundance data, we employed the Bray-Curtis index, using the formula (Baselga 2013):

$$\beta_{Bray} = \beta_{bal} + \beta_{gra} \equiv \frac{B+C}{2A+B+C} = \frac{\min(B,C)}{A+\min(B,C)} + \frac{|B-C|}{2A+B+C} * \frac{A}{A+\min(B,C)}$$

Where β_{Bray} is the Bray-Curtis dissimilarity, β_{bal} is the balanced variation in abundance component, and β_{gra} is the abundance gradient, *A* is the number of individuals of each species that exist in the two years (shared species), and *B* and *C* are the number of individuals of the unique species in each year.

To describe the temporal changes of each of the beta diversity components of the rodent communities over time, we used Pearson correlations (Pearson's coefficient) or Spearman correlations (rho), according to the normality of distribution of the beta diversity components evaluated, which was determined using Shapiro's test. Correlations were performed in each season (rainy and dry) separately, and per year (pooling both seasons) in each vegetation type, throughout the 15 years of sampling.

To assess whether differences in precipitation and temperature have a significant relationship with rodent beta diversity, we performed multiple regressions based on distance matrices (MRM, Lichstein 2007). We used total dissimilarity matrices (Sorensen and Bray-Curtis) and their respective components as response matrices. The original climate databases were transformed into Euclidean distance matrices (ΔP = Precipitation and ΔT = Temperature). Probability values for matrix independence (null hypothesis) and regression coefficients for the MRMs were obtained by generating permutations (9,999). This method makes inferences about relationships between distances, not between raw data (Lichstein 2007). MRMs were performed considering beta diversity between years in each vegetation type. For the analyses, we performed MRM using climatic data (mean temperature and the sum of precipitation) from one year prior to sampling (t_1), and from two years prior to sampling (t_2), considering the possible delayed response of rodents to the climatic conditions.

All analyses were performed in the R program (R Core Team 2024), using the beta.temp and bray.part functions of the betapart package (Baselga and Orme 2012) and the ecodist package for the MRM (Goslee and Urban 2007).

Results

In most cases, the correlation analyses showed no evidence of change in rodent beta diversity over time. The complete results of the correlations (Pearson or Spearman) of beta diversity (with incidence and abundance data) of rodents in the shrubland and grassland are shown in table S1. However, in the grassland, there was a decrease in the turnover component (β_{sim}) during the rainy season (r_s = -0.53, $p < 0.05$, fig. 2A), and a decrease in total beta diversity with abundance data (β_{Bray}), using the annual data (r = -0.55, $p < 0.05$, fig. 2B). In the shrubland, we found no evidence of change in beta diversity over time.

Climatic variables and beta diversity between years

Changes in temperature showed no evidence of relationships with changes in rodent beta diversity. However, in the analysis of changes in beta diversity with changes of precipitation between years (ΔP) of two years prior to sampling (t_2), we found significant relationships in the two rodent communities (table 1, table S5). In analyses based on incidence data, we observed moderate evidence of an increase in the nestedness component of beta diversity (β_{sne}) when the ΔP increased in the shrubland ($R^2 = 0.05$, $p < 0.05$), whereas in the grassland we found that the turnover component (β_{sim}) decreased with increasing ΔP ($R^2 = 0.09$, $p < 0.05$), and a very strong evidence of an increase in the nestedness component (β_{sne}) when the ΔP increased ($R^2 = 0.28$, $p < 0.001$, fig. 3A).

When we performed the analysis using species abundance data, the β_{Bray} beta diversity components of rodent diversity in the shrubland and grassland responded significantly. Increasing ΔP positively influenced β_{Bray} ($R^2 = 0.07$, $p < 0.01$) and β_{gra} ($R^2 = 0.17$, $p < 0.01$) diversity in the shrubland. In contrast, we observed a decrease of β_{bal} when the difference in precipitation increased ($R^2 = 0.20$, $p < 0.01$). The same trend was observed in the grassland, where balanced variation in abundance decreased with precipitation ($R^2 = 0.16$, $p < 0.01$) and the abundance gradient was positively significant ($R^2 = 0.30$, $p < 0.01$; fig. 3B). This indicates that there is a greater abundance gradient in rodent communities when the difference in precipitation

