PROCEEDINGS
OF THE

CENTER FOR TROPICAL FOREST SCIENCE – ARNOLD ARBORETUM INTERNATIONAL FIELD BIOLOGY COURSE 2007

Xishuangbanna Tropical Botanic Garden, Yunnan Province, China

2 Sep – 13 Oct 2007

Edited by
Manju Vasudevan, Chinthaka D. Kaluthota, and Rhett D. Harrison

Cover photo: Organizers, resource staff and participants of the seventh CTFS-AA International Field Biology Course 2007 (IFBC-2007) outside the XTBG Research Station, after the week long field trip in Ailao Mountain Forest Reserve on 24th September 2007.

Preface

The CTFS-AA International Field Biology Course is an annual, graduate-level field course in tropical forest biology run by the Center for Tropical Forest Science – Arnold Arboretum Asia Program (CTFS-AA; www.ctfs.si.edu) in collaboration with institutional partners in South and Southeast Asia. The CTFS-AA International Field Biology Course 2007 was held at and hosted by the Xishuangbanna Tropical Botanical Garden of the Chinese Academy of Sciences, Yunnan, China, from 2 September to 13 October. It was the sixth such course organised by CTFS-AA. The previous course was held at the Sinharaja World Heritage site in Sri Lanka and the 2008 course will be held at Pasoh Forest Reserve in Malaysia.

The aim of these courses is to provide high-level training in the biology of forests in South and Southeast Asia. The courses are aimed at upper-level undergraduate and graduate students from the region, who are at the start of their thesis research or professional careers in forest biology. During the course topics in forest biology are taught by a wide range of experts in tropical forest science. There is also a strong emphasis on the development of independent research projects. Students are exposed to different ecosystem types, as well as forest related industries, through course excursions.

The CTFS-AA International Field Biology Course 2007 was attended by 21 students from nine countries (China, Malaysia, Thailand, Philippines, Switzerland, Taiwan, China, Singapore, India, and Sri Lanka) and a total of 18 resource staff from a variety of national and international institutions gave lectures and practical instruction. The course in 2007 was implemented by Dr. Rhett Harrison (CTFS-AA), Xiaodong Yang (Xishuangbanna Tropical Botanical Garden, Yunnan, China), Luan Keng Wang (Raffles Museum, Singapore), and John Harting (Texas Tech). Due to their efforts the course proved to be a huge success. The following report illustrates the hard work of the organizers and the enthusiasm and commitment of the students.

Stuart J. Davies
Director, Center for Tropical Forest Science

Acknowledgements

As co-ordinator of the CTFS-AA International Field Biology Course 2007 I wish to thank all the resource staff who gave their time to teach on the course. Without the commitment of these researchers, many of whom have become a regular fixture in the field course schedule; to the success of the field course in XTBG nothing could have been achieved. In particular I would like to thank Ms Luan Keng Wang (Raffles Museum, Singapore), who as always assisted greatly in the smooth running of the course, John Harting (Texas Tech), who was an invaluable teaching assistant, and Xiaodong Yang (XTBG), who was tireless in his efforts to see the course went smoothly. We would also like to acknowledge the considerable help of the Xishuangbanna Tropical Botanical Garden staff, especially Jin Chen. A list of all the resource staff that contributed to the course appears at the end of these proceedings.

Thank you also to the staff at Ailaoshan Field station, especially Mr Lui, the field station manager, and the district government for hosting us to an incredible meal on our arrival.

Thank you also to the research staff and students from XTBG who participated in many different ways to help the course, and who hosted us so graciously.

Financial support for the field course came from the Center for Tropical Forest Science – Arnold Arboretum Asia Program of the Smithsonian Tropical Research Institute and the Arnold Arboretum of Harvard University. Xishuangbanna Tropical Botanical Garden also sponsored the course substantially, covering all the accommodation and local transport costs. The University of Aberdeen cover the costs of flights for Dr David Burslem. We are very grateful to all for the assistance.

Thank you.

Rhett Harrison
Center for Tropical Forest Science –Arnold Arboretum

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Field Course Program

Overview

Date	Location	Programme
Sun 2 Sep 2007	XTBG	• Opening Ceremony (2 pm)
Sun 2 – Wed 5 Sep	XTBG	• Introduction to study of plant taxa
Thu 6 – Sat 8 Sep	Menla	• Ecology of Dipterocarp forests
Mon 10 – Fri 14 Sep	XTBG	• Introduction to study of animal taxa
Sat 15 – Mon 24 Sep	Ailaoshan	• Ecology of montane forest
Tue 18 – Wed 19 Sep	Ailaoshan	• Group projects
Tue 25 – Wed 26 Sep	Cai Yang He	• Introduction to Evergreen broadleaf forest
Thu 27 Sep – Wed 3 Oct	XTBG	• Ecology of lowland forest
Thu 4 Oct – Thu 11 Oct	XTBG	• Independent projects
Fri 12 Oct	XTBG	• Course symposium
Sat 13 Oct	XTBG	• Closing ceremony (7 pm)

Detailed Programme

2 Sep	XTBG	14:00		Opening ceremony	
		16:00		Tour of gardens / herbarium	Zhu Hua
		19:00	Lecture	Role of botanic gardens in Asia	Jin Chen
3 Sep	XTBG	8:00	Practical	Plant identification (limestone forest)	Zhu Hua Wan Hong
		19:30	Lecture	Plant biogeography of S China	Zhu Hua
4 Sep	XTBG	8:00	Practical	Plant identification (55 km forest)	Zhu Hua Wan Hong
		19:30	Lecture	Forest types of SW China	Zhu Hua
5 Sep	XTBG	8:00	Practical	Plant identification	Zhu Hua Wan Hong
		15:00		Student presentations	
		19:00	Lecture	Introduction to FDPX	Cao Min
6 Sep	Menla	12:00	Tour	Dipterocarp forest	Cao Min
		19:30	Lecture	The regeneration niche	David Burslem
7 Sep	Menla	8:00	Practical	Seedling ecology	David Burslem
8 Sep	XTBG	8:00	Practical	Introduction to statistics using R	Rhett Harrison
		19:30	Lecture	Habitat specialisation in plants	David Burslem
9 Sep	XTBG			Day off	
		18:00		Poster session & mixer	XTBG students
10 Sep	XTBG	8:00	Practical	Analysing plant distributions	David Burslem
		19:30	Lecture	Introduction to insects	David Lohman
11 Sep	XTBG	8:00	Practical	Insect sampling and identification	David Lohman Yan-Qiong Peng
		19:30	Lecture	Ants	David Lohman
		20:00	Lecture	Bees	Rhett Harrison
		20:30	Lecture	Soil arthropods	Yang Xiaodong
12 Sep	XTBG	8:00	Practical	Insect sampling and identification	David Lohman Yan-Qiong Peng
		19:30	Lecture	Ecology of forest birds	George Gale
13 Sep	XTBG	8:00	Practical	Bird ecology	George Gale
		19:30	Lecture	Estimating animal abundance	George Gale
14 Sep	XTBG	8:00	Practical	Estimating animal abundance	George Gale
15 Sep		8:00		Travel to Ailaoshan	
16 Sep	Ailaoshan	8:00	Lecture	Ecology of tropical montane forests	
		9:00	Practical	Introduction to Ailaoshan	
17 Sep	Ailaoshan	8:00	Practical	20 Questions	Rhett Harrison
		19:30		Proposals for group projects	Students
18–20 Sep	Ailaoshan			Group projects	

20 Sep		19:30	Lecture	Forest hydrology	Sha Liqing
21 Sep	Ailaoshan	8:00	Practical	Forest hydrology	Sha Liqing
		19:30	Lecture	Forest soil and nutrient cycling	Yang Xiaodong
22 Sep	Ailaoshan	8:00	Practical	Forest soil and nutrient cycling	Yang Xiaodong
		19:30	Lecture	R Practice workshop	
23 Sep	Ailaoshan	8:00		Earthworms – Field Practical	
		19:30	Lecture	Evolutionary biology of Stone Oaks	Chuck Cannon
24 Sep	Ailaoshan	8:00	Practical	Evolutionary biology of Stone Oaks	Chuck Cannon
25 Sep	CYH	8:00		Travel to Cai Yang He	
		19:30	Lecture	Evergreen broadleaf forest	Zhu Hua
26 Sep	CYH	8:00	Practical	Introduction to evergreen broadleaf forest	Zhu Hua
		13:00		Travel to XTBG	
27 Sep	XTBG	8:00	Lecture	Eco-physiology	Kun-Fang Cao
		9:30	Practical	Eco-physiology	Kun-Fang Cao
		19:30	Lecture	Theories of species co-existance	I Fang Sun
28 Sep	XTBG	8:00	Lecture	Seed predation	I Fang Sun
			Practical	Seed predation	I Fang Sun
		19:30	Lecture	Frugivory	Richard Corlett
29 Sep	XTBG	8:00	Practical	Frugivory	Richard Corlett
		19:30	Lecture	Tropical forests compared	Richard Corlett
30 Sep	XTBG			Day off	
			16:30	Proposals for independent projects I	
			19:30	Introduction to evolution	Shawn Lum
1 Oct	XTBG	8:00	Lecture	Molecular ecology	Shawn Lum
		9:30	Practical	Molecular ecology	Shawn Lum
		19:30	Lecture	Figs and fig wasps	Rhett Harrison
2 Oct	XTBG	8:00	Practical	Figs and fig wasps	Rhett Harrison Yan-Qiong Peng
		19:30	Lecture	Conservation biology	Chuck Cannon
3 Oct	XTBG	8:00	Practical	Conservation biology	Chuck Cannon
		19:30		Proposals for independent projects II	
4 Oct	XTBG	19:30	Lecture	How to publish in high impact journals	Jin Chen
5 – 11 Oct	XTBG			Independent projects Analysis and Write up	
12 Oct	XTBG	9:00	Symposium	Presentation of projects	Students
13 Oct	XTBG	9:00		Trip to Dai village	
		19:00		Closing ceremony	

