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RESEARCH ARTICLE

Communities of soil macrofauna in green spaces of an urbanizing city at east China

Comunidades de macrofauna del suelo en espacios verdes de una ciudad en proceso de urbanización en el este de China

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ABSTRACT

We evaluated the diversity of soil macrofauna communities inhabiting urban green spaces in Yancheng City, an urbanizing city located east of China. In the end of April 2011, the taxonomic richness, abundance and composition of soil macrofauna communities were assessed and compared among five types of green space (poplar forest, rapeseed farm, grassland in park, lawn and nursery garden) and three depth layers in the soil, with taxonomic resolution attained at the order level. Taxonomic richness (orders) and abundance were significantly different among green spaces. Diversity indices (Margalef's taxonomic richness R and Shannon-Weaver diversity index H') were higher in poplar forest, grassland in park and nursery garden than in rapeseed farm and lawn. Taxonomic richness (Chao 2) showed a similar trend. There were significant effects of green space type and soil layer, which showed a significant interaction affecting macrofauna composition. We recommend that urban green spaces can be used for maintaining biodiversity, not only for landscape purposes.

Key words: China, diversity, soil layer, urbanization, Yancheng City.

RESUMEN

Evaluamos la diversidad de las comunidades de macrofauna del suelo que habitan los espacios verdes urbanos en la ciudad de Yancheng, una ciudad en proceso de urbanización situada al este de China. A fines de abril 2011, la riqueza taxonómica, abundancia y composición de comunidades de macrofauna del suelo fueron evaluadas y comparadas entre cinco tipos de espacio verde (bosque de álamos, granja de colza, pastizal de parque, césped y jardín vivero) y tres capas de profundidad del suelo, con resolución taxonómica a nivel de orden. La riqueza taxonómica (de órdenes) y la abundancia fueron significativamente diferentes entre los espacios verdes. Los índices de diversidad (riqueza taxonómica R de Margalef y diversidad H' de Shannon-Weaver) fueron mayores en el bosque de álamos, pastizal de parque y jardín vivero que en la granja de la colza y el césped. La riqueza taxonómica (Chao 2) mostró una tendencia similar. Hubo efectos significativos del tipo de espacio verde y capa del suelo, los cuales mostraron una interacción significativa afectando la composición de la macrofauna. Recomendamos que los espacios verdes urbanos se puedan utilizar para mantener la biodiversidad, y no solo con propósitos de paisaje.

Palabras clave: capa del suelo, China, ciudad de Yancheng, diversidad, urbanización.

INTRODUCTION

Green spaces are particularly important in urban environments where the soil biota may enhance the environmental quality of the city through degradation of pollutants and reduction of surface water run-off due to the development and preservation of soil structure (Smith et al. 2006). However, urban biodiversity is subject to a number of natural processes and anthropogenic activities, making it difficult to identify a general conservation strategy (Scalenghe & Marsan 2009). Studies on above-ground invertebrates of habitat fragments in urban areas have identified several factors that influence species diversity, including: fragment size, degree of isolation, fragment age, edge effects, disturbance levels, habitat characteristics, and invasion by exotic species (Bolger et al. 2000, Gibb & Hochuli 2002). However, data on below-ground taxa are scarce (Rossi et al. 2006). In many cities, the majority

TABLE 1
Characteristics of the green spaces selected in the study.
Características de los espacios verdes seleccionados en el estudio.

Type of green space	Geographic coordinates	Age (years)	Vegetation characters		
			Arbor (coverage)	Shrub (coverage)	Herbage (coverage)
Poplar forest	33.366° N, 120.199° E	7	*Populus euramericana* Guinier (40 %)	None	*Setaria viridis* (L.) P.Beauv., *Conyza canadensis* (L.) Cronquist (30 %)
Rapeseed farm	33.364° N, 120.195° E	> 10	None	None	*Brassica napus* L. (90 %)
Grassland in park	33.346° N, 120.166° E	3	*Cedrus deodara* (Roxb. ex Lamb.) G. Don, *Metasequoia glyptostroboides* Hu & W. C. Cheng (10 %)	*Buxus sinica* (Rehder & E. H. Wilson) M. Cheng, *Ligustrum lucidum* W. T. Aiton (10 %)	*Vicia cracca* L., *Conyza canadensis* (L.) Cronquist and *Chenopodium album* L. (100 %)
Lawn	33.349° N, 120.175° E	3	None	None	*Ophiopogon japonicus* (Thunb.) Ker Gawl. (100 %)
Nursery garden	33.352° N, 120.182° E	8	None	*Ligustrum lucidum* W. T. Aiton (80 %)	*Conyza canadensis* (L.) Cronquist, *Stellaria alsine* Grimm (30 %)