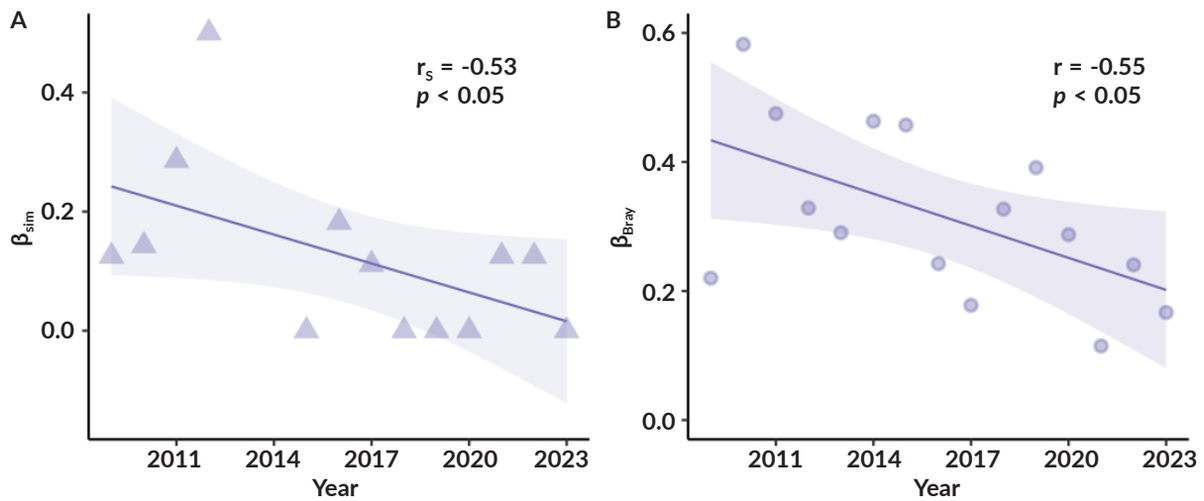

Fig. 2. Change in temporal beta diversity of grassland rodents over time. A, trend in the turnover component (β_{sim}) during the rainy season as a function of time; B, trend in total beta diversity and abundance data (β_{Bray}) as a function of elapsed time. The shaded part is the 95% CI, r_s is the Spearman correlation coefficient, and r is the Pearson correlation coefficient.

Table 1. Results of multiple regressions based on distance matrices (MRM) of each component of the annual beta diversity of rodent communities and precipitation for the two preceding years (t_2). Coefficient = Precipitation coefficient; β_{sor}: Sorensen dissimilarity (incidence); β_{sim}: Species turnover; β_{sne}: Nestedness; β_{Bray}: Bray-Curtis dissimilarity (abundance); β_{gra}: Abundance gradients; β_{bal}: Balanced variation. Significance levels: *p < 0.05, **p < 0.01, ***p < 0.001, (–) p > 0.05.

	Incidence				Abundance		
	F	R^2	Coefficient		F	R^2	Coefficient
Shrubland							
β_{sor}	1.32	0.02	–	β_{Bray}	4.87	0.07	0.00052**
β_{sim}	0.86	0.01	–	β_{bal}	15.06	0.20	-0.00054**
β_{sne}	3.36	0.05	0.00021*	β_{gra}	12.42	0.17	0.00107**
Grassland							
β_{sor}	5.12	0.08	0.00038*	β_{Bray}	6.72	0.10	0.00084*
β_{sim}	6.36	0.09	-0.00045*	β_{bal}	11.39	0.16	-0.00054**
β_{sne}	23.64	0.28	0.00021***	β_{gra}	25.07	0.30	0.00107**

is greater, and vice versa. The complete results of the MRM analysis of beta diversity and climatic variables between years are shown in table S5.

Discussion

The 15 years of long-term rodent monitoring in the MBR have allowed us to detect certain degree of biotic homogenization in one of the vegetation types studied. In the grassland, we observed a slight decrease in temporal beta diversity components (β_{sim} and β_{Bray}), indicating that rodent communities have become increasingly similar over the years. In the shrubland, beta diversity remained unchanged. This result may be linked to grassland productivity, as this habitat exhibits greater variability in ecological responses to precipitation events, making it particularly sensitive to larger dry periods and temperature fluctuations. Additionally, the extensive bare-soil gaps between vegetation patches experience high evaporative losses (Peters et al 2021), indicating that these ecosystems may have a reduced capacity to respond to precipitation variability. These environmental conditions may be affecting the species in the grassland, which tend to be captured following periods of intense rainfall (e.g., *Sigmodon hispidus*; Hernández et al 2005).

