Are dominant plant species more susceptible to leaf-mining insects? A case study at Saihanwula Nature Reserve, China

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Abstract
Dominant species significantly affect interspecific relationships, community structure, and ecosystem function. In the field, dominant species are often identified by their high importance values. Selective foraging on dominant species is a common phenomenon in ecology. Our hypothesis is that dominant plant groups with high importance values are more susceptible to leaf-mining insects at the regional level. Here, we used the Saihanwula National Nature Reserve as a case study to examine the presence-absence patterns of leaf-mining insects on different plants in a forest-grassland ecotone in Northeast China. We identified the following patterns: (1) After phylogenetic correction, plants with high importance values are more likely to host leafminers at the species, genus, or family level. (2) Other factors including phylogenetic isolation, life form, water ecotype, and phytogeographical type of plants have different influences on the relationship between plant dominance and leafminer presence. In summary, the importance value is a valid predictor of the presence of consumers, even when we consider the effects of plant phylogeny and other plant attributes. Dominant plant groups are large and susceptible targets of leaf-mining insects. The consistent leaf-mining distribution pattern across different countries, vegetation types, and plant taxa can be explained by the "species-area relationship" or the "plant apparency hypothesis."

KEYWORDS
apparency, importance value, Leafminer, phylogenetic generalized linear mixed model (PGLMM), species–area relationship

1 | INTRODUCTION

Not all species play equal roles in a given community or ecosystem. Dominant species are the small number of species that significantly affect other species (McNaughton & Wolf, 1970; Whittaker, 1965). Due to their high biomass, large size, high productivity, and other traits (Bouchenak-Khelladi, Slingsby, Verboom, & Bond, 2014; Collins & Duffy, 2016), they can change environmental conditions and resource availability and thus shape community structure (Frieswyk, Johnston, & Zedler, 2007; Okullo, Greve, & Moe, 2013), community diversity (Kunte, 2008; Okullo et al., 2013), community phylogeny (Chalmendier, Münkemüller, Lavergne, & Thuiller, 2015), trophic structure (Miller, Brodeur, Rau, & Omori, 2010), and ecosystem functions (Behera et al., 2017; Furey, Tecco, Perez-Harguindeguy, Giorgis, & Grossi, 2014; Grime, 1998; Mokany, Ash, & Roxburgh, 2008; Seabloom et al., 2015). Both dominant species and keystone
species are functionally important, but keystone species are much less abundant (Christianou & Ebenman, 2005; Hurlbert, 1997; Mouquet, Gravel, Massol, & Calcagno, 2013; Power et al., 1996). Therefore, dominant species with high abundance might contribute more to an ecosystem (Perry, 2010). Furthermore, dominance can be measured as the functional categories of predation tolerance and resource requirements between dominant and subordinate species can affect the outcome of competition (Engelkes et al., 2016; Hendon & Briske, 2002; Kohyani, Bossuyt, Bonte, & Hoffmann, 2009; Lotze & Schramm, 2000).

The above mentioned selective foraging on dominant species is a common phenomenon in ecological systems. Why do the dominant tree taxa in zonal vegetation host more parasites than subordinate taxa do; that is, why do “the outstanding usually bear the brunt of attack?” One explanation is that dominants are generally apparent plants, which might attract more consumers (Dai et al., 2017). According to plant apparency, ecological apparency, and optimal foraging hypotheses, apparent dominants are more likely to be found and preferred by parasites, natural enemies, pollinators, and humans (Feeny, 1976; Gonçalves et al., 2016; Phillips & Gentry, 1993; Schlinkert et al., 2015). Plant dominance can facilitate the evolutionary adaptation of consumers, and many consumers use plant defensive compounds to locate host plants (Smilanich, Fincher, & Dyer, 2016).

The larvae of leafminers feed on and live inside leaf tissues between the upper and lower epidermis and produce distinct leaf mines, which may persist for many days (Hering, 1951; Liu, Dai, & Xu, 2015). Therefore, leaf mines might provide important insights regarding the life history, taxonomy, interspecific relationships, and evolution of leaf-mining insects (Hirowatari, 2009; Liu et al., 2015). High incidences and abundances of leafminers on dominant plants have been demonstrated at global, regional, and community levels (Dai et al., 2017). For example, the highest reported abundance and richness values of leaf-mining insects are found for members of Fabaceae and Myrtaceae (i.e., the most dominant plant families in the Northern and Southern Hemispheres, respectively) (Bairstow, Clarke, McGeoch, & Andrew, 2010; Claridge & Wilson, 1982; Dai, Xu, & Cai, 2014; Dai, Xu, & Ding, 2013; Faeth & Mopper, 1981; Ishida, Hattori, & Kimura, 2004; Kollár & Hrubík, 2009; Lopez-Vaamonde, Godfray, & Cook, 2003; Nakamura, Hattori, Ishida, Sato, & Kimura, 2008; Opler & Davis, 1981; Sato, 1991; Sinclair & Hughes, 2008a,b). The variation in leafminer species richness among different host plants might be described by the species–area (i.e., leafminer species to host plant area) or species–apparency (i.e., leafminer species to host plant apparency) relationship (Dai et al., 2017; MacArthur & Wilson, 1967; Opler, 1974). “Area” here is a function of the distribution area, body size, number of individuals, and other indicators of plant dominance (Chaij, Devoto, Oleiro, Chanetton, & Mazia, 2016; Feeny, 1976; Joy & Crespi, 2012; Kamiya, O’Dwyer, Nakagawa, & Poulin, 2014; Miller, 2012). However, the unapparent relatives of apparent hosts might be utilized by leafminers due to the chemical similarities among phylogenetically closed plants (Dai et al., 2017). Therefore, the effects of plant phylogeny on the incidence of leafminers should be also considered (Claridge & Wilson, 1982; Dai et al., 2017; Godfray, 1984; Lawton & Price, 1979; Lopez-Vaamonde et al., 2003).

In this study, we used Saihanwula National Nature Reserve as a case study to examine the presence–absence patterns of leaf-mining insects on different plants in a forest-grassland ecotone in Northeast China. To the best of our knowledge, there are fewer publications on the occurrence of leaf mining on different plants in East Asia than there are in Europe, America, and Australia. Different from our previous work on the relationship between plant apparency or...
phylogenetic isolation and plant utilization by leafminers and other consumers at the global scale (Dai et al., 2017), our hypothesis in this study is that dominant plant groups with high importance values are more susceptible to leaf-mining insects at the regional level. Although there are many studies on leafminer species diversity based on plant characteristics, our study might be the first to use the importance value to study the leafminer species-to-area relationship. Moreover, in the previous work, we fit the dependence of consumer incidence on plant apparency or plant phylogeny separately (Dai et al., 2017), while in this study, we adopted phylogenetic generalized linear mixed model to consider plant apparency and plant phylogeny together in a model.

