JEE
ISSN: 2288-1220
https://doi.org/10.5141/jee.23.050
Journal of Ecology and Environment (2023) 47:24

RESEARCH

Comparison of terrestrial insect communities associated with the crabgrass (*Digitaria ciliaris*) community, Korea

Jeong Ho Hwang* and Jong-Hak Yun

Wetland Center, National Institute of Ecology, Changnyeong 50303, Republic of Korea

ARTICLE INFO
Received August 29, 2023
Revised November 22, 2023
Accepted December 8, 2023
Published on December 19, 2023

***Corresponding author**
Jeong Ho Hwang
E-mail chsh123@naver.com

Background: Crabgrass (*Digitaria ciliaris*, Poaceae) is a globally distributed weed, including in Afro-Eurasia, America, and Australia. As a highly gregarious plant, crabgrass is an important habitat for a diverse array of insects, and a potential habitat for agricultural pests. To compare the insect communities associated with the crabgrass community, insects were sampled using sweep sampling (100 sweeps per sample) at five sites, including Daejeon (Daejeon and Gap rivers), Anseong, Namhae, and Inje, with a focus on the Daejeon River.
Results: A total of 5,888 individual insects belonging to eight orders, 42 families, and 115 species were collected from the five sites. Both the number of species and individuals of Hemiptera were the highest at all of the sites. In the present study, 73% of the insect population fed on *D. ciliaris* as a host plant. The dominant species in the *D. ciliaris* community was *Laodelphax striatellus* (Delphacidae), being ubiquitous at all the sites which showed a high abundance of rice pests in the communities and the suitability of *D. ciliaris* as an alternative host plant for them. The Shannon–Wiener diversity index was highest in Inje on 17 September (2.88), and the Chao1-bc diversity index was highest in the Gap River on 5 September (80). The sampling efficiency of 100 sweep samples (sample coverage) was calculated to be as high as 90%. The results of the samples taken from September to November in the Daejeon River showed that the number of species and individuals decreased gradually over time, and the number of dominant species decreased sharply between September and October. Similarity analysis indicated that sampling dates that were closer together yielded sampled assemblages with higher faunal similarity. In addition, in each sampling, the difference in the minimum temperature during the two-week period prior to sampling and faunal similarities were negatively correlated.
Conclusions: This study provides foundational data that could enhance our understanding of insect diversity in *D. ciliaris*. The data can facilitate ecological conservation and management of Korean grasslands generally, as well as identification of potential pests that may disperse from *D. ciliaris* communities to nearby farmland.

Keywords: assemblages, grassland, insect diversity, sampling, seasonality, similarity, sweep-netting

Introduction

Crabgrass (*Digitaria ciliaris*, Poaceae) is a globally distributed weed, including in Afro-Eurasia, America, and Australia (GBIF 2023; Rojas-Sandoval and Acevedo-Rodríguez 2022). It is also a common weed found in grasslands and farmlands such as paddy banks and other crop field margins in Korea. In particular, as a characteristic C4 plant, *D. ciliaris* increases its biomass and proportional abundance in the community from late August after the rainy season, when growth conditions are the most suitable (Kim et al. 2012; Lee and Lee 1999). As a widespread and extensively gregarious plant, *D. ciliaris* is a potential habitat for various insects, including agricultural pests. Such pests may directly attack crops and reduce their quality, or act as vectors transmitting viruses to crops (Luisoni and Conti 1970).

Insects using plants as their main habitat or food source often form a distinct association with a specific dominant plant community, so plant communities with a single dominant plant species generally have similar association trends with insects under the same climatic conditions (Farrell et al. 1992; Hwang et al. 2022). Recent studies on insect communities associated with a specific plant community have mainly been related to cultivated plants, whereas studies on insect communities in a specific wild plant community have been rather limited (Frenzel and Brandl 2003; Hwang et al. 2022; Lee et al. 2022).

Because of its ecological and agricultural importance, many studies on vegetation associated with *D. ciliaris* have been conducted. However, to the best of our knowledge, no study has specifically evaluated the insect communities inhabiting *D. ciliaris* (Ahn and Kim 2005; Lee et al. 2018; Shim et al. 2013). This study focused on analyzing the characteristics and similarities of *D. ciliaris* insect communities at different spatiotemporal scales in Korea, comparing insect community composition through quantitative sweep sampling and evaluating the optimal sampling size based on the sampling coverage.

Materials and Methods

Study site characteristics

Insect community samplings in *D. ciliaris* communities were conducted in autumn (September to November) in Korea, when *D. ciliaris* dominates at the highest density (Kim et al. 2012; Lee and Lee 1999). We sampled insects on six different dates to compare their community composition over a time series in the Daejeon River (36.3414° N, 127.4141° E), located in Daejeon city, in 2020. For comparison with other *D. ciliaris* communities, samples were also collected twice at the Gap River, another river in Daejeon (36.370249° N, 127.372875° E), twice in Anseong (37.117019° N, 127.432771° E), and once each in Inje (38.108407° N, 128.179852° E) and Namhae (34.811487° N, 127.835146° E) (Fig. 1, Table S1). The four administrative sites investigated in this study have different climates, variations in latitude, and contrasting average temperatures (KMA 2023). Also, as the study progressed, seasonal temperatures decreased, so we assumed that a site at a higher latitude sampled at an earlier date site would have a similar insect community to a site at a lower latitude sampled at a later date. To test for correlations between insect community similarity and the regional climate, the minimum temperature during the two-week period prior to the sampling date was obtained from the meteorological station closest to each site (KMA 2023). The Daejeon and Gap rivers, located in Daejeon city, are urban rivers with waterside facilities, such as riverside roads, sidewalks, and bicycle roads, whereas the other three sites were in rural environments, with cultivated land, including rice paddies or other crop fields, around them (Fig. 1).

Sampling methods

Terrestrial insect communities associated with the *D. ciliaris* plant community were sampled at the Daejeon River site on 9 September, 9, 18, and 24 October, and 7 and 21 November 2020, between 12:00 and 17:00. We also sampled other regions for comparing insect communities: the Gap River (5 September and 8 November), Anseong (11 and 30 October), Namhae (10 October), and Inje (17 September). According to the National Natural Environment Survey guidelines, *D. ciliaris* communities are determined based on the plants that dominate the uppermost layer by more than 70%, and *D. ciliaris* dominated all the communities in the sites by more than 80% (NIE 2019).

