**Moss species richness along elevational gradient in a temperate semi-humid monsoon climate mountain of China**

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**Abstract**

The utility of elevational gradients as tools to test either ecological hypotheses and delineate elevation-associated environmental factors that explain the species diversity patterns is critical for moss species conservation. We examined the elevational patterns of species richness and evaluated the effects of spatial and environmental factors on moss species predicted a priori by alternative hypotheses, including mid-domain effect (MDE), habitat complexity, energy, and environment proposed to explain the variation of diversity. Last, we assessed the contribution of elevation toward explaining the heterogeneity among sampling sites.We observed the hump-shaped distribution pattern of species richness along elevational gradient. The MDE and the habitat complexity hypothesis were supported with MDE being the primary driver for richness patterns, whereas little support was found for the energy, and the environment. Moss species richness pattern in the mountain is driven by ecological and evolutionary effects, whereas evolutionary factors predominately shape the large heterogeneity through dispersal, extinction and speciation processes.

**KEYWORDS**

elevational gradient, habitat complexity, heterogeneity, mid-domain effect, moss species

**1 INTRODUCTION**

Understanding biogeographic variation in species diversity patterns is important for conservation of biological diversity (Vetaas and Grytnes 2002; Socolar *et al*. 2016). Elevational patterns of species richness, in recent decades, has received much attention in ecological and biogeographic studies (Brown 2001; McCain 2004; Stevens *et al*. 2019), given the advantages of elevational gradients, such as global ubiquity and smaller spatial scale (Rahbek 2005; Wu *et al*. 2013). Moreover, many of the world’s biodiversity hotspots are associated with montane regions, resulting in a crucial importance for biogeography, biodiversity and conservation research to understand the underlying mechanisms of montane diversity (Fjeldså *et al*. 2012). For these reasons, a growing body of research is focusing on the utility of elevational gradients as a tool for testing ecological hypotheses and uncovering the mechanisms and constraints that shape both patterns of biodiversity and the functioning of ecosystems (Rahbek 1995, 2005; Colwell and Lees 2000; Lomolino 2001; McCain 2004, 2009; Wu *et al*. 2013; Phillips *et al*. 2019) in various taxa, such as fungi (Geml *et al*. 2017), plants (Wang *et al*. 2007; Gong *et al*. 2019), insects (Brehm *et al*. 2007), small mammals (Wu *et al*. 2013), birds (Kattan and Franco 2004; Wu *et al*. 2014) and reptiles (McCain 2010).

Numerous hypotheses have been proposed to account for species richness patterns along elevational gradients, but no one currently has unequivocal support (Lomolino 2001; Sanders and Rahbek 2012; Chen *et al*. 2020). Specifically, the mid-domain effect (MDE) indicates that if species’ ranges are distributed randomly within a bounded domain, more ranges will overlap in the middle of the domain than at the edges which will produce a hump-shaped pattern of species richness (Colwell and Hurtt 1994; Colwell and Lees 2000). The energy hypothesis proposes that higher ambient energy and productivity often results in higher species diversity (Hawkins *et al*. 2003). The environment hypothesis propose that species richness patterns are generated by the climatic factors such as rainfall, temperature and water availability (Heaney 2001; Sánchez-Cordero 2001; McCain 2007). Moreover, habitat complexity has also been regarded as a potential driver of species richness (Brown 2001; Wu *et al*. 2013).

Despite its wide applications, there is still limitation of elevational richness patterns. Species are generally not homogeneously distributed along elevational gradients, and the heterogeneity in biodiversity within (α) and among (β) sampling sites cannot be revealed by the elevational richness pattern. As envisioned by the combination of additive diversity partitioning and species–area relationship, β-diversity among sampling sites may partly explained by a factor gradient (Golodets *et al*. 2011; Zajac *et al*. 2013; Gao and Perry 2016); thereby, we suggest elevational richness pattern alone cannot quantify how much of the total β-diversity is due to elevation (βelevation) and how much is due to other factors (βreplace). Moreover, the comparison of the diversity within (α) and among (β) sampling sites and the contributions made by elevation (βelevation) and other factors (βreplace) are important for strategic conservation planning. A low α-diversity with a high β-diversity suggests that species assemblages are heterogeneous and species are often endemic to individual sampling sites, while a high α-diversity with a low β-diversity indicates that species assemblages are homogenous and species within each sampling site are a subsample of the same species pool (Francisco-Ramos and Arias-González 2013). A high βelevation with a low βreplace indicates that species richness varies in a more predictable manner determined by factors that have a strong association with elevation, while a low βelevation with a high βreplace suggests that factors such as speciation, dispersal, and extinction have a greater role in influencing patterns of β-diversity (Rahbek *et al*. 2019a).

The majority of elevational richness patterns studies on flora have focused on vascular plants (e.g. Kitayama 1992; Liberman *et al*. 1996; Bhattarai and Vetaas 2003; Kessler *et al*. 2011; Nervo *et al*. 2019), although the success of land plants is apparent in the diversification of the nonvascular mosses (Bryophyta) with over 12,700 species (Crosby *et al*. 1999; Laenen *et al*. 2014), second after angiosperms (Magnoliophyta) with about 270,000 species (Soltis and Soltis 2004), and likely exceeding the ferns (Monilophyta) with about 10,000 species (Schneider *et al*. 2004; Smith *et al*. 2006). Although the origin of the lineage may be ancient, much of the radiation of mosses is relatively recent. In contrast to many vascular plants, mosses are dispersed by means of small spores and establish new populations in distant localities. They colonize almost all terrestrial habitats, exhibit less frequent speciation, and have a long evolutionary history. Because of these unique features, our aims were to: (1) depict the species richness pattern of mosses along elevational gradient, (2) evaluate the importance of four ecological hypotheses in predicting variation of moss species diversity along elevational gradient and (3) examine how much contribution that elevation made toward explaining the among-sampling heterogeneity.