## 2 MATERIALS AND METHODS

### 2.1 Study area

The study was conducted in the Saihanwula National Nature Reserve, Inner Mongolia, China (43°59′–44°27′N, 118°18′–118°55′E). Its area is about 1000 km². The climate is temperate semi-arid, with long winters and short summers. The annual average temperature and rainfall are 2°C and 400 mm, respectively. The vegetation is in the transition zone between grassland and forest, and the forest types are transitional between the broad-leaved forests of eastern Asia and the coniferous forests of the Greater Hinggan Mountains. Dominant trees include *Larix* spp., *Betula platyphylla*, *Quercus mongolica*, *Populus davidiana* and *P. davidiana*, and the dominant grasses are *Stipa baicalensis*, *Artemisia sacrorum*, *Filifolium sibiricum* and *Carex duriuscula* (Li, Zhang, & Bater, 2005; Li, Zhang, & Han, 1998; Zhang, 2007; Zheng, Gao, Teng, Feng, & Tian, 2015).

Saihanwula, as a National Natural Reserve, is under strict regulation and protection. Therefore, its vegetation has not changed as radically as the surrounding unprotected area. Moreover, host selection of leafminers might not only relate to the current general vegetation structure but may also show lags and accumulated responses to the plant composition of past decades (Godfray, 1984; Sugiuira, 2010). It might be difficult to completely survey all vegetation again at the regional scale, as in the Saihanwula. In particular when considering only the presence–absence of leaf mine in a plant, the reuse of historical vegetation data might be reasonable at this stage.

### 2.2 Data collection

Plant attribute data, including importance value, were obtained from the records of Saihanwula National Nature Reserve (Li et al., 1998, 2005; Zhang, 2007): (1) In each forest community type, a 20 × 20 m main plot was chosen. Trees were investigated individually within each 10 × 10 m subplot. Shrubs and tree seedlings were investigated in five subplots of 5 × 5 m at the four corners and the center of the main plot. Herbaceous species were investigated inside three 1 × 1 m subplots within each shrub subplot. (2) In each shrub community type, a 20 × 20 m main plot was chosen. Shrub or grass individuals were recorded within five 5 × 5 m subplots or three 1 × 1 m subplots, respectively, similar to the investigation conducted in the forest communities. (3) In each herbaceous community type, a 10 × 10 m main plot was chosen, twenty 1 × 1 m subplots were set up, and grass individuals were recorded.

The data were carefully reviewed and corrected for data consistency. The importance value (IV) of one tree species is the average of its relative density (RD), relative frequency (RF), and relative GBH (girth at breast height, i.e., 1.3 m from the ground; RG) (Equation 1), whereas the IV of one grass species is the average of its RD, RF, and relative coverage (RC) (Equation 2).

\[
IV = \frac{(RD + RF + RG)}{3}
\]  

\[
IV = \frac{(RD + RF + RC)}{3}
\]

where \(RD\) = the density of a species/the total density of all species, \(RF\) = the frequency of a species/the sum of all frequencies, \(RG\) = the GBH of a tree species/the sum of all GBH values, and \(RC\) = the coverage of a grass species/the sum of all coverage values (Curtis & McIntosh, 1951; Gonmadj et al., 2011; Mori et al., 1983; Zhang, 2007).

We adopted the total importance value (TIV) to indicate the dominance or apparency of a plant species across all vegetation types in Saihanwula. The TIV of one plant species is the sum of all products of its IV in each community type and the area ratio (AR) of the corresponding community type (Equation 3). The relative TIV (RTIV) of one plant species is the ratio of the TIV of one plant species to the TIVs of all plant species in Saihanwula (Equation 4) (Li et al., 1998).

\[
TIV_i = \sum_{j=1}^{C} IV_{ij} \times AR_j
\]

\[
RTIV_j = \frac{TIV_j}{\sum_{j=1}^{S} TIV_j} \times 100%
\]

where \(TIV_j\) is the total importance value of plant species \(j\), \(RTIV_j\) is the relative total importance value of plant species \(j\), \(IV_{ij}\) is the importance value of species \(j\) in the \(i\)th community type, \(AR_j\) = the area of the \(i\)th community type/the total area, \(C\) is the number of community types, and \(S\) is the number of plant species (Li et al., 1998).

The group importance value (GIV) of one plant group is the sum of the TIVs of all plant species in the group (Equation 5). The relative GIV (RGIV) of one plant group is the ratio of the TIVs of all plant species in the group to the TIVs of all plant species in Saihanwula (Equation 6) (Li et al., 1998). The group here could be categorized according to plant life form, water ecotype, phytogeographic distribution type, taxon (i.e., family or genus), and other plant attributes.

\[
GIV_n = \sum_{i=1}^{N_n} TIV_{ni}
\]

\[
RGIV_n = \frac{GIV_n}{\sum_{j=1}^{S} TIV_j}
\]
where $GIV_m$ is the total importance value of plant group $m$, $RTIV_m$ is the relative total importance value of plant group $m$, $N_m$ is the number of plant species in plant group $m$, $TIV_n$ is the total importance value of plant species $n$, and $M$ is the total number of plant groups (Li et al., 1998).

### 2.3 Host plant sampling

Leaf mines (i.e., the distinct feeding marks left by leafminers) can remain visible for a considerable period (Liu et al., 2015), including after larvae have emerged or after leaf fall. When we encountered damage on leaves from an inconclusive source, we carefully assessed whether the mesophyll tissues were eaten while both the upper and lower leaf epidermis were maintained (or at least the outer wall remaining undamaged) (Liu et al., 2015).

Sampling sites and the corresponding survey trails were systematically chosen according to vegetation maps, historical data, and expert knowledge. Our sampling sites and trails covered and represented all 10 vegetation subtypes (cold-temperate deciduous needle-leaved forest, cold-temperate evergreen needle-leaved forest, typical deciduous broad-leaved forest, montane *Populus-Betula* deciduous forest, temperate deciduous broad-leaved thicket, montane evergreen broad-leaved thicket, meadow steppe, typical steppe, forb meadow, and Carex meadow) and most of the typical formations in the natural reserve (Figure 1). In July 2014 and October 2015, we (3–5 individuals per investigation group, with at least one experienced local guide) carefully examined all the trees, shrubs, and grasses that were visible along the studied trails and attempted to sample as many plant species with leaf mines as possible. Branches with mined leaves were collected and placed in plastic re-sealable bags in the field. The host plants were then identified and recorded. Host plants and mined leaves were scanned, and their digital images were stored in our laboratory for future studies. When living larvae were found, we attempted to rear the mining species. During the studied period, if we could not find any leaf mines in one plant species, we assumed that leaf-mining damage was absent from the plant species.

