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Supplementary Information for

Assembly of modern mammal community structure driven by Late Cretaceous dental evolution, rise of flowering plants, and dinosaur demise

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Dataset S1

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Supplementary Information Text

This study is the first to analyze the ecological structure of Mesozoic mammaliaform communities with the aim of identifying evolutionary and ecological drivers that have shaped mammaliaform communities through time. We used three ecological parameters of mammaliaform species to calculate two taxon-free ecological indices for each community, and we analyze the ecospace occupation of each extinct mammaliaform community in comparison to extant counterparts from diverse biomes. Our results indicate that Mesozoic mammaliaform communities and extant, small-bodied mammalian communities differ significantly, and these differences might stem from the intrinsic and extrinsic factors, such as developmental constraints, ecological selective pressures, and environmental changes. Here, we provide full description of the materials and methods and the results of our study.

Materials and Methods

Environmental and taxonomic data for extant, small-bodied mammalian communities. To develop modern analogs against which we interpret the ecology of extinct mammaliaform communities, we surveyed the literature to find the available studies on extant, small-bodied mammalian communities (mid-range body mass mostly ≤ 5 kg, following 1, 2). We then assembled a dataset based on whether the publication provided the details of the species composition of the community and had environmental factors (habitat type, climate type, vegetation type) listed and compiled their taxonomic and ecological data for our analyses. The 98 extant, small-bodied mammalian communities in our dataset cover most continents and all major environmental types (see Fig. 1, *SI Appendix*, Dataset S1). Because no Mesozoic flying mammaliaform has been recovered so far, we excluded only the volant taxa (bats) from the extant communities in order to keep the extant small-bodied mammalian communities maximally analogous to their Mesozoic counterparts (3, 4). In total, 410 extant, small-bodied mammalian species (57 families, 25 orders) were included in the dataset (*SI Appendix*, Dataset S1). Each community was categorized using three environmental classification schemes: (i) habitat openness (i.e., open or closed); (ii) climate type (i.e., tropical, arid, temperate, or cold [5]); and (iii) vegetation type (i.e., tropical rainforest, tropical seasonal forest, savanna, grassland, shrubland, desert, temperate forest, or boreal forest [6]; World Wild Fund (WWF) Ecoregions [https://www.worldwildlife.org/biomes]; International Geosphere-Biosphere Programme [IGBP, http://www.igbp.net]). The climate type of each local community was assigned primarily on the basis of criteria in the Köppen-Geiger climate classification and was verified using a high-resolution (5 arc minute) Köppen-Geiger map (7, 8; http://koeppen-geiger.vu-wien.ac.at/present.htm) in Google Earth Pro (version 7.3.2.5491, 64-bit). We recognize that vegetation classifications vary depending on different environmental criteria used, and there is no universal approach for classifying vegetation types of local communities. Thus, we integrated multiple classification schemes, including IGBP land classification, Whittaker Biomes (6), and WWF Terrestrial Ecoregions (https://www.worldwildlife.org/biome-categories/terrestrial-ecoregions), to ensure accurate and consistent vegetation assignment for each local community (*SI Appendix*, Dataset S1). Habitat openness was also inferred on the basis of these vegetation classes, with savanna, grassland, shrubland, and desert considered open and the rest closed. For each community, we also compiled available geographic and environmental data for the locality (i.e., latitude, longitude, elevation, mean annual precipitation [MAP], and mean annual temperature [MAT]) from the primary literature (*SI Appendix*, Dataset S1).

Taxonomic and autecology data for five extinct, small-bodied mammaliaform communities. Most Mesozoic mammaliaform fossil localities yield isolated elements, predominantly teeth and fragmentary jaws; delicate skulls and associated postcranial skeletons are very rarely preserved. Thus, the opportunity to comprehensively infer the paleoecology of the represented paleocommunities is limited. The Konservat Lagerstätten from the Mid-Upper Jurassic and Lower Cretaceous of northeastern China represent possible exceptions (9). Many of the fossil taxa known from these Lagerstätten are represented by nearly complete skulls and skeletons (9–12), such that robust paleoecological inferences are possible for most members of the paleocommunities (*sensu* 13). Using recent stratigraphic and biostratigraphic correlations of the assemblages (14, 15, but see 16), we compiled four Mesozoic mammaliaform paleocommunities (*SI Appendix*, Table S1): two from the Mid-Late Jurassic, approximately 164–160 million years ago (Ma), namely the Jiulongshan (JLS) paleocommunity from the Jiulongshan Formation and the Tiaojiashan (TJS) paleocommunity from the

Tiaojishan Formation, and two from the Early Cretaceous, approximately 125–122 Ma, namely the Lujiatun-Jianshangou (LJT-JSG) and Dawangzhangzi (DWZZ), both from the Yixian Formation. More precise age data are available for each of these assemblages in the *SI Appendix*, Table S1. The Jiulongshan fossil assemblage was recovered from one locality, whereas the other three assemblages are each a composite of two to three localities correlated to the same stratigraphic horizon and within 80 km of each other. *Acristatherium yanensis*, *Gobiconodon zofiae*, *Juchilestes liaoningensis*, and *Meemanodon lujiatunensis* are all represented by specimens with relatively complete, well-preserved skulls but no postcranial elements. For each, we inferred locomotor mode on the basis of inferences of the phylogenetically closest relative with a well-preserved postcranial skeleton. We excluded three eutriconodontans, *Liaotherium gracile* and *Manchurodon simplicidens* from the Mid-Late Jurassic paleocommunities and *Gobiconodon luoianus* from the Early Cretaceous paleocommunities, due to poor stratigraphic correlation or poor fossil preservation (17–19); our qualitative assessment is that the inclusion of these taxa would not strongly affect the ecospace occupation. As a Cenozoic point of comparison, we included small-bodied species (≤ 5 kg) from the middle Eocene mammalian assemblage from the Messel Oil Shale Lagerstätte in Germany, which is approximately 47 Ma in age (*SI Appendix*, Table S1).

Ecological parameters. We categorized each species in each community according to three ecological parameters: body size, dietary preference, and locomotor mode (*SI Appendix*, Table S2). These ecological parameters reflect important aspects of a species autecology, including physiology, food resource use, habitat use, and survival strategies (20). For most extant, small-bodied mammals, these traits are documented in natural history compendia and the primary literature (21–23), and, for extinct taxa, they can be inferred from well-preserved fossils (24–27). It should be noted that the ecological parameters in the literature are often provided either as descriptive information or explicit details based on the field experiments. In cases in which ecological assessments of different authors were contradictory, we made an assessment based on the evidenced presented. We used body mass as a proxy for body size, with the mid-range value when it was reported as a range in the literature (*SI Appendix*, Dataset S1). For extinct species, we used published estimates of body mass, or estimated it ourselves by applying taxon- and morphology-appropriate regression formulae (28, 29) to relevant skeletal measurements from the literature or from personal observations of available specimens (*SI Appendix*, Table S1). We acknowledge that it would be best to use the same skeletal measurement and same formula to estimate the body mass for all of the fossil species. However, the incomplete nature of the fossil record prevents us from doing so. A secondary analysis to estimate body mass indicates that our body-size ranking scheme of the Mesozoic species is robust to the variation introduced by the skeletal measurement and formula used (*SI Appendix*, Table S3). We transformed all body masses to a $\log_2$-scale (as opposed to a $\log_{10}$-scale) so as to not overly compress the subtle differences in body mass among small-bodied mammaliaforms. Based on the transformed body mass, we ranked the body size from one to five (*SI Appendix*, Table S2).

For dietary preference, we categorized extant, small-bodied species into one of six dietary categories (carnivory, insectivory, omnivory, granivory, frugivory, or herbivory; *SI Appendix*, Table S2). Carnivory refers to species preying on animals as their primary food source; insectivory is restricted to species primarily feeding on insects; omnivory refers to species eating both animal and plant products. Herbivory is used broadly to include extant, small-bodied mammalian species that consume diverse plant materials (seeds, fruits, leaves, roots, etc.); whereas frugivory and granivory are restricted to those species that have diets predominantly of fruits or seeds, respectively. We note that the dietary preference of many extant, small-bodied mammalian species can vary according to fluctuating ecological and environmental conditions (e.g., competition, seasonality, and geography [30]), but for practical reasons we did not incorporate that level of detail into the dataset in this study.

We created an ordinal scale of the six dietary preferences following the ordinal scale from the orientation patch count (OPC) of extant mammalian species. OPC, which is a measure of dental complexity, strongly correlates with dietary preferences among extant mammals (e.g., carnivorans, rodents, chiropterans, and marsupials; [26, 31, 32]); namely, values increase from carnivory to omnivory to herbivory (26). It has been used as a predictor of primary dietary preference of extinct mammals (e.g., plesiadapids and multituberculates [33, 34]). We re-visited published OPC datasets (26, 31) and refined the dietary preferences of the sampled extant taxa according to our six categories. Then, we re-calculated the OPC range for each category. These new ranges provided an ordinal ranking scheme for our dietary categories; carnivory has the lowest mean OPC values, followed by insectivory, omnivory, granivory, frugivory, and herbivory (*SI Appendix*, Table S2).

Ideally, OPC (or some other quantitative proxy) should be used to infer the dietary preference of each fossil species. However, because most of the fossil specimens in this study are preserved as flattened (two-dimensional) slabs, they are less amenable to OPC and other quantitative methods that require undistorted three-dimensional preservation of the tooth crowns. Thus, to infer the dietary preference of each fossil species in our study we relied on our own assessment of gross dental morphology, wear facets, and gut contents as well as assessments by previous studies (*SI Appendix*, Table S4). Because of the importance of the possible co-evolution of mammals and angiosperms, we designated an herbivorous and omnivorous diets that included fruit by using "*" in *SI Appendix*, Table S1. Future studies will aim to directly measure OPC and other dental shape metrics in these and other extinct taxa (35).

Chen and Wilson (27) conducted quantitative analyses of osteological indices derived from linear measurements of appendicular skeletons of 107 extant, small-bodied mammalian species. The results of those analyses were used to infer locomotor mode in a sample of Mesozoic mammaliaform taxa. They identified a major morphofunctional continuum that extends from terrestrial to scansorial, arboreal, and gliding modes, reflecting an increasingly slender postcranial skeleton with longer limb output levers adapted for speed and agility. The continuum also extends from terrestrial to semiaquatic/semifossorial, and fossorial modes, reflecting an increasingly robust postcranial skeleton with shorter limb output levers adapted for powerful, propulsive strokes (27). Following that study (27), we categorized the locomotor mode of each extant and extinct species as gliding, arboreal, scansorial, terrestrial, semiaquatic, semifossorial, fossorial, or saltatorial (*SI Appendix*, Table S2). The locomotor mode information of extant, small-bodied mammalian species was taken from the primary literature (*SI Appendix*, Dataset S1). We ranked locomotor modes from one to eight according to the locomotor continuum established in (27:fig. 4*A*), where all modes but the saltatorial mode were assigned in a more-or-less linear fashion along Canonical Function 2 from gliding to fossoriality. To verify this continuum, we used the published dataset of (27) to calculate the morphological distances using the centroid of the gliding mode against the centroid of each other seven locomotor modes (*SI Appendix*, Table S2). We designated the gliding mode as rank 1 and the other locomotor modes were assigned successive ranks according to increasing morphological distance from the gliding mode along the locomotor continuum (*SI Appendix*, Table S2). Because the continuum is not absolutely linear, particularly for the saltatorial mode, we explored the alternative ordinations by applying three alternative ranking schemes of the locomotor modes. We placed the saltatorial at locomotor ranks 5, 6, or 7 in each alternative ranking scheme because the function and morphology of the postcranial skeletons of saltatorial species more closely resemble ground-dwelling species (terrestrial, semiaquatic, semifossorial, and fossorial) than they resemble tree-living species (gliding, arboreal, and scansorial). As a result, three alternative schemes to rank locomotor modes from 1 to 8 are (a) gliding, arboreal, scansorial, terrestrial, saltatorial, semiaquatic, semifossorial, fossorial; (b) gliding, arboreal, scansorial, terrestrial, semiaquatic, saltatorial, semifossorial, fossorial; and (c) gliding, arboreal, scansorial, terrestrial, semiaquatic, semifossorial, saltatorial, fossorial. We ultimately chose the scheme in *SI Appendix* Table S2 for our analysis, see Results for details.

For the fossil species, we assigned locomotor mode based on published studies of the functional morphology or morphometrics of the fossil taxa and their closest relatives (*SI Appendix*, Table S1).

Ecological structure analysis. Ecological parameters (body size, dietary preference, and locomotor mode) were used to form a three-dimensional theoretical ecospace of 240 ecological-parameter-value combinations (~"niches," hereafter, eco-cells) (5 body-size ranks × 6 dietary preference ranks × 8 locomotor ranks). Using the parameter values for each species, we plotted the ecospace occupation of each extant, small-bodied mammalian community in our study. We then quantified the magnitude of the filled ecospace of each community using two indices: ecological disparity (EDisp) and ecological richness (ERich). Ecological disparity measures the magnitude of ecological differences among species in a given ecospace. It is calculated as the mean pairwise distance of all species pairs in the same community. The calculation for one pair of species (*i, j*) is:

$$EDisp_{(i,j)} = |\ BS_i - BS_j\ | + |\ DT_i - DT_j\ | + |\ LM_i - LM_j\ |$$

where *BS* is the body-size rank, *DT* is the dietary preference rank, and *LM* is the locomotor mode rank for species *i* and *j*. As an example of a species-pair comparison, the elegant fat-tailed opossum *Thylamys elegans*, which weighs between 18 g and 55 g (mid-range body mass 37 g), primarily eats insects, and uses scansorial locomotion, was assigned to eco-cell 2-2-3; whereas the Bolivian chinchilla rat *Abrocoma bennetti* was assigned to eco-cell 3-6-3 because it weighs slightly more (mid-range body mass 263 g), primarily eats a range of plant materials, and uses scansorial locomotion. The ecological disparity between *T. elegans* and *A. bennetti* is calculated as $EDisp_{(M.\ elegans,\ A.\ bennetti)} = | 2 - 3 | + | 2 - 6 | + | 3 - 3 | = 5$. ERich measures the number of cells occupied by a community in the theoretical ecospace. Both EDisp and ERich are taxon-free indices; the latter resembles the functional richness index, which can be used with continuous or ordinal variables (36, 37). However, ERich differs from functional richness in measuring the number of occupied eco-cells rather than the smallest convex hull volume that encloses all species (37). We expect ERich is highly correlated with species richness: the higher the number of species, the higher the ERich in a community. It should be noted that the results of EDisp analyses may be changed by using alternative ranking schemes of locomotor modes (see Results for details); ERich analyses as well as the rest of other analyses, however, could not be altered regardless of ranking schemes.

We calculated 95% confidence intervals for EDisp values by resampling extant, small-bodied mammalian communities in each of the two habitat types, four different climate types, and eight vegetation types with replacements (1,000 bootstraps). To assess whether species richness influences EDisp, we constrained the number of species in each community in successive resampling runs. More specifically, we constrained successive resampling runs to five, seven, and ten species to mirror the species richness of the four assembled Mesozoic mammaliaform paleocommunities and, in turn, provide more balanced comparisons.

It is commonly assumed that extant mammalian communities are ultimately shaped by climate change at local, regional, and global scales (38–40). To test this assumption, we investigated whether ecological structure of the extant communities is correlated with environmental factors. Specifically, we tested whether EDisp and ERich are correlated with latitude, mean annual temperature (MAT), mean annual precipitation (MAP), and elevation. For each combination of ecological structure metric (EDisp and ERich) and environmental factor, we ran a simple linear regression analysis and calculated 95% confidence intervals.

Ecospace occupation analysis. We also compared ecospace occupation of small-bodied mammaliaform communities (i.e., which eco-cells were filled) within and across environmental categories. For extant communities, we calculated ecological beta diversity within each environmental type (habitat, climate or vegetation) using multivariate dispersion (41, 42). We calculated the Euclidean distance of the centroid of each community from the grand centroid of all communities within that environmental category (e.g., tropical climate) (43). Ecological beta diversity of that environmental category was then calculated as the mean Euclidean distance of all communities in that category from the grand centroid—smaller values indicate smaller variations in ecospace occupation among communities in that environmental category. Because we do not have more than two extinct communities from any time horizon or any paleoenvironmental grouping, we could not apply multivariate dispersion to measure beta diversity among extinct mammaliaform communities. Instead, to compare ecospace occupations of extinct communities to extant communities, we calculated Jaccard dissimilarity index for each pairwise combination of an extinct and an extant community.

To compare ecospace plots across environmental types that are represented by variable numbers of communities, we used resampling to construct exemplar plots of ecospace occupation for each environmental type. First, we determined the number of species typical for each environmental type by resampling the number of species of each community in that environmental type (e.g., grassland). Then, we bootstrapped the occupied eco-cells of all communities in that environmental type (e.g., grassland) up to that number of species for that environmental type.

Discriminant function analysis. We conducted a series of discriminant function analyses (DFA) using data of extant, small-bodied mammalian communities to assess how well ecological parameters can be used to infer the environmental categories of both extinct and extant mammaliaform communities (44, 45). We standardized the data by calculating the relative proportion of each rank for each ecological parameter for each environmental type (44; *SI Appendix*, Table S5) and then arcsine-transformed these data prior to the DFA (46). The results of the DFA provide a quantitative assessment on how well the extant, small-bodied mammalian communities can be used for categorizing habitat openness, climate type, and vegetation type. We then used this training set as a basis to predict the paleoenvironment of each of the five extinct mammaliaform communities for which we had also performed the same data transformation.

Null model test. To evaluate the significance of patterns of ecospace occupation across different environmental types, we calculated a checkerboard score. This metric was originally developed for evaluating species co-occurrence pattern by measuring the number of "checkerboard units" of all species in an assemblage (47). In our study we instead treat each unique eco-cell (e.g., 2-2-3 and 3-6-3 in the example above) as a "species." The number of checkerboard units for each possible pair of eco-cells is calculated as

$$C_{i,j} = (r_i – S) \times (r_j – S),$$

where r_i and r_j are the row totals of eco-cells *i* and *j*, respectively, and *S* is the total number of co-occurrences of eco-cells *i* and *j* (47). The *C*-score is the mean of checkerboard units across all eco-cell pairs and was evaluated for eco-cell occurrence matrices for all environmental categories. Eco-cells that always occur together will have zero *C*-score, whereas the eco-cells that are largely segregated will have a large *C*-score. Observed *C*-scores were used to compare to the average *C*-scores generated from 1000 randomized co-occurrence matrices (47). We used the EcoSimR with the fixed-fixed model (SIM9; 48) that is developed for R language programming to generate the null distribution of the *C*-scores. The SIM9 preserves the number of occurrences of the row and column totals in data metrics and is robust against the Type I and II errors (49).

Because our extant, small-bodied mammalian communities differ from each other in the number of species, we cannot directly compare the community *C*-score to one another in each environmental type. Thus, we calculated the standard effect size (*SES*) of each environment. The *SES* measures the number of standard deviations that the observed index is above or below the mean of simulated communities (50). The *SES* is calculated as

$$SES = (I_{obs} - I_{sim}) / S_{sim},$$

where I_{obs} corresponds to the index of the observed community, I_{sim} corresponds to the simulated community and S_{sim} is the standard deviation of the simulated communities.

Software. We performed all analyses and constructed all figures using the R statistical environment (51) and Mathematica 11.

Results

Ecological structure. Ecological disparity (EDisp) and ecological richness (ERich) vary according to habitat openness, climate type, and vegetation type. On average, both closed- and open-habitat communities have relatively high ecological disparity (student t-test, P = 0.083; *SI Appendix*, Tables S6, S7 and Fig. S1), although the closed-habitat communities fill significantly more eco-cells than open-habitat communities do ($ERich_{closed}$ = 8.40, $ERich_{open}$ = 4.75; student's t-test, P < 0.001; *SI Appendix*, Tables S6, S8 and Fig. S1). Among the four climate types, tropical mammalian communities have, on average, low ecological disparity ($EDisp_{tropical}$ = 3.49) but high ecological richness ($ERich_{tropical}$ = 8.63); whereas mammalian communities in arid climates occupy more disparate regions of the ecospace ($EDisp_{arid}$ = 3.75) and have lower ecological richness ($ERich_{arid}$ = 4.31; *SI Appendix*, Table S6 and Figs. S1, S2). Temperate and cold climate communities have significantly higher ecological disparity than communities in both tropical and arid climates ($EDisp_{temperate}$ = 4.12, $EDisp_{cold}$ = 4.54; pairwise Student's t-test, P < 0.015) and intermediate ecological richness ($ERich_{temperate}$ = 7.10, $ERich_{cold}$ = 6.04; *SI Appendix*, Tables S6–S8 and Figs. S1, S2). Among the eight vegetation types, tropical communities differ from each other in that tropical rain forest communities have markedly lower ecological disparity than tropical seasonal forest communities do ($EDisp_{tropicalrainforest}$ = 3.20, $EDisp_{tropicalseasonalforest}$ = 4.07, P < 0.000), though both types of tropical forest communities have high ecological richness ($ERich_{tropicalrainforest}$ = 9.33, $ERich_{tropicalseasonalforest}$ = 10.13, P= 0.764; *SI Appendix*, Tables S6–S8 and Figs. S1, S2). Conversely, communities in more open vegetation types (i.e., savanna, grassland, shrubland, and desert) tend to have low ecological richness ($ERich_{[range]}$ = 3.78–5.65), and, with the exception of savanna communities, have relatively high ecological disparity ($EDisp_{[range]}$ = 3.54–4.22; *SI Appendix*, Tables S6, S7). Communities in temperate and boreal forests are high in ecological disparity ($EDisp_{temperateforest}$ = 4.27, $EDisp_{borealforest}$ = 4.26), but have low ecological richness ($ERich_{temperateforest}$ = 8.19, $ERich_{borealforest}$ = 6.00; *SI Appendix*, Tables S6, S7). The resampled ecological disparity of each environmental category shows no or little difference from the observed average values (*SI*

Appendix, Table S9). However, the resampled ecological disparity shows significant difference across most of environmental categories; only three pairwise comparisons show insignificant difference (tropical seasonal forest *vs.* grassland, tropical seasonal forest *vs.* shrubland, and desert *vs.* temperate forest; *SI Appendix*, Table S10). The three alternative ranking schemes for locomotor mode produced similar EDisp patterns across different environmental types (*SI Appendix*, Tables S11).

Among Mesozoic mammaliaform communities, Tiaojishan (TJS) and Dawangzhangzi (DWZZ) mammaliaform communities are both low in ecological disparity ($EDisp_{[range]}$ = 2.87–3.40) and ecological richness ($ERich_{[range]}$ = 5.00–6.00; *SI Appendix*, Table S6). In contrast, Jiulongshan (JLS) mammaliaform community has high ecological disparity ($EDisp_{JLS}$ = 4.40) but low ecological richness ($ERich_{JLS}$ = 5.00), whereas Lujiatun-Jianshangou (LJT-JSG) mammaliaform community is low in ecological disparity ($EDisp_{LJT\text{-}JSG}$ = 3.27) but high in ecological richness ($ERich_{LJT\text{-}JSG}$ = 9.00; *SI Appendix*, Table S6). Unlike all of the Mesozoic mammaliaform communities, the Messel Oil Shale Pit mammalian communities are high in both ecological disparity and ecological richness ($EDisp_{Messel}$ = 5.73, $ERich_{Messel}$= 19.0; *SI Appendix*, Table S6).