ABSTRACTS

Introduction to Xishuangbanna Tropical Botanic Garden

Zhu Hua
Xishuangbanna Tropical Botanic Garden

Founded in 1959, the Xishuangbanna Tropical Botanical Garden (XTBG), Chinese Academy of Sciences (CAS) is located at 21º55' N, 101º15'E, covering an area of 900 ha. Over 10, 000 species of tropical plants are well preserved in its 34 living collections.

XTBG is a comprehensive research institution engaged in biodiversity conservation and sustainable uses of plant resources, focusing on forest ecosystem ecology, conservation biology, and resource plant development. Facilities available for scientific research include two national field research stations (Xishuangbanna Tropical Rainforest Ecosystem Station, and Ailaoshan Station for Forest Ecosystem Studies); laboratories for Biogeochemistry, Molecular Biology & Biotechnology, Plant Phylogenetics & Conservation Biology, Physiological Ecology; a Germplasm Bank for Rare & Endangered Plants; and a Herbarium of Tropical Plants, etc. Apart from the headquarters in Xishuangbanna, an important division has been setup in Kunming, the capital city of Yunnan Province.

The Herbarium of Xishuangbanna Tropical Botanical Garden (HITBC) was founded in 1959. It is equipped with compact chambers, fire alarm, humidity and temperature automatic control system. Disinfection and cleaning of specimens is conducted under the temperature of minus 30º C.

The herbarium collections are mainly vascular plants and from tropical Yunnan and neighbouring SE Asian countries such as Laos, Vietnam, Cambodia, Malaysia and Thailand. The herbarium has a total of 110,000 collections, of which 700 are gymnosperms, 13000 are ferns, and the rest are angiosperms. Additionally, there are 501 type collections and c.20000 duplicates with 30000 sheets. Currently, identified specimens make up 60% of the total collections. Specimens are arranged by three systems: ferns by R. C. Ching's System (1978), gymnosperms by W. J. Zheng 's System (1978) and angiosperms by J. Hutchinson's System (1926, 1934). The specimens are deposited by genus and species alphabetically. Digital photos of all the identified specimens are available from the website of XTBG (http://www.xtbg.org.cn) as well as much other useful information about the gardens.

Role of botanic gardens in SE Asia

Jin Chen
Xishuangbanna Tropical Botanic Garden

Historically, botanical gardens (BGs) were the places where researchers conducted plant introduction, plant domestication and exploration of the economic use of plant resources. With the establishment of Convention on Biological Diversity (CBD) and the recognition of the problems caused by the invasion of some exotic plants to introduced habitats, BGs have been expected to emphasize more on providing support to local biological diversity conservation. This role could be achieved by providing relevant information to local biodiversity conservation, ex-situ conservation for seeds as well as for endangered species in that region, and raising peoples' awareness for conservation through various educational programs.

Compared to BGs in Europe, BGs in Asia have a rather short history and are varied in scale, quality of maintaining and roles they played to society. The distribution of BGs does not reflect local biodiversity. Instead, the number of BGs is correlated to the development of local/national economy. This limitation may weaken the role that BGs as a whole play to biodiversity conservation. The local capacity and mechanisms for sustaining the development in each garden are still the key issues for BGs in Asia.

For the future, countries in Asia should take supporting BGs as a component to the implementation of CBD. BGs themselves should revise their mission and strategy of development. Regional networking and North-South BGs cooperation need to be enhanced in order to achieve the role that the BG community plays in the world today.

Field practical on tree identification

Zhu Hua
Xishuangbanna Tropical Botanic Garden

We will explore the three main types of forest around XTBG; secondary forest within XTBG, limestone forest, and old growth forest (55 km forest). During this period we will discuss some of the most important families and genera, their biogeography, basic ecology, and the spot characters you can use to recognise them. Dong Wang from XTBG herbarium has prepared a key to some of the main families to help you (given at the end of the workbook).

Plant biogeography of southern Yunnan, SW China

Zhu Hua
Xishuangbanna Tropical Botanic Garden

The flora of southern Yunnan consists of more than 3340 native species of 1178 genera and 182 families of seed plants. The families with highest species richness include Orchidaceae (94 genera/328 species), Fabaceae (65/211), Rubiaceae (45/142), Poaceae (63/132), Euphorbiaceae (36/117), Asteraceae (59/106), Moraceae (7/73), Lauraceae (14/70), Urticaceae (13/70), Zingiberaceae (16/70), Acanthaceae (32/68), Lamiaceae (28/61), Asclepiadaceae (26/58), Apocynaceae (23/51).

Tropical floristic elements at the generic level form a major contribution (ca. 83.5%) to the total flora of southern Yunnan, of which the dominant geographical elements are those of tropical Asian distribution. Comparison with the mainland Southeast Asia and Malaysia floras reveals that most of the dominant families from southern Yunnan are also dominant in mainland Southeast Asian and Malaysian floras. The floristic similarities between the flora of southern Yunnan and those of tropical Asia are more than 80% at the family level and more than 64% at the generic level. This suggests that the tropical flora of southern Yunnan has a close affinity with the tropical Asian flora and supports the idea that the flora of southern Yunnan, together with the mainland Southeast Asian flora, belongs to the Indo- Malaysia floristic subkingdom of the Paleotropical kingdom as suggested by Takhtajan (1978), or the Malaysia subkingdom of the Paleotropical kingdom as suggested by Wu and Wu (1996).

However, situated at the northern margin of tropical Asia, the flora of southern Yunnan comprises less strictly tropical elements compared to the Malaysian flora, and consequently represents only a marginal type of Indo- Malaysian flora.

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Forest types of Southern Yunnan, SW China

Zhu Hua
Xishuangbanna Tropical Botanic Garden

Southern Yunnan is a region of extreme interest to biologists and also a hotspot for biodiversity conservation. It is located in a transitional zone from tropical Southeast Asia to temperate East Asia biogeographically. Southern Yunnan lies between 21°09' and 22°36' N, 99°58' and 101°50' E. The region has an area of 19690 km^2.

By combining physiognomic and floristic characteristics with ecological performances and habitats, the primary forest vegetation in southern Yunnan can be organised into four main vegetation types: tropical rain forest, tropical seasonal moist forest, tropical montane evergreen broad-leaved forest and tropical monsoon forest.

The **tropical rain forest** can be classified into two subtypes, i.e. **tropical seasonal rain forest** in the lowlands and **tropical montane rain forest** on higher elevations. The tropical seasonal rain forest shows similar forest profile and physiognomic characteristics to those of equatorial lowland rain forests and is a type of world tropical rain forest. Because of conspicuous similarity on floristic composition, the tropical seasonal rain forest in Xishuangbanna is a type of tropical Asian rain forest. The tropical montane rain forest occurs in wet montane habitats and is similar to the lower montane rain forests in equatorial Asia in floristic composition and physiognomy.

The **tropical seasonal moist forest** occurs on middle and upper limestone mountains and is similar to the tropical montane evergreen broad-leaved forest of the region in physiognomy, but it differs from the latter in floristic composition.

The **monsoon forest** in southern Yunnan is a tropical deciduous forest under the influence of a strong monsoon climate and is considered to be a transitional vegetation type between tropical rain forest and savanna in physiognomy and distribution.

The **tropical montane evergreen broad-leaved forest** is the main vegetation type in mountain areas. It is dominated by the tree species belonging to Fagaceae, Euphorbiaceae, Theaceae and Lauraceae. It is considered to be a distinct vegetation type in the northern margin of mainland southeastern Asia controlled by a strong monsoon climate, based on its floristic and physiognomic characteristics.