of urban green spaces are domestic with human made environment patches. These unique environments, although highly modified and disturbed, have recently been identified as an important source of native biodiversity (Gaston et al. 2004). Land use has a strong influence on the overall abundance, diversity and community composition of soil macrofauna (Barros et al. 2002, Barrios et al. 2005). Significant differences have been detected among the urban green spaces on the vegetation cover (Ge et al. 2005), and the soil macrofauna in the green spaces can be used to evaluate the health of the urban ecosystem (McIntyre 2001).

The world is undergoing the largest wave of urban growth in history. In 2008, for the first time in history, more than half of the world's population was living in towns and cities (UNFPA 2010). Urbanization in China is taking place at an unprecedented pace and will continue over the next decades. The level of urbanization in China has risen from 18 % in 1978 to 30 % in 1995 and to 39 % in 2002 (Song & Ding 2007), and then 47 % in 2010 (UNDESA 2010). It is expected that China will quadruple its total GDP and reach 55 % of urbanization by 2020 (Song & Ding 2007). In the urbanization, the land use types in the cities would be changed eventually, and then the green spaces is a very important kind of land use for the health of the cities (McIntyre 2001), and therefore the biodiversity in the green spaces of the cities should be evaluated with the urban sprawl.

In this study, we used different diversity indices and structure composition to compare the macrofauna communities in five green spaces of Yancheng City, Jiangsu Province, China, aiming to apply the results to the planning of urban green spaces and the conservation of biodiversity in cites.

METHODS

Study area and green spaces

Yancheng City is located on the west-Pacific coast at the transition between subtropical and temperate zones in Jiangsu Province, eastern China. Annual rainfall, primarily between June and August, averages 900 to 1100 mm. Average daily temperatures were 14.6 to 15.9 ºC (Committee of Jiangsu Provincial Atlas Compilation 2004). The urban area of Yancheng City has risen from 70.6 km^2 in 2006 to 118 km^2 in 2011, while some suburban areas have turned to be urban in recent years.

Along Xindu Road, five types of green space (see Table 1) were selected at the end of April 2011 in Yancheng City, and Xindu Road was a main traffic road passing through the old area and new area. The habitats were selected on the basis of the function of green spaces in the city, such as typical green spaces (the river green belt, park and lawn for road greenization) and patches embedded in the city following with the urbanization (nursery garden and farm).

The maximum distance among different green spaces was about 6 km. Yancheng is a city diked from the sea, and their soils corresponded to Fluvisols (FAO/UNESCO Taxonomy) or Inceptisols (Soil Taxonomy).

Sampling and identification

A sample plot was settled at each type of green space, where five soil blocks of 20 cm × 20 cm to 15 cm depth were collected and sorted. Sampling units were located 5 m apart and distributed randomly in the plot. The soil block was removed from the ground, divided into three layers of 5 cm depth (I: 0-4.9 cm, II: 5-9.9 cm and III: 10-15 cm), and hand-sorted for soil macrofauna. Each soil block was hand-sorted for about 60 min and any macrofauna encountered was counted for assessing abundance, preserved in 70 % ethanol, and identified to order level (Pauli et al. 2011).

Data analysis

The taxonomic richness was used in the analysis of soil macrofauna communities with the macrofauna identified at the order/class level (Pauli et al. 2011). We also used some general diversity indices such as Shannon-Weaver diversity index H' (Shannon & Weaver 1949), Margalef's richness index R (Margalef 1957) and Pielou's evenness index J (Pielou 1966) based on the communities' composition data sets for each soil block (n = 5 for each type of green space). In addition, Chao 2 richness index was employed to estimate the taxonomic richness with a 95 % confidence interval for each green space using bootstrap replicates method (Hammer et al. 2001). Based

TABLE 2

Number of soil macrofauna individuals (identified to order level) collected in the studied green spaces.