In addition, our analyses indicate that ecological disparity is not highly correlated with environmental factors except that it is positively correlated with latitude (*SI Appendix*, Fig. S4*A*). In contrast, ecological richness is highly positively correlated with latitude, mean annual precipitation (MAP), and mean annual temperature (MAT), and negatively correlated with elevation (*SI Appendix*, Fig. S4*E*, *F*, *G*, *H*). These correlations might reflect that ecological richness, as we expected, is highly correlated with species richness (r^2 = 0.955, $P < 0.001$).

Ecospace occupation. Together, all extant, small-bodied mammalian communities occupy only 41% of the theoretically possible modes of life in our ecospace (i.e., 99 of the 240 eco-cells; *SI Appendix*, Tables S12). Very small- (< 32 g) to medium body-size categories (128–512 g), ground dwellers predominate in our dataset of extant, small-bodied mammalian species (*SI Appendix*, Table S13 and Fig. S5). The most frequently occupied eco-cell is that for very small (< 32 g), terrestrial insectivores (67 unique occurrences), followed closely by small (32–128 g), terrestrial herbivores (61 unique occurrences) and very small (< 32 g), scansorial omnivores (38 unique occurrences) (*SI Appendix*, Table S13). Large regions of the ecospace are unoccupied, in some cases because those ecological combinations might not be viable (20). For example, we do not record any semiaquatic, semifossorial, fossorial, or saltatorial frugivores, likely because of the limited availability of fleshy fruit in the habitats where these locomotor modes are most advantageous (open environments and aquatic environments, respectively; *SI Appendix*, Table S13; 50). Similarly, the restriction of extant, small-bodied gliding mammals to omnivory might reflect selective pressure to maintain a broad diet, but it might reflect competitive exclusion from more specialized diets by volant mammals (i.e., bats, not included in this study; *SI Appendix*, Table S13). A conspicuous, sparsely filled region of the ecospace is that for medium- to large body-size (128–2048 g) mammals with locomotor modes associated with open habitats (i.e., saltatorial, fossorial, and semifossorial; *SI Appendix*, Table S13 and Fig. S6). It does not seem a case of ecological inviability because those eco-cells are filled by some fossil taxa in our study (see *SI Appendix*, Table S1).

The different environmental types show distinctive patterns of ecospace occupation (Figs. 1, 2 and *SI Appendix*, Table S13 and Figs. S5-S7). Our analysis shows that, within the realized ecospace of extant, small-bodied mammalian communities, ecological structure varies with habitat openness (*SI Appendix*, Tables S12, S13 and Figs. S5*A*, S6*A*, S7*A*). Open-habitat communities fill 56 eco-cells, with the most ones being small-bodied (32–128 g) terrestrial herbivores, very small-bodied (< 32 g) terrestrial insectivores, and small-bodied (32–128 g) terrestrial omnivores (*SI Appendix*, Tables S5, S13 and Fig. S5*A*). Granivory is also a common dietary preference in open-habitat communities (*SI Appendix*, Tables S5, S13 and Fig. S5*A*). Closed-habitat communities differ from open-habitat communities in filling more ecospace (86 eco-cells), densely populating the region of ecospace that corresponds to tree-dwelling locomotor modes, and occupying the full range of diet types (*SI Appendix*, Tables S5, S13 and Figs. S5*A*, S6*A*); frugivory is not recorded in open-habitat communities (*SI Appendix*, Table S13 and Figs. S5*A*, S6*A*).

Ecospace occupation of extant, small-bodied mammalian communities also varies with climate type. A caveat is that some climate categories are a composite of multiple vegetation types with divergent ecological signals; thus, our characterization of ecological structure in these climate types might be influenced by differential sampling of vegetation types. Tropical climate communities, for example, are predominantly drawn from tropical forests; in turn, the ecological signal from these forests overwhelms the signal from savannas, which have a markedly different ecospace occupation (see below in vegetation type). Nevertheless, like closed-habitat communities, tropical communities (filling 69 eco-cells) are shifted toward the region of the ecospace that corresponds to tree-dwelling locomotor modes (Figs. 2*E* [left side of ecospace] and *SI Appendix,* Table S13 and Figs. S5*B*, S6*B,* S7*B*). Many species are small- (32–128 g) to medium-sized (128–512 g) omnivores (*SI Appendix,* Tables S5, S13 and Fig. S5*B*). Arid, temperate, and cold communities more densely populate the regions of the ecospace that correspond to ground-dwelling and subterranean locomotion (Figs. 2*E* [right side] and *SI Appendix,* Tables S5, S13 and Fig. S6*B*), and are generally more spread out in the ecospace than tropical communities are (although temperate communities less so). In arid climate, the very small- (< 32 g) to small-bodied (32-128 g) species are more predominant than they are in temperate and cold climates (*SI Appendix,* Tables S5, S13 and Figs. S5*B*, S6*B*).

At the level of vegetation types, our results show the clearest pattern of variation in ecological structure. Tropical forest communities, including both tropical rain forest and tropical seasonal forest communities, form a tight and densely packed cluster in the region of the ecospace corresponding to tree-dwelling locomotor modes (*SI Appendix,* Tables S5, S13 and Figs. S5*C*, S6*C,* S7*C*), with tropical seasonal forest communities showing slightly greater variation in locomotor type. Arboreal and scansorial locomotion are the most predominant in those communities (*SI Appendix,* Tables S5, S13 and Fig. S5*C*). Savanna communities more sparsely populate the ecospace, with focus on its central parts (*SI Appendix,* Fig. S6*C*) and nearly all species adopt terrestrial locomotor mode (*SI Appendix,* Table S5 and Fig. S5*C*). All other vegetation types have communities that better span the ecospace and are less densely packed than tropical forest communities.

The beta diversity of ecospace occupation among closed-habitat communities is lower than it is in open-habitat communities (*SI Appendix,* Fig. S8*A*). This pattern likely relates to the fact that temperate and boreal forest mammalian communities have low beta diversity (*SI Appendix,* Fig. S8*C*). Likewise, many extant, small-bodied mammalian communities in temperate climates have relatively low beta diversity of ecospace occupation (*SI Appendix,* Fig. S8*B*).

The results of the null model test indicate that extant, small-bodied mammalian communities of most environmental types show non-random occupation of the ecospace (*SI Appendix,* Table S14 and Fig. S9). The observed *C*-scores of the communities, except in tropical seasonal forest and savanna, are much higher than those of the simulated communities. This result indicates that the pattern of ecospace occupation of those environments is not random. Extant, small-bodied mammalian communities in tropical seasonal forests and savannas cover a great range of ecological variation with limited sample sizes. Savannas, for example, show different tree coverage, rainfall seasonality, soil texture, and fire frequency in Africa, Australia, and South America (52), each of which is represented by two communities in our dataset. Together, this large ecological variation and limited sample size might have led to simulated *C*-scores that are indistinguishable from the observed ones.

DFA. The DFA results strongly segregate extant, small-bodied mammalian communities according to different environmental types. Although some ecologies are common in both open- and closed-habitat types (scansorial and terrestrial locomotion, omnivorous and insectivorous diets; *SI Appendix,* Table S5 and Figs. S5*A*), the DFA indicates that the ecological compositions of these communities are distinct from each other (Figs. 1D and *SI Appendix,* Fig. S10). The discriminant function 1 (DF1) accounts for 100% of variance in the dataset (*SI Appendix,* Table S15). Open- and closed-habitat communities were well segregated along DF1, which is strongly positively correlated with small body size (32–128 g), granivory, and semifossorial and saltatorial locomotion, but negatively correlated with medium to very large body size (> 128 g), omnivory, frugivory, and tree-dwelling locomotor modes (gliding, arboreal, and scansorial; *SI Appendix,* Table S15). It correctly classified 77.55% of all extant, small-bodied mammalian communities (80.00% and 75.47% of closed and open habitats, respectively; *SI Appendix,* Table S16). In total, 22 out of 98 communities were misclassified (*SI Appendix,* Table S16). In closed-habitat communities, the distribution of body sizes is more even, whereas in open-habitat communities smaller-bodied species (< 128 g) predominate (*SI Appendix,* Table S5 and Fig. S5*A*). Open-habitat communities also have more granivores (they lack frugivores entirely) and more ground-dwelling (saltatorial) and subterranean (semifossorial) mammals; whereas closed-habitat communities have more mammals that climb and live within trees (gliding, arboreal, and scansorial) and, in addition to frugivores, have more carnivores and omnivores (*SI Appendix,* Table S5 and Fig. S5*A*).

The DFA discriminates well among climate types (Fig. 1*D* and *SI Appendix,* Fig. S11*A*, *C*). The first three DFs together account for 100% of the variance in the dataset (DF1=56.68%, DF2=31.75%, DF3=11.57%; *SI Appendix,* Table S15). In the ecospace formed by DF1 and DF2, the tropical and cold communities are well separated from each other and the remaining communities (*SI Appendix,* Fig. S11*A*). In contrast, the arid and temperate communities overlap in the ecospace. However, in the ecospace formed by DF1 and DF3, all types of extant, small-bodied mammalian communities segregate well (*SI Appendix,* Fig. S11*C*). DF1 is strongly positively correlated with omnivory, frugivory, arboreality, and negatively correlated with very small body size (< 32 g), herbivory, and saltatorial locomotion (*SI Appendix,* Table S15 and Fig. S11*B*, *D*). DF2 is strongly correlated with medium to large body size (128–2048 g), frugivory, arboreality, and negatively correlated with very small body size (< 32 g), carnivory, and fossoriality (*SI Appendix,* Table S15 and Fig. S11*B*, *D*). DF3 shows strong positive correlation with the carnivory and scansoriality and negative correlation with fossoriality and saltatorial locomotion (*SI Appendix,* Table S15 and Fig. S11*D*, *F*). In total, the DFA correctly classified 84.69% of the communities (83.33% of tropical communities, 72.00% of arid communities, 90% of temperate communities, and 93.10% of cold communities), and 15 of 98 communities were misclassified (*SI Appendix,* Table S17). Tropical communities are characterized by mammals of above the small body-size category (> 128 g), frugivorous and omnivorous diets, and arboreal locomotion (*SI Appendix,* Figs. S5*B*). Cold communities strongly segregate by herbivorous, gliding, semiaquatic, semifossorial, and saltatorial mammals. Although temperate and arid communities both have many mammals of the very small body-size category (< 32 g), temperate communities differ from arid ones in having more carnivorous, insectivorous, and scansorial mammals; whereas arid communities tend to have more mammals with granivorous diets and fossorial locomotion (*SI Appendix,* Fig. S11*E*, *F*).

The DFA clearly separates communities in the ecospace according to the eight vegetation types (*SI Appendix,* Fig. S12). The first three DFs account for 87.02% of variance of the dataset (DF1=56.00%, DF2=19.81%, DF3=11.21%; *SI Appendix,* Table S15). In the ecospace formed by DF1 and DF2, tropical rain forest, tropical seasonal forest, and savanna communities are well separated from all other vegetation types (*SI Appendix,* Fig. S12*A*), whereas the temperate forest communities are well separated from all others in the ecospace formed by DF1 and DF3 (*SI Appendix,* Fig. S12*C*). Most communities related to open habitats (grasslands, shrublands, and deserts) largely overlap (*SI Appendix,* Fig. S12*A*, *C*, *E*). DF1 is strongly positively correlated with medium to large body size (128–2048 g), frugivory, and arboreality (*SI Appendix,* Table S15 and Fig. S12*B*, *D*). Tropical rain forest and tropical seasonal forest communities are separated from others, primarily due to their mammals of the medium body-size category or larger (> 128 g), frugivory, and arboreality (*SI Appendix,* Figs. S12*A–D*). DF2 is strongly negatively correlated with omnivory and terrestrial locomotion (*SI Appendix,* Table S15 and Fig. S12*B*, *D*), which drives savanna communities to form a relatively distinct grouping (*SI Appendix,* Fig. S11*A*). DF3 is strongly positively correlated with very small (< 32 g) and very large (> 2048 g) body size, carnivorous and omnivorous diets, and gliding, scansorial, terrestrial, and semiaquatic locomotion (*SI Appendix,* Table S15 and Fig. S12*D*, *F*). As a result, boreal and temperate forest communities segregate from most open-habitat communities (savannas, grasslands, shrublands, and deserts) in the ecospace formed by DF1 and DF3 (*SI Appendix,* Fig. S12*C*). In total, the DFA correctly classified 70.41% of the communities (75.00% of tropical rain forest communities, 62.50% of tropical seasonal forest communities, 100% of savanna communities, 55% of grassland communities, 55.56% of shrubland communities, 77.78% of desert communities, 87.50% of temperate forest communities, and 77.78% of boreal forest communities), and 29 of 98 communities were misclassified (*SI Appendix,* Table S18).

Paleoenvironmental inference. The DFA predictions of the environmental types of the extant, small-bodied mammalian communities was relatively reliable. Thus, we used those results as a framework to infer the paleoenvironments of five extinct mammaliaform communities. For each extinct community, we inferred paleoenvironment using three different environmental criteria (habitat openness, climate type, vegetation type) (*SI Appendix,* Table S19). The inferences varied considerably across these criteria. Two Mid-Late Jurassic mammaliaform communities (Jiulongshan and Tiaojishan) were both inferred as having lived in a closed-habitat, cold-climate, or tropical rain forest environment, respectively, depending on the environmental criterion used. In contrast, the inferred paleoenvironments of the two Early Cretaceous mammaliaform communities were drastically different when using habitat openness vs. climate type, despite both paleoenvironments being inferred as tropical seasonal forest when using vegetation type. The Lujiatun mammaliaform community was reconstructed in a closed, tropical environment, and the Dawangzhangzi mammaliaform community in an open, arid environment. Unlike the other extinct mammaliaform communities, the Eocene Messel mammalian community was reconstructed in an open, tropical rain forest in a tropical climate.

In addition, DF1 of each analysis shows strong correlations with MAT and MAP (*SI Appendix,* Figs. S13*B*, *D*, *F*, S14). We used these correlations to predict the paleo MAT and MAP for each extinct mammaliafom community (*SI Appendix,* Table S20). We used these predicted paleo MAT and MAP to plot each extinct community in Whittaker biome plots. The Jiulongshan community (Mid-Late Jurassic, China) falls in either temperate forest or shrubland/woodland, the Tiaojishan community (Mid-Late Jurassic, China) in either tropical seasonal forest/savanna or shrubland/woodland, the Lujiatun-Tiaojishan community (Early Cretaceous, China) in temperate seasonal forest or tropical seasonal forest/savanna, the Dawangzhangzi community (Early Cretaceous, China) in shrubland/woodland, and the Messel community (Eocene, Germany) in either shrubland/woodland or tropical seasonal forest/savanna (*SI Appendix,* Table S19 and Fig. S15). The results of the inferences from these Whittaker biome plots show some discrepancies with the paleoenvironmental inferences from the DFAs as well as with other paleoenvironmental proxy data from the literature.

Supplementary figures

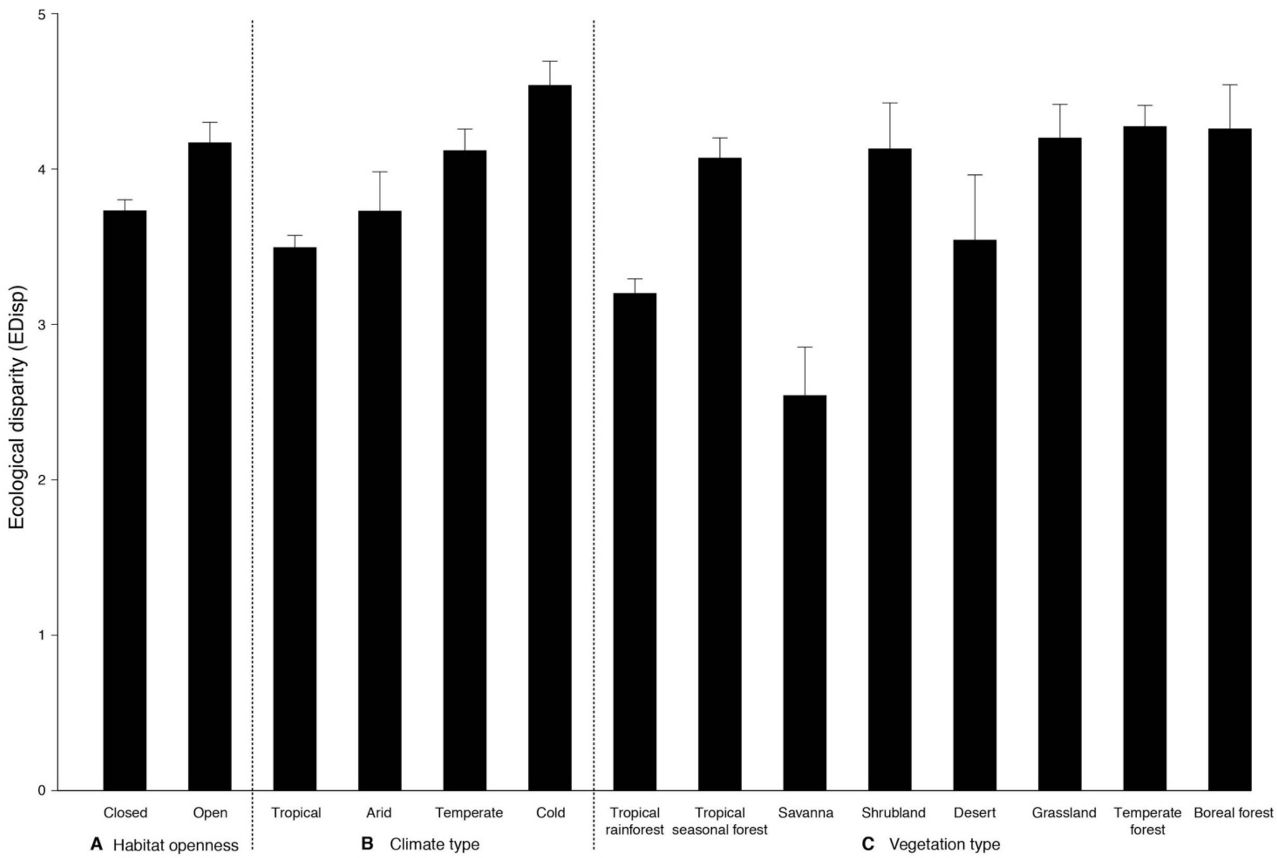

Fig. S1. Ecological disparity (EDisp) of 98 extant, small-bodied mammalian communities arranged by environmental classification: habitat openness (A), climate type (B), and vegetation type (C).

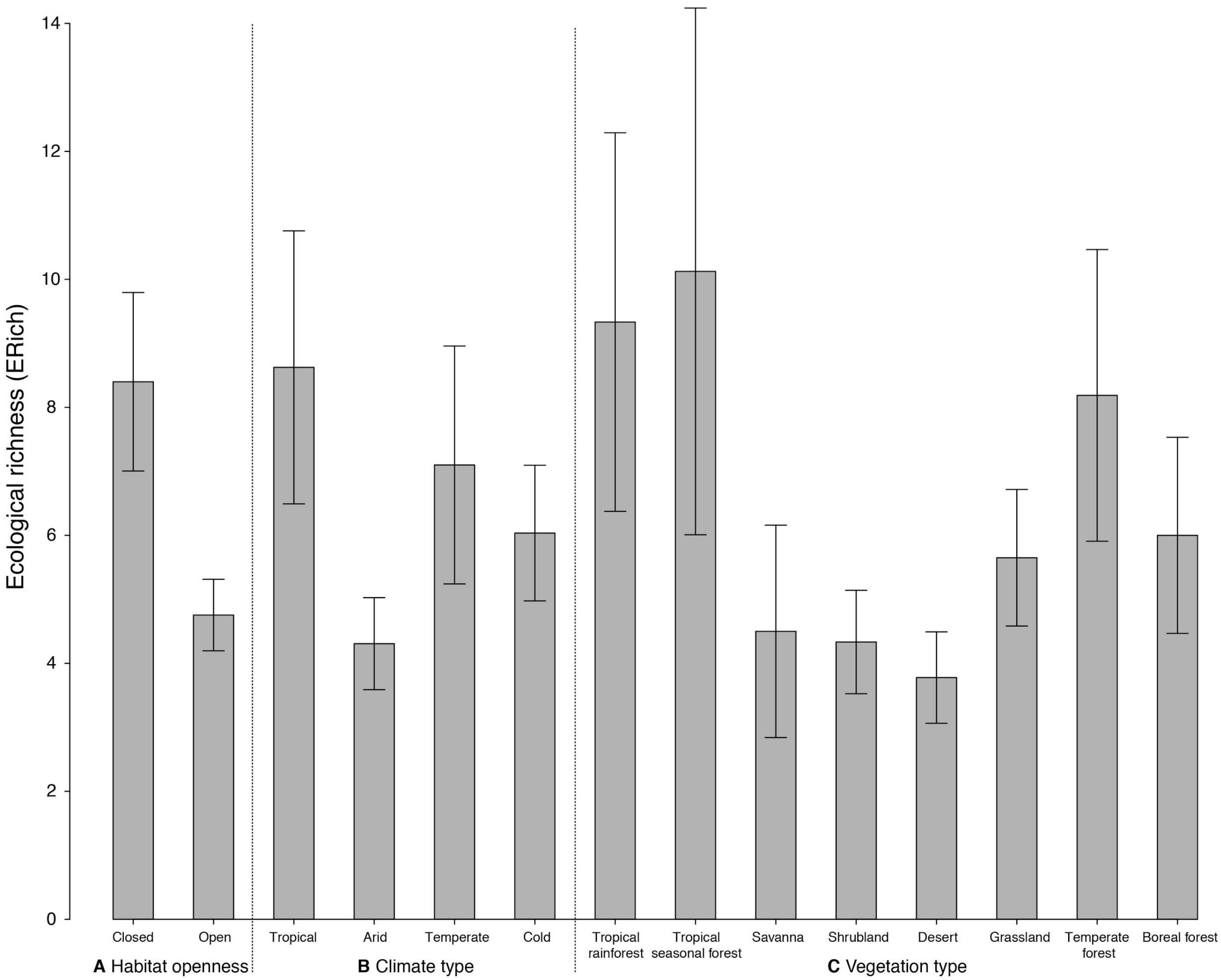

Fig. S2. Ecological richness (ERich) of 98 extant, small-bodied mammalian communities arranged by environmental classification: habitat openness (A), climate type (B), and vegetation type (C).