**2 MATERIALS AND METHODS**

**2.1 Study area**

This study was conducted on the Mt Tuofeng (maximum elevation 2282 m). It sits within the Tuoliang National Reserve, in the middle of the Taihang Mountains in central west Hebei Province, China (38°33′–38°45′N, 113°41′–113°53′E). The study area is in the transition between warm and cold temperate zone and generally has a semi-humid semi-arid continental monsoon mountain climate with four distinct seasons, abundant sunshine, large temperature difference between day and night, moderate rainfall, and an annual average temperature of 8.0 °C.

**2.2 Sampling and species identification**

The present study was conducted along the elevational gradient of the Mt Tuofeng between 923 and 2282 m during July–September 2018 within Tuoliang National Reserve. 73 sampling sites (10 m × 10 m) were totally surveyed, and in each site, we collected all moss species from the ground to two meters above the ground. Moss specimens were taken back to the laboratory of Hebei Normal University where all species were identified from October 2018 to May 2019. Finally, the outcome of species occurrence for each sampling site was summarized in Table S1.

**2.3 Ecological variables: MDE, habitat, and climate**

We utilized the MDE model in RangeModel ver. 5 (Colwell 2006) to test the MDE. We conducted 100,000 simulations of random range placement within the bounded domain of moss species in the Mt Tuofeng as described in Box 5 of Colwell and Lees (2000). The computed mean richness and its 95% confidence interval were used to evaluate the explanatory power of the MDE on the species richness pattern. A 250-m resolution digital elevation model (DEM) was derived from the Processed SRTM Data v4.1 (Jarvis *et al*. 2008).

We applied two habitat indices, including vegetation type (VT) and community type (CT; Chen 1958, 1963) to quantify habitat complexity for each sampling site. We totally categorized six vegetation types, including coniferous forest, broad-leaved forest, bush wood, shrub grass, grass, and meadow; and four community types, including aquatic community, stone community, soil community, and woody community. We recorded the vegetation type (VT) for each sampling site and the community type (CT) occupied by each moss specimen. Last, we counted the total number of vegetation types and community types as the habitat complexity for each sampling site.

We obtained climate data from the WorldClim v2 database (Fick and Hijmans 2017) in 30-arc-second (c. 1 km2) digital maps, including solar radiation (SR), annual precipitation (AP), annual average temperature (AT), and wind speed (WS). The data extraction was implemented in ArcGIS 10.2 (ESRI, CA, USA). Finally, the summary of environmental and richness data was shown in Table S2.

**2.4 Data analyses**

We applied polynomial regressions (PRs) to estimate the relationship between species richness and elevation, guided by the corrected Akaike information criterion (AICc) value. Acknowledged that these relationships may not be linear, especially that the elevational gradient of species richness can take many shapes but most often takes a hump-shaped pattern (Rahbek *et al*. 2019b), generalized linear models (GLMs) were used to evaluate the elevational pattern for each ecological predictor, with polynomials of elevation up to the second degree. We also applied GLMs to discover the relationship between moss species richness and habitat complexity. We collected random samples from posterior distribution to estimate the 95% credible intervals for model parameters for each PR and GLM through the ARM package (Gelman and Su 2016). The elevational trends of the predictors are shown in Figure 1.

We used an information-theoretic approach (Anderson *et al*. 2000; Stephens *et al*. 2005; Chen *et al*. 2020) to evaluate the relative importance of the mid-domain effect, the habitat complexity hypothesis, the energy hypothesis, and the environment hypothesis to moss species. First, we log-transformed the seven potential drivers (MDE, VT, CT, SR, AP, AT, and WS) to obtain the normality and homoscedasticity of the data. Then, we used GLM to develop a set of candidate models based on a priori hypotheses. Owing to the complication of habitat complexity hypothesis and environment hypothesis, we establish the models that included all the possible combinations of two habitat-related factors (VT and CT) for habitat complexity theory and three environment-related factors (AP, AT, and WS) for environment theory. A null model (richness ~ 1) was added for comparison. We calculated the variance inflation factor (VIF) of each variable in these models to account for collinearity. To minimize the multicollinearity, only the models with VIFs < 10 were considered (Dormann *et al*. 2013; Chen *et al*. 2020). Finally, a set of nine candidate models were retained for further analysis (Table 1). We performed model averaging to evaluate the relative importance of each variable in shaping the elevational richness pattern (Galipaud *et al*. 2017; Chen *et al*. 2020). Last, we selected the best model through a forward stepwise selection algorithm. In the initial stage, we selected the model using a single variable with the minimum AICc. In the second stage, we then examined all two-variable models that included the variable chosen in the first step and chose the model with the minimum AICc. We then repeated the procedure for all three-variable models that included the two already selected, and so on, until AICc could not be further reduced. And this procedure was completed in the MuMIn package (Bartoń 2015).

