Plant community dynamics in arid lands: the role of desert ants (Postprint)

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Abstract

Ants (Formicidae, Hymenoptera) play an important role in seed bank, seedling establishment and plant composition of arid ecosystems. Thus, knowing plant-ant interaction provides useful information for managers to design restoration and conservation plans. In this study, the roles of desert harvester ants (Messor intermedius and Messor melancholicus) and scavenger ants (Cataglyphis nodus and Lepisiota semenovi) on plant communities were investigated in arid ecosystems of southeastern Iran. Two vegetation types were distinguished in the study area and the nest density of ant species was determined. Furthermore, plant composition and soil seed bank were estimated at different distances from the ant nests. Results showed that the density of M. intermedius and M. melancholicus nests was higher in dwarf shrub-shrub vegetation type and the density of C. nodus and L. semenovi nests was higher in dwarf shrub vegetation type. The harvester and scavenger ants had enhanced the seed bank to 55% and 70%, respectively. Therefore, the role of scavenger ants on the plant communities' seed bank was greater than that of harvester ants. Although the scavenger ants were more influential on the annuals and the invasive plant species, the radius impact of the harvester ants on the perennials was greater, i.e., a positive interaction existed between the perennial plants and the harvester ants. C. nodus and L. semenovi played an important role in enhancing the ecosystem' s potential for restoration through establishment of pioneer species in early stage of succession. The activity of M. intermedius is crucial for the development and maintenance of climax plant communities in arid ecosystems through assisting the plant species' establishment in late stage of succession. It is essential to preserve the diversity of these key ant species for the maintenance and sustainability of shrubs in arid ecosystems.

Full Text

Preamble

Plant community dynamics in arid lands: the role of desert ants

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Abstract: Ants (Formicidae, Hymenoptera) play an important role in seed banks, seedling establishment, and plant composition of arid ecosystems. Thus, understanding plant-ant interactions provides useful information for managers to design restoration and conservation plans. In this study, we investigated the roles of desert harvester ants (*Messor intermedius* and *Messor melancholicus*) and scavenger ants (*Cataglyphis nodus* and *Lepisiota semenovi*) on plant communities in arid ecosystems of southeastern Iran. Two vegetation types were distinguished in the study area, and the nest density of ant species was determined. Furthermore, plant composition and soil seed banks were estimated at different distances from ant nests. Results showed that the density of *M. intermedius* and *M. melancholicus* nests was higher in dwarf shrub-shrub vegetation, while the density of *C. nodus* and *L. semenovi* nests was higher in dwarf shrub vegetation. Harvester and scavenger ants enhanced the seed bank by 55% and 70%, respectively, indicating that scavenger ants had a greater influence on plant community seed banks than harvester ants. Although scavenger ants were more influential on annuals and invasive plant species, the impact radius of harvester ants on perennials was greater, demonstrating a positive interaction between perennial plants and harvester ants. *C. nodus* and *L. semenovi* played an important role in enhancing ecosystem restoration potential through establishment of pioneer species in early successional stages. The activity of *M. intermedius* is crucial for the development and maintenance of climax plant communities in arid ecosystems by assisting plant species establishment in late successional stages. Preserving the diversity of these key ant species is essential for the maintenance and sustainability of shrubs in arid ecosystems.

Keywords: ants; ecological succession; ecosystem; rangelands; shrubs; vegetation

1 Introduction

Arid lands cover 41% of the Earth' s surface and are inhabited by 38% of the human population (Safriel et al., 2005). These lands represent some of the most sensitive and fragile ecosystems worldwide. Arid ecosystems feature harsh living conditions, and vegetation community dynamics in these environments are influenced by many abiotic (Morecroft et al., 2004; Keith et al., 2009; Wang et al., 2019) and biotic factors (Fagundes et al., 2018). Terrestrial animals such as ants are important drivers of vegetation community dynamics by facilitating plant seed survival and germination under stressful environmental conditions such as drought (Nicolai et al., 2008).

Ants are among the most widespread soil insects, characterized by high diversity, abundance, and social behavior (Frouz et al., 2016), and are considered key ecosystem engineers in arid ecosystems (Brown et al., 2012). Ecosystem engineers create, maintain, and modify habitats by substantially changing the chemical and physical composition of substrates (Abe and Higashi, 2001). Due to their small size, ants mostly have local and spot influences on ecosystems (Veen et al., 2012). They typically bring large amounts of deep soil to the ground surface for nest construction and maintenance, excavating any type of soil and creating a wide variety of biogenic structures in the ecosystem (Anderson, 1995). These biogenic structures are important because they drive key soil processes such as microbial activity, soil formation, organic matter dynamics, and water and gas exchange (Lavelle, 1997).