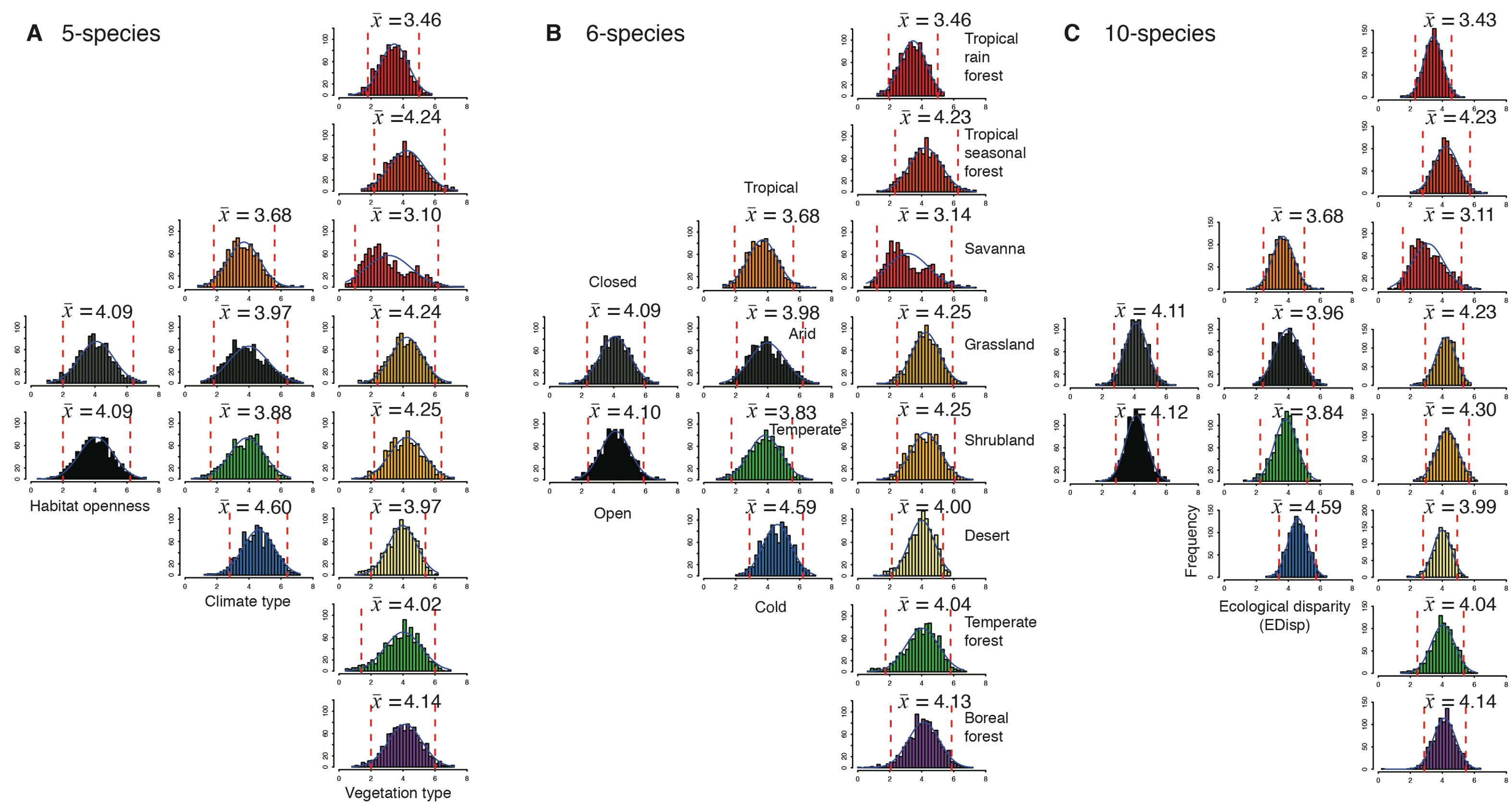

Fig. S3. Resampled ecological disparity by habitat openness, climate type, and vegetation type. The numbers of species (five, six, and ten) correspond to the number of species in the Mesozoic mammaliaform communities. The mean value of each resampled ecological disparity is listed above its histogram.

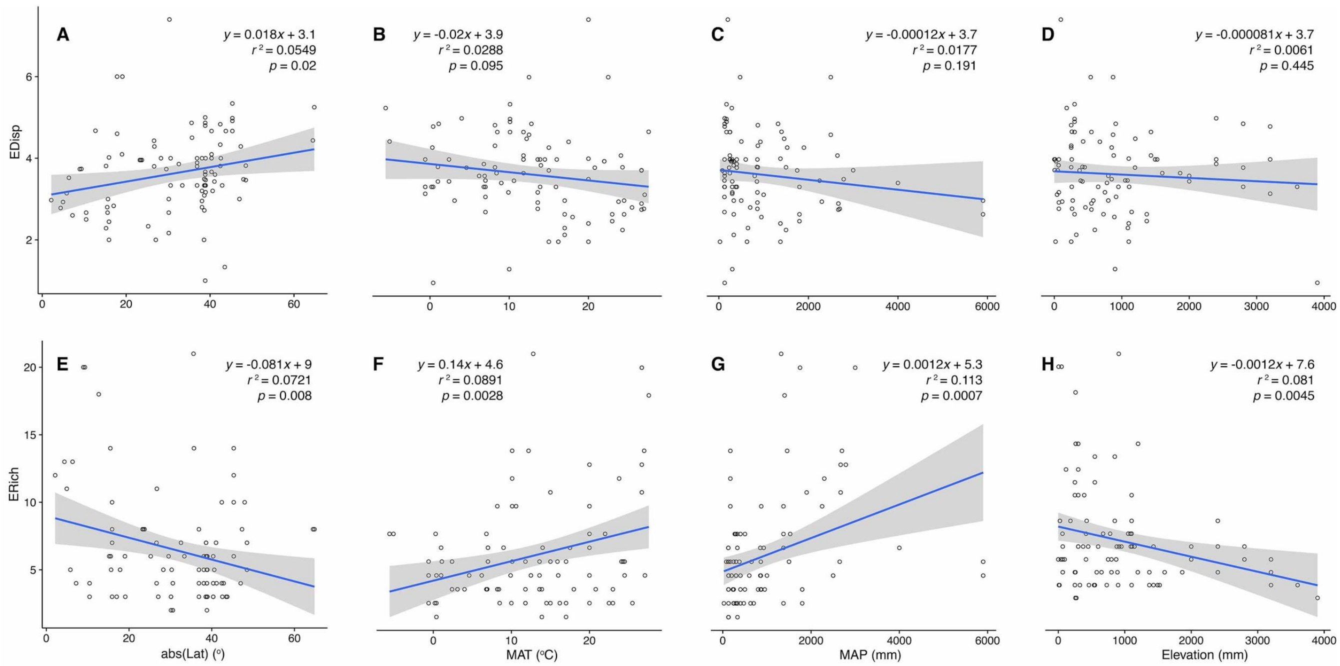

Fig. S4. Linear regression analyses of ecological disparity (EDisp, A–D) and ecological richness (ERich, E–H) of 98 extant small-bodied mammalian communities versus environmental factors: latitude (A, E), mean annual temperature (B, F), mean annual precipitation (C, G), and elevation (D, H). Grey area indicates the 95% confidence intervals. Abbreviations: abs, absolute value; Lat, latitude; MAP, mean annual precipitation; MAT, mean annual temperature.

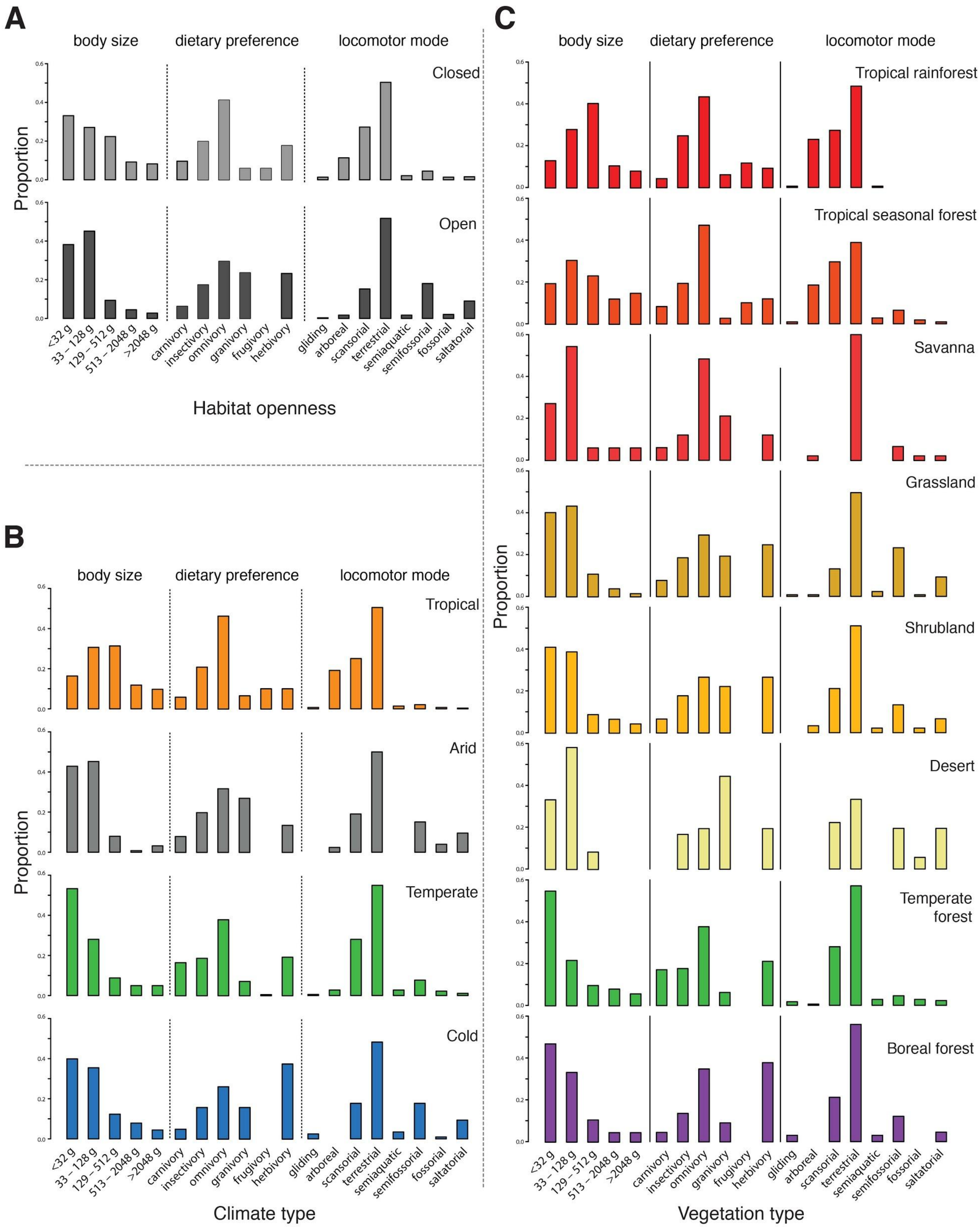

Fig. S5. Proportion (%) of ecological parameters for 98 extant, small-bodied mammalian communities arranged by environmental classification: habitat openness (A), climate type (B), and vegetation type (C).

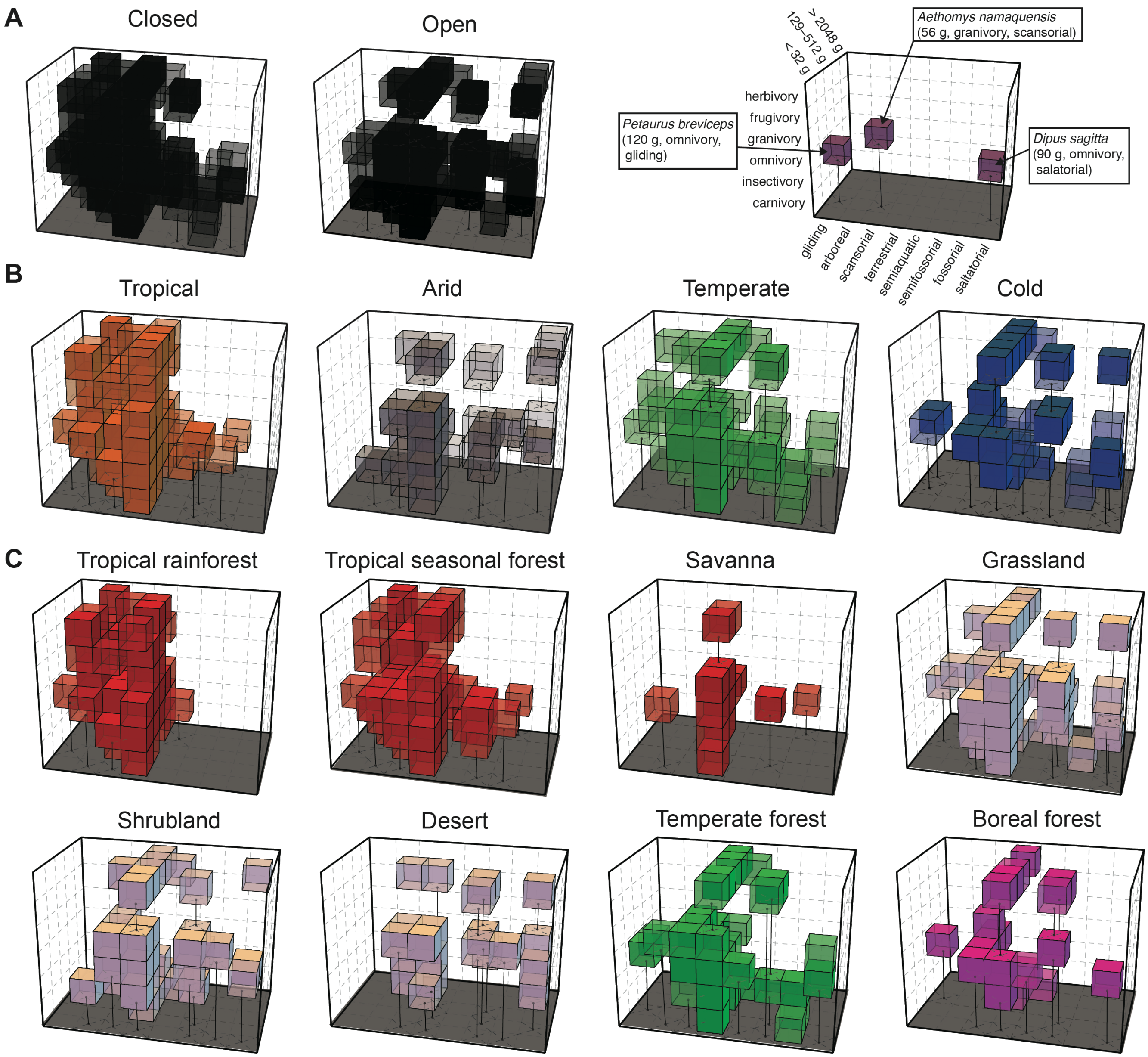

Fig. S6. Composite plots of ecospace occupation of 98 extant, small-bodied mammalian communities arranged by environmental classification: habitat openness (A), climate type (B), and vegetation type (C). The composite plots show all occupied eco-cells for the communities in that environmental type. Each composite plot was generated by plotting all eco-cells in each environmental type. See *SI Appendix*, Materials and Methods for details.

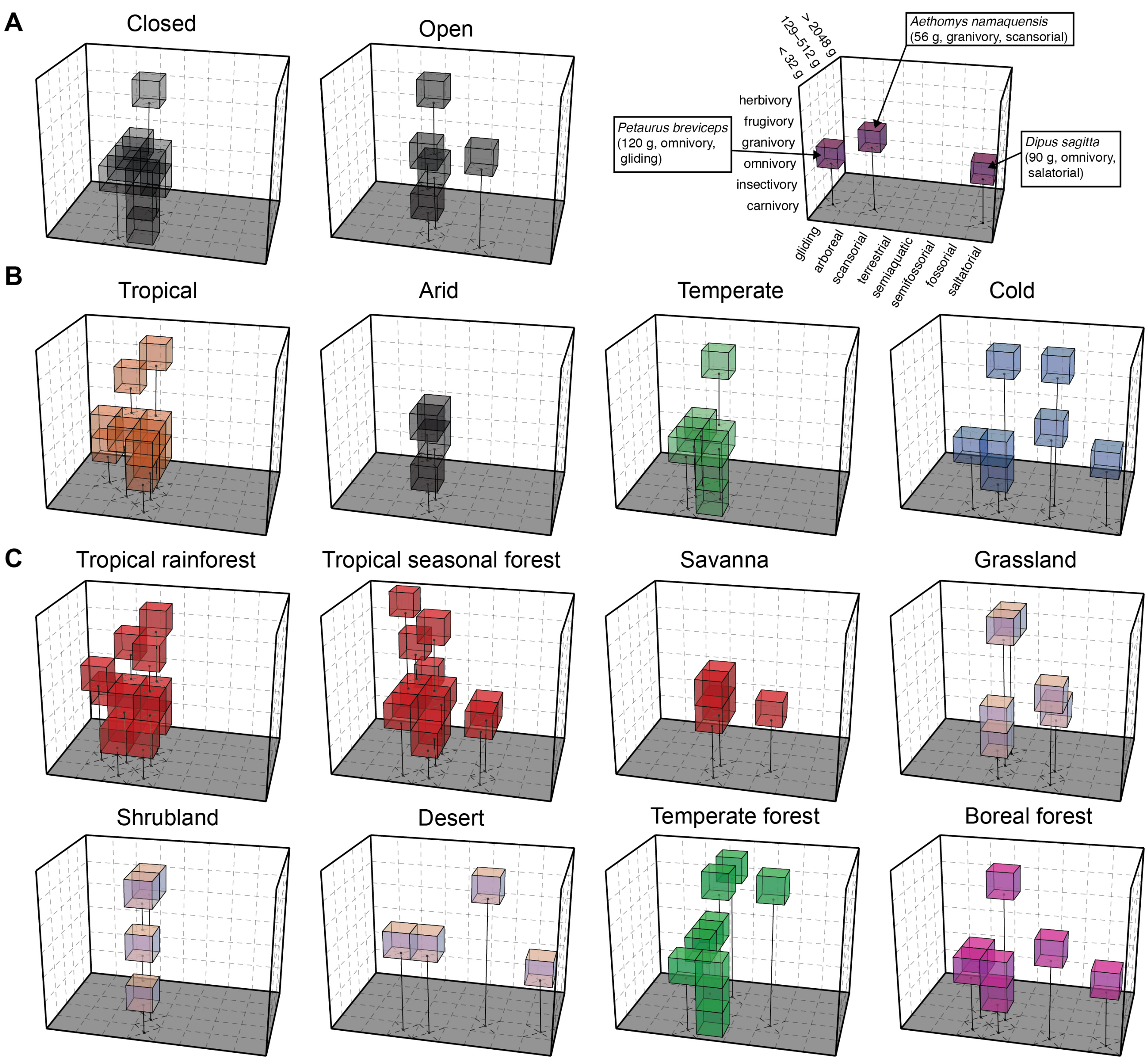

Fig. S7. Exemplar plots of ecospace occupation of 98 extant, small-bodied mammalian communities arranged by environmental classification: habitat openness (A), climate type (B), and vegetation type (C). Each exemplar plot was generated by bootstrapping the eco-cells in each environmental type. See *SI Appendix*, Materials and Methods for details.

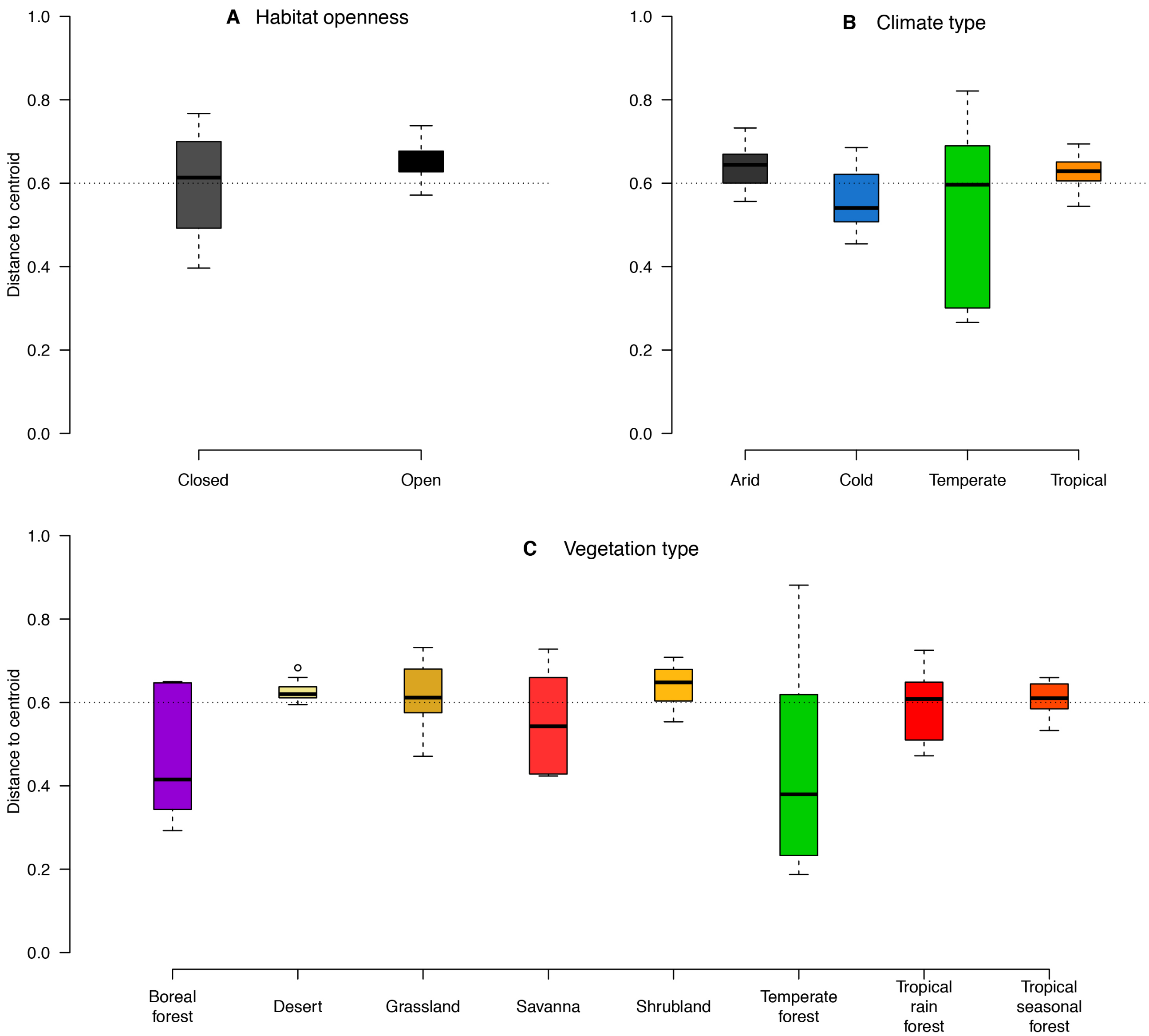

Fig. S8. Beta diversity of ecospace occupation of extant, small-bodied mammalian communities arranged by environmental classification: habitat openness (A), climate type (B), and vegetation type (C).

