Journal of Asia-Pacific Biodiversity xxx (2017) 1–7

JAPB
Supported by National Science Museum of Korea Korea National Arboretum

Contents lists available at ScienceDirect

Journal of Asia-Pacific Biodiversity

journal homepage: http://www.elsevier.com/locate/japb

Journal of Asia-Pacific Biodiversity

Original article

Ants foraging on grasses in South Korea: high diversity in the Jeju island and negative correlation with aphids

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A R T I C L E I N F O

Article history:
Received 22 February 2017
Received in revised form
15 May 2017
Q1 Accepted 10 June 2017
Available online xxx

Keywords:
ants
Aphididae
diversity
foraging
grassland

A B S T R A C T

In South Korea, insects inhabiting grasslands have been decreasing in population sizes and are vulnerable to environmental changes, because grasslands have greatly decreased in area due to the vegetation change (the nationwide reforestation). This study aimed to find the difference of ant assemblages on grasses between the mainland with small fragmented grasslands and the Jeju island with large grasslands. In addition, a relationship between aphid and ant abundance was examined. Sampling was carried out by sweeping at 24 grassland sites in eight cities/counties in the mainland and 27 grassland sites in the Jeju island. Species richness was higher in the Jeju island than in the mainland. Species composition and species abundance structure were quite different between the two regions. Southern ant species have adapted to the warm climate that predominates in the Jeju island, and have contributed to the high diversity and the characteristic species composition in the Jeju island. Abundance of ants was negatively correlated with that of aphids. A hypothesis for the unexpected negative correlation was proposed.

Introduction

Grasses lack the complexity of habitat structure and secondary compounds, but insect diversity is not decreased (Tscharntke and Greiler 1995). Grasslands and forests are the main habitats of terrestrial insects. Grasslands have decreased greatly in areas as the denuded mountains have been forested in South Korea (Bae and Lee 2006), and insects inhabiting grasslands have decreased greatly in population sizes and have been vulnerable to the recent environmental changes such as climate change and land use. Kwon et al (2010) reported that the northern grassland butterfly species Q2 decreased most greatly due to the influences of the climate warming and the nationwide forestation. Large natural grasslands are nearly absent in the mainland of South Korea, and only small grass patches are present along stream and river sides and banks, burned forests, forest edges, roadsides, parks, abandoned fields, and around arable lands. Meanwhile, in the Jeju island, grasslands occupy large areas along beaches, and in the numerous large pastures scattered in the Q3 mid-altitude mountain slides and from high altitudes (> 1,600 m) to the mountain top of the Halla mountain. Furthermore, warm climate and vicinity to southern Asia may provide the opportunity for invasions of southern insect species in this island (Joo et al 2008). Therefore, a diverse and characteristic insect fauna with numerous southern insect species has been produced in the Jeju island (Joo and Kim 2002; Jung 2001; Seo and Jung 2004).

Ants are the dominant insects in most terrestrial ecosystems. They prey on other insects, and feed on dead arthropods and living and dead plants, and honeydew from aphids and plants (Hölldobler Q4 and Wilson 1990). Ants are numerically and behaviorally dominant insects in grasslands as well as in forests (Alsina et al 1988; Pfeiffer et al 2003). In grasslands, ants play key functions with respect to nutrient dynamics, and have many direct and indirect influences on the performance of above ground insects (Tscharntke and Greiler 1995). In South Korea, ant assemblages are different between open habitats such as burned forests and closed habitats such as forests (Kwon et al 2013). However, most ant species occur in both habitats. Four ant species, *Formica japonica*, *Camponotus japonicus*, *Tetramorium caespitum*, and *Lasius japonica*, occur abundantly and frequently in open habitats, and, therefore, these species are considered as indicator species for open habitats and disturbed forests (Kwon et al 2013). However, these open habitat species occur also in forested areas (Kwon et al 2012). Thus, the obligate habitat specialist ant species are nearly absent in South Korea.

Therefore, the species abundance structure is more different between two habitat types compared to the species composition.

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Peer review under responsibility of National Science Museum of Korea (NSMK) and Korea National Arboretum (KNA).

http://dx.doi.org/10.1016/j.japb.2017.06.002
pISSN2287-884X eISSN2287-9544/

Please cite this article in press as: Kwon T-S, Ants foraging on grasses in South Korea: high diversity in the Jeju island and negative correlation with aphids, Journal of Asia-Pacific Biodiversity (2017), http://dx.doi.org/10.1016/j.japb.2017.06.002

For example, when a forest was disturbed by insect pests and/or heavy rainfall, the open habitat preferring species such as *F. japonica* and *L. japonicus* increased in abundance with the decrease of the forest preferring ant species such as *Aphaenogaster japonica* and *Pheidole fervida* (Kwon et al 2014b). Despite the long study on Korean ant fauna, no study on ants foraging on grasses has been reported to date. The case is similar in other regions. As ants forage on grasses, they are likely to have a great influence on herbivorous (sucking and chewing) insects, predator arthropods, and parasitic insects, because of their aggressiveness towards other insects.

