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RESEARCH ARTICLE

Spatial and Temporal Variation of Spiders in Northwest Libya

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ABSTRACT

Spiders are considered one of the most important groups in terrestrial arthropods since they are highly efficient predators as well as cornerstones in the food web. Since no adequate attention was paid to them in Africa in general, and particularly in Libya, this group still needs research. This study aims to measure spider beta diversity and species turnover in three habitats (wild, farmland and urban) during four seasons in northwest Libya. The study sites are located between Tripoli City and Msallata Town, from winter 2016 to autumn 2017. Samples were collected by sweep nets, beating, visual searching, and pitfall traps. A total of 11,224 individuals were collected, representing 90 species belonging to 73 genera and 28 families. Three of them were morphospecies (three genera). The highest individual count was in the summer with 4603 individuals, while according to the habitats, the highest was 4458 in the wild habitat. Bray-Curtis's test and species turn-over (measured using Harrison βh) were used to study the similarity between different habitats during every season (Beta diversity). The obtained beta diversity values were low (high similarity). Clustering analysis and nMDS outputs divided habitats and seasons into three groups based on species similarity levels: 1) winter, 2) summer, and 3) spring + autumn. Species turn-over was low, ranging between 0.09 and 19.0.

INTRODUCTION

Beta diversity, crucial for understanding biodiversity patterns, has been understudied in arboreal spiders, despite their ecological importance (Socolar et al., 2016; Hossain et al., 2024). This study investigates how environmental factors, spatial distance, and ballooning propensity influence the beta diversity of arboreal spider communities. Niche theory suggests habitat variation drives species turnover, with tree structure being a key factor for arboreal spiders (Gilbert & Lechowicz, 2004; Halaj et al., 2000; Jam et al., 2018). We aim to explore the link between specific tree architecture and spider diversity.

Spatial distance also influences beta diversity, potentially reflecting dispersal limitations (Jiménez-Valverde et al., 2010). Ballooning behaviour, a form of aerial dispersal using silk, varies among spider species (Richardson et al., 2006). We hypothesize that ballooning propensity has a stronger impact than spatial distance alone. Highly mobile species can select favourable habitats, while less mobile ones are more restricted by distance (Araújo et al., 2005). This suggests that spatial variation in environmental conditions might be a stronger determinant of beta diversity for highly mobile species.

This study evaluates the relative contributions of spatial and temporal variables, including environmental features and ballooning propensity, to the beta diversity patterns of arboreal spider communities across three habitats over four seasons. We use beta (β) and Harrison (βh) diversity measures to quantify species turnover. We hypothesize that both spatial and temporal variables, along with species turnover, will significantly shape arboreal spider beta diversity patterns.

MATERIALS AND METHODS

Study site

Historically, Libya was divided into three main provinces: Tripolitania (Northwest), Cyrenaica (East and Southeast), and Fezzan (South and Southwest). Tripolitania is the most populated province, with an area of 263,960 square kilometers. The study area is located between Tripoli in the west and Khoms in the east, reaching Masallātah in the north. It extends approximately 92 km along the coast, between 32º 34\` 49.02\`\` N, 14º 02\` 19.02\`\` E and 32º 47\` 08.62\`\` N, 12º 47\` 44.62\`\` E (Figure 1). Sampling sites were selected from three different habitats: city, farmland, and wild habitat. Samples were collected from nineteen sites (n= 19). The city area covers, between Tajura region (east of Tripoli) and Janzur sector (west of Tripoli), approximately 49 km long. Six sites (C1, C2, C3, C4, C5, and C6) were selected from houses' gardens and a public park. The farmland study area is located between Qasr al-Akhyyar area from the east and Tajara from the west; it is approximately 51 km long. Six sites (F1, F2, F3, F4, F5, and F6). The wild area in this study extends about 102 km (Al Qarabulli Qasr Khiyar, Al-Allus, Ganimah, Alkomus, Masallātah, and Ash Shi'āfīyūn near Masallātah). It is described as a transitional zone between steppe and mountain regions. Samples were collected from seven sites (W1, W2, W3, W4, W5, W6, and W7), one of these sites is inside Masallātah Nature Reserve and National Park (MNRNP).