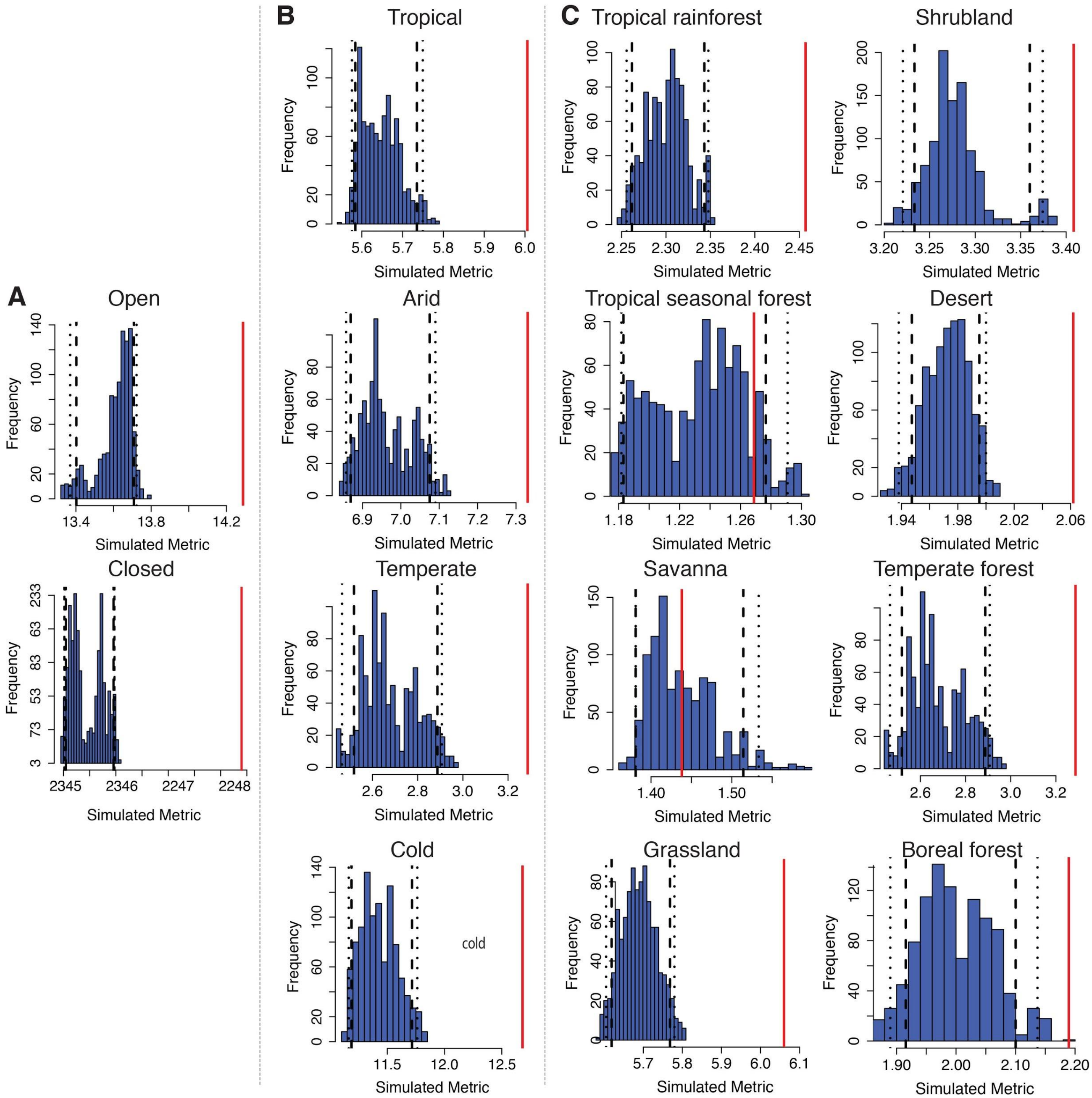

Fig. S9. Results of the null model tests for significance of patterns of ecospace occupation arranged by environmental classification: habitat openness (A), climate type (B), and vegetation type (C). The solid red vertical lines indicate the observed metrics for the collected data. The long-dash lines indicate the 95% one-tailed cutoff point, and the short-dash lines indicate the 95% two-tailed cutoff points.

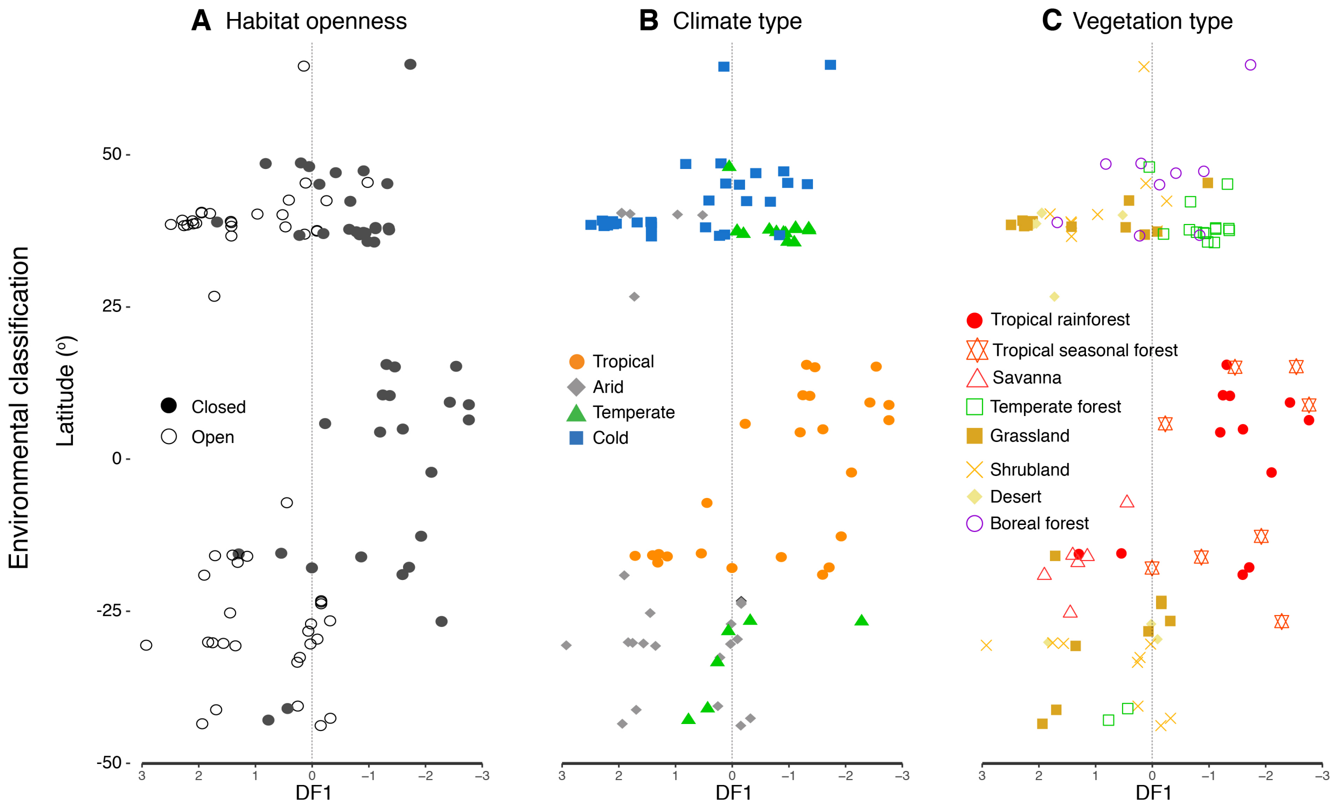

Fig. S10. Ordination of habitat openness of 98 extant, small-bodied mammalian communities by DF1 scores and latitude. The plots are annotated by environmental classification: habitat openness (A), climate type (B), and vegetation type (C). Abbreviations: DF1, discriminant function 1, MAP, mean annual precipitation; MAT, mean annual temperature.

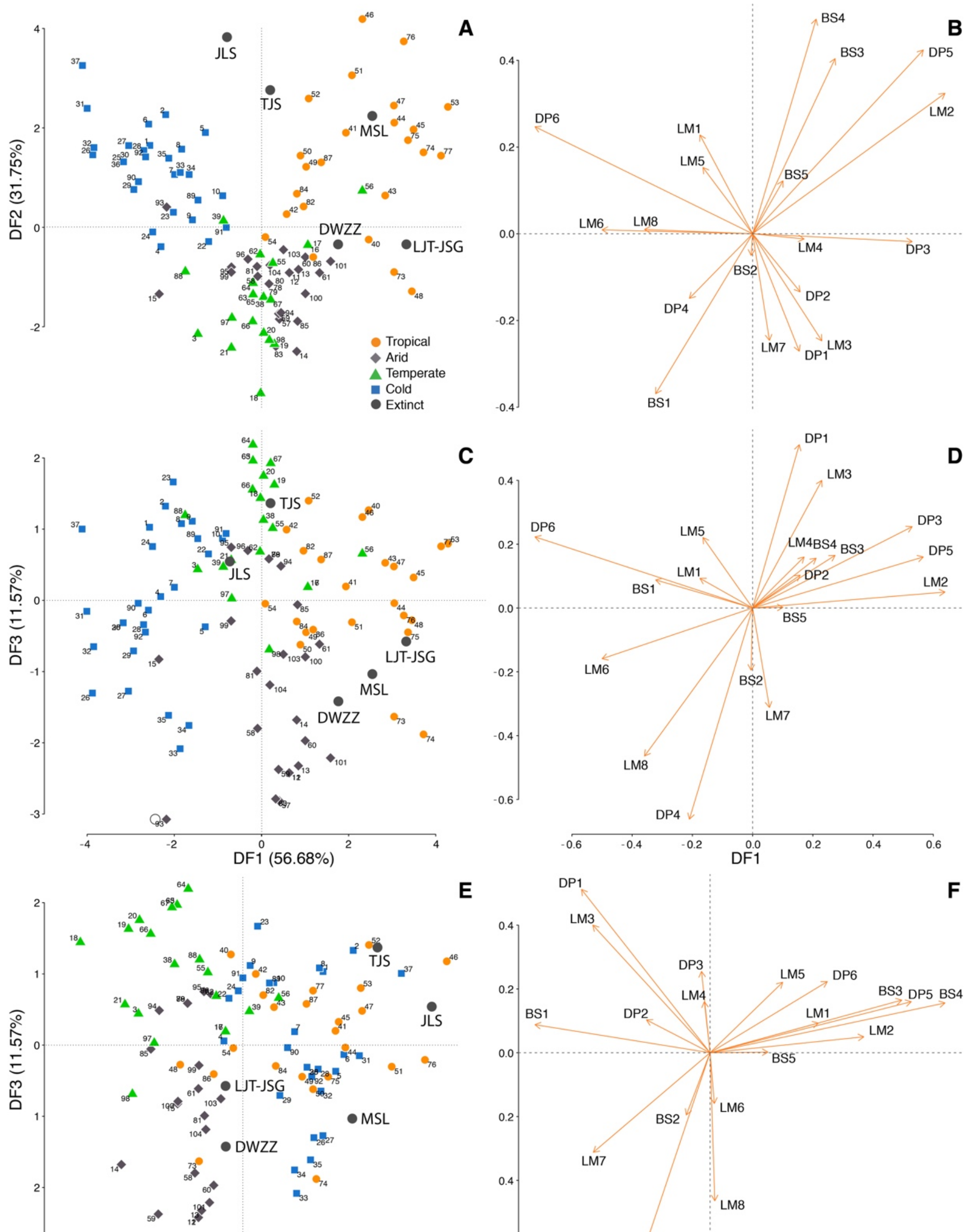

Fig. S11. Projection of five extinct mammaliaform communities in the discriminant function analysis (DFA) of four climate types. A, Plot of discriminant function (DF) 1 vs. DF2; C, Plot of DF1 vs. DF3; E, Plot of DF2 vs. DF3; B, D, and F, plots of structure correlations between the ecological parameters and the first three DFs. Abbreviations: DWZZ, Dawangzhangzi mammaliaform community (Early Cretaceous, China); JLS, Jiulongshan mammaliaform community (Mid-Late Jurassic, China); LJT-JSG, Lujiatun-Jianshangou mammaliaform community (Early Cretaceous, China); MSL, Messel mammalian community (Eocene, Germany); TJS, Tiaojishan mammaliaform community (Mid-Late Jurassic, China). Abbreviations for the ecological parameters with prefixes BS (body size), DP (dietary preference), and LM (locomotor mode) are in Table S2.

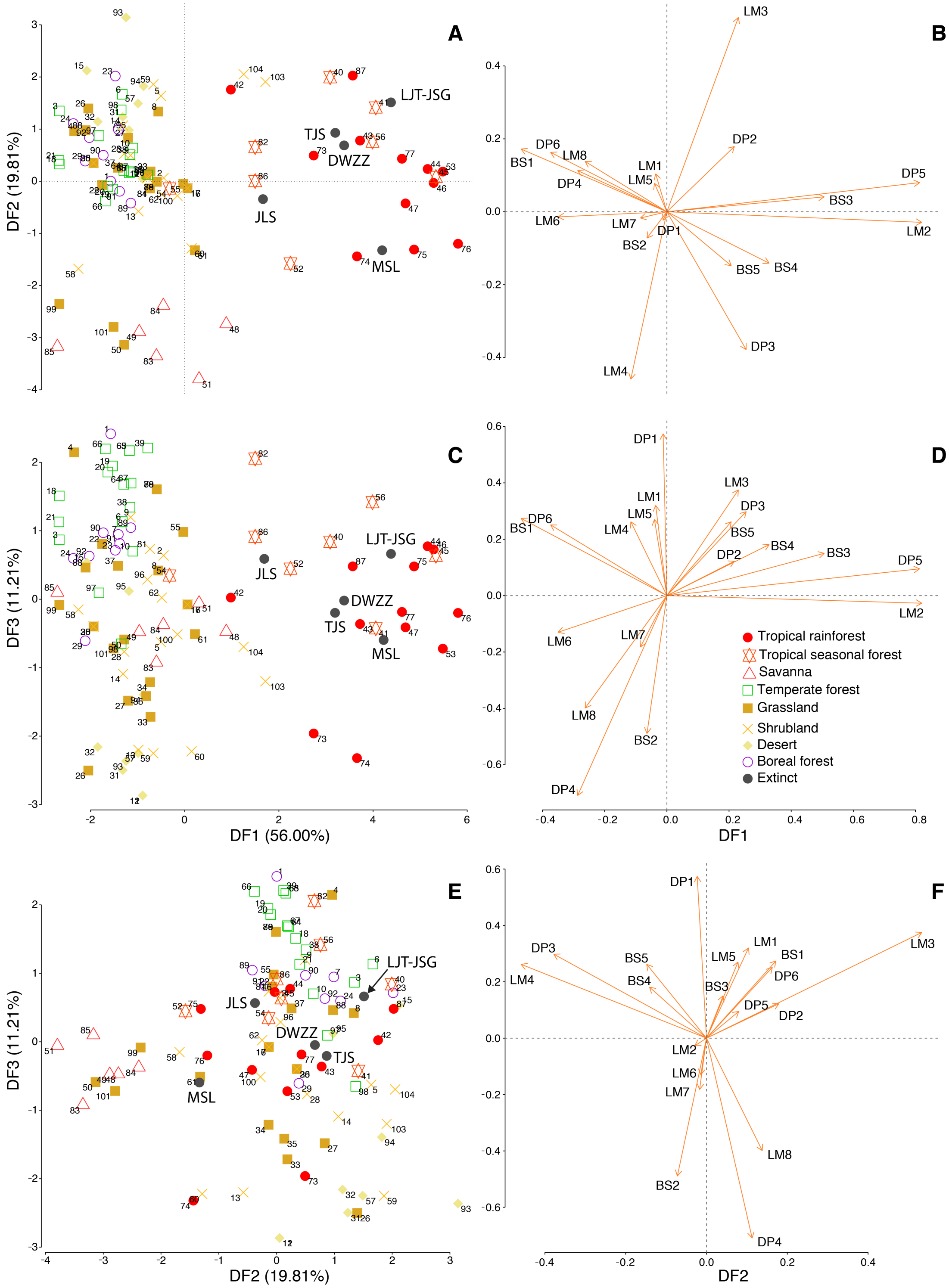

Fig. S12. Projection of five extinct mammaliaform communities in the discriminant function analysis (DFA) of eight vegetation types. A, Plot of discriminant function (DF) 1 vs. DF2 form the DFA; C, Plot of DF1 vs. DF3; E, Plot of DF2 vs. DF3; B, D, and F, plots of structure correlations between the ecological parameters and the first three DFs. Abbreviations: DWZZ, Dawangzhangzi mammaliaform community (Early Cretaceous, China); JLS, Jiulongshan mammaliaform community (Mid-Late Jurassic, China); LJT-JSG, Lujiatun-Jianshangou mammaliaform community (Early Cretaceous, China); MSL, Messel mammalian community (Eocene, Germany); TJS, Tiaojishan mammaliaform community (Mid-Late Jurassic, China). Abbreviations for the ecological parameters with prefixes BS (body size), DP (dietary preference), and LM (locomotor mode) are in Table S2.

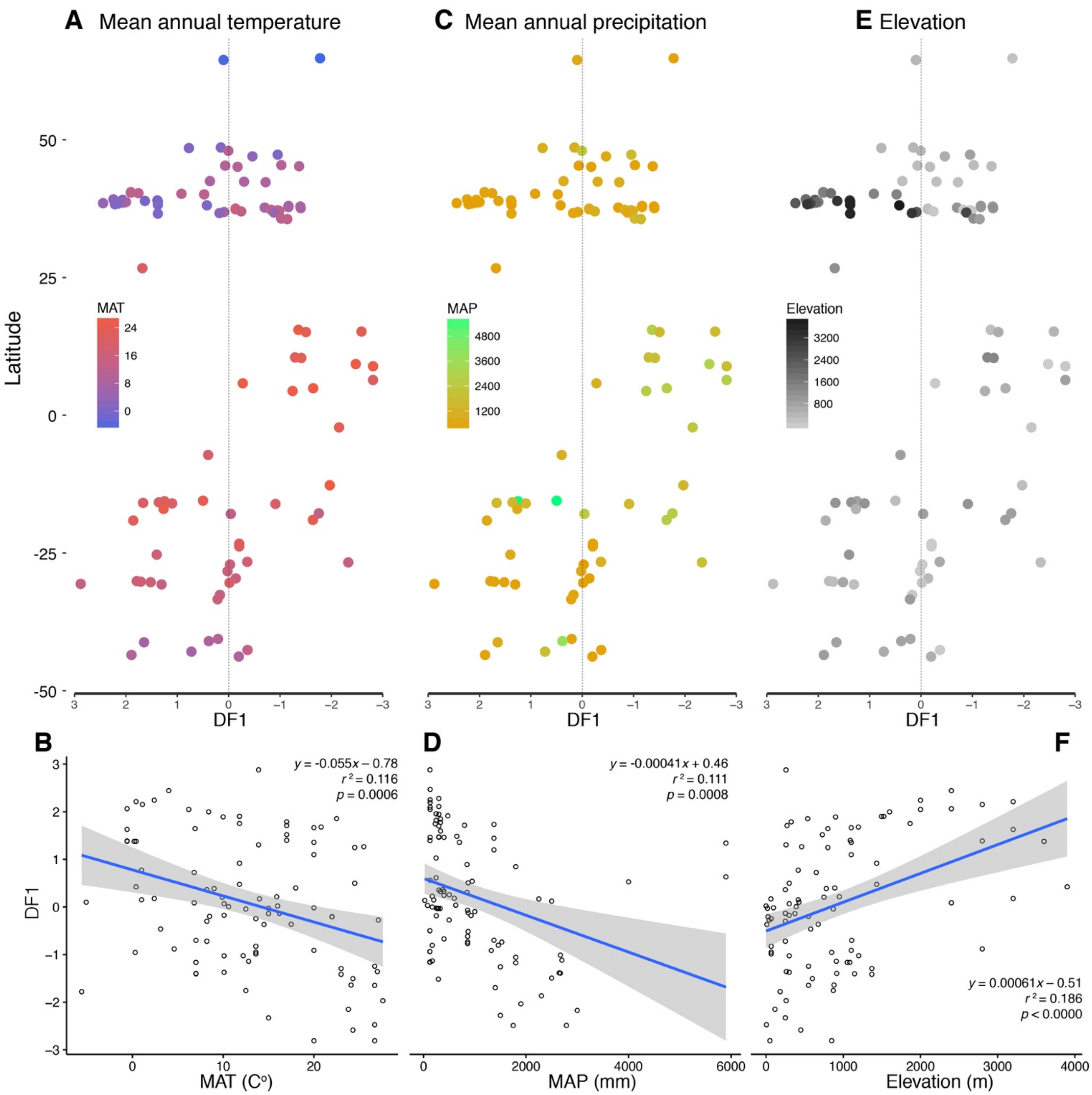

Fig. S13. Plot of discriminant function (DF) 1 scores from the discriminant function analysis (DFA) of habitat openness vs. latitude with markers color-coded for environmental factors: MAT (A), MAP (C), and elevation (E); Correlation analysis of the DF1 scores and environmental factors: MAT (B), MAP (D), and elevation (F). Abbreviations: MAP, mean annual precipitation; MAT, mean annual temperature. The blue line and grey shaded area indicate the best fit and 95% confidence interval, respectively.

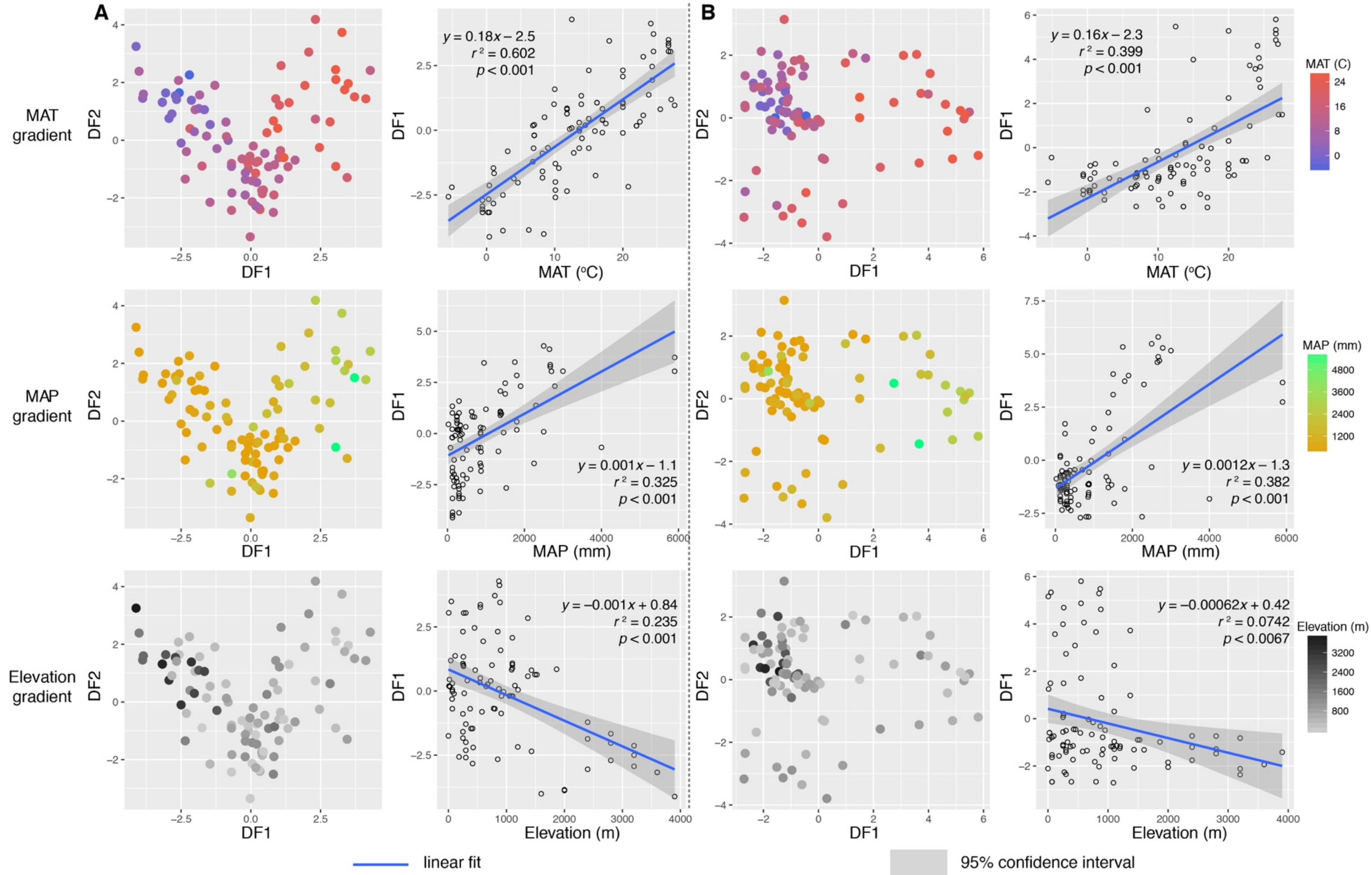

Fig. S14. Plots of discriminant function (DF) 1 vs. DF2 of the discriminant function analysis (DFA) of four climate types (A) and eight vegetation types (B) with markers color-coded for environmental factors: MAT, MAP, and elevation (top to bottom). Correlation analysis are of the DF1 scores and the same environmental factors. Abbreviations: MAP, mean annual precipitation; MAT, mean annual temperature.

