



Regional and environmental effects on the species richness of mammal assemblages

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ABSTRACT

Aim Variation in species richness has been related to (1) environmental conditions (water, energy and habitat characteristics) and (2) regional differences (contingent historical events and regional particularities that result in differences between regional faunas acting at broad extents). Whereas climatic factors have been widely studied, the effects of regional differences are less often quantified. This work aims to characterize global trends in the species richness of mammal assemblages with respect to both current and historical influences.

Location All terrestrial biogeographical realms except Antarctica.

Methods Species richness in checklists from 224 sites distributed worldwide were investigated by partitioning the variation between a general set of habitat/climate factors, biogeographical regions, and their overlaps. Additional analyses studied the specific overlaps of region, water and energy. Data were also divided according to area to determine if the strength of these effects varies according to the size of sites.

Results Environmental effects explained 38% of richness variation across all sites, whereas environmentally independent regional effects explained 11% and the overlap between region and environment explained 13%. Results were similar when only larger sites (between 1000 km² and 10,000 km²) were considered. However, the importance of the overlap between region and all environmental variables was greater in smaller sites (between 100 km² and 1000 km²). In contrast, the specific importance of water and energy variables and their overlap with region was greater in larger sites. The strength of the independent effect of region remained almost invariant regardless of the size of the sites studied.

Main conclusions The relationship between species richness and climate varies with scale and among regions. Although environmental variables are the strongest correlates of richness, the unique history and physiographic characteristics of a region produce differences between the richness of mammal assemblages and their response to environmental gradients. The importance of environmental variables varies with scale: climatic gradients are more important at coarse grain (larger sites), possibly as a result of their effects on species ranges, whereas habitat type is more important at the smaller sites, where the importance of ecological interactions increases. Therefore, regional differences and the scale at which richness is measured should be taken into account when evaluating species richness–energy hypotheses.

Keywords

Climate, environmental factors, grain, habitat, local communities, macroecology, mammals, regional effects, scale, water–energy dynamics.

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INTRODUCTION

Geographic gradients in species richness can be related statistically to many variables (Rahbek & Graves, 2001). Among them, the characteristics of the sites where the species occur, including the environment (climate and habitat) and its physical characteristics (area and topographic and landscape heterogeneity), are frequently mentioned as the primary drivers of species richness (Kerr & Packer, 1997; Francis & Currie, 1998, 2003; Waide *et al.*, 1999; Jetz & Rahbek, 2001; Kerr *et al.*, 2001; Rahbek & Graves, 2001; Currie *et al.*, 2004; Tognelli & Kelt, 2004; Evans & Gaston, 2005; Evans *et al.*, 2005; Field *et al.*, 2005; Scheiner & Willig, 2005). Communities are not, however, affected only by the characteristics of the site where they occur; they are also the result of the assembling of species from those available in the regional pool (Ricklefs, 2004), which includes the characteristics and evolutionary history of the species present in the regional pool (Nieto *et al.*, 2005; Rodríguez *et al.*, 2006; J. Hortal, J. Rodríguez, D. Nogués-Bravo, M. B. Araújo & C. Rahbek, unpublished), the geomorphological and environmental characteristics of the region (Jetz & Rahbek, 2001; Rahbek & Graves, 2001), and region-specific historical variation in climate and habitat (see, for example, Hawkins & Porter, 2003; Hawkins *et al.*, 2005; Svenning & Skov, 2005, 2007; Montoya *et al.*, 2007). Therefore, some differences in the species richness of similar assemblages in different regions are to be expected (Ricklefs, 1987, 2004; Ricklefs & Schluter, 1993; Ricklefs *et al.*, 1999; Hawkins *et al.*, 2003a,b; Willig *et al.*, 2003; Wiens & Donoghue, 2004). Regional effects are often unmeasured, however, in spite of their widely appreciated potential importance in shaping biodiversity patterns at broad extents.

In this paper, we study the effects of environmental and regional factors on the species richness of non-volant mammal assemblages at the global extent. To do this, we use species inventories from a large set of localities of variable size distributed worldwide, and a set of predictors to account for broad-extent environmental gradients. Species-richness estimates come from exhaustive checklists. Our approach differs from that of most large-scale studies, in which richness is estimated as the sum of species range maps overlapping in grid cells (grid cell richness; see Kerr *et al.*, 2001; Whittaker *et al.*, 2001; Qian & Ricklefs, 2004; Grenyer *et al.*, 2006). Here we use high-quality checklists instead of gridded richness because they provide the most reliable information of the species that actually co-occur as assemblages in spatially defined areas. However, these localities vary substantially in area, and the relative importance of correlates of richness are known to be sensitive to the grain size used to measure species richness (Whittaker & Field, 2000; Whittaker *et al.*, 2001; Hawkins *et al.*, 2003b; Evans *et al.*, 2005; Hurlbert & White, 2005; Rahbek, 2005; Hurlbert & Jetz, 2007). To assess this, we chose checklists for sites ranging in area from 100 to 10,000 km². We also investigate the effects of area and habitat heterogeneity in our analyses. Furthermore, we split the data into two groups according to the area sampled (100–1000

and 1000–10,000 km²) to examine possible effects of grain size.

We examine four factors that have been widely related to species richness: three environmental factors, namely (1) energy, i.e. temperature and productive energy (following Hawkins *et al.*, 2003b; see also Mittelbach *et al.*, 2001; Evans *et al.*, 2005), (2) water, i.e. precipitation and water balance, and (3) habitat type, i.e. the kind of biome (*sensu lato*) where the mammal assemblages occur; and a proxy for long-standing historical differences between locations, namely (4) biogeographic region (see, for example, Huston, 1999; Ricklefs, 2004; Hawkins *et al.*, 2005). Since these factors are collinear (e.g. Hawkins *et al.*, 2003b), we used variation partitioning (see Legendre & Legendre, 1998; Lobo *et al.*, 2001) to separate their joint and independent effects.

DATA AND METHODS

Data

A data base of checklists of continental non-volant mammal species (i.e. all orders except Chiroptera, Cetacea, and Pinnipedia) was used to calculate species richness in 311 localities distributed worldwide (see the data base description in Rodríguez, 1999; and examples of its application in Nieto *et al.*, 2005 and Rodríguez *et al.*, 2006). For this analysis we selected the 224 sites ranging from 100 to 10,000 km² in area. These sites were further divided into two groups: 119 sites ranging from 100 km² to 1000 km², and 105 sites ranging from 1000 km² to 10,000 km² (Fig. 1; Appendix S1 in the Supplementary Material). Analyses were conducted in all sites combined, and for small and large sites separately. Although the geographic coverage of the localities has gaps (see Fig. 1), most of the world's environmental and species-richness gradients are included within these data.

Area (*Ar*), spatial location (central latitude and longitude), and the shape of each site were obtained from the original sources or digitized from information available on the internet. We used four variables to account for topographic and landscape heterogeneity within each site: altitude range (*Altrng*), mean slope (*Slopemed*), aspect variability (the standard deviation of the aspects; *AspectSD*), and land-cover diversity (i.e. the number of different land-cover categories; *GLC_DIV*). Topographic variables were calculated from a global Digital Elevation Model at 1-km² resolution (Clark Labs, 2000), and the number of land-cover categories was obtained using the Global Land Cover 2000 data base at 1-km² resolution (European Commission, 2003).

Environmental factors (*Env*) were obtained from available worldwide coverage sources, re-sampled at 0.5° grain in a GIS (*IDRISI 3z*; Clark Labs, 2001). Climatic variables were obtained from the United Nations Environmental Programme GRID data set (Deichmann & Eklundh, 1991; GRID data base available at <http://www.grid.unep.ch/>).

Five annual variables were used to measure energy (*Eg*): actual evapotranspiration (AET) and potential evapotranspi-

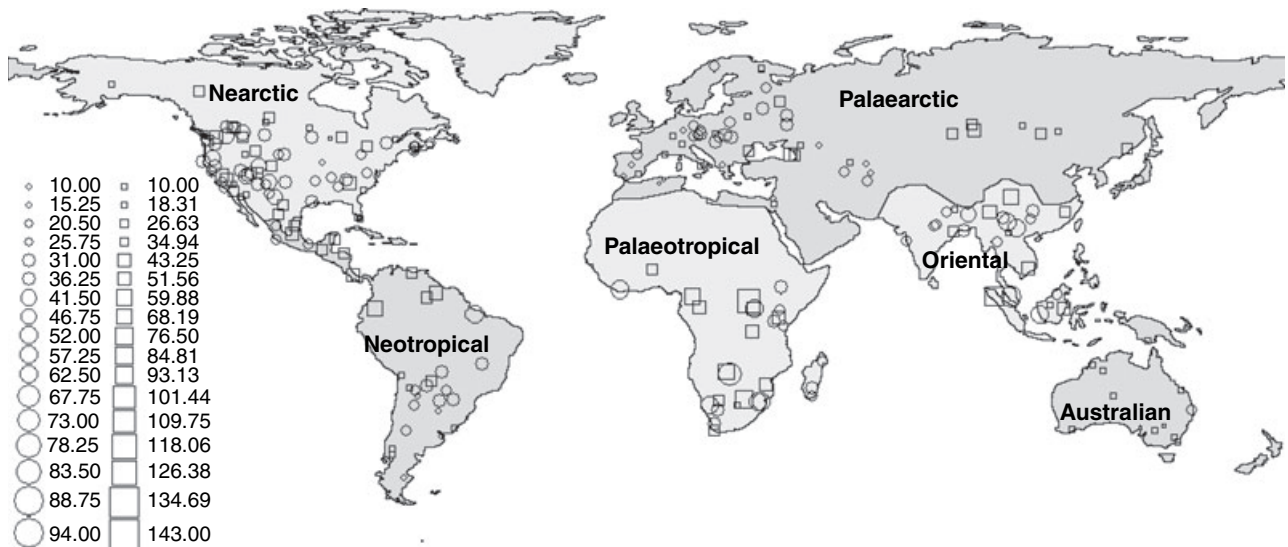


Figure 1 The geographical location of the 224 sites used for the analyses. Circles represent small sites (areas ranging from 100 to 1000 km²) and squares represent large sites (from 1000 to 10,000 km²); the size of the symbol indicates the site richness. The biogeographical regions used in the analyses have been adapted from the mammal zoogeographic regions proposed by Cox (2001).

ration (PET) [both calculated in millimetres through a combination of the Priestley-Taylor and Thornwaite methods (Ahn & Tateishi, 1994)], and mean, maximum and minimum monthly temperatures (TMEAN, TMAX and TMIN) (from Leemans & Cramer, 1991). AET is equivalent to energy when precipitation exceeds PET, and equivalent to precipitation when PET exceeds precipitation. It can therefore be considered either as an indirect measure of water balance or as a surrogate for net primary production. Hence, for animals AET can be regarded as a measure of available energy, in the sense of the general availability of plant food. Therefore, although AET does not represent the thermal energy regime, we have included it within the energy components instead of within the water measures because it can represent one component of the energy regime for mammals (see discussion in O'Brien, 1998, 2006; Andrews & O'Brien, 2000; Whittaker & Field, 2000).

Water (*Wt*) was measured using six variables accounting for precipitation and water balance: monthly precipitation (Leemans & Cramer, 1991) was transformed into five variables, namely mean annual precipitation (PMEAN), and winter, spring, summer and autumn precipitation (PWTR, PSPR, PSUM and PFALL, respectively); and water balance (WBL), a measure of the deficit or surplus of available water derived from AET, precipitation and soil water-holding capacity, was obtained from the GRID data set (Ahn & Tateishi, 1994).

Habitat type (*Hb*) (i.e. the general biome type within which the localities are placed; see Bailey, 1989/1993) was measured using Bailey Divisions (BECDIV, a multinomial qualitative variable), extracted from the World Ecoregions map (Bailey Ecoregions of the Continents, available at <http://www.ngdc.noaa.gov/>; see Bailey, 1989/1993).

Finally, to account for regional effects (*Rg*), we used the biogeographical realm in which each site is located (BgReg) (Fig. 1; realm limits as in Cox, 2001). As biogeographical

realms/regions were designed to account for major divisions in mammal faunas, all species present in each realm are assumed to constitute the region's species pool, which, to some extent, is common to all localities of the region.