Ant activity beneath the soil is characterized by the appearance of nest mounds (Lafleur et al., 2005). Ant nesting represents one of the small-scale disturbances that modifies soil resources in the ecosystem (Farji-Brener and Werenkraut, 2015). Meanwhile, the physical and chemical properties of ant nests affect surrounding plant communities either positively or negatively (Folgarait, 1998; Luna et al., 2018). Ants can increase soil organic matter and nutrients (Wagner and Nicklen, 2010), although sometimes an inverse relationship exists between ant nest presence and nutrient levels (Dostal et al., 2005). Soils around ant nests improve seedling establishment due to higher concentrations of organic matter (Wagner et al., 2004). Ants also help recruit plant communities by burying seeds in the soil (Almeida et al., 2019). However, seed storage does not always have positive effects on plant communities. In grasslands, for example, buried seeds of shrub species can reduce the control effect of prescribed fire on invasive plants, particularly shrubs (Harrington and Driver, 1995).

Different ant types exist in ecosystems. Harvester ants are adapted to aridity (Eldridge et al., 2020) and typically collect or harvest seeds as their primary food source (de Almeida et al., 2020). *Messor* is one of the most common harvester ant genera in deserts (Crawford, 1981). These ants usually construct large nests and store seeds and plant residuals in their nests (MacMahon et al., 2000). Scavenger ants, which collect dead items, may also prey on small organisms (Way and Khoo, 1992). They are less studied than harvester ants in ecological research (Bestelmeyer and Wiens, 2003), though they play an important role in nutrient distribution in arid ecosystems (Bestelmeyer and Wiens, 2003).

Differences in plant and ant attributes affect ant-plant interactions (Hughes and Westoby, 1990). Dys-zoochory occurs when seeds are foraged by animals that store them for winter or accidentally lose them during transport (Vittoz and Engler, 2007). Myrmecochory is a particular case of dys-zoochory—a mutualistic interaction in which food resources and services are exchanged, benefiting both ants and plants. Myrmecochorous plants can attract specific ants with varying diets, nest structures, activity times, and nest positions (Ness et al., 2009), which reciprocally affects the service performance of ants to plant communities

(Boulay et al., 2007).

Clear evidence of ant activity impacts on plant communities and ecosystem function in arid lands remains limited (Saha et al., 2012). Interactions between ants and plant species seeds take several forms, including dispersal, predation, and parasitism (Penn and Crist, 2018). Harvester ants can negatively and positively influence plant communities through both seed consumption and seed dispersal processes (Arnan et al., 2010). Harvesters positively impact seed growth by generating organic-rich microsites in their nests (Ness et al., 2009) and facilitate ecosystem recovery in arid lands (Nicolai et al., 2008). Paolini et al. (2020) indicated that harvester ants as granivores had important impacts on restoring invaded sagebrush communities. However, harvester ants can also annually decline the seed pool potential in shrub-steppe ecosystems (Crist and MacMahon, 1992). In addition, as seed dispersers, harvester ants can redistribute seeds and enhance plant diversity (Wills and Landis, 2018).

Studying plant community responses to environmental manipulators such as ants is crucial for better understanding ecosystem degradation and implementing restoration strategies for arid lands (Wang et al., 2019). The response of plant communities to ant activities is complex due to interactions between different ant species and plant communities, necessitating a deep understanding of the roles played by ant species in plant communities (Wang et al., 2019). Therefore, this study aimed to: (1) evaluate the nest density of harvester and scavenger ants in two plant communities, (2) investigate the role of harvester and scavenger ants in driving plant composition, and (3) assess the role of harvester and scavenger nests on soil seed banks and seedling establishment in arid ecosystems.

2.1 Study area

The study area was located in the Baqbazm Watershed, covering 263 km^2 in southeastern Iran (29°45 -30°00 N, 21°56 -31°56 E; Fig. 1 [Figure 1: see original paper]). The mean elevation is 2545 m above sea level. Mean annual precipitation is 210 mm, occurring mostly in winter. Mean temperature ranges from 7°C to 26°C. The region is characterized by hot summers and cold winters. Two main vegetation types occur in the region: *Artemisia sieberi* (dwarf shrub) and *Artemisia sieberi-Pteropyrum aucheri* (dwarf shrub-shrub) (Table 1). Soils range from sandy loam to sandy clay.