Workers of the open habitat ant species are likely to forage abundantly on grasses. In the Jeju island, some southern open habitat ant species rarely found in the mainland are expected to forage on grasses with the four common open habitat ant species. Honeydew of aphids is one of the main target foods for ants foraging on herbs and trees (Stadler and Dixon 2005). Therefore, it is hypothesized that an abundance of ants foraging on grasses is positively correlated with that of aphids sucking grasses. This study aimed to find whether or not ant species foraging on grasses are different between the mainland and the Jeju island, and to test the correlation between ants and aphids. Generally, species richness (number of species) is higher in the large area than in the small area (Rosenzweig 1995). Therefore, it is expected that species richness of ants foraging on grasses is higher in the mainland than in the Jeju island. Finally, this prediction was examined.

Materials and methods

Ants were sampled at 24 grassland sites in the mainland, and at 27 grassland sites in the Jeju island (Appendix 1). There were grasses and herbs at the sites without shrubs and trees. The counties range from the southernmost county (Goseong) to the northernmost county (Cheolwon). Sites within a county were separated by more than 5 km. In the Jeju island, sites were selected widely throughout the whole region of the island. Using data of latitude, longitude, and altitude of sites, the mean annual temperatures of sites were calculated by the regression model of Kwon et al (2012) that were made from the climate data of 365 sites. Ants and aphids were sampled by the sweeping net (diameter 38 cm, pole length 50 cm). At each site, the grasses were swept 60 times over while walking linearly about 30–40 m. Ants were identified to the species level by the Korean ant key (Kwon et al 2012), and the number of aphids was counted without the identification of species. The samples (100% ethyl alcohol preserved) of aphids and ants were deposited at the Insect Diversity Laboratory in the National Institute of Forest Science.

Species richness (number of species) was estimated using the Chao 1 index of EstimateS version 9 (Colwell 2013). Mean and standard deviation (SD) of species richness were calculated in terms of the number of sites. Difference of species richness between the mainland and the Jeju island was examined by the two sample *t* tests using the values of mean and SD following Zar (1999). The numbers of sites are different (i.e. 27 sites of the Jeju island *vs.* 24 sites of the mainland), therefore the mean and SD values at the minimum value (24 sites) were used for the two sample *t* tests. Pearson correlation analysis of R (R Core Team 2014) was used for the correlation between aphid and ant abundance. In the correlation analysis, sites without aphids and ants were excluded (3 sites in the mainland, and 4 sites in the Jeju island; Appendices 2 and 3). The nonparametric Wilcoxon signed-rank test was used for comparison of abundance and richness between two regions due to the low fitness of data with the normal distribution. The χ^2-test was used to find the significant difference of occurrence (number of occurred sites) with the contingency table of 2 × 2 cells (presence *vs.* absence; the mainland *vs.* the Jeju island).

Results

The ant species collected are shown in Table 1, and the data for the ants and aphids at each site is provided in Appendix 2 (mainland) and Appendix 3 (Jeju island). The mean annual temperatures of the sites are 10.8 ± 1.66°C (mean ± SD, range 7.34–13.3°C) in the mainland, and 13.78 ± 0.56°C (range 12.29–14.38°C) in the Jeju island, showing a significant difference (t test, df = 27.543, $p < 0.0001$) and higher variation in the mainland. Fourteen ant species were collected (Table 1) with eight species in the mainland and 10 species in the Jeju island. Of the 14 species, only four species,

Table 1. Ant species collected in the main island and the Jeju island. Occurrence is proportion (%) of occurred sites, and abundance is number of individuals. The χ^2-test was used to find the significant difference of occurrence (number of occurred sites) with the contingency table of 2 × 2 cells (presence *vs.* absence; the mainland *vs.* the Jeju island). Significance in the χ^2-test and the Wilcoxon signed-rank (WSR) test.

Species	Mainland ($n = 24$)		Jeju ($n = 27$)		Occurrence	Abundance
	Occurrence (%)	Abundance (mean ± SE)	Occurrence (%)	Abundance (mean ± SE)	χ^2-test	WRS-test
Camponotus japonicus	8.33	0.08 ± 0.06	3.70	0.07 ± 0.07	ns	ns
Camponotus sp. 2			7.41	0.07 ± 0.05	ns	ns
Formica japonica	33.33	0.83 ± 0.30	3.70	0.07 ± 0.07	*	‡
Lasius japonicus	25.00	0.67 ± 0.29	37.04	4.22 ± 2.41	ns	ns
Lasius spathepus			3.70	0.33 ± 0.33	ns	ns
Monomorium chinense			14.81	0.93 ± 0.59	ns	*
Monomorium intrudens	8.33	0.21 ± 0.17			ns	ns
Myrmica kotokui	4.17	0.04 ± 0.04			ns	*
Nylanderia yaeyamensis			11.11	0.11 ± 0.06	ns	ns
Ochetellus itoi			44.44	1.78 ± 0.74	ns	§
Pheidole noda			3.70	0.04 ± 0.04	ns	ns
Pristomyrmex pungens	8.33	1.63 ± 1.39	11.11	0.48 ± 0.35	ns	ns
Temnothorax sp. 3	4.17	0.04 ± 0.04			ns	ns
Temnothorax sp. 4	4.17	0.21 ± 0.21			ns	ns
Ants (number of species)		0.96 ± 0.20		1.41 ± 0.28		ns
Ants (number of individuals)	62.5	3.71 ± 1.54	66.67	8.11 ± 2.81	ns	ns
Aphids (number of individuals)	50.00	6.96 ± 2.47	62.96	4.85 ± 1.46	ns	ns

* $p < 0.1$.
† $p < 0.05$.
‡ $p < 0.01$.
‡ $p < 0.001$.
§ $p < 0.0001$.
ns = not significant; SE = standard error.