Our 8 years of experience with leafminer collection in China, which began in 2007, has made us thoroughly familiar with most types of leaf mines, allowing us to easily identify plants with leaf mines and some leafminer groups (Bai, Xu, & Dai, 2015, 2016; Dai et al., 2013, 2014, 2018; Liao, Liu, Xu, Staines, & Dai, 2018; Liu et al., 2015; Xu, Dai, Liao, Diškus, & Stonis, 2018; Xu et al., 2017). According to our rearing records and leaf mine characteristics, leafminers in Saihanwula belong to four insect orders: Lepidoptera (moths), Diptera (flies), Coleoptera (beetles), and Hymenoptera (wasps, bees, and ants). The study of leafminers in Saihanwula is crucial for understanding the ecological interactions between leafminers and their host plants, as well as for developing effective management strategies to mitigate the impact of leafminers on forest ecosystems.
(sawflies). Dominant leafminer families and the corresponding genera are as follows: Nepticulidae: Stigmella; Agromyzidae: Phytomyza, Agromyza, Liriomyza; Gracillariidae: Phyllopronctery, Caloptilia, Acrocercops, Cosmopterix; Elachistidae: Elachista; Tischeriidae: Tischeria; Tenthredinidae: Fenusa, Profenusa; Curculionidae: Rhynchaeus; Buprestidae: Trachys; Coleophoridae: Coleophora; Heliozelidae; Lyonetiidae: Lyoneta; Psychidae; Bucculatricidae: Bucculatrix; Eriocronia; Gelechiidae; Yponomeutinae. Among these leafminers, some have only one generation per year, while others have two or more generations per year. Most leafminer species on deciduous trees or grasses finish their mining stages before late October and overwinter as pupae. In an interesting manner, some leaf-mining larvae remain alive in the green islands on the dry or fallen leaves of some deciduous trees in Saihanwula. This provides the larvae with enough food to complete their life cycle before winter (Giron, Kaiser, Imbault, & Casas, 2007; Kaiser, Huguet, Casas, Commín, & Giron, 2010; Liu et al., 2015).

2.4 | Data preparation

However, some leaf-mining species and their life histories in China (including Saihanwula) remain unknown for the following reasons: (1) Many leaf mines were empty; (2) many leafminers died in transport or in the laboratory; (3) many leafminers were parasitized by parasitoid wasps; (4) some leafminer groups could not be identified at the species or even genus level as there were no available taxonomists with expertise in these groups, especially in the unfamiliar Chinese species; (5) no long-term investigations of Chinese leafminers were officially performed on either the national or regional level beyond the preliminary work of our group. Moreover, there might be some types of gregarious leaf miners whose larvae share a single mine. Therefore, in this study, we had to consider the presence–absence of leaf mines at the regional level rather than the individual number, incidence rate, or leaf area damage. However, when we collect enough detailed data in the future, the latter quantitative parameters may provide more valuable information than the former binary presence–absence data, especially at the community level.

The presence or absence of leaf mines in each plant group was coded as binary data. Compared with abundance data, presence–absence data have several advantages: (1) Presence–absence data can increase efficiency in ecological and conservation research because they are easier to collect than abundance data and are much less costly in terms of time, price, and human resources, especially at large spatial or temporal scales (Badenhauser, Amouroux, & Bretagnolle, 2007; Casner, Forister, Ram, & Shapiro, 2014; Fukuda, Mouton, & De Baets, 2012; Furnas, 2013; Gu & Swihart, 2004; Gutiérrez, Harcourt, Diez, Gutiérrez Ilín, & Wilson, 2013; Joseph, Field, Wilcox, & Possingham, 2006; MacKenzie & Nichols, 2004; Ribas & Padial, 2015). (2) In many cases, when differences among groups are large, presence–absence data can provide adequate indicators to describe ecological patterns, which are often in agreement with those obtained from abundance data (Carneiro, Bini, & Rodrigues, 2010; Landeiro et al., 2012; Melo, 2005; Ribas & Padial, 2015; Tweedley, Warwick, & Potter, 2015). (3) Presence–absence data can remove much of the noise induced by sampling biases or errors, whereas large sampling errors can lead to unreliable abundance data (Hirst & Jackson, 2007; Jackson & Harvey, 1997). (4) In some cases, only presence–absence data can be recorded, for example, when organisms grow clonally, are too abundant to count, or are difficult for nonexperts to identify taxonomically (Beisner, Peres-Neto, Lindström, Barnett, & Longhi, 2006; Colwell, Chang, & Chang, 2004). (5) Presence–absence data are more appropriate than are abundance data for clarifying the effects of host characteristics on parasite similarity (Locke, Mclaughlin, & Marcogliese, 2013; Poulin, 2010; Poulin & Krasnov, 2010; Seifertová, Vyskočilová, Morand, & Šimková, 2008).

All plant species names, including host plant species names, were verified with the Taxonomic Name Resolution Service (TNRS), V 4.0 (Boyle et al., 2013). The plant names that could not be resolved at TNRS were verified at The Plant List (TPL), V 1.1 (http://www.the-plantlist.org/).

2.5 | Plant phylogeny and statistical analyses

As closely related organisms are more likely to share similar biological traits, PGLMMs (phylogenetic generalized linear mixed models) can be adopted to correct for phylogenetic effects (Gallien, Saladin, Boucher, Richardson, & Zimmermann, 2016; Ives & Garland, 2010; Paradis & Claude, 2002; Takemoto & Aie, 2017). To determine the relationship between the presence–absence of leaf mines on a given plant (as a binary variable) and the plant’s TIV values, phylogenetic signal was measured, and phylogenetic logistic regression was performed. These procedures were performed using the binaryPGLMM function of the R package “rr2” and the phyloglm function of the R package “phyloim” (Ho & Ané, 2014; Ives & Ané, 2014; Ives & Garland, 2010, 2014; Ives, Helmus, & Ves, 2011; Paradis, Claude, & Strimmer, 2004). In the binaryPGLMM function, s2 is the scaling component of the variance in the PGLMM, where s2 = 0 suggests no phylogenetic signal and a high s2 value implies strong phylogenetic signal (Jamrozy et al., 2017). In the phyloglm function, alpha is the phylogenetic correlation parameter (an alpha value close to 0 suggests strong phylogenetic signal, alpha = 1 indicates a phylogenetic signal of trait evolution consistent with the expectation under Brownian motion, and an alpha value close to infinity implies low phylogenetic signal) (Blumstein et al., 2015; Gallien et al., 2016; O’Meara, Graham, Pellis, & Burgardt, 2015). Using the fitted coefficients from the phyloglm models, we plotted phylogenetic logistic regression curves using the plogis function of the R package “stats.” For comparison, we also fitted logistic link regressions of the presence–absence of leaf mines and TIV values using the glm function of the R package “stats.”