Statistical analyses

Mammal species richness (*S*) was analysed with respect to the environmental and regional variables. All predictors were modelled separately using generalized linear models (GLMs), in which the variability explained by the model is estimated from the change in deviance from a null model and statistical significance measured by an *F*-ratio test (McCullagh & Nelder, 1989). A Poisson distribution was assumed for richness (see Dobson, 1999), and was related to the explanatory variables by a logarithmic link function. The cubic, quadratic or linear function of each continuous variable was selected in order to account for curvilinear relationships. Since the autocorrelation in the data might affect this selection, we used a restrictive approach to the inclusion of these high-order terms, using a mixed forward-backward stepwise analysis, in which the term was selected if it produced a significant change in deviance from the former model (calculated as above) and if the parameters of the resulting model were significant (stable) according to the Wald statistic (StatSoft Inc., 2003).

Variation partitioning

Partial regression analyses (Borcard *et al.*, 1992; Legendre, 1993; Legendre & Legendre, 1998; Lobo *et al.*, 2001) were used to identify the relative statistical effect on local species richness of the regional factors and the environmental factors identified by the GLMs. Here, each predictor is regressed against other predictors, and the residuals of these regressions are used to

produce 'residual models' (see Appendix S3). Environmental and geographic variables are often mutually non-independent and usually show the same autocorrelated pattern (Miller, 2004), making it difficult to discriminate their isolated influence. The estimation of these residual models helps to elaborate hypotheses on the independent influences of each factor. Positive values in the shared variability of factors indicate collinear variation, whereas negative values indicate probable synergistic effects (i.e. a function of the two factors together is able to explain more than the sum of the separate functions of these two factors; see Legendre & Legendre, 1998). Although using partial regression (i.e. using the residuals of regressing predictors against some of the other explanatory variables as new predictors) could lead to biased parameter estimates, it allows estimation of the magnitude of the independent effects of factors (see Freckleton, 2002).

Two partial regression analyses were performed. First, the magnitude of the effects of all environmental factors and the effect of region were examined. Here, variation in species richness is partitioned into four fractions: two account for the independent effects of environment and region, one accounts for the collinear variation of both sets of factors, and a fourth is for the unexplained variation (see, for example, Hawkins *et al.*, 2003a; Nieto *et al.*, 2005). In the second analysis, region, water and energy were analysed in concert to partition their effects. Here, variation in species richness is broken down into eight components: three account for the pure effects of each predictor variable, four quantify their shared variation, both by pairs and by all three combined, and the eighth accounts for unexplained variation (see Lobo *et al.*, 2001 and Appendix S3).

Additional analyses

Model predictions and residuals of environmental and regional factors are shown on a global scale using interpolated maps (generated with the simple-mean mobile techniques in IDRISI 32). The maps are used only as spatial representations of the geographical richness patterns in local mammal communities.

Spatial autocorrelation

To evaluate the ability of our statistical models to account for the spatial structure of species richness, we followed Diniz-Filho *et al.* (2003). First, we generated correlograms of the residuals of the environmental and regional models, as well as of the residuals obtained after adding region to the environmental model. The correlograms identified region-dependent spatially structured effects by identifying the spatial structure remaining unexplained in each model (i.e. the autocorrelation remaining in the residuals). These analyses were undertaken using SAM (Rangel *et al.*, 2006).

RESULTS

Region had a significant effect on richness across all localities. The Palaeotropical and Oriental regions had the richest

localities (60.5 and 47 median richness, respectively), Nearctic, Neotropical and Palaearctic sites were similar in richness (41, 38 and 34.5 median species, respectively), and Australian localities were much less rich (28 median species) (Fig. 2).

Area accounted for small, although significant, amounts of the variance, especially in larger sites (Fig. 3; Appendix S2). However, its effect was independent from the rest of the factors (not shown), so we did not include it in the partial regressions. The heterogeneity models also had very low explanatory power (usually non-significant; see Fig. 3 and Appendix S2), so they too were excluded from further analyses.

In contrast, water, energy, habitat type and region explained significant amounts of variation in species richness (Fig. 3 and Appendix S2). In general, the variation explained by single factors was greater in large sites, although the general pattern was consistent across scales; the three environmental factors and region were of similar importance when studied separately (between 20% and 30% of total variability except for larger sites, where the variation by these factors was always higher than 30%). The three environmental factors together explained more variation in richness, from 41% in the subset of small sites, to 59% in the subset of large sites, although the addition of regional effects to the environmental functions increased the explained deviance in all three data sets (Fig. 3). In spite of the generally better fit for the large-sites subset, the strongest model was that for the small sites (76% of explained variability), probably as a result of the increased importance of habitat type and its overlap with region at this grain size (see below). The inclusion of area or heterogeneity in these models did not significantly increase explained variability (not shown).

The structure of the partial regressions varied depending on the size of the areas (Fig. 4; Appendix S3). Across all sites, the region-independent environmental factors represented the greatest fraction of explained variation, whereas region and the overlap between region and environment explained

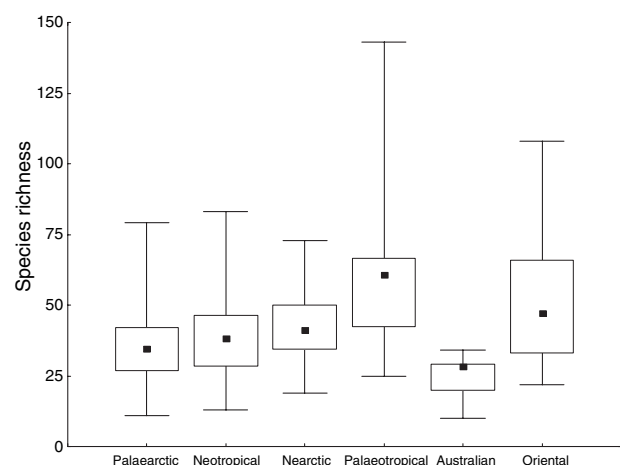


Figure 2 Differences in species richness between biogeographical regions. The central points are the median, boxes are the first and third quartiles, and whiskers are minimum and maximum values.

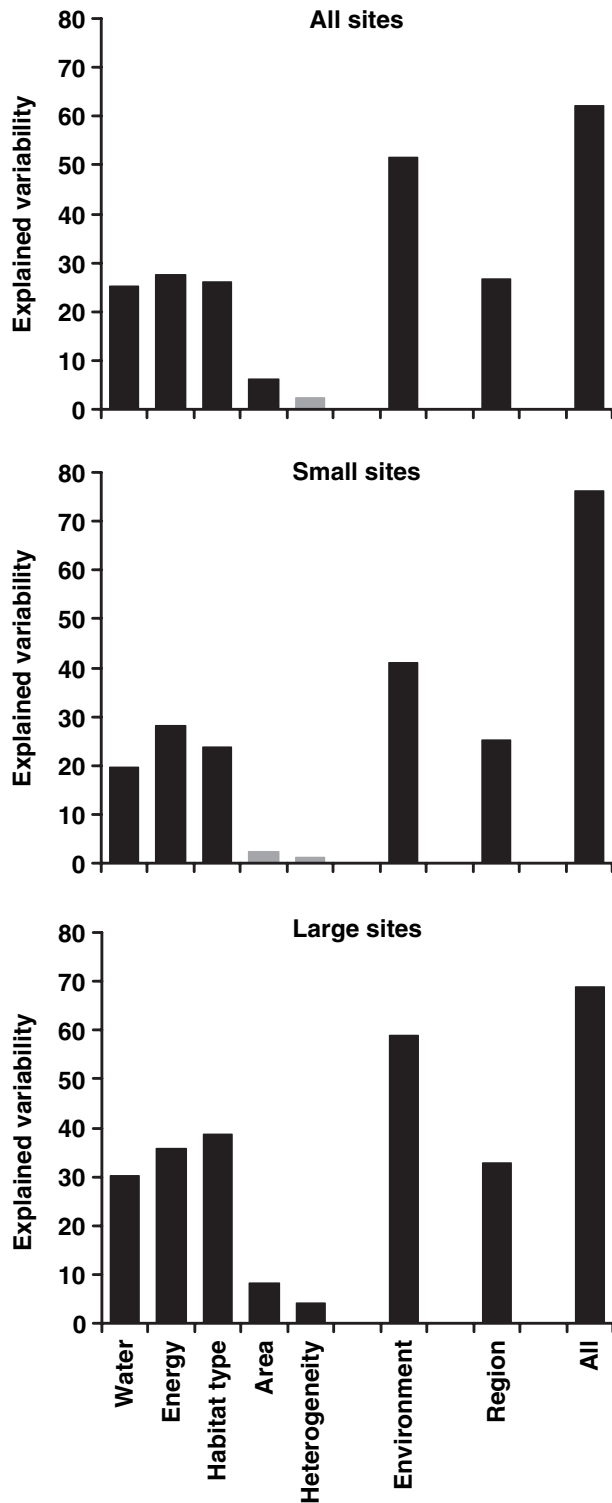


Figure 3 Variation in mammal species richness explained by GLMs; the columns to the left correspond to the models of the three environmental factors (water, energy and habitat type), and of the area and landscape/topographic heterogeneity; Environment represents a model of water, energy and habitat type, and All is a model including these factors and Region. Small sites have areas between 100 and 1000 km², and large sites have areas between 1000 km² and 10,000 km². Grey bars indicate non-significant factors. GLM results are listed in Appendix S2.

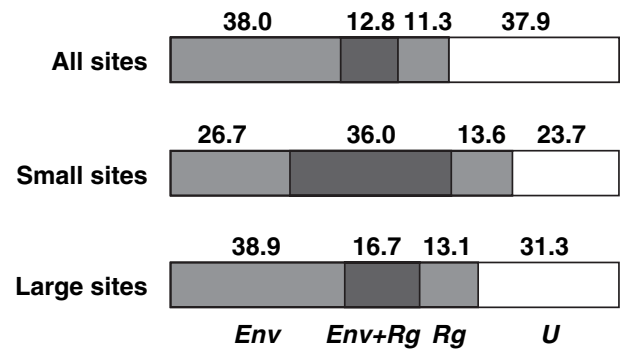


Figure 4 Variation partitioning of mammal species richness into the independent effects of Environmental (*Env*) and Regional (*Rg*) factors, as well as into their overlap (*Env+Rg*) (see Appendix S3). *U* is the unexplained variation. Small sites have areas between 100 and 1000 km², and large sites have areas between 1000 and 10,000 km². GLM results are listed in Appendix S3.

substantially less variation (Fig. 4). The model of the large sites was very similar. However, in small sites the overlap between region and environment was much stronger, with a smaller independent effect of environment. Interestingly, the independent effect of region was very similar in all analyses (Fig. 4).

The residual model based only on environmental variables underpredicted the richness of the Palaeotropical realm, as well as that of some areas of tropical South America and Malaysia, although the level of underprediction was less in the large-sites data set (Fig. 5). This model overpredicted richness in Australia, and to a lesser extent that in some parts of the Mediterranean basin and southern South America. The residual model based on region (independent from the environment) showed within-region differences in richness (Fig. 5). Richness was underpredicted in sub-Saharan Africa, in tropical America, in the Rocky Mountains, and in south-eastern Asia (including central China). Underpredictions also appeared in northern Africa and in Australia, especially when all sites were considered together (Fig. 5).

The environmental models removed almost all significant spatial autocorrelation in the all-sites and small-sites data sets, although some residual autocorrelation remained in the small-sites data at both short and long distances (Fig. 6). The inclusion of region in the models eliminated all remaining residual spatial structure in all three data sets. Interestingly, the spatial structure of the residuals from the regional models was quite similar to the structure of the models of environment and region (although with higher Moran's *I* coefficients in some distance lags), and significantly smaller than the structure remaining in the residuals of the environmental models in all three data sets (not shown).