Among the climatic variables, differences in precipitation were the main determinant of rodent beta diversity, while temperature changes did not have as marked an effect on the temporal beta diversity of rodents. The relationship between the difference in precipitation (ΔP) and

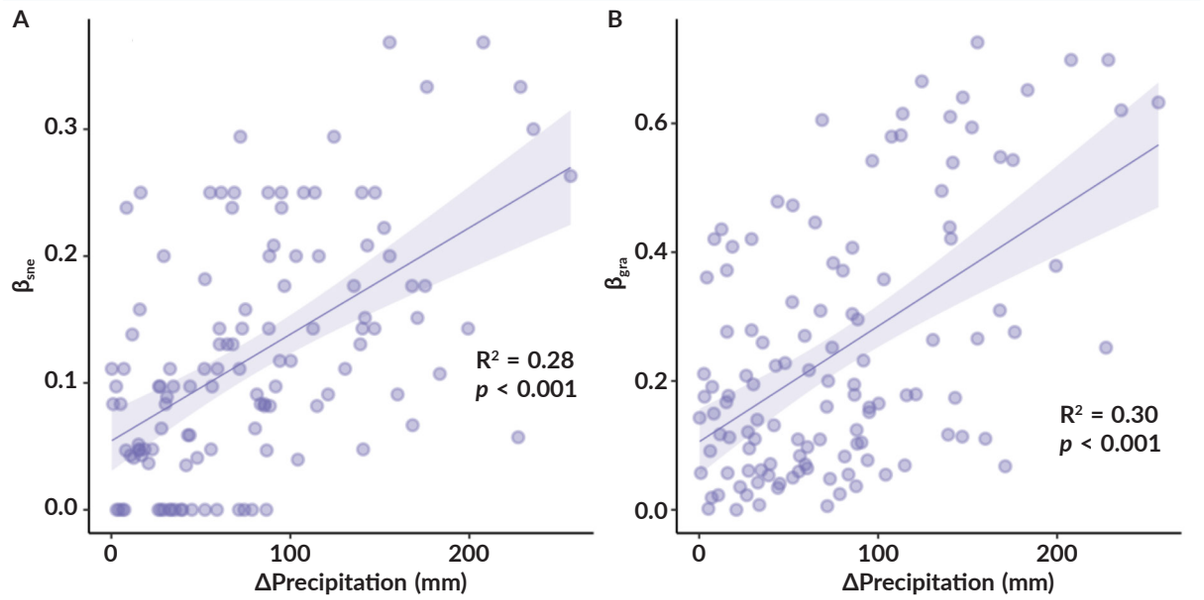

Fig. 3. Significant regressions based on distance matrices (MRM) of grassland rodent beta diversity and differences in precipitation for the two preceding years. A, nestedness and annual precipitation (t_2); B, abundance gradient and annual precipitation (t_2). The shaded part denotes the 95% CI.

the components of beta diversity differed depending on the year analyzed. We observed delayed responses in the beta diversity components of the two rodent communities to the climatic conditions of the preceding two years (t_2), which has been observed in rodent density and biomass at the study site (Hernández et al 2011). The steepest responses were observed in the components derived from the β_{Bray} dissimilarity. In both rodent communities, the balanced variation and abundance gradient components were statistically related to ΔP, but in opposite directions. The balanced variation in abundance (β_{bal}) decreased with increasing differences in precipitation, while the abundance gradient (β_{gra}) increased. Considering the results obtained in both analyses (incidences and abundances), the structure of rodent communities over time was represented by an abundance gradient and its similar component, nestedness (Baselga 2013). Therefore, with a greater difference in precipitation, the dissimilarity of rodent communities was due to the loss of individuals and species from one year to the next. Taking species identity into account, in the shrubland, differences in abundance were driven by increases in species such as *Peromyscus eremicus* and *Chaetodipus eremicus*, along with declines in several previously dominant species, including *C. collis* and *Neotoma leucodon*. In the grassland, shifts in abundance were reflected in the decrease in *N. leucodon* individuals and the increase of *Dipodomys merriami* and *C. eremicus* (table S2, S3 and S4).