The plant phylogenetic trees, which were required for the above phylogenetic regression models, were constructed in the following
The megatree R20120829mod.new and the corresponding ages of the main clades (Gastauer & Meira-Neto, 2016) were updated to include all families of vascular plants. Therefore, lycophytes and their three extant families were added, and Athyriaceae was moved into the family Aspleniaceae (Christenhusz & Chase, 2014). The online Phylomatic program (http://phylodiversity.net/phylomatic/) was used to obtain the local plant phylogeny based on the megatree and our plant species list (Webb & Donoghue, 2005). Branch lengths were then adjusted with the Phylocom Bladj algorithm (Webb, Ackerly, & Kembel, 2008) based on the above modified ages file. A megatree of only plant families was also generated from the above modified megatree. Then, local plant phylogenies at the genus or family level were also obtained using the later megatree and our plant genus or family list. The R package "plantlist" (https://github.com/helixcn/plantlist/) was used to create a family/genus/species table for the Phylomatic software (Zhang, 2017). Note that

### TABLE 1

| Plant groups | binaryPGLMM | phyloglm | GLM |
|--------------|-------------|----------|-----|
| Plant groups |             |          |     |
| species      | 0.0020      | 0.0020   | 0.0020 |
| genus        | 0.0018      | 0.0028   | 0.0028 |
| family       | 0.0003      | 0.0054   | 0.0054 |

**Notes.** \( B \) is the regression coefficient, \( s^2 \) is the scaling component of the variance in the PGLMM (phylogenetic generalized linear mixed model), \( \text{alpha} \) is the phylogenetic correlation parameter, and \( \text{AIC} \) is the Akaike Information Criterion score. Values in bold indicate a significant \( p \) value (< 0.05).

**FIGURE 2** Phyllogenetic generalized linear mixed models were fitted to show the incidence of leaf mines as a function of plant dominance (total importance value). (a) At the plant species level, (b) at the plant genus level, and (c) at the plant family level.
the family/genus/genus or family/family/family table was generated for the plant genus or family list, respectively.

All of the plant species were ranked based on their TIV values (TIV > 0) and classified into 12 groups. Plant species with TIV = 0 were omitted from the following analyses. Then, the plant species were aggregated to the genus or family level. All of the plant genera/families were also ranked based on their TIVs and classified into a certain number of groups, but several plant genera/families with the smallest nonzero TIVs may have been omitted as the number of plant genera/families was not precisely divisible. We then counted the number of host plant species/genera/families in each ranked group and calculated the ratio of leafminer hosts.

The data analyses were mainly conducted in R 3.4.4 (R Core Team 2018) and RStudio 1.1.442 (RStudio Team 2018).

3 | RESULTS

3.1 | Roles of plant phylogeny and plant dominance

Both phylogenetic logistic regression models exhibited a strong phylogenetic signal at the plant species, genus, and family level (binaryPGLMM: \( \sigma^2 = 0.320–0.453, p < 0.001 \); phyloglm: \( \alpha = 0.0021–0.0023 \); Table 1). After correcting for phylogenetic effects, a significant positive effect of TIV was observed on the presence–absence of leaf mines at the plant species, genus, and family level (binaryPGLMM: \( B = 0.0018–0.0063, p < 0.05 \); phyloglm: \( B = 0.0028–0.0054, p < 0.05 \); Table 1). That is, the incidence probability of leaf mines among plant groups increased positively with TIV in a logistic way (Figure 2). Unexpectedly, the regression coefficients \( B \) of the nonphylogenetic logistic models (i.e., GLMs) were nearly equal to those obtained with binaryPGLMM, and the

3.2 | Relationship between plant importance value and host probability

Only those plant species/genera/families with nonzero importance values were considered. Dominant plant species tended to host leafminers (host ratio of 21.6%–45.9% for the top two ranked plant species groups with the highest RGIVs), whereas the remaining ranked plant species groups exhibited host ratios of 2.7%–16.2% (Table 2). Dominant plant genera also tended to host leafminers (host ratios of 33.3%–61.9% for the top three plant genus groups with the highest RGIVs), whereas the remaining ranked plant genus groups presented host ratios of 4.8%–23.8% (Table 3). Dominant plant families tended to host leafminers as well (host ratios of 100.0% for the first plant family group with the highest GIV, i.e., all ten dominant plant families with the largest GIVs suffered leaf-mining damage), whereas the remaining ranked plant family groups displayed host ratios of 10.0%–50.0% (Table 4; Figure 2c).

3.3 | Impacts of plant life form, water ecotype, and phytogeographic distribution type

Trees were much more likely to be leafminer hosts (60.0%) than were shrubs, subshrubs, or grasses (<18.0%) (Table 5).

Among the different water ecotypes, xeromesophytes, mesophytes, hygrophytes, mesoxerophytes, and hygromesophytes were more likely to exhibit leaf-mining damage, while plants in extreme environments (hydrophytes and xerophytes) rarely hosted leafminers (Table 6).

| Rank of plant species group | Relative group importance value (RGIV) | Number of host plant species | Ratio of host plant species |
|-----------------------------|--------------------------------------|-----------------------------|-----------------------------|
| 1                           | 81.82                                | 17                          | 0.459                       |
| 2                           | 9.66                                 | 8                           | 0.216                       |
| 3                           | 4.55                                 | 3                           | 0.081                       |
| 4                           | 2.20                                 | 3                           | 0.081                       |
| 5                           | 1.19                                 | 6                           | 0.162                       |
| 6                           | 0.41                                 | 4                           | 0.108                       |
| 7                           | 0.10                                 | 4                           | 0.108                       |
| 8                           | 0.04                                 | 3                           | 0.081                       |
| 9                           | 0.02                                 | 4                           | 0.108                       |
| 10                          | 0.01                                 | 1                           | 0.027                       |
| 11                          | 0.01                                 | 2                           | 0.054                       |
| 12                          | 0.00                                 | 3                           | 0.081                       |

Notes. A total of 444 plant species with available importance values were recorded in Saihanwula. These plant species were ranked based on their importance values and then classified into 12 groups (37 species per group). Host ratio = number of host species/total number of species in each group (i.e., 37).
Among the different phytogeographic distribution types, only those plant species belonging to the top seven types (East Palaearctic species, East Asia species, Palaearctic species, Holarctic species, Northeast China species, North China species, and Dahuric-Mongolia species) with high RGIVs (>5.0) sustained damage from leaf-mining insects (Table 7).

