ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

Final Technical Report
CRYS2017-03SY-Sing

Urban biodiversity and human well-being in Asia's megacities

The following collaborators worked on this project:

1. Sing Kong Wah, Kunming Institute of Zoology, China, garysingkongwah@qq.com
2. John James Wilson, University of South Wales, United Kingdom, johnjameswilson@qq.com
3. Narong Jaturas, Naresuan University, Thailand, narongjaturas@gmail.com
4. Wang Wenzhi, Kunming Institute of Zoology, China, wangwz@mail.kiz.ac.cn
5. Masashi Soga, University of Tokyo, Japan, soga06154053@yahoo.com

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Project Overview

Project Duration	:	1 year
Funding Awarded	:	US$ 15,000 for Year 1
Key organisations involved	:	1. Sing Kong Wah, Kunming Institute of Zoology, China 2. John James Wilson, University of South Wales, United Kingdom 3. Narong Jaturas, Naresuan University, Thailand 4. Wang Wenzhi, Kunming Institute of Zoology, China 5. Masashi Soga, University of Tokyo, Japan 6. Tao Thien Nguyen, Vietnam Academy of Science and Technology, Vietnam

Project Summary

In urban green spaces, such as city parks, native insects provide important ecosystem services including pollination of plants that provide food for humans and other animals, and enrich human well-being. These important services proceed largely unnoticed and have received limited attention. Several studies of insect diversity in city parks, thought of as urban wildlife refuges, have been conducted in Europe and North America but few have been conducted in rapidly urbanizing countries in Asia. Without further research on the diversity of insects in urbanization hotspots we cannot predict how future development will affect the ecosystem services and benefits they provide. In this project, butterflies – a model "biodiversity indicator" up for biodiversity studies were sampled in parks in Bangkok, Beijing, and Hanoi cities. Butterfly and questionnaire surveys were conducted in ten parks in each city followed standardized butterfly sampling. The questionnaire survey aimed to explore park users' perceptions on butterfly diversity in urban parks and its relationship with human well-being. This report will focus on findings in Beijing's urban parks and the results from Bangkok and Hanoi are still in analysis phase which will not include in this technical report.

Keywords: butterflies; megacities; human-well beings; urban parks

Project outputs and outcomes

Outputs	Outcomes

Generate regional data from three cities (Bangkok, Beijing, Ho Chi Minh) to combine with data from published studies of urban butterfly biodiversity (Kuala Lumpur, Singapore, Hong Kong, Shenzhen, Guangzhou, Seoul Tokyo, Olongapo City) to perform a region-wide meta-analysis of butterfly diversity in Asia parks.	The butterfly biodiversity in Asia parks is still in compiling phase and the update can be view at: http://uba-net.simplesite.com/436284345
To examine the value of urban parks as refuges for butterflies - a model bioindicator group for biodiversity studies, and a charismatic flagship group for insect conservation - through investigating the relationships between butterfly species richness and the age, size and distance from the central business district of parks in three Asian cities	The correlation between butterfly species with other indicator species (birds and plants) in Beijing's urban parks was performed and we will further analyse the relationships between butterfly species richness and the age, size and distance from the central business district of parks in the studied cities.
To identify which type of microhabitat within urban parks provides suitable breeding and foraging habitat for butterflies.	Unmanaged microhabitat provides suitable breeding and foraging habitat for butterflies.
To determine whether the human communities in Asia megacities perceive and appreciate butterflies.	Urban residents tend to have positive experience with butterflies in cities.
To build DNA barcode reference libraries of urban butterflies to enable rapid surveys of these species in future studies	All generated DNA barcodes from butterflies were deposited to Barcode of Life Datasystems.

Key facts/figures

1. We collected 587 individual butterflies belonging to 31 species from five families; 77% of the species are considered widespread.
2. The estimated butterfly species richness in Beijing's urban parks was 30 species and Chao 2 richness estimator was 57 species based on the pooled sample of 587 butterfly individuals.
3. The highest butterfly species richness and abundance was recorded from the parks located at the edge of city.
4. Butterfly species richness showed weak positive correlations with bird and plant species richness ($p > 0.05$) in Beijing's urban parks.
5. A specimen of *Danaus chrysippus*, recorded in Beijing city during our study, represents the first record of the species in northern China.

6. One undergraduate student from China Agricultural University, five undergraduate/postgraduate students from Hanoi National University of Education and one young researcher from Vietnam Academy of Science and Technology were trained in conducting social research methodology included questionnaire survey approaches.

Potential for further work

1. Initiate a citizen science project in city that involving publics in urban biodiversity monitoring will be further improve our understanding the biodiversity persist in city.

2. Promote biodiversity conservation in school by conducting education based project such as mobility butterfly lab will allow school children have close contact with butterflies.

3. Further investigate will be focus on how to improve urban green infrastructure to promote survival of biodiversity.

Publications

1. Sing KW, Luo J, Wang WZ, Jaturas N, Soga M, Yang X, Dong H, Wilson JJ. (2018) Ring roads and urban biodiversity: distribution of butterflies in urban parks in Beijing city and correlations with other indicator species. Scientific Report: (*Under review*)**.**

2. Sing KW. (2018) Butterflies. Poster displayed at the Kunming Natural History Museum of Zoology entrance on Science Day (18-20 May 2018). http://270280972.ax.nofollow.51wyfl.com/index.php/toupiao/h5/detail?id=532271&vid=270280972

Awards and honours

A photo taken during butterfly survey in a park in Beijing under APN funded project won an Excellence Award in the "China in the Eyes of Foreign Teachers" competition. Detail can be find at:
http://vote.talent.org.cn/plugin.php?id=hejin_toupiao&model=detail&zid=221&from=singlemessage

Pull quote

"We conducted the **FIRST** urban butterfly survey in Beijing and we recorded the **FIRST** *Danaus chrysippus* butterfly in northern China! We are toward better understand the biodiversity in Asia's city through this project"

John James Wilson, University of South Wales

Acknowledgments

We thank the Asia Pacific Network for Global Change Research (CRYS2017-03SY-Sing), and grant to the Animal Branch of the Germplasm Bank of Wild Species of Chinese Academy of Sciences - the Large Research Infrastructure Funding (KFZD-SW-208) for supporting this study. We are grateful to park managers who provided permission to conduct butterfly surveys. We thank Dr. Le Trung Dzung, Dr. Tran Duc Hau, Kunming Institute of Zoology, Chinese Academy of Sciences, Naresuan University, Fairylake Botanical Garden Facilities, Vietnam Academy of Science and Technology, Nilai University Malaysia and volunteers provided assistances, lab spaces and facilities throughout the project.