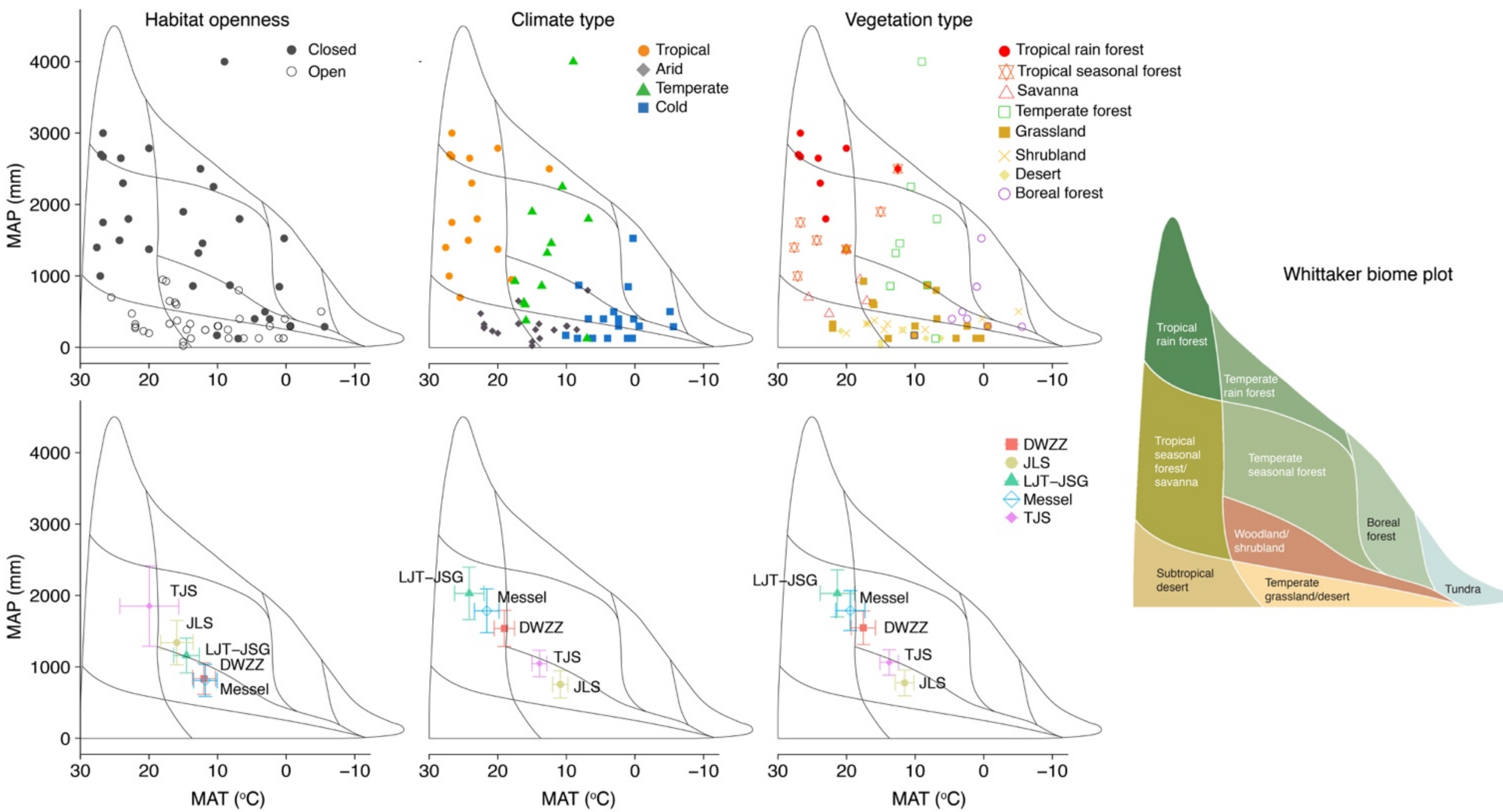

Fig. S15. Whittaker biome plot of the 98 extant mammalian communities (top row) according to environmental classification: habitat openness, climate type, and vegetation type (left to right); and the Whittaker biome plot of the inferred mean annual temperature (MAT) and mean annual precipitation (MAP) of four Mesozoic and one Eocene mammaliaform communities (bottom row) according to the environmental classification (left to right). Abbreviations: DWZZ, Dawangzhangzi mammaliaform community (Early Cretaceous, China); JLS, Jiulongshan mammaliaform community (Mid-Late Jurassic, China); LJT-JSG, Lujiatun-Jianshangou community (Early Cretaceous, China); MSL, Messel mammaliaform community (Eocene, Germany); TJS, Tiaojishan mammaliaform community (Mid-Late Jurassic, China).

Supplementary tables

Table S1. Mesozoic and Eocene mammaliaform paleocommunity lists and inferred ecological parameters of associated taxa.

CM[a]	Specimen No[b]	Higher-level taxon	Species[c]	Age (Ma)[d]	Formation	Locality	Biota	Body size (g)	Dietary preference[e]	Locomotor mode[f]
TJS	STM 33-9	Haramiyida	*Arboroharamiya jenkinsi* (53)	160 (15)	Tiaojishan	Mutoudeng	Yanliao	354	o	a
TJS	LDN HMF2001	Haramiyida	*Shenshou lui* (54)	160.89 –160.25 (55)	Tiaojishan	Daxishan, Linglongta	Yanliao	300	o	a (sc)
TJS	BMNH PM003253	Haramiyida	*Xianshou songae* (54)	160.89 –160.25 (55)	Tiaojishan	Daxishan, Linglongta	Yanliao	40	o	a (sc)
TJS	IVPP V16707	Haramiyida	*Xianshou linglong* (54)	160.89 –160.25 (55)	Tiaojishan	Daxishan, Linglongta	Yanliao	83	o	a (sc)
TJS	BMNH 2940	Haramiyida	*Maiopatagium furculiferum* (56)	160.89 –160.25 (55)	Tiaojishan	Daxishan, Linglongta	Yanliao	120-178	h	g
TJS	BMNH 1142	Multituberculata	*Rugosodon eurasiaticus* (57)	160.89 –160.25 (55)	Tiaojishan	Daxishan, Linglongta	Yanliao	65–80	o	sc
TJS	BMNH PM1143	Eutheria	*Juramaia sinensis* (58)	160.7±0.4 (58)	Tiaojishan	Daxigou, Jianchang	Yanliao	13–15	i	sc (a)
TJS	BMNH 2942	Haramiyida	*Vilevolodon diplomylos* (59)	160±0.99 (60)	Tiaojishan	Qinglong County, Hebei	Yanliao	35-55	o	a
TJS	HG M018	Haramiyida	*Arboroharamiya allinhopsoni* (61)	160±0.99 (60)	Tiaojishan	Nanshimen, Gangou	Yanliao	17-87	o	g
TJS	BMNH 131735	Docodonta	*Docofossor brachydactylus* (62)	160±0.99 (60)	Tiaojishan	Nanshimen, Gangou	Yanliao	9–17	i	f
JLS	BMNH 001138	Docodonta	*Agilodocodon scansorius* (63)	164 (63)	Jiulongshan	Daohugou, Nincheng	Yanliao	27–40	o	a
JLS	PMOL AM00007A	Haramiyida	*Megaconus mammaliaformis* (64)	165-164 (60, 65)	Jiulongshan	Daohugou, Nincheng	Yanliao	120–280	o	t
JLS	JZMP 04-117	Docodonta	*Castorocauda lutrasimilis* (66)	165-164 (60, 65)	Jiulongshan	Daohugou, Nincheng	Yanliao	500–800	c	sq
JLS	IVPP V14739	Eutriconodonta	*Volaticotherium antiquum* (67)	165-164 (60, 65)	Jiulongshan	Daohugou, Nincheng	Yanliao	70	i	g
JLS	CAG S040811	Yinotheria	*Pseudotribos robustus* (68)	164 (68)	Jiulongshan	Daohugou, Nincheng	Yanliao	19	i	t
DWZZ	CAG S01-IG1	Eutheria	*Eomaia scansoria* (69)	122.2–124.6 (70–72)	Yixian	Dawangzhangzi, Lingyuan	Jehol	11–49	i	a
DWZZ	NJU P06001	Eutriconodonta	*Yanoconodon allini* (73)	122.2–124.6 (70–72)	Yixian	Daluozigou, Fengning, Heibei	Jehol	9–28	i	sq
DWZZ	CAGS 00-IG03	Eutheria	*Sinodelphys szalayi* (74)	122.2–124.6 (70–72)	Yixian	Dawangzhangzi, Lingyuan	Jehol	29	i	sc
DWZZ	IVPP V12517	Multituberculata	*Sinobaatar lingyuanensis* (75)	122.2–124.6 (70–72)	Yixian	Dawangzhangzi, Lingyuan	Jehol	61	o	a
DWZZ	NIGPAS139381	Symmetrodonta	*Akidolestes cifellii* (76)	122.2–124.6 (70–72)	Yixian	Dawangzhangzi, Lingyuan	Jehol	3–9	i	sf
DWZZ	JZT 005-2010	Eutriconodonta	*Chaoyangodens lii* (77)	122.2–124.6 (70–72)	Yixian	Dawangzhangzi, Lingyuan	Jehol	18–53	i	t
LJT-JSG	IVPP V15004	Eutheria	*Acristatherium yanensis* (78)	123.2±1.0 (79)	Yixian	Lujiatun village, Beipiao	Jehol	26	i	sc
LJT-JSG	IVPP V12585	Eutriconodonta	*Gobiconodon zofiae* (80)	123.2±1.0 (79)	Yixian	Lujiatun village, Beipiao	Jehol	152	c	t
LJT-JSG	DMHN 2607	Eutriconodonta	*Juchilestes liaoningensis* (81)	123.2±1.0 (79)	Yixian	Lujiatun village, Beipiao	Jehol	101	c	sc
LJT-JSG	IVPP V13102	Eutriconodonta	*Meemannodon lujiatunensis* (82)	123.2±1.0 (79)	Yixian	Lujiatun village, Beipiao	Jehol	1959	c	t
LJT-JSG	IVPP V12549	Eutriconodonta	*Repenomamus giganticus* (83)	123.2±1.0 (79)	Yixian	Lujiatun village, Beipiao	Jehol	2528–6514	c	t
LJT-JSG	IVPP V14155	Eutriconodonta	*Repenomamus robustus* (84)	123.2±1.0 (79)	Yixian	Lujiatun village, Beipiao	Jehol	1336–2638	c	sf
LJT-JSG	GMV 2139	Eutriconodonta	*Jeholodens jenkinsi* (85)	125±0.18 – 124.6±0.3 (71, 72)	Yixian	Sihetun, Chaoyang	Jehol	3–15	i	a
LJT-JSG	HGM 41H-III-0321	Symmetrodonta	*Maotherium asiaticus* (86)	123.2±1.0 (79)	Yixian	Lujiatun village, Beipiao	Jehol	72–135	i	t

LJT-JSG	NGMC 97-4-15	Symmetrodonta	*Maotherium sinensis* (87)	123.2±1.0 (79)	Yixian	Lujiatun village, Beipiao	Jehol	62–114	i	t
LJT-JSG	IVPP V7466	Symmetrodonta	*Zhangheotherium quinquecuspidens* (88)	124.6±0.1 (71)	Yixian	Jiangshangou valley	Jehol	56–248	i	sc
MSL	HLMD ME 8035	Metatheria	*"Peradectes"* sp. (89, 90, 91, 92)	48.25–47.61 (93)	Messel	Messel Pit fossil site		12–50	o*	a
MSL	SMNK PAL 464	Pantolesta	*Buxolestes piscator* (94, 95)	48.25–47.61 (93)	Messel	Messel Pit fossil site		563–1589	o*	sq (sf)
MSL	IRScNB I.G. 26533	"Creodonta"	*Lesmesodon edingeri* (91, 94, 96)	48.25–47.61 (93)	Messel	Messel Pit fossil site		300–570	c	t
MSL	HLMD ME 15566	"Creodonta"	*Lesmesodon behnkeae* (91, 94, 96)	48.25–47.61 (93)	Messel	Messel Pit fossil site		3000–4000	o	t
MSL	SMF MEA 263	Pholidota	*Eomanis waldi* (91, 94, 95, 97)	48.25–47.61 (93)	Messel	Messel Pit fossil site		520–1696	o	f
MSL	SMF MEA 261	Pholidota	*Eurotamandua joresi* (94, 95)	48.25–47.61 (93)	Messel	Messel Pit fossil site		237–3693	i	f
MSL	HLMD Me 1288	Eulipotyphla	*Macrocranion tenerum* (91, 98, 99)	48.25–47.61 (93)	Messel	Messel Pit fossil site		15–121	i	sa
MSL	SMF ME 2691a	Eulipotyphla	*Macrocranion tupaiodon* (91, 95, 99, 100)	48.25–47.61 (93)	Messel	Messel Pit fossil site		114–611	o	t
MSL	HLMD ME 8011	Leptictida	*Leptictidium tobieni* (91, 101, 102, 103)	48.25–47.61 (93)	Messel	Messel Pit fossil site		500–1000	i	sa
MSL	SMF ME 1143	Leptictida	*Leptictidium nasutum* (91, 101, 102, 103)	48.25–47.61 (93)	Messel	Messel Pit fossil site		500–1000	c	sa
MSL	SMF ME 11377	Leptictida	*Leptictidium auderiense* (91, 102, 103, 104)	48.25–47.61 (93)	Messel	Messel Pit fossil site		466–627	i	sa
MSL	HLMD ME 7577	Eulipotyphla	*Pholidocercus hassiacus* (99, 105, 106)	48.25–47.61 (93)	Messel	Messel Pit fossil site		285	i	sf
MSL	HLMD ME 8850	Apatotheria	*Heterohyus nanus* (91, 94, 95)	48.25–47.61 (93)	Messel	Messel Pit fossil site		27–165	i	a
MSL	SMF ME 1228	Primates	*Europolemur koenigswaldi* (91, 94, 101)	48.25–47.61 (93)	Messel	Messel Pit fossil site		500	o	a
MSL	SMF ME 3379	Primates	*Europolemur kelleri* (89, 94, 101)	48.25–47.61 (93)	Messel	Messel Pit fossil site		2200	c	a
MSL	PMO 214.214	Primates	*Darwinius masillae* (101, 107)	48.25–47.61 (93)	Messel	Messel Pit fossil site		650–900	h*	a
MSL	GMH L-2	Primates	*Godinotia neglecta* (91, 94, 108)	48.25–47.61 (93)	Messel	Messel Pit fossil site		957–2009	o	a
MSL	SMF ME 4554	Rodentia	*Masillamys beegeri* (91, 94, 105)	48.25–47.61 (93)	Messel	Messel Pit fossil site		31–254	o*	t
MSL	WDC C-MG202	Rodentia	*Eogliravus wildi* (91, 109)	48.25–47.61 (93)	Messel	Messel Pit fossil site		8–36	h*	a
MSL	SMF ME 510	Artiodactyla	*Messelobunodon schaeferi* (91, 95)	48.25–47.61 (93)	Messel	Messel Pit fossil site		1446–2061	h*	t
MSL	SMF ME 1527a	Artiodactyla	*Aumelasia cf. A. gabineaudi* (91, 95)	48.25–47.61 (93)	Messel	Messel Pit fossil site		1036–2074	h*	t

a. Extinct small-bodied mammaliaform community (CM): DWZZ, Dawangzhangzi community; JLS, Jiulongshan community; LJT-JSG, Lujiatun-Jianshangou community; MSL, Messel community; TJS, Tiaojishan community.

b. Institutional abbreviations: BMNH, Beijing Museum of Natural History, Beijing (China); CAG, Chinese Academy of Geology, Beijing (China); DMNH, Dalian Museum of Natural History, Dalian (China); GMH, Geiseltalmuseum der Martin Luther-Universität, Halle (Germany); GMV, National Geological Museum of China, Beijing (China); HG, Paleontological Center, Bohai University, Bohai (China); HGM, Henan Geological Museum, Zhengzhou (China); HLMD Me, Hessisches Landmuseum, Darmstadt (Germany); IRScNB, Institut Royal des Sciences naturelles de Belgiques, Bruxelles (Belgium); IVPP, Institute of Vertebrate Paleontology and Paleoanthropology, Academy of Science, Beijing (China); JZMP, Jinzhou Museum of Paleontology, Jinzhou (China) ; JZT, Jizantang Paleontological Museum (China); LND, Lande Museum of Natural History (China); NGMC, National Geological Museum of China, Beijing (China); NIGPAS, Nanjing Institute of Geology and Paleontology, Academy of Science, Nanjing (China); NJU, Nanjing University, Nanjing (China); PMO, Geological Museum, Natural History Museum, University of Oslo

(Norway); PMOL, Paleontological Museum of Liaoning, Shenyang (China); SMF Me, Messel collection of the Forschungsinstitut Senckenberg, Frankfurt (Germany); SMNK, Staatiliches Museum für Naturkunde Karlsruhe (Germany); STM, Tianyu Museum of Nature, Pingyi (China); WDC, Wyoming Dinosaur Center, Wyoming (USA).
c. Species name with numbered reference in parentheses.
d. Age (Ma) based on radioisotopic dates: 55, 60, 65, 70–72, 89, 93.
e. Dietary preference: c, carnivory; fr, frugivory; gr, granivory; h, herbivory; i, insectivory; o, omnivory;
  * denotes omnivorous or herbivorous diet that includes fruit and/or seeds based on either tooth morphology and/or gut contents (90, 110).
f. Locomotor mode: a, arboreal; f, fossorial; g, gliding; sa, saltatorial; sc, scansorial; sf, semifossorial; sq, semiaquatic; t, terrestrial.

Table S2. Description and ranking schema of the ecological parameters used in the ecological structure analyses.

Body size	Description	Log$_2$-transformed		Abbreviation	Rank
< 32 g	(very small)	< 5		1	BS1
32–128 g	(small)	5–7		2	BS2
128–512 g	(medium)	7–9		3	BS3
512–2048 g	(large)	9–11		4	BS4
> 2048 g	(very large)	> 11		5	BS5
Dietary preference	Descriptive definition	OPC			Rank
		Lower	Upper		
Carnivory	Consumes animals as their primary food source	91 ± 54	126 ± 62	c	DP1
Insectivory	Consumes insects as their primary food source	139 ± 39	174 ± 43	i	DP2
Omnivory	Consumes a considerable amount of both animal and plant materials	170 ± 41	187 ± 36	o	DP3
Granivory	Consumes seeds as their primary food source	180 ± 31	205 ± 27	gr	DP4
Frugivory	Consumes fruits as their primary food source	189 ± 56	208 ± 48	fr	DP5
Herbivory	Consumes diverse plant materials (seeds, fruits, leaves, roots, etc.)	219 ± 43	255 ± 49	h	DP6
Locomotor mode	Descriptive definition	Locomotor disparity (relative to Gliding)			Rank
Gliding	Bridges gaps between trees by gliding usually with a patagium	0.00		g	LM1
Arboreal	Spends most of the time in trees foraging, traveling, resting, but occasionally travels on the ground	3.55		a	LM2
Scansorial	Capable of climbing for escape, eating, or leisure; spends a considerable amount of time both in the trees and on the ground	5.02		sc	LM3
Terrestrial	Spends most of the time on the ground, but able to swim, climb, and burrow occasionally, but not specialized for those modes	5.16		t	LM4
Semiaquatic	Capable of swimming for dispersal, escape, or foraging but also active on the ground	6.32		sq	LM5
Semifossorial	Regularly digs for food or to build burrows for shelter, but does not exclusively live underground	6.58		sf	LM6
Fossorial	Efficiently digs burrows for shelter or foraging underground exclusively	8.59		f	LM7
Saltatorial	Capable of jumping using both hind limbs simultaneously for high-speed transportation over long distances	9.34		sa	LM8

Table S3. The evaluation of the body size estimation of Mesozoic mammaliaform species using seven different formulae from skull length, dentary length, humerus length and femur length.

CM	Specimen No	Higher-level taxon	Species	Measurements (mm)				BM estimation (g)							Range (g)	Midrange (g)	Rank	*SI Appendix*	
				SL	DL	HL	FL	F1	F2	F3	F4	F5	F6	F7				BM (g)	Rank
TJS	STM33-9	Haramiyida	*Arboroharamiya jenkinsi*	-	35.0	-	44.8	-	-	131.2	360.9	502.2	0.0	399.3	45–502	274	3	354	3
TJS	LDN HMF2001	Haramiyida	*Shenshou lui*	46.3	35.5	26.1	42.7	257.6	199.2	136.8	320.4	437.9	160.4	345.4	27–438	233	3	300	3
TJS	BMNHC-PM003253	Haramiyida	*Xianshou songae*	26.0	-	18.0	19.9	35.2	23.8	-	49.3	50.8	55.4	35.2	20–55	38	2	40	2
TJS	IVPP V16707	Haramiyida	*Xianshou linglong*	32.0	27.2	-	25.6	72.1	51.2	61.9	91.5	103.5		74.9	51–104	78	2	83	2
TJS	BMNH 2940	Haramiyida	*Maiopatagium furculiferum*	33.0	-	26.5	30.0	80.1	57.3	-	134.9	161.8	168.5	120.2	120–169	145	3	120–178	3
TJS	BMNH 1142	Multituberculata	*Rugosodon eurasiaticus*	36.0	28.0	21.1	29.9	108.2	78.9	67.9	133.7	160.1	87.8	118.9	67–160	114	2	65–80	2
TJS	BMNH PM1143	Eutheria	*Juramaia sinensis*	22.0	17.0	-	-	19.8	12.9	15.4	-	-	-	-	13–20	17	1	13–15	1
TJS	BMNH 2942	Haramiyida	*Vilevolodon diplomylos*	24.0	16.0	17.2	21.5	26.7	17.7	12.9	59.6	63.1	48.9	44.4	13–63	38	2	35–55	2
TJS	HG-M018	Haramiyida	*Arboroharamiya allinhopsoni*	30.8	17.3	17.9	21.0	63.2	44.4	16.3	56.2	59.1	54.4	41.3	16–64	40	2	17–87	2
TJS	BMNH 131735	Docodonta	*Docofossor brachydactylus*	22.0	17.0	-	12.5	19.8	12.9	15.4	15.7	13.6	-	8.8	9–20	15	1	9–17	1
JLS	BMNH 001138	Docodonta	*Agilodocodon scansorius*	30.0	23.0	14.0	13.5	57.7	40.3	37.9	19.0	17.0	27.1	11.0	11–58	35	2	27–40	2
JLS	PMOL AM00007A	Haramiyida	*Megaconus mammaliaformis*	-	35.5	30.0	39.0	-	-	137.3	256.8	339.4	240.3	263.7	138–340	239	3	120–280	3
JLS	JZMP 04-117	Docodonta	*Castorocauda lutrasimilis*	65.0	55.0	-	-	829.7	694.3	503.4	-	-	-	-	503–830	667	4	500–800	4
JLS	IVPP V14739	Eutriconodonta	*Volaticotherium antiquum*	-	28.3	26.5	30.7	-	-	70.1	142.8	172.6	168.5	128.8	70–173	122	2	70	2
JLS	CAG S040811	Yinotheria	*Pseudotribos robustus*	-	17.0	7.1	8.5	-	-	15.3	6.2	4.6	3.9	2.8	3–16	10	1	19	1
DWZZ	CAG S01-IG1	Eutheria	*Eomaia scansoria*	27.5	22.7	13.6	16.1	42.7	29.3	36.2	29.3	27.9	25.1	18.7	18–43	30	1	11–49	1
DWZZ	NJU P06001	Eutriconodonta	*Yanoconodon allini*	-	20.7	12.5	14.1	-	-	27.8	21.1	19.2	19.7	12.5	13–28	21	1	9–29	1
DWZZ	CAGS00-IG03	Eutheria	*Sinodelphys szalayi*	-	20.9	10.2	13.6	-	-	28.6	19.4	17.3	11.0	11.3	11–20	16	1	29	1
DWZZ	IVPP V12517	Multituberculata	*Sinobaatar lingyuanensis*	32.3	21.8	12.6	18.1	74.3	52.8	32.1	38.8	38.5	20.1	26.3	20–75	48	2	61	2
DWZZ	NIGPAS139381	Symmetrodonta	*Akidolestes cifellii*	-	-	9.1	9.8	-	-	-	8.7	6.9	7.9	4.2	4–9	7	1	3–9	1
DWZZ	JZT005-2010	Eutriconodonta	*Chaoyangodens lii*	31.3	-	15.9	17.7	66.9	47.2	-	37.1	36.6	39.0	24.9	25–67	46	2	18–53	2
LJT-JSG	IVPP V15004	Eutheria	*Acristatherium yanensis*	24.3	19.7	-	-	28.1	18.7	24.0	-	-	-	-	18–28	23	1	26	1
LJT-JSG	IVPP V12585	Eutriconodonta	*Gobiconodon zofiae*	43.2	36.7	-	-	202.7	154.2	151.8	-	-	-	-	152–203	178	3	152	3
LJT-JSG	DMHN 2607	Eutriconodonta	*Juchilestes liaoningensis*	-	32.0	-	-	-	-	101.0	-	-	-	-	101	101	2	101	2
LJT-JSG	IVPP V13102	Eutriconodonta	*Meemannodon lujiatunensis*	-	86.9	-	-	-	-	1958.4	-	-	-	-	1959	1959	4	1959	4
LJT-JSG	IVPP V12549	Eutriconodonta	*Repenomamus giganticus*	160	127.8	83.0	95.0	18527.0	19105.6	6145.8	2282.9	4198.3	4425.4	3787.3	2282–19106	10694	5	2528–6514	5
LJT-JSG	IVPP V 14155	Eutriconodonta	*Repenomamus robustus*	-	80.8	67.1	69.3	-	-	1578.1	1051.9	1720.7	2404.2	1472.0	1052–2405	1729	4	1336–2638	4
LJT-JSG	GMV 2139	Eutriconodonta	*Jeholodens jenkinsi*	-	15.3	8.8	11.5	-	-	11.3	12.7	10.7	7.2	6.8	7–13	10	1	3–15	1
LJT-JSG	HGM 41H-III-0321	Symmetrodonta	*Maotherium asiaticus*	36.5	28.5	18.5	24.5	113.4	83.0	71.5	82.1	91.3	60.2	65.6	60–114	87	2	72–135	2