### Table 3
Relationship between the total importance value of plant genus groups and the ratio of leaf-mining insect hosts among plant genera

| Rank of plant genus group | Relative group importance value (RGIV) | Number of host plant genera | Ratio of host plant genera |
|---------------------------|---------------------------------------|----------------------------|---------------------------|
| 1                         | 80.29                                 | 13                         | 0.619                     |
| 2                         | 11.61                                 | 7                          | 0.333                     |
| 3                         | 4.51                                  | 7                          | 0.333                     |
| 4                         | 1.82                                  | 1                          | 0.048                     |
| 5                         | 1.01                                  | 3                          | 0.143                     |
| 6                         | 0.56                                  | 5                          | 0.238                     |
| 7                         | 0.13                                  | 3                          | 0.143                     |
| 8                         | 0.03                                  | 3                          | 0.143                     |
| 9                         | 0.02                                  | 2                          | 0.095                     |
| 10                        | 0.01                                  | 1                          | 0.048                     |
| 11                        | 0.00                                  | 2                          | 0.095                     |
| 12                        | 0.00                                  | 3                          | 0.143                     |

Notes: A total of 254 plant genera with available importance values were recorded in Saihanwula. These plant genera were ranked based on their importance values and then classified into 12 groups (21 genera per group). The two plant genera with the smallest nonzero importance values were omitted. Host ratio = number of host genera/total number of genera in each group (i.e., 21).

### Table 4
Relationship between the total importance value of plant family groups and the ratio of leaf-mining insect hosts among plant families

| Rank of plant family group | Relative group importance value (RGIV) | Number of host plant families | Ratio of host plant families |
|----------------------------|----------------------------------------|-------------------------------|------------------------------|
| 1                         | 87.13                                  | 10                            | 1.000                        |
| 2                         | 10.06                                  | 5                             | 0.500                        |
| 3                         | 1.86                                   | 3                             | 0.300                        |
| 4                         | 0.69                                   | 2                             | 0.200                        |
| 5                         | 0.23                                   | 5                             | 0.500                        |
| 6                         | 0.02                                   | 1                             | 0.100                        |
| 7                         | 0.00                                   | 1                             | 0.100                        |

Notes: A total of 71 plant families with available importance values were recorded in Saihanwula. These plant families were ranked based on their importance values and then classified into seven groups (10 families per group). The plant family with the smallest nonzero importance value was omitted. Host ratio = number of host families/total number of families in each group (i.e., 10).

### Table 5
Plant species of different life forms and information regarding their status as hosts of leaf-mining insects

| Life form                  | Relative group importance value (RGIV) | Total number of plant species | Number of host plant species | Host ratio |
|----------------------------|----------------------------------------|-------------------------------|------------------------------|------------|
| Perennials                 | 48.34                                  | 458                           | 32                           | 0.070      |
| Trees                      | 28.48                                  | 25                            | 15                           | 0.600      |
| Shrubs                     | 13.57                                  | 51                            | 9                            | 0.176      |
| Annuals and biennials      | 7.73                                   | 105                           | 13                           | 0.124      |
| Subshrubs                  | 1.88                                   | 12                            | 0                            | 0.000      |

Note: Host ratio = number of host species/total number of species.
In this study, we measured plant dominance using the importance value, which is the sum of the relative density, relative frequency, and relative basal area of the plant group (Curtis & McIntosh, 1951). Relative density is related to the number of individuals, relative frequency is related to the distribution type, and the relative basal area is related to body size. As such, dominant plant groups with high importance values are abundant in number, exhibit a wide distribution, or are large in size. Previous studies have indicated that common plants are more likely to exhibit leaf-mining damage than are rare plants, that widely distributed plants exhibit a higher leafminer incidence than do narrowly distributed plants, and that large plants with a complicated structure might be more vulnerable to leafminers than are small plants with a simple structure. For example, the number of leaf-mining insects on Fagaceae plants in California is closely associated with the host distribution area (Opler, 1974). The distribution area and height of various tree

| Water ecotype           | Relative group importance value (RGIV) | Total number of plant species | Number of host plant species | Host ratio |
|-------------------------|----------------------------------------|-------------------------------|----------------------------|------------|
| Hydrophyte              | 0.00                                   | 2                             | 0                           | 0.000      |
| Hygrophyte              | 0.72                                   | 35                            | 4                           | 0.114      |
| Hygromesophyte          | 5.33                                   | 37                            | 2                           | 0.054      |
| Mesophyte               | 74.01                                  | 369                           | 47                          | 0.127      |
| Mesoxerophyte           | 10.86                                  | 81                            | 8                           | 0.099      |
| Xeromesophyte           | 6.85                                   | 52                            | 8                           | 0.154      |
| Xerophyte               | 2.23                                   | 75                            | 2                           | 0.027      |

Note. Host ratio = number of host species/total number of species.