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Construction of a 20-ha Forest Dynamics Plot in Xishuangbanna, SW China

Cao Min
Xishuangbanna Tropical Botanic Garden

Xishuangbanna is located in SW China, on the northern edges of tropical Asia. The climax forest types in this area are tropical seasonal rain forest and monsoon forest, representing an important distribution area of tropical rain forests in continental China. Due to the botanical transition between the Paleo-Tropic floristic region and the Holarctic floristic region from the south to the north, and the East-Asian floristic region and the Himalayan floristic region from the east to the west, the area harbors affluent flora and fauna, evolving a high biodiversity complex. On the other hand, this area is also of significance in monitoring the responses of ecosystems to global change because of its climatic marginality and biogeographical transitions.

The high tree species diversity in tropical forest ecosystems has been described by a number of workers over the last century (Richards, 1952; Whitmore, 1990). Mechanisms in biodiversity maintenance of tropical forests, however, are still mysterious. To answer this question, quite a few hypotheses were proposed on the basis of field investigations in tropical forest ecosystems of different continents (e.g. Connell 1978; Hubbell et al. 2001; Wright 2002), although those need to be testified with large-scale forest dynamics plots established in the tropics of America, Asia and Africa.

The construction of the 20-ha forest dynamics plot in Xishuangbanna (FDPX) was supported by the Chinese Biodiversity Committee, Chinese Academy of Sciences, with the purpose of examining the biodiversity variations in different climatic zones of the country. A total of 4 forest dynamics plots ranging from 20-24 ha were set up in temperate, subtropical and tropical forest ecosystems respectively. These plots are to be re-censused every 5 years.

The first tree species inventory of FDPX was started in November 2006 and finished in April 2007. This plot (400 m E-W x 500 m S-N) was established in a *Shorea chinensis* forest tract in Mengla County, bordering with Laos in the south and the east. It is geographically located at 101°35’ E, 21°37’ N. This forest is a part of tropical rain forests in Southeast Asia dominated by the tree species of Dipterocarpaceae. The plot was sub-divided into 500 20 x 20 m quadrates. The species name, DBH and coordinates of each tree ≥ 1 cm DBH were documented. Each tree species in the plot was tagged and mapped at individual level, in order to survey the correlations between tree species distribution and habitat heterogeneity (e.g. soil moisture and nutrients) that will be investigated next year.

The history of the forest use in this area was associated with shifting cultivation system, which dominated mountain agriculture during the first half of 20th century. However, this kind of traditional agriculture has started adapting to the rapid growth of human population in this area by establishing large area of plantations for rubber and other tropical crops since the last half century.

The practical session in FDPX includes a tour in the forest looking at the forest structure, dominant tree species and typical forest habitats walking both over the forest canopy and under the forest canopy. And an on-the-spot interpretation on the techniques of the plot construction will be given in the forest.

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The Opening Ceremony of the Seventh International Field Biology Course, September 2007

The room where students discovered learning, fun and even sleep!

Introductory walk around XTBG, home away from home for the next six weeks

Organizer, teacher, field guide - all rolled into one name
Dr Rhett Harrison!

Luan- You could ask her for anything under the sun

Regeneration niche

David Burslem
University of Aberdeen, UK

The Regeneration Niche concept was coined by Peter Grubb in a 1977 paper on the maintenance of species-richness in plant communities. Grubb defined the regeneration niche as "an expression of the requirements for a high chance of success in the replacement of one mature individual by a new mature individual of the next generation …". It includes the processes involved in production of viable seed, dispersal in time and space, germination, establishment and onward growth of seedlings. Differences in the regeneration niches of coexisting species are proposed to be influential in the maintenance of species richness, particularly in hyper-diverse tropical rain forest communities where several hundred tree species may coexist within a single hectare. In this lecture we will discuss the Regeneration Niche concept in the context of recent developments in tropical forest science, in particular the challenge posed by neutral theory to classical theories of niche partitioning.

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Seedling ecology practical

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All plants need the same resources (water, light, nutrients and carbon dioxide) for their survival, growth and reproduction. Recent research has demonstrated that the growth and survival of tropical tree seedlings are limited by environmental conditions and impacted by natural enemies, but the most significant factor is the availability of light. Different species are arrayed along a continuum of response to light and possess traits that characterise their ability to capture and use available light.

The objectives of the practical are to:

1. Review and conduct field implementation of techniques for characterising canopy structure and light availability in tropical forests.
2. Investigate seedling morphological and architectural traits that are associated with light-based niche partitioning.

Habitat specialisation in plants

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Many plants are distributed non-randomly in space. One cause of this may be that resource availability influences plant growth, survival or reproductive output, and species have differential responses to these resources. Tropical trees species distributions may be associated with heterogeneity in hydrological status, nutrient availability and soil texture, at scales ranging from the local to the continental. Habitat associations may be detected from spatially explicit tree position data on contiguous large plots, or from changes in stem density and frequency on replicated small plots. However, detecting habitat associations requires careful analysis, because stem positions are inherently autocorrelated because of dispersal limitation at similar spatial scales to the distribution of many habitat variables. Therefore an association between stem density and a habitat variable may arise through a chance accumulation of non-independent dispersal events rather than performance-mediated responses to habitat variation. Therefore, analyses must employ statistical methods that account for the autocorrelation in tree position data. Recent research on habitat specialisation in tropical tree populations will be reviewed in the lecture, including the limited research available on the mechanisms of habitat association in tropical trees. In the practical, students will obtain an opportunity to implement some techniques for detecting habitat associations in tropical tree species on data-sets obtained from the CTFS forest dynamics plot network.

Further reading

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An introduction to statistics using R

Rhett Harrison
Smithsonian Tropical Research Institute

In nature everything varies. Therefore, to compare any two or more entities we cannot simply line them up and say, "Oh! A is bigger than B". We need to be able to assess the probability that our observation might have occurred by chance. For that we need statistics. The power of desktop computers and the availability of user-friendly statistical packages have both been a blessing and a bane. They have improved the complexity and power of statistics available to us, but they also often mean that one can generate a result with little idea of what it means (both through insufficient statistical knowledge or simply because the machine is doing things we don't know about).

Increasingly, ecologists are using the free software R for their statistical needs, from basic data summaries to complex analyses. R is an object-based programming language optimised for statistics. It is the open-source implementation of the S language developed at AT&T Bell Laboratories. Among its strengths are the ability to construct complicated, repeatable analyses from raw text data to publishable graphics. There are many contributed packages (libraries) that can be imported to extend the analyses. R distributions, packages and documentation can be found at <http://cran.r-project.org>.

Using R requires some adjustment for people used to point-and-click software. The commands are written line by line like a computer program. However, like programming, R is empowering, because it enables you to write your own analyses and know exactly what you are doing. We will go though the basics of the language and some functions, such as how to generate graphs. The help functions in R enable you to explore different functions, so you can teach yourself more complicated operations as you go along. Please refer to the 'Introduction to R' prepared by Cam Webb, which is at the end of this workbook

We will generate a dataset from a simple practical, which we will then analyse using R. Participants are required to use R for all their analyses and for producing graphs during the field course.

Further reading

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Introduction to insect biology

David Lohman
Raffles Museum of Biodiversity, National University of Singapore

Insects are the most abundant and diverse macroscopic, terrestrial animals on the planet, and their species richness and high rate of reproduction make them ideal subjects for investigations in ecology, evolution, and behavior. We will discuss the traits that characterize insects and learn to identify several of the most important orders and families. Insects play a variety of key roles in every terrestrial and freshwater ecosystem, and we will investigate some of the ways in which their interactions with other organisms influence ecosystem functioning. Because of their varied life histories, there is no single best insect sampling method. We will review the various collection methods and their relative merits before considering other logistical aspects of studying insects.

Further reading

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Myrmecology: The study of ants

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Ants belong to the single family Formicidae of the Hymenoptera, an order which also includes the wasps and bees. Formicidae is divided into about 20 subfamilies, each of which has a suite of defining morphological and sometimes behavioral characteristics. As of July 10th, 2007, there are 12,030 described species, and this figure is thought to be much smaller than the actual number of ant species. By comparison, there are around 9,800 described species of birds in the world.

Ants play important roles in litter decomposition, aeration of forest soils, and as symbiotic partners to many plants and other insects. All ant species are haplodiploid—a genetic system in which females have two sets of chromosomes and males have one. We will scratch the surface of myrmecology by examining basic anatomy, life cycle, social structure, and habits of ants. We will also examine some of the more unusual and evolutionarily derived ant lifestyles: slave-making ants, fungus gardening ants, and weaver ants.

