Insect Diversity: Addressing an Important but Strongly Neglected Research Topic in China

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Abstract: Insects are not only the most species-rich group on Earth, they also play numerous crucial roles in ecosystem functioning and the global economy. The conservation of insect diversity is therefore a topic of global importance. However, insects are mostly ignored by “biodiversity” research; for example, relationships between insect diversity and vegetation or climate change remain widely unknown. This paper makes suggestions for further research into insect diversity patterns based on two typical forest types in northern China: Changbai Mountain, northeast China and Dongling Mountain, central northern China. Plants and climate have been well studied in these areas but substantial knowledge gaps prevail in relation to insect diversity patterns. It is therefore important to investigate insect biodiversity patterns in these regions.

Key words: insects; diversity; research gaps; Northern China

1 Insect diversity

Biodiversity is the basis for human survival. The composition and richness of species assemblages also strongly influences ecosystem functioning and stability (Naeem et al. 1994; Tilman and Downing 1994; McCann 2000). However, following the industrial revolution, the rapid expanding human population and its economic activities have caused a dramatic loss in global biodiversity, resulting in significant disturbance to ecosystems and our living conditions. Accordingly, the conservation of biodiversity has become one of the most important challenges on our planet.

Insects have important economic roles, supporting and providing livelihoods for numerous people, from the silk trade to beekeeping and the pollination of most of our fruit and a range of other agricultural produce. The description of insects and their colourful body patterns have initiated prominent contributions to our art, literature and culture and offer great educational tools (Pyle et al. 1981). In many regions, insects also form an important component of the human diet. Some insects have great value in Chinese medicine. For instance, the Chinese fungal drug Dongchongxiacao (Cordyceps sinensis), is the fruiting body of a parasitic fungus which develops inside the caterpillar of a ghost moth and has a very prominent role and very long history in traditional Chinese medicine. Another important application of insects is biological pest management. Insect predators are known to be more effective than many chemicals in controlling economically damaging insects (Dempster 1968). Because of their conspicuousness and susceptibility to environmental factors many insect taxa can be used as bioindicators (Kati et al. 2004; Choi 2006). For example, butterfly population dynamics have been suggested as indicators of species richness for pollinators overall and of the structural and floristic diversity of habitats, as indicators of climate change and further ecological parameters, and of landscape distinctiveness (Pyle 1976; Heath 1981; Kremen 1994; Pe’er and Settele 2008). Ground beetles are also commonly used as bioindicators for changes in environmental conditions due to their sensitivity to habitat change and because carabid studies are being highly cost-efficient (Rainio and Niemelä 2003).

In addition to their intellectual and economic value, insects are vital ecosystem components. Many of the
key ecosystem functions that insects fulfill relate to interactions with vegetation. This includes various types of herbivorous links, but also many mutualistic relationships like pollination, seed dispersal or predator defence in exchange for shelter (Qin and Wang 2001). Plants provide the key habitat parameters for many insect species ranging from shelter to breeding sites. Plant-insect interactions have direct effects, for example on the storage and cycling of carbon and nutrients, as well as strongly influencing succession and competition patterns in plant communities and food web interactions (Swank et al. 1981; Weisser and Siemann 2004).

2 Research status

2.1 Knowledge gaps

Insects are by far the most species-rich taxonomic group on Earth. To date, 950 000 insect species have been described and many millions await discovery (Groombridge 1992). Insect species are estimated to account for more than half of all species on Earth, and beetles alone currently represent a quarter of all described species (Southwood 1978; Stork 1988). Due to our very limited knowledge base regarding the exact number of species of insects, their distribution and rarity, only a small number of species have been listed in regional and global conservation lists. It has been estimated that 44 000 extinctions of insect species have occurred in the last 600 years, but only 70 such events have actually been documented (Dunn 2005). Of the predicted 29 000 insect species endangered or threatened in North America alone, only 37 are included in regional red lists (Redak 2000; Dunn 2005). Overall, the diversity of insects has received very little attention, due not least to constraints in time, energy and funds to thoroughly investigate mega-diverse insect taxa. Their small body sizes and variability in colour patterns mean it is difficult to identify insects and makes insect diversity studies more challenging than studies on vascular plants or vertebrate species.

2.2 Relationship between insect diversity and plants

Relationships between insect assemblages and plant communities are another key topic requiring urgent research attention. Insect diversity could be affected by parameters related to vegetation structure such as plant height, plant size or leaf shape (Price and Wilson 1979; Lawton 1983; Haysom and Coulson 1998, Axmacher et al. 2004). Insect species richness often increases with an increase in vegetation height, with the highest diversity recorded in full-grown forests (e.g. Trewack et al. 1997; Haysom and Coulson 1998; Pöyry et al. 2006). This has been related to greater resource availability in mature forest ecosystems (Lawton 1983). Nonetheless, interactions are highly complex, and higher diversity has also been observed in open habitats as compared to closed forests, potentially in reaction to changes in microclimatic conditions (e.g. Axmacher et al. 2004; 2009).