The importance of water, energy and region in the partial regressions also varied with the size of the areas considered (Fig. 7). The variability in species richness explained by water and energy variables was greater in large sites, or when all the areas were considered. In these cases, energy explained the largest independent fraction of the variation (*c.* 20%). Region explained a similar amount of richness variance to previous

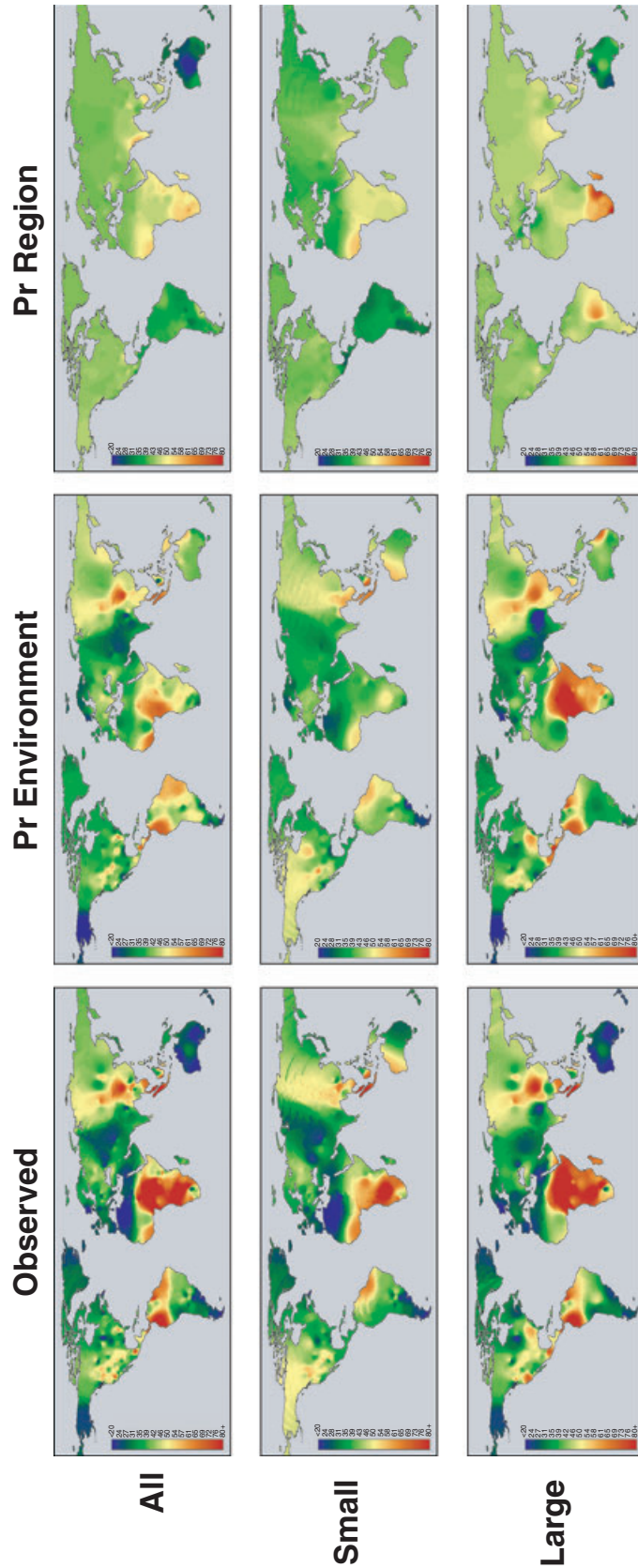


Figure 5 Spatial representation of the results of Environmental and Regional models for three sets of sites: all areas (upper row), small areas (central row) and large areas (lower row). The left column (Observed) shows maps of the observed richness of non-volant mammal richness interpolated from the original data (see Appendix S1). Maps in the central column (Pr Environment) show the richness predicted by the independent effect of Environmental factors (raw *Env*; see Fig. 4 and Appendix S3). The right column (Pr Region) shows maps of the environment-independent relationship between richness and region (raw *Rg*; see Fig. 4 and Appendix S3). All maps were spatially interpolated from the results of the original data points for representation purposes, using a mobile mean procedure (Clark Labs, 2001). Richness values (the number of species per locality) are grouped in equal intervals that vary from blue (fewer species) to red (more species); all maps have the same richness scaling to allow direct comparison.

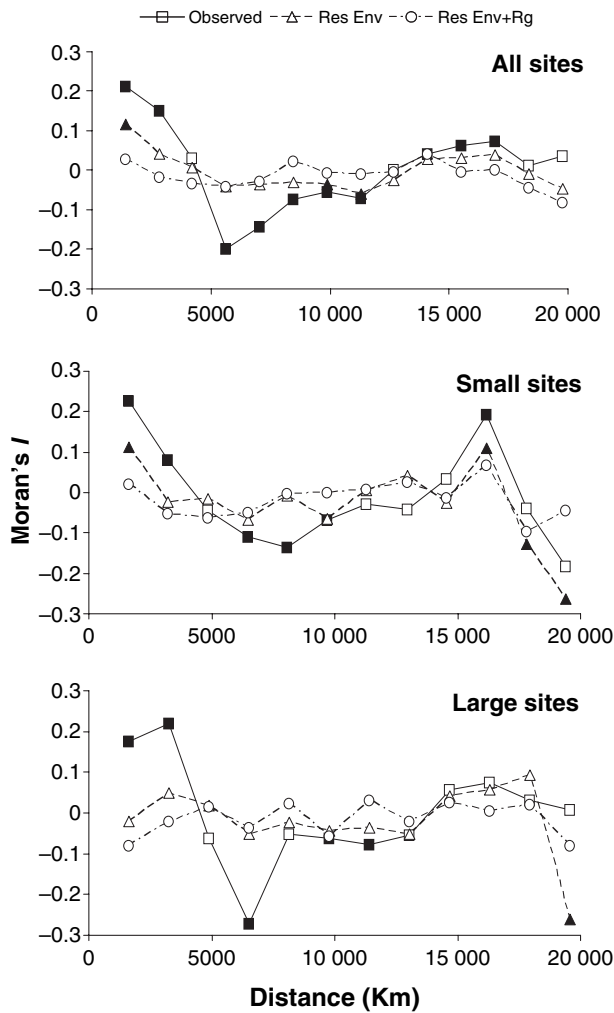


Figure 6 Correlograms for the raw richness data (Observed), for the residuals of the model built from environmental variables (Res Env), and for the residuals of the model of environmental and regional variables combined (Res Env+Rg). Significant Moran's *I* scores are marked as filled symbols. The correlograms for the residuals of the regional models are not shown because of their high overlap with the correlograms of the Environmental+Regional models (see text).

models, this amount of variance being also similar in the three data sets. However, the overlaps between region and water-energy variables varied with the scale of analysis in an opposite direction to the overlaps in the region versus environment analyses; their overlaps were greater in large sites, where both kinds of variables account for 25% of total variability (Fig. 7).

The variability explained by the overlap between region and environment in the small-sites data set varied widely between the two partition analyses; whereas this overlap explained more than a third of the variation in the general analysis (Fig. 4), the sum of the overlaps of region with water and energy was much smaller (Fig. 7). Because of this, the overlap between regional and all environmental effects could be attributed almost exclusively to habitat type (the only factor not included in the

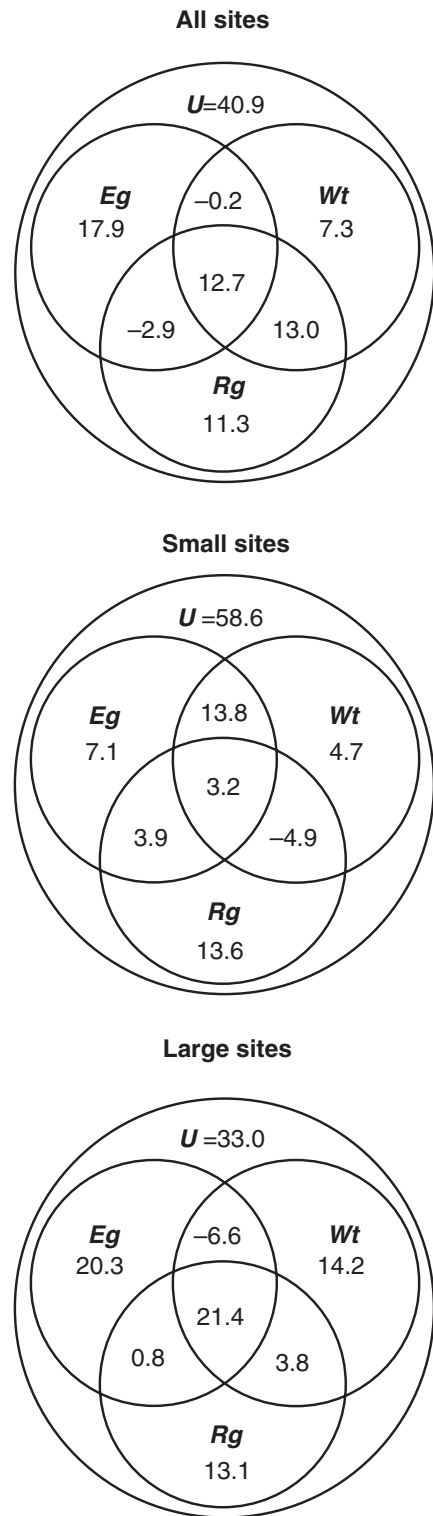


Figure 7 Variation partitioning of mammal species richness into the independent effects of Energy (*Eg*), Water (*Wt*) and Regional (*Rg*) factors, and their overlaps (see Appendix S3). *U* is the unexplained variation. Negative values indicate synergy, i.e. the combined effect of both groups of variables explains species richness better than the sum of individual effects. Small sites have areas between 100 and 1000 km², and large sites have areas between 1000 km² and 10,000 km². GLM results are listed in Appendix S3.