Thereafter, we used additive diversity partitioning to quantify the heterogeneity in biodiversity by comparing the diversity within (α) and among (β) sampling sites and by comparing the contributions made by elevation (βelevation) and other factors (βreplace). In the additive approach, diversity can be explored across spatial scales (Gering and Crist 2002), and γ-diversity (regional scale) is partitioned into the sum of the average diversity of sampling sites (α) and the heterogeneity among sampling sites (β). When a species is missing from a sampling site, one reason might be that the sampling site is bearing more geometric constraints of montane topography according to the MDE. So, we used additive diversity partitioning combined with species richness pattern predicted by the MDE and quadratic polynomial regression, respectively to partition β into βelevation, which represents the average difference between α and the maximum diversity predicted by the MDE or quadratic polynomial regression (Smax) and βreplace, the average number of missing species that are not explained by elevation. Because α, β, βelevation, βreplace, and γ-diversity are measured using the same units, their relative importance can be quantified (Crist and Veech 2006). We performed all analyses using R 3.5.2 (R Development Core Team 2018).

**3 RESULTS**

**3.1 Species richness pattern**

A total of 191 moss species, belonging to 73 genera under 26 families were identified in 1301 specimens at 73 sampling sites along the elevational gradient, in which, four species (*Drummondia sinensis*, *Sanionia uncinate*, *Tayloria indica*, and *Funaria hygromexrica*) were endemic. Pottiaceae (41 species), Brachytheciaceae (35 species), Bryaceae (20 species), Entodontaceae (12 species), Hypnaceae (10 species) and Grimmiaceae (9 species) are the most common moss families taking up to 66% of the species composition (Table S3). Moss species in the Mt Tuofeng showed a hump-shaped richness pattern along the elevational gradient, with a distinct peak at 1,500 m and 1,600 m (Fig. 2). This result was confirmed by the polynomial regressions, where the quadratic polynomial regression (AICc = 540.80) with a hump-shaped pattern performed best (Fig. 3).

**3.2 Relationship between species richness and explanatory factors**

The information-theoretic statistics for the nine candidate models showed that MDE was suggested as the best model, which had an Akaike weight (*W*i) of 0.98 and explained a largest proportion of variation for moss species richness pattern (*R*2 = 0.245, *p* < .001; Table 1). Two alternative habitat-related models also provided a significant proportion of variation, one including only CT (*R*2 = 0.146, *p* < .001), and the other including CT and VT (*R*2 = 0.135, *p* < .01), but their ΔAICc exceed two. The null model (Richness ~ 1) had little support to the species richness pattern (ΔAICc = 19.33, *W*i = 0.00). The best model for our dataset was the combination of MDE and CT, which reduced the AICc from 490.16 for MDE alone to 484.32 for MDE and CT, suggesting the MDE and the habitat complexity hypothesis were supported (Table 2).

**3.3 Additive partitioning of diversity**

According to the additive diversity partitioning, α (12.79) explained only 6.7% of the variation in species richness, whereas β (178.21) explained about 93.3% of the variation in species richness (Fig. 4).

We calculated the contribution of elevation toward the variation in species richness by using MDE prediction and quadratic polynomial regression, respectively. The contribution of elevation ranged from 44.6% in the MDE prediction (Fig. 4a) to 53.3% in the quadratic polynomial regression (Fig. 4b), with an average of 49.0% toward the variation in species richness.

We also compared βelevation and βreplace through MDE prediction and quadratic polynomial regression, respectively. The proportion of βelevation to the total β ranged from 1.3% in the MDE prediction (Fig. 4a) to 3.0% in the quadratic polynomial regression (Fig. 4b), with an average of 2.2%. The proportion of βreplace to the total β was 97.8% on average, about 44 times the proportion of βelevation.

**4 DISCUSSION**

**4.1 Species richness pattern of mosses on the Mt Tuofeng**

The overall moss species richness pattern along the elevational gradient on the Mt Tuofeng is a hump-shaped pattern, peaking at mid-elevation between 1500 m and 1600 m, consistent with some studies in moss species (Grau *et al*. 2007; Wolf 1993). However, in other studies, moss species richness was found to have either no statistically significant trend (Grytnes *et al*. 2006; Sun *et al*. 2013) or an increasing trend (Bruun *et al*. 2006) with altitude. The hump-shaped richness pattern is popular in studies from around the world, but there is no consistent explanation for this pattern. Our analysis showed that the MDE and the habitat complexity hypothesis concur to the elevational moss species richness. Model selection among alternative models showed that MDE is the primary driver for richness patterns, whereas little support was found for the energy, and the environment. It is not surprising that the energy and the environment hypothesis is not supported in our data, as moss species are characterized by their poikilohydric condition and cold tolerance. The cuticle that seals the vascular plants body is often reduced or even lacking on the gametophyte of mosses, making mosses tolerant of desiccation and poikilohydric, which means that their water content is directly regulated by ambient humidity (Proctor *et al*. 2007). Moreover, a common feature among most mosses is their ability to grow at low temperature, and studies have showed that subglacial bryophytes following up to six centuries of ice entombment successfully regenerate (La Farge *et al*. 2013; Roads *et al*. 2014; Cannone *et al*. 2017). These ecophysiological features enable them to grow on rocks and tree trunks that are inhospitable for most vascular plants, thereby reducing the impact of energetic and environmental factors. The habitat complexity hypothesis was accepted because habitat diversity plays an important role in maintaining biodiversity, and the removal of habitat types will obliterate species, especially habitat specialists (Sfenthourakis and Triantis 2009). What’s more, the CT pattern along the elevational gradient on the Mt Tuofeng is also hump-shaped (Fig. 1b), implying a positive correlation between CT and moss species richness, which is proved by the GLM analysis (Fig. 5b). A possible reason for the good support of MDE in our study is the high dispersal capacity of moss species (Patiño and Vanderpoorten 2018), which makes a wide distributional range for most moss species, resulting in a high degree of overlap in the central area.