Further reading

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MOREAU, C.S., C.D. BELL, R. VILA, S.B. ARCHIBALD AND N.E. PIERCE. 2006 Phylogeny of the ants: diversification in the age of angiosperms. Science. 312: 101-104.

TOPOFF, H. 1999. Slave-making queens. Scientific American. November 1999: 84-90.

Introduction to the endless world of insects by Dr David Lohman; students get a feel of insect trapping and pinning techniques

R kept us all quite busy and absorbed – at any time, at any place!

Having fun with Statistics

Bees

Rhett D. Harrison
Smithsonian Tropical Research Institute, Panama

Bees are essentially sphecoid wasps that began eating pollen about 80-100 million yr ago. For this reason, bees are often called simply Apidae by some taxonomists, but their biologies suggest there are too many differences among them to be contained in a single family. So, therefore, the two long-tongued bee groups are known as Apidae and Megachilidae, while the four short-tongued bee groups are called Halictidae, Andrenidae, Colletidae and Melittidae. There are about 20 000 valid names and about 95% of bee species have nothing to do with honey or colonies (with queens and workers, and drones). Most bees are solitary, seasonal, and lay eggs in one or more nests, and then die. Their larvae may develop over a few weeks to several months or even years, and the adults sometimes visit flowers of a narrow range of plant taxa, or may visit many diverse flowers (and other resources) throughout the year. About 20% are parasites, mostly of other bees.

In the tropics, there are fewer species of bees than in much of the warm and dry temperate zones (Mediterranean climates). Moreover, there is a strong shift in dominance from solitary to eusocial species. Especially important in the lowland rain forests are honey bees (Apidinae; Asia & Africa only) and stingless bees (Meliponinae). Other families are represented but less important; they are better represented in disturbed habitats and dry forest types.

Eusocial colonies (those with reproductives and a sterile worker caste) function as a single super-organism. The reason for their importance in lowland rain forest most probably lies in the pattern of resource distribution. In the lowland rain forest, flowers, and other resources such as honey dew and resins, are often rare and unpredictable in space and time. Moreover, bees are central point foragers (ie returning to a nest), hence are restricted in their ability to range over the forest. Having large numbers of forages employing a scout-and-recruit strategy is an efficient way to locate and capitalise on rare, unpredictable resources. Moreover, the colony's ability to store resources enables it to even out temporal fluctuations in resource abundance. The ubiquitous presence of these bees and their abundance at flowers makes them important pollinators. In some forests in Borneo there can be as many as four species of honey bee and 27 species of stingless bee living sympatrically.

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Litter and soil arthropod communities

Xiaodong Yang
Xishuangbanna Tropical Botanic Gardens

Soil arthropod communities are important decomposers. Their abundance and species composition varies according to forest type, and this has an effect on decomposition processes. Soil arthropods are usually extracted from litter by the Tullgren funnel method. Important groups include Acari, Collembola, Ants, Coleoptera, Diptera and Archaeognatha. In Xishuangbanna we have found a higher individual density and relative individual density of soil arthropods in old (35-year) secondary forest (10, 067 ind.$*$ m^{-2} and 22.72 ind.$*$ g^{-1} dry litter) as compared to the seasonal rainforest (5, 654 ind.$*$ m^{-2} and 18.44 ind.$*$ g^{-1} dry litter) and 23-year secondary forest (2, 881 ind.$*$ m^{-2} and 5, 818 ind.$*$ g^{-1} dry litter). Taxonomic diversity (Pielou and Shannon-Wiener index) was significantly higher in the 23-year secondary forest than all other forests, but the richness (Margalef index) of soil arthropod community in seasonal rainforest, and the dominance (Simpson index) of soil arthropod community in 35-year secondary forest was the highest among the three forests. The individual density (ind.$*$ m^{-2}) of soil arthropods was positively correlated with floor litter mass in all three forests, and they were correlated with the standing stock of N of the floor litter in 23-year secondary forest, and the standing stock of N of the floor woody detritus in seasonal rainforest. These results have shown that the development of soil arthropod communities in tropical forests is closely linked to vegetation succession, regulated through plant litter, but other environmental effects including predator effect and human disturbance should not be ignored.

Further Reading

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SCHEU, S., AND S. MATTHIAS. 1998. Bottom-up control of the soil macrofauna community in a beechwood on limestone: manipulation of food resources. Ecology. 79: 1573–1585.

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Ecology of forest birds

George Gale
King Mongkut's University of Technology, Thonburi, Thailand

Forest birds represent approximately 6,450 species of the current total of the roughly 9,700 described bird species. Forest birds are of particular interest due to their functional roles as seed dispersers, particularly in the tropics, and as predators of phytophagous insects. Knowledge of the reproductive ecology of forest birds has become particularly important as the impact of forest fragmentation has become increasingly problematic and now greater than 1,550 forest species are considered threatened. Furthermore, while data on the structure of temperate zone communities is relatively well developed, this is not the case for the tropics. In general, even the most basic knowledge of the natural history, such as nesting ecology, of common species in the tropics is lacking, especially in Asia. In this lecture we will highlight the evidence for the functional roles of birds in forest ecosystems and highlight basic differences between temperate and tropical forest birds.

Practical Session

This exercise will focus on identification of birds and observations of frugivory at fruiting trees to give students a taste of field ornithology and practical experience in assessing the functional roles of birds as seed dispersers. We will observe two species of fleshy fruiting trees, one with relatively large fruit and one relatively smaller fruit. We will identify birds that visit trees, estimate the duration and visitation rate, foraging behavior, and when possible distance moved after leaving the focal tree.

Further Reading

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Estimating Animal Abundance

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Estimating the abundance of populations is typically the first stage in the conservation and management of wildlife. During the past 10 years, distance sampling and other methods that estimate the probability of detection are fast becoming the standard for field biologists for estimating abundance, although there are still many agencies that rely on uncorrected counts. There is now a huge literature explaining why detectability-based density estimates are preferable to index counts such as fixed-radius point counts. Briefly, the problem is that index counts have to assume a consistent, positive correlation with actual animal density. To meet this assumption, detectability must remain constant regardless of factors that can have a substantial influence on counts; particularly (1) observer performance, (2) environmental variables such wind velocity, precipitation, cloud cover, as well as vegetation & topography and (3) physical and behavioral characteristics of the animals make them more or less detectable to human observers.

While methods using empirical models of detectability such as distance sampling do not require constant detectability, nevertheless there are three assumptions that have to be met, which still may pose problems in the field: (1) all animals on the line or point are detected, (2) animals are detected prior to evasive movement, and (3) distances are measured accurately. This lecture will provide a brief introduction to distance sampling and an introduction to the program DISTANCE.

Practical Session

This exercise will focus on distance sampling using colored flagged to represent animals. Students will walk along a trail and count and estimate the distance to the flags. Both manual methods with graph paper as well as DISTANCE software will be used to familiarize students with the methodology.

Further Reading

GALE, G. A. AND S. THONGAREE. 2006. Density estimates of nine hornbill species in a lowland forest site in southern Thailand. Bird Conservation International. 16: 57-69

HUSSON, H., S. E. PAGE AND J. O. RIELEY. 2003. Population status of the Bornean orang-utan (*Pongo pygmaeus*) in the Sebangau peat swamp forest, Central Kalimantan, Indonesia. Biological Conservation. 110: 141–152.

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Twenty questions

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This is an exercise in scientific thinking and the development of appropriate questions for investigation. Participants will go into the forest with instructions to observe the forest and come up with 20 questions of interest. Then working in groups, the participants will discuss each question and gradually focusing on the more interesting ones. Each group will develop these questions into testable scientific hypotheses. Finally, selecting just one question each group will propose a suitable project to test of the idea and examine it in a two-day field study. These projects will be written up for the course report and presented orally at the end of the course.

Students found many ways to relax during the six weeks

Forest Hydrology

Sha Liqing
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Course objectives:

1. To understand the role of water cycling in ecosystems.
2. To emphasize the importance of forest hydrology to productivity, water yield, water quality, and sustainable management of ecosystems.
3. To understand how changing land-use practices will affect the hydrology.
4. To get some information about catchment hydrology and instruments through case study.

Contents:

- Introduction
- Historic background
- Global water cycle
- Main water pools, water fluxes, water distribution patterns
- Water cycling in forest ecosystem: Precipitation, Interception, Evaporation, Through fall, Stem flow, Soil water storage, Infiltration, Runoff, Stream flow
- Catchment study: Catchment, Weir, Hydrograph
- Case studies in Ailaoshan and Xishuangbanna:
- Land use vs. discharge
- Erosion plot
- Hydrology instruments
- Forests and streamflow- consistence and complexity

Further Reading

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SWANK, W. T. AND C. E. JOHNSON. 1994. Small catchment research in the evaluation and development of forest management practices. *In* Moldan, B. and J. Cerny (Eds.). Biogeochemistry fo small catchments: A tool for environmental research. John Wiley & Sons Ltd, New York.