1. Introduction

China is a megadiverse country, harboring more than ten percent of the world's known species. More than fifty percent of the world's known species of seed plants are endemic to China (Lawrence, 2008; Huang, Chen, Ying, & Ma, 2011; Pyne, 2013). However, the country is rapidly losing biodiversity as a consequence of explosive socioeconomic development and expansion of urban land during the past three decades (Lu, Liang, Bi, Duffy, & Zhao, 2011; Zheng & Cao 2015). Between 2000 and 2010, urban land coverage in China expanded 28% from 98,819 km^2 to 126,661 km^2 and is predicted to keep increasing rapidly (Schneider et al., 2015).

Beijing has been the capital city of China for four dynasties of Chinese history, spanning 865 years (Li, Ouyang, Meng, & Wang, 2006a). One of the world's original megacities, Beijing was the only city in the world with a population over one million in 1860 CE (Reba, Reitsma, & Seto, 2016). Nevertheless, Beijing has experienced further, rapid urban development since the establishment of the People's Republic of China in 1949, expanding from the inner core (the "Forbidden City") to retreating outskirts in a "pancake-shaped" pattern bordered by concentric ring roads. A central business district developed between the 2nd and 3rd ring roads between 1950 and 1980, followed by urban development between the 3rd and 4th ring roads during the next decade (1980s), and between the 4th and 5th ring road the decade after that (1990s) (Su, Zhang, & Qiu, 2011). Since 2000, there has been conversion of former cropland and grassland outside the 5th ring road into residential and commercial districts (Su, Zhang, & Qiu, 2011); urban land across the wider Beijing Municipality increased 234 km^2 to 2720 km^2 in the last decade (Schneider et al., 2015; Xiao, 2015).

With the continuous expansion of urban land across the country, the Chinese government has recognized the key role of urban green spaces, such as urban parks, in the preservation of biodiversity. In order to protect and conserve biodiversity in urban areas, the "Measures for Application and Evaluation of National Garden Cities and the Standards for National Garden Cities" policy (Ministry of Environmental Protection, 2008) required city developers to build gardens and parks; use native plant species in parks and gardens; and conserve natural landscapes, vegetation, water systems and wetlands as a component of urban planning (Ministry of Environmental Protection, 2008). The Beijing People's Government also developed a comprehensive policy for urban greening based on ecological principals with a long-term goal of connecting urban green spaces, such as parks, with green wedges and corridors to form a sustainable, green urban ecosystem (Li, Wang, Paulussen, & Liu, 2005).

Insights into the effectiveness of such policies in Beijing, have been provided by surveys of birds (Huang, Zhao, Li, & von Gadow, 2015; Morelli et al., 2017; Xie, Lu, Cao, Zhou, & Ouyang, 2016), plants (Li, Ouyang, Meng, & Wang, 2006a; Wang et al., 2007; Wang et al., 2011; Zhou et al., 2010), weevils (Su, Zhang, & Qiu, 2011), ground beetles (Warren-Thomas et al., 2014), and insect communities (Huang, Zhao, Li, & von Gadow, 2015) in urban green spaces, particularly urban parks. Beijing’s parks are important for migratory birds as only 37% of the 52 birds species recorded during the breeding season were residence type (Xie, Lu, Cao, Zhou, & Ouyang, 2016), suggesting that Beijing is a major node in the East Asian-Australasian Flyway. Beijing urban parks have a high number of exotic plant species that were introduced into parks as ornamentals and most of the rare tree species are only found in older parks (Li, Ouyang, Meng, & Wang, 2006a; Xiao, 2015). In general, urban parks located further from the inner core retained higher species richness of birds and plants (Li, Ouyang, Meng, & Wang, 2006a; Huang, Zhao, Li, & von Gadow, 2015; Xiao, 2015; Xie, Lu, Cao, Zhou, & Ouyang, 2016; Morelli et al., 2017). High species richness of birds was recorded from parks that maintained high species richness of insects (Huang, Zhao, Li, & von Gadow, 2015).

Surprisingly, to the best of our knowledge, there have been no reports of the distribution and influence of urbanization on butterflies in Beijing. Butterflies, diurnal Lepidoptera, have often been focus of urban biodiversity studies (see Ramirez-Restrepo & McGregor-Fors, 2016, and references therein) because butterflies are thought to react rapidly to environmental changes due to their high mobility and short generation time (McIntyre, 2000). Patterns of butterfly diversity are often reflected in other distantly related taxonomic groups (Chong et al., 2014; Syaripuddin, Sing, & Wilson, 2015), including other "indicator species" such as birds and plants. A potential warning note from another ancient capital, is the finding that Rome experienced the highest rates of extirpation of butterflies over the city's long history, during a period of urbanization between 1871 and 1930 (Fattorini, 2011). Consequently, we conducted the first butterfly survey in Beijing urban parks with the aim to: (i) estimate the total number of butterfly species in the city; (ii) study the distribution pattern of butterfly species in a megacity; and (iii) examine the correlation between butterfly species with other indicator species (birds and plants) in urban parks.

2. Methodology

In this section, we provided material and methods used in Beijing's urban butterfly data and these methods will be employed for analysis data from Bangkok and Hanoi cities in future.