**4.2 Two pieces of evidence support the MDE**

In the tangled complexity of environmental and non-environmental factors affecting diversity gradients, new null models of the MDE helped to pare down the complexity, which is predicted where landmass boundaries such as oceans and mountaintops limit species ranges and the simple overlap of many, variously sized ranges create a peak in species richness at mid-elevation (Colwell and Hurtt 1994; Colwell and Lees 2000). In our dataset, we found three evidence conforming to the mid-domain effect. First, moss species richness peaked at mid-elevation (Fig. 2). Second, based on the edge effect or community overlap hypotheses, the greatest species richness exists in the ecotone areas of overlap between two distinct faunal communities (Lomolino 2001). However, in our case, we found moss species richness had a negative relationship with the number of occupied VT (Fig. 5a), implying the inner of a faunal community harbors the highest species richness, given the fact that the higher wind speed and lower humidity at ecotone areas are adverse to moss species survival (Liu *et al*. 2007). Therefore, our result, on the contrary, supports the MDE.

**4.3 How could elevation contribute to the heterogeneity**

Elevation contributed toward explaining the heterogeneity, likely because of two facts. On one hand, the elevational gradient could provide heterogeneous environments (Rahbek 1995; Hoorn *et al*. 2018), and different taxonomic groups survive at different elevation by selecting different physical conditions (Letten *et al*. 2013). On the other hand, the elevational gradient may enable habitat segregation among moss species. Indeed, sympatric taxonomic species sharing similar resources should demonstrate some degree of niche overlap, leading to interspecific competition (Chesson 2000; Dufour *et al*. 2015). In turn, to buffer competition and allow for coexistence, sympatric species may avoid each other in space and/or time and can generate differences in habitat selection (Holt 1987; Milleret *et al*. 2018). Both the two facts associated with elevation help to explain why species assembly varies among sampling sites, contributing the heterogeneity explained by elevation.

**4.4 Elevation had a very limited contribution toward explaining heterogeneity**

191 species have been identified in the study, with as many as 34 on the single sampling site; however, α-diversity explained only 6.7% of γ-diversity. The small α (12.79) indicates low species evenness, for the degree of species overlap varied across the elevational gradient. Elevation explained 49.0%, a medium predictive power, for the variation of species richness. Because the unique ecophysiological features of mosses make them likely independent of factors that associated with elevation (Fig. 1), such as temperature, rainfall, and humidity which usually well govern the species richness of other taxa (Heaney 2001; Sánchez-Cordero 2001; McCain 2007), thereby lowering the Smax predicted either by the MDE or quadratic polynomial regression (Fig. 4). Moreover, elevation explained 2.2%, a weak predictive power, for the heterogeneity, and this may be due to four facts. First, according to the calculation formula (βelevation = Smax - α), a lower predicted Smax will further reduce the βelevation. Second, elevation or factors highly associated with elevation cannot adequately captured the high spatial heterogeneity of ecological and environmental variables characteristic of mountains. Third, mountain regions are home to aggregations of small-ranged species which could form centers of endemism. Fourth, moss species are supposed to have a high dispersal capacity, however, the large βreplace in our study implies a high extinction rate when they colonize a new locality, as can be seen from Table S1 that many moss species appear discretely from sampling sites despite their wide distribution.

To conclude, current species richness distribution pattern may bear the signatures of ecological and evolutionary effects. To further explore the extent to which each factor shape the current pattern, we agree with Rahbek *et al*. (2019a) that geological and evolutionary approaches should be combined for an accurate reconstruction of geological dynamics and reliable inference of the timing and location of changes in effective population sizes and genetic bottlenecks.

**4.5 Applicability to biodiversity conservation**

The practical importance of these results for conservation is threefold. First, the positive relationship between species richness and community types suggests habitat diversity is essential for sustaining species diversity, so conservation of habitat diversity is the key to maintain moss species diversity in the mountain. Second, the unimodal richness pattern we detected suggests that the highest moss species richness appears at mid-elevation, however, due to the large β-diversity and very small βelevation, conservation efforts should be paid to the whole elevational range rather than the mid-elevation only. Last, species of the moss families that have a very narrow distribution along the elevational gradient such as Fabroniaceae, Funariaceae, Orthotrichaceae, and Scorpidiaceae are likely to form small-ranged endemism. And special attention should be paid to preserve these irreplaceable species according to their distribution.

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**SUPPORTING INFORMATION**

Additional Supporting Information may be found online in the supporting information tab for this article:

**Table S1.** Occurrence data for moss species along elevational gradient. In the body of the table, 1 indicates presence, 0 indicates that the species was not detected at that sampling site.

**Table S2.** Environmental variables and richness data along elevational gradient.

**Table S3.** Checklist of moss species identified in the 73 sampling sites.

**ACKNOWLEDGMENTS**

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**CONFLICT OF INTEREST**

The authors declare there are no competing interests.

**AUTHOR CONTRIBUTIONS**

DG and ZC conceived the idea and performed data analyses; DG, JS, YL, and JZ conducted the field work; JS and YL identified moss species and build the datasets; DG wrote the first version of the manuscript; and all authors contributed and approved the final version.

**DATA AVAILABILITY**

All datasets used in this study are sourced from the literature which can be found in Supporting Information.