| Phytogeographic distribution type | Relative group importance value (RGIV) | Total number of plant species | Number of host plant species | Host ratio |
|-----------------------------------|----------------------------------------|-------------------------------|----------------------------|------------|
| East Palaearctic species          | 32.59                                  | 90                            | 13                          | 0.144      |
| East Asia species                 | 23.03                                  | 184                           | 26                          | 0.141      |
| Palaearctic species               | 12.27                                  | 94                            | 10                          | 0.106      |
| Holarctic species                 | 8.84                                   | 95                            | 9                           | 0.095      |
| Northeast China species           | 7.93                                   | 14                            | 2                           | 0.143      |
| North China species               | 6.64                                   | 20                            | 5                           | 0.250      |
| Dahanic-Mongolia species          | 5.32                                   | 74                            | 5                           | 0.068      |
| Eastern Siberia species           | 1.03                                   | 11                            | 0                           | 0.000      |
| Cosmopolitan species              | 0.68                                   | 12                            | 0                           | 0.000      |
| Unknown distribution type         | 0.66                                   | 11                            | 0                           | 0.000      |
| Mongolia species                  | 0.39                                   | 2                             | 0                           | 0.000      |
| Europe-Siberia species            | 0.30                                   | 5                             | 0                           | 0.000      |
| Black Sea-Kazakhstan-Mongolia species | 0.17                               | 3                             | 0                           | 0.000      |
| Kazakhstan-Mongolia species       | 0.12                                   | 11                            | 0                           | 0.000      |
| Central Asia species              | 0.04                                   | 16                            | 0                           | 0.000      |
| East Asia-North America species   | 0.00                                   | 2                             | 0                           | 0.000      |
| Siberia species                   | 0.00                                   | 1                             | 0                           | 0.000      |
| Arctoalpine species               | 0.00                                   | 1                             | 0                           | 0.000      |
| Tethys species                    | 0.00                                   | 3                             | 0                           | 0.000      |
| Tropicopolitan species            | 0.00                                   | 1                             | 0                           | 0.000      |
| Yinshan-Helan Mountain species    | 0.00                                   | 1                             | 0                           | 0.000      |

Note. Host ratio = number of host species/total number of species.
species can partially explain differences in leafminer richness in Britain (Claridge & Wilson, 1982). A majority of the variation in species richness among agromyzid miners on British umbellifers was attributed to the distribution area, local abundance, number of habitats occupied, and body size of different host plants (Fowler, Lawton, Lawton, Fowler, & Lawton, 1982; Lawton & Price, 1979). Compared with normal Q. falcata saplings, smaller trees sprouting from root stalks near the ground hosted fewer miner species (Faeth & Simberloff, 1981; Lawton, 1983). At the global level, the presence of leaf-mining chrysomelid beetles, tischerioid moths, agromyzid flies, and gracillariid moths strongly depends on the distribution range of plant families (Dai et al., 2017). In Saihanwula, the ratio of leafminer hosts among plants at the species, genus, and family level increased with the total importance value of the plant taxonomic group after phylogenetic correction. Thus, dominant plant taxonomic groups with high importance values were highly likely to host leafminers (Figure 2, Tables 1–4). Among plant species of different phytogeographic distribution types in Saihanwula, widely distributed plant species showed high importance values and were likely to host leafminers, whereas narrowly distributed plant species exhibited the opposite patterns (Table 7). In general, dominant plant groups were more likely than their corresponding subordinate groups to suffer leaf-mining damage. Our results are consistent with those of previous studies (Claridge & Wilson, 1982; Dai et al., 2017; Fowler et al., 1982; Lawton & Price, 1979; Opler, 1974).

Other factors may account for some variation in the species-area regression between plant dominance and leafminer incidence (Claridge & Wilson, 1982; Lawton & Price, 1979). In general, biotic factors play much important roles than abiotic ones in leaf-mining distribution patterns (Sinclair & Hughes, 2008a). Plant phylogeny, which is highly related to plant chemistry, may have large influences on the species-area relationship of leafminers (Claridge & Wilson, 1982; Godfray, 1984). Among the plant species of different life forms, tree groups did not exhibit the highest total importance values but were much more likely to suffer leaf-mining damage than any other life form in Saihanwula (Table 5). Among plant species of different water ecotypes in Saihanwula, plants in extremely dry or wet environments had very little likelihood of hosting leafminers (Table 6). In the same way, no leafminers were discovered at two driest places in Australia (Sinclair & Hughes, 2008a); aquatic habitats may be unfavorable for the agromyzid leafminers (Lawton & Price, 1979). The presence-absence of leaf mining might be obviously related to leaf physical traits such as leaf size, leaf length, leaf thickness, or leaf form (Dai, Zhu, Xu, Liu, & Wang, 2011; Fowler et al., 1982; Godfray, 1984; Lawton & Price, 1979; Sinclair & Hughes, 2008a). Adult leafminers should lay eggs on leaves that are large enough for the larvae to complete their life histories (Dai et al., 2011). Therefore, many leafminers prefer larger leaves to smaller ones (Faeth, 1991; Hileman & Lieto, 1981). In contrast, plant phylogenetic isolation, life history, interspecific competition, and natural enemies had no important impacts on the number of agromyzid flies on the British Umbelliferae (Lawton & Price, 1979).

Although the influence of importance value on the presence-absence of leaf mines was not independent of plant phylogenetic relationships, the role of plant dominance on the probability of being mined was clear (Table 1, Figure 2). One possible explanation for the similar regression coefficients or intercepts between the PGLMMs and nonphylogenetic logistic models is that the close relatives of the dominant plants were more dominant than the other plants and were thus more susceptible to plant parasites.

Vegetation parameters such as density, frequency, coverage, diversity, and importance value have been used to measure the apparent or dominance of plant species (Gonçalves et al., 2016; Guo & Rundel, 1997). Higher dominance is associated with more host-consumer encounters (random placement hypothesis) and more ecological niches for consumers (habitat diversity hypothesis) (Miller, 2012; Strona & Fattorini, 2014). For example, the occurrence of more species in a plant family implies the existence of a greater number of available niches (de Araújo, dos Santos, & Gomes-Klein, 2012; de Araújo, Silva, dos Santos, & Gomes-Klein, 2013; Joy & Crespi, 2012; Mendonça, 2007). Therefore, according to the plant family size hypothesis, larger plant families are expected to host more parasites (de Araújo, 2011; de Araújo et al., 2012, 2013; Cuevas-Reyes, Quesada, Hanson, & Oyama, 2007; Dai et al., 2017; Fernandes, 1992; Gonçalves-Alvim, Fernandes, & Goncalves-Alvim, 2001; Lawton & Price, 1979; Mendonça, 2007; Price, 1977; Veldtman & McGeoch, 2003; Ward & Spalding, 1993). In general, high dominance can be related to a high risk of pest or pathogen attack. As the importance value encompasses several plant traits related to plant dominance, it is expected to be a valid predictor of consumer occurrence (de Albuquerque & de Lucena, 2005; de Lucena, de Lima Araújo, & de Albuquerque, 2007; de Lucena, de Medeiros, Araújo, Alves, & de Albuquerque, 2012), as verified in the present study.

In summary, dominant plant groups are large and susceptible targets for leaf-mining insects even when we consider the effects of plant phylogeny and other plant attributes. Such a consistent leaf-mining distribution pattern across different countries, vegetation types and plant taxa can be explained by the "species-area relationship" (i.e., the leafminer species incidence to plant importance value relationship) or the "species-apparency relationship."