These changes are consistent with the environmental dynamics of each habitat. The difference in precipitation reflects a greater difference in the availability of resources and refuge available to the rodents, which was most clearly observed in the grassland, where the plants usually respond faster to precipitation events, with vegetation cover growth being more evident after intense rainfall (Hernández et al 2005, Zhao et al 2023). This could also be related to the response time of the rodent communities.

In grasslands, when surface soils become moistened during rainfall, grasses can respond rapidly, as most of their root system is concentrated in upper soil layers. Their dense network of fine roots further enables then to quickly capture water from even small precipitation events (Ogle and Reynolds 2004).

In arid regions, the total annual precipitation is highly variable (Zhao et al 2023). During the sampling period, the recorded precipitation ranged from 103.2 mm in 2011 to 357.5 mm in 2006 (fig. S1). The wettest years were 2006 and 2018 (341.1 mm). During the dry season, the average precipitation was 47.90 ± 13.05 (SE) mm, but there was an atypical precipitation event in 2013, totaling 199 mm for that dry season. During the rainy season, the quantity of precipitation was similar in almost all seasons, except 2009 and 2015, which were the seasons with below-average rainfall (194 ± 13.84 mm). These periods of low and high precipitation impact the response of rodent communities, and the dynamics of arid ecosystems in general (Peters et al 2021). We correlated annual precipitation with the time of sampling and observed a slight decrease in total precipitation, although this correlation was not significant (r_s = -0.10, p = 0.12, fig. S2). In the future, if the differences in precipitation decrease, we could therefore expect greater biotic homogenization in the rodent communities of the MBR.

Regarding temperature, it was evident that the maximum temperature (r_s = 0.18, p = 0.005, fig. S2) and the average temperature (r_s = 0.16, p = 0.01, fig. S2) of the study site increased during the sampling period. In the final year, the maximum temperature reached the highest

record for the region (> 45 °C). However, despite the increase in temperature, the temperature difference had no significant impact on the dissimilarity components of beta diversity. This may be related to the endothermic capacity of this group of organisms (Boyles et al 2011). In addition to being able to regulate their temperature, rodents in arid areas use strategies such as building nests or burrows that protect them from extreme conditions (Khaliq et al 2014). It should be noted that high temperatures cause physiological consequences that affect the survival of rodents in arid areas (Villar and Naya 2018, Ramirez et al 2022) and considering the estimated increase in temperature for these regions, we cannot rule out that there will be a significant relationship between the increase in temperature and the beta diversity of rodents in the future, as has been seen in other groups that are sensitive to increasing temperatures (White et al 2018, Hulshof et al 2024).

Finally, although the temporal correlation analysis did not show a generalized pattern of biotic homogenization, it is a global phenomenon (Baiser et al 2012, Olden et al 2018, Hidasi-Neto et al 2019, Finderup Nielsen et al 2019) that has several ecological implications (Clavel et al 2011). In our results, species abundance was more sensitive to changes in precipitation, which highlights the importance of including abundance in biotic homogenization studies. The results obtained with incidence and abundance data followed the same direction but, in other groups, the direction of change in beta diversity differed (Cassey et al 2008, Schipper et al 2016). To date, nestedness patterns had been observed in desert rodent communities (Patterson and Brown 1991) but, in this study, we observed the same pattern with the abundance. We also highlight the importance of the monitoring carried out as part of the LTER – Mapimí project, which has provided a continuous series of long-term data that have allowed us to study the change in rodent communities and the challenges they could face under changing climatic conditions. The patterns we report are robust within the temporal scale and ecological system analyzed, although longer-term datasets may ultimately be required to fully characterize the process of biotic homogenization.

Conclusions

Through the 15 years assessment of rodent communities at the Mapimí Biosphere Reserve, we found evidence showing that beta diversity at the grassland has declined, suggesting the onset of biotic homogenization, whereas at the shrubland beta diversity has remained more stable. The changes in rodent beta diversity were related to differences in precipitation over a two-year lagged response, while temperature did not show a significant relationship with rodent beta diversity. These patterns were mainly associated with nestedness and abundance gradients. Given the observed decrease in precipitation and rise in temperature, continued long-term monitoring will be essential to understand how ongoing climatic shifts shape community dynamics and the risk of increasing biotic homogenization in drylands habitats.