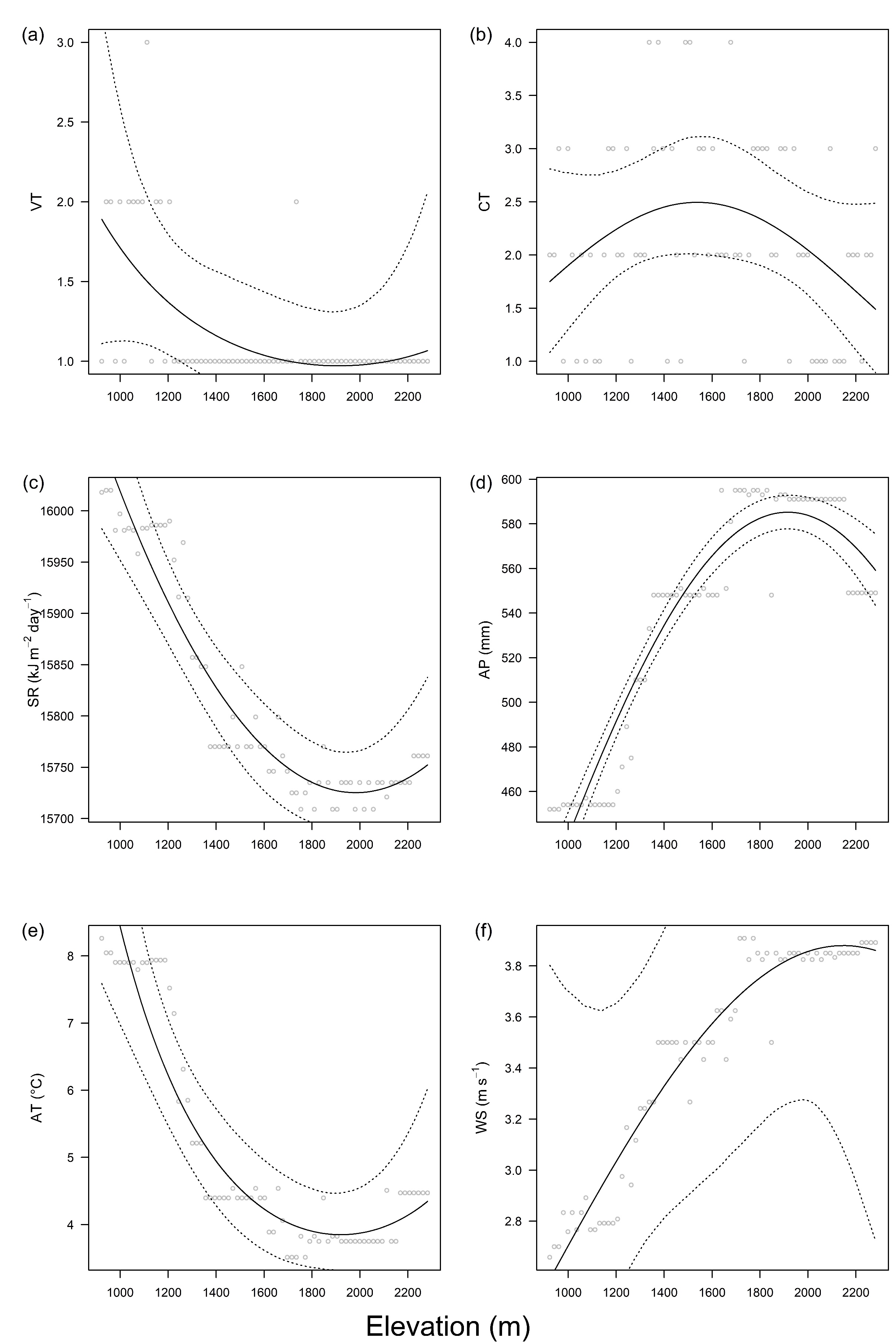
Table 1 Results of candidate models explaining variation for moss species richness pattern in the Mt Tuofeng.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Hypothesis | Model | *K*a | Adjust *R*2 | AICc | ΔAICc | AICc *W*i |
| Null model | Richness ~ 1 | 2 | n.a. | 509.49 | 19.33 | 0.00 |
| Mid-domain effect | MDE | 3 | 0.245\*\*\* | 490.16 | 0.00 | 0.98 |
| Habitat complexity | VT | 3 | -0.006 | 511.05 | 20.89 | 0.00 |
|  | CT | 3 | 0.146\*\*\* | 499.15 | 8.99 | 0.01 |
|  | CT + VT | 4 | 0.135\*\*\* | 501.28 | 11.12 | 0.00 |
| Energy | SR | 3 | -0.004 | 510.92 | 20.76 | 0.00 |
| Environment | AP | 3 | 0.005 | 510.25 | 20.09 | 0.00 |
|  | AT | 3 | 0.017 | 509.39 | 19.23 | 0.00 |
|  | WS | 3 | -0.013 | 511.57 | 21.41 | 0.00 |
| Abbreviations: MDE, the mid-domain effect; VT, vegetation type; CT, community type; SR, solar radiation; AP, annual precipitation; AT, annual average temperature; WS, wind speed.  aNumber of estimable parameters.  \*\**p* < .01, \*\*\**p* < .001. | | | | | | |