The quantitative sweep sampling method reflects the reality that it is not possible to collect all the species in a studied area. Therefore, it has been used as an effective method for rapidly sampling large numbers of insects to effectively compare the biodiversity of different regions

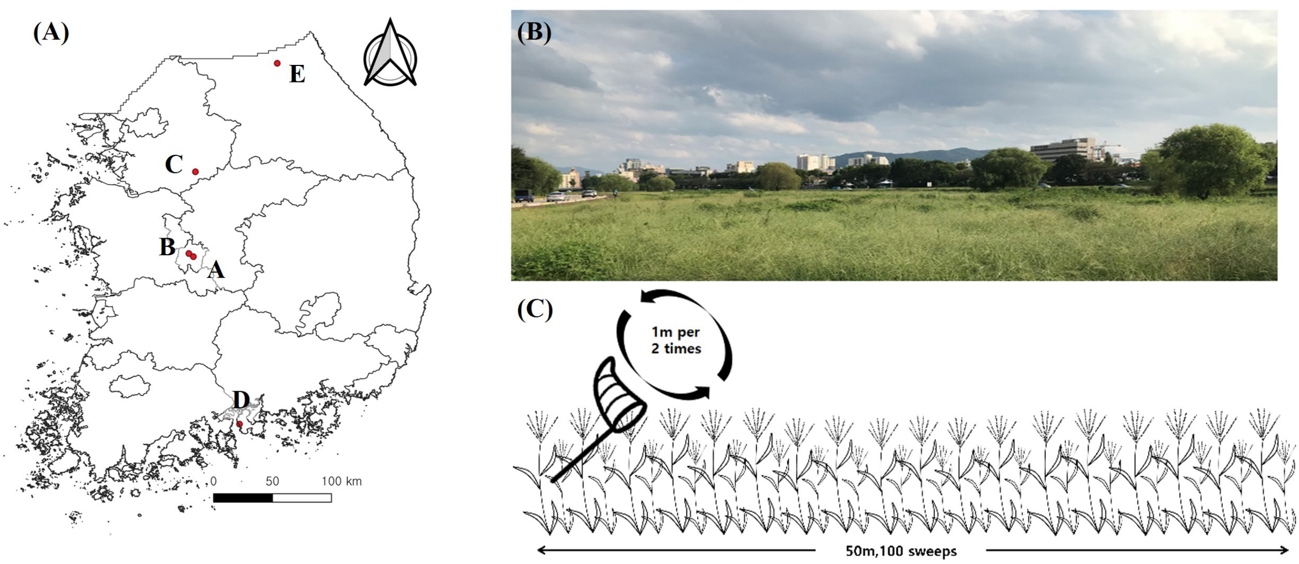

Fig. 1 (A) A map of sampling sites, (B) a panoramic photograph of the *Digitaria ciliaris* grassland in Daejeon River, and (C) a sampling design to collect insects in *D. ciliaris* grassland. In (A), sampling sites are A: Daejeon River; B: Gap River; C: Anseong; D: Namhae; and E: Inje.

(Spafford and Lortie 2013; Yi et al. 2012). Furthermore, the efficiency of sweep sampling in various habitats has been evaluated (Doxon et al. 2011; Hwang et al. 2022; Spafford and Lortie 2013; Swart et al. 2017).

For quantitative statistics at each site, 100 sweeps (50 m transects) were performed in each investigated date (Fig. 1). Insect nets with a total length of 1,200 mm, net depth of 700 mm, and diameter of approximately 300 mm were used. Before sorting, the terrestrial insects collected with 100 sweeps were shaken off into a zipper bag (25 × 30 cm). Afterward, sampled insects were placed in 94% ethanol and sorted in the laboratory before being classified under a stereomicroscope (Olympus SZ1145; Olympus, Tokyo, Japan). Various faunal atlases and papers were referred to for identification (Ahn et al. 2018; An 2011; An and Kim 2020; Hong et al. 2011, 2012; Park et al. 2012; Takizawa 2005), and experts were consulted for species that were difficult to classify. In addition, host plants were searched with various encyclopedias and papers to confirm insect species, and by implication, the percentage of sampled insects, that fed on Poaceae (including *D. ciliaris*) as host plants (Ahn et al. 2018; Bieńkowski and Orlova-Bienkowskaja 2018; Danthanarayana 1967; David et al. 2020; Denno and Perfect 2012; Doopedia 2023a, 2023b, 2023c; Greber 1990; Information of Korean Alien Species 2023; Kim and Kil 2014; Hossain and Kwon 2019; Korea National Arboretum 2023; Knight 1987; Lee 2012; Li et al. 2012; Lodos and Kalkandelen 1983; NIBR 2023a, 2023b, 2023c, 2023d; Park et al. 2018; Takeda 1998; Susumu and Hiroyuki 2010; Teakle et al. 1991; Zhou et al. 2013). The classification system was based on the 2020 National Species List (NIBR 2022). The collected insects were prepared as immersion specimens in 94% ethanol, or dried specimens, and stored at the Natural History Laboratory of the National Science Museum in Daejeon, Korea.

Statistical analysis

For the diversity index, the Shannon–Wiener function (H') derived from the information theory of Margalef (1958) and modified by Lloyd and Ghelardi (Pielou 1966) was used. The dominance index was calculated using McNaughton's dominance index (DI) (McNaughton 1967), the abundance index was calculated using Margalef's (1958) index, and the evenness index was calculated using Pielou's (1975) formula. The Chao1 bias-corrected index (Chao1-bc), which is widely used together with the diversity index and evaluated to have excellent performance, was calculated using the SPADE program (Chao and Shen 2010; Głowacki 2011).

Sørensen's similarity index, an incidence-based similarity measure, and the Bray–Curtis similarity index, an abundance-based measure, which are both generally used to assess community composition and are resistant to sampling errors, were calculated using species prediction and diversity estimation (SPADE) (Beals 1984; Chao and Shen 2010; Giovas 2021; Schroeder and Jenkins 2018; Sørensen 1948). The calculated similarity indices were used to create a hierarchical clustering dendrogram using the unweighted pair group method with arithmetic means using SPSS version 21 (IBM Co., Armonk, NY, USA). Furthermore, to determine the relationship between insect communities and temperature, the minimum temperature during the two-week period prior to the sampling date and the Bray–Curtis similarity index were analyzed using Spearman's correlation analysis, calculated in SPSS. In addition, on three sampling dates (Daejeon River on 9 September and 9 October, and Gap River on 5 September) the species richness estimation curves and sample coverage were built based on 10 sweep sampling units of 10 sweeps each using the R software package iNEXT in R version 3.6.0 (Hsieh et al. 2016). We assumed that sample coverage values in same dominant species are similar compared to different dominant species. Interpolation and extrapolation of the species richness estimation curves were extended to only twice the sampling units to maintain a reliability of 95% using the default setting.

Results

Community analysis

In total, eight orders, 42 families, 115 species, and 5,888 individuals of insects were collected. In the samples from Daejeon River, the number of species and individuals were the highest in early September. In the present study, approximately 73% of the insect population fed on *D. ciliaris* as a host plant (Tables 1, S2, S3) (An 2011; An and Kim 2020; Ahn et al. 2018; Bieńkowski and Orlova-Bienkowskaja 2018; Danthanarayana 1967; David et al. 2020; Doopedia 2023a, 2023b, 2023c; Denno and Perfect 2012; Greber 1990; Hong et al. 2011, 2012; Hossain and Kwon 2019; Information of Korean Alien Species 2023; Kim et al. 2016; Knight 1987; Korea National Arboretum 2023; Lee 2012; Li et al. 2012; Lodos and Kalkandelen 1983; NIBR 2023b, 2023c, 2023d; Susumu and Hiroyuki 2010; Takeda 1998; Zhou et al. 2013). Most of them were Hemiptera species. Both the number of species and individuals of Hemiptera were the highest at all sites, and most of them accounted for more than half the proportion (Table 2).