LJT-JSG	NGMC-97-4-15	Symmetrodonta	*Maotherium sinensis*	-	27.1	-	23.1	-	-	61.6	71.0	77.3	-	55.0	55–78	67	2	62–114	2
LJT-JSG	IVPP V7466	Symmetrodonta	*Zhangheotherium quinquecuspidens*	-	31.9	23.2	30.3	-	-	99.6	138.5	166.7	114.9	124.1	100–167	134	3	56–248	3

Abbreviations: CM, Mesozoic community; BM, body mass; FL, femur length; HL, humerus length; DL, dentary length; SL, skull length.
Body mass estimation formulae: F1, BM = 3.488 × log SL – 3.332 (128); F2, log BM = 3.68 × log SL – 3.83 (129); F3, ln BM = 2.9677 × ln ML – 5.6712 (28); F4, BM = 0.032 × FL2.454 (130); F5, log BM = 2.825 × log FL –1.964 (128); F6, log BM = 2.8626 × log HL – 1.8476 (29); F7, log BM = 2.993 × log FL – 2.341 (29).

Table S4. Dietary inference based on gross dental morphology of fossil species

Gross dental morphology	Function	Dietary inference
cusps-in-line/three-cusps-in-triangle	cutting/shearing	carnivory/insectivory
tribosphenic/pseudo-tribosphenic	shearing and crushing, and possibly grinding	insectivory possibly omnivory and herbivory
multiple-cusp-rows	crushing and grinding	omnivory/herbivory

Table S5. Percentages of ecological parameters for the 98 extant, small-bodied mammalian communities arranged by environmental classification.

Environmental category	Body size[a]					Dietary preference[b]							Locomotor preference[c]					
	1	2	3	4	5	c	i	o	gr	fr	h	g	a	sc	t	sq	sf	f	s
Closed	33.1	27.1	22.4	9.2	8.2	9.6	19.8	41.2	5.9	5.9	17.6	1.4	11.4	27.3	50.4	2.2	4.5	1.4	1.6
Open	38.2	45.1	9.4	4.5	2.8	6.3	17.4	29.5	23.6	0.0	23.3	0.3	1.7	15.3	51.7	1.7	18.1	2.1	9.0
Tropical	16.4	30.7	31.4	11.8	9.8	5.9	20.9	46.3	6.6	10.1	10.1	0.7	19.2	25.1	50.5	1.4	2.1	0.7	0.3
Arid	42.9	45.2	7.9	0.8	3.2	7.9	19.8	31.7	27.0	0.0	13.5	0	2.4	19.0	50.0	0.0	15.1	4.0	9.5
Temperate	53.3	28.0	8.8	4.9	4.9	16.5	18.7	37.9	7.1	0.5	19.2	0.5	2.7	28.0	54.9	2.7	7.7	2.2	1.1
Cold	39.9	35.5	12.3	7.9	4.4	4.9	15.8	26.1	15.8	0.0	37.4	2.5	0.0	17.7	48.3	3.4	17.7	1.0	9.4
Tropical rainforest	13.0	28.0	40.4	10.6	8.1	4.3	24.8	43.5	6.2	11.8	9.3	0.6	23.0	27.3	48.4	0.6	0.0	0.0	0.0
Tropical seasonal forest	19.4	30.6	23.1	12.0	14.8	8.3	19.4	47.2	2.8	10.2	12.0	0.9	18.5	29.6	38.9	2.8	6.5	1.9	0.9
Savanna	27.3	54.5	6.1	6.1	6.1	6.1	12.1	48.5	21.2	0.0	12.1	0.0	3.0	0.0	81.8	0.0	9.1	3.0	3.0
Grassland	40.3	43.4	10.9	3.9	1.6	7.8	18.6	29.5	19.4	0.0	24.8	0.8	0.8	13.2	49.6	2.3	23.3	0.8	9.3
Shrubland	41.1	38.9	8.9	6.7	4.4	6.7	17.8	26.7	22.2	0.0	26.7	0.0	3.3	21.1	51.1	2.2	13.3	2.2	6.7
Desert	33.3	58.3	8.3	0.0	0.0	0.0	16.7	19.4	44.4	0.0	19.4	0.0	0.0	22.2	33.3	0.0	19.4	5.6	19.4
Temperate forest	54.9	21.7	9.7	8.0	5.7	17.1	17.7	37.7	6.3	0.0	21.1	1.7	0.6	28.0	57.1	2.9	4.6	2.9	2.3
Boreal forest	47.0	33.3	10.6	4.5	4.5	4.5	13.6	34.8	9.1	0.0	37.9	3.0	0.0	21.2	56.1	3.0	12.1	0.0	4.5

[a]**Abbreviations:** 1, < 32 g; 2, 32–128 g; 3, 128–512 g; 4, 512–2048 g; 5, > 2048 g
[b]**Abbreviations:** c, carnivory; fr, frugivory; gr, granivory; h, herbivory; i, insectivory; o, omnivory.
[c]**Abbreviations:** a, arboreal; f, fossorial; g, gliding; sa, saltatorial; sc, scansorial; sf, semifossorial; sq, semiaquatic; t, terrestrial.

Table S6. Descriptive statistics of ecological disparity (EDisp) and ecological diversity (ERich) of 98 extant, small-bodied mammalian communities arranged by environmental classification and of five extinct mammaliaform paleocommunities.

Environmental category		MAT (°C)	MAP (mm/year)	NPP[a] (g C m−2 yr−1)	Mean No. of species	EDisp		ERich	
						$\bar{x}$	*sd*	$\bar{x}$	*sd*
Habitat openness	Closed	variable	variable	high	11	3.82	2.14	8.40	4.77
	Open	variable	variable	low	5	3.97	2.32	4.75	2.07
Climate type	Tropical	high	high	high	12	3.49	1.96	8.63	5.33
	Arid	high	low	low	5	3.75	2.34	4.31	1.87
	Temperate	variable	variable	intermediate	9	4.12	2.29	7.10	4.24
	Cold	low	variable	low	7	4.54	2.32	6.04	2.86
Vegetation type	Tropical rainforest	high	high	high	13	3.20	1.82	9.33	5.23
	Tropical seasonal forest	high	intermediate	high	14	4.07	2.07	10.13	5.94
	Savanna	high	intermediate	intermediate	6	2.54	1.54	4.50	2.07
	Grassland	intermediate	low	low	7	4.22	2.39	5.65	2.43
	Shrubland	intermediate	low	intermediate	5	4.13	2.36	4.33	1.75
	Desert	high	low	low	4	3.54	1.64	3.78	1.09
	Temperate forest	intermediate	intermediate	high	11	4.27	2.34	8.19	4.65
	Boreal forest	low	intermediate	intermediate	7	4.26	2.26	6.00	2.35
Extinct Community	Messel	12–21*	834–1758*	-	21	5.73	2.74	19.0	-
	Dawangzhangzi	12–14*	869–1025*	-	6	2.87	1.36	6.0	-
	Lujiatun-Jianshangou	15–24*	1161–2031*	-	10	3.27	1.76	9.0	-
	Tiaojishan	12–20*	881–1872*	-	10	3.40	2.82	7.0	-
	Jiulongshan	11–17*	761–1433*	-	5	4.40	1.65	5.0	-

*estimated values from Table S20.

Abbreviations: MAP, mean annual precipitation; MAT, mean annual temperature; NPP, net primary productivity; EDisp, ecological disparity; ERich, ecological richness. MAT scale: high, > 20 °C; intermediate, 5–20 °C; low, < 5 °C; MAP scale: high, > 2000 mm; intermediate, 400–2000 mm; low, < 400 mm; based on (6).

[a]NPP ranges based on dataset of (111) reported in (6) and criteria from (112).

Table S7. Pairwise *t*-tests of mean ecological disparity (EDisp) of different environmental categories among extant, small-bodied mammalian communities.

	Pairwise comparisons*	*t*	*df*	*p*-value
Habitat openness	Closed *vs.* Open	-1.737	1218.179	0.083
Climate type	Tropical *vs.* Arid	-1.911	387.321	0.057
	Tropical *vs.* Temperate	-7.650	1713.452	0.000
	Tropical *vs.* Cold	-11.717	1297.622	0.000
	Arid *vs.* Temperate	-2.459	532.530	0.014
	Arid *vs.* Cold	-5.147	582.345	0.000
	Temperate *vs.* Cold	-3.933	1802.372	0.000
Vegetation type	Tropical rainforest *vs.* Tropical seasonal forest	-10.631	1919.141	0.000
	Tropical rainforest *vs.* Savanna	3.951	110.829	0.000
	Tropical rainforest *vs.* Grassland	-8.426	647.682	0.000
	Tropical rainforest *vs.* Shrubland	-5.897	295.782	0.000
	Tropical rainforest *vs.* Desert	-1.564	64.043	0.123
	Tropical rainforest *vs.* Temperate forest	-12.652	2087.330	0.000
	Tropical rainforest *vs.* Boreal forest	-6.938	299.349	0.000
	Tropical seasonal forest *vs.* Savanna	8.866	127.637	0.000
	Tropical seasonal forest *vs.* Grassland	-1.140	804.269	0.254
	Tropical seasonal forest *vs.* Shrubland	-0.389	343.579	0.697
	Tropical seasonal forest *vs.* Desert	2.358	69.605	0.021
	Tropical seasonal forest *vs.* Temperate forest	-2.101	2106.185	0.036
	Tropical seasonal forest *vs.* Boreal forest	-1.179	351.482	0.239
	Savanna *vs.* Grassland	-8.640	195.793	0.000
	Savanna *vs.* Shrubland	-7.256	256.746	0.000
	Savanna *vs.* Desert	-3.750	117.487	0.000
	Savanna *vs.* Temperate forest	-9.958	131.784	0.000
	Savanna *vs.* Boreal forest	-7.975	246.153	0.000
	Grassland *vs.* Shrubland	0.443	500.679	0.658
	Grassland *vs.* Desert	2.803	92.443	0.006
	Grassland *vs.* Temperate forest	-0.419	848.194	0.675
	Grassland *vs.* Boreal forest	-0.222	517.764	0.824
	Shrubland *vs.* Desert	2.261	122.996	0.025
	Shrubland *vs.* Temperate forest	-0.829	355.628	0.408
	Shrubland *vs.* Boreal forest	-0.590	486.199	0.555
	Desert *vs.* Temperate forest	-3.245	70.945	0.002
	Desert *vs.* Boreal forest	-2.771	117.399	0.007
	Temperate *vs.* Boreal forest	0.089	364.700	0.929

*Grey rows indicate statistically significant results ($p < 0.05$). **Abbreviations:** *df*, degrees of freedom; *t*, *t*-statistic.

Table S8. Pairwise *t*-tests of mean ecological richness (ERich) of different environmental categories among extant, small-bodied mammalian communities.

	Pairwise comparisons*	*t*	*df*	*p*-value
Habitat openness	Closed *vs.* Open	4.755	57.980	0.000
Climate type	Tropical *vs.* Arid	3.759	28.194	0.001
	Tropical *vs.* Temperate	1.056	41.928	0.297
	Tropical *vs.* Cold	2.131	33.992	0.040
	Arid *vs.* Temperate	-2.746	24.695	0.011
	Arid *vs.* Cold	-2.645	46.868	0.011
	Temperate *vs.* Cold	0.975	31.047	0.337
Vegetation type	Tropical rainforest *vs.* Tropical seasonal forest	-0.306	13.764	0.764
	Tropical rainforest *vs.* Savanna	2.793	15.611	0.013
	Tropical rainforest *vs.* Grassland	2.296	13.911	0.038
	Tropical rainforest *vs.* Shrubland	3.196	12.657	0.007
	Tropical rainforest *vs.* Desert	3.578	12.262	0.004
	Tropical rainforest *vs.* Temperate forest	0.601	22.198	0.554
	Tropical rainforest *vs.* Boreal forest	1.961	16.101	0.067
	Tropical seasonal forest *vs.* Savanna	2.485	9.123	0.034
	Tropical seasonal forest *vs.* Grassland	2.063	7.959	0.073
	Tropical seasonal forest *vs.* Shrubland	2.707	7.545	0.028
	Tropical seasonal forest *vs.* Desert	2.979	7.422	0.019
	Tropical seasonal forest *vs.* Temperate forest	0.807	11.449	0.436
	Tropical seasonal forest *vs.* Boreal forest	1.841	8.925	0.099
	Savanna *vs.* Grassland	-1.143	9.557	0.281
	Savanna *vs.* Shrubland	0.177	7.528	0.864
	Savanna *vs.* Desert	0.784	6.876	0.459
	Savanna *vs.* Temperate forest	-2.564	19.054	0.019
	Savanna *vs.* Boreal forest	-1.302	11.800	0.218
	Grassland *vs.* Shrubland	1.929	34.401	0.062
	Grassland *vs.* Desert	2.859	26.978	0.008
	Grassland *vs.* Temperate forest	-1.977	21.479	0.061
	Grassland *vs.* Boreal forest	-0.367	16.047	0.718
	Shrubland *vs.* Desert	1.010	23.484	0.323
	Shrubland *vs.* Temperate forest	-3.124	18.747	0.006
	Shrubland *vs.* Boreal forest	-1.886	12.609	0.083
	Desert *vs.* Temperate forest	-3.619	17.769	0.002
	Desert *vs.* Boreal forest	-2.577	11.318	0.025
	Temperate *vs.* Boreal forest	1.561	22.866	0.132

*Grey rows indicate statistically significant results ($p < 0.05$). **Abbreviations:** *df*, degrees of freedom; *t*, *t*-statistic.

Table S9. Estimated ecological disparity (EDisp) of extant, small-bodied mammalian communities when resampled at five, six, and ten species for comparison with extinct Mesozoic mammaliaform paleocommunities.

Environmental category		Five-species		Six-species		Ten-species	
		Mean	SD*	Mean	SD*	Mean	SD*
Habitat openness	Closed	4.09	1.07	4.09	0.94	4.11	0.71
	Open	4.09	1.06	4.10	0.91	4.12	0.67
Climate type	Tropical	3.68	0.99	3.68	0.92	3.68	0.67
	Arid	3.97	1.21	3.98	1.08	3.96	0.80
	Temperate	3.88	1.08	3.83	1.00	3.84	0.72
	Cold	4.60	0.98	4.59	0.87	4.59	0.60
Vegetation type	Tropical rainforest	3.46	0.87	3.46	0.81	3.43	0.58
	Tropical seasonal forest	4.24	1.10	4.23	1.01	4.23	0.75
	Savanna	3.10	1.40	3.14	1.29	3.11	0.98
	Grassland	4.24	0.97	4.25	0.86	4.23	0.62
	Shrubland	4.25	1.07	4.25	0.94	4.30	0.69
	Desert	3.97	0.90	4.00	0.80	3.99	0.56
	Temperate forest	4.02	1.14	4.04	1.02	4.04	0.74
	Boreal forest	4.14	1.04	4.13	0.98	4.14	0.70

*SD, standard deviation.

Table S10. Pairwise *t*-tests of mean ecological disparity (EDisp) of resampled, extant, small-bodied mammalian communities with five, six, and ten species for comparison with sampled extinct Mesozoic mammaliaform paleocommunities.

	Pairwise comparisons of resampled, extant, small-bodied mammalian communities*	Five-species			Six-species			Ten-species		
		t	*df*	*p*-value	*t*	*df*	*p*-value	*t*	*df*	*p*-value
Habitat openness	Closed *vs* Open	0.05	1997.99	0.963	-0.39	1996.77	0.699	-0.35	1991.84	0.724
Climate type	Tropical *vs* Arid	-5.77	1921.91	0.000	-6.68	1950.12	0.000	-8.50	1943.68	0.000
	Tropical *vs* Temperate	-4.21	1982.68	0.000	-3.52	1986.20	0.000	-5.31	1990.40	0.000
	Tropical *vs* Cold	-20.86	1997.99	0.000	-22.79	1989.52	0.000	-32.10	1974.85	0.000
	Arid *vs* Temperate	1.76	1972.78	0.079	3.21	1985.11	0.001	3.40	1975.60	0.001
	Arid *vs* Cold	-12.89	1920.37	0.000	-13.95	1905.99	0.000	-20.16	1861.73	0.000
	Temperate *vs* Cold	-15.71	1981.93	0.000	-18.21	1958.70	0.000	-25.42	1942.57	0.000
Vegetation type	Tropical rainforest *vs* Tropical seasonal forest	-17.55	1898.85	0.000	-18.79	1907.41	0.000	-26.54	1879.33	0.000
	Tropical rainforest *vs* Savanna	6.81	1667.20	0.000	6.79	1674.96	0.000	8.98	1631.33	0.000
	Tropical rainforest *vs* Grassland	-18.91	1973.33	0.000	-20.98	1989.30	0.000	-29.50	1991.04	0.000
	Tropical rainforest *vs* Shrubland	-18.03	1917.15	0.000	-20.03	1952.66	0.000	-30.39	1944.79	0.000
	Tropical rainforest *vs* Desert	-13.02	1996.06	0.000	-14.98	1997.73	0.000	-21.79	1995.44	0.000
	Tropical rainforest *vs* Temperate forest	-12.29	1864.71	0.000	-13.90	1895.93	0.000	-20.37	1898.82	0.000
	Tropical rainforest *vs* Boreal forest	-15.77	1934.51	0.000	-16.58	1930.74	0.000	-24.45	1937.84	0.000
	Tropical seasonal forest *vs* Savanna	20.10	1887.88	0.000	21.11	1885.17	0.000	28.78	1877.85	0.000
	Tropical seasonal forest *vs* Grassland	-0.06	1969.75	0.948	-0.40	1951.71	0.686	0.22	1924.76	0.826
	Tropical seasonal forest *vs* Shrubland	-0.19	1996.82	0.846	-0.43	1988.86	0.671	-2.09	1982.09	0.037
	Tropical seasonal forest *vs* Desert	5.86	1922.07	0.000	5.64	1898.39	0.000	8.12	1848.35	0.000
	Tropical seasonal forest *vs* Temperate forest	4.37	1994.58	0.000	4.28	1997.56	0.000	5.86	1996.84	0.000
	Tropical seasonal forest *vs* Boreal forest	2.07	1993.14	0.038	2.33	1995.88	0.020	3.00	1985.74	0.003
	Savanna *vs* Grassland	-21.02	1778.71	0.000	-22.60	1741.04	0.000	-30.53	1689.95	0.000
	Savanna *vs* Shrubland	-20.45	1867.59	0.000	-22.00	1825.54	0.000	-31.50	1796.45	0.000
	Savanna *vs* Desert	-16.51	1698.29	0.000	-18.00	1663.31	0.000	-24.73	1596.61	0.000
	Savanna *vs* Temperate forest	-15.95	1919.56	0.000	-17.26	1897.09	0.000	-23.99	1857.15	0.000
	Savanna *vs* Boreal forest	-18.67	1845.48	0.000	-19.35	1857.46	0.000	-27.03	1807.07	0.000
	Grassland *vs* Shrubland	-0.14	1979.84	0.889	-0.04	1982.96	0.968	-2.54	1975.24	0.011
	Grassland *vs* Desert	6.35	1985.01	0.000	6.63	1985.98	0.000	8.88	1980.23	0.000
	Grassland *vs* Temperate forest	4.67	1947.91	0.000	5.00	1942.86	0.000	6.19	1940.75	0.000
	Grassland *vs* Boreal forest	2.27	1988.04	0.024	2.92	1968.70	0.004	3.08	1970.42	0.002
	Shrubland *vs* Desert	6.16	1938.42	0.000	6.35	1945.80	0.000	10.99	1921.12	0.000
	Shrubland *vs* Temperate forest	4.61	1989.44	0.000	4.85	1984.47	0.000	8.24	1989.43	0.000
	Shrubland *vs* Boreal forest	2.30	1996.74	0.022	2.84	1995.52	0.005	5.33	1997.75	0.000
	Desert *vs* Temperate forest	-0.95	1890.74	0.343	-0.85	1886.53	0.396	-1.58	1869.46	0.114
	Desert *vs* Boreal forest	-3.75	1953.55	0.000	-3.16	1922.68	0.002	-5.08	1913.08	0.000
	Temperate forest *vs* Boreal forest	-2.44	1981.74	0.015	-2.04	1993.51	0.041	-3.05	1992.07	0.002

*Grey rows indicate statistically significant results ($p < 0.05$). **Abbreviations:** *df*, degrees of freedom; *t*, *t*-statistic.

Table S11. Estimated ecological disparity (EDisp) of 98 extant, small-bodied mammalian communities with alternative ranking schemes of locomotor modes.