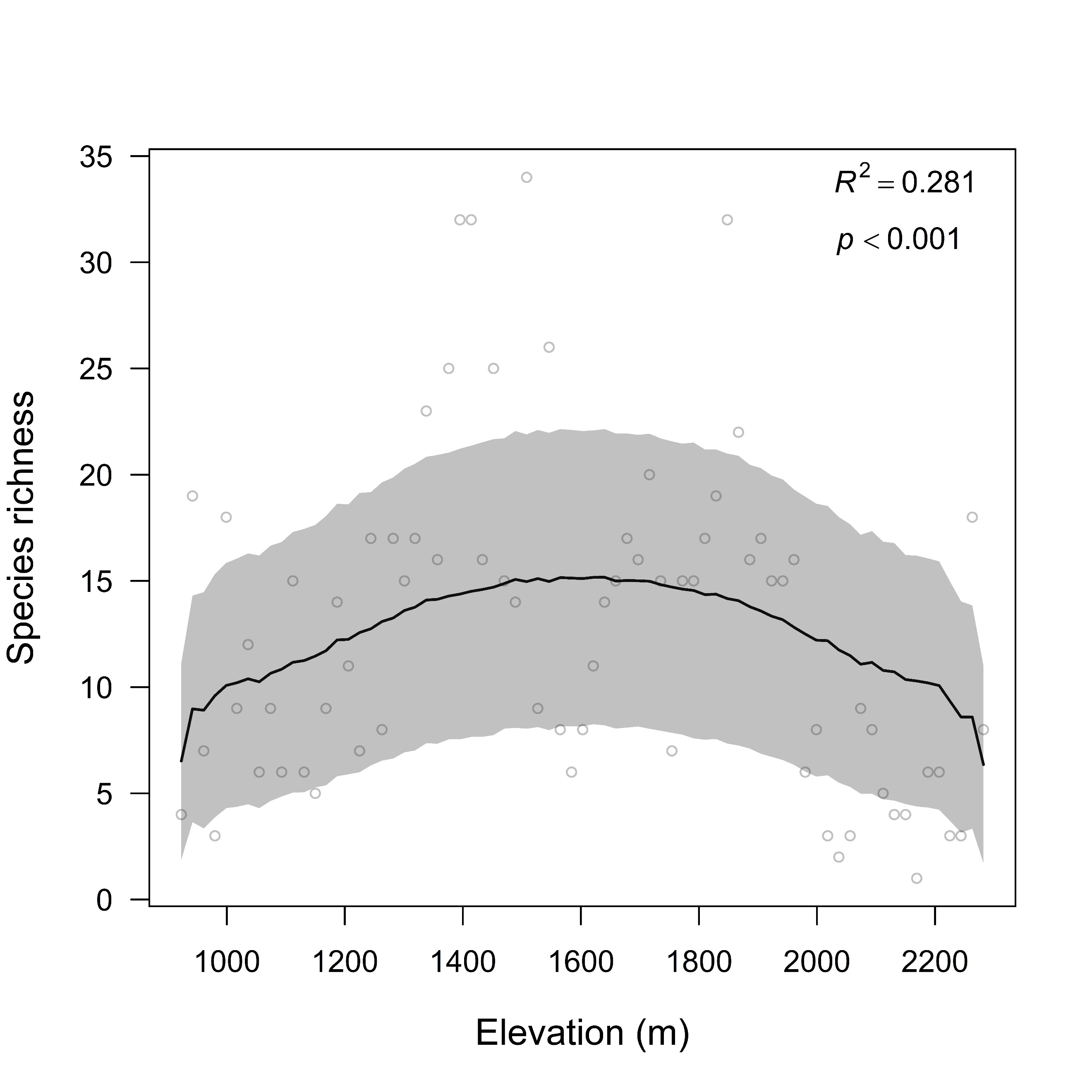
Table 2 Final model selection for candidate explanatory variables for moss species richness pattern in the Mt Tuofeng. Variables that entered each model are numbered in order of entry. Slope is the standardized partial regression slope of the variable in the final model. For the numbered variables, adjust *R*2 is the increase in total variance explained as each variable entered the model. For the final model, adjust *R*2 is the total explained variance for the final model. AICc is the corrected Akaike Information Criterion for each model.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Hypothesis | Model | Slope | Adjust *R*2 | AICc |
| Mid-domain effect | 1. MDE | 5.35 | 0.245 | 490.16 |
| Habitat complexity | 2. CT | 9.55 | 0.069 | 484.32 |
|  | Final model |  | 0.314 | 484.32 |
| Abbreviations: MDE, the mid-domain effect; CT, community type. | | | | |