Número de individuos de la macrofauna del suelo (identificados a nivel de orden) colectados en los espacios verdes estudiados.

Order	Poplar forest	Rapeseed farm	Grassland in park	Lawn	Nursery garden	Total	Frequency (%)
Anoplura	1	0	1	0	1	3	0.58
Araneae	2	2	4	0	12	20	3.90
Coleoptera	6	3	9	3	7	28	5.46
Diplura	6	2	9	10	11	38	7.41
Diptera	0	0	0	0	2	2	0.39
Geophilomorpha	0	0	1	1	0	2	0.39
Hemiptera	3	4	8	3	0	18	3.51
Hymenoptera	35	25	28	25	50	163	31.77
Isopoda	16	0	40	0	84	140	27.29
Isoptera	0	0	3	0	2	5	0.97
Lepidoptera	0	2	0	1	1	4	0.78
Lumbricida	0	0	1	0	1	2	0.39
Mesogastropoda	13	0	4	0	0	17	3.31
Opiliones	1	0	4	1	2	8	1.56
Protura	0	0	7	6	21	34	6.63
Scolopendromorpha	1	0	2	1	1	5	0.97
Stylommatophora	2	2	9	0	4	17	3.31
Tubificida	3	0	2	0	2	7	1.36

on the same data sets, a one-way ANOVA was used to compare taxonomic richness and abundance among green spaces, and a Tukey test was used if significant differences occurred.

Based on the taxonomic richness and abundance data sets for each block with diffrent layers, two-way ANOVAs of taxonomic richness and abundance were used to determine the effects of green spaces types and of soil layers.

Based on an Euclidean distance matrix (75 × 18) created from the communities' composition data, ANOSIM (with 9999 permutations) was used for testing the statistical significance of the factors green space type (n = 5) and soil layer (n = 3).

SPSS 16.0 (SPSS Inc.), Primer 5.0 (Primer-E Ltd.) and PAST (freeware, Hammer et al. 2001) were employed for statistical analyses.

RESULTS

A total of 18 soil macrofauna taxa were identified in the investigation: arthropods (14 orders), molluscs (two orders) and annelids (two orders). Hymenoptera (all of them ants) and Isopoda were the dominant taxa (Table 2).

There were significant differences in taxonomic richness ($F_{4, 20}$ = 15.483, P < 0.001), abundance ($F_{4, 20}$ = 41.261, P < 0.001), H' index ($F_{4, 20}$ = 7.510, P = 0.001) and R index ($F_{4, 20}$ = 4.988, P = 0.006) among green spaces. while no significant differences occured in the J index ($F_{4, 20}$ = 4.988, P = 0.063) (Table 3).

The soil macrofauna communities found in nursery garden, grassland of park and poplar forest had the higher taxonomic richness, abundance, R and H' values. Lowest values occurred in lawn and rapeseed farm (Fig. 1).

Chao 2 richness index show that the highest value also occurred in nursery garden, grassland in park and poplar forest, the lowest value occurred in lawn and rapeseed farm (Fig. 2).

TABLE 3

One-way ANOVA results for the variation in abundance, taxonomic richness, diversity, richness and evenness of soil macrofauna among five different types of green space.

Resultados de ANDEVA de una vía sobre la variación en abundancia, riqueza taxonómica, diversidad, riqueza y uniformidad de la macrofauna del suelo entre cinco diferentes tipos de espacio verde.

Source		SS	d.f.	MS	F	P
Taxonomic richness	Between Groups	107.760	4	26.940	15.483	< 0.001
	Within Groups	34.800	20	1.740		
	Total	142.560	24			
Abundance	Between Groups	3462.640	4	865.660	41.261	< 0.001
	Within Groups	419.600	20	20.980		
	Total	3882.240	24			
R	Between Groups	2.255	4	0.564	7.510	0.001
	Within Groups	1.502	20	0.075		
	Total	3.757	24			
H'	Between Groups	3.808	4	0.952	4.988	0.006
	Within Groups	3.817	20	0.191		
	Total	7.625	24			
J	Between Groups	0.059	4	0.015	2.662	0.063
	Within Groups	0.111	20	0.006		
	Total	0.170	24			

TABLE 4

ANOSIM results for the composition of macrofauna communities in different types of green spaces and soil layers.