In this study, there were three cases of sampling (Gap River on early September, Daejeon River on early September and early October) where the 100 sweep samples were comprised of ten subsamples of ten sweeps each, to make it possible to estimate the number of species per ten sweeps. The numbers of species were similar between the Daejeon and Gap rivers in September, but when estimating the richness based on 200 sweeps (two extrapolations), the number of species in Dajeon River on early September

Table 1 Summary of the result on insect communities associated with *Digitaria ciliaris* plant communities in Korea, sampled by sweep-netting in September–November 2020

Sampling site and date	Abbreviation	Orders	Families	Species	Individuals	Percentage of individuals that feed on *D. ciliaris*
Daejeon River 9 September	A-ES (early September)	5	18	42	1,829	90.3
Daejeon River 9 October	A-EO (early October)	4	16	36	427	56.7
Daejeon River 18 October	A-MO (mid-October)	5	15	23	270	65.9
Daejeon River 24 October	A-LO (late October)	4	7	11	87	79.3
Daejeon River 7 November	A-EN (early November)	2	8	14	59	47.5
Daejeon River 21 November	A-LN (late November)	1	3	4	20	90.0
Gap River 5 September	B-ES (early September)	6	24	45	1,693	58.1
Gap River 8 October	B-EO (early October)	6	11	18	400	87.3
Anseong 11 October	C-MO (mid-October)	5	15	26	160	55.0
Anseong 30 October	C-LO (late October)	4	7	9	22	22.7
Namhae 10 October	D-MO (mid-October)	5	17	33	704	79.1
Inje 17 September	E-MS (mid-September)	6	20	41	217	58.5
Total		8	42	115	5,888	73.0

Site abbreviations refer to localities in Fig. 1.

Table 2 Species richness and abundance (in parenthesis) by insect orders sampled by sweep-netting in *Digitaria ciliaris* grassland in Korea in September–November 2020

Order	Species richness (abundance)											
	Sampling sites											
	A-ES	A-EO	A-MO	A-LO	A-EN	A-LN	B-ES	B-EO	C-MO	C-LO	D-MO	E-MS
Hemiptera	24 (1,711)	23 (382)	15 (242)	7 (78)	10 (55)	4 (20)	21 (1,214)	8 (350)	17 (134)	5 (16)	22 (643)	24 (171)
Coleoptera	7 (49)	6 (25)	2 (3)		4 (4)		12 (396)	4 (29)		1 (1)	2 (4)	10 (15)
Diptera	8 (60)	5 (10)	4 (9)	2 (2)			6 (63)	3 (18)	4 (13)	2 (4)	4 (33)	2 (7)
Orthoptera	2 (8)	2 (10)	1 (2)				3 (13)	1 (1)	3 (11)	1 (1)	3 (13)	1 (2)
Hymenoptera	1 (1)		1 (14)	1 (6)			2 (6)		1 (1)		2 (11)	3 (21)
Odonata				1 (1)			1 (1)	1 (1)	1 (1)			
Lepidoptera								1 (1)				
Mantodea												1 (1)

Abbreviations of sampling sites were given in Table 1.

tended to converge with that of the Daejeon River on early October. All sample coverages were calculated to be as high as 90% (Fig. 2).

In the Daejeon River samples, community analysis showed that the Shannon–Wiener diversity index was the highest in early October (2.71), and the Chao1-bc diversity index was the highest in early September (57.6). The most frequently dominant and sub-dominant species at each site were *Laodelphax striatellus* (Delphacidae), *Psammotettix striata*, and *Balclutha rubrinervis* (both Cicadellidae) (Table 3).

Similarity analysis based on species presence and abundance

The results of the Sørensen/Bray–Curtis similarity analysis by sampling dates in the Daejeon River *D. ciliaris* community showed that sampling dates closer to each other had higher similarity (Table 4, Fig. 3). As such, the samples taken at the start and end of the study dates were the most dissimilar.

The Sørensen/Bray–Curtis similarity analysis results for all samples, including Daejeon and Gap River, Inje, and Namhae, also showed that regardless of the inter-site dis-

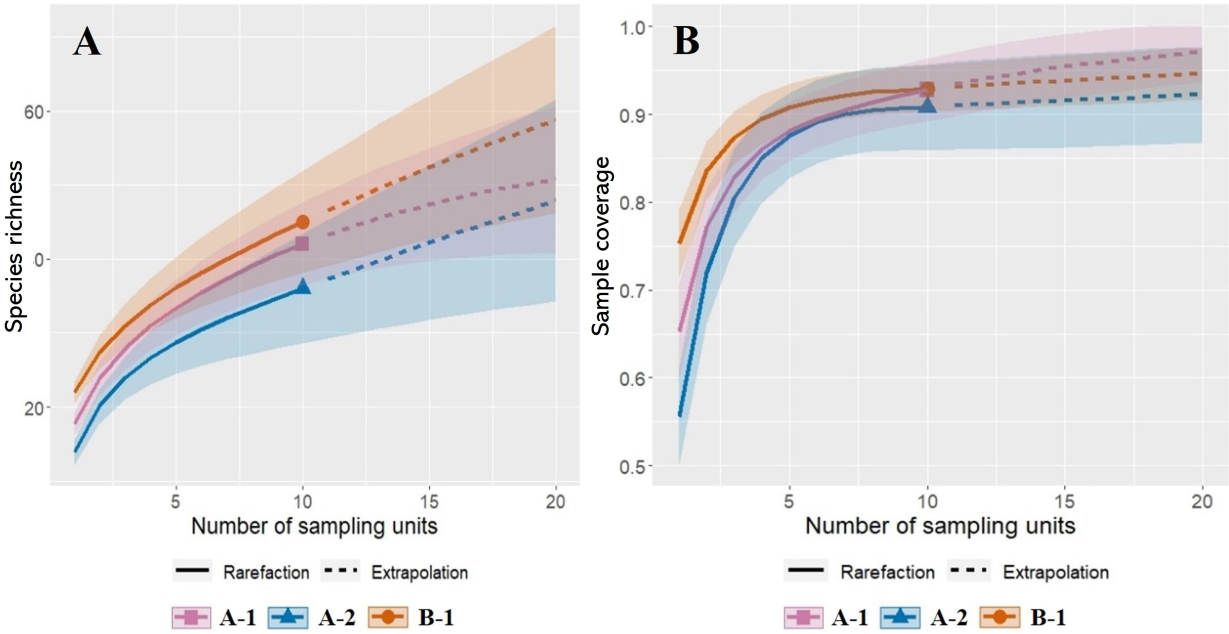

Fig. 2 Species richness (A) and sample coverage (B) of insect communities sampled from *Digitaria ciliaris* grassland in three particular sample events, divided into 10 subsamples of 10 sweeps each.