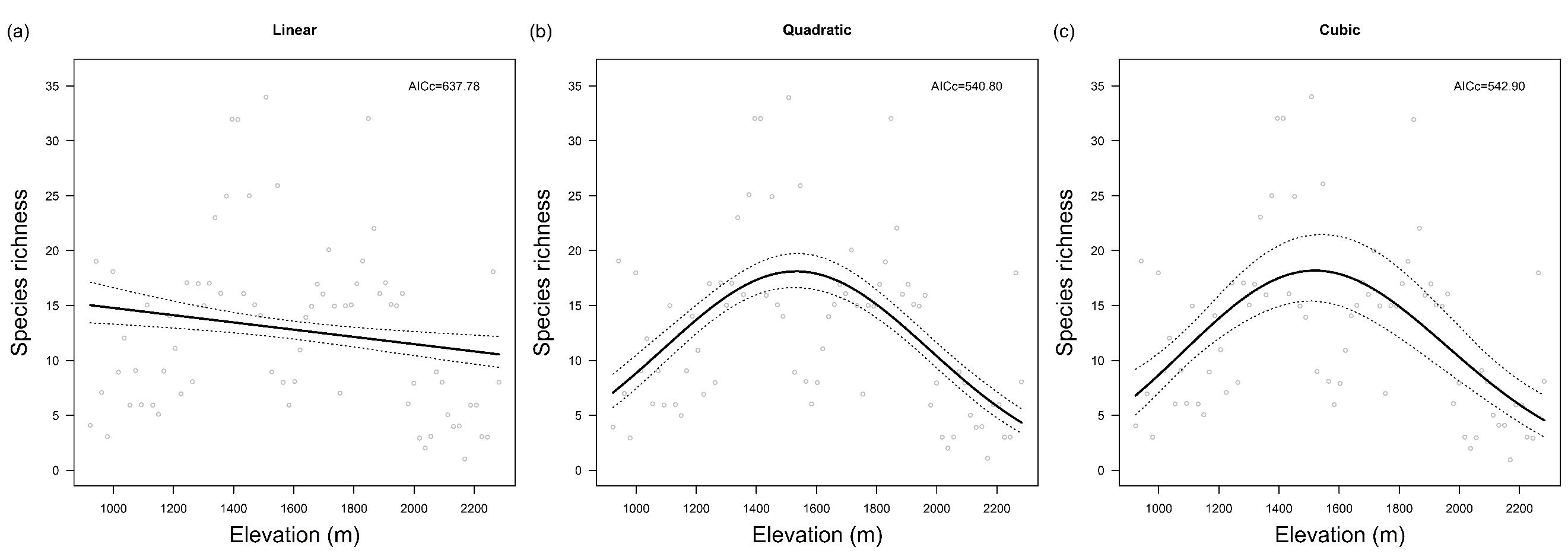
**Fig. 1.** Elevational pattern of Mt Tuofeng for (a) vegetation type (VT), (b) community type (CT), (c) solar radiation (SR), (d) annual precipitation (AP), (e) average temperature (AT), and (f) wind speed (WS) with regression line (black line) and 95% credible interval (dotted lines). Hollow circles represent observed values



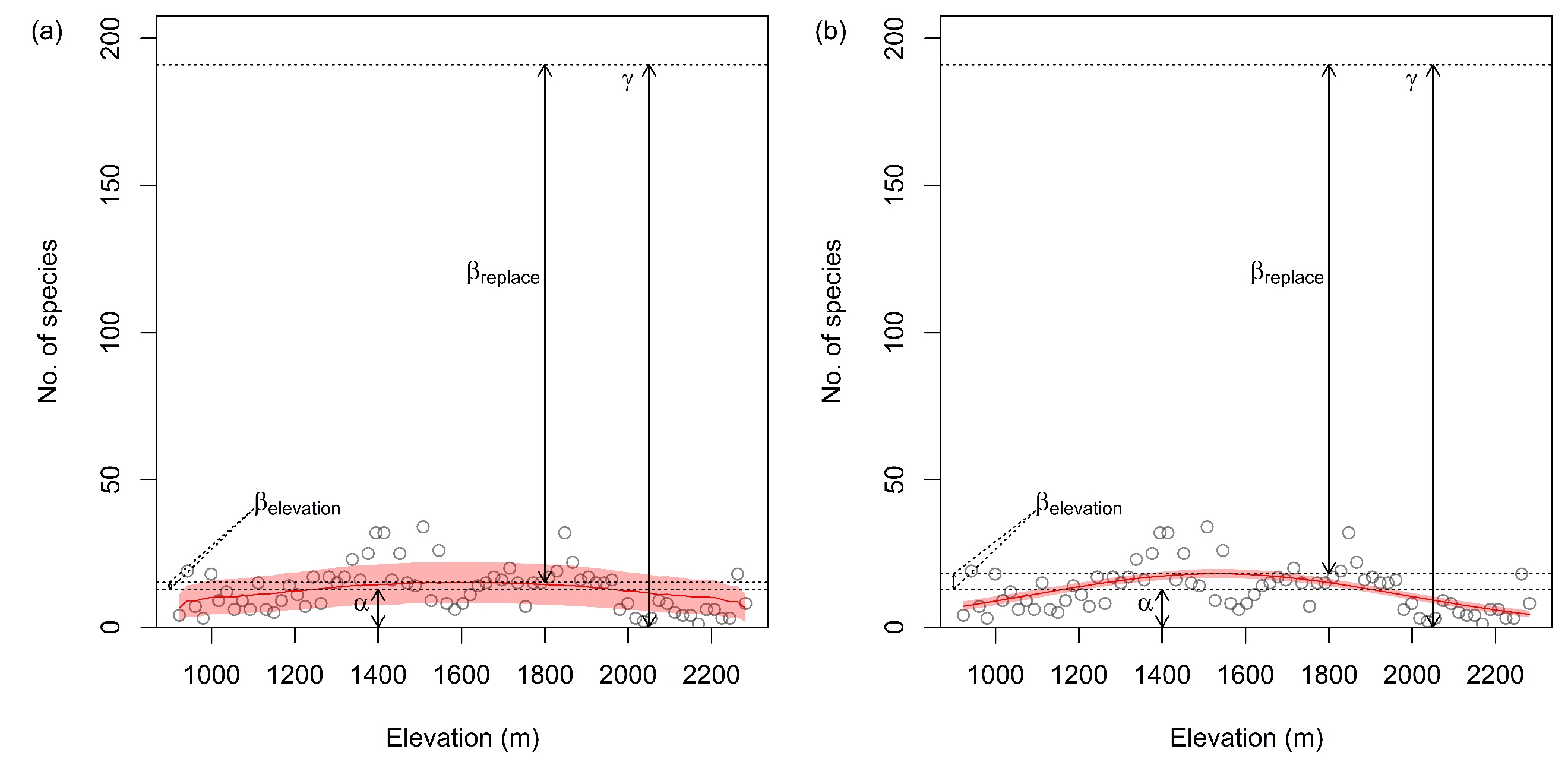
**Fig. 2.** Relationship between the MDE and species richness. Hollow circles represent the species richness, the black line is the predicted mean richness derived from RangeModel. Shaded areas show the 95% confidence interval of the prediction. The *R*2 and *p*-values were obtained by doing a linear regression of the observed richness on the predicted values to estimate the impact of the null model