Data collection

Monthly samplings were carried out for one year (between December 2016 and November 2017) at 19 selected sampling sites (n= 19), to cover four seasons of that locality. At each study area, the sampling was conducted using pitfall traps on a transect line of 100 meters. The pitfall traps were separated from each other by 10 meters. Spiders were collected using pitfall traps. In each of the 19 selected sites, 10 pitfall traps were placed in a transect line, with 10 meters between each trap. In case of loss, an additional trap was added. Traps are made of two plastic cup containers with a 500 ml capacity. Each trap was filled with 200 ml Ethylene-glycol (anti-freeze fluid) as a preservative (Cardoso et al., 2008). Sample collection sites were visited every 50 days. The samples were collected from pitfall traps; all the caught spiders from the pitfall traps at a single site were pooled together. Then, the samples were separated so that the spiders were caught and kept in alcohol. Visual searching, sweeping, and beating samples were taken within each transect at a distance of 50 m on each side of the transect line, avoiding repetition of a previously sampled area.

Data analysis

Beta diversity, or diversity between habitats, is the degree of species replacement or biotic change through environmental gradients (Whittaker, 1972). Unlike the alpha and gamma diversities that can be easily measured based on the number of species, the measurement of beta diversity has different dimensions because it is based on proportions or differences (Magurran, 1988). These proportions can be evaluated based on indices or coefficients of similarity, dissimilarity, or distance between samples from qualitative data (presence of species absence) or quantitative (proportional abundance of each species measured as number of individuals, biomass, density, and coverage) or with beta diversity indices themselves (Magurran, 1988; Wilson & Shmida, 1984).

Measuring beta diversity (β diversity) at a spatial-temporal scale

The variations in Araneae fauna composition between sites in different habitats during different seasons in the study area were calculated using beta diversity measurement. Two common beta diversity measurements were used: (1) $\beta = \gamma/\alpha$ (Whittaker, 1972), where β is beta diversity, γ is gamma diversity (within the landscape), and α is alpha diversity (within the habitat). The beta diversity values (dissimilarity values) were obtained via 1 – Bray – Curtis, while the similarity values were obtained via Bray – Curtis. The beta diversity value ranges between zero and one; zero indicates similarity, while one indicates dissimilarity. Beta diversity was calculated as global beta-diversity (Whittaker's measure βW) in each site by Paleontological Statistics (PAST) software (Hammer & Harper, 2001). Resemblance measures used in this study were Bray-Curtis similarity, cluster, and nMDS (non-metric multidimensional scaling). They were calculated by Primer 6 software.

Measuring turnover species

Harrison (βh) is represented by the following equation (it is a modification of Whittaker's measure (βw)):

$$\beta = \left\{ \frac{\left[\left(S/\overline{\alpha} - 1 \right) \right]}{(N-1)} \right\} x100$$

Where α is the average species richness of the samples. This measure ranges between 0 and 100, the value of the scale is zero when there is no turnover, while the value of 100 indicates that each sample includes a distinct group of species. It makes it possible to compare transects of various sizes.

RESULTS AND DISCUSSION

This study delved into the intricate relationship between habitat type (city, farmland, wild) and season (spring, summer, autumn, winter) on the distribution, abundance, and diversity of spider communities in northwestern Libya. A total of 11,224 individuals, representing 90 species, were meticulously collected across the study area (Table 1).

The investigation revealed a fascinating interplay between habitat type and season in shaping spider diversity. The wild habitat emerged as a haven for spider richness, particularly during the summer months, boasting an impressive 88 species (Table 2). Conversely, the city environment proved to be the least hospitable, harbouring only 61 species during the harsh winter. This aligns with the findings of Rosenzweig (1995) and Mobaied et al. (2016), who emphasize the profound impact of environmental characteristics on biodiversity patterns.