Resultados de ANOSIM para la composición de las comunidades de la macrofauna en diferentes tipos de espacios verdes y capas del suelo.

Factor	Group	Globle R	
		Statistic	P
Green spaces type	Poplar forest vs. rapeseed farm	0.203	0.016
	Poplar forest vs. grassland in park	0.125	0.071
	Poplar forest vs. lawn	0.306	0.002
	Poplar forest vs. nursery garden	0.644	< 0.001
	Rapeseed farm vs. grassland in park	0.313	0.001
	Rapeseed farm vs. lawn	0.067	0.129
	Rapeseed farm vs. nursery garden	0.633	< 0.001
	Grassland in park vs. lawn	0.289	0.001
	Grassland in park vs. nursery garden	0.395	0.001
	Lawn vs. nursery garden	0.577	< 0.001
Soil layer	I (0-4.9 cm) vs. II (5-9.9 cm)	0.650	< 0.001
	I (0-4.9 cm) vs. III (10-15 cm)	0.766	< 0.001
	II (5-9.9 cm) vs. III (10-15 cm)	0.421	< 0.001

By two-way ANOVAs, there was significant effect of green space type ($F_{4, 60}$ = 12.011, P < 0.001) and significant effect of soil layer ($F_{2, 60}$ = 94.939, P < 0.001) for taxonomic richness, we also detected a significant interaction between them ($F_{8, 60}$ = 2.430, P = 0.024). For abundance, we found significant effect of green space type ($F_{4, 60}$ = 20.068, P < 0.001), soil layer ($F_{2, 60}$ = 218.822, P < 0.001), and interaction between them ($F_{8, 60}$ = 5.802, P < 0.001).

ANOSIM revealed significant effects of green space type (Global R = 0.320, P < 0.001) and soil layer (Global R = 0.539, P < 0.001). Significant differences were detected in most of the pairwise tests, despite the fact that there were no significant differences between poplar forest vs. grassland in park (Global R = 0.125, P = 0.071), and rapeseed farm vs. lawn (Global R = 0.067, P = 0.129). Significant differences were detected in all pairwise tests among different soil layers (Table 4).

DISCUSSION

The green spaces sampled in this study had a high taxonomic richness and a wide abundance range of soil macrofauna (Table 1). Thus, our results supported the idea that the type of green space has a significant effect on the composition of soil macrofauna communities, which was similar to other studies in urban green spaces (Ge et al. 2005, Smith et al. 2006). The results indicated that the higher diversity would occur in the complexity habitat, which could be determined by the soil quality and vegetation enviromental characters (Mathieu et al. 2005). In the post researches, it has been reported that the soil quality and soil macromorphology could be the factors determining the biodiversity which were affected by urbanization (Manta et al. 2002, Acosta et al. 2011).

In the study, the diversity indices of H’, R and the estimate taxonomic richness (Chao 2)

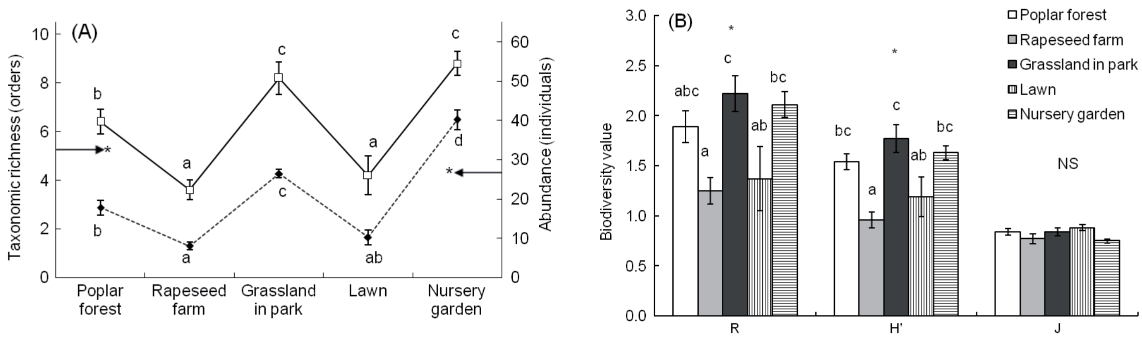

Fig 1: Biodiversity of soil macrofauna communities in different green spaces. (A) Taxonomic richness and abundance, (B) Shannon-Weaver diversity index H', Margalef's richness index R and Pielou's evenness index J. Values: mean ± SE. *: significant, NS: non-significant. Means with different letters are significantly different (Tukey test, $\alpha = 0.05$).