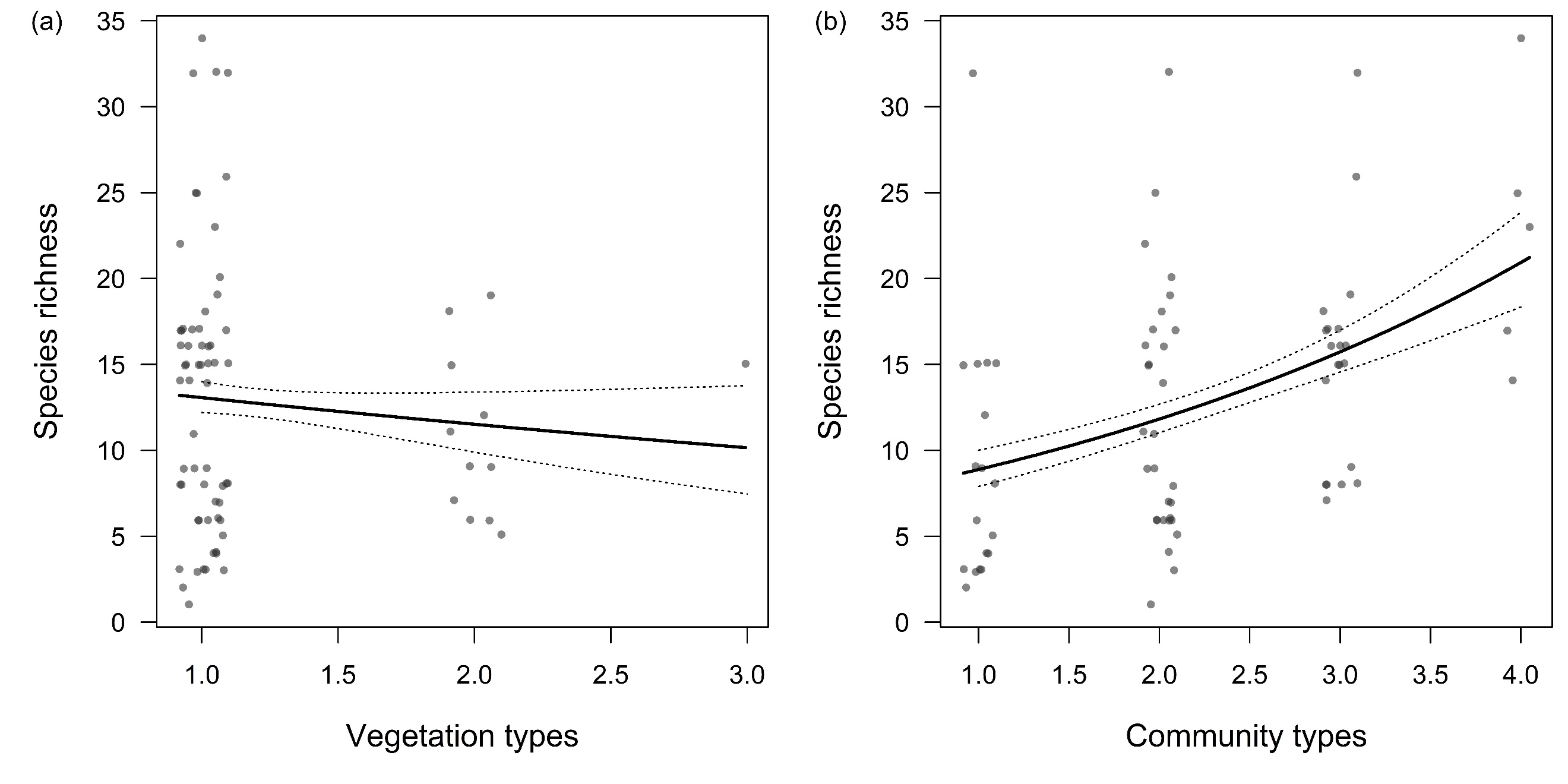
**Fig. 3.** Polynomial regressions of moss species richness along elevational gradient with regression line (black line) and 95% credible interval (dotted lines). Hollow circles represent observed values

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**Fig. 4.** Combination of additive diversity partitioning and the relationship between species richness and elevation predicted by (a) the mid-domain effect and (b) quadratic polynomial regression, showing α, β, and γ-diversity. β is partitioned into βelevation (contributions made by elevation) and βreplace (contributions made by other factors). The solid red line represents the MDE null predicted line in (a) or quadratic polynomial regression line in (b). Shaded areas show the 95% confidence interval of the prediction in (a) or 95% model credible interval in (b)



**Fig. 5.** Moss species richness versus (a) the number of vegetation types and (b) the number of community types with regression line and 95% credible interval (dotted lines). Black dots represent observed value that jittered in the vertical direction

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