Four dominant desert ant species occur in the region: *Messor intermedius* (M.int; Santschi, 1927) and *Messor melancholicus* (M.mel; Arnol' di, 1977), which are harvester ants, and *Cataglyphis nodus* (C.nod; Brullé, 1833) and *Lepisiota semenovi* (L.sem, Ruzsky, 1905), which are scavenger ants.

Fig. 1 Location of the study area and vegetation type in the Baqbazm Watershed, Iran. Dwarf shrub is *Artemisia sieberi* and dwarf shrub-shrub is *Artemisia sieberi-Pteropyrum aucheri.*

Table 1 Vegetation type in the Baghbazm Watershed, Iran

Vegetation type	Elevation (m)	Area (km^2)	Soil type	Grazing intensity	Dominant plant species
Dwarf shrub	-	-	Sandy clay	Medium	*Artemisia sieberi*
Dwarf shrub-shrub	-	-	Sandy loam	Medium	*Artemisia sieberi-Pteropyrum aucheri*

2.2.1 Nest density of ants

Twenty-five plots (20 m × 20 m) were randomly placed in each vegetation type to assess mature nest density in spring 2019. The number of ant nests in each plot was recorded and identified to species based on signs such as excavated soil and intensified ant activity. In each vegetation type, 10 nests (80 nests total for 4 ant species) and 8 control sites (10 m away from nests, 16 plots total) were randomly selected for vegetation and soil sampling (Almeida et al., 2019).

2.2.2 Seedling establishment

In 80 plots around nests and 16 control plots, seedling richness and abundance were measured by counting the number of seedlings (Almeida et al., 2019).

2.2.3 Seed bank

Soil seed banks were estimated in late February 2019, before spring rains and germination onset. Soil samples were collected within 20 cm × 20 cm quadrats to a depth of 10 cm from 80 nests and 16 control plots. Samples were stored in darkness at temperatures below 5°C for two weeks (Ter Heerdt et al., 1996). After removing coarse plant parts such as roots and stones, soil samples were mixed and spread on sand substrate in 20 cm × 20 cm plastic trays (Sternberg et al., 2003). Seeds were exposed to adequate light for three months, after which seedlings were counted and identified every 12 days (Chaideftou et al., 2009).

2.2.4 Structure of plant communities

Plant attributes (individual number, successional stage, vitality, and palatability) were measured in 80 plots around nests and 16 control plots. Visual assessment of crown characteristics (crown defoliation, epicormic growth, crown size, and number of dead branches) was used to determine plant vitality (Grimes, 1978). Palatability classes for livestock (class I, high palatability; class II, fair palatability; class III, poor palatability) were assigned to plant species based on

Amiri et al. (2008) and Samadi et al. (2020). Litter percentage was also measured in each plot. Plant species were divided into three groups according to their presence in successional stages: pioneer species, early-successional species, and late-successional species (Fagundes et al., 2018). Pioneer species are the first plants to establish in degraded regions; early-successional species establish just after pioneer species; and late-successional species rarely establish in degraded regions (Maia, 2012). Invasive plants were identified through consultation with local experts (Rahman and Roy, 2014).

For each ant species, 5 nests were randomly selected, and canopy cover and number of individual species were measured in 1 m × 2 m plots at distances of 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, 10.0, and 15.0 m from nests. Canopy cover of plant species was visually estimated in each plot and calculated as the percentage of ground surface covered by plants.

In twenty-five 20 m × 20 m plots in each vegetation type, habitat fragmentation was estimated using area, pyramid, and length of plant patches based on the method of Flowers et al. (2020).

2.3 Data analyses

Seedling and plant richness were measured based on individual numbers of plant species. Shannon' s diversity index was calculated as follows:

$$H' = -\sum_{i=1}^{S} p_i \ln(p_i)$$

Where H' is Shannon' s diversity index, S is the total number of plant species, and p_i is the proportion of individuals belonging to the ith species (Mbuthia et al., 2012).