The analysis of species composition further unveiled a captivating mosaic. Notably, several medically important species, such as *Loxosceles rufescens* (264 individuals), *Latrodectus geometricus* (227 individuals), and *Latrodectus tredecimguttatus* (112 individuals), were documented across all habitats and seasons. This highlights the adaptability of these species to diverse environmental conditions. However, a distinct pattern emerged for other species. Some exhibited a remarkable degree of habitat fidelity, with *Uroctea compactilis* and *Segestria florentina* being exclusive residents of the wild habitat during the summer (Table 2). This observation underscores the importance of habitat heterogeneity in supporting a diverse array of spider species.

By employing beta diversity and turnover analyses, the study sheds light on the spatial and temporal dynamics of spider communities. The generally positive beta diversity values (greater than zero) indicated a clear differentiation in species composition across habitats and seasons (Table 3). While the global beta-diversity was low, suggesting a degree of overall similarity, pairwise comparisons revealed significant differences between specific seasons and habitats. This finding aligns with the observations of Pitta et al. (2019), who reported a marked influence of seasonal and spatial variations on spider communities.

Furthermore, the analysis of species turnover revealed a fascinating trend. The turnover rate, reflecting the degree of species replacement between sites, remained relatively low across the study area (Table 3). Interestingly, the highest turnover values were observed between the city during winter and the wild habitat during summer and autumn. This suggests a more substantial shift in species composition between these contrasting environments and seasons.

A closer examination of seasonal variations revealed a noteworthy pattern. Both species richness and abundance exhibited a marked increase during the summer months compared to the colder seasons (Figures 3 and 4). This observation aligns with the findings of Pitta et al. (2019) and suggests that climatic factors, particularly temperature, play a pivotal role in shaping the seasonal composition of spider communities. Valladares et al. (2002) emphasize the importance of such temporal variability in Mediterranean landscapes, highlighting the need for species to be genetically adapted to these fluctuations in resource availability.

While the study demonstrated the undeniable influence of climate, particularly temperature, on spider diversity, the role of habitat heterogeneity (vegetation complexity) cannot be overlooked. The analysis revealed a significant correlation between vegetation complexity and species composition similarity (Figures 3 and 4). This finding aligns with the observations of Jiménez-Valverde and Lobo (2007) who emphasize the role of habitat complexity in determining the number of species a locality can harbor. However, the influence of vegetation complexity in this study appeared to be less pronounced compared to temperature.

Interestingly, the study did not reveal a significant effect of geographic distance between sampling sites on species composition. This suggests that the spider community in this region possesses a relatively good dispersal ability, potentially facilitated by ballooning behavior (using silk threads for aerial dispersal). This finding stands in contrast to the previous observations (Samu et al., 2018; Walker et al., 2020; Wu et al., 2021) that reported a clear influence of geographic distance on spider dispersal.

CONCLUSION

This study sheds light on the factors shaping spider diversity in northwestern Libya. We investigated how habitat type (city, farmland, or wild) and seasonal variations influence spider communities. While the overall species composition showed similarity (low beta diversity), some key differences emerged. City winters harboured distinct spider communities compared to summer and autumn in other habitats. Temperature, closely tied to the season, emerged as the primary driver of spider diversity. This aligns with the idea that spiders adapt to seasonal fluctuations in resource availability. Interestingly, the complexity of vegetation played a less prominent role than temperature in shaping spider assemblages. Furthermore, the study revealed a surprising finding: good dispersal ability among spider species. This explains the low species turnover observed across the study area. In simpler terms, spiders seem adept at moving between habitats, leading to a relatively even distribution throughout the seasons. Understanding these factors, habitat, seasonality, climate, and dispersal ability, is crucial for developing effective conservation strategies for these ecologically important predators. As climate change continues to alter our environment, this knowledge is vital for ensuring the survival of Libya's diverse spider communities.