Table 3 Community structure of insects associated with *Digitaria ciliatus* in Korea

	Abbreviation of sampling sites	Community analysis indices					Dominant (subdominant) species
		H′	DI	RI	EI	Chao1-bc	
Daejeon River 9 September	A-ES	2.16	0.55	5.46	0.40	57.60	*Laodelphax striatellus* · *Stenotus rubrovittatus*
Daejeon River 9 October	A-EO	2.71	0.40	5.78	0.52	54.33	*Balclutha rubrinervis* · *Nabis stenoferus*
Daejeon River 18 October	A-MO	2.00	0.60	3.93	0.44	25.50	*B. rubrinervis* · *N. stenoferus*
Daejeon River 24 October	A-LO	1.37	0.72	2.24	0.40	26.00	*B. rubrinervis* · *Psammotettix striata*
Daejeon River 7 November	A-EN	1.88	0.64	3.19	0.49	32.00	*P. striata* · *N. stenoferus*
Daejeon River 21 November	A-LN	0.59	0.90	1.00	0.29	7.00	*P. striata* · *L. striatellus*
Gap River 5 September	B-ES	2.71	0.38	5.92	0.49	80.00	*Trigonotylus caelestialium* · *L. striatellus*
Gap River 8 October	B-EO	1.90	0.53	2.84	0.46	25.00	*P. striata* · *B. rubrinervis*
Anseong 11 October	C-MO	2.36	0.54	4.93	0.50	35.00	*S. rubrovittatus* · *Nephotettix cincticeps*
Anseong 30 October	C-LO	1.68	0.64	2.59	0.53	16.50	*N. cincticeps* · *Sepedon aenescens*
Namhae 10 October	D-MO	2.27	0.49	4.88	0.45	6.40	*B. rubrinervis* · *S. rubrovittatus*
Inje 17 September	E-MS	2.88	0.37	7.44	0.54	60.00	*P. striata* · *L. striatellus*
Total		2.99	0.31	13.13	0.44	164.40	*L. striatellus* · *S. rubrovittatus*

Abbreviations of sampling sites were given in Table 1. H′: diversity index; DI: dominance index; RI: richness index; EI: evenness index.

tance, the similarities between the samples with a large temporal difference between them were conspicuously low (Table 5, Fig. 4). Furthermore, Bray–Curtis similarities were more indicative of the dominant species in samples, showing high similarity between the samples with the same dominant species.

Table 4 Comparison of the index of Sørensen and Bray–Curtis (in parenthesis) on insect communities sampled in different sampling times in the Daejeon River

	A-ES	A-EO	A-MO	A-LO	A-EN
A-EO	0.74 (0.28)				
A-MO	0.43 (0.21)	0.51 (0.55)			
A-LO	0.26 (0.08)	0.30 (0.30)	0.41 (0.47)		
A-EN	0.29 (0.05)	0.32 (0.22)	0.38 (0.24)	0.24 (0.27)	
A-LN	0.13 (0.02)	0.15 (0.09)	0.22 (0.10)	0.13 (0.15)	0.33 (0.48)

Abbreviations of sampling sites were given in Table 1.

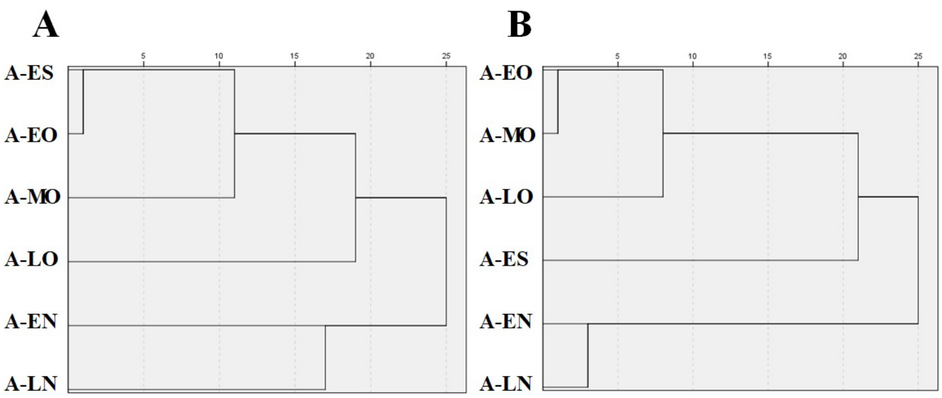

Fig. 3 Comparison of the Sørensen (A) and Bray–Curtis (B) indices on insect communities sampled in different sampling times in the Daejeon River. Abbreviation of sampling sites were given in Table 1.

Table 5 Comparison of the index of Sørensen and Bray–Curtis (in parenthesis) on insect communities from all sites

	A-ES	A-EO	A-MO	A-LO	A-EN	A-LN	B-ES	B-EO	C-MO	C-LO	D-MO
A-EO	0.74 (0.28)										
A-MO	0.43 (0.21)	0.51 (0.55)									
A-LO	0.26 (0.08)	0.30 (0.30)	0.41 (0.47)								
A-EN	0.29 (0.05)	0.32 (0.22)	0.38 (0.24)	0.24 (0.27)							
A-LN	0.13 (0.02)	0.15 (0.09)	0.22 (0.10)	0.13 (0.15)	0.33 (0.48)						
B-ES	0.53 (0.53)	0.54 (0.18)	0.38 (0.09)	0.21 (0.03)	0.20 (0.04)	0.12 (0.02)					
B-EO	0.40 (0.33)	0.41 (0.44)	0.44 (0.36)	0.48 (0.30)	0.31 (0.14)	0.18 (0.09)	0.41 (0.27)				
C-MO	0.38 (0.10)	0.42 (0.32)	0.49 (0.27)	0.43 (0.24)	0.15 (0.14)	0.13 (0.11)	0.31 (0.09)	0.41 (0.29)			
C-LO	0.20 (0.01)	0.22 (0.03)	0.38 (0.05)	0.30 (0.07)	0.17 (0.05)	0.15 (0.05)	0.11 (0)	0.30 (0.02)	0.46 (0.23)		
D-MO	0.40 (0.29)	0.41 (0.31)	0.39 (0.39)	0.18 (0.17)	0.17 (0.04)	0.16 (0.03)	0.38 (0.14)	0.27 (0.24)	0.37 (0.19)	0.19 (0.01)	
E-MS	0.46 (0.15)	0.49 (0.30)	0.44 (0.21)	0.19 (0.11)	0.29 (0.25)	0.13 (0.16)	0.47 (0.16)	0.31 (0.34)	0.33 (0.18)	0.08 (0.02)	0.43 (0.16)

Abbreviations of sampling sites were given in Table 1.

Analyses comparing sampling date and temperature with individuals and similarity

The population trends at Daejeon River showed that the abundance of most of the dominant species (*L. striatellus*, *Stenotus rubrovittatus* [Miridae], *Trigonotylus caelestialium* [Miridae], and *P. striata*) in the *D. ciliaris* community declined sharply between September and October (Fig. 5). However, *B. rubrinervis* showed a relatively gradual decline, whereas *Nabis stenoferus* (Nabidae), the only predator among the dominant species, increased slightly in early October, when other prey decreased, before declining steadily (Fig. 5).