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Author contributions
PD Ventura-Rojas curated the data, performed formal analyses, and wrote the first draft of the manuscript. **A González-Romero** conducted fieldwork and conceived the study. **VJ Sosa** conceived the study. **CE Moreno** conceived the study, conducted formal analyses, and provided supervision. All authors reviewed, edited, and approved the final manuscript.

Conflicts of interest
The authors declare that they have no conflict of interest.

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Supplementary material

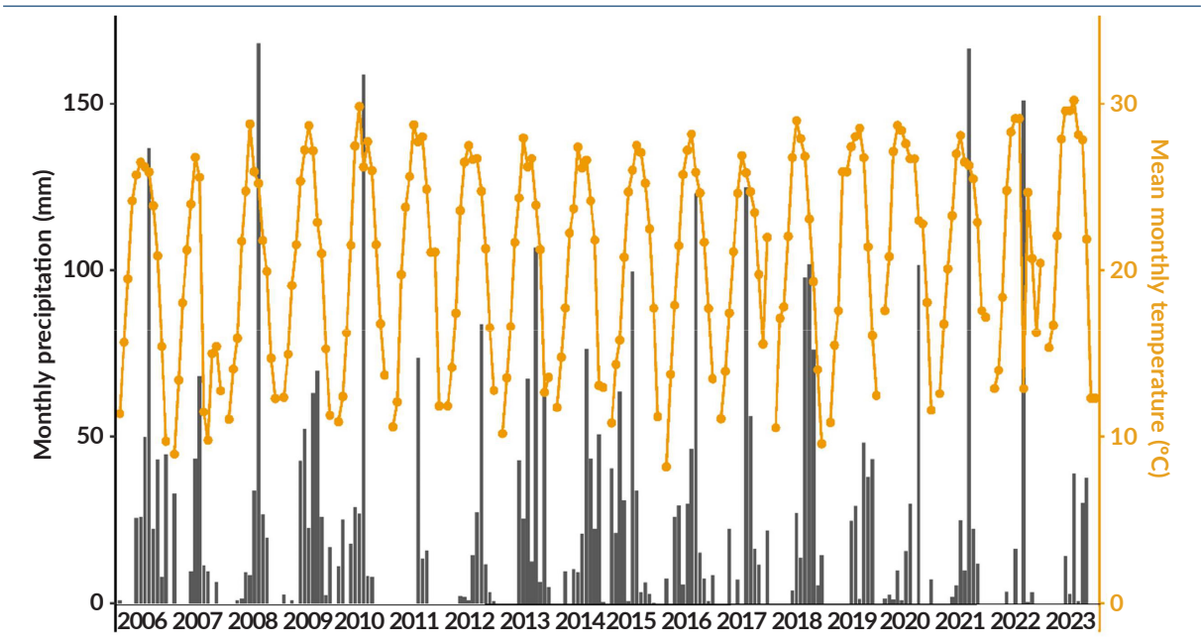

Fig. S1. Climatic data during the sampling period (2006-2023).