Figure 1. Map of Libya (inset) showing the approximate locations of the study the area (red rectangle); data on spiders was collected. The red pins of U, F, and W indicate the urban (U), farmland (F), and wilderness (W) areas and the small pins of blue (urban), green (farmland), and yellow (wilderness) show the sampling sites around the three major landscapes surveyed in this study.

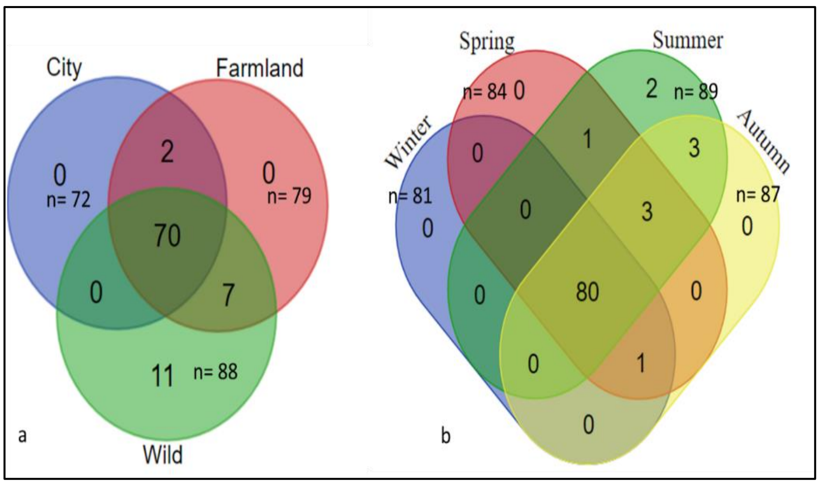

Figure 2. Venn diagram showing the number of species and species overlapping according to (a) habitats and (b) seasons.

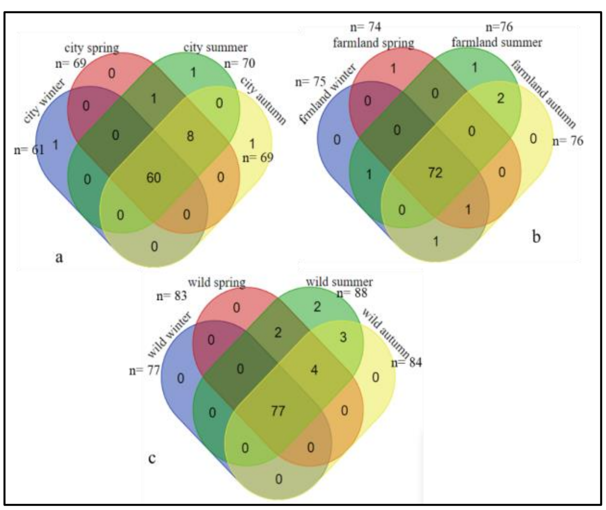

Figure 3. Venn diagram showing the number of species and species overlapping according to the habitats in different seasons for (a) city, (b) farmland, and (c) wild (n = number of species).

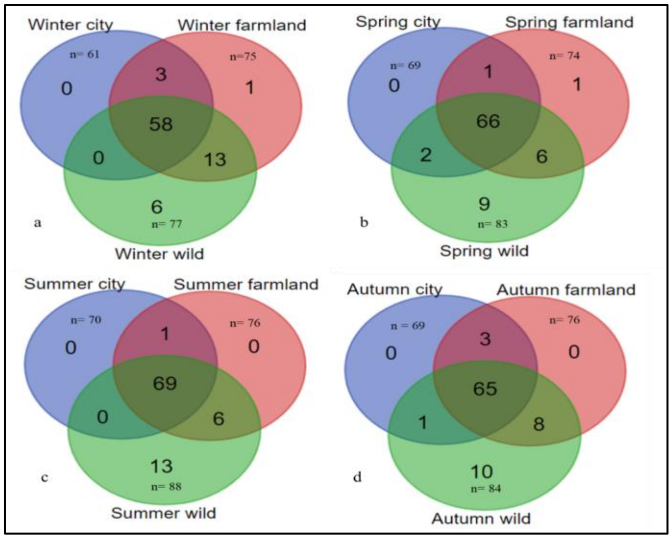

Figure 4. Venn diagram showing the number of species and species overlapping according to season at different habitats: (a) winter, (b) spring, (c) summer, and (d) autumn (n = number of species).