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DATA ACCESSIBILITY

Data for this study are available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.sc3fr20

CONFLICT OF INTEREST

None declared.

AUTHOR CONTRIBUTIONS

X.D. conceived and designed the study, performed the fieldwork, managed the project, analyzed the data, and wrote the manuscript. C.L. extracted the data from publications, rechecked the field data, reanalyzed all the data, and modified the vegetation map. J.X. helped identify leaf mines and guide the writing of Chinese version manuscript. Q.G. helped to analyze the data and improve the manuscript in English. W.Z. performed the fieldwork and analyzed the data. Z.Z. wrote the first version of the manuscript in Chinese. Bater provided the background data of Saihanwula and aided the fieldwork.

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REFERENCES

Badenhausser, I., Amouroux, P., & Bretagnolle, V. (2007). Estimating acridid densities in grassland habitats: A comparison between presence-absence and abundance sampling designs. *Environmental Entomology*, 36, 1494–1503. https://doi.org/10.1603/0046-25X(2007)36[1494:EADIGH]2.0.CO;2

Bai, H., Xu, J., & Dai, X. (2015). Three new species, two newly recorded genus of Libdocolletinae (Lepidoptera: Gracillariidae) from China. *Zootaxa*, 4032, 229–235. https://doi.org/10.11646/zootaxa.4032.2.10

Bai, H., Xu, J., & Dai, X. (2016). Two new and one newly recorded species of Gracillariidae from China (Lepidoptera). *ZooKeys*, 559, 139–150. https://doi.org/10.3897/zookeys.559.6812

Bairstow, K. A., Clarke, K. L., McGeoch, M. A., & Andrew, N. R. (2010). Leaf miner and plant galler species richness on Acacia: Relative importance of plant traits and climate. *Oecologia*, 163, 437–448. https://doi.org/10.1007/s00442-010-1604-6

Behera, S. K., Sahu, N., Mishra, A. K., Bargali, S. S., Behera, M. D., & Tuli, R. (2017). Aboveground biomass and carbon stock assessment in Indian tropical deciduous forest and relationship with stand structural attributes. *Ecological Engineering*, 99, 513–524. https://doi.org/10.1016/j.ecoleng.2016.11.046

Beisner, B. E., Peres-Neto, P. R., Lindström, E. S., Barnett, A., & Longhi, M. L. (2006). The role of environmental and spatial processes in structuring lake communities from bacteria to fish. *Ecology*, 87, 2985–2991. https://doi.org/10.1890/0012-9658(2006)87[2985:TROEAS]2.0.CO;2

Blumstein, D. T., Buckner, J., Shah, S., Patel, S., Alfaro, M. E., & Natterson-Horowitz, B. (2015). The evolution of capture myopathy in hooved mammals: A model for human stress cardiomyopathy? *Evolution, Medicine, and Public Health*, 2015, 195–203. https://doi.org/10.1093/emph/eov015

Bouchenak-Khelladi, Y., Slingsby, J. A., Verboom, G. A., & Bond, W. J. (2014). Diversification of C4 grasses (Poaceae) does not coincide with their ecological dominance. *American Journal of Botany*, 101, 300–307. https://doi.org/10.3732/ajb.1300439

Boyle, B., Hopkins, N., Lu, Z., Raygoza Garay, J. A., Mozzherin, D., Rees, T., & Weakley, A. (2013). The taxonomic name resolution service: An online tool for automated standardization of plant names. *BMC Bioinformatics*, 14, 16. https://doi.org/10.1186/1471-2105-14-16

Brandt, R., Zimmermann, H., Hensen, I., Mariscal Castro, J. C., & Rist, S. (2012). Agroforestry species of the Bolivian Andes: An integrated assessment of ecological, economic and socio-cultural plant values. *Agroforestry Systems*, 86, 1–16. https://doi.org/10.1007/s10457-012-9503-y

Carneiro, F. M., Bini, L. M., & Rodrigues, L. C. (2010). Influence of taxonomic and numerical resolution on the analysis of temporal changes in phytoplankton communities. *Ecological Indicators*, 10, 249–255. https://doi.org/10.1016/j.ecolind.2009.05.004

Casner, K. L., Forister, M. L., Ram, K., & Shapiro, A. M. (2014). The utility of repeated presence data as a surrogate for counts: A case study using butterflies. *Journal of Insect Conservation*, 18, 13–27. https://doi.org/10.1007/s10841-013-9610-8

Chaij, J., Devoto, M., Oleiro, M., Chaneton, E. J., & Mazia, N. (2016). Complexity of leaf miner-parasitoid food webs declines with canopy height in Patagonian beech forests. *Ecological Entomology*, 41, 599–610. https://doi.org/10.1111/een.12332

Chalmendrier, L., Münkemüller, T., Lavergne, S., & Thuiller, W. (2015). Effects of species ‘similarity and dominance on the functional and phylogenetic structure of a plant meta-community. *Ecology*, 96, 143–153. https://doi.org/10.1890/13-2153.1

Christenhusz, M. J. M., & Ebenman, B. (2005). Keystone species and vulnerable species in ecological communities: Strong or weak interactors? *Journal of Theoretical Biology*, 235, 95–103. https://doi.org/10.1016/j.jtbi.2004.12.022

Claridge, M. F., & Wilson, M. R. (1982). Insect herbivore guilds and species-area relationships: Leafminers on British trees. *Ecological Entomology*, 7, 19–30. https://doi.org/10.1111/j.1365-2311.1982.tb00640.x

Collins, O. C., & Duffy, K. J. (2016). Consumption threshold used to investigate stability and ecological dominance in consumer-resource dynamics. *Ecological Modelling*, 319, 155–162. https://doi.org/10.1016/j.ecolmodel.2015.03.021

Colwell, R. K., Chang, X. M., & Chang, J. (2004). Interpolating, extrapolating, and comparing incidence-based species accumulation curves. *Ecology*, 85, 2717–2727. https://doi.org/10.1890/03-0557

Cuervas-Reyes, P., Quesada, M., Hanson, P., & Oyama, K. (2007). Interactions among three trophic levels and diversity of parasites: A case of top-down processes in Mexican tropical dry forest. *Environmental Entomology*, 36, 792–800. https://doi.org/10.1093/ee/36.4.792

Curtis, J. T., & McIntosh, R. P. (1951). An upland forest continuum in the prairie-forest border region of Wisconsin. *Ecology*, 32, 476–496. https://doi.org/10.2307/1931725