Environmental category		Scheme (a)		Scheme (b)		Scheme (c)	
		Mean	SD*	Mean	SD*	Mean	SD*
Habitat openness	Closed	4.03	2.41	3.93	2.29	3.82	2.16
	Open	4.31	2.55	4.22	2.44	3.86	2.24
Climate type	Tropical	3.65	2.16	3.56	2.04	3.51	1.98
	Arid	3.92	2.29	4.01	2.34	3.63	2.14
	Temperate	4.58	2.76	4.39	2.62	4.16	2.35
	Cold	4.81	2.56	4.67	2.44	4.44	2.29
Vegetation type	Tropical rainforest	3.26	1.91	3.20	1.82	3.20	1.82
	Tropical seasonal forest	4.41	2.39	4.28	2.26	4.10	2.11
	Savanna	2.65	1.71	2.63	1.65	2.54	1.53
	Grassland	4.63	2.52	4.55	2.48	4.09	2.30
	Shrubland	4.52	2.71	4.33	2.46	4.07	2.29
	Desert	3.75	2.09	3.64	1.94	3.31	1.58
	Temperate forest	4.58	2.71	4.44	2.58	4.30	2.39
	Boreal forest	4.50	2.50	4.41	2.40	4.14	2.17

*SD, standard deviation.

Three alternative ranking schemes of locomotor modes from 1 to 8 sequentially: (a) gliding, arboreal, scansorial, terrestrial, saltatorial, semiaquatic, semifossorial, fossorial; (b) gliding, arboreal, scansorial, terrestrial, semiaquatic, saltatorial, semifossorial, fossorial; and (c) gliding, arboreal, scansorial, terrestrial, semiaquatic, semifossorial, saltatorial, fossorial.

Table S12. Descriptive statistics of the ecological occupation of 98 extant, small-bodied mammalian communities by environmental category.

Environmental category		No. of unique eco-cells occupied	Total count of eco-cells occupied	Average reoccurrence of an eco-cell	% of theoretical ecospace
Habitat openness	Closed	86	510	5.93	35.83
	Open	56	288	5.14	23.33
Climate type	Tropical	65	287	4.42	27.08
	Arid	36	126	3.50	15.00
	Temperate	49	182	3.71	20.41
	Cold	32	203	6.34	13.33
Vegetation type	Tropical rainforest	52	161	3.10	21.67
	Tropical seasonal forest	56	108	1.93	23.33
	Savanna	15	33	2.20	6.25
	Grassland	38	129	3.39	15.83
	Shrubland	37	90	2.43	15.42
	Desert	21	36	1.71	8.75
	Temperate forest	37	175	4.73	15.42
	Boreal forest	20	66	3.30	8.33
Total		99	798	8.06	41.25

Table S13. The statistics of the occurrence in the eco-cells (ecological parameter value combinations) among different environmental categories.

Habitat openness

All sampled communities		**Open habitat**		**Closed habitat**	
Ecological parameter value combination	Freqency	Ecological parameter value combination	Frequency	Ecological parameter value combination	Frequency
<32 g – insectivory – terrestrial	67	32-128 g – herbivory – terrestrial	24	<32 g – insectivory – terrestrial	46
32-128 g – herbivory – terrestrial	61	<32 g – insectivory – terrestrial	21	32-128 g – herbivory – terrestrial	37
<32 g – omnivory – scansorial	38	32-128 g – omnivory – terrestrial	17	<32 g – omnivory – scansorial	29
<32 g – omnivory – terrestrial	35	<32 g – granivory – terrestrial	16	<32 g – carnivory – terrestrial	25
32-128 g – omnivory – terrestrial	34	<32 g – granivory – semifossorial	14	128-512 g – omnivory – scansorial	25
<32 g – carnivory – terrestrial	31	<32 g – omnivory – terrestrial	13	128-512 g – omnivory – terrestrial	23
32-128 g – omnivory – scansorial	30	32-128 g – granivory – terrestrial	11	<32 g – omnivory – terrestrial	22
128-512 g – omnivory – terrestrial	28	<32 g – omnivory – scansorial	9	32-128 g – omnivory – scansorial	22
128-512 g – omnivory – scansorial	25	32-128 g – omnivory – semifossorial	9	32-128 g – omnivory – terrestrial	17
<32 g – granivory – terrestrial	19	32-128 g – granivory – semifossorial	9	128-512 g – insectivory – terrestrial	12
<32 g – granivory – semifossorial	18	128-512 g – herbivory – terrestrial	9	512-2048 g – omnivory – scansorial	12
128-512 g – herbivory – terrestrial	18	32-128 g – omnivory – scansorial	8	128-512 g – frugivory – scansorial	9
32-128 g – herbivory – semifossorial	15	<32 g – herbivory – terrestrial	7	128-512 g – herbivory – terrestrial	9
32-128 g – granivory – terrestrial	14	32-128 g – insectivory – saltatorial	7	32-128 g – herbivory – semifossorial	8
512-2048 g – omnivory – scansorial	13	32-128 g – herbivory – semifossorial	7	512-2048 g – herbivory – terrestrial	8
32-128 g – insectivory – terrestrial	12	32-128 g – herbivory – saltatorial	7	>2048 g – omnivory – scansorial	8
32-128 g – omnivory – semifossorial	12	<32 g – carnivory – terrestrial	6	128-512 g – omnivory – arboreal	7
128-512 g – insectivory – terrestrial	12	<32 g – granivory – scansorial	6	>2048 g – herbivory – terrestrial	7
<32 g – herbivory – terrestrial	11	32-128 g – insectivory – terrestrial	6	<32 g – insectivory – scansorial	6
512-2048 g – herbivory – terrestrial	10	32-128 g – omnivory – saltatorial	6	<32 g – omnivory – saltatorial	6
>2048 g – herbivory – terrestrial	10	128-512 g – omnivory – terrestrial	5	32-128 g – insectivory – terrestrial	6
<32 g – insectivory – scansorial	9	128-512 g – omnivory – semifossorial	5	32-128 g – insectivory – scansorial	5
32-128 g – insectivory – scansorial	9	<32 g – granivory – fossorial	4	32-128 g – omnivory – arboreal	5
32-128 g – granivory – semifossorial	9	32-128 g – insectivory – scansorial	4	32-128 g – frugivory – terrestrial	5
128-512 g – frugivory – scansorial	9	32-128 g – insectivory – semifossorial	4	128-512 g – insectivory – arboreal	5
<32 g – omnivory – saltatorial	8	<32 g – insectivory – arboreal	3	128-512 g – granivory – scansorial	5
<32 g – granivory – scansorial	8	<32 g – insectivory – scansorial	3	512-2048 g – carnivory – semiaquatic	5
>2048 g – omnivory – scansorial	8	<32 g – omnivory – semifossorial	3	>2048 g – carnivory – terrestrial	5
32-128 g – insectivory – semifossorial	7	32-128 g – carnivory – scansorial	3	>2048 g – herbivory – arboreal	5
32-128 g – insectivory – saltatorial	7	32-128 g – granivory – scansorial	3	<32 g – granivory – semifossorial	4
32-128 g – herbivory – saltatorial	7	128-512 g – herbivory – scansorial	3	<32 g – herbivory – arboreal	4
128-512 g – omnivory – arboreal	7	512-2048 g – omnivory – terrestrial	3	<32 g – herbivory – terrestrial	4
128-512 g – granivory – scansorial	7	>2048 g – herbivory – terrestrial	3	32-128 g – omnivory – gliding	4

512-2048 g – carnivory – semiaquatic	7
512-2048 g – omnivory – terrestrial	7
>2048 g – carnivory – terrestrial	7
32-128 g – omnivory – saltatorial	6
128-512 g – carnivory – terrestrial	6
<32 g – omnivory – semifossorial	5
32-128 g – carnivory – scansorial	5
32-128 g – omnivory – arboreal	5
32-128 g – granivory – arboreal	5
32-128 g – granivory – scansorial	5
32-128 g – frugivory – terrestrial	5
128-512 g – insectivory – arboreal	5
128-512 g – omnivory – semifossorial	5
>2048 g – herbivory – arboreal	5
<32 g – omnivory – arboreal	4
<32 g – granivory – fossorial	4
<32 g – herbivory – arboreal	4
32-128 g – omnivory – gliding	4
128-512 g – insectivory – scansorial	4
128-512 g – omnivory – gliding	4
512-2048 g – insectivory – terrestrial	4
512-2048 g – omnivory – arboreal	4
>2048 g – omnivory – arboreal	4
<32 g – insectivory – arboreal	3
<32 g – omnivory – semiaquatic	3
<32 g – herbivory – semifossorial	3
32-128 g – carnivory – terrestrial	3
32-128 g – insectivory – fossorial	3
128-512 g – frugivory – terrestrial	3
128-512 g – herbivory – scansorial	3
512-2048 g – granivory – arboreal	3
>2048 g – frugivory – arboreal	3
<32 g – granivory – saltatorial	2
<32 g – frugivory – arboreal	2
32-128 g – carnivory – fossorial	2
32-128 g – frugivory – arboreal	2
32-128 g – frugivory – scansorial	2
128-512 g – granivory – terrestrial	2

<32 g – omnivory – saltatorial	2
128-512 g – carnivory – terrestrial	2
128-512 g – granivory – scansorial	2
512-2048 g – carnivory – semiaquatic	2
512-2048 g – omnivory – semiaquatic	2
512-2048 g – herbivory – terrestrial	2
>2048 g – carnivory – terrestrial	2
<32 g – omnivory – arboreal	1
<32 g – granivory – saltatorial	1
<32 g – herbivory – semifossorial	1
32-128 g – carnivory – terrestrial	1
32-128 g – carnivory – fossorial	1
32-128 g – granivory – arboreal	1
32-128 g – granivory – saltatorial	1
32-128 g – herbivory – scansorial	1
128-512 g – omnivory – gliding	1
512-2048 g – insectivory – terrestrial	1
512-2048 g – omnivory – scansorial	1
512-2048 g – herbivory – semiaquatic	1
512-2048 g – herbivory – saltatorial	1
>2048 g – carnivory – scansorial	1
>2048 g – insectivory – fossorial	1
>2048 g – herbivory – saltatorial	1
Total	**288**

32-128 g – granivory – arboreal	4
128-512 g – carnivory – terrestrial	4
128-512 g – insectivory – scansorial	4
512-2048 g – omnivory – arboreal	4
512-2048 g – omnivory – terrestrial	4
>2048 g – omnivory – arboreal	4
<32 g – omnivory – arboreal	3
<32 g – omnivory – semiaquatic	3
<32 g – granivory – terrestrial	3
32-128 g – insectivory – semifossorial	3
32-128 g – insectivory – fossorial	3
32-128 g – omnivory – semifossorial	3
32-128 g – granivory – terrestrial	3
128-512 g – omnivory – gliding	3
128-512 g – frugivory – terrestrial	3
512-2048 g – insectivory – terrestrial	3
512-2048 g – granivory – arboreal	3
>2048 g – frugivory – arboreal	3
<32 g – omnivory – semifossorial	2
<32 g – granivory – scansorial	2
<32 g – frugivory – arboreal	2
<32 g – herbivory – semifossorial	2
32-128 g – carnivory – scansorial	2
32-128 g – carnivory – terrestrial	2
32-128 g – granivory – scansorial	2
32-128 g – frugivory – arboreal	2
32-128 g – frugivory – scansorial	2
128-512 g – granivory – terrestrial	2
512-2048 g – herbivory – scansorial	2
>2048 g – insectivory – scansorial	2
>2048 g – insectivory – terrestrial	2
>2048 g – omnivory – terrestrial	2
>2048 g – frugivory – terrestrial	2
<32 g – carnivory – fossorial	1
<32 g – insectivory – semifossorial	1
<32 g – omnivory – fossorial	1
<32 g – granivory – arboreal	1
<32 g – granivory – saltatorial	1

512-2048 g – omnivory – semiaquatic	2			<32 g – frugivory – scansorial	1
512-2048 g – herbivory – scansorial	2			32-128 g – carnivory – fossorial	1
512-2048 g – herbivory – semiaquatic	2			32-128 g – insectivory – arboreal	1
>2048 g – insectivory – scansorial	2			32-128 g – herbivory – arboreal	1
>2048 g – insectivory – terrestrial	2			128-512 g – carnivory – arboreal	1
>2048 g – insectivory – fossorial	2			128-512 g – omnivory – semiaquatic	1
>2048 g – omnivory – terrestrial	2			128-512 g – herbivory – arboreal	1
>2048 g – frugivory – terrestrial	2			512-2048 g – carnivory – arboreal	1
>2048 g – herbivory – saltatorial	2			512-2048 g – carnivory – scansorial	1
<32 g – carnivory – fossorial	1			512-2048 g – carnivory – terrestrial	1
<32 g – insectivory – semifossorial	1			512-2048 g – insectivory – semiaquatic	1
<32 g – omnivory – fossorial	1			512-2048 g – frugivory – arboreal	1
<32 g – granivory – arboreal	1			512-2048 g – herbivory – semiaquatic	1
<32 g – frugivory – scansorial	1			>2048 g – insectivory – fossorial	1
32-128 g – insectivory – arboreal	1			>2048 g – herbivory – saltatorial	1
32-128 g – granivory – saltatorial	1			**Total**	**510**
32-128 g – herbivory – arboreal	1				
32-128 g – herbivory – scansorial	1				
128-512 g – carnivory – arboreal	1				
128-512 g – omnivory – semiaquatic	1				
128-512 g – herbivory – arboreal	1				
512-2048 g – carnivory – arboreal	1				
512-2048 g – carnivory – scansorial	1				
512-2048 g – carnivory – terrestrial	1				
512-2048 g – insectivory – semiaquatic	1				
512-2048 g – frugivory – arboreal	1				
512-2048 g – herbivory – saltatorial	1				
>2048 g – carnivory – scansorial	1				
Total	**798**				

Climate type

Tropical		**Arid**		**Temperate**	
Ecological parameter value combination	Frequency	Ecological parameter value combination	Frequency	Ecological parameter value combination	Frequency
128-512 g – omnivory – terrestrial	23	<32 g – granivory – terrestrial	13	<32 g – insectivory – terrestrial	23
32-128 g – omnivory – terrestrial	22	<32 g – insectivory – terrestrial	8	<32 g – carnivory – terrestrial	22
32-128 g – omnivory – scansorial	16	<32 g – omnivory – terrestrial	8	<32 g – omnivory – scansorial	21
128-512 g – omnivory – scansorial	15	32-128 g – omnivory – terrestrial	7	32-128 g – herbivory – terrestrial	18
<32 g – insectivory – terrestrial	13	32-128 g – omnivory – semifossorial	7	<32 g – omnivory – terrestrial	13

128-512 g – insectivory – terrestrial	12
128-512 g – frugivory – scansorial	9
128-512 g – herbivory – terrestrial	8
<32 g – omnivory – terrestrial	7
32-128 g – insectivory – terrestrial	7
128-512 g – omnivory – arboreal	7
512-2048 g – omnivory – terrestrial	7
32-128 g – granivory – terrestrial	6
<32 g – carnivory – terrestrial	5
<32 g – insectivory – scansorial	5
32-128 g – insectivory – scansorial	5
32-128 g – omnivory – arboreal	5
32-128 g – omnivory – semifossorial	5
32-128 g – frugivory – terrestrial	5
128-512 g – insectivory – arboreal	5
>2048 g – herbivory – arboreal	5
<32 g – omnivory – arboreal	4
<32 g – granivory – terrestrial	4
<32 g – herbivory – arboreal	4
32-128 g – granivory – arboreal	4
128-512 g – insectivory – scansorial	4
512-2048 g – omnivory – arboreal	4
512-2048 g – omnivory – scansorial	4
512-2048 g – herbivory – terrestrial	4
>2048 g – omnivory – arboreal	4
>2048 g – omnivory – scansorial	4
128-512 g – frugivory – terrestrial	3
512-2048 g – insectivory – terrestrial	3
512-2048 g – granivory – arboreal	3
>2048 g – frugivory – arboreal	3
32-128 g – carnivory – scansorial	2
32-128 g – carnivory – terrestrial	2
32-128 g – omnivory – gliding	2
32-128 g – frugivory – arboreal	2
32-128 g – frugivory – scansorial	2
32-128 g – herbivory – terrestrial	2
128-512 g – granivory – terrestrial	2
512-2048 g – carnivory – semiaquatic	2

32-128 g – granivory – terrestrial	7
<32 g – granivory – scansorial	6
32-128 g – omnivory – saltatorial	6
32-128 g – herbivory – terrestrial	5
<32 g – carnivory – terrestrial	4
<32 g – granivory – fossorial	4
32-128 g – insectivory – semifossorial	4
32-128 g – omnivory – scansorial	4
128-512 g – omnivory – semifossorial	4
<32 g – insectivory – arboreal	3
<32 g – insectivory – scansorial	3
32-128 g – carnivory – scansorial	3
32-128 g – insectivory – scansorial	3
32-128 g – insectivory – terrestrial	3
32-128 g – herbivory – saltatorial	3
128-512 g – omnivory – terrestrial	3
<32 g – herbivory – terrestrial	2
32-128 g – granivory – scansorial	2
128-512 g – herbivory – scansorial	2
<32 g – omnivory – semifossorial	1
<32 g – granivory – semifossorial	1
<32 g – herbivory – semifossorial	1
32-128 g – carnivory – terrestrial	1
32-128 g – granivory – saltatorial	1
32-128 g – herbivory – semifossorial	1
128-512 g – herbivory – terrestrial	1
512-2048 g – herbivory – saltatorial	1
>2048 g – carnivory – scansorial	1
>2048 g – carnivory – terrestrial	1
>2048 g – insectivory – fossorial	1
>2048 g – herbivory – saltatorial	1
Total	**126**

128-512 g – omnivory – scansorial	7
32-128 g – omnivory – scansorial	6
32-128 g – omnivory – terrestrial	5
32-128 g – herbivory – semifossorial	4
>2048 g – omnivory – scansorial	4
<32 g – omnivory – semifossorial	3
32-128 g – insectivory – semifossorial	3
32-128 g – granivory – scansorial	3
512-2048 g – omnivory – scansorial	3
512-2048 g – herbivory – terrestrial	3
<32 g – omnivory – semiaquatic	2
<32 g – granivory – scansorial	2
<32 g – granivory – terrestrial	2
32-128 g – insectivory – terrestrial	2
32-128 g – insectivory – fossorial	2
128-512 g – carnivory – terrestrial	2
128-512 g – herbivory – terrestrial	2
512-2048 g – carnivory – semiaquatic	2
>2048 g – carnivory – terrestrial	2
>2048 g – herbivory – terrestrial	2
<32 g – carnivory – fossorial	1
<32 g – insectivory – scansorial	1
<32 g – insectivory – semifossorial	1
<32 g – omnivory – saltatorial	1
<32 g – granivory – arboreal	1
<32 g – granivory – saltatorial	1
<32 g – frugivory – arboreal	1
<32 g – herbivory – terrestrial	1
<32 g – herbivory – semifossorial	1
32-128 g – carnivory – fossorial	1
32-128 g – insectivory – arboreal	1
32-128 g – insectivory – scansorial	1
32-128 g – omnivory – gliding	1
32-128 g – granivory – arboreal	1
32-128 g – granivory – terrestrial	1
32-128 g – granivory – semifossorial	1
32-128 g – herbivory – scansorial	1
128-512 g – omnivory – terrestrial	1

512-2048 g – herbivory – scansorial	2
>2048 g – carnivory – terrestrial	2
>2048 g – insectivory – scansorial	2
>2048 g – insectivory – terrestrial	2
>2048 g – frugivory – terrestrial	2
<32 g – omnivory – semifossorial	1
<32 g – omnivory – fossorial	1
<32 g – frugivory – arboreal	1
<32 g – frugivory – scansorial	1
<32 g – herbivory – terrestrial	1
32-128 g – herbivory – arboreal	1
128-512 g – carnivory – arboreal	1
128-512 g – omnivory – semiaquatic	1
512-2048 g – carnivory – arboreal	1
512-2048 g – carnivory – scansorial	1
512-2048 g – carnivory – terrestrial	1
512-2048 g – insectivory – semiaquatic	1
512-2048 g – frugivory – arboreal	1
>2048 g – insectivory – fossorial	1
>2048 g – omnivory – terrestrial	1
>2048 g – herbivory – terrestrial	1
>2048 g – herbivory – saltatorial	1
Total	**287**

128-512 g – omnivory – semifossorial	1
128-512 g – granivory – scansorial	1
128-512 g – herbivory – arboreal	1
128-512 g – herbivory – scansorial	1
512-2048 g – herbivory – semiaquatic	1
>2048 g – omnivory – terrestrial	1
Total	**182**

Cold	
Ecological parameter value combination	Frequency
32-128 g – herbivory – terrestrial	36
<32 g – insectivory – terrestrial	23
<32 g – omnivory – scansorial	17
<32 g – granivory – semifossorial	17
32-128 g – herbivory – semifossorial	10
32-128 g – granivory – semifossorial	8
<32 g – omnivory – terrestrial	7
<32 g – omnivory – saltatorial	7
<32 g – herbivory – terrestrial	7

32-128 g – insectivory – saltatorial	7
128-512 g – herbivory – terrestrial	7
>2048 g – herbivory – terrestrial	7
128-512 g – granivory – scansorial	6
512-2048 g – omnivory – scansorial	6
32-128 g – omnivory – scansorial	4
32-128 g – herbivory – saltatorial	4
128-512 g – carnivory – terrestrial	4
128-512 g – omnivory – gliding	4
128-512 g – omnivory – scansorial	3
512-2048 g – carnivory – semiaquatic	3
512-2048 g – herbivory – terrestrial	3
512-2048 g – omnivory – semiaquatic	2
>2048 g – carnivory – terrestrial	2
<32 g – omnivory – semiaquatic	1
<32 g – granivory – saltatorial	1
<32 g – herbivory – semifossorial	1
32-128 g – carnivory – fossorial	1
32-128 g – insectivory – fossorial	1
32-128 g – omnivory – gliding	1
128-512 g – omnivory – terrestrial	1
512-2048 g – insectivory – terrestrial	1
512-2048 g – herbivory – semiaquatic	1
Total	**203**

Vegetation type

Tropical rainforest		**Tropical seasonal forest**		**Savanna**	
Ecological parameter value combination	Frequency	Ecological parameter value combination	Frequency	Ecological parameter value combination	Frequency
128-512 g – omnivory – terrestrial	17	32-128 g – omnivory – terrestrial	10	32-128 g – omnivory – terrestrial	7
128-512 g – insectivory – terrestrial	12	128-512 g – omnivory – scansorial	6	32-128 g – granivory – terrestrial	4
32-128 g – omnivory – scansorial	11	<32 g – insectivory – terrestrial	5	<32 g – granivory – terrestrial	3
128-512 g – omnivory – scansorial	10	32-128 g – omnivory – scansorial	5	32-128 g – omnivory – semifossorial	3