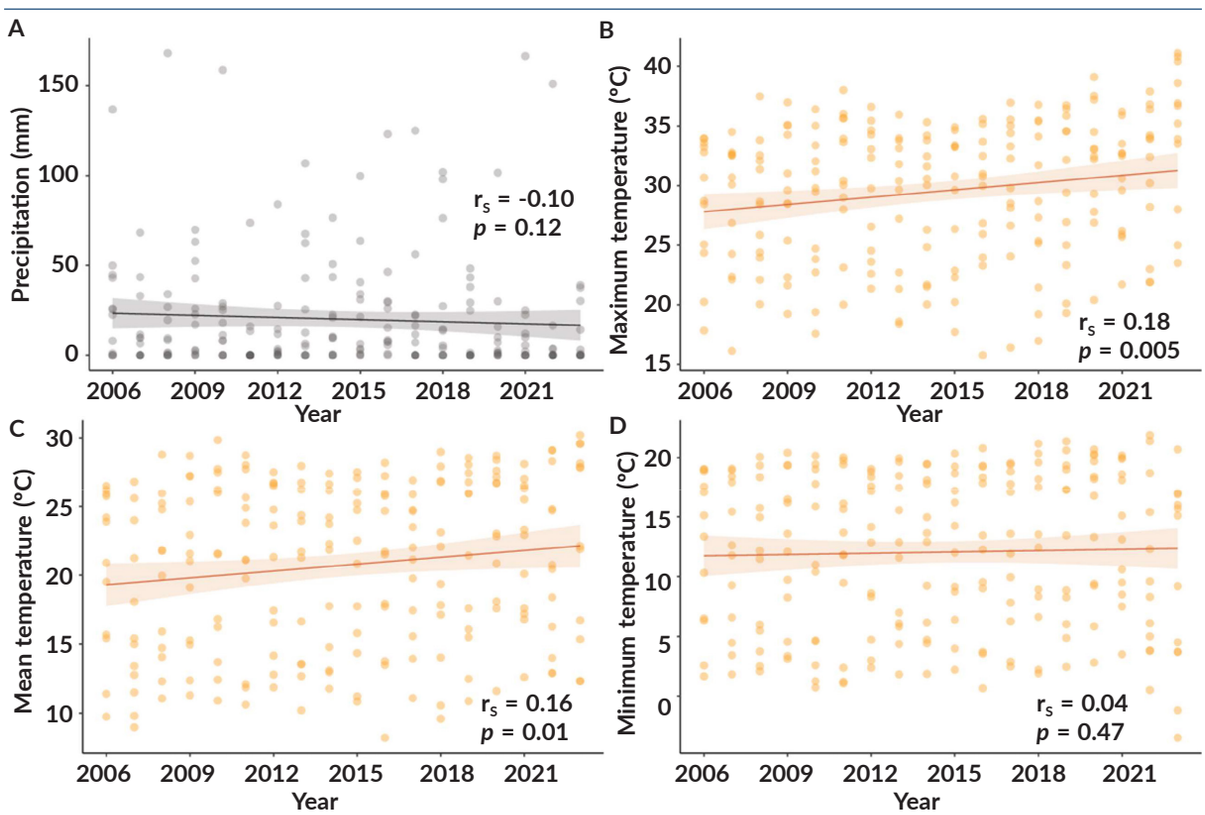

Fig. S2. Scatterplot showing the spearman correlation of: A, the sum of monthly precipitation; B, maximum temperature; C, mean temperature; and D, minimum temperature and time from 2006 to 2023. The shaded areas represent the 95% CI.

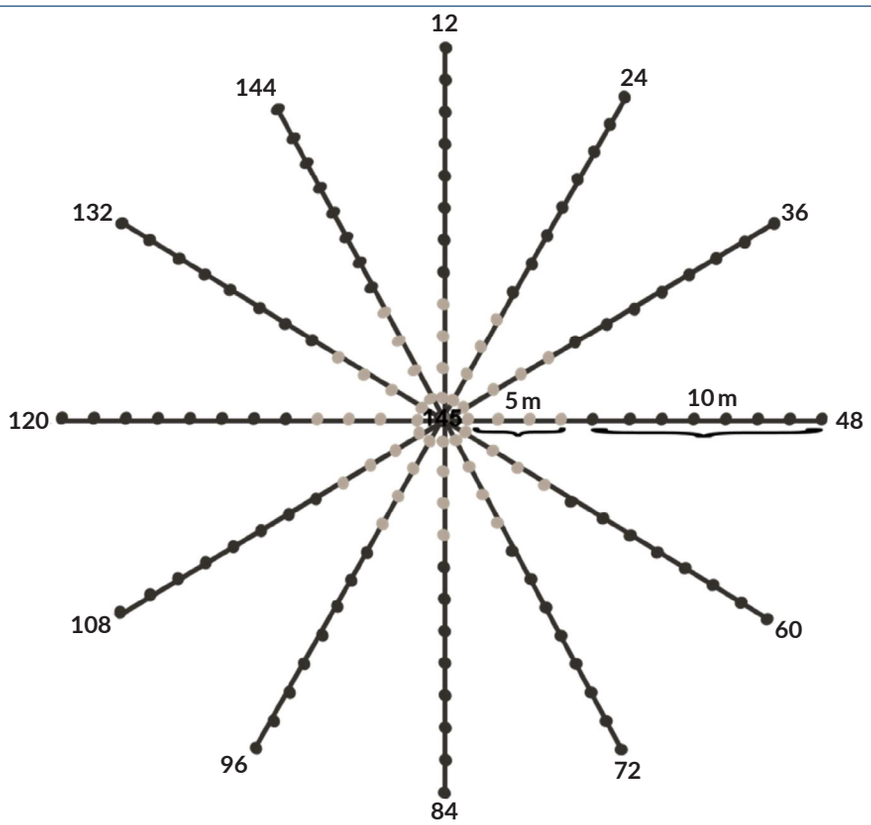

Fig. S3. Radial trapping webs for rodents. Each point is a Sherman trap. The first four traps were placed at 5 meters intervals (grey points). Eight traps were placed at 10 m intervals (black points). Each web was 3.1 ha.