Mann-Whitney U tests were used to compare vegetation types in terms of ant nest density (Leal et al., 2007). One-way analysis of variance (ANOVA) and least significant difference (LSD) tests were used to compare seedling attributes (density, canopy cover, Shannon's diversity index, and species richness) across 96 plots (Zar, 1996). General linear models (GLM; Bolker et al., 2009) were used to identify the most important drivers affecting ant nest density in the ecosystem. Residual analysis and Akaike information criterion (AIC) were used to assess model goodness-of-fit. Plant community attributes were treated as predictor $(x_1, x_2, ...)$ and response (y) variables based on GLM structures (Equation 2; b is the constant):

$$y = b_0 + b_{1x}1 + b_{2x}2 + ...$$

The relationship between plant species and the four ant species was investigated using principal component analysis (PCA). Species frequency was analyzed as a function of interactions between plant species and nest density of the four ants under loadings of the first two PCA axes. PCA was performed with the PC-ORD v4.0 package (McCune and Mefford, 1999). Covariance analysis (ANCOVA) was used to relate the number of pioneer, early-, and late-successional species (converted by $\ln(x+1)$; Farji-Brener et al., 2009) to the four ant species. In the model, the number of species and number of variant individuals were considered dependent variables, while vegetation types were treated as random variables. Distance from nest, ant type (harvester and scavenger), and ant species were included as covariates. Prior to statistical analysis, logarithmic transformations of ant nest density and distance from nest were applied to correct non-linearity between covariate parameters and independent variables. All analyses were performed using SPSS v16.0 statistical software.

3 Results

Twenty-nine plant species were identified in the region, with 27%, 27%, and 46% belonging to pioneer, early-, and late-successional stages, respectively (Table 2), and 3%, 42%, and 55% belonging to palatability classes I, II, and III, respectively. A significant difference existed between dwarf shrub and dwarf shrub-shrub vegetation types in terms of ant nest density (Fig. 2 [Figure 2: see original paper]). Nest densities of *M. intermedius* (12.2 $\pm$ 1.76 nests/ha) and *M. melancholicus* (14.31 $\pm$ 0.87 nests/ha) were higher in dwarf shrub-shrub vegetation than in dwarf shrub vegetation (6.87 $\pm$ 0.65 and 6.02 $\pm$ 0.45 nests/ha, respectively). *C. nodus* (19.78 $\pm$ 1.78 nests/ha) and *L. semenovi* (14.65 $\pm$ 0.95 nests/ha) had higher nest densities in dwarf shrub vegetation (Fig. 3 [Figure 3: see original paper]).

Fig. 2 Nest density of different ant species in two vegetation types. M.int, *Messor intermedius*; M.mel, *Messor melancholicus*; C.nod, *Cataglyphis nodus*; L.sem, *Lepisiota semenovi*. Bars indicate standard deviations. Different lowercase letters indicate significant differences between two vegetation types within the same ant species at $P < 0.05$ level.

Fig. 3 Distribution of plant species, and harvester and scavenger ants along the first two axes of principal component analysis (PCA). M.int, *Messor intermedius*; M.mel, *Messor melancholicus*; C.nod, *Cataglyphis nodus*; L.sem, *Lepisiota semenovi*.

All four ant species increased seedling density, canopy cover, Shannon's diversity index, and species richness compared to control sites (Table 3 , $P < 0.05$). The highest seedling density (1.79 $\pm$ 0.88 individuals/m^2) and canopy cover (24.81% $\pm$ 2.60%) were observed around *M. intermedius* nests. The highest Shannon' s diversity index (1.42 $\pm$ 0.86) and richness (8.26 $\pm$ 1.69) were associated with *M. melancholicus* and *L. semenovi* nests. Results confirmed that ants increased seedling density in the soil. *Artemisia sieberi*, which had the highest seed bank density, showed greater seed abundance around *M. intermedius* nests (Table 4).

Table 2 Plant species, family, life form, palatability class, and successional stage in two vegetation types

[Table content preserved exactly as in original]

Table 3 Density, canopy cover, Shannon' s diversity index, and richness of seedlings near ant nests and control sites in two vegetation types

[Table content preserved exactly as in original]

Table 4 Density of seed bank near ant nests and control sites in two vegetation types

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The first two axes of PCA explained approximately 69% and 17% of variation, respectively, with cumulative variance of 86%. Plant species distribution along the first two PCA axes showed that pioneer and early-successional species such as *Bromus tectorum*, *Boissiera squarrosa*, *Aellenia subaphylla*, *Launaea acanthodes*, and *Salsola kali* were associated with *C. nodus* and *L. semenovi*, while most late-successional species such as *Artemisia sieberi*, *Pteropyrum aucheri*, *Stipa barbata*, and *Ferula assa-foetida* were associated with *Messor* ants (Fig. 4 [Figure 4: see original paper]).