<32 g – insectivory – terrestrial	7
32-128 g – omnivory – terrestrial	6
128-512 g – omnivory – arboreal	6
32-128 g – insectivory – scansorial	5
32-128 g – frugivory – terrestrial	5
128-512 g – frugivory – scansorial	5
128-512 g – herbivory – terrestrial	5
32-128 g – granivory – arboreal	4
128-512 g – insectivory – arboreal	4
<32 g – insectivory – scansorial	3
<32 g – herbivory – arboreal	3
32-128 g – insectivory – terrestrial	3
32-128 g – omnivory – arboreal	3
512-2048 g – omnivory – terrestrial	3
>2048 g – omnivory – arboreal	3
<32 g – carnivory – terrestrial	2
<32 g – omnivory – terrestrial	2
32-128 g – granivory – terrestrial	2
32-128 g – frugivory – arboreal	2
128-512 g – insectivory – scansorial	2
128-512 g – granivory – terrestrial	2
128-512 g – frugivory – terrestrial	2
512-2048 g – omnivory – arboreal	2
512-2048 g – omnivory – scansorial	2
512-2048 g – granivory – arboreal	2
512-2048 g – herbivory – terrestrial	2
>2048 g – omnivory – scansorial	2
>2048 g – herbivory – arboreal	2
<32 g – omnivory – arboreal	1
<32 g – frugivory – arboreal	1
<32 g – frugivory – scansorial	1
<32 g – herbivory – terrestrial	1
32-128 g – carnivory – scansorial	1
32-128 g – carnivory – terrestrial	1
32-128 g – omnivory – gliding	1
32-128 g – herbivory – arboreal	1
512-2048 g – carnivory – arboreal	1
512-2048 g – carnivory – terrestrial	1
128-512 g – omnivory – terrestrial	5
128-512 g – frugivory – scansorial	4
32-128 g – insectivory – terrestrial	3
32-128 g – omnivory – semifossorial	3
>2048 g – omnivory – scansorial	3
>2048 g – herbivory – arboreal	3
<32 g – carnivory – terrestrial	2
<32 g – insectivory – scansorial	2
<32 g – omnivory – arboreal	2
<32 g – omnivory – scansorial	2
<32 g – omnivory – semifossorial	2
32-128 g – omnivory – arboreal	2
32-128 g – frugivory – scansorial	2
32-128 g – herbivory – terrestrial	2
128-512 g – insectivory – scansorial	2
128-512 g – herbivory – terrestrial	2
512-2048 g – carnivory – semiaquatic	2
512-2048 g – insectivory – terrestrial	2
512-2048 g – omnivory – arboreal	2
512-2048 g – omnivory – scansorial	2
>2048 g – frugivory – arboreal	2
<32 g – insectivory – semifossorial	1
<32 g – omnivory – terrestrial	1
<32 g – omnivory – fossorial	1
<32 g – granivory – terrestrial	1
<32 g – frugivory – arboreal	1
<32 g – herbivory – arboreal	1
32-128 g – carnivory – scansorial	1
32-128 g – carnivory – terrestrial	1
32-128 g – insectivory – arboreal	1
32-128 g – insectivory – semifossorial	1
32-128 g – omnivory – gliding	1
32-128 g – granivory – terrestrial	1
128-512 g – carnivory – arboreal	1
128-512 g – insectivory – arboreal	1
128-512 g – omnivory – arboreal	1
128-512 g – omnivory – semiaquatic	1
128-512 g – frugivory – terrestrial	1
<32 g – carnivory – terrestrial	2
<32 g – omnivory – terrestrial	2
32-128 g – insectivory – terrestrial	2
32-128 g – herbivory – terrestrial	2
512-2048 g – omnivory – terrestrial	2
<32 g – insectivory – terrestrial	1
<32 g – omnivory – arboreal	1
128-512 g – omnivory – terrestrial	1
128-512 g – herbivory – terrestrial	1
>2048 g – insectivory – fossorial	1
>2048 g – herbivory – saltatorial	1
Total	**33**

512-2048 g – insectivory – terrestrial	1	128-512 g – herbivory – arboreal	1
512-2048 g – insectivory – semiaquatic	1	512-2048 g – carnivory – scansorial	1
512-2048 g – frugivory – arboreal	1	512-2048 g – omnivory – terrestrial	1
512-2048 g – herbivory – scansorial	1	512-2048 g – granivory – arboreal	1
>2048 g – carnivory – terrestrial	1	512-2048 g – herbivory – scansorial	1
>2048 g – insectivory – scansorial	1	512-2048 g – herbivory – terrestrial	1
>2048 g – insectivory – terrestrial	1	>2048 g – carnivory – terrestrial	1
>2048 g – omnivory – terrestrial	1	>2048 g – insectivory – scansorial	1
>2048 g – frugivory – arboreal	1	>2048 g – insectivory – terrestrial	1
>2048 g – frugivory – terrestrial	1	>2048 g – insectivory – fossorial	1
Total	**161**	>2048 g – omnivory – arboreal	1
		>2048 g – frugivory – terrestrial	1
		>2048 g – herbivory – terrestrial	1
		>2048 g – herbivory – saltatorial	1
		Total	**108**

Grassland		**Shrubland**		**Desert**	
Ecological parameter value combination	Frequency	Ecological parameter value combination	Frequency	Ecological parameter value combination	Frequency
<32 g – insectivory – terrestrial	12	32-128 g – herbivory – terrestrial	12	<32 g – granivory – terrestrial	5
32-128 g – herbivory – terrestrial	10	<32 g – insectivory – terrestrial	7	<32 g – granivory – scansorial	2
<32 g – granivory – semifossorial	9	<32 g – omnivory – scansorial	4	<32 g – granivory – fossorial	2
<32 g – omnivory – terrestrial	8	<32 g – granivory – scansorial	4	32-128 g – insectivory – scansorial	2
32-128 g – omnivory – semifossorial	6	<32 g – granivory – terrestrial	4	32-128 g – insectivory – saltatorial	2
32-128 g – granivory – semifossorial	6	<32 g – granivory – semifossorial	4	32-128 g – omnivory – scansorial	2
128-512 g – herbivory – terrestrial	6	<32 g – herbivory – terrestrial	4	32-128 g – omnivory – terrestrial	2
<32 g – omnivory – scansorial	5	32-128 g – omnivory – terrestrial	4	32-128 g – omnivory – saltatorial	2
32-128 g – insectivory – saltatorial	5	32-128 g – omnivory – saltatorial	4	32-128 g – granivory – terrestrial	2
32-128 g – herbivory – saltatorial	5	<32 g – insectivory – arboreal	3	32-128 g – granivory – semifossorial	2
<32 g – carnivory – terrestrial	4	<32 g – omnivory – terrestrial	3	32-128 g – herbivory – semifossorial	2
<32 g – granivory – terrestrial	4	32-128 g – omnivory – scansorial	3	32-128 g – herbivory – saltatorial	2
32-128 g – omnivory – terrestrial	4	32-128 g – granivory – terrestrial	3	<32 g – insectivory – terrestrial	1
32-128 g – herbivory – semifossorial	4	128-512 g – omnivory – semifossorial	3	<32 g – granivory – semifossorial	1
128-512 g – omnivory – terrestrial	4	<32 g – granivory – fossorial	2	<32 g – herbivory – semifossorial	1
<32 g – insectivory – scansorial	3	32-128 g – insectivory – scansorial	2	32-128 g – insectivory – terrestrial	1

<32 g – herbivory – terrestrial	3	32-128 g – insectivory – semifossorial	2	32-128 g – granivory – scansorial	1
32-128 g – carnivory – scansorial	3	128-512 g – herbivory – scansorial	2	32-128 g – granivory – saltatorial	1
32-128 g – omnivory – scansorial	3	>2048 g – carnivory – terrestrial	2	128-512 g – omnivory – semifossorial	1
<32 g – omnivory – semifossorial	2	<32 g – omnivory – semifossorial	1	128-512 g – herbivory – scansorial	1
32-128 g – insectivory – terrestrial	2	<32 g – omnivory – saltatorial	1	128-512 g – herbivory – terrestrial	1
32-128 g – insectivory – semifossorial	2	32-128 g – carnivory – terrestrial	1	**Total**	**36**
32-128 g – granivory – terrestrial	2	32-128 g – insectivory – terrestrial	1		
512-2048 g – omnivory – semiaquatic	2	32-128 g – granivory – scansorial	1		
>2048 g – herbivory – terrestrial	2	32-128 g – granivory – semifossorial	1		
<32 g – omnivory – saltatorial	1	32-128 g – herbivory – semifossorial	1		
<32 g – granivory – saltatorial	1	128-512 g – carnivory – terrestrial	1		
32-128 g – carnivory – fossorial	1	128-512 g – granivory – scansorial	1		
32-128 g – granivory – arboreal	1	128-512 g – herbivory – terrestrial	1		
32-128 g – granivory – scansorial	1	512-2048 g – carnivory – semiaquatic	1		
32-128 g – herbivory – scansorial	1	512-2048 g – insectivory – terrestrial	1		
128-512 g – carnivory – terrestrial	1	512-2048 g – omnivory – scansorial	1		
128-512 g – omnivory – gliding	1	512-2048 g – herbivory – terrestrial	1		
128-512 g – omnivory – semifossorial	1	512-2048 g – herbivory – semiaquatic	1		
128-512 g – granivory – scansorial	1	512-2048 g – herbivory – saltatorial	1		
512-2048 g – carnivory – semiaquatic	1	>2048 g – carnivory – scansorial	1		
512-2048 g – omnivory – terrestrial	1	>2048 g – herbivory – terrestrial	1		
512-2048 g – herbivory – terrestrial	1	**Total**	**90**		
Total	**129**				

Temperate forest		**Boreal forest**	
Ecological parameter value combination	Frequency	Ecological parameter value combination	Frequency
<32 g – insectivory – terrestrial	25	32-128 g – herbivory – terrestrial	16
<32 g – carnivory – terrestrial	21	<32 g – insectivory – terrestrial	9
<32 g – omnivory – scansorial	21	<32 g – omnivory – scansorial	6
32-128 g – herbivory – terrestrial	19	<32 g – omnivory – terrestrial	5
<32 g – omnivory – terrestrial	14	<32 g – granivory – semifossorial	4

128-512 g – omnivory – scansorial	8	<32 g – omnivory – saltatorial	3
512-2048 g – omnivory – scansorial	6	32-128 g – omnivory – scansorial	3
32-128 g – herbivory – semifossorial	5	32-128 g – herbivory – semifossorial	3
512-2048 g – herbivory – terrestrial	5	<32 g – herbivory – terrestrial	2
>2048 g – herbivory – terrestrial	4	128-512 g – omnivory – gliding	2
<32 g – omnivory – saltatorial	3	128-512 g – granivory – scansorial	2
32-128 g – insectivory – fossorial	3	512-2048 g – omnivory – scansorial	2
32-128 g – omnivory – scansorial	3	>2048 g – herbivory – terrestrial	2
128-512 g – carnivory – terrestrial	3	<32 g – omnivory – semiaquatic	1
128-512 g – granivory – scansorial	3	<32 g – herbivory – semifossorial	1
>2048 g – omnivory – scansorial	3	128-512 g – carnivory – terrestrial	1
<32 g – omnivory – semiaquatic	2	128-512 g – omnivory – scansorial	1
<32 g – granivory – scansorial	2	128-512 g – herbivory – terrestrial	1
<32 g – granivory – terrestrial	2	512-2048 g – carnivory – semiaquatic	1
32-128 g – insectivory – semifossorial	2	>2048 g – carnivory – terrestrial	1
32-128 g – omnivory – gliding	2	**Total**	**66**
32-128 g – granivory – scansorial	2		
512-2048 g – carnivory – semiaquatic	2		
>2048 g – carnivory – terrestrial	2		
<32 g – carnivory – fossorial	1		
<32 g – insectivory – scansorial	1		
<32 g – granivory – arboreal	1		
<32 g – granivory – saltatorial	1		
<32 g – herbivory – terrestrial	1		
<32 g – herbivory – semifossorial	1		
32-128 g – carnivory – fossorial	1		
32-128 g – omnivory – terrestrial	1		
128-512 g – omnivory – gliding	1		
128-512 g – omnivory – terrestrial	1		
128-512 g – herbivory – terrestrial	1		
512-2048 g – herbivory – semiaquatic	1		
>2048 g – omnivory – terrestrial	1		
Total	**175**		

Extinct Mammaliaform Commnities

Jiulongshan

Ecological parameter value combination	Frequency
<32 g – insectivory – terrestrial	1
<32-128 g – insectivory – gliding	1
32-128 g – omnivory – arboreal	1
128-512 g – omnivory – terrestrial	1
512-2048 g – carnivory – semiaquatic	1
Total	**5**

Tiaojishan

Ecological parameter value combination	Frequency
<32 g – insectivory – scansorial	1
<32 g – insectivory – fossorial	1
32-128 g – omnivory – gliding	1
32-128 g – omnivory – arboreal	3
32-128 g – omnivory – scansorial	1
128-512 g – omnivory – arboreal	2
128-512 g – herbivory – gliding	1
Total	**10**

Lujiatun-Jianshangou

Ecological parameter value combination	Frequency
<32 g – insectivory – arboreal	1
<32 g – insectivory – scansorial	1
32-128 g – carnivory – scansorial	1
32-128 g – insectivory – terrestrial	2
128-512 g – carnivory – terrestrial	1
128-512 g – insectivory – scansorial	1
512-2048 g – carnivory – terrestrial	1
512-2048 g – carnivory – semifossorial	1
>2048 g – carnivory – terrestrial	1
Total	**10**

Dawangzhangzi

Ecological parameter value combination	Frequency
<32 g – insectivory – arboreal	1
<32 g – insectivory – scansorial	1
<32 g – insectivory – semiaquatic	1
<32 g – insectivory – semifossorial	1
32-128 g – insectivory – terrestrial	1
32-128 g – omnivory – arboreal	1
Total	**6**

Messel

Ecological parameter value combination	Frequency
<32 g – omnivory – arboreal	1
<32 g – herbivory – arboreal	1
32-128 g – insectivory – arboreal	1
32-128 g – insectivory – saltatorial	1
32-128 g – omnivory – terrestrial	1
128-512 g – carnivory – terrestrial	1
128-512 g – insectivory – semifossorial	1
128-512 g – omnivory – arboreal	1
128-512 g – omnivory – fossorial	1
512-2048 g – carnivory – saltatorial	1
512-2048 g – insectivory – fossorial	1
512-2048 g – insectivory – saltatorial	2
512-2048 g – omnivory – arboreal	1
512-2048 g – omnivory – semiaquatic	1
512-2048 g – omnivory – fossorial	1
512-2048 g – herbivory – arboreal	1
512-2048 g – herbivory – terrestrial	2
>2048 g – carnivory – arboreal	1
>2048 g – omnivory – terrestrial	1
Total	**21**

Table S14. Observed and simulated *C*-scores of ecospace occupation of 98 extant, small-bodied mammalian communities arranged by habitat openness, climate type, and vegetation type.

Environmental category		Observed *C*-score	Lower 95% CI	Upper 95% CI	Lower-tail P	Upper-tail P	Standardized effect size (SES)
Habitat openness	Open	15.232	14.579	14.787	> 0.999	< 0.001	8.5719
	Closed	11.583	10.237	10.668	> 0.999	< 0.001	9.5293
Climate type	Tropical	6.0058	5.5726	5.7543	> 0.999	< 0.001	6.9773
	Arid	7.1302	6.727	6.9238	> 0.999	< 0.001	6.9943
	Temperate	3.6165	2.9396	3.1344	> 0.999	< 0.001	12.29
	Cold	12.681	11.089	11.76	> 0.999	< 0.001	6.8895
Vegetation type	Tropical rainforest	2.457	2.276	2.365	> 0.999	< 0.001	5.9586
	Tropical seasonal forest	1.2688	1.1896	1.2857	0.814	0.195	1.0426
	Savanna	1.4381	1.381	1.5714	0.419	0.681	-0.40948
	Grassland	5.7653	5.3229	5.5677	> 0.999	< 0.001	5.2567
	Shrubland	3.3949	3.2162	3.3093	> 0.999	< 0.001	5.2778
	Desert	2.0619	1.9381	2.0048	> 0.999	< 0.001	5.4206
	Temperate forest	3.2868	2.4549	2.8559	> 0.999	< 0.001	5.8811
	Boreal forest	2.1895	1.8895	2.1474	0.996	0.004	2.9567

Confidence intervals are the 95% two-tailed cutoff points for the null distribution generated from 1000 simulations. P-values indicate whether the observed value fall beyond the lower or upper confidence intervals. The standardized effect size (SES) is the number of standard deviations that the observed *C*-score is above or below the mean *C*-score value of the simulated communities. Grey rows indicate statistically significant results ($P < 0.05$).

Table S15. Structural matrices, eigenvalues, and proportions of the variance explained by each function of the discriminant function analyses of 98 extant, small-bodied mammalian communities of different environmental classifications.

Ecological parameter	Habitat openness	Climate type			Vegetation type		
	DF1	DF1	DF2	DF3	DF1	DF2	DF3
< 32 g	0.054	-0.322	-0.369	0.088	-0.469	0.172	0.274
33–128 g	0.4	-0.005	-0.05	-0.195	-0.064	-0.072	-0.489
129–512 g	-0.424	0.274	0.404	0.165	0.506	0.041	0.15
513–2048 g	-0.307	0.211	0.495	0.156	0.329	-0.141	0.181
> 2049 g	-0.298	0.101	0.122	0.002	0.207	-0.148	0.262
Carnivory	-0.447	0.155	-0.271	0.512	-0.012	-0.023	0.574
Insectivory	-0.218	0.158	-0.134	0.103	0.217	0.179	0.122
Omnivory	-0.392	0.53	-0.018	0.255	0.255	-0.378	0.298
Granivory	0.679	-0.21	-0.149	-0.662	-0.287	0.113	-0.709
Frugivory	-0.597	0.567	0.424	0.16	0.813	0.08	0.095
Herbivory	0.072	-0.723	0.247	0.223	-0.374	0.163	0.251
Gliding	-0.322	-0.175	0.228	0.093	-0.036	0.104	0.32
Arboreal	-0.47	0.639	0.324	0.05	0.82	-0.029	-0.027
Scansorial	-0.63	0.23	-0.247	0.4	0.23	0.533	0.375
Terrestrial	-0.026	0.171	-0.012	0.16	-0.116	-0.459	0.262
Semiaquatic	-0.149	-0.165	0.153	0.221	-0.04	0.078	0.27
Semifossorial	0.479	-0.5	0.009	-0.159	-0.35	-0.014	-0.13
Fossorial	0.106	0.056	-0.246	-0.312	-0.085	-0.017	-0.182
Saltatorial	0.426	-0.359	0.01	-0.464	-0.263	0.138	-0.399
Eigenvalue	9.233	9.525	7.128	4.302	7.700	4.580	2.711
Variance explained (%)	100	56.68	31.75	11.57	56.00	19.81	11.21

Table S16. Classification predictions of the discriminant function analysis of habitat openness.

Assigned Habitat openness	% Correct	Inferred Habitat openness	
		Closed	Open
Closed	80.00	36	9
Open	75.47	13	40
Total	77.55	49	49

Table S17. Classification predictions of the discriminant function analysis of climate type.

Assigned Climate type	% Correct	Inferred Climate type			
		Tropical	Arid	Temperate	Cold
Tropical	83.33	20	3	1	0
Arid	72.00	0	18	6	1
Temperate	90.00	1	1	18	0
Cold	93.10	0	0	2	27
Total	84.69	21	22	27	28

Table S18. Classification predictions of the discriminant function analysis of vegetation type.

Assigned Vegetation type	% Correct	Inferred Vegetation type							
		Tropical rain forest	Tropical seasonal forest	Savanna	Grassland	Shrubland	Desert	Temperate forest	Boreal forest
Tropical rain forest	75.00	9	2	0	0	1	0	0	0
Tropical seasonal forest	62.50	2	5	0	0	1	0	0	0
Savanna	100.00	0	0	6	0	0	0	0	0
Grassland	55.00	0	0	3	11	2	1	0	3
Shrubland	55.56	0	0	1	3	10	3	0	1
Desert	77.78	0	0	0	0	1	7	1	0
Temperate forest	87.50	0	0	0	0	0	1	14	1
Boreal forest	77.78	0	0	0	1	1	0	0	7
Total	70.41	11	7	10	15	16	12	15	12

Table S19. Paleoenvironmental inferences of extinct mammaliaform communities using DFA, Whittaker biomes, and auxiliary paleo-proxy data.

<table>
<tr><th rowspan="3">Epoch</th><th rowspan="3">Paleocommunity</th><th colspan="6">Paleoenvironmental inference</th><th colspan="2" rowspan="2">Auxiliary paleo-proxy data[a]</th></tr>
<tr><th colspan="3">DFA inference</th><th colspan="3">Whittaker biome inference</th></tr>
<tr><th>Habitat openness</th><th>Climate type</th><th>Vegetation type</th><th>$DF1_{habitat\ openness}$</th><th>$DF1_{climate\ type}$</th><th>$DF1_{vegetation\ type}$</th><th>Climate type</th><th>Vegetation type</th></tr>
<tr><td>Eocene</td><td>MSL</td><td>Open</td><td>Tropical</td><td>Tropical rainforest</td><td>Shrubland/ woodland</td><td>Tropical seasonal forest/savanna</td><td>Tropical seasonal forest/savanna</td><td>Humid, subtropical, frost-free climate, with slight seasonality; MAT= 22°C, MAP =2540 mm [113–115]</td><td>Multistratal canopy forest with lots of lianas; some herbaceous components, perhaps in open swampy settings; possibly drier habitats in distant uplands [110]</td></tr>
<tr><td rowspan="2">Early Cretaceous</td><td>DWZZ</td><td>Open</td><td>Arid</td><td>Tropical seasonal forest</td><td>Shrubland/ woodland</td><td>Shrubland/ woodland</td><td>Shrubland/ woodland</td><td rowspan="2">Temperate, semi-humid[117]; subtropical to warm temperate with seasoanl arid, to warm-temperate and humid with seasonal variations [118, 119]; warm and seasonal, short wet but long arid periods[120]</td><td rowspan="2">Cool temperate moist forest consisting of ginkgoes cycads, seed ferns, and conifers[116]; mainly conifer forest and steppe[117]; conifer and ginkgophytes dominating[121]</td></tr>
<tr><td>LJT-JSG</td><td>Closed</td><td>Tropical</td><td>Tropical seasonal forest</td><td>Temperate seasonal forest</td><td>Tropical seasonal forest/savanna</td><td>Tropical seasonal forest/savanna</td></tr>
<tr><td rowspan="2">Mid-Late Jurassic</td><td>TJS</td><td>Closed</td><td>Cold</td><td>Tropical rainforest</td><td>Tropical seasonal forest/savanna</td><td>Shrubland/ woodland</td><td>Shrubland/ woodland</td><td rowspan="2">Warm temperate[122, 123]; warm-temprate and moist conditions[124]; mountain[125]; hot, dry climate[126]; subtropical, humid, seasonal[127]</td><td rowspan="2">N/A</td></tr>
<tr><td>JLS</td><td>Closed</td><td>Cold</td><td>Tropical rainforest</td><td>Temperate seasonal forest</td><td>Shrubland/ woodland</td><td>Shrubland/ woodland</td></tr>
</table>

[a]**Auxiliary evidence for paleoenvironment** based on fossil plants, fossil insects, stable isotopic data and/or sedimentology, see cited references.

Table S20. Estimated mean annual temperature (MAT) and mean annual precipitation (MAP) of extinct mammaliaform communities using DF1 scores by three different environmental categories.

Epoch	Paleocommunity	Estimated MAT and MAP*					
		Habitat openness		Climate type		Vegetation type	
		MAT (ºC)	MAP (mm)	MAT (ºC)	MAP (mm)	MAT (ºC)	MAP (mm)
Eocene	MSL	12 ± 1.6	811 ± 225	22 ± 1.8	1786 ± 307	19 ± 2.1	1790 ± 280
Early Cretaceous	DWZZ	12 ± 1.6	836 ± 220	19 ± 1.5	1539 ± 252	18 ± 1.8	1548 ± 235
	LJT-JSG	15 ± 1.9	1161 ± 245	24 ± 2.1	2031 ± 366	21 ± 2.5	2031 ± 330
Mid-Late Jurassic	TJS	20 ± 4.3	1853 ± 563	14 ± 1.1	1048 ± 186	14 ± 1.3	1064 ± 178
	JLS	16 ± 2.3	1341 ± 310	11 ± 1.1	756 ± 191	12 ± 1.3	778 ± 181

* The MAT and MAP is estimated by using the relationships between DF1 scores of DFA and the environmental factors in the correlation analysis in *SI Appendix*, Figs. S13, S14.

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