Table S1. Results of correlations (Pearson or Spearman, as applicable) of temporal beta diversity (with incidence and abundance data) of rodents in the shrubland and grassland over time in the Mapimí Biosphere Reserve. r: Pearson's correlation; r_s: Spearman's correlation (rho); β_{sor}: Sorensen dissimilarity (incidence); β_{sim}: species turnover; β_{sne}: nestedness; β_{Bray}: Bray-Curtis dissimilarity (abundance); β_{gra}: abundance gradients; β_{bal}: balanced variation; *p*: probability value associated with the correlation.

	Shrubland						Grassland					
	Dry season		Rainy season		Annual		Dry season		Rainy season		Annual	
	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*
Incidence												
β_{sor}	r = -0.01	0.97	r_s = -0.31	0.29	r = -0.27	0.28	r = 0.16	0.57	r_s = 0.11	0.69	r = -0.07	0.8
β_{sim}	r_s = 0.02	0.95	r_s = -0.30	0.30	r_s = 0.07	0.78	r_s = -0.01	0.98	r_s = -0.53	< 0.05	r_s = 0.03	0.9
β_{sne}	r = -0.01	0.98	r = -0.22	0.46	r_s = -0.21	0.43	r_s = 0.07	0.79	r = 0.54	0.05	r = -0.12	0.66
Abundance												
β_{Bray}	r = -0.12	0.66	r_s = -0.15	0.6	r = -0.29	0.28	r = 0.12	0.66	r_s = -0.15	0.6	r = -0.55	<0.05
β_{gra}	r = -0.08	0.77	r_s = -0.06	0.83	r_s = -0.05	0.84	r = -0.08	0.77	r_s = -0.06	0.83	r_s = -0.34	0.2
β_{bal}	r = -0.02	0.92	r_s = -0.18	0.55	r = -0.13	0.63	r = -0.02	0.92	r_s = -0.18	0.55	r = -0.18	0.52

Table S2. Species captured during monitoring. We use de classification proposed by Hernández et al (2005). Dominant species abundance (> 20 % of the total abundance), subdominant (1-19 %), occasional (1-4 %) and rare species represented (< 1 %).

Species	Shrubland	Grassland
Chaetodipus collis	Subdominant	Rare
Chaetodipus eremicus	Subdominant	Subdominant
Dipodomys merriami	Dominant	Dominant
Dipodomys nelsoni	Subdominant	Subdominant
Perognathus flavus	Rare	Subdominant
Neotoma leucodon	Subdominant	Dominant
Peromyscus eremicus	Subdominant	Subdominant
Peromyscus labecula	Rare	Rare
Onychomys torridus	Rare	Rare
Reithrodontomys fulvescens	Rare	Rare
Reithrodontomys megalotis	Rare	Occasional
Sigmodon hispidus	Rare	Occasional
Ictidomys parvidens	Occasional	Occasional
Xerospermophillus spilosoma	Occasional	Occasional

Table S3. Detailed data on the abundance of species captured in the shrubland from 2008 to 2023.