Spearman's correlation between the difference in minimum temperature during the two weeks before sampling

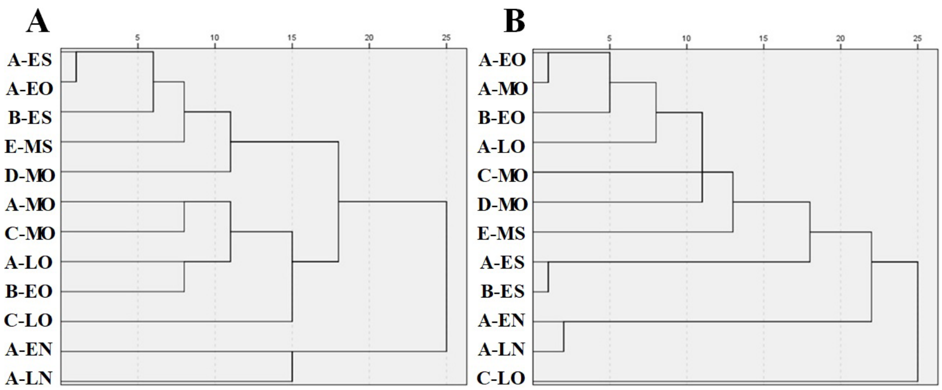

Fig. 4 Comparison of the Sørensen (A) and Bray–Curtis (B) indices on insect communities sampled from all sites. Abbreviation of sampling sites were given in Table 1.

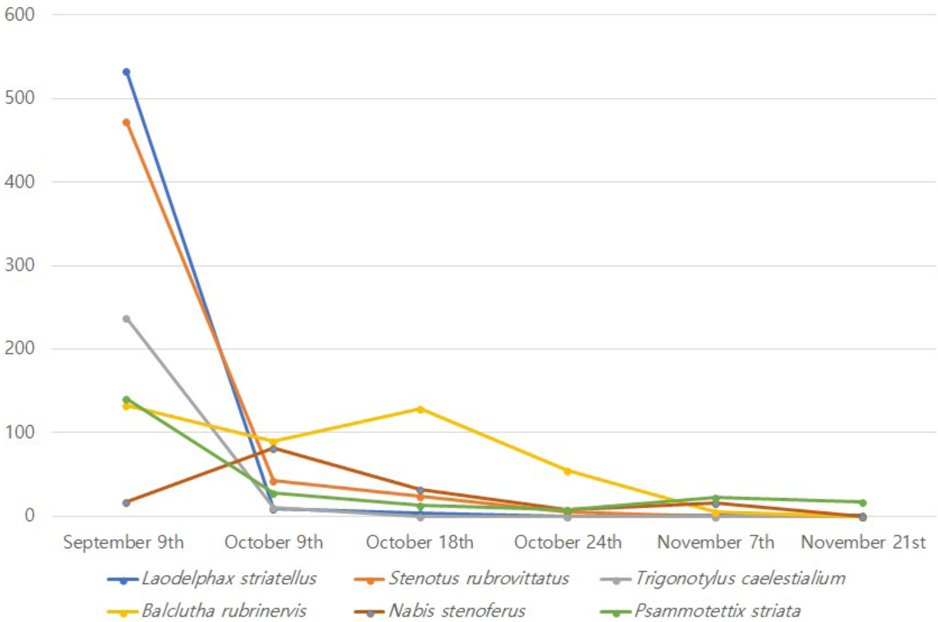

Fig. 5 Seasonal changes of six dominant insect species in the *Digitaria ciliaris* community at Daejeon River from September–November 2020.

and the Bray–Curtis similarity was significant for all the comparisons ($p < 0.01$), being very high (−0.798) at the Daejeon River site. In addition, when considering all samples excluding the Daejeon River, the correlation was −0.601. When considering all the samples in this study, the correlation was −0.59 (Tables S4, S5).

Discussion

The results of the insect community sampling of the *D. ciliaris* plant community showed that the number of species was relatively high in the Daejeon and Gap Rivers, and Inje in September, with 42, 45, and 41 species, respectively. September was warmer than the other sampling dates, and the minimum temperatures for the two weeks prior to the sampling dates were 16.3°C, 20.6°C, and 14.8°C at Daejeon River, Gap River, and Inje, respectively. Therefore, a more conducive temperature for insect growth in September was assumed to have influenced the higher number of species in September than in October and November. Between 6–24 species were collected during the Shinan insect community study, which sampled the *Phragmites japonica* (Poaceae), *Miscanthus sinensis* (Poaceae), and *Artemisia indica* (Asteraceae) communities in September of the same season (Hwang et al. 2023). In contrast, 41–45 species were collected in the present study in September, representing far higher species richness. This indicates that the *D. ciliaris* community is an important habitat for insect diversity.

Sample coverage was calculated to evaluate the sampling efficiency of 100 sweeps in collecting insects in the *D. ciliaris* community, and it was consistently high at around 90%. Compared with other plant communities evaluated in Korea, i.e., the *A. indica* and *Beckmannia syzigachne* (Poaceae) communities, the sample coverage of the *B. syzigachne* community was more comparable to that of *D. ciliaris* (Hwang et al. 2022).

The dominant species in the *D. ciliaris* community were *L. striatellus*, *P. striata*, and *B. rubrinervis*, being ubiquitous at all the sites. All of them used Poaceae plants as hosts and thrived during the period when the *D. ciliaris* community dominated the grassland (Doopedia 2023b; Knight 1987; NIBR 2023b). Proper monitoring is necessary, because *L. striatellus* is a major rice pest that causes the rice stripe virus disease (Noh et al. 2013; Son et al. 2014). The carnivorous *Nabis stenoferus*, which is known to prey on planthoppers, was the most abundant on 9 October, showing typical predator-prey population dynamics (Crawley 1975; Paik 1974). In Australia, the genus *Balclutha* is common on *Digitaria* plants, and because the genus *Nabis* is a natural enemy, the situation is similar to plants in Korea (Narhardiyati and Bailey 2005).

Digitaria plants are C4 grasses that prosper after the rainy season, with the seeds ripening from early July to early September. It is expected that as the biomass and protein content increase, the populations of the dominant herbivorous species will be high in early September and decrease gradually as ambient temperatures decrease (Lee and Lee 1999; Shin and Kim 1983). Based on a results of the Daejeon River, the most dominant species tended to decrease after 9 September. The mortality rate of *L. striatellus* is over 90% when exposed to temperatures of 12.5°C, and the minimum temperature was confirmed to be below 13°C for six consecutive days prior to the sampling on 9 October; therefore, it can be deduced that the decrease in the population of the dominant Delphacidae and Cicadellidae speciesis closely related to the ambient temperature (Park et al. 2011).