Dahdouh-Guebas, F., Koedam, N., Satyanarayana, B., & Cannicci, S. (2011). Human hydrographical changes interact with propagule predation behaviour in Sri Lankan mangrove forests. *Journal of Experimental Marine Biology and Ecology*, 399, 188–200. https://doi.org/10.1016/j.jembe.2010.11.012

Dahdouh-Guebas, F., Verheyden, A. De Genst, W., Hettiarachchi, S., & Koedam, N. (2000). Four decade vegetation dynamics in Sri Lankan mangrove as detected from sequential aerial photography: A case study in Galle. *Bulletin of Marine Science*, 67, 741–759.
Kunte, K. (2008). Competition and species diversity: Removal of dominant species increases diversity in Costa Rican butterfly communities. Oikos, 117, 69–76. https://doi.org/10.1111/j.2007.0030-1299.16125.x

Landeiro, V. L., Bini, L. M., Costa, F. R. C., Franklin, E., Nogueira, A., De Souza, J. L. P., ... Magnussin, W. E. (2012). How far can we go in simplifying biomonitoring assessments? An integrated analysis of taxonomic surrogacy, taxonomic sufficiency and numerical resolution in a megadiverse region. Ecological Indicators, 23, 366–373. https://doi.org/10.1016/j.ecolind.2012.04.023

Lawton, J. H. (1983). Plant architecture and the diversity of phytophagous insects. Annual Review of Entomology, 28, 23–39. https://doi.org/10.1146/annurev.en.28.010183.000323

Lawton, J. H., & Price, P. W. (1979). Species richness of parasites on hosts: Agromyzid flies on the British Umbelliferae. Journal of Animal Ecology, 48, 619–637. https://doi.org/10.2307/4183

Li, G., Zhang, S., & Bater, (2005). Notes of Saihanwula Nature Reserve. Chifeng, China: Science and Technology Press of Inner Mongolia.

Li, G., Zhang, S., & Han, L. (1998). Comprehensive Scientific Investigation Reports on Saihanwula National Nature Reserve. Chifeng, China: Saihanwula National Nature Reserve.

Liao, C., Liu, P., Xu, J., Staines, C. L., & Dai, X. (2018). Description of the last-instar larva and pupa of a leaf-mining hispine – Prionispa champaka Maulik, 1919 (Coleoptera, Chrysomelidae, Cassidinae, Oonopephilini). ZooKeys, 729, 47–60. https://doi.org/10.3897/zookeys.729.21041

Lie, K. J. (1973). Larval trematode antagonism: Principles and possible application as a control method. Experimental Parasitology, 33, 343–349. https://doi.org/10.1016/0014-4894(73)90038-6

Liu, W., Dai, X., & Xu, J. (2015). Influences of leaf-mining insects on their host plants: A review. Collectanea Botanica, 34, e005.

Locke, S. A., McLaughlin, D. J., & Marcogliese, D. J. (2013). Predicting the similarity of parasite communities in freshwater fishes using the phylogeny, ecology and proximity of hosts. Oikos, 122, 73–83. https://doi.org/10.1111/j.1600-0706.2012.20211.x

Lopez-Vaamonde, C., Godfray, H. C. J., & Cook, J. M. (2003). Evolutionary models for the retention of adult–adult social play in primates: The roles of diet and other factors associated with resource acquisition. Adaptive Behavior, 23, 381–391. https://doi.org/10.1177/1059712315611773

Opler, P. A. (1974). Oaks as evolutionary islands for leaf-mining insects: the evolution and extinction of phytophagous insects is determined by an ecological balance between species diversity and area of host occupation. American Scientist, 62, 67–73.

Opler, P. A., & Davis, D. R. (1981). The leafmining moths of the genus Cameraria associated with Fagaceae in California (Lepidoptera: Gracillariidae). Smithsonian Contributions to Zoology, 333, 1–58. https://doi.org/10.5479/si.00810282.333

Paradis, E., & Claude, J. (2002). Analysis of comparative data using generalized estimating equations. Journal of Theoretical Biology, 218, 175–185. https://doi.org/10.1006/jtbi.2002.3066

Paradis, E., Claude, J., & Strimmer, K. (2004). APE: Analyses of phylogenetics and evolution in R language. Bioinformatics, 20, 289–290. https://doi.org/10.1093/bioinformatics/btg412

Perry, N. (2010). The ecological importance of species and the Noah's Ark problem. Ecological Economics, 69, 478–485. https://doi.org/10.1016/j.ecolecon.2009.09.016

Phillips, O., & Gentry, A. H. (1993). The useful plants of Tambopata, Peru: II. Additional hypothesis testing in quantitative ethnobotany. Economic Botany, 47, 33–43. https://doi.org/10.1007/BF02862204

Pierce, S., Luzzaro, A., Caccianiga, M., Ceriani, R. M., & Cerabolini, B. (2007). Disturbance is the principal α-scale filter determining niche differentiation, coexistence and biodiversity in an alpine community. Journal of Ecology, 95, 698–706. https://doi.org/10.1111/j.1365-2745.2007.01242.x

Poulin, R. (2010). Decay of similarity with host phylogenetic distance in parasite faunas. Parasitology, 137, 733–741. https://doi.org/10.1017/S003118200991491

Poulin, R., & Krasnov, B. (2010). Similarity and variability of parasite assemblages across geographical space. In S. Morand, & B. R. Krasnov
forest gaps compared with the understory in an oak-pine mixed forest. *Acta Theriologica*, 59, 495–502. https://doi.org/10.1007/s13364-014-0192-y

Yu, Q., Wilcox, K., La Pierre, K., Knapp, A. K., Han, X., & Smith, M. D. (2015). Stoichiometric homeostasis predicts plant species dominance, temporal stability and responses to global change. *Ecology*, 96, 2328–2335. https://doi.org/10.1890/14-1897.1

Zhang, S. (2007). *Study on plants diversity and conservation in Saihanwula Nature Reserve, Inner Mongolia*. (Doctoral Dissertation). Beijing, China: Beijing Forestry University.

Zhang, J. (2017). plantlist: Looking up the status of plant scientific names based on the plant list database. R package version 0.3.0. https://github.com/helixcn/plantlist/

Zheng, H., Gao, J., Teng, Y., Feng, C., & Tian, M. (2015). Temporal variations in soil moisture for three typical vegetation types in Inner Mongolia, Northern China. *PLoS One*, 10, e0118964. https://doi.org/10.1371/journal.pone.0118964

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