Earthworms and nutrient cycling

Xiaodong Yang
Xishuangbanna Tropical Botanic Gardens

Earthworms play important roles in regulating soil processes through stimulating the activity of soil microbes. There are differences in earthworm species and population in different forests. Pheretima is the dominant native earthworm species in seasonal rainforest and limestone rainforests. An exotic earthworm, Pontoscolex corethrurus, has invaded rubber plantation and is now the dominant species, accounting for 97.6% by abundance and 92.5% of biomass. There are higher abundances of earthworm in rubber plantations, but the highest biomass of earthworms is in limestone rainforest. Earthworm populations are influenced by soil water and temperature, so there is a significant difference between dry and wet seasons.

Electroshocking is an effective nondestructive technique for reducing earthworm populations under field conditions. In our experiments Earthworm populations were reduced by 85% in seasonal rainforest and limestone rainforest, and 54.93% in rubber plantations.

This enabled us to examine the effect of earthworms on the soil N mineralization. Earthworms increased the nitrate rate and net N mineralization rate in dry and wet season in all three forests. Earthworms increased the ammonification rate in wet season in seasonal rainforest, in dry season in limestone rainforest and had no effect in rubber plantations. NH_4^+ decreased in earthworm-reduced plots in all three forests, and NO_3^- and total inorganic nitrogen also decreased in seasonal rainforest and limestone rainforest. However, no significant effect of earthworms on soil microbial biomass carbon or nitrogen was found in the three tropical forests in our experiment.

In the practical we will revisit some of the long-term experiments set up to measure the effect of earthworm exclusion in montane forest.

Further Reading

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Evolutionary biology of Stone oaks

Chuck Cannon
Xishuangbanna Tropical Botanical Garden

The oak or beech family (Fagaceae) is one of the few tree groups to be ecologically dominant in both temperate and tropical forest ecosystems. The stone oaks (Lithocarpus) form the second most diverse genus in the family and are restricted in their distribution to Asia, with centers of diversity in Indochina and Borneo. A number of interesting comparisons can be made between the temperate and tropical oaks in their ecology and evolution. During the lecture, we will examine the overall phylogenetic structure of the family and the evolution of major reproductive traits. Most of the taxonomy in the stone oaks is based upon the fruit and cupule morphology. These characters are not only powerful for distinguishing among species but also have major implications for seed dispersal and life history traits. The stone oaks are also a useful model group for examining the historical distribution of rainforest habitat. During the practical, we will discuss some of the issues of field identification in this difficult group and some of the possible biological explanations for the observed patterns. We will also attempt to measure some aspects of population demography to better understand the interplay between fruit and seed type and life history strategies.

Ecophysiology of tropical rainforest plants: comparing photosynthesis and hydraulics of trees with contrasting successional status

Kun-Fang Cao
Xishuangbanna Tropical Botanical Garden

The objective of this lecture and the practical is to introduce some basic theory and techniques that are commonly used in plant ecophysiology, specifically photosynthesis and plant hydraulics. Strong irradiance, high temperature and high vapor pressure deficit around midday on clear days, even in the rainy season, can cause rapid decrease of leaf water potential, stomatal conductance or even partial loss of hydraulic functions in leaf and/or stem xylems, and lead to suppression of photosynthesis in tropical plants in exposed environments. Suppression of photosynthesis results in excessive excited light energy in chloroplasts that can cause potential damages to photosystems. Under this kind of circumstances, down-regulation or inactivation of photosynthetic reaction centers and enhancement of heat dissipation is often activated. Despite these compensation mechanisms, severe suppression of photochemistry, i.e. photoinhibition can sometimes happen. These changes can be characterised using chlorophyll fluorescence techniques. The degree of midday suppression in hydraulic conductivity and photosynthetic function may be different in different plants species depending on their hydraulic and photosynthetic characteristics as well as growing conditions. Tropical rainforests host highly diverse plants that vary strongly in photosynthetic and hydraulic functional traits. Pioneer tree species usually have higher photosynthetic capacity and hydraulic conductivity compared to the climax species and thus may have different patterns of responses to midday environmental conditions.

During the lecture, I will introduce some basic concepts in photosynthesis, chlorophyll fluorescence and plant hydraulics. During the practicals, we will introduce some related techniques by conducting some measurements on two tree species of contrasting successional status, i.e. pioneer and climax species.

Outline of the practical:

- The class will be divided into three groups.
- Group one: measuring diurnal changes in leaf water potential, gas exchange and chlorophyll fluorescence in two tree species, a climax and a pioneer species, guided by Kun-Fang Cao
- Group two: measurement of photosynthetic light response and CO_2 response (A-C_i), guided by Jiao-lin Zhang (Ph.D. student)
- Group three: measurement of actual and maximum hydraulic conductivity and construction of leaf pressure-volume curves. guided by Guang-You Hao (Ph.D. student)
- Each group will swap about every two hours. Finally, every group will make the all measurements assigned to the three groups indicated above, and we will get some preliminary data and analyse them.

Further Reading

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Chinese cuisine and its endless variety – that took us all by awe!

At Ailaoshan, where students did their group projects and also drifted away exploring the scenic, picture perfect landscape

Farewell to Ailaoshan - Barbeque, Corn liquor and Scottish dance!

Tropical montane evergreen broadleaf forest

Zhu Hua
Xishuangbanna Tropical Botanic Garden

Tropical montane evergreen broad-leaved forests occur on montane slopes between 900 m – 1800 m altitudes in southern Yunnan. They usually have two conspicuous tree layers, of which the upper tree layer is 15~30 m tall with dense crowns, and the lower tree layer is 3~18 m tall with a cover of c. 50%. These forests are dominated by Fagaceae, Theaceae and Lauraceae families, but diversified in species composition in different sites.

These forests are similar to lower montane rain forests in equatorial southeastern Asia in floristic composition and altitudinal distributions, but differ in physiognomy by having few epiphytes, but more lianas and more plants with compound leaves. These differences could be due to strongly seasonal climate and so-called mass elevation effect in southern Yunnan. Three forest types were recognised and named by their dominant and subdominant species as following: *Schima wallichii--Castanopsis hystrix* forest, *Schima wallichii-- Lithocarpus fohaiensis* forest and *Castanopsis echinocarpa* forest in southern Yunnan.

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Frugivory and Seed Dispersal

Richard T. Corlett
University of Hong Kong, China

Adult plants are fixed in space for their whole lives. However, movement is essential at two points in the life cycle – during sexual reproduction (i.e. pollination) and during the dispersal of offspring (i.e. seeds) away from the parent plant. Seed dispersal has two potential benefits for the offspring: it gets the seed away from the immediate surroundings of the mother plant, where competition with both parent and siblings is greatest and pests and pathogens are concentrated; and it increases the chance of the seed getting to a suitable site for germination, establishment and growth.

Dispersal by wind depends on the aerodynamic properties of the dispersal unit (seed or fruit), the height at which it is released, and the wind speed during its fall. Seeds will be dispersed further if they fall slowly, from a great height, or in strong winds. The terminal velocity of a seed is strongly correlated with its wing loading (weight per unit area), which can be decreased by wings, plumes etc. In tropical rain forests, wind dispersal below the canopy is only practical for the smallest of seeds (e.g. orchids) and spores, but it is quite common among emergent and upper canopy trees and climbers, and also pioneers of open sites. Most tropical forest plants are dispersed by animals. Ants are important mostly in the secondary dispersal of small seeds that were initial dispersal by vertebrates, although some plants produce seeds or fruits that are targeted directly at ants. Seed dispersal by vertebrates may take place externally or internally, but internal dispersal is most important by far in tropical forests. Internal dispersal requires that the seeds are packaged in nutritious tissues and are advertised.

Dispersal relationships in tropical forests are extremely diverse. In the tropical Asia, most species of forest birds and mammals eat at least some fruit, and specialized frugivores range in size from 5 g flowerpeckers to 1.5 kg flying foxes, 2-3 kg hornbills and 70 kg orangutans. These frugivores differ not only in diet and size, but also in locomotory and sensory capabilities, fruit and seed handling techniques, digestive physiologies, gut passage times and ranging behaviours. Most animals that eat fruits are capable of dispersing some seeds, but the consequences for a plant's fitness of its fruit being eaten by different animals vary greatly. Fruits, too, vary tremendously in phenology, size, morphology and chemistry, and thus also in their potential contribution to animal fitness. The number of possible pairs of plants and frugivores is enormous, but fruit-frugivore relationships in tropical forests are structured in a variety of ways, so only a small subset of the possible interactions actually occurs.