In addition, in the community analysis related to temperature, the Bray–Curtis similarity tended to be high among the samples with similar minimum temperatures for the 2 weeks prior to sampling, which was clearly confirmed by Spearman's correlation analysis. This is because the minimum temperature is related to the survival rate of insects and greatly affects the community, especially the abundance of the dominant species, such as Delphacidae and Cicadellidae (Park et al. 2011).

In the Daejeon River, the closer the sampling dates, the higher the insect community similarity (Fig. 3). This is assumed to reflect the characteristics of insects with short life cycles and high minimum temperatures required for survival. Also, when comparing the similarities of all samples, there is a tendency for the similarities to be high if the sampling dates are similar, even if the sites are different. In the case of the Sørensen's similarity values, samples were divided into one group belonging to samples mainly collected in September, and another group mainly collected in October. Similarly, in the case of Bray–Curtis similarity, there was a tendency for similarities to be higher between samples with proximate sampling dates, except for Angeong, which had a dominant species (*Nephotettix cincticeps*) different to the other sites (Fig. 4). In addition, the Daejeon and Gap rivers showed relatively high similarity, which is assumed to be because these localities are proximate, with similar climate and habitat conditions (Fig. 4).

Sweeping is a collecting method that targets insects living on plants, and the sampling results can vary greatly depending on which vegetation is swept. However, if sampling is performed in a specific dominant plant community, it is possible to reduce the variability attributable to vegetation composition and obtain basic data to identify the insect community trends in a specific dominant plant community (Hwang et al. 2022). The insect community data for *D. ciliaris* in the present study cannot be generalized to *D. ciliaris* communities elsewhere because of the limited number of samples and the influence of climatic and other environmental factors across regions. A clearer statistical trend could be expected if the number of samples is increased. As a result of the *D. ciliaris* community sampling, even if there are differences between some sites related to distance, there are many cases where the similarity is relatively high, with at least Sørensen 0.4 and Bray–Curtis 0.3 or higher. Therefore, it is plausible that generalization of the insect communities is possible, to some extent.

As *D. ciliaris* communities are often close to cultivated fields, they are considered potential habitats for agricultural pests. In the present study, pests including the delphacids *L. striatellus*, *Sogatella furcifera*, *Nilaparvata lugens*, and *Pachygrontha antennata* (Pachygronthidae), were sampled (Paik et al. 2009; Tindall et al. 2005). Monitoring and management of the *D. ciliaris* community is important, because the pest species sampled can directly harm crops and transmit viruses.

Conclusions

Digitaria ciliaris is considered one of the most common and competitive weeds in farmlands worldwide and is also common throughout Korea (Jones et al. 2021; Lee and Lee 1999). Since there are correlations between plant communities with the same dominant plant species and their associated insect communities, it is important to understand and accumulate data on the insect community associated with *D. ciliaris*, which is a prominent component of grassland and agricultural ecosystems in Korea (Hwang et al. 2022). This study provides foundational data that could enhance our understanding of the relationship between *D. ciliaris* and insect communities in future, and the data can facilitate ecological conservation and management of Korean grasslands in general, as well as identification of potential pests that may disperse from *D. ciliaris* communities to nearby farmland. The latter aspect is of particular importance, as several rice pests were sampled in abundance from *D. ciliaris* in this study, indicating that it is a suitable host plant for these pests. This suggests that *D. ciliaris* could potentially serve as a population sink, allowing these pests to recolonize even well-managed crop fields and affect crop yields. Effective monitoring of grassland stands dominated by *D. ciliaris* is therefore necessary to improve pest management on a landscape scale. The data provided in the present study can be used as baseline data to inform pest management practices and promote ecological conservation of *D. ciliaris* communities.

Supplementary Information

Supplementary information accompanies this paper at https://doi.org/10.5141/jee.23.050.

Table S1. Annual temperature and precipitation in the sites. **Table S2**. Insect inventory in the *Digitaria ciliaris* communities. **Table S3**. Percentage of the number of individuals of Poaceae-feeding insects from each sampling. **Table S4**. The minimum temperature during the 2-week period prior to each sampling. **Table S5**. Pairwise comparisons of differences in minimum temperature during the 2-week period before the sampling dates across all sites.

Abbreviations
Not applicable.

Acknowledgements
We thank Mean-Young Yim for supporting the identification of host plants and also appreciate Dong Hee Kim for receiving research grant.

Authors' contributions
JHH did conceptualization, data curation, investigation, and writing the original draft. JHY did methodology, supervision, writing the review and editing. All the authors approved the manuscript.

Funding
This work was supported by the National Research Foundation of Korea (grant numbers 2022M3H9A109717911).

Availability of data and materials
All data generated or analyzed during this study are included in this published article and its supplementary information files.

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

References

Ahn KW, Kim JW. Classification and characteristics of the roadbed plant communities in Daegu, Korea. Korean J Ecol. 2005;28(1):31-6. https://doi.org/10.5141/JEFB.2005.28.1.031.

Ahn SJ, Kim WG, Kim SS, Park JK. Terrestrial heteroptera of Korea. Seoul: Nature & Ecology; 2018.

An SL. Leafbeetle (Chrysomelidae) of Korea. Daejeon: National Science Museum; 2011.

An SL, Kim E. A guide book of Korean leaf beetles. Seoul: Nature & Ecology; 2020.

Beals EW. Bray-curtis ordination: an effective strategy for analysis of multivariate ecological data. Adv Ecol Res. 1984;14:1-55. https://doi.org/10.1016/S0065-2504(08)60168-3.

Bieńkowski AO, Orlova-Bienkowskaja MJ. Alien leaf beetles of European Russia: native ranges, invasion history, biology and vectors of dispersal. BioRxiv. 252510 [Preprint]. 2018 [cited 2023 Jan 12]. Available from: https://doi.org/10.1101/252510.

Chao A, Shen TJ. User's Guide for Program SPADE (Species Prediction And Diversity Estimation). Hsinchu: National Tsing Hua University; 2010.

Crawley MJ. The numerical responses of insect predators to changes in prey density. J Anim Ecol. 1975;44(3):877-92. https://doi.org/10.2307/3725.

Danthanarayana W. Host specificity of Sitona beetles. Nature. 1967;213:1153-4. https://doi.org/10.1038/2131153a0.

David KJ, Hancock DL, Salini S, Gracy RG, Sachin K. Taxonomic notes on the genus Campiglossa Rondani (Diptera, Tephritidae, Tephritinae, Tephritini) in India, with description of three new species. Zookeys. 2020;977:75-100. https://doi.org/10.3897/zookeys.977.57875.

Denno RF, Perfect JR. Planthoppers: their ecology and management. Berlin: Springer Science & Business Media; 2012.

Doopedia. Nephotettix cincticeps. 2023a. https://www.doopedia.co.kr/doopedia/master/master.do?_method=view&MAS_IDX=101013000793983/. Accessed 5 Jun 2023.

Doopedia. Psammotettix striatus. 2023b. https://www.doopedia.co.kr/doopedia/master/master.do?_method=view&MAS_IDX=101013000850961/. Accessed 5 Jun 2023.