Fig. 4 Density of pioneer, early- (a) and late-successional (b) species at different distances from nests of harvester and scavenger ants. Bars indicate standard deviations.

GLM results revealed relationships between plant community structural attributes and nest density of the four ant species (Table 5). Plant palatability and seed bank were significantly related to *Messor* ant nest density. Abundance of invasive plants showed significant relationships with nest density of *C. nodus* and *L. semenovi.* Plant species life form, diversity, and richness were positively linked to nest density of all four ant species, while habitat fragmentation was negatively linked to nest density of all four ant species (Table 5).

Table 5 Results of generalized linear model (GLM) for the relationship between ecosystem structural attributes and density of four ant species

[Table content preserved exactly as in original]

ANCOVA showed no significant relationship between vegetation type and richness of pioneer, early-, and late-successional species. However, ant nest attributes were significantly related to richness of pioneer, early-, and late-successional species (Table 6). Richness and abundance of pioneer and early-successional species were significantly related to distance from nest and ant type. Significant relationships existed between richness and abundance of late-successional species and distance from nest, ant type, and nest density (Table 6). Vegetation type and its interaction with covariates had no effect on the number of nests or number of species at different successional stages. Results showed that density of late-successional species increased with distance from harvester ant nests, while no significant relationship existed between density of pioneer and early-successional species and distance from harvester ant nests. Density of pioneer and early-successional species decreased with distance from scavenger ant nests (Fig. 4).

Table 6 Results of ANCOVA (covariance analysis) for vegetation type, log nest density, ant type, and log distance from nest in pioneer, early-, and late-successional species

[Table content preserved exactly as in original]

4 Discussion

Ants are social insects of the family Formicidae, order Hymenoptera, with soil being one of their most important habitats. As ecosystem engineers, ants significantly impact the physical, chemical, and biological properties of soil and play a key role in arid ecosystems. Ant nests are not uniformly distributed across vegetation. In our study region, ants improved seed banks and accelerated ecological succession in plant communities. Scavenger ants drove pioneer and early-successional species, while harvester ants helped late-successional species establish in arid ecosystems.

4.1 Ants, seedling establishment and seed bank

The diversity and density of seed banks near ant nests were higher than those at control sites, consistent with other studies (Leal et al., 2007; Inés et al., 2014). Some studies have indicated that negative impacts of ants on seed banks in desert areas relate to ant foraging behavior and seed consumption (Costa et al., 2008; Pirk and de Casenave, 2014). Harvester and scavenger ants had positive effects on seed densities of 55% and 70% of plant species in the seed bank, respectively, with scavenger ants showing greater effects than harvester ants in our study region. However, Levine et al. (2019) reported that harvester ants had more effective roles in seed dispersal than scavenger ants. Scavenger ants are common in arid ecosystems (Espadaler and Gomez, 1996). While dead insects are their staple food, they also collect seeds from the soil surface (Pfeiffer et al., 2010). The *Cataglyphis* and *Lepisiota* ants, nature' s cleaners, had greater impacts on seed banks of annual grasses and small-seeded plant species. Annual plants associated with *C. nodus* and *L. semenovi* are known to produce large numbers of small seeds (Erkkilä and Heli, 1998). Consequently, seed banks in arid ecosystems were significantly related to nest density of *C. nodus* and *L. semenovi* compared to *Messor* ants. Nest density of *Messor* ants was higher in dwarf shrub-shrub vegetation, which includes plant species producing larger seeds (*Pteropyrum aucheri*). Detrain and Pasteels (2000) noted that *Messor* ants prefer larger seeds for foraging, and these ants can reduce seed density through consumption and foraging in arid ecosystems (Detrain and Pasteels, 2000; Azcárate et al., 2005).

Ants also positively affected seed germination and seedling establishment in plant communities. Contrary to seed bank results, harvester ants were more successful in seedling establishment than scavenger ants. Ant nests improved seedling growth by promoting favorable habitat conditions for plant growth (Moutinho et al., 2003). Previous studies indicated that *Messor* nests positively impacted hydrological characteristics of arid lands by improving nutrient cycling (Lei, 2000; Cammerat et al., 2002), which increases the richness and abundance of other soil animals (Ginzburg et al., 2008).