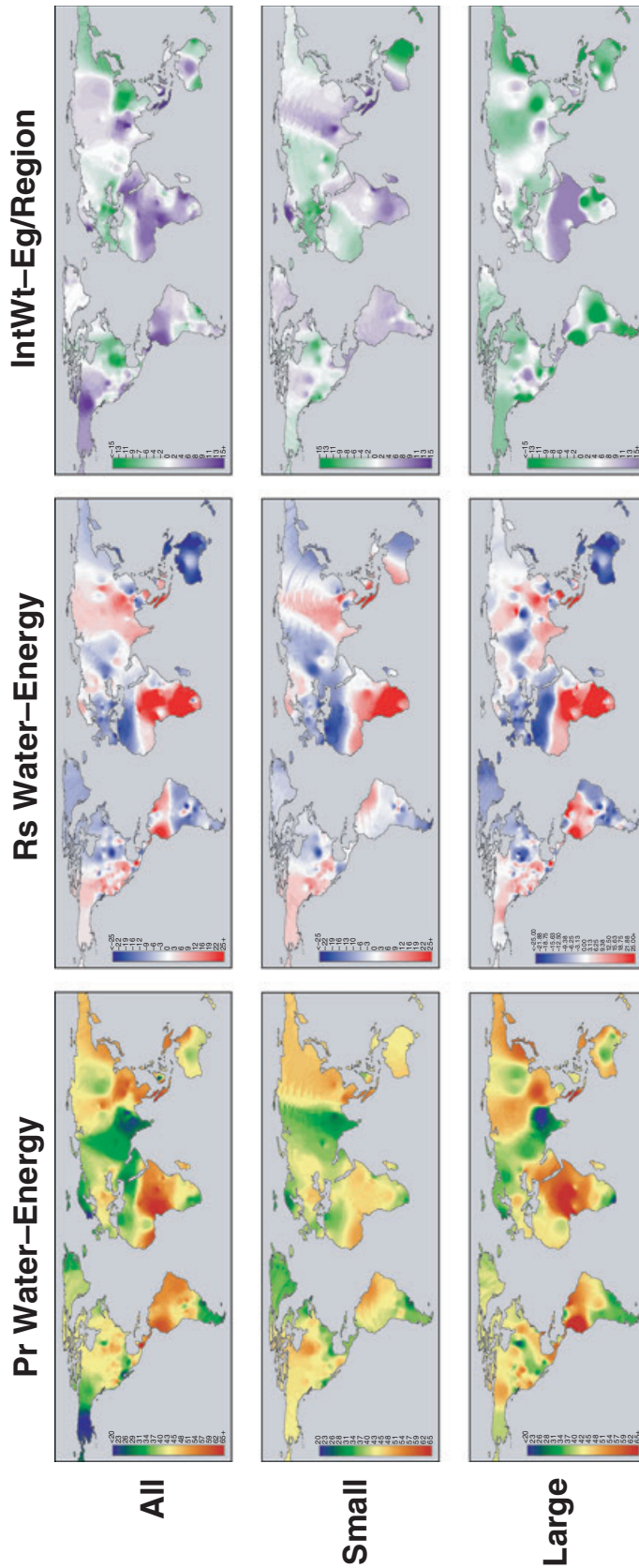


Figure 8 Spatial representation of the results of water and energy models, and of their overlap with region. The maps in the left column (Pr Water–Energy) show the relationships between species richness and the region-independent fractions of energy and water variables (see Fig. 6 and Appendix S3); colour scaling is similar to that used in Fig. 5. The central column (Rs Water–Energy) shows the residuals of models of the region-independent fractions of water and energy variables (raw Eg plus raw Wt; see Fig. 6 and Appendix S3); colours identify areas where the number of species is overpredicted (blue) or underpredicted (red) (i.e. blue areas are where there are fewer species than expected by water–energy effects, and red areas are where there are more species than expected). Maps in the right-hand column (Int Wt–Eg/Region) show the richness predicted solely by the overlap between energy and water, and region (Eg+Rg, Wt+Rg, and Eg+Wt+Rg; see Fig. 7 and Appendix S3); positive (green) and negative (purple) areas are located where regional differences in water–energy predict more species than expected by the global trend, whereas green areas identify areas where these regional differences result in fewer species than expected). These values were calculated by subtracting the predictions of the Eg and Wt predictors independent from Rg, and the predictions of Rg independent from Eg and Wt, from the predictions of a model of the three factors altogether. All maps were interpolated using the same technique as for those presented in Fig. 5.

water–energy analyses), as the amount of variation non-overlapping with region was similar when either all environmental variables (Fig. 4) or only water and energy correlates (Fig. 7) were included in the analyses (*c.* 26%). Shared effects of habitat type and region on species richness at small sites appeared to be synergistic, as their shared variance was greater than the single effect of habitat type (36 vs. 24%; see Fig. 4 and Table S2.2 in Appendix S2).

Water–energy models for the three data sets predicted high species richness in tropical areas, especially towards the south, and low richness in the Holarctic, southern South America, the Transvaal region at South Africa, and some parts of central and southern Australia (Fig. 8). These predicted gradients were weaker in the small sites than in the large sites or in all sites combined. When the residual models of water and energy (which depict the relationships with these variables that are independent from the region) were considered, they under-predicted richness in most tropical areas, overpredicting especially in the north, east and west of Australia, although less so in the small-sites data set (Fig. 8). When the overlap between water–energy and region (which identifies differences between regions in the water–energy relationship with richness) was mapped, it showed a positive effect (increasing richness) in the Palaeotropics, and a negative effect in Australia and the western coast of Northern Africa (Fig. 8, right column). Whereas these shared effects increase the richness of small localities in South America, they also decrease the modelled number of species in larger localities.

DISCUSSION

We found that more than 60% of the variation in non-volant mammal species richness of a large set of globally scattered localities was accounted for by environment (including water, energy and habitat) and region. Thus, mammal richness patterns, even when derived from actual presence data gathered from checklists of natural areas, show strong deterministic structure, although the nature of this structure varies across scales.

Environmental effects and scale dependence

The environmental factors affecting biodiversity patterns are presumed to be essentially climatic gradients (Currie, 1991); species richness is usually related to the availability of both water and energy (water–energy dynamics; see O'Brien, 1998, 2006; Andrews & O'Brien, 2000; Whittaker & Field, 2000; Hawkins *et al.*, 2003b; Whittaker *et al.*, 2007). Since the geographic patterns of these factors are often collinear, separating the specific effects of energy and water on richness is difficult (see, for example, H-Acevedo & Currie, 2003). Here, we use an analytical approach that partitions the variability explained by these correlates into the independent parts and their overlaps. Although it is impossible to separate the effects of water and energy, since life requires that both are suitable, it is possible to identify partially

independent effects within the general framework of water–energy dynamics. We argue that (1) the independent effect of energy is the result of both productivity and ambient temperature (i.e. the effect of physiological restrictions to life; see Brown *et al.*, 2004) in places where water is not limiting, (2) the independent effect of water is the result of water availability in places where temperature is not limiting (i.e. the constraints imposed by the physical properties of the water to organisms, see O'Brien, 2006), and (3) the overlap of energy and water operates in places where neither of these factors is the main constraint.

The relationship between mammal richness and the various environmental factors varied according to the size of the localities analysed, both in strength and relative importance. This is consistent with the widely recognized realization that the strength of species richness correlates is contingent on the type and scale of the data (Whittaker *et al.*, 2001; van Rensburg *et al.*, 2002; Willis & Whittaker, 2002; Hurlbert & White, 2005; Hurlbert & Jetz, 2007), and that climate does not account for many local/landscape patterns of diversity (Whittaker & Field, 2000). By splitting the data into two grains we obtain a crude representation of the perspectives of diversity discussed by O'Brien (2006): large sites represent *geographic richness* (i.e. the result of the current aggregation of the distributional ranges of species in the geographic space); and small sites represent *ecological richness/diversity* (i.e. the outcome of biotic dynamics in ecological time). Our results suggest that climatic gradients (energy and water) are stronger predictors of geographic richness (i.e. in large areas), whereas other interactions partly related to the overlap of habitat type and region become more important for the ecological richness of mammal assemblages in small areas. We hypothesize that: (1) regional effects correspond to the general limitations of the evolutionary solutions (species) available, and therefore remain more or less constant regardless of the scale, although they also interact with the environmental variables most relevant at each scale (see below); (2) the frequently reported correlation between climate and species richness occurs mainly at the large scale, probably owing to the effect of climatic gradients on species ranges (see Rahbek *et al.*, 2007); and (3) habitat selection, between-species interactions and other ecological factors become increasingly important at finer scales, so the importance of water and energy as drivers of biodiversity patterns becomes less evident.

Regional differences in global determinants of species richness

Although biological relativity to water–energy dynamics (*sensu* O'Brien, 2006) clearly influences species-richness patterns at broad scales (at least for woody plants), the climate patterns driving these dynamics are not the only effects shaping diversity gradients. Strong relationships between energy, water and species richness have been extensively reported (e.g. Currie, 1991; Kerr & Packer, 1997; Francis & Currie, 1998;

O'Brien, 1998; Hawkins *et al.*, 2003b; Field *et al.*, 2005; Whittaker *et al.*, 2007). Based on this evidence, environmental factors have been claimed as the main determinants of biodiversity pattern (Francis & Currie, 1998, 2003). However, regional effects were not appropriately tested in many analyses (Qian & Ricklefs, 2004), as either: (1) their scope was reduced to a single biogeographical region (e.g. Nearctic: Currie, 1991; Neotropical: Tognelli & Kelt, 2004); or (2) species-richness estimates were standardized by the size of the regional pool (e.g. Olff *et al.*, 2002).

In our analyses, region was always a significant correlate of richness, accounting for 25–33% of the spatial structure of richness, both overlapping with environmental correlates and independently. The exact nature of the relationship between biodiversity and the environment can vary from region to region (Ricklefs *et al.*, 1999; Hawkins *et al.*, 2003b, 2007a; Qian & Ricklefs, 2004; our results). We also found that covariation between regional and environmental effects varies with scale (see above): at the larger grains region overlaps mainly with water–energy factors, whereas at the smaller grains it overlaps with habitat. However, regional effects appear not only as regional differences in the relationship between richness and environment. The independent effect of region explained a significant proportion of richness in all data sets. More importantly, the proportion of the variance was almost scale-invariant.

Regions are a crude proxy for historical processes (Hawkins *et al.*, 2003a). However, environmentally independent regional differences are not a black box for all unknown historical processes (Harrison & Cornell, 2007). Rather, regional differences arise from evolutionary differences, the effects of climate change through time, and current differences in climate, topography, and the distribution of biomes (Jetz & Rahbek, 2001; Ricklefs, 2004, 2007; Hawkins *et al.*, 2005, 2007a). Owing to the correlation between current and past climate, most of the historical signal in the diversity gradient is masked by current climate (see Hawkins *et al.*, 2007a, and references therein), making it difficult to disentangle their effects (Whittaker & Field, 2000). Our results show that, although a portion of the differences among regions cannot be separated from environmental effects, other portions are independent from these factors. We hypothesize that: (1) the overlap between region and environment is caused by the interactions between the characteristics of the species available in the regional pool and current and past climate and habitat conditions, which shape the richness–environment relationships within each region (see, for example, Hawkins *et al.*, 2003a); and (2) the independent effects of region are a consequence of the constraints of the regional species pool (i.e. the functional characteristics of clades), which limit the partitioning of ecological space within each region (see discussion in Ricklefs, 2007). Although an integration of effects operating in both ecological and evolutionary time certainly provides more powerful explanations for current richness gradients (Ricklefs, 2004; Hawkins *et al.*, 2007a), some macroevolutionary processes

operating at regional scales have a distinct effect on the richness of mammal communities.

In sum, although environmental variables are the most important correlates of mammal richness at the global scale, the inclusion of region increases the explanatory power of the models. The overlap between regional and environmental variables (Hawkins *et al.*, 2003a; our results) and the correlation between current and past climate (see, for example, Hawkins *et al.*, 2005, 2007a) demonstrate that geographic differences in species richness and community structure are linked not only to present-day environmental conditions but also to historical processes acting at evolutionary and ecological time-scales (see Hawkins *et al.*, 2005; Svenning & Skov, 2005; Rodríguez *et al.*, 2006). Although our results are restricted to terrestrial non-volant mammal assemblages, it is likely that they can be extrapolated to many other groups. The evolutionary history and *bauplan* of each group within each region imposes several constraints, which determine their regional responses (see Hawkins *et al.*, 2003b; Ricklefs, 2004; Nieto *et al.*, 2005). Variable relationships between richness and environment also appear when different groups are studied within the same region (see, for example, Hawkins *et al.*, 2007b), so different global patterns for groups with different environmental requirements and/or dispersal dynamics should also be expected (see Svenning & Skov, 2005; Whittaker *et al.*, 2007). As Ricklefs (2004, 2007) points out, the species present in a given locality are the outcome of the interactions of species distributions within the region as a whole, not only of local environmental effects. Any explanation of global diversity patterns that ignores the influence of the species pool leaves untested one determinant affecting local communities.

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SUPPLEMENTARY MATERIAL

The following supplementary material is available for this article online:

Appendix S1 Sites used for the analyses.

Appendix S2 Generalized linear model analyses.

Appendix S3 Variation partition analyses.

This material is available as part of the online article from: <http://www.blackwell-synergy.com/doi/abs/10.1111/j.1365-2699.2007.01850.x>

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BIOSKETCHES

Joaquín Hortal is interested in the factors influencing current and past biodiversity patterns, especially those affecting the assemblage and structure of communities through time, as well as evolutionary processes in a biogeographical context. He is also interested in biodiversity estimators, conservation biogeography, predictive modelling, island biogeography, and the ecology, evolution and biogeography of dung beetles.

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SUPPLEMENTARY MATERIAL

Regional and environmental effects on the species richness of mammal assemblages

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Supplementary material

Appendix S1.- Sites used for the analyses

Appendix S2.- GLM Analyses

Appendix S3.- Variation Partition Analyses

Appendix S1: Sites used for the analyses.

Codes are those in the database developed by Rodríguez (1999). Each locality represents a territory of homogeneous biome that is managed as a whole, so it can be treated as a single land unit at a global extent. Twenty-two sites from the 333 currently available in the database have been discarded due to possible errors in their inventories and/or area covered, or because they were composed of multiple biomes or land units. An additional set of 87 localities has been excluded because they were too large (area > 10,000 km²) or too small (area < 100 km²).