Doopedia. Laodelphax striatellus. 2023c. https://www.doopedia.co.kr/doopedia/master/master.do?_method=view&MAS_IDX=101013000851214/. Accessed 5 Jun 2023.

Doxon ED, Davis CA, Fuhlendorf SD. Comparison of two methods for sampling invertebrates: vacuum and sweep-net sampling. J Field Ornithol. 2011;82(1):60-7.

Farrell BD, Mitter C, Futuyma DJ. Diversification at the insect-plant interface. BioScience. 1992;42(1):34-42. https://doi.org/10.2307/1311626.

Frenzel M, Brandl R. Diversity and abundance patterns of phytophagous insect communities on alien and native host plants in the Brassicaceae. Ecography. 2003;26(6): 723-30. https://doi.org/10.1111/j.0906-7590.2003.03649.x.

Giovas CM. A simple method for quantifying compositional correspondence between zooarchaeological assemblages using paired similarity indices. J Archaeol Method Theory. 2021;28:823-44. https://doi.org/10.1007/s10816-021-09512-y.

Global Biodiversity Information Facility (GBIF). Digitaria ciliaris (Retz.) Koeler. 2023. https://www.gbif.org/species/5289998. Accessed 12 Jan 2023.

Głowacki Ł. Accuracy of species richness estimators applied to fish in small and large temperate lowland rivers. Biodivers Conserv.

2011;20:1365-84. https://doi.org/10.1007/s10531-011-0032-1.

Greber RS. Discrimination by gel-diffusion serology of digitaria striate, maize sterile stunt and other rhabdoviruses of Poaceae. Ann Appl Biol. 1990;116(2):259-64. https://doi.org/10.1111/j.1744-7348.1990.tb06605.x.

Hong KJ, Park S, Han K. Weevils I: arthropoda: insecta: coleoptera: curculionidae: bagoninae, baridinae, ceutorhynchinae, conoderinae, cryptorhynchinae, molytinae, orobitidinae. Incheon: National Institute of Biological Resources; 2011.

Hong KJ, Park S, Han K. Weevils II: arthropoda: insecta: coleoptera: curculionidae: cueculioninae, cossoninae, mesoptiliinae. Incheon: National Institute of Biological Resources; 2012.

Hossain MS, Kwon J. Taxonomic revision of the microleafhopper genus Ziczacella Anufriev 1970 from Korea (Hemiptera: Cicadellidae: Typhlocybinae). Zootaxa. 2019;4571(3):363-72. https://doi.org/10.11646/zootaxa.4571.3.4.

Hsieh TC, Ma KH, Chao A. iNEXT: an R package for rarefaction and extrapolation of species diversity (Hill numbers). Methods Ecol Evol. 2016;7(12):1451-6. https://doi.org/10.1111/2041-210X.12613.

Hwang JH, Yim MY, Kim SY, Ji SJ, Lee WH. Sweep sampling comparison of terrestrial insect communities associated with herbaceous stratum in the riparian zone of the Miho River, Korea. Insects. 2022;13(6):497. https://doi.org/10.3390/insects13060497.

Hwang JH, Yim MY, Yun JH. Terrestrial insect fauna of the herbaceous stratum of reservoir embankment slopes, Korea. J Asia-Pac Biodivers. 2023;16(4):540-6. https://doi.org/10.1016/j.japb.2023.05.006.

Information of Korean Alien Species. Clover Leaf Weevil: Hypera punctata. 2023. https://kias.nie.re.kr/home/for/for02002v.do?clsSno=20984&searchClsGbn=for/. Accessed 5 Jun 2023.

Jones EA, Contreras DJ, Everman WJ. Digitaria ciliaris, Digitaria ischaemum, and Digitaria sanguinalis. In: Chauhan BS, editor. Biology and management of problematic crop weed species. London: Academic Press; 2021. p. 173-95.

Kim DE, Kil J. Geographical distribution and host plants of Corythucha marmorata (Uhler) (Hemiptera: Tingidae) in Korea. Korean J Appl Entomol. 2014;53(2):185-91. https://doi.org/10.5656/KSAE.2013.11.0.073.

Kim MH, Oh YJ, Kim MR. Seasonal change in C3/C4 mixed vegetation populations over paddy levees in South Korea. Korean J Agric For Meteorol. 2012;14(4):196-206. https://doi.org/10.5532/KJAFM.2012.14.4.196.

Kim SG, Lee SM, Park JH, Song K, Shin BS. Host dependent oviposition and development of Azuki Bean Weevil (*Callosobruchus chinensis* L.) in different leguminous seeds. Korean J Environ Biol. 2016;34(4):346-52. https://doi.org/10.11626/KJEB.2016.34.4.346.

Knight WJ. Leafhoppers of the grass-feeding genus Balclutha (Homoptera, Cicadellidae) in the Pacific region. J Nat Hist. 1987;21(5):1173-224. https://doi.org/10.1080/00222938700770731.

Korea Meteorological Administration (KMA). Temperature Analysis. 2023. https://data.kma.go.kr/stcs/grnd/grndTaList.do?pgmNo=70. Accessed 10 Jan 2023.

Korea National Arboretum. Claw Leaf Beetle Monolepta shirozui. 2023. http://www.nature.go.kr/kbi/insct/pilbk/selectInsctPilbkDtl.do?insctPilbkNo=ZOBT0221. Accessed 5 Jun 2023.

Lee HS. Taxonomy, phylogeny and DNA barcoding of the Korean Lauxaniidae (Diptera: Lauxanioidea) [PhD dissertation]. Seoul: Yonsei University; 2012.

Lee ID, Lee HS. A study on the dry matter yield and nutritive values of crabgrass (Digitaria Sanguinalis L.) dominant swards. J Korean Grassl Sci. 1999;19(3):197-202.

Lee ST, Li C, Davis JA. Predator-pest dynamics of arthropods residing in Louisiana soybean agroecosystems. Insects. 2022;13(2):154. https://doi.org/10.3390/insects13020154.

Lee SY, Jang RH, Han YS, Jung YH, Lee SI, Lee EP, et al. Health condition assessment using the riparian vegetation index and vegetation analysis of Geumgang mainstream and Mihocheon. Korean J Environ Ecol. 2018;32(1):105-17. https://doi.org/10.13047/KJEE.2018.32.1.105.

Li YZ, Cao Y, Zhou Q, Guo H, Ou G. The efficiency of southern rice black-streaked dwarf virus transmission by the vector Sogatella furcifera to different host plant species. J Integr Agric. 2012;11:621-7. https://doi.org/10.1016/S2095-3119(12)60049-5.

Lodos N, Kalkandelen A. Preliminary list of Auchenorrhyncha with notes on distribution and importance of species in Turkey. XlI. Family Cicadellldae, Typhlocybinae, Empoascini. Tirk Bit Kor Derg. 1983;7(3):153-65.

Luisoni E, Conti M. Digitaria sanguinalis (L.) Scop., a new natural host of maize rough dwarf virus. Phytopathol Mediterr. 1970;9(2-3):102-5.