Plant species richness and community composition affect insect diversity. Despite the unimodal model often used to describe relationships between diversity and productivity (Grime 1973; Rosenzweig 1992; Abrams 1995), an increase in plant diversity could monotonically improve ecosystem productivity (Tilman et al. 1996; Hooper et al. 2005). Ecosystem productivity could potentially enhance diversity at higher trophic levels and likewise increase the diversity of herbivorous insects, parasites and predators (Hunter and Price 1992; Siemann 1998; Siemann et al. 1998). An increase in plant diversity would have a stronger positive effect on species richness at higher tropical levels. However, a recent review found that lower trophic species responded more strongly to an increase in plant diversity than higher trophic levels in grassland (Scherber et al. 2010). Increases in plant diversity would decrease the effects of biological invasion, pathogen and hyperparasitism (Scherber et al. 2010). This pattern also means that increasing plant diversity could potentially enhance ecosystem stability (Tilman et al. 2006).

Predators are more effective in controlling herbivores in low habitat stability ecosystems than in highly stable ones (Southwood and Comins 1976). As positive relationship been found between plant diversity and habitat stability (Tilman et al. 2006), plant diversity then would likely affects the relationship between herbivorous insects and predators. In addition, according to the resource concentration hypothesis by Root (1973), herbivores are more likely to find and remain on hosts in monocultures. Reduced plant diversity therefore increases the potential damage to vegetation by pest species, while simultaneously reducing overall insect diversity. Supported by experiments, it has been predicted that herbivorous insect diversity is positively correlated with plant species diversity (Tilman 1986; Niemelä et al. 1996; Chey et al. 1997; Siemann et al. 1998; Intachat et al. 1999; Beck et al. 2002; Ghazoul 2002; Lewinsohn and Roslin 2008). Increasing diversity in herbivores could further enhance the diversity of predators and parasites (Root 1973). However, the relationship between plant diversity and insect diversity is not always positive, and some studies investigating natural habitats have found an opposite trend. For example, the diversity of geometrid moths on Mount Kilimanjaro decreases with increasing vascular plant diversity (Axmacher et al. 2004; 2009).

2.3 Effects of climate change on insects

The global climate has changed significantly during the 20th century. The average global air temperature near the Earth’s surface and oceans rose by 0.74°C between 1906 and 2005 (IPCC 2007). At a global level, climate change is
predicted to be a key factor affecting future developments in biodiversity (Hawkins et al. 2003; Rahbek et al. 2007; Beck et al. 2010b), with wide-ranging effects on forest structure and local spatial distribution patterns (Sang and Bai 2009). Insect species richness and species composition are known to be particularly strongly affected by environmental factors such as temperature and moisture (Breinh et al. 2003; Axmacher et al. 2009). Global climate change is accordingly predicted to change the distribution and therefore also diversity patterns of insect communities. Many insect species have already observed to be spreading northwards in the northern hemisphere, some benefiting from warmer temperatures, e.g. the silver-spotted skipper butterfly (Hesperia comma), Rosel’s bush cricket (Metrionter roeselii), etc, see Thomas et al. (2001); however, most species have declined in reaction to climatic change (Masters and Clarke 1998; Asher et al. 2001; Warren et al. 2001).

Despite the development of some models to predict insect diversity based on environmental factors (Ferrier and Guisan 2006; Beck et al. 2010, 2011), very few in-depth investigations into potential long-term changes have been conducted. How and to what extent long-term environmental change, in particular global climate change, affects insect diversity should be a key future research topic.

3 Further research in northern China

In China, research and model approaches focusing on insect diversity patterns are widely lacking. Therefore, the problems above mentioned should be addressed recently. First, the distribution of different insect taxa and functional groups needs to be addressed at various spatial scopes, providing insight into potential cross-taxon relationships of diversity patterns. In addition to the bioindicator insects for biodiversity and environmental conditions (beetles and butterflies), more work should focus on those species listed as being of conservation concern or of potential concern. Second, the question of how insect diversity is affected by elevational change and associated climatic factors should be addressed. Third, the relationship between insect and plant diversity needs to be scrutinized, investigating how this relationship might be affected by environmental factors like changes in climatic conditions. Based on these research areas, global and local future insect diversity patterns can be investigated in long-term historical studies of climate and vegetation status. This approach will also allow an investigation into the status of pest insects and their relationships with host plants and predators.

China has a very rich insect fauna. Some estimates render insects in China to account for 10% of the total global species number (You 1997), with some studies indicating an even bigger contribution (Wu 1992). In addition to high species diversity, there are many rare and endangered species in China. China harbours 120 species belonging to the Protura, the most primitive insects, from 400 known species totally (You 1997). These endangered species are very important to both biodiversity conservation and the explosion of system evolution angles. The study of insect diversity patterns in China is of great value.