Area (Ar) is given in km², and geographic position (Lat and Long) in decimal degrees (negative values correspond to the southern hemisphere and the sites west of Greenwich Meridian). Regions (BgReg) follow the mammal zoogeographic regions proposed by Cox (2001) (see text and Fig. 1). *S* is the number of mammal species (excluding Chiroptera) present in each site. NP means National Park, and BR Biosphere Reserve.

| Code | Locality | Ar | Lat | Long | BgReg | S |
|------|---------------------------|------|--------|--------|----------------|----|
| 5 | Petrified forest | 379 | 35.1 | -109.5 | Nearctic | 43 |
| 8 | White sands | 582 | 32.4 | -106.2 | Nearctic | 33 |
| 10 | Zinave | 5000 | -21.15 | 33.3 | Palaeotropical | 61 |
| 11 | Rancho Acurizal | 137 | -17.45 | -57.37 | Neotropical | 42 |
| 12 | Crater Lake | 742 | 42.55 | -122.1 | Nearctic | 54 |
| 15 | Mount Rainier | 954 | 46.5 | -121.5 | Nearctic | 46 |
| 16 | Badlands NP | 982 | 43.5 | -102 | Nearctic | 47 |
| 17 | Chamela, Jalisco (Mexico) | 350 | 19.31 | -104.3 | Neotropical | 36 |
| 18 | Canyonlands | 1366 | 38.2 | -109.5 | Nearctic | 42 |
| 22 | Big Cypress | 2898 | 25.55 | -81.1 | Nearctic | 28 |
| 25 | Shenandoah | 795 | 38.3 | -78.5 | Nearctic | 38 |
| 26 | North Cascades | 2043 | 48.45 | -121.2 | Nearctic | 58 |
| 27 | Organ Pipe Cactus | 1339 | 32 | -112.5 | Nearctic | 35 |
| 33 | Dinosaur NM | 853 | 40.3 | -109 | Nearctic | 53 |
| 34 | Zion | 593 | 37.2 | -112.5 | Nearctic | 57 |
| 35 | Doñana | 773 | 37.3 | -6.35 | Palaearctic | 24 |
| 36 | Los Tuxlas | 540 | 18.25 | -95 | Neotropical | 38 |
| 39 | Kalahari Transvaal 39 | 5019 | -27 | 25.2 | Palaeotropical | 25 |
| 40 | Hardangervida | 3422 | 60.5 | 6.25 | Palaearctic | 19 |
| 42 | Transvaal 42 | 8784 | -25.15 | 27.15 | Palaeotropical | 98 |
| 45 | El Cielo | 1145 | 23.5 | -99.15 | Nearctic | 40 |
| 46 | Cedarberg 46 | 644 | -32.21 | 19.1 | Palaeotropical | 43 |
| 49 | Repetek | 346 | 38.16 | 63.13 | Palaearctic | 21 |
| 50 | Guadalupe Mountains | 349 | 31.55 | -104.5 | Nearctic | 56 |
| 52 | Mount Kenya | 718 | 0.1 | 37.19 | Palaeotropical | 40 |
| 53 | Cazorla | 1900 | 38.1 | -2.41 | Palaearctic | 23 |
| 54 | Capitol Reefs | 979 | 38.2 | -111.3 | Nearctic | 44 |
| 55 | Isle Royal | 2314 | 48 | -88.83 | Nearctic | 19 |
| 56 | Voyagers NP | 882 | 48.3 | -94 | Nearctic | 48 |
| 58 | El Malpais | 462 | 35 | -107.2 | Nearctic | 40 |
| 59 | Lassen Volcanic NP | 430 | 40.3 | -121.3 | Nearctic | 49 |
| 63 | Cercedilla/Navacerrada | 131 | 40.45 | -4.3 | Palaearctic | 28 |
| 64 | Buffalo N River | 382 | 36 | -93.1 | Nearctic | 40 |
| 66 | Rocky Mountain NP | 1067 | 40.2 | -105.4 | Nearctic | 51 |
| 69 | Krkonoše 69 | 603 | 49.4 | 15.38 | Palaearctic | 48 |
| 70 | Berezinsky | 1139 | 54.3 | 28.3 | Palaearctic | 37 |
| 71 | Bialowieza | 105 | 52.44 | 23.52 | Palaearctic | 32 |
| 72 | Karkonosze 72 | 603 | 50.22 | 15.4 | Palaearctic | 32 |
| 73 | Montes Tatra | 1236 | 49.15 | 19.56 | Palaearctic | 26 |

| Code | Locality | Ar | Lat | Long | BgReg | S |
|-------------|-------------------------------|-----------|------------|-------------|----------------|----------|
| 74 | Baikal-Barguizinsky | 2005 | 51.5 | 105.5 | Palaearctic | 33 |
| 75 | Oka Valley | 772 | 54.43 | 39.2 | Palaearctic | 48 |
| 76 | Voronezhskiyi | 388 | 52 | 39.41 | Palaearctic | 42 |
| 78 | Lago Torne | 965 | 68.25 | 19 | Palaearctic | 37 |
| 79 | Carpathian Ukraina | 578 | 48.36 | 23.55 | Palaearctic | 43 |
| 80 | Big Bend | 2832 | 29.3 | -102.3 | Nearctic | 50 |
| 81 | Sta Mónica | 607 | 34.09 | -118.77 | Nearctic | 38 |
| 82 | Redwood NP | 446 | 41.45 | -124.5 | Nearctic | 45 |
| 83 | Point Reyes National Seashore | 288 | 38.5 | -122.5 | Nearctic | 31 |
| 84 | Big South Fork | 506 | 36.3 | -84.4 | Nearctic | 41 |
| 85 | Everglades NP | 8717 | 25.22 | -80.55 | Nearctic | 33 |
| 86 | Denali | 7820 | 63.2 | -150.3 | Nearctic | 24 |
| 87 | Yosemite NP | 3081 | 37.5 | -119.3 | Nearctic | 72 |
| 88 | Glacier | 4101 | 48.37 | -113.5 | Nearctic | 54 |
| 90 | Yoshua Tree NM | 3205 | 34.9 | -116.2 | Nearctic | 31 |
| 91 | East Usambara | 900 | -4.45 | 38.2 | Palaeotropical | 39 |
| 92 | Great Smoky Mountains NP | 2109 | 35.3 | -83.3 | Nearctic | 60 |
| 93 | Sequoia & Kings Canyon | 3495 | 36.45 | -118.3 | Nearctic | 62 |
| 94 | Augabries Falls | 147 | -28.35 | 20.21 | Palaeotropical | 46 |
| 95 | Olympic NP | 3734 | 47.49 | -123.5 | Nearctic | 39 |
| 96 | Delta del Danubio | 5762 | 44.47 | 28.58 | Palaearctic | 42 |
| 98 | Trebon Basin | 700 | 49 | 14.5 | Palaearctic | 39 |
| 99 | Vosges du Nord | 1200 | 48.57 | 7.35 | Palaearctic | 31 |
| 101 | Eastern Beskid | 271 | 49.1 | 22.2 | Palaearctic | 45 |
| 102 | Spreewald | 476 | 51.53 | 13.47 | Palaearctic | 34 |
| 103 | Aggtelek | 197 | 48.3 | 20.36 | Palaearctic | 35 |
| 104 | Long point | 270 | 43.35 | -80.2 | Nearctic | 34 |
| 105 | Guatopo | 1224 | 10 | -66 | Neotropical | 40 |
| 111 | Belém | 150 | -1.27 | -48.29 | Neotropical | 64 |
| 120 | Sikhote-Alinskiy | 3402 | 45.15 | 135.12 | Palaearctic | 46 |
| 121 | Tsentr'al'no-lesnoy | 213 | 56.3 | 32.52 | Palaearctic | 46 |
| 123 | Astrakhanskiy | 668 | 46.1 | 48.38 | Palaearctic | 24 |
| 124 | Laplanskiy | 2784 | 67.37 | 32.15 | Palaearctic | 31 |
| 125 | Waterton | 526 | 49.6 | -113.5 | Nearctic | 56 |
| 128 | Kahuzi Biéga | 6000 | 2.31 | 28.45 | Palaeotropical | 143 |
| 129 | Mahale | 1613 | -6.12 | 29.4 | Palaeotropical | 63 |
| 130 | Yasuni | 6797 | 0.47 | -76.2 | Neotropical | 83 |
| 131 | Sian Ka'an | 4080 | 19.53 | -87.66 | Neotropical | 50 |
| 132 | Mlawula | 144 | -26 | 32 | Palaeotropical | 65 |
| 133 | Dja | 5260 | 3.6 | 13 | Palaeotropical | 95 |
| 134 | Gunung Palung | 900 | -1.19 | 110.24 | Oriental | 69 |
| 135 | Kanha | 940 | 22.2 | 89.39 | Oriental | 51 |
| 136 | Badghyz Zapovednik | 880 | 36 | 62 | Palaearctic | 35 |
| 140 | Wolong | 2000 | 31.5 | 102.38 | Palaearctic | 79 |
| 142 | Fujian Wuyi Shan | 1000 | 27.4 | 117.45 | Oriental | 47 |
| 143 | Prince Regent | 6338 | -15.5 | 125.25 | Australian | 20 |
| 144 | Ubsunurskaya Kotlovina | 2843 | 50.15 | 92.35 | Palaearctic | 66 |
| 147 | Fang Jing Shan) | 383 | 27.53 | 108.47 | Palaearctic | 48 |
| 149 | Cilento and Vallo di Diano | 1810 | 40.2 | 15.2 | Palaearctic | 27 |
| 150 | Kavkazskiy | 2957 | 43.47 | 40.15 | Palaearctic | 58 |
| 151 | Sokhondinskiy Zapovednik | 2110 | 49.44 | 110.58 | Palaearctic | 54 |
| 154 | Kogelberg | 1036 | -34.14 | 19 | Palaeotropical | 55 |
| 156 | Malolotjia Nature Reserve) | 180 | -26 | 31.3 | Palaeotropical | 68 |
| 157 | Kibale Forest Corridor | 560 | 0.3 | 30.2 | Palaeotropical | 65 |
| 158 | Mae Sa-Kog Ma | 421 | 18.8 | 98.52 | Oriental | 40 |
| 159 | Gunung Leuser | 7927 | 3.54 | 97.6 | Oriental | 108 |
| 160 | Manas NP | 658 | 26.53 | 90.56 | Oriental | 55 |