Species	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Chaetodipus collis	121	162	68	114	69	49	77	104	140	137	158	155	156	77	50	49
Chaetodipus eremicus	36	161	7	11	2	9	20	23	36	21	38	12	7	58	67	21
Dipodomys merriami	77	128	56	49	64	64	99	192	188	132	95	164	150	94	172	101
Dipodomys nelsoni	5	4	4	3	11	5	7	28	53	30	26	37	31	27	41	22
Perognathus flavus	1	2	1	1	0	0	6	1	4	6	4	1	0	0	0	0
Neotoma leucodon	109	48	14	6	8	1	5	32	67	83	77	62	27	151	20	5
Onychomys torridus	0	0	3	6	2	0	4	3	2	5	4	3	1	0	0	0
Peromyscus eremicus	20	24	28	31	23	10	39	46	32	26	12	27	20	21	34	22
Peromyscus labecula	0	0	0	0	1	0	7	1	0	0	1	0	0	0	0	0
Reithrodontomys fulvescens	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Reithrodontomys megalotis	1	0	0	2	2	0	1	0	0	0	0	2	0	1	1	0
Sigmodon hispidus	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Ictidomys parvidens	17	10	15	8	4	3	1	8	32	10	3	23	24	42	12	2
Xerospermophillus spilosoma	13	4	7	5	4	1	2	3	16	7	1	4	4	1	5	3

Table S4. Detailed data on the abundance of species captured in the grassland from 2008 to 2023.

Species	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Chatodipus collis	0	0	0	0	0	0	0	0	3	0	0	0	0	1	1	0
Chaetodipus eremicus	16	31	10	16	9	11	25	32	40	46	24	11	46	55	40	45
Dipodomys merriami	61	50	5	37	24	13	26	68	38	70	27	61	62	64	44	46
Dipodomys nelsoni	6	7	0	5	6	2	1	14	18	19	2	22	18	19	25	18
Neotoma leucodon	78	60	1	4	3	3	4	51	64	63	79	42	21	22	8	3
Onychomys torridus	0	0	0	0	0	0	0	1	6	4	3	0	0	0	0	0
Peromyscus eremicus	8	21	23	15	6	9	23	27	18	24	9	29	9	16	21	7
Perognathus flavus	5	14	8	11	0	3	15	8	8	20	8	10	2	1	4	3
Peromyscus labecula	0	0	3	0	0	0	8	2	0	0	0	0	0	8	0	0
Reithrodontomys fulvescens	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0
Reithrodontomys megalotis	1	3	10	0	1	0	0	3	1	0	0	1	4	3	1	0
Sigmodon hispidus	0	6	2	2	0	0	1	9	14	9	3	7	2	0	0	0
Ictidomys parvidens	0	5	3	0	0	0	0	1	3	0	0	3	5	2	1	0
Xerospermophillus spilosoma	3	7	4	1	3	0	5	2	18	3	0	1	6	0	9	0

Table S5. Results of all multiple regressions based on distance matrices (MRM) of each component of the temporal beta diversity of rodents and annual climatic variables. MRMs included the total sum of precipitation and mean monthly temperature. t_1: 1 year before trapping; t_2: 2 years; p_P: precipitation (*p*-values); p_T: temperature (*p*-values); (–) $p > 0.05$; β_{sor}: Sorensen dissimilarity (incidence); β_{sim}: species turnover; β_{sne}: nestedness; β_{Bray}: Bray-Curtis dissimilarity (abundance); β_{gra}: abundance gradients; β_{bal}: balanced variation.

	t_1					t_2				
	F	R^2	*p*	p_P	p_T	F	R^2	*p*	p_P	p_T
Incidence; Shrubland										
β_{sor}	0.34	0.005	–	–	–	1.32	0.02	–	–	–
β_{sim}	0.06	0.01	–	–	–	0.86	0.01	–	–	–
β_{sne}	0.15	0.002	–	–	–	3.36	0.05	–	< 0.05	–
Incidence; Grassland										
β_{sor}	1.32	0.02	–	–	–	5.12	0.08	–	< 0.05	–
β_{sim}	2.72	0.04	–	–	–	6.36	0.09	–	< 0.05	–
β_{sne}	1.40	0.02	–	–	–	23.64	0.28	< 0.01	< 0.001	–
Abundance; Shrubland										
β_{Bray}	0.03	0.005	–	–	–	4.87	0.07	–	0.01	–
β_{bal}	5.13	0.08	–	–	–	15.06	0.20	< 0.01	0.01	–
β_{gra}	2.30	0.03	–	–	–	12.42	0.17	< 0.05	0.01	–
Abundance; Grassland										
β_{Bray}	2.18	0.03	–	–	–	6.72	0.10	–	< 0.05	–
β_{bal}	1.83	0.03	–	–	–	11.39	0.16	0.05	0.01	–
β_{gra}	2.67	0.04	–	–	–	25.07	0.30	0.01	< 0.01	–