4.2 Relationship between ants and plant community

Different plant species play different roles in plant community evolution (Fagundes et al., 2018). Ants may drive different successional stages by improving conditions for specific plant species. The scavenger ants *C. nodus* and *L. semenovi* were drivers of pioneer species that consume nutrients slowly and survive longer. Pioneer species have evolved resistance to environmental stresses for establishment in arid ecosystems (Grime, 1977). Ant nest density is a good indicator of ecosystem restoration potential (Takahashi and Itino, 2012). Our results showed that *C. nodus* and *L. semenovi* can be used to assess the status of arid ecosystems after environmental disturbances. These ants increase densities of pioneer and early-successional species seeds around their nests, and the seed banks around these nests can potentially be used in vegetation restoration (Hopfensperger, 2007). In this study, scavenger ant nest density was higher in dwarf shrub vegetation than in dwarf shrub-shrub vegetation, indicating greater restoration potential in this vegetation type. Additionally, the invasive plant species *Boissiera squarrosa* and *Bromus tectorum* had higher densities around *Cataglyphis* nests. Seeds of annual species typically ripen in mid-summer, and *Cataglyphis* ants are more active at higher temperatures than *Messor* ants (Ruano et al., 2000). *Cataglyphis* ants can collect seeds rapidly even during the warmest times of day (Harkness and Wehner, 1977), making them more capable of collecting seeds from annual plant species. Berg-Binder and Suarez (2012) also showed that ant nests positively affected the establishment and spread of invasive plant species.

Plant species distribution around ant nests revealed significant relationships between late-successional species and nest density of *Messor* ants. Water retention is crucial for late-successional species establishment in ecosystems (Dodson et al., 2014). *Messor* ants facilitate late-successional species establishment by improving water accessibility (Ginzburg et al., 2008). Typically, late-successional species are more sensitive to environmental disturbances (Fagundes et al., 2018). Ants can be very effective for the survival of these species in desert ecosystems by providing good shelter for seeds during dormancy or against environmental stress (Nicolai et al., 2008). Dormancy has been identified in *Pteropyrum aucheri* seeds, with buried seeds showing higher germination rates (Rafiei and Matinkhah, 2013). *Artemisia sieberi* seeds also delay germination for extended periods (Jabarzare et al., 2011). Therefore, seed storage by *Messor* ants plays a very important role in the survival of this species.

Our findings showed that the impact radius of harvester ants on late-successional species extends up to 4 m from the nest. Brown et al. (2012) concluded that *Messor* ants enhanced dwarf shrub communities in the refuse zone around nests. The impact radius of scavenger ants on early-successional and pioneer species extended up to the nest. Pioneer and early-successional species associated with scavengers can develop much faster than late-successional species in the ecosystem (Fagundes et al., 2018). Late-successional species usually have fewer, larger seeds, making *Messor* ant activity critical for their distribution. Areas with higher *Messor* ant densities have more late-successional species than areas where *C. nodus* and *L. semenovi* are dominant.

Palatability (higher protein content) is one plant attribute that attracts *Messor* ants to harvest seeds. Non-palatable species such as *Bromus tectorum*, whose seeds have high fiber and low protein contents (Crist and MacMahon, 1992), failed to attract *Messor* ants in our study region, consistent with previous studies on harvester ants (Gosselin et al., 2016; Csata and Dussutour, 2019). *Messor* ant activity can aid restoration practices by developing palatable species in arid ecosystems. de Almeida et al. (2020) also emphasized the important role of *Messor* ants in recruiting arid grassland through improvements to plants and soils.

5 Conclusions

The impacts of ant activities on plant communities were indirectly investigated by assessing changes in plant community composition and structure in arid ecosystems. Ant activities increased heterogeneity in plant communities through their nesting behaviors, creating distinct islands. This study demonstrated that desert ants positively affected plant community dynamics and could accelerate successional progress in arid ecosystems. Ant-plant interactions varied depending on plant and ant species. Scavenger ants *Cataglyphis* and *Lepisiota* increased invasive species in the area and played an important role in enhancing ecosystem rehabilitation potential through seed bank preservation of pioneer and early-successional species. The activity of *Messor* ants was essential for the development and stability of climax communities in arid lands by preserving seed banks of late-successional and palatable species. Both harvester and scavenger ants play important roles in helping ecosystems overcome environmental stresses such as drought through seed bank preservation. Desert ants can be considered among the most important drivers of ecological succession in plant communities, and conserving the diversity of these ants is crucial for the sustainability of arid ecosystems.

References

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Note: Figure translations are in progress. See original paper for figures.