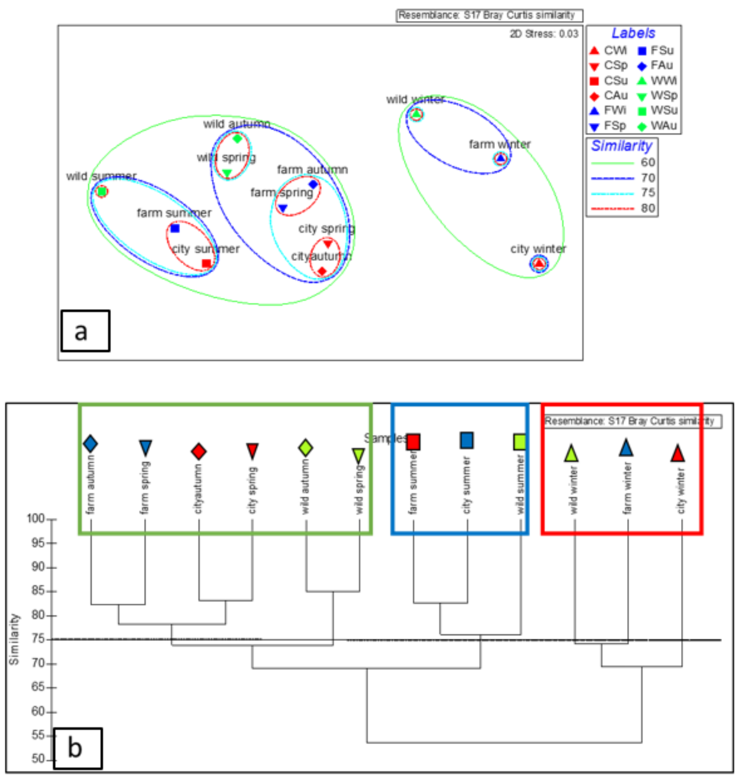

Figure 5. A dendrogram showing the similarity of the spider's community, (a) Cluster analyses (Bray-Curtis) showed three groups: I group red box (winter), II group blue box (summer), and III group green box (spring and autumn). (b) nMDS formatted at 60% (green line), 70% (dark blue line), and 75% (light blue line) of similarity are superimposed on the 2-dimensional nMDS obtained from the similarity matrixes. City winter (CWi), City spring (CSp), City summer (CSu), City autumn (CAu), Farm winter (FWi), Farm spring (FSp), Farm summer (FSu), Farm autumn (FCAu), Wild winter (WWi), Wild spring (WSp), Wild summer (WSu), and Wild autumn (WAu).

Table 1. The temporal and spatial distribution of the collected spider species from the area of study