| Code | Locality | Ar | Lat | Long | BgReg | S |
|-------------|-----------------------------|-----------|------------|-------------|----------------|----------|
| 161 | Andringitra | 312 | -22.15 | 46.54 | Palaeotropical | 41 |
| 162 | Uluru | 1330 | -24.25 | 131 | Australian | 32 |
| 163 | Croajingolong | 1010 | -37.37 | 149.29 | Australian | 28 |
| 164 | Shoalwater and Corio Bays | 2391 | -22.57 | 150.45 | Australian | 29 |
| 165 | The Grampians | 1670 | -34.16 | 142.7 | Australian | 24 |
| 167 | Purnululu NP | 2000 | -17.29 | 128.15 | Australian | 21 |
| 169 | Aguas Emendadas | 105 | -15.34 | -46.36 | Neotropical | 42 |
| 170 | Mamili | 320 | -18.23 | 23.38 | Palaeotropical | 94 |
| 171 | Katunsky | 6953 | 49.45 | 86 | Palaearctic | 43 |
| 172 | Sierra Gorda | 3836 | 21.2 | -99.5 | Nearctic | 73 |
| 179 | Iguazú NP | 492 | -25.3 | -54.2 | Neotropical | 46 |
| 181 | Mujib (Jordan) | 205 | 31.27 | 35.48 | Palaearctic | 27 |
| 182 | Anjanaharibe-S | 321 | -14.45 | 49.2 | Palaeotropical | 32 |
| 183 | Andohahela | 760 | -24.4 | 46.44 | Palaeotropical | 37 |
| 185 | Terra Nova NP | 400 | 48.31 | -53.57 | Nearctic | 20 |
| 186 | Nahanni | 4765 | 61.35 | -125.5 | Nearctic | 40 |
| 187 | Namdapha NP | 1985 | 27.31 | 96.37 | Oriental | 58 |
| 188 | Prespa NP | 277 | 40.45 | 21.5 | Palaearctic | 28 |
| 189 | West Caprivi Game Reserve | 6371 | -17.55 | 22.37 | Palaeotropical | 89 |
| 191 | Chernye Zemli BR | 5329 | 46.13 | 43.1 | Palaearctic | 22 |
| 192 | Daurskiy BR | 2277 | 49.85 | 115.46 | Palaearctic | 36 |
| 193 | Darvinsky Zapovednik | 1127 | 58.32 | 37.48 | Palaearctic | 39 |
| 194 | Teberdinskiy BR | 5360 | 43.21 | 41.42 | Palaearctic | 41 |
| 195 | Sayano-Shushenskiy BR | 3900 | 51.9 | 91.67 | Palaearctic | 49 |
| 196 | Syunt-Khasardagh Zapovednik | 264.61 | 38.5 | 55.5 | Palaearctic | 40 |
| 197 | Amudarya Zapovednik | 485 | 41 | 61.8 | Palaearctic | 24 |
| 198 | Royal Chitwan NP | 932 | 27.29 | 84.33 | Oriental | 39 |
| 199 | Iwokrama Forest | 3700 | 4.5 | -59 | Neotropical | 75 |
| 200 | Ulu Temburong | 489 | 4.27 | 115.11 | Oriental | 35 |
| 201 | Nechisar NP | 700 | 6 | 37.54 | Palaeotropical | 46 |
| 202 | Tierra Del Fuego NP | 630 | -54.38 | -68.31 | Neotropical | 13 |
| 203 | Laguna de Pozuelos | 4000 | -22.2 | -66.48 | Neotropical | 30 |
| 204 | Lanin NP | 3790 | -39.31 | -71.29 | Neotropical | 32 |
| 205 | El Rey | 441 | -24.4 | -64.34 | Neotropical | 28 |
| 206 | Bosque Pertificado | 612 | -47.39 | -68.13 | Neotropical | 25 |
| 208 | Mergueb | 125 | 35.35 | 3.58 | Palaearctic | 11 |
| 209 | Luberon | 1796 | 43.57 | 5.25 | Palaearctic | 32 |
| 210 | Djurdjura | 356 | 36.29 | 4.8 | Palaearctic | 15 |
| 213 | Cat Tien | 2573 | 11.34 | 107.22 | Oriental | 66 |
| 214 | Xishuangbanna | 2417 | 21.47 | 101.6 | Oriental | 33 |
| 216 | Wadi Rum | 1875 | 29.58 | 35.63 | Palaearctic | 22 |
| 217 | Bayerische Wald | 133 | 48.55 | 13.23 | Palaearctic | 37 |
| 218 | Lauca | 3583 | -18.48 | -68.98 | Neotropical | 28 |
| 219 | Fitzgerald River | 3290 | -33.83 | 119.55 | Australian | 20 |
| 220 | Kosciuszko | 6255 | -36.1 | 148.28 | Australian | 28 |
| 221 | Wasur-Rawa | 4138 | -8.6 | 140.8 | Australian | 34 |
| 222 | Mapimi | 1030 | 26.67 | -103.6 | Nearctic | 41 |
| 224 | La Amistad | 6556 | 9.5 | -82.4 | Neotropical | 72 |
| 225 | Parc National Suisse | 1740 | 46.4 | 10.1 | Palaearctic | 29 |
| 226 | Urdaibai | 219 | 43.32 | -2.68 | Palaearctic | 30 |
| 227 | Yellowstone NP | 8983 | 44.58 | -110.1 | Nearctic | 52 |
| 228 | Craters of the Moon (USA) | 3400 | 43.33 | -113.1 | Nearctic | 38 |
| 229 | Great Basin | 312 | 38.95 | -114.2 | Nearctic | 50 |
| 230 | Lake Meredith | 182 | 35.61 | -101.6 | Nearctic | 50 |
| 231 | Big ticket | 391 | 30.31 | -94.19 | Nearctic | 41 |
| 232 | Wheeler NWR | 140 | 34.38 | -86.56 | Nearctic | 30 |
| 233 | Carolinian South Atlantic | 1255 | 33.25 | -79.67 | Nearctic | 32 |

| Code | Locality | Ar | Lat | Long | BgReg | S |
|-------------|-----------------------------------------|-----------|------------|-------------|---------------|----------|
| 235 | Cuyahoga | 132 | 41.17 | -91.31 | Nearctic | 27 |
| 236 | Redberry Lake | 1122 | 52.42 | -107.1 | Nearctic | 26 |
| 238 | Grasslands NP | 450 | 49.1 | -107.4 | Nearctic | 42 |
| 239 | Algonquin Provincial Park | 7725 | 45.83 | -78.7 | Nearctic | 42 |
| 240 | Cape Breton NP | 950 | 46.71 | -60.63 | Nearctic | 35 |
| 241 | Forillon NP | 240 | 48.88 | -64.35 | Nearctic | 27 |
| 242 | Fundy NP | 206 | 45.6 | -65.1 | Nearctic | 37 |
| 244 | Kejimikujik NP | 381 | 44.36 | -65.3 | Nearctic | 38 |
| 246 | Kouchibouguac NP | 235 | 45.85 | -64.95 | Nearctic | 37 |
| 247 | La Mauricie NP | 536 | 46.8 | -72.95 | Nearctic | 42 |
| 248 | Mount Arrowsmith NP | 1186 | 49.23 | -124.48 | Nearctic | 22 |
| 249 | Mount Revelstoke | 256 | 51.1 | -118.2 | Nearctic | 45 |
| 250 | Vessertal Thüringen Forest | 170 | 50.36 | 10.48 | Palaearctic | 24 |
| 252 | Pukaskwa NP | 1873 | 48.26 | -85.83 | Nearctic | 42 |
| 254 | Woodland Caribou NP | 4620 | 51 | -94.73 | Nearctic | 30 |
| 255 | Baja California | 9347 | 31.52 | -114.4 | Nearctic | 33 |
| 257 | Kootenay | 1378 | 50.95 | -115.98 | Nearctic | 47 |
| 258 | Nahuel Huapi | 3300 | -41 | -71.5 | Neotropical | 38 |
| 259 | Prince Albert | 3875 | 53.96 | -106.21 | Nearctic | 50 |
| 260 | Rio Pilcomayo | 500 | -25.7 | -58.14 | Neotropical | 47 |
| 261 | Shiga highland | 130 | 36.43 | 138.3 | Palaearctic | 31 |
| 265 | Tansa Wildlife Sanctuary | 216 | 19.14 | 73.2 | Oriental | 39 |
| 266 | Krau | 530 | 3.42 | 102.11 | Oriental | 83 |
| 269 | Montes Azules | 3310 | 16.5 | -91.1 | Neotropical | 49 |
| 271 | Sanjay | 365 | 23.77 | 81.37 | Oriental | 30 |
| 272 | Bandhavgarh | 344 | 23.39 | 80.77 | Oriental | 32 |
| 273 | Simlipal | 2750 | 21.7 | 86.35 | Oriental | 40 |
| 274 | Ñacuñán | 123 | -34.2 | -67.54 | Neotropical | 30 |
| 275 | Bañados del Este | 2000 | -33.5 | -54 | Neotropical | 24 |
| 276 | Mburucuyá | 151 | -28.5 | -58.4 | Neotropical | 21 |
| 278 | Los Alerces | 1875 | -42.15 | -71.72 | Neotropical | 16 |
| 280 | Taï NP | 350 | 5.46 | -7.35 | Palaetropical | 64 |
| 284 | Amboseli NP | 4832 | -2.39 | 37.15 | Palaetropical | 67 |
| 285 | Maolan | 213 | 25.25 | 107.93 | Oriental | 30 |
| 286 | Kaplankyr | 2828 | 41.16 | 57.1 | Palaearctic | 27 |
| 288 | Kivach Zapovednik | 109 | 62.18 | 33.53 | Palaearctic | 40 |
| 289 | Lake Manyara | 230 | -3.3 | 35.6 | Palaetropical | 50 |
| 290 | Queen Elisabeth | 2200 | 0.4 | 29.92 | Palaetropical | 60 |
| 291 | Anza-Borrego Desert State Park | 2226 | 33.23 | -116.26 | Nearctic | 48 |
| 292 | Bandelier Natl Mon | 133 | 35.79 | -106.3 | Nearctic | 57 |
| 293 | Bryce Canyon NP | 145 | 37.58 | -112.21 | Nearctic | 44 |
| 294 | Carrizo Plains Ca | 800 | 35.7 | -119.43 | Nearctic | 36 |
| 300 | Lacassine National Wildlife Refuge, | 141 | 29.86 | -92.93 | Nearctic | 24 |
| 301 | Land Between the Lakes | 188 | 36.85 | -88.6 | Nearctic | 37 |
| 302 | Lake Roosevelt National Recreation Area | 406 | 48.55 | -118.13 | Nearctic | 59 |
| 303 | Southern Appalachian | 2470 | 35.5 | -83.5 | Nearctic | 59 |
| 304 | Wind Cave NP, | 114 | 43.58 | -103.42 | Nearctic | 35 |
| 305 | Yoho NP | 1290 | 51.38 | -116.52 | Nearctic | 46 |
| 306 | Baritú NP | 724 | -22.57 | -64.8 | Neotropical | 36 |
| 308 | Reserva de la Biosfera de Mar Chiquita | 250 | -35.65 | -57.37 | Neotropical | 22 |
| 309 | Sierra de San Javier | 202 | -26.78 | -65.37 | Neotropical | 37 |
| 310 | Bentuang Karimun NP | 8000 | 1.23 | 113.33 | Oriental | 33 |
| 312 | Pendjari | 8800 | 11 | 1.5 | Palaetropical | 42 |
| 313 | Yathong | 1072 | -32.61 | 145.53 | Australian | 10 |
| 315 | Teniente Enciso NP | 400 | -21.3 | -61.66 | Neotropical | 41 |
| 316 | Defensores del Chaco NP | 7800 | -20.22 | -60.24 | Neotropical | 48 |
| 317 | Cerro Cora NP | 120 | -22.61 | -56.3 | Neotropical | 29 |

| Code | Locality | Ar | Lat | Long | BgReg | S |
|------|-------------------------------|------|--------|--------|----------------|----|
| 318 | R B Charlevoix | 5600 | 47.67 | -70.53 | Nearctic | 26 |
| 319 | Kiskunsag BR | 221 | 46.9 | 19.36 | Palaearctic | 41 |
| 321 | Changshanerhai | 797 | 25.78 | 100.14 | Oriental | 51 |
| 322 | Ailaoshan | 504 | 24.26 | 101.23 | Oriental | 66 |
| 323 | Dawuishan | 440 | 22.81 | 103.82 | Oriental | 66 |
| 324 | Parc National d'Odzala | 1100 | 0.803 | 14.88 | Palaeotropical | 62 |
| 325 | Naute Dam | 225 | -26.97 | 17.96 | Palaeotropical | 66 |
| 326 | Mount Everest (Sagarmatha) NP | 1148 | 27.93 | 86.72 | Oriental | 22 |
| 327 | Kalahari Gemsbok NP | 9591 | - | 20.365 | Palaeotropical | 56 |
| | | | | 25.676 | | |
| 329 | Lamington NP | 206 | -28.25 | 153.1 | Australian | 29 |
| 330 | Maracá Ecological Reserve | 1013 | 3.34 | -61.68 | Neotropical | 42 |
| 331 | Kutai NP | 1986 | 0.377 | 117.28 | Oriental | 60 |
| 332 | Rio Plátano | 5000 | 15.417 | -85 | Neotropical | 46 |
| 333 | Reserva de la Michilia | 420 | 23.46 | -104.3 | Nearctic | 35 |