Biodiversidad de las comunidades de macrofauna del suelo en diferentes espacios verdes. (A) Riqueza taxonómica y abundancia, (B) Índice de diversidad H' de Shannon-Weaver, índice de riqueza R de Margalef, e índice de equitatividad J de Pielou. Valores: media ± SE. *: Significativo, NS: no significativo. Medias con letras distintas son significativamente diferentes (prueba de Tukey, $\alpha = 0.05$).

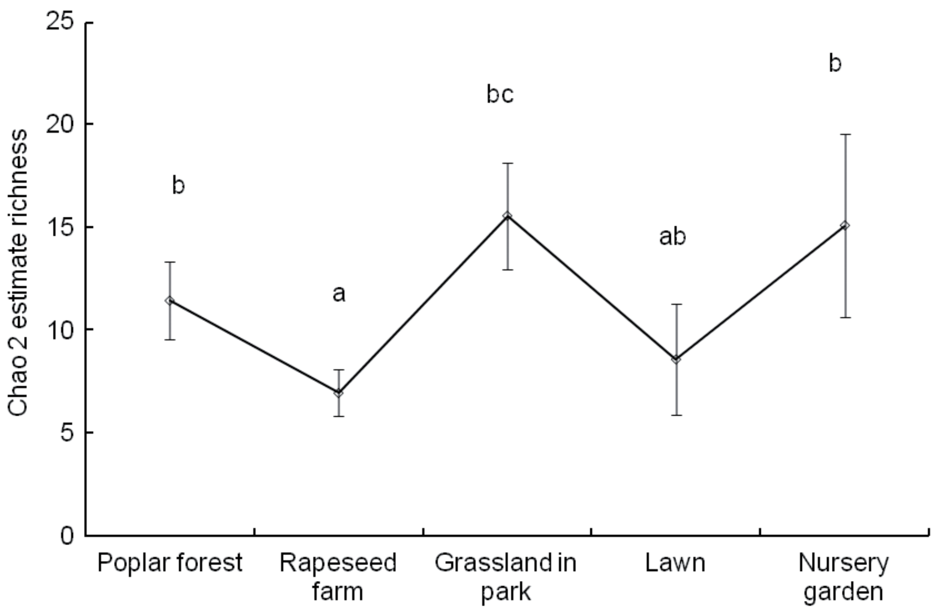

Fig 2: Taxonomic richness of different green spaces as estimated by Chao 2 with a 95 % confidence interval. Means with different letters are significantly different (if the confidence intervals overlap, they are not significantly different; $\alpha = 0.05$).

Riqueza taxonómica de los diferentes espacios verdes estimada mediante Chao 2, con un intervalo de confianza de 95 %. Medías con letras distintas son significativamente diferentes (si los intervalos de confianza se superponen, no son significativamente diferentes; $\alpha = 0.05$).

showed the similar trend, and then the highest value occured at the grassland in park. Our results indicated that in the urbanizing city, complex habitats can offer a higher diversity of soil macrofauna, and that the effect of trees on biodiversity should be especially considered in the planning of green spaces (Binkley & Giardina 1998, Barbier et al. 2008).

The soil macrofauna distribution (including taxonomic richness and abundance) was affected significantly by the type of green space, soil layer and the interaction. The results showed that not only green space but also the soil depth was strongly related to patterns of soil macrofauna distribution and community composition (Gibb & Hochuli 2002, Pauli et al. 2011). In addition to individual factors, the interaction between type of green space and soil layer was an important factor which could determine the vertical distribution patterns. The significant interaction indicated that soil macrofauna vertical distribution was also affected by the change of soil layers which collaborated with types of green spaces.

It has been reported that soil macrofauna in urban green spaces is different to the macrofauna in the forest or in the countryside (Smith et al. 2006, Scalenghe & Marsan 2009). Nevertheless, the green space should be used for maintaining the biodiversity in urban ecosystem, not only for designing them as landscape. Our results indicated that the types of green spaces should be the main driving force for the biodiversity variation in the study.

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