When fruit and frugivore coincide in space and time, frugivores are more likely to be attracted to fruits that signal their ripeness by colour or odour cues tuned to their particular sensory capabilities, and may overlook fruits

that do not. Different crop sizes and degrees of ripening synchrony may also attract different types of frugivores. Fruit and seed size interact with the size, gape width and oral processing capabilities of frugivores. Frugivores also differ in their ability to reach fruits displayed in different positions relative to potential perches, while mechanical barriers to the fruit rewards will restrict access to animals with the necessary strength and/or skill to overcome them. The nutritional content of the fruit pulp will interact with the digestive capabilities of the consumer, while the non-nutrient chemical content could potentially narrow the range of consumers. Discrete plant guilds are most obvious among species dispersed largely by primates, by fruit bats, and by terrestrial mammals. The lengths of the fruit lists compiled for well-studied animal species suggest a general lack of specialization among frugivores, but when the quantity of each fruit species consumed is taken into account, there is much less overlap in diet between animal species. The most important dispersal agents in tropical Asian forests are a few families of birds (Megalaimidae, Bucerotidae, Columbidae, Pycnonotidae, plus some species from a wide range of other families) and mammals (Pteropodidae, Cercopithecinae, Hylobatidae, Viverridae, plus some large terrestrial herbivores and some scatter-hoarding rodents).

Post-dispersal processes, such as seed predation, may effectively decouple patterns of plant regeneration from patterns of seed dispersal, making it very difficult to assess the conservation consequences of frugivore losses. Although dispersal relationships may be less specialized than those for pollination, the animals that disperse seeds are, in general, much larger than the animals that pollinate flowers. This makes them more vulnerable to both forest fragmentation and direct exploitation. Complete failures of dispersal mutualisms may be rare so far, but changes in the composition and spatial pattern of the seed rain must already be widespread. In the longer term, this will inevitably lead to the erosion of plant diversity.

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Tropical forests compared

Richard T. Corlett
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Tropical forests are variable on all spatial scales, but I will concentrate on the broadest – biogeographical regions – and consider only lowland evergreen rainforests. There are five major rainforest regions: the Neotropics (S. & C. America); Africa (C. & W. Africa); Asia (SE Asia and various outliers); New Guinea (and Australia); and Madagascar. Rainforests in these five regions are similar because the laws of physics are the same, but they differ because they contain different organisms, and many key processes are under biological control, including seed dispersal, predation, herbivory and decomposition. The major biological differences between regions result largely from the interaction between phylogeny, plate tectonics, and past climates and sea levels. Most modern rainforests are on fragments of the Mesozoic southern supercontinent of Gondwana, which drifted apart during the Cretaceous and early Tertiary. The fragments were widely separated during the period when most rainforest genera and many families evolved. Barriers between the major fragments have generally declined over the last 20 million years, but the absence of rainforest connections between the regions has maintained much of their distinctiveness.

The Neotropical rainforests are the most extensive, the most diverse for plants, birds, butterflies and many other groups, and in many ways the most distinctive. The rainforest vertebrate fauna includes: groups of possible Gondwanic origin that radiated in South America during the long period of isolation (e.g. sloths, anteaters, suboscine passerines); groups that arrived during the period of isolation (e.g. primates, caviomorph rodents); and groups that arrived only after the Panama land bridge connected South America with the north 3 million years ago (e.g. carnivores, deer, squirrels). The most distinctive botanical feature is the abundance and diversity of epiphytes in the Bromeliaceae.

African rainforests were once (c. 30 m years ago) as extensive, diverse and distinctive as those of the Neotropics, but intermittent connections to Eurasia since the Miocene have reduced their distinctiveness and the drying of the continent has reduced their diversity and extent. Today they are mostly drier, lower, more open, and less diverse than the other major regions. Most major families of plants and animals are shared with Asian rainforests, but very few species. The most distinctive feature of Southeast Asian rainforests are the everwet climate, the dominance of dipterocarps and – probably related to both of these – the supra-annual pattern of community-level mass flowering and mast fruiting. This results in an irregular alternation of brief "feasts" and prolonged "famines" for animals dependent on flowers, fruits or seeds.

New Guinea and Australia were joined during Pleistocene low sea levels but have never been connected to Asia, so the contrast across Wallace's Line is sharp, despite the relative proximity of the two regions. Rainforest covered much of northern Australia in the early to middle Miocene, but has since become restricted to a tiny area in the northeast by drying. Rainforest in New Guinea, in contrast, largely occupies land that was uplifted above sea level only 10-15 million years ago. The lowland rainforest flora of New Guinea is largely Asian, while the vertebrate fauna is largely non-Asian. Rats and bats are the only native placental mammals. Marsupials fill the mammalian herbivore, frugivore and small carnivore niches, but there are no large mammalian carnivores. The bird fauna includes some Asian groups and several endemic families, such as the birds of paradise.

Madagascar has been isolated for 90 million years by a deep ocean barrier. The entire non-flying mammal fauna of 101 species has resulted from only 4 colonization events: an ancestral lemur c. 65 m years ago, an ancestral carnivore c. 20 m years ago, an ancestral insectivore, and an ancestral rodent. Other groups show the same pattern: very few colonization events followed by adaptive radiation into a wide range of habitats and niches. Many groups are absent, such as woodpeckers and grazing mammals, and mass extinctions of large vertebrates followed the arrival of the first humans c. 2000 years ago.

What are the consequences of these differences? In theory, convergent evolution could ensure that niches are filled from whatever lineages are available, but, although there are clear examples of convergent evolution in some groups (e.g. flycatching birds), convergence is incomplete in others (e.g. frugivores and browsers). Non-convergence is most obvious for Madagascar and New Guinea, where many vertebrate niches appear to be unfilled, but there are also striking examples from the three largest and most diverse regions (e.g. leaf-cutter ants are confined to the Neotropics). Do these differences in the organisms present have any consequences for community function? The lack of comparable measurements between sites with matched physical environments makes this question almost impossible to answer at present.

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Identifying plants was an exciting game, even for the non-botanist!

Waiting for earthworms - during the session on earthworm sampling techniques

Many new ornithologists were born at the end of 6 weeks in the bird rich habitats in China

Dr. Chuck Cannon sharing his passion for Stone Oaks and Conservation biology in Ailaoshan

Evolutionary philosophy

Shawn Lum
National Institute of Education, Singapore

The plant population ecologist John Harper once referred to Chapter 3 of Darwin's On the Origin of Species as one of the greatest ecological treatises ever written. What was the basis for Harper's assertion? To find out, this session will begin with a review of the basic tenets of Darwinian evolution. We will then try to see how an evolutionary approach could be incorporated into ecological studies.

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Molecular ecology

Shawn Lum
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Molecular ecology is a broad field that has elements of evolutionary biology, population genetics and, as the term suggests, ecology. We will start by learning what kinds of work are generally placed under the umbrella of "molecular ecology" and read through a couple of studies as examples of molecular ecology research. Following the introductory activity, we will go to the field to plan possible ecological studies that could benefit from the addition of molecular-based techniques.

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Figs and fig wasps: Evolutionary ecology of a mutualism

Rhett D. Harrison
Smithsonian tropical Research Institute, Panama

Figs (Ficus, Moraceae) are important plants in lowland tropical rain forests. Over approximately 60-80M years they have co-evolved with fig wasps (Agaoninae, Agaonidae, Chalcidoidea) in an intricate mutualism. The fig inflorescence is a closed urn-shaped receptacle lined with tiny uni-ovular flowers. Female fig wasps enter the inflorescence through a tiny bract covered entrance, losing their wings in the process, and pollinate the flowers inside. Simultaneously, the fig wasps attempt to oviposit on some ovules. Ovules that receive a wasp egg form a gall and the fig wasp larva feeds on the gall tissue. Pollinated ovules missed by the wasps develop into seeds normally. The fig wasp is thus a seed predator – pollinator, and well illustrates the fact that mutualisms are perhaps best understood as mutual exploitation. After approximately one month the adult fig wasp offspring emerge. The wingless males emerge fist and mate with the gall-enclosed females. The females then emerge and collect pollen, either passively or by actively filling pollen pockets on the meso-thorax. Meanwhile, the male wasps cut a tunnel through the fig wall, which the female wasps use to escape from the fig. The adult female wasps live only 1-3 days, and thus must locate a receptive fig within this brief lifespan to reproduce. However, many fig species occur at low densities and only a small proportion of individuals are receptive at any point in time. Thus, in their search for trees with receptive inflorescences the pollinators of these figs disperse further than is known for any other pollinator (>30 km). They achieve this by flying above the canopy and using the wind. However, there is diversity in the dispersal ecology of fig wasps, and other species fly much shorter distances.