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Appendix S2: GLM Results

Table S2.1.- GLM results for the global analyses with all sites. Deviance and change in the deviance from a null model for mammal species number (S), considering explanatory variables one by one with their respective code. The linear, quadratic or cubic functions of each variable have been selected if they accounted for a significant change in the deviance ($p < 0.05$). *Eg*, *Env* and *Rg* are the functions selected to account for all the effect on S of water-energy dynamics, environment and region respectively. *Dev* is deviance, ΔDev is the change in deviance, F is the score of the F statistic, and *Vexp* is the percentage of explained variability. *Ar* stands for area, *Altrng* for altitudinal range, *Slopemed* for the mean slope in the locality, *AspectSD* for the standard deviation of the aspects of all the 1 km² cells included within the polygon of the natural area, *GLC_DIV* for the diversity of land cover categories; *AET* and *PET* account for Actual and Potential Evapotranspiration, respectively; *TMEAN*, *TMAX* and *TMIN* stand for mean, maximum and minimum annual temperature, respectively; *PMEAN*, *PWIN*, *PSPR*, *PSUM*, *PFALL* account for annual, winter, spring, summer and autumn precipitation, respectively; *WBL* does for Water Balance, *BECDIV* for the Bayley Divisions of the Ecoregions of the World, and *BgReg* for the Biogeographic Region. See text for more details on the origin of these variables.

| <i>Variables</i> | <i>Dev</i> | <i>d.f.</i> | ΔDev | F | <i>Vexp</i> |
|----------------------------------------------------------------------------------------------------------------------------------------------------|------------|-------------|--------------|-------|-------------|
| Null model | 1397.6 | 223 | | | |
| <i>Area</i> | | | | | |
| <i>Ar</i> | 1397.6 | 222 | 89.5 | 14.21 | 6.02 |
| <i>Heterogeneity</i> | | | | | |
| <i>Altrng</i> | 1478.6 | 222 | 8.4 | 1.26 | 0.57 |
| <i>Slopemed</i> | 1480.5 | 222 | 6.6 | 0.98 | 0.44 |
| <i>AspectSD</i> | 1467.1 | 222 | 19.9 | 3.01 | 1.34 |
| <i>GLC_DIV</i> | 1452.8 | 222 | 34.3 | 5.24 | 2.30 |
| <i>Energy</i> | | | | | |
| <i>AET+AET</i> ² | 1220.9 | 221 | 266.1 | 48.17 | 17.90 |
| <i>PET</i> | 1326.2 | 222 | 160.8 | 26.92 | 10.82 |
| <i>TMEAN+TMEAN</i> ² + <i>TMEAN</i> ³ | 1372.1 | 220 | 115.0 | 18.44 | 7.73 |
| <i>TMAX+TMAX</i> ² + <i>TMAX</i> ³ | 1408.8 | 220 | 78.3 | 12.22 | 5.26 |
| <i>TMIN+TMIN</i> ² + <i>TMIN</i> ³ | 1275.5 | 220 | 211.5 | 36.48 | 14.22 |
| <i>Eg</i>: <i>AET+PET+TMEAN+TMEAN</i>²+<i>TMEAN</i>³+<i>TMAX+TMAX</i>²+<i>TMAX</i>³+<i>TMIN</i> | 1078.6 | 214 | 408.4 | 81.03 | 27.47 |
| <i>Water</i> | | | | | |
| <i>PMEAN</i> | 1361.1 | 220 | 126.0 | 20.36 | 8.47 |
| <i>PWIN</i> | 1431.8 | 220 | 55.2 | 8.49 | 3.71 |
| <i>PSPR</i> | 1309.1 | 220 | 177.9 | 29.90 | 11.97 |
| <i>PSUM+PSUM</i> ² | 1415.4 | 220 | 71.6 | 11.13 | 4.82 |
| <i>PFALL</i> | 1324.7 | 220 | 162.4 | 26.96 | 10.92 |
| <i>WBL+WBL</i> ² + <i>WBL</i> ³ | 1453.3 | 220 | 33.7 | 5.10 | 2.27 |
| <i>Wt</i>: <i>PMEAN+PSPR+PWIN+PWIN</i>²+<i>PWIN</i>³+<i>PFALL+PFALL</i>²+<i>PFALL</i>³ | 1111.7 | 215 | 375.3 | 72.58 | 25.24 |

(cont...)

(...cont)

| <i>Variables</i> | <i>Dev</i> | <i>d.f.</i> | <i>ΔDev</i> | <i>F</i> | <i>Vexp</i> |
|---------------------------------------------|------------|-------------|-------------|----------|-------------|
| Habitat type | | | | | |
| <i>Hb</i> : BECDIV | 1101.3 | 199 | 385.7 | 69.69 | 25.94 |
| Environmental model: <i>Eg+Wt+Hb</i> | 722.0 | 182 | 765.1 | 192.9 | 51.4 |
| Region | | | | | |
| <i>Rg</i> : BgReg | 1091.5 | 218 | 395.5 | 79.0 | 26.6 |
| Complete model: <i>Eg+Wt+Hb+Rg</i> | 563.9 | 177 | 923.1 | 289.7 | 62.1 |

Table S2.2.- GLM results for the global analyses with the small sites (from 100 to 1,000 km²). Presentation as in Table S2.1.

| <i>Variables</i> | <i>Dev</i> | <i>d.f.</i> | <i>ΔDev</i> | <i>F</i> | <i>Vexp</i> |
|-------------------------------------------------------------------------|------------|-------------|-------------|----------|-------------|
| Null model | 519.4 | 118 | | | |
| Area | | | | | |
| Ar | 507.7 | 117 | 11.7 | 2.69 | 2.25 |
| Heterogeneity | | | | | |
| Altrng | 511.2 | 117 | 8.2 | 1.89 | 1.59 |
| Slopemed | 512.5 | 117 | 7.0 | 1.59 | 1.34 |
| AspectSD | 512.3 | 117 | 7.1 | 1.63 | 1.37 |
| GLC_DIV | 514.0 | 117 | 5.4 | 1.23 | 1.04 |
| Energy | | | | | |
| AET | 446.5 | 117 | 72.9 | 19.12 | 14.04 |
| PET | 474.2 | 117 | 45.2 | 11.15 | 8.70 |
| TMEAN+TMEAN ² | 478.2 | 116 | 41.3 | 10.01 | 7.95 |
| TMAX | 519.4 | 117 | 0.1 | 0.01 | 0.01 |
| TMIN+TMIN ² | 451.6 | 116 | 67.8 | 17.41 | 13.05 |
| <i>Eg</i> : AET+PET+TMEAN+TMEAN ² +TMAX+TMIN | 374.0 | 112 | 145.4 | 43.55 | 28.00 |
| Water | | | | | |
| PMEAN | 503.4 | 117 | 16.0 | 3.72 | 3.08 |
| PWIN+PWIN ² +PWIN ³ | 453.5 | 115 | 65.9 | 16.71 | 12.69 |
| PSPR | 500.9 | 117 | 18.5 | 4.33 | 3.57 |
| PSUM | 503.2 | 117 | 16.3 | 3.78 | 3.13 |
| PFALL | 501.0 | 117 | 18.5 | 4.31 | 3.56 |
| WBL | 516.8 | 117 | 2.7 | 0.61 | 0.52 |
| <i>Wt</i> : PWIN+PWIN ² +PWIN ³ + PSPR+PSUM+PFALL | 416.9 | 112 | 102.5 | 27.54 | 19.73 |
| Habitat type | | | | | |
| <i>Hb</i> : BECDIV | 395.6 | 96 | 123.8 | 30.05 | 23.84 |
| Environmental model: <i>Eg+Wt+Hb</i> | 305.8 | 86 | 213.6 | 60.1 | 41.1 |
| Region | | | | | |
| <i>Rg</i> : BgReg | 388.7 | 113 | 130.7 | 37.99 | 25.16 |
| Complete model: <i>Eg+Wt+Hb+Rg</i> | 123.2 | 56 | 396.3 | 180.2 | 76.3 |

Table S2.3.- GLM results for the global analyses with the large sites (from 1,000 to 10,000 km²). Presentation as in Table S2.1.

| <i>Variables</i> | <i>Dev</i> | <i>d.f.</i> | <i>ΔDev</i> | <i>F</i> | <i>Vexp</i> |
|---------------------------------------------------------------------------------------------------------------|------------|-------------|-------------|----------|-------------|
| Null model | 951.1 | 104 | | | |
| Area | | | | | |
| Ar | 872.6 | 103 | 78.5 | 9.27 | 8.25 |
| Heterogeneity | | | | | |
| Altrng | 950.2 | 103 | 0.9 | 0.09 | 0.09 |
| Slopedmed | 950.6 | 103 | 0.4 | 0.05 | 0.05 |
| AspectSD | 935.2 | 103 | 15.9 | 1.75 | 1.67 |
| GLC_DIV | 913.4 | 103 | 37.7 | 4.26 | 3.97 |
| Energy | | | | | |
| AET+AET ² +AET ³ | 828.6 | 101 | 122.5 | 14.93 | 12.88 |
| PET | 833.9 | 103 | 117.2 | 14.48 | 12.32 |
| TMEAN+TMEAN ² | 873.8 | 102 | 77.3 | 9.02 | 8.12 |
| TMAX+TMAX ² +TMAX ³ | 849.2 | 101 | 101.9 | 12.12 | 10.71 |
| TMIN +TMIN ² | 811.0 | 102 | 140.1 | 17.63 | 14.73 |
| Eg: AET+AET ² +PET+TMEAN+TMAX+TMAX ² +TMAX ³ +TMIN | 609.8 | 96 | 341.3 | 53.72 | 35.88 |
| Water | | | | | |
| PMEAN+PMEAN ² +PMEAN ³ | 864.6 | 101 | 86.5 | 10.11 | 9.10 |
| PWIN+PWIN ² | 943.7 | 102 | 7.4 | 0.79 | 0.77 |
| PSPR+PSPR ² +PSPR ³ | 804.0 | 101 | 147.1 | 18.48 | 15.47 |
| PSUM+PSUM ² +PSUM ³ | 889.8 | 101 | 61.3 | 6.96 | 6.45 |
| PFALL+PFALL ² +PFALL ³ | 842.8 | 101 | 108.3 | 12.98 | 11.39 |
| WBL | 932.8 | 103 | 18.3 | 2.02 | 1.92 |
| Wt: PMEAN+PSPR+PSUM+PSUM ² +PSUM ³ +PFALL+PFALL ² +PFALL ³ | 663.3 | 96 | 287.8 | 41.65 | 30.26 |
| Habitat type | | | | | |
| Hb: BECDIV | 583.1 | 82 | 368.0 | 51.75 | 38.69 |
| Environmental model: Eg+Wt+Hb | 390.5 | 72 | 560.6 | 103.4 | 58.9 |
| Region | | | | | |
| Rg: BgReg | 640.2 | 99 | 310.9 | 48.1 | 32.7 |
| Complete model: Eg+Wt+Hb+Rg | 297.4 | 67 | 653.7 | 147.3 | 68.7 |

Appendix S3: Variation Partition Analyses

Two different partition analyses were performed to separate the independent and shared contributions (i.e., overlaps) of, respectively, two and three different factors (i.e., environmental and regional factors, and water, energy and region). To do this, partial regressions are used to obtain variables accounting for the variation in each factor that is independent from the others; i.e., to regress each predictor (or set of predictors one by one) against the other factors involved in the analysis, and keep the residuals as a new variable (or a set of new variables) independent of these factors.

For the partition of two factors (see Fig. 4 in the text, Hawkins *et al.*, 2003, or Nieto *et al.*, 2005), each predictor is regressed against the variables pertaining to the other factor, and the residuals are kept as a new predictor. In our case, all environmental variables are regressed against a model of all regional variables (in this case, only one variable) one by one, and all variables in *Rg* are regressed against a model of all variables in *Env* (in this case, all entering in the model for environmental factors, see Appendix S2). These new explanatory variables provide the independent effects of environment and region, and the difference between the variation explained by a model using all original variables (both environmental and regional) and these two models is attributable to their shared contribution or overlap (see Tables S3.1, S3.2 and S3.3).