Family / Species	Winter	Spring	Summer	Autumn	City	Farmland	Wild
Agelenidae							
Benoitia lepida	14	46	68	51	53	46	80
Tegenaria domestica	17	49	70	68	65	55	84
Textrix caudata	12	35	58	61	49	54	63
Araneidae							
Araneus circe	12	37	58	43	28	76	46
Araneus diadematus	11	22	64	62	30	59	70
Argiope lobata	6	19	44	39	12	51	45
Argiope sector	3	5	17	10	0	7	28
Argiope trifasciata	16	38	55	35	60	50	34
Larinioides suspicax	10	35	56	32	30	64	39
Cyclosa insulana	5	26	35	19	3	23	59
Cyrtophora citricola	13	32	54	34	29	33	71
Clubionidae							
Clubiona comta	24	44	61	36	45	58	62
Dictynidae							
Lathys sp	21	48	69	44	46	49	87
Dysderidae							
Dysdera crocata	29	62	91	58	65	78	97
Eresidae							
Adonea sp	17	25	45	27	37	36	41
Dorceus quadrispilotus	1	2	2	3	0	0	8
Eresus albopictus	26	49	71	38	55	72	57
Loureedia annulipes	2	1	0	3	2	4	0
Stegodyphus dufouri	20	46	67	37	38	64	68
Stegodyphus manicatus	26	48	71	40	71	36	78
Filistatidae							
Filistata insidiatrix	7	19	39	17	0	38	44
Gnaphosidae							
Anagraphis pallens	23	46	84	48	72	43	86
Echemus sp	22	46	69	33	56	48	66
Drassyllus sp	18	43	53	23	33	58	46
Drassodes unicolor	16	33	92	53	49	68	77
Haplodrassus dalmatensis	6	6	13	7	1	5	26
Parasyrisca sp	0	1	3	0	0	0	4
Phaeocedus	19	34	59	39	39	45	67
Pterotricha conspersa	23	44	84	49	66	67	67
Urozelotes sp.	19	40	57	38	58	36	60
Zelotes laetus	9	33	81	37	23	50	87
Hersiliidae							
Hersilia caudata	26	55	90	51	71	64	87
Hersiliola simoni	19	58	89	44	48	74	88
Linyphiidae							
Brachycerasphora monocerotum	17	34	47	38	47	39	50
Ostearius melanopygius	11	21	69	40	35	50	56
Lycosidae							
Arctosa fulvolineata	26	61	87	49	65	70	88

Evippa arenaria	27	49	82	47	56	61	88
Pardosa paleata	27	46	52	23	33	43	72
Pardosa confalonierii	15	42	69	42	22	52	94
Trochosa urbana	22	61	61	32	48	54	74
Oecobiidae							
Uroctea compactilis	0	0	1	0	0	0	1
Oecobius navus	11	34	68	44	76	73	8
Oecobius sp	14	29	52	26	68	53	0
Oxyopidae							
Oxyopes sp	17	27	43	17	39	44	21
Palpimanidae							
Palpimanus gibbulus	26	65	88	52	78	75	78
Philodromidae							
Rhysodromus lepidus	5	24	60	24	18	34	61
Tibellus armatus	24	47	94	39	52	59	93
Pholicidae							
Holocnemus caudatus	9	16	36	11	0	18	54
Pholcus phalangioides	26	63	94	53	113	77	46
Salticidae							
Aelurillus ambiguus	0	0	2	2	0	0	4
Euophrys frontalis	19	53	97	49	63	58	97
Evarcha arcuata	11	56	84	40	36	62	93
Evarcha laetabunda	17	21	66	29	25	50	58
Hasarius adansoni	17	36	84	34	61	47	63
Heliophanus equester	9	31	92	43	39	52	84
Icius congener	5	34	72	23	29	52	53
Menemerus sp	11	15	23	12	20	21	20
Mogrus logunovi	0	6	16	9	9	4	18
Phlegra sp1	1	3	5	3	0	1	11
Phlegra sp2	1	3	4	2	0	0	10
Phlegra sp3	0	0	2	1	0	0	3
Plexippus paykulli	28	51	110	59	93	68	87
Thyene imperialis	26	37	111	54	75	63	90
Scytodidae							
Scytodes univittata	8	29	75	30	57	41	44
Segestriidae							
Segestria florentina	0	0	2	0	0	0	2
Selenopidae							
Selenops radiatus	3	5	6	4	0	0	18
Sicariidae							
Loxosceles rufescens	30	58	110	66	114	67	83
Sparassidae							
Micrommata formosa	14	49	68	29	38	65	57
Micrommata sp	16	29	36	23	32	34	38
Tetragnathidae							
Tetragnatha nitens	18	22	31	13	43	28	13
Tetragnatha sp	17	19	25	9	22	35	13
Metellina merianae	9	7	8	7	0	0	31
Theridiidae							
Anelosimus pulchellus	0	2	3	4	0	1	8
Anelosimus vittatus	0	3	8	5	0	0	16
Argyrodes argyrodes	5	14	23	9	18	15	18