A few days after the emergence of the fig wasps the fig inflorescence softens and ripens into a fruit (pseudo-carp) that is eaten by a variety of vertebrate seed dispersers. Over 1200 species of vertebrate feed on figs worldwide and year-round availability of fig fruit makes figs a critical component in the diet of many species, especially at times of the year when few other fruit are available.

The monoecious system described above is the ancestral system in figs, but in Asia there are also many dioecious figs in which the sexual roles are separated. On female trees the fig wasp enters the inflorescence and pollinates the flowers, but fails to lay its eggs because the styles are too long and too thin. It, therefore, dies without reproducing. This can be considered a deceit pollination system. On male trees the flowers are modified to receive a wasp egg and only wasps and pollen are produced; the male role of the fig.

The alignment of the reproductive interests of the fig wasp with delivery of the fig's pollen has led to an incredibly efficient pollination system. The fig - wasp interaction has often been used as a model system to investigate co-evolution and other aspects of evolutionary theory, such as sex ration theory (Local Mate Competition), the evolution of virulence, convergent evolution, and co-speciation.

In addition to pollinating wasps there exists in most fig species a diverse community of non-pollinating wasp. Some species enter the fig at the receptive stage like the pollinators, but the majority of species lay their eggs by piercing the wall of the inflorescence with a very long ovipositor. Species have diverse ecological roles and include ovule gallers (i.e. competitiors of the pollinators) and gallers that use the tissue of the inflorescence wall, inquilines (gall parasites), and parasitoides.

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Figs and fig wasps of Xishuangbanna

Yan-Qiong Peng
Xishuangbanna Tropical Botanic Gardens

There are about 70 Ficus species at Xishangbanna Tropical area, and 26 species are monoecious and others are functionally dioecious. Ficus species show a large diversity, which vary from huge trees to creepers, and they are distributed in different sites including old-growth forest, secondary forest, and even wasteland.
Thirty-six species of agaonid wasps (pollinators) have been recorded at XTBG and they come from seven genera. Figs are also exploited by a large community of chalcidoid wasps that develop within the figs but do not transfer pollen. These wasps include gallers, inquilines, cleptoparasites, parasitoids of the pollinators, and parasitoids of other non-pollinating wasp species. There are more than 100 non-pollinating fig wasps are distributed in this area. In the practical students will learn to distinguish monoecious and dioecious figs, collect and identify figs and fig wasps, and observe some biology characters of fig wasps.

Conservation biology

Chuck Cannon
Texas Tech Univeristy

Scientists and experts have continued to bang the gong of the impending disaster facing the forests of Southeast Asia and the biodiversity it contains. The list of issues is seemingly endless, from logging to conversion for plantations to hunting. To make it even more complicated, each piece of remaining forest appears to face a unique combination of these issues, including differences in human culture and economy. During the lecture, we'll examine the different geographic scales, from the global to the local, at which these issues play out. We'll also discuss what strategy can truly have impact? Do we need more scientific studies or should we all be debating policy or is it as simple as enforcing laws?

During the practical, students will be expected to identify the major issues facing their favorite piece of forest and discuss with the class various possible resolutions. We'll also go over the current trend to use 'criteria and indicators' for creating conservation strategy and students will be encouraged to suggest improvements and to identify shortcomings in these approaches.

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Excursions

Projects

EXCURSION REPORTS

Excursion to the Xishuangbanna Tropical Botanic Garden (XTBG), 2 September 2007

Chinthaka D. Kaluthota, Charlie D. Heatubun and **Chen Xin-sheng**

JUST AFTER THE OFFICIAL OPENING CEREMONY of the CTFS field biology course, we were able to make a guided tour of the Xishuangbanna Tropical Botanical Garden (XTBG). Since it was going to be the home for all of us for next six weeks, it was a great opportunity to familiarise ourselves with the garden on this excursion. We also had the rare opportunity to have the guidance of Prof. Hua Zhu, who is well known figure in the XTBG faculty and an expert botanist.

XTBG of the Chinese Academy of Sciences was established in 1959. During the past few decades it has developed in to international level garden, which provides many facilities for scientists as well as tourists. It is one of the main attractions of Southern Yunnan, as can be witnessed during the day when the garden is filled with tourists.

The garden is located on an island surrounded by the river Luosuo, which is a tributary of famous Lanchang or Mekong River. It covers nearly 900 ha in a picturesque environment.

First we visited the Herbarium which is one of the main facilities of XTBG. It is very sophisticated and equipped with modern technology such as compact chambers, fire alarm, humidity and temperature automatic control system. More than 110,000 plant specimens from China, as well as many other countries, are deposited here and classified according to the Hutchinson system. Information on all the specimens is stored in a web based database with photographs and can be accessed by anyone.

The public gardens of the XTBG are well maintained and cover 34 living collections of plants. The Palm garden, Orchid collection and Water plant collection are among the main attractions in the garden. The Ethnobotanical Museum is another important feature. It provides information not only the flora and fauna, but also the ethnic diversity and its importance of the people living in the area. And as one of the botanic gardens in world, XTBG also play role to in situ and ex situ conservation, by providing local biodiversity information, collection of seeds and endangered species in the region, and raising people's awareness for conservation through various educational programs.

Panoramic view of the Museum, XTBG

XTBG has many tourist attractions

A Unique Habitat: The Limestone Forest, 3 September 2007

Rai Kristie Salve Gomez, S. Syahida-Emiza, and **Song Bo**

THE LIMESTONE FOREST IN XISHUANGBANNA is approximately 8 km from the Xishuangbanna Tropical Botanic Garden (XTBG). It is one of a number of habitat types found in Yunnan Province. This habitat type is managed and protected by Xishuangbanna Natural Reserve (XNR). Extraction of wildlife and plants in the limestone forest is prohibited by the XNR. There are two main types of limestone topography, one of which is the typical karst mountain with rocky tops without soil, and slope partially covered by thin soil. The other is a bigger mountain again with a rocky top without soil, but having slopes especially in the lower area covered by thick soil with fewer limestone outcrops. Limestone vegetation is very rich in endemic taxa.

On 3 September 2007, a field trip to limestone forest was conducted with Dr. Zhu Hua as our guide and teacher on the plant identification. Transportation to the site was by the electric trams that are usually used by tourists visiting XTBG. The journey takes only 15 minutes from XTBG. It was a very rainy day.

During the fieldtrip, we learned about the limestone forest and identified the dominant tree species in the area. This habitat type is dominated by the family Euphorbiaceae, Malvaceae and Ulmaceae. The simple character for family Euphorbiaceae is that they have 3-locule ovary. For family Rutaceae, we can identify by characters of leaves such as oil dots and aroma. Rubiaceae members have distinct inter-petiolar stipules. Dr. Zhu Hua also explained the difference between ecological endemic and taxonomic endemic for some species. Ecological endemic simply means that the species is found in one specific habitat type while taxonomic endemic refers to a species that is locally distributed.

Due to the limestone substrate and the lack of soil and moisture, plants in the area have developed a unique root system. Many strangling figs can live on the rocks and the roots creep to the ground to get the nutrients. From our observations, most of the trees were not large and also had small leaves, which might be an adaptation to resource limitation from the rocky substrate.

After 20 minutes of walk into the forest, we reached a small viewing hut. Here, we were able to observe the Luosuo River from inside the limestone forest. On the way back, the cemented trail was slippery due to the rain. Near the entrance, we saw a big tree with huge buttresses. The emergent tree is *Tetrameles nudiflora* (Tetrameliaceae). This deciduous tree can reach up to 35m tall. We went back to XTBG for a brief summary of the tour to compensate for the heavy rain.

The limestone forest is a unique habitat harboring interesting vegetation. Research about the vegetation and ecological interactions are being conducted in the area by students from XTBG of the Chinese Academy of Science.

The Limestone Forest as seen from the road

The strangler figs are common in limestone forest

Visit to the 55km forest, 4 September 2007

Jiffy james, Qie Lan and **Martin Stenflo**

ON THE 4TH OF SEPTEMBER, we went to the 55 km. forest for the second session of our plant identification practical. The destination was a 30 minute drive from XTBG and we were driven to the location in one of the XTBG vans. As there were some torrential rains the previous night and in the morning, it was decided by Dr. Zhu Hua that we stick to the roads bordering the forest, rather than go directly into it. There were plenty of trees along the roadside, so identifying them would be much easier too. We started our downhill walk, always weary of the rock-laden trucks that plied the tattered roads carrying iron ore to the smelter (owned by an influential local-baron) in the next town.

The session started out with the Family *Combretaceae* and its representative member *Terminalia*, a dominant tree in the region having characteristic twin glands at the base of the leaf blade. Dr. Zhu would carefully explain to us the characteristics of the family and later give diagnostic features for identifying the particular genus. With a gentle drizzle still continuing, it was hard work catching up with the botanist and taking down notes at the same time. Five families and several incomplete notes later we were introduced to the Family *Anacardiaceae* composed of members producing poisonous latex. It was hard to believe that one of the contenders for the title "King of Fruits", the tasty mango, actually a member of this feared clan. Some of the other plant families that we learned to recognise included *Verbenaceae*, *Euphorbiaceae*, *Ulmaceae*, *Lauraceae* and *Rubiaceae*.