Butterfly sampling

Beijing has a temperate, humid, continental climate with hot summers and cold winters and the average temperature is 12 ºC (Li, Ouyang, Meng, & Wang, 2006). Annually, the city receives 400－500 mm of rain which mostly falls between June－September (Li, Ouyang, Meng, & Wang, 2006). Our survey was conducted between June and July 2017 when the temperature is 13－38ºC and humidity is 13－96%, representing the optimal season for adult butterfly activity.

We conducted butterfly sampling in ten urban parks that are roughly evenly spread throughout Beijing city, that are open to the general public and are managed by the People's Government of Beijing Municipality except the Chao Yang Park that is operated by private company. Each park was sampled three days comprising 180 minutes each day. We followed the timed survey method, used in butterfly surveys in Kuala Lumpur (Sing, Jusoh, Hashim, & Wilson, 2016) and Shenzhen (Sing, Dong, Wang, & Wilson, 2016), to allow a full search of green areas in parks and avoid sampling biases due to differences in size and shape between parks. Due to the homogeneity of the landscape in Beijing parks, we did not designate microhabitat types. Butterflies were collected by an experienced collector using a hand net between 09:00 and 14:00 during calm weather to correspond with the peak flight activity period of adult butterflies.

Butterfly identification and diversity

All collected butterflies were brought back to laboratory. A specimen of Tirumala limniace found dead on a roadside in Olympic Forest Park during the butterfly sampling, was retrieved and also included in the analysis. DNA was extracted from a single leg, or 2－3 legs in the case of small lycaenids, of each butterfly using TIANamp extraction kit following the manufacturer's instructions (Tiangen Biotech, Beijing). DNA barcode fragments of COI mtDNA (Wilson, Sing, Floyd, & Hebert, 2017) were amplified (following standard protocols in Wilson, 2012) using LCO1490/HCO2198 primers (Folmer, Black, Hoeh, Lutz, & Vrijenhoek, 1994) as a first pass and mlCOlintF/HCO2198 primers (Leray et al., 2013; Brandon et al., 2015) as a second pass. PCR products were Sanger sequenced by a local company and checked for quality (following standard protocols in Wilson, Sing & Jaturas, 2018). Generated DNA barcodes and associated specimen data were submitted to Barcode of Life Datasystems (BOLD; Ratnasingham & Herbert, 2007) under the project "Urban Butterflies in Beijing Parks" (Project code: BJUP)". In BOLD, the DNA barcodes were automatically sorted into Barcode Index Numbers (BINs; Ratnasingham & Herbert, 2013). 435 DNA barcodes were assigned Linnaean species names when their sequence grouped into a BIN which included DNA barcodes with Linnaean species names submitted by other BOLD users. 110 DNA barcodes were not assigned to any BIN (due to their short sequenced length or because they contained more than 1% ambiguous bases) but were assigned Linnaean species name on the basis of > 98% sequence similarity to named DNA barcodes in BOLD. 42 butterflies that failed to generate DNA barcodes were assigned Linnaean species names based on their wing patterns following a local butterfly reference book (Chou, 1994).

We followed the zoogeographic regions for butterflies developed by Wu et al (2015) and categorized butterfly species as "endemic" when the species was only reported from one zoogeographic region and "widespread" when the species was reported from more than one zoogeographic region (using distribution records from Savela, 2013). The predicted butterfly species richness (expected number of species and Chao 2 rarefactions) based on incidences in Beijing urban parks were calculated using EstimateS (Colwell, Mao, & Chang, 2004).

Butterfly distribution in Beijing megacity

In urban ecology, study sites are generally classified into three categories according to the proportion of impervious surface (PIS): urban (PIS>50%), suburban (20%<PIS<50%) and rural (PIS<20%) (McKinney 2002). Based on the ring road system and the spatial pattern of PIS, Beijing has been divided into five urban zones (UZs) (Figure 1; Su, Zhang, & Qiu, 2011). Our survey included three parks in UZ1, one in UZ2, one in UZ3, three in UZ4 and two in UZ5.

Correlation of butterfly species with other indicator species in urban parks

We obtained species richness data from published literature for birds (Morelli et al., 2017), and plants (Li, Ouyang, Meng, & Wang, 2006)) recorded in any of the ten urban parks in

Beijing where we sampled butterflies (Figure 1). The species richness values (including butterflies) were natural logarithm ln (species richness+1) transformed prior further analysis. Pearson correlation coefficients between species richness of butterflies and the other taxa were calculated using Paleontological Statistical software (PAST; Hammer Harper, & Paul, 2001).

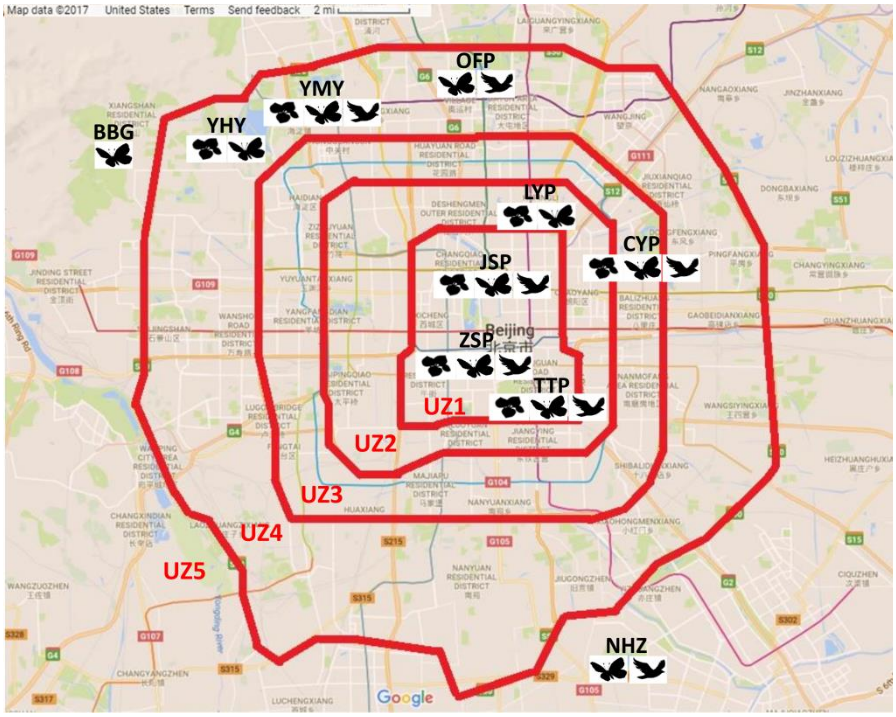

Figure 1: Ten urban parks in Beijing where butterfly survey was conducted in this study, and locations of species richness of birds (Morelli et al 2017) and plants (Li et al 2006) used for correlation tests.