Latrodectus geometricus	38	63	63	63	83	65	79
Latrodectus tredecimguttatus	16	32	32	32	30	35	47
Steatoda latifasciata	8	19	24	14	1	29	35
Steatoda paykulliana	6	6	12	7	0	14	17
Steatoda ephippiata	5	6	6	7	0	3	21
Theridion melanostictum	19	29	41	24	27	42	44
Theridion pinicola	18	25	38	19	16	40	44
Theridion varians	21	49	77	39	63	45	78
Thomisidae							
Ozyptila perplexa	4	4	10	5	3	3	17
Thomisus onustus	27	47	62	20	48	46	62
Tmarus staintoni	14	29	46	14	29	33	41
Xysticus sabulosus	17	40	53	33	54	50	39
Titanoecidae							
Titanoeca sp	0-	0	2	1	0	0	3
Uloboridae							
Uloborus plumipes	21	43	57	25	48	61	37
Zodariidae							
Zodarion nitidum	18	37	45	19	18	45	56

Table 2. The spider species richness and individuals in habitats and seasons.

	Winter		**Spring**		**Summer**		**Autumn**	
	Species	Indi.	Species	Indi.	Species	Indi.	Species	Indi.
City	<u>61</u>	<u>*332*</u>	69	767	70	1305	69	774
Farmland	75	408	74	897	76	1468	76	815
Wild	77	526	83	1094	**88**	**1830**	84	1008

Note: 1. An underlined value indicates the lowest species richness and individuals. 2. Values in bold indicate the highest species richness and individuals. Indi. = Number of individuals

Table 3. Similarity values (Bray-Curtis, lower diagonal) and beta diversity (dis) similarity values (upper diagonal), city winter (CWi), city spring (CSp), city summer (CSu), city autumn (CAu), farm winter (FWi), farm spring (FSp), farm summer (FSu), farm autumn (FCAu), wild winter (WWi), wild spring (WSp), wild summer (WSu), and wild autumn (WAu).

	CWi	CSp	CSu	CAu	FWi	FSp	FSu	FAu	WWi	WSp	WSu	WAu	
CWi		8	8	8	10	10	11	11	16	17	19.0 †	19.0 †	Turnover species Beta diversity (Harrison β_h X 100)
CSp	0.6		1.0*	1.0*	6	6	5	6	11	11	13	12	
CSu	0.4	0.7		2	6	7	4	5	10	10	13	12	
CAu	0.6	**0.8**	0.7		6	6	6	6	12	12	15	14	
FWi	0.7	0.6	0.5	0.6		2	3	2	7	8	0.1	0.09	
FSp	0.5	**0.8**	0.7	0.8	0.6		4	3	9	8	0.11	0.1	
FSu	<u>0.4</u>	0.7	**0.8**	0.7	0.4	0.8		3	6	6	9	8	
FAu	0.6	0.8	0.7	0.8	0.6	**0.8**	0.7		7	7	0.1	9	
WWi	0.7	0.7	0.5	0.7	0.7	0.7	0.5	0.7		4	7	4	
WSp	0.4	0.7	0.8	0.7	0.5	**0.8**	0.8	0.8	0.6		3	3	

WSu	0.3	0.6	0.7	0.5	0.4	0.6	0.8	0.6	0.5	0.7		2	
WAu	0.4	0.7	0.7	0.7	0.5	0.8	0.7	0.8	0.7	**0.9**	0.7		
	Similarity (Bray-Curtis)												

Note: 1. Values in underlined values indicate the lowest values of similarity. 2. Values in bold indicates the highest values of similarity. 3. * Values in bold indicate the lowest values of species turnover, and † Values indicate the highest values of species turnover.

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