We also came across a patch of "dead forest", a term used to describe a piece of forest where the undergrowth has been replaced by an invasive species, which prevents the regrowth of the natural forest, in this case by a cultivated cash crop from the Family *Zingiberaceae*. Dr. Zhu explained that although such forests seem to be continuous because of the intact forest canopy, they were virtually devoid of any biodiversity. It was disheartening to learn that the phenomenon was pretty common in the locality and that a feud still continued between the villagers (owners of the dead forests) and the forest officials over proper management of the forests. The introduction to this phenomenon was a grim reminder to how humans can impact the fragile balance that sustains our planet.

But one look at the mighty and gentle limestone hills draped in the eternal green attire cleansed all hint of dismay from our hearts. Overjoyed at this sight and with growing anticipation for the rest of the long day that lay before us, we started on our journey back to the XTBG.

Yunnan's Dipterocarps, 6 September 2007

Pipat Ketdee, Socrates Letana, and **Manju V. Sharma**

THE TYPICAL DIPTEROCARP FOREST IN YUNNAN, reaches up to a height of 60 m and is composed of four canopy layers. The top layer is 30- 60 m tall, with very uneven, discontinuous crowns covering about 30 percent of the forest. The second layer with a crown cover of 80 percent forms the main canopy (Zhu 1997). *Shorea chinensis* is the characteristic emergent tree, and it has the largest girth. Somewhat smaller than *Shorea* but still tall, emergents are *Pometia tomentosa,* and *Neaonauclea grifithii*. *Garcinia* and *Cinnamomum* are the common genera in the second layer. The third layer is 10-20 m and the dominant is a Euphorb we had learnt to identify during the Field Botany sessions over the past 3 days – *Baccaurea ramiflora.* The fourth layer is 6-10 m high with *Pittosporopsis kerii* dominating.

The drive from XTBG to Mengla was scenic, through lush green paddy fields bordered by misty mountains. The highlight of the day was to be the 'canopy walkway' not far from Mengla town. Called the 'Air corridor among the Look-up-into-the sky trees', the walkway along the towering trees is a captivating experience. The group had a 200-meter walk 30 meters above the ground with a "bird's-eye" view of the forest.

The second stop was at the Forest Dynamics Plot in Xishuangbanna (101º35'E, 21º 37'N).The 20-

hectare plot (400 m E-W X 500 m S-N) was established in a *Shorea chinensis* forest tract in Mengla County, which borders Laos in the south and the east, and is dominated by dipterocarp trees.

Standing tall: students experiencing the canopy walkway

The plot was subdivided into five hundred 20 x 20 m quadrats wherein coordinates and identity of all the tree species over 1 cm DBH were documented. Each individual has been tagged and mapped to monitor the distribution and habitat heterogeneity, and will be censured every five years. Dr. Cao Min walked us through the forest plot. Walking along a stream on the edge of the forest, we found ourselves standing in a valley, and Prof Ciao Min told us that it is in such valleys *Shorea chinensis* is common; it is not found on the upper ridges. Our first field exercise was to be in this patch of forest, but not until the next morning. We hiked further up to the ridge, chewing on sour sweet fruits of *Garcinia* until we noticed that the tree composition around us had changed, there seemed to be the dominance of a new tree species and there was only one tree layer with no sub canopy and understorey. The tree in this transition zone was *Castanopsis* spp. which may be indicator of past disturbance. There is almost no information on the history of vegetation in this forest. This and the fact that *Shorea* is present in the valleys alone, made it a perfect site for a testable question in our regeneration field research the following day. Dr David Burslem suggested that we try and examine the cause of the gradation from *Shorea* to 'no-*Shorea'* as we went up from the valley to the ridge. We wanted to make use of the current cohort of *Shorea* seeds and seedlings to investigate whether the distribution was the result of dispersal limitation or if the species genuinely has a habitat niche in the valley. To test this, we laid out about 10 quadrats of 2m x 2m at a distance of 20 metres apart along 4 transects, that go up the slope. We counted the number of seedlings just sprouted from this season's seed dispersal and kept a separate count of seedlings established from previous years' cohorts and not more than 1 m in height.

And as it turned out, the seedlings count from the current and established cohorts showed a clear pattern of a narrowing in distribution as seedlings age, indicating the importance of habitat over dispersal limitation. Back in XTBG while we did some interesting learning on 'R' to analyse the data gathered from the 20 ha plot, images of the winged fruits of *Shorea* spiralling down the canopy walkway refused to leave the mind.

Young seedlings of *Shorea chinensis* in a clump

A winged *Shorea* fruit on the forest floor after making its journey from the emergent canopy.

Ailaoshan Ecological Field Station, 15 - 24 September 2007

Joann Christine, Pei Sin Tong and **Chi-Shiun Wu**

WE WERE GREETED WITH CHILLING BREEZE as we arrived at Ailaoshan after a 12 hours journey from Xinshuangbanna. The Ailaoshan ecological system field station established by the Xishuangbanna Tropical Botanical Garden (XTBG) is located at 24'32' N, 101'01'E with an elevation of 2491 m above sea level in Jingdong District, Yunnan Province. Ailaoshan is blessed with intact forest structure and function and is one of the best representations of an evergreen broadleaf forest in southern China. The forest covers an area of 50,000 ha. It has been gazetted as a national nature reserve since 1986, which is the highest protection classification in Chinese forestry management. The average annual temperature is 11 ^{o}C and annual rainfall volume is 1800 mm. However, there has been an unusual rainfall volume this year as the total volume from January to September is estimated to have reached 1900 mm. The field station was built in 1981. Over the years, it has improved its facilities and infrastructure to increase its research capacity.

Sunset at the lake by the Ailaoshan Field Station

A total of 12 staff is based at the station to monitor and collect data from hydrological, meteorological and ecological studies on plants and animals. There are also some international students who have based their research in Ailaoshan. By joining the China Ecosystem Research Network (CERN) in 2005, the station is contributing important data to better understand the different forest ecosystems in China.

Ailaoshan is home to some 1482 species of plants excluding lichens and mosses. Fagaceae are common, with *Lithocarpus* and *Castanopsis* being the dominant genera. Not to forget the fauna, there are 43 species of small mammals, 24 species of big mammals, 24 species of amphibians and 343 species of birds.

Soil and nutrients practical by Dr Yang

On the first day, we went exploring the beautiful forest up to the peak at 2620 asl and were rewarded with a breath taking view of a reservoir, a result of a dam built in 1958. The class spent nine days at the field station to carry out various activities and practicals, including group projects, learning about forest hydrology, soil and nutrient cycling, and evolutionary biology of stone oaks. Although we were greeted with two rainy days, we were blessed with sunshine through the rest of our stay. We also had a chance to do some leisurely activities such as bird-watching and mixing with some locals as they brought freshly harvested walnuts on their donkeys!

Bird watching on a cold morning

Cai Yang He: An Introduction to Evergreen Broadleaf Forest, 25 September 2007

Manoon Pliosungnoen, Ng Wai Pak and **Zhu Yan**

ON 25 SEPTEMBER 2007, we travelled to Cai-Yang-He Forest Reserve, which is a distinctive tropical montane evergreen broad-leaved forest. We stayed in a new hotel that located on the top of the mountain. There is a nature exhibition hall inside the hotel, where useful information of the flora and fauna are displayed together with a good collection of insect, mammals, birds and reptiles specimens.

Dr Zhu sharing with students some important key to identify the forest vegetation

The next day, we attended Dr Zhu Hua's lecture on the evergreen broadleaf forests of Southern Yunnan. After the lecture we went to the top of the hotel to get a bird view of the whole forest reserve. We then had a walk to the tropical montane evergreen broad-leaved forest.

According to Dr Zhu, tropical montane evergreen broad-leaved forest can be found above lowland zone of tropical seasonal rain forest and usually distributes on mountain slopes and summits above 1000 m elevation and valleys above 1300 m. This forest has two conspicuous tree layers, of which the top layer is 15-25 m tall with dense crown coverage. It dominated mainly by Fagaceae, Lauraceae and Theaceae species, such as *Castanopsis fleuryi, Machilus tenuipila* and *Schima wallichii.*

We found a lot of *Schima wallichii* flowers were blooming. Their pollinators such as butterflies and bees could be easily spotted even though we were far away from the flowering tree.

Compared to other montane forests, this montane forest has lesser woody liana and epiphyte, higher abundant herbaceous phanerophytes but fewer