Table S3.1.- Variation partitioning of mammal species richness into the independent effects of Environmental (*Env*) and Regional (*Rg*) factors, as well as their overlap (*Env+Rg*) for all sites. raw *Env* and raw *Rg* are the independent effects of Environmental variables and Region, respectively. *Dev* is deviance, ΔDev is the change in deviance, *F* is the score of the *F* statistic, and *Vexp* is the percentage of explained variability; the rest of the abbreviations as in the text.

| Environmental vs Regional effects (All sites) | | <i>Dev</i> | d.f. | ΔDev | <i>F</i> | <i>Vexp</i> | |
|-----------------------------------------------|-------------------------------|----------------------|--------|--------------|----------|-------------|------|
| | null | 1487.0 | 223 | | | | |
| (a) raw <i>Env</i> | 38.0 <i>Env</i> | 722.0 | 182 | 765.1 | 192.9 | 51.4 | |
| (b) raw <i>Rg</i> | 11.3 <i>Rg</i> | 1091.5 | 218 | 395.5 | 79.0 | 26.6 | |
| Shared effect | 12.8 <i>Env+Rg</i> | 563.9 | 177 | 923.1 | 289.7 | 62.1 | |
| | [(<i>Env+Rg</i>) – (a+b)] | residuals <i>Env</i> | 922.1 | 181 | 564.9 | 110.9 | 38.0 |
| | Error [100-(<i>Env+Rg</i>)] | residuals <i>Rg</i> | 1318.7 | 217 | 168.3 | 27.7 | 11.3 |

Table S3.2.- Variation partitioning of mammal species richness into the independent effects of Environmental (*Env*) and Regional (*Rg*) factors, as well as their overlap (*Env+Rg*) for small sites (between 100 and 1,000 km²). Abbreviations are as in Table S3.1.

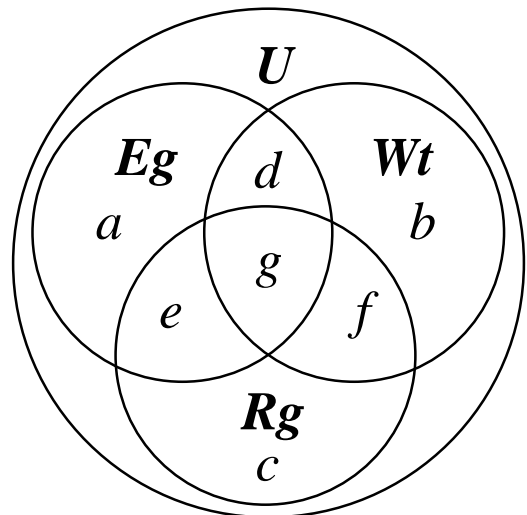
| Environmental vs Regional effects (Small sites) | | | <i>Dev</i> | d.f. | ΔDev | <i>F</i> | <i>Vexp</i> |
|-------------------------------------------------|------|----------------------|------------|------|--------------|----------|-------------|
| | | null | 519.4 | 118 | | | |
| (a) raw <i>Env</i> | 26.7 | <i>Env</i> | 305.8 | 86 | 213.6 | 60.1 | 41.1 |
| (b) raw <i>Rg</i> | 13.6 | <i>Rg</i> | 388.7 | 113 | 130.7 | 38.0 | 25.2 |
| Shared effect | 36.0 | <i>Env+Rg</i> | 123.2 | 56 | 396.3 | 180.2 | 76.3 |
| $[(Env+Rg) - (a+b)]$ | | residuals <i>Env</i> | 380.6 | 85 | 138.8 | 31.0 | 26.7 |
| Error [100-(<i>Env+Rg</i>)] | 23.7 | residuals <i>Rg</i> | 448.9 | 113 | 70.6 | 17.8 | 13.6 |

Table S3.3.- Variation partitioning of mammal species richness into the independent effects of Environmental (*Env*) and Regional (*Rg*) factors, as well as their overlap (*Env+Rg*) for large sites (between 1,000 and 10,000 km²). Abbreviations are as in Table S3.1.

| Environmental vs Regional effects (Large sites) | | | <i>Dev</i> | d.f. | ΔDev | <i>F</i> | <i>Vexp</i> |
|-------------------------------------------------|------|----------------------|------------|------|--------------|----------|-------------|
| | | null | 951.1 | 104 | | | |
| (a) raw <i>Env</i> | 38.9 | <i>Env</i> | 390.5 | 72 | 560.6 | 103.4 | 58.9 |
| (b) raw <i>Rg</i> | 13.1 | <i>Rg</i> | 640.2 | 99 | 310.9 | 48.1 | 32.7 |
| Shared effect | 16.7 | <i>Env+Rg</i> | 297.4 | 67 | 653.7 | 147.3 | 68.7 |
| $[(Env+Rg) - (a+b)]$ | | residuals <i>Env</i> | 581.1 | 71 | 370.0 | 45.2 | 38.9 |
| Error [100-(<i>Env+Rg</i>)] | 31.3 | residuals <i>Rg</i> | 826.5 | 99 | 124.6 | 14.9 | 13.1 |

For the partition of three factors, total variation is broken down into eight different components (see Venn diagram and Fig. 7 in the text):

- (i) three accounting for the pure effects on the dependent variable of each factor considered;
- (ii) four quantifying their shared variation, both by pairs and all together; and
- (iii) a final component quantifying the variation unexplained by the factors used.



To do this, five consecutive steps are needed:

Step 1) Independent models for each factor (in our case, Eg , Wt and Rg) were developed using all the statistically significant functions of their variables in a backward-stepwise selection procedure. These models are a measure of all the variability explained by each factor (the three circles in the Venn diagram).

Step 2) These models were put together to obtain the percentage of variability explained by each pair of factors (i.e., $Eg+Wt$, $Eg+Rg$ and $Wt+Rg$), and of the three factors altogether (i.e., $Eg+Wt+Rg$).

Step 3) Similarly to the two-factor analysis, each independent variable was regressed against a function of all the significant predictors included in the models of the other two factors. The residuals of such regressions constitute the variability of such a variable that is independent from the predictors included in the other factors (Borcard *et al.*, 1992).

Step 4) These residuals are used as predictors to determine the independent effect of each factor. Here, the variability explained by the models obtained in step 1 is recalculated using the residual variables obtained in step 3. Such a score is the variability in the dependent variable explained by the factor that is independent from the effect of the other two factors.

Step 5) The variability explained by the remaining fractions (i.e., the shared components, that is, the overlapping sections in the Venn diagram) is calculated by solving two sets of equations (see an example in Lobo *et al.*, 2001):

Set 5.1

$$d + e + g = Eg - a$$

$$d + f + g = Wt - b$$

$$e + f + g = Rg - c$$

Set 5.2

$$d = (Eg + Wt) - (e + f + g) - (a + b)$$

$$e = (Eg + Rg) - (d + f + g) - (a + c)$$

$$f = (Wt + Rg) - (d + e + g) - (b + c)$$

$$g = (d + e + g) - d - e = (d + f + g) - d - f = (e + f + g) - e - f$$

For example, the results for the case of all localities are shown at Table S3.4.

Table S3.4.- Variation partitioning of mammal species richness into the independent effects of Energy (*Eg*), Water (*Wt*) and Regional (*Rg*) factors, and their overlaps for all sites. Abbreviations are as in Table S3.1.

| Energy vs Water vs Regional effects (All sites) | <i>Dev</i> | d.f. | ΔDev | <i>F</i> | <i>Vexp</i> |
|-------------------------------------------------|------------|------|--------------|----------|-------------|
| <i>Eg+Wt</i> | 887.4 | 206 | 599.6 | 139.2 | 40.3 |
| <i>Eg+Rg</i> | 830.6 | 209 | 656.5 | 165.2 | 44.1 |
| <i>Wt+Rg</i> | 874.1 | 210 | 613.0 | 147.3 | 41.2 |
| Complete model (<i>Eg+Wt+Rg</i>) | 693.0 | 201 | 794.0 | 230.3 | 53.4 |
| Partial regressions | | | | | |
| res <i>Eg</i> vs. <i>Env+Rg</i> | 1221.4 | 214 | 265.6 | 46.5 | 17.9 |
| res <i>Env</i> vs. <i>Eg+Rg</i> | 1377.9 | 215 | 109.1 | 17.0 | 7.3 |
| res <i>Rg</i> vs. <i>Eg+Env</i> | 1318.7 | 217 | 168.3 | 27.7 | 11.3 |

And the two sets of equations are solved from these results (see also Fig. 5):

| | | | | |
|------------------|---------------------|---------------------|---------------------|------------------------|
| Step 1 | <u><i>Eg</i></u> | <u><i>Wt</i></u> | <u><i>Rg</i></u> | |
| | 27.47 | 25.24 | 26.60 | |
| Step 2 | <u><i>Eg+Wt</i></u> | <u><i>Eg+Rg</i></u> | <u><i>Wt+Rg</i></u> | <u><i>Eg+Wt+Rg</i></u> |
| | 40.32 | 44.15 | 41.22 | 53.4 |
| Steps 3/4 | <u><i>a</i></u> | <u><i>b</i></u> | <u><i>c</i></u> | |
| | 17.86 | 7.34 | 11.32 | |
| Step 5.1 | <u><i>d+e+g</i></u> | <u><i>d+f+g</i></u> | <u><i>e+f+g</i></u> | |
| | 9.60 | 17.90 | 15.28 | |
| Step 5.2 | <u><i>d</i></u> | <u><i>e</i></u> | <u><i>f</i></u> | <u><i>g</i></u> |
| | -0.15 | -2.94 | 12.96 | 12.70 |

The same is made for the other two sets of sites (Tables S3.5 and S3.6):

Table S3.5.- Variation partitioning of mammal species richness into the independent effects of Energy (*Eg*), Water (*Wt*) and Regional (*Rg*) factors, and their overlaps for small sites. Abbreviations are as in Table S3.1.

| Energy vs Water vs Regional effects (Small sites) | <i>Dev</i> | d.f. | ΔDev | <i>F</i> | <i>Vexp</i> |
|---------------------------------------------------|------------|------|--------------|----------|-------------|
| <i>Eg+Wt</i> | 326.4 | 106 | 193.1 | 62.7 | 37.2 |
| <i>Eg+Rg</i> | 313.8 | 107 | 205.7 | 70.1 | 39.6 |
| <i>Wt+Rg</i> | 341.3 | 107 | 178.1 | 55.8 | 34.3 |
| Complete model (<i>Eg+Wt+Rg</i>) | 279.7 | 101 | 239.7 | 86.6 | 46.2 |
| Partial regressions | | | | | |
| res <i>Eg</i> vs. <i>Env+Rg</i> | 482.7 | 113 | 36.7 | 8.6 | 7.1 |
| res <i>Env</i> vs. <i>Eg+Rg</i> | 495.0 | 112 | 24.4 | 5.5 | 4.7 |
| res <i>Rg</i> vs. <i>Eg+Env</i> | 448.9 | 113 | 70.6 | 17.8 | 13.6 |

Table S3.6.- Variation partitioning of mammal species richness into the independent effects of Energy (*Eg*), Water (*Wt*) and Regional (*Rg*) factors, and their overlaps for large sites. Abbreviations are as in Table S3.1.

| Energy vs Water vs Regional effects (Large sites) | <i>Dev</i> | d.f. | ΔDev | <i>F</i> | <i>Vexp</i> |
|---------------------------------------------------|------------|------|--------------|----------|-------------|
| <i>Eg+Wt</i> | 499.9 | 88 | 451.2 | 79.4 | 47.4 |
| <i>Eg+Rg</i> | 473.3 | 91 | 477.8 | 91.9 | 50.2 |
| <i>Wt+Rg</i> | 507.2 | 91 | 443.9 | 79.6 | 46.7 |
| Complete model (<i>Eg+Wt+Rg</i>) | 384.8 | 83 | 566.3 | 122.1 | 59.5 |
| Partial regressions | | | | | |
| res <i>Eg</i> vs. <i>Env+Rg</i> | 758.0 | 96 | 193.1 | 24.5 | 20.3 |
| res <i>Env</i> vs. <i>Eg+Rg</i> | 816.0 | 96 | 135.1 | 15.9 | 14.2 |
| res <i>Rg</i> vs. <i>Eg+Env</i> | 826.2 | 99 | 124.9 | 15.0 | 13.1 |

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