Ecological models indicate that China’s forest ecosystems are moving northwards and that alpine forests are shrinking (Ni et al. 2000; Zhao et al. 2002). In northern China, particularly north of 33° latitude, forests ecosystem productivity is more sensitive to climate change than in southern China, so that forests in northern China provide ideal study objects to investigate their reaction to climate change (Yu et al. 2001). There are two key forest types in northern China: Conifer-broadleaf mixed forest in the northeast and deciduous broad-leaved forest in central northern China. In northeast China, the forests of Changbai Mountain form one of the best protected Chinese large-scale natural forested environments, and also one of the world’s largest temperate forest ecosystems. The protection is engrained in the Changbaishan Nature Reserve (CNR) established in 1960. Forests with strong Korean pine (Pinus koraiensis) components are the representative types in this area. Following the altitudinal gradient, mixed coniferous and broad-leaved forests at 800–1000 m are replaced by mixed coniferous forest zone at 1100–1300 m, by sub-alpine coniferous forest between 1500–1700 m and finally by birch forests at 1800–2000m, which form the upper forest boundary (Sang and Bai 2009). The abundant flora and fauna of the CNR not only provides an important economical resource for local people, but maintains a complex and stable set of ecosystems and is an excellent scientific research resource. In central northern China natural forests have been depleted and degraded following a long history of human disturbance, leaving chiefly secondary, homogeneously structural forests of comparatively low phytodiversity. Most of these forests lack mature and original old growth trees, being composed of pioneer tree species representing early stages of succession, low productivity of usable timber and other forest products, and high prevalence to disease. The remnants of Beijing forest represent such temperature deciduous broad-leaved forests typically found in central northern China. The forests of Dongling Mountain, located in the Yanshan Mountains in northeastern Beijing, represents a relative pristine forest community with high forest elements which remained due to low human population density and low levels of local forest development. Despite representing secondary forest ecosystems, the restored natural secondary forest harbours high levels of phytodiversity and a more complex structure than many similar representatives of this forest type. With increasing elevation, it is bordered by a deciduous broad-
leaf shrub zone dominated by Vitex negundo at elevations below 800 m and a sub-alpine meadow zone at highest elevations above 1700 m. The mid-elevation between 800 m and 1900 m is dominated by temperate deciduous broad-leaved forests, mainly Liaodong oak woods Quercus liaotungensis between 800 m and 1600m, several human planted pine Pinus tabulaeformis forests and larch Larix gmelinii forests, and birch forests again forming the uppermost forest type between 1600 m and 1900–2000 m.

Across the Changbai and Dongling Mountains past studies have focused primarily on vegetation (Chen et al. 1964; Ma et al. 1995; Liu 1997; Sun et al. 2004; Chen 2006; Sang and Bai 2009). At Changshan Shan, studies of the vegetation composition and climate started during the early establishment of the CNR. Since the late 1980s, studies of biodiversity patterns and community succession have been resumed (Hao and Tao 1994; Hao and Yang 2002; Zhao et al. 2004; Li et al. 2008; Sang and Bai 2009). In Dongling Mountain, historical vegetation studies can be traced to the mid-20th century. Since the mid-1950s, a series of studies have been conducted by the Institute of Botany, Chinese Academy of Sciences investigating forest structure, biodiversity and productivity across different forest types (e.g. Jiang et al. 1994; Huang and Chen 1994; Ma et al. 1995). At both Changshan Shan and Dongling Shan, very little attention has been given to species-rich insect communities, their conservation status, the likely influence of past and future climate change on these communities, and interactions between vegetation and insects. Previous long-term vegetation surveys and climate monitoring at both sites have nonetheless already laid a solid foundation for such studies. To carry out an analysis of insect species richness and distribution in these areas is a highly important and valuable endeavor.

References

昆虫多样性：一个被忽略的全球性重要问题

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摘要：昆虫不仅是世界上最多的物种，同时也对生态系统功能和全球经济有着十分重要的作用。因此，昆虫多样性的保护对全球来说都是有着十分重要的意义。然而，昆虫多样性常被“生物多样性”研究者们所忽略，昆虫多样性与植物、气候变化的关系更是不明确。本文对昆虫多样性的研究方向提出了几点建议，基于中国北部两大典型的森林生态系统——东北长白山地区和华北太行山地区。这两大地区的植被和气候都已经有长期并且完整的调查，而对于其中昆虫多样性的了解却不深。因此在这两个地区开展研究认识昆虫多样性格局和进一步分析昆虫和植物的关系具有重要的科学和应用价值。

关键词：昆虫；多样性；研究不足；中国北部