3. Results & Discussion

Results

(i) Butterfly diversity in Beijing's urban parks

A total of 587 individual butterflies belonging to 31 species were collected from ten urban parks in Beijing (Table 1). Of the 31 species, twelve species belonged to the family Nymphalidae, nine to Lycaenidae, four to Papilionidae, four to Pieridae and two to Hesperiidae (Table 1). Pieris rapae and Pontia daplidice were the only species recorded from all ten surveyed parks (Table 1). Twenty-one species (68%) were only sampled in a single park (Table 1). Nearly half (47%) of the collected butterfly individuals were *Pieris rapae* (Table 1). Nineteen species (61%) were represented by fewer than five individuals (Table 1). Of the 31 species recorded, seven species are endemic to the Sino-Japanese region whereas the other 24 species (77%) are widespread (Table 1). The expected species richness was 30 species (Figure 2a) and Chao 2 richness estimator was 57 species (Figure 2b) based on the pooled sample of 587 butterfly individuals.

(ii) Distribution pattern of butterfly species in the Beijing city

The butterfly species richness recorded in urban parks ranged from two species (in UZ1) to 18 species (in UZ4) (Figure 3). The highest butterfly species richness was recorded in Beijing Botanical Garden (18 species). The park closest to the Forbidden City, Zhong Shan Park, had the lowest species richness, with only two species sampled (Figure 3).

(iii) Correlation between butterfly species with other indicator species (birds and plants) in urban parks

There were seven overlapping records for butterflies and birds in urban parks and seven overlapping records for butterflies and plants. The correlations between butterfly species richness and bird species richness ($p = 0.43$) and butterfly species richness and plant species richness ($p = 0.14$) were both positive, but not statistically significant (at $p < 0.05$; Figure 4).

Discussion

There are more than 70,000 cities and towns in China, and 16 are defined as megacities with a population exceeding 5 million (Huang, Yan, & Wu, 2016; Lu, Liang, Bi, Duffy, & Zhao, 2011). For Xalapa, Mexico, a city with a human population of half a million, Ramirez-Restrepo and colleagues (2015) estimated that more than one million butterflies also inhabited the city. Such data about butterfly populations are important for urban management and planning, as well as environmental education (Ramirez-Restrepo, Cultid-Medina, & MacGregor-Fors, 2015). A comprehensive review of urban butterfly studies found only one of 173 studies published between 1956 and 2015 was from mainland China (Ramirez-Restrepo & MacGregor-Fors, 2016). This was the report of our butterfly survey in Shenzhen (Sing, Dong, Wang, & Wilson, 2016). There are additional data available in Chinese language publications, but as far as we know, the present study is the first report of the species richness and distribution of butterflies in Beijing, the Chinese capital.

Five hundred and eighty-seven butterflies representing 31 species from five families were sampled across ten urban parks in the Beijing city, representing 2.5% of the known butterfly fauna of China (Chao, 1994). The total species count of this study is similar to studies from other megacities in the Sino-Japanese and East Paleartic zoogeographic region; 31 butterfly species were recorded in four urban parks in Seoul, South Korea (Lee et al., 2015), and 30 butterfly species in Osaka City, Japan, a city that experienced prolonged urbanization between the early 1930s and late 1980s (Imai, 1998). However, the total species count is lower than those reported from other megacities in China. Forty-three butterfly species were recorded in urban green spaces in Guangzhou (Li et al., 2009); 73 species in 10 urban parks in Shenzhen (Sing et al, 2016b) and 58 species in 13 parks in Hong Kong (Tam & Bonebrake, 2016). All three cities are located in the Pearl River Delta in subtropical southern China, close to the boundary of the Sino-Japanese and East Palearctic and Oriental zoogeographic regions (Wu et al., 2015); an area of higher butterfly diversity compared to northern China (Chao, 1994). Another possible factor contributing to the relatively low butterfly species richness in Beijing urban parks is the lack of an intrinsic ecological concept in the design of most parks. Beijing parks tend to be dominated by architectural landscapes, including historic edifices, with the main emphasis of park design on aesthetics and recreation (Li, Ouyang, Meng, & Wang, 2006).

Twenty-four butterfly species recorded in Beijing parks have wide geographic ranges. Fourteen of these species were also reported from urban parks in Seoul, South Korea (Lee et al., 2015). These species likely persist in urban parks because they can exploit a wide range of food resources (Lee et al., 2015) and have good dispersal abilities which allow them to occupy a broad range of ecological niches (Harcourt, Coppeto, & Parks, 2002; Lee et al., 2015). Pieris rapae was the most common and abundant butterfly species collected in Beijing parks. This is similar to the findings from both Chicago, United States (Matteson & Langellotto, 2012) and Seoul (Lee et al., 2015), where P. rapae was the most common species in these cities. The success of P. rapae in urban habitats is attributed to the ability of the butterfly to: disperse (Rochat, Manel, Deschamps-Cottin, Widmer, & Joost 2017), utilize a variety of plants as food sources as both adult and larvae (Ohsaki, 1980), move through and locate floral resources in heavily developed landscapes (Matteson & Langellotto, 2012), tolerate high temperatures, and use ephemeral habitats within urban green spaces (Takami, 2004).

The Danaus chrysippus, recorded at Jing Shan Park in this study, represents the first record of the species in northern China. The species previously has only been reported in southern provinces, the most northern being Shaanxi (Chao, 1994; Figure 5). Burton (2003) collated range distribution data for D. chrysippus over the past two decades and revealed that the range had increased considerably and extended north from North African coastal regions to the southern coastal regions of Europe. Likewise, studies in Europe have suggested 63%－75% of European Lepidoptera have extended their ranges northward in response to environmental changes such as climatic and/or habitat alteration (Parmesan et al., 1999; Burton, 2003). Interestingly, another oriental butterfly, Acraea terpsicore, which is endemic to lowland areas of India and Sri Lanka has extended its range southward across the equator by ~6000 km in 28 years, from Chiang Mai, Thailand (18º47'N) in the northern hemisphere to Adelaide River, Australia (13º14'S) in the southern hemisphere (Brady, Bertelsmeier, Sanderson, & Thistleton, 2013). Brady and colleagues (2013) hypothesized that habitat and climate change are the factors contributing to the range expansion of A. terpsicore given the species' preference for disturbed and open degraded areas and it is likely to retract in response to climate change. Further records and surveys of larval host plants are required to verify whether D. chrysippus has expanded its range northward in China, as only single individual butterfly was collected in our study. Interestingly, this single individual was collected in the urban core.

Releasing butterflies at special occasions such as wedding is a recent trend around the world, including China. Thousands of butterflies were released during the Butterfly Popular Science Exhibition event in Xingxiang, Henan Province, China (You & Chow, 2015). Pyle (2010) argued that butterfly releases are a disruptive practice which will interfere with our knowledge on species' distributions and biogeography. Such an event might explain the presence of another tiger butterfly, Tirumala limniace, in Olympic Forest Park. Both adult butterflies and larvae host plants have only previously been reported in southern China.

Butterfly communities in urban parks are strongly influenced by the surrounding landscape matrix that may act as an environmental filter excluding butterfly species, particularly those with narrow ecological niches (Blair & Launer, 1997; Öckinger, Dannestam, & Smith, 2009). In the present study, the highest butterfly species richness and abundance was recorded from the two parks in UZ5. Notably, 18 species were recorded at Beijing Botanical Garden, a park that adjoins a large area of semi-natural landscape. This is consistent with findings from Singapore (Koh & Sohdi, 2004) and Shenzhen (Sing, Dong, Wang, & Wilson, 2016) where urban parks adjoining forest retained higher butterfly species richness compared to isolated urban parks that have small areas or impoverished floras (Koh & Sodhi, 2004). As expected, parks in the inner core had very low species richness. Tian Tan Park (known in English as Temple of Heaven), an ancient park with larger green spaces compared to the other two parks (Zhong Shan Park and Jing Shan Park) in UZ1 had a higher species richness (6 butterfly species).

The butterfly species richness in Beijing parks showed positive relationships with the species richness of birds and plants, but the correlations were weak and not statistically significant. Plants, butterflies, and birds are often directly connected in food webs; leaves are the food resources for butterfly larvae and butterfly larvae are food resources for birds. Significant positive correlations between the species richness of butterflies and plants in urban spaces have been observed in the city of Halle/Saale, Germany (Bräuniger, Knapp, Kühn, & Klotz, 2010) and Sheffield, United Kingdom (Dallimer et al., 2012). However, the patterns observed in single taxon such as the butterflies is unlikely to broadly represent how other taxa might be distributed in a heterogeneous urban setting (Bräuniger, Knapp, Kühn, & Klotz, 2010; Dallimer et al., 2012).

In the absence of historical records of butterfly diversity in Beijing, our findings serve as baseline data for further surveys and conservation efforts. For example, an experimental butterfly conservation project in Beijing city organized by the Shan Shui Conservation Center has the aim of enhancing the richness of native butterfly species in Beijing by planting host plants in residential areas (Shan Shui Conservation Center, 2017).

In urban areas, butterflies provide important ecosystem services and are an ideal animal group through which to reconnect people with nature (Soga & Gaston, 2016; Wilson et al., 2015). Although most of the butterflies in Beijing urban parks are common species, populations of “common” species are increasingly in decline as well. Between 1992－2007, butterfly species that used to be omnipresent in gardens and parks in the Netherlands suffered severe declines under land-use change pressure (Van Dyck, Van Strien, Maes, & Van Swaay, 2008). Data on the distribution and species richness of butterflies in urban landscapes are particularly valuable for the development of butterfly conservation strategies but are currently lacking in China. Management schemes and techniques for conserving butterflies in urban parks in megacities like Beijing, that regularly receive large number of visitors or are dominated by structures with historical value, are especially valuable. Habitat-specific management strategies such as setting unmanaged areas in urban parks (Li, Ouyang, Meng, & Wang, 2006; Sing, Dong, Wang, & Wilson, 2016) and linking isolated urban parks through greenways could be effective in improving the ability of parks to sustain butterfly populations in the growing number of Asian megacities.

Table 1: Butterflies species and abundance recorded in ten urban parks in the Beijing city. The 10 sampled parks and their abbreviation are: Beijing Botanical Garden (BBG), Chao Yang park (CYP), Jing Shan park (JSP), Liu Yin park (LYP), Nan Hai Zhi park (NHZ), Olympic Forest park (OFP), Tian Tan park (TTP), Yi He Yuan park (YHY), Yuan Ming Yuan park (YMY), Zhong Shan park (ZSP)

Species	Distribution	BBG	CYP	JSP	LYP	NHZ	OFP	TTP	YHY	YMY	ZSP
Papilionidae											
Papilio maackii	Endemic	1	0	0	0	0	0	0	0	0	0
Papilio machaon	Widespread	0	0	0	0	2	0	0	0	0	0
Papilio xuthus	Widespread	1	0	4	1	1	0	2	1	1	0
Sericinus montela	Endemic	9	0	0	0	0	0	0	0	0	0
Pieridae											
Colias erate	Widespread	0	0	0	0	10	5	7	0	1	0
Pieris canidia	Widespread	13	0	0	0	0	0	0	1	0	0

Pieris rapae	Widespread	19	23	31	45	14	41	47	7	33	15
Pontia daplidice	Widespread	11	8	4	1	21	4	26	2	12	1
Nymphalidae											
Apatura ilia	Widespread	0	0	0	0	2	0	0	2	2	0
Argynnis hyperbius	Widespread	1	0	0	0	0	0	0	0	0	0
Argynnis laodice	Widespread	3	0	0	0	0	0	0	0	0	0
Danaus chrysippus	Widespread	0	0	1	0	0	0	0	0	0	0
Fabriciana nerippe	Endemic	0	0	0	0	0	1	0	0	0	0
Hestina persimilis	Widespread	1	0	0	0	0	0	0	0	0	0
Melitaea didymoides	Endemic	0	1	0	0	0	0	0	0	0	0
Neptis sappho	Widespread	3	0	0	0	0	0	0	0	0	0
Polygonia c-album	Widespread	1	0	0	0	0	0	0	0	0	0

Tirumala limniace	Widespread	0	0	0	0	0	1	0	0	0	0
Vanessa cardui	Widespread	0	1	1	0	1	0	0	0	0	0
Ypthima motschulskyi	Endemic	3	0	0	0	0	0	0	0	0	0
Lycaenidae											
Celastrina argiolus	Widespread	0	0	0	0	0	0	1	0	0	0
Cupido argiades	Widespread	0	3	0	2	4	21	0	0	0	0
Lycaena dispar	Widespread	0	0	0	0	1	0	0	0	0	0
Lycaena phlaeas	Widespread	3	0	0	0	0	0	0	0	0	0
Plebejus idas	Widespread	0	0	0	0	6	4	0	0	0	0
Rapala caerulea	Endemic	1	0	0	0	0	0	0	0	0	0
Rapala rectivitta	Endemic	15	0	0	0	0	0	0	0	0	0
Satyrium w-album	Widespread	0	0	0	0	0	1	0	0	0	0

Tongeia filicaudis	Endemic	3	0	18	0	15	6	4	13	2	0
Hesperiidae											
Lobocla bifasciata	Widespread	1	0	0	0	0	0	0	0	0	0
Ochlodes subhyalina	Widespread	13	0	0	0	0	0	0	0	0	0

Table 2: Number of indicator species recorded in ten surveyed urban parks.

Indicator Species	BBG	CYP	JSP	LYP	NHZ	OFP	TTP	YHY	YMY	ZSP
Butterflies	18	5	6	4	12	9	6	6	6	2
Birds	-	17	5	-	21	25	8	-	14	11
Plants	-	46	45	96	-	-	73	94	71	31

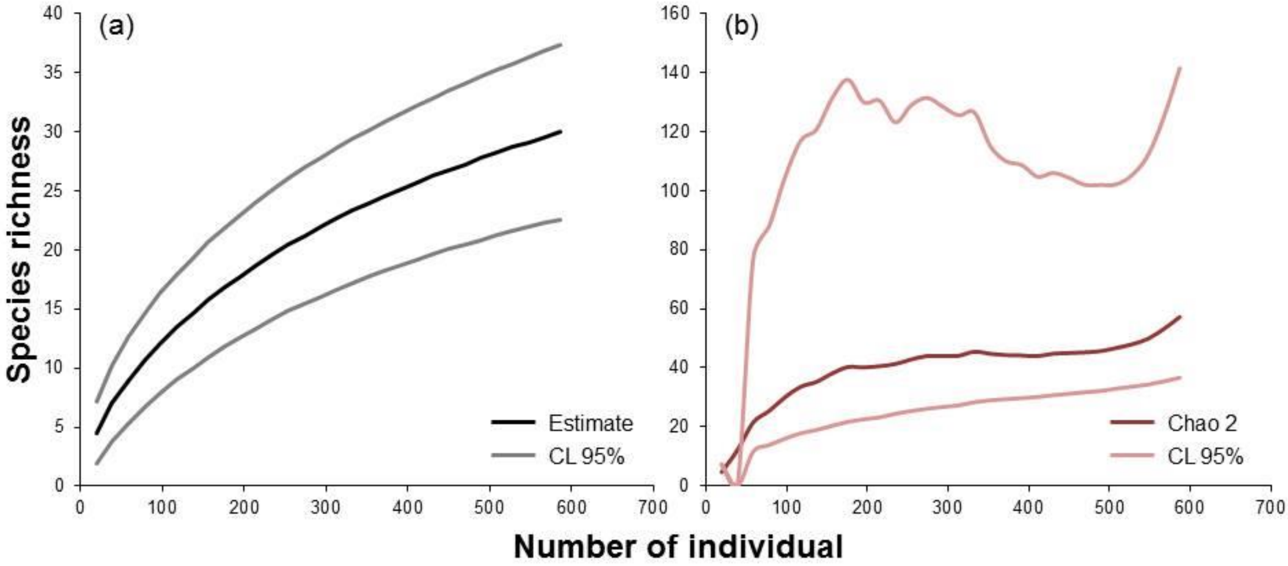

Figure 2: Rarefaction curves of (a) expected number of species and (b) Chao 2 estimated in 587 butterfly individuals pooled samples.

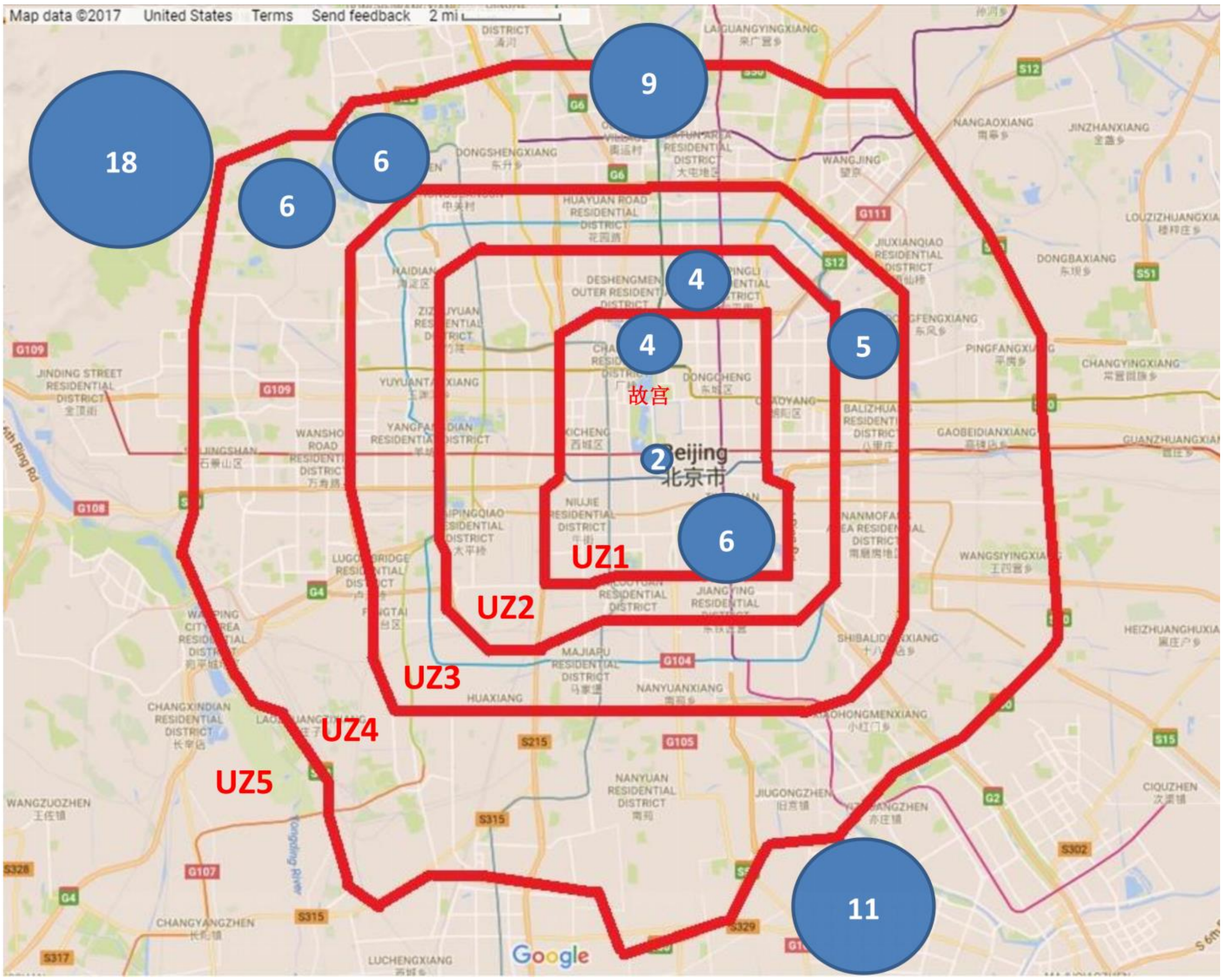

Figure 3: Number of butterfly species recorded in ten urban parks Beijing city

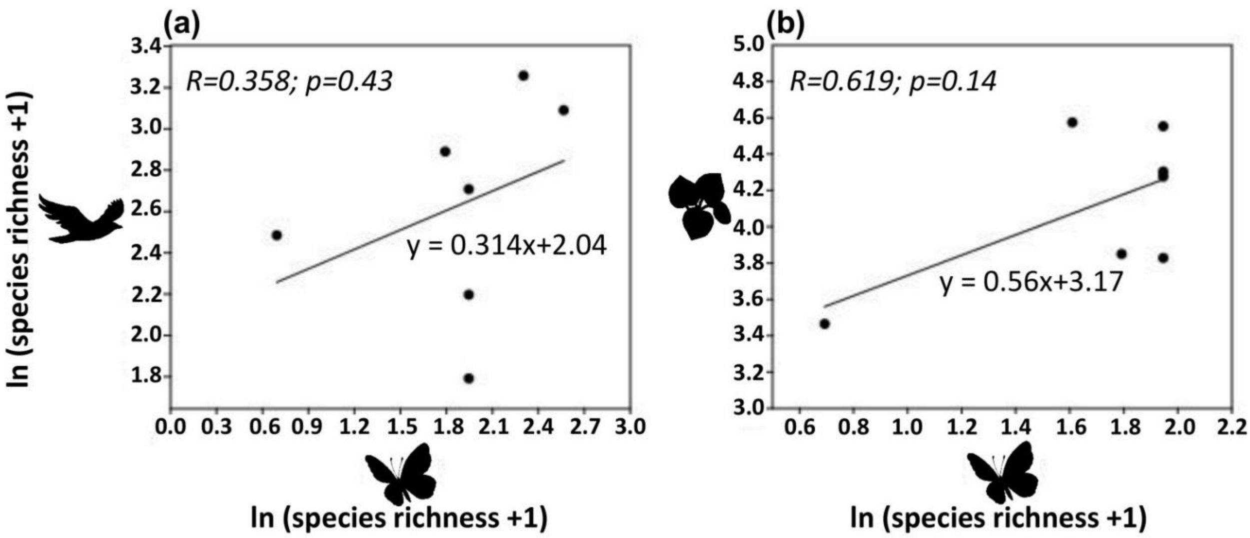

Figure 4: Scatterplots of observed (a) bird species richness, (b) plant species richness and butterfly species richness in Beijing urban parks.

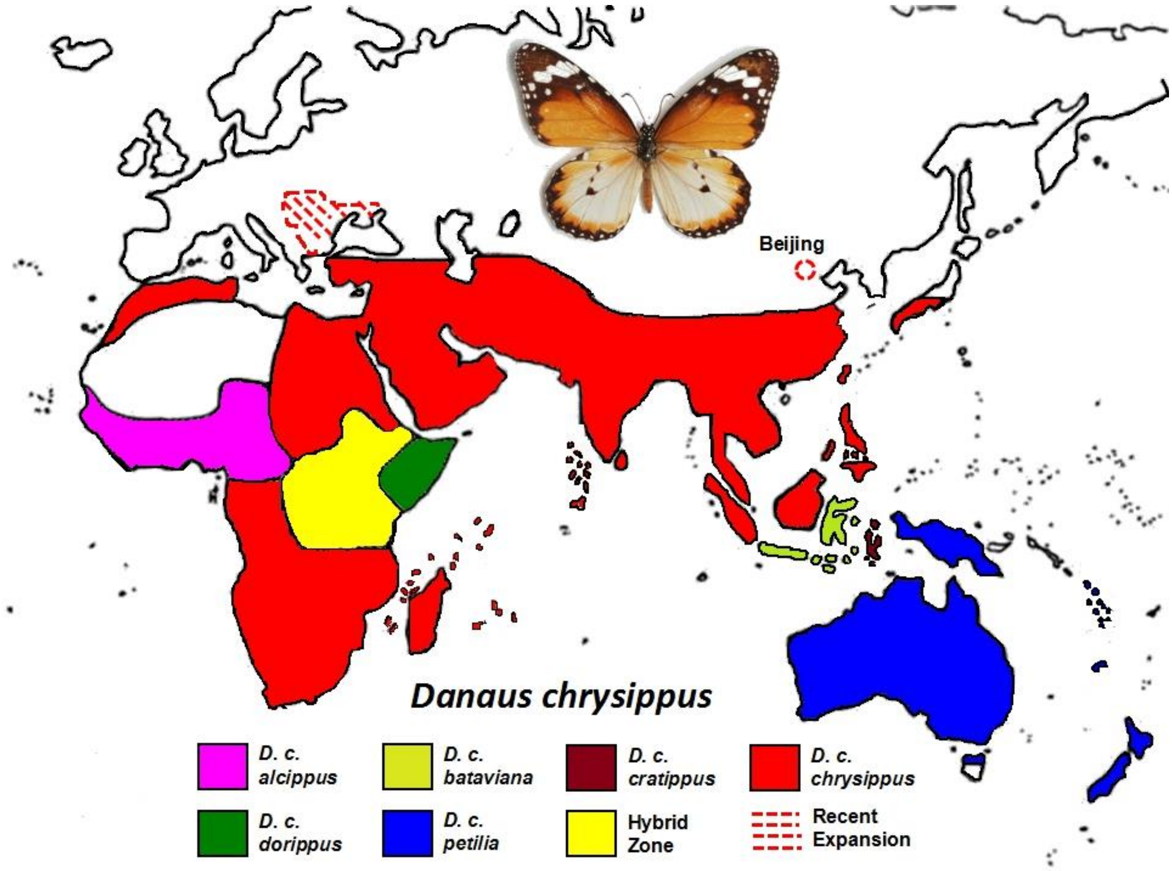

Figure 5: The distribution of *Danaus chrysippus* and its recent range expansion (modified from Lushai et al. 2005). The *Danaus chrysippus* photo comes from http://malaysiabutterflies.myspecies.info.

4. Conclusions

The total species count of this study is similar to studies from other megacities in the Sino-Japanese and East Paleartic zoogeographic region but the lack of an intrinsic ecological concept in the design of most parks may contribute to the relatively low butterfly species richness in Beijing urban parks. This is the first butterfly data collected for Beijing urban landscapes and highlights the importance and need for long-term butterfly monitoring.

5. Future Directions

A long-term butterfly and other biodiversity monitoring is necessary for all cities. Promote urban biodiversity conservation by using certain charismatic animals/plants might improve the interest of public to involve in conservation activities.

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7. Appendix

Meeting

"Urban biodiversity and human-well beings in East-Southeast Asia's megacities" meeting at Naresuan University, Thailand

21 August 2017: Arrive at Phisanulok and check in hotel next to Naresuan University.

22 August 2017 (9am-5pm): APN meeting at Naresuan University.

23 August 2017 (9am-3pm): DNA barcoding workshop at Faculty of Medical Science, Naresuan University (also open to Naresuan University community).

23 August 2017 (after 4pm): Depart to Sukhothai Historical Park and stay overnight.

24 August 2017 (morning): Field visit at Sukhothai Historical Park. Back to Phitsanulok airport and return home.

The meeting was attended by Mr. Narong Jaturas (from far left), Dr. John James Wilson, Dr. Sing Kong Wah and Dr. Masashi Soga.

<u>Conferences</u>

1. Urban parks: effects of management and planting schemes on insect diversity. 27 July 2017, Shenzhen Convention & Exhibition Center. Attended by Dr. Sing Kong Wah, Dr. John James Wilson and Mr. Narong Jaturas and a group of secondary students

2. Butterfly diversity in Asia's megacities. 7th International Barcode of Life Conference, South Africa. Oral presentation by Dr. Sing Kong Wah

Funding sources outside the APN

1. The Kunming Institute of Zoology, Chinese Academy of Sciences provided co-funding, approximately USD 60000.

2. Approximately 1000 Thai Bahts in-kind support provided by the Naresuan University, Thailand.

List of Young Scientists

One undergraduate student from China Agricultural University, five undergraduate/postgraduate students from Hanoi National University of Education and one young researcher from Vietnam Academy of Science and Technology were trained in conducting social research methodology included questionnaire survey approaches.

1. Yang Xiaozhe, China Agricultural University
2. DZUNG Truong Tien, Hanoi National University of Education
3. THUY Dang Thi, Hanoi National University of Education
4. HOA Ninh Thi, Hanoi National University of Education
5. TRANG Le Thi Thu, Hanoi National University of Education
6. ANH Dao Ngoc, Hanoi National University of Education
7. Le Quynh Trang, Vietnam Academy of Science and Technology