Margalef R. Information theory in biology. Gen Syst. 1958;3:36-71.

Mcnaughton S. Relationships among functional properties of Californian grassland. Nature. 1967;216:168-9. https://doi.org/10.1038/216168b0.

Narhardiyati M, Bailey WJ. Biology and natural enemies of the leafhopper Balclutha incisa (Matsumura) (Hemiptera: Cicadellidae: Deltocephalinae) in south-western Australia. Aust J Entomol. 2005;44(2):104-9. https://doi.org/10.1111/j.1440-6055.2005.00460.x.

National Institute of Biological Resources (NIBR). National Species List of Korea. 2022. https://kbr.go.kr/stat/ktsnfiledown/downpopup.do. Accessed 12 Jun 2022.

National Institute of Biological Resources (NIBR). Maiestas oryzae (Matsumura, 1902). 2023a. https://species.nibr.go.kr/species/speciesDetail.do?ktsn=120000230677&tab=/. Accessed 5 Jun 2023.

National Institute of Biological Resources (NIBR). Cletus punctiger (Dallas, 1852). 2023b. https://species.nibr.go.kr/home/mainHome.do?cont_link=009&subMenu=009002&contCd=009002&ktsn=120000025629. Accessed 5 Jun 2023.

National Institute of Biological Resources (NIBR). Campiglossa deserta (Hering, 1939). 2023c. https://species.nibr.go.kr/home/mainHome.do?cont_link=009&subMenu=009002&contCd=009002&ktsn=120000023486. Accessed 5 Jun 2023.

National Institute of Biological Resources (NIBR). Apolygus nigrovirens (Kerzhner, 1988). 2023d. https://species.nibr.go.kr/home/mainHome.do?cont_link=009&subMenu=009002&contCd=009002&ktsn=120000026293. Accessed 5 Jun 2023.

National Institute of Ecology (NIE). The fifth national ecosystem survey guide. Seocheon: National Institute of Ecology; 2019.

Noh TH, Jung KH, Seo SJ, Shim HK, Choi MY, Park JC, et al. RSV (rice stripe virus) disease index according to density of SBPH (small brown plant hopper, Laodelphax stritellus) and rice growing stage. J Agric Life Sci. 2013;44(1):1-4.

Paik CH, Lee GH, Kang JG, Jeon YK, Choi MY, Seo HY. Plant flora and insect fauna in the fallow paddy fields of Jeonnam and Jeonbuk province. Korean J Appl Entomol. 2009;48(3):285-94. https://doi.org/10.5656/KSAE.2009.48.3.285.

Paik WH. Natural enemies (parasites) of plant and leafhoppers. Korean J Appl Entomol. 1974;13(1):47-51.

Park BY, Lee SK, Park HH, Jeon SW, Jeong IH, Park SK, et al. Occurrence patterns of three planthopper species in rice fields in Bangladesh, Cambodia, Thailand and Vietnam. Korean J Org Agric. 2018;26(3):489-500.

Park CG, Park HH, Kim KH. Temperature-dependent development model and forecasting of adult emergence of overwintered small brown planthopper, Laodelphax striatellus Fallen, population. Korean J Appl Entomol. 2011;50(4):343-52.

Park KT, Kwon YJ, Park JK, Bae YS, Bae YJ, Byeon BG, et al. Insects of Korea. Seoul: Geobook; 2012.

Pielou EC. Shannon's formula as a measure of specific diversity: its use and misuse. Am Nat. 1966;100(914):463-5. https://doi.org/10.1086/282439.

Pielou EC. Ecological diversity. New York: Wiley; 1975.

Rojas-Sandoval J, Acevedo-Rodríguez P. Digitaria ciliaris (southern crabgrass). 2022. https://www.cabidigitallibrary.org/doi/full/10.1079/cabicompendium.18912. Accessed 5 Jun 2023.

Schroeder PJ, Jenkins DG. How robust are popular beta diversity indices to sampling error? Ecosphere. 2018;9(2):e02100. https://doi.org/10.1002/ecs2.2100.

Shim IS, Kim HB, Cho KJ. Syntaxonomical characteristics of abandoned paddy fields by seral stages in South Korea. Korean J Environ Agric. 2013;32(3):185-92. https://doi.org/10.5338/KJEA.2013.32.3.185.

Shin DH, Kim KU. Ecological characteristics of Digitaria sanguinalis in temperate climate. Korean J Weed Sci. 1983;3(1):29-38.

Son BI, Jung JK, Lee JH. Wing morphs and parasitism rates of the small brown planthopper, Laodelphax striatellus (Hemiptera: Delphacidae) in Korea. Korean J Appl Entomol. 2014;53(4):497-501. https://doi.org/10.5656/KSAE.2014.11.0.064.

Sørensen T. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and ist application to analyses of the vegetation on Danish commons. København: Munksgaard; 1948.

Spafford RD, Lortie CJ. Sweeping beauty: is grassland arthropod community composition effectively estimated by sweep netting? Ecol Evol. 2013;3(10):3347-58. https://doi.org/10.1002/ece3.688.

Susumu M, Hiroyuki Y. A host record of Anadastus atriceps (Coleoptera, Erotylidae, Languriinae, Languriini). Elytra. 2010;38(2):211-2.

Swart RC, Pryke JS, Roets F. Optimising the sampling of foliage arthropods from scrubland vegetation for biodiversity studies. Afr Entomol. 2017;25(1):164-74. https://doi.org/10.4001/003.025.0164.

Takeda M. Genetic basis of photoperiodic control of summer and winter diapause in geographic ecotypes of the rice stem maggot, Chlorops oryzae. Entomol Exp Appl. 1998;86(1):59-70. https://doi.org/10.1046/j.1570-7458.1998.00265.x.

Takizawa H. A revision of the genus Psylliodes Latreille in Japan (Chrysomelidae: Alticinae). J Fac Agric Hokkaido Univ. 2005;62:175-85.

Teakle DS, Hicks S, Karan M, Hacker JB, Greber RS, Donaldson JF. Host range and geographic distribution of pangola stunt virus and its planthopper vectors in Australia. Aust J Agric Res. 1991;42:819-26. https://doi.org/10.1071/AR9910819.

Tindall KV, Williams BJ, Stout MJ, Geaghan JP, Leonard BR, Webster EP. Yield components and quality of rice in response to graminaceous weed density and rice stink bug populations. Crop Protection. 2005;24(11):991-8. https://doi.org/10.1016/j.cropro.2005.01.023.

Yi Z, Jinchao F, Dayuan X, Weiguo S, Axmacher JC. A comparison of terrestrial arthropod sampling methods. J Resour Ecol. 2012;3(2):174-82.

Zhou WW, Liang QM, Xu Y, Gurr GM, Bao YY, Zhou XP, et al. Genomic insights into the glutathione S-transferase gene family of two rice planthoppers, Nilaparvata lugens (Stål) and Sogatella furcifera (Horváth) (Hemiptera: Delphacidae). PLoS One. 2013;8(2):e56604. https://doi.org/10.1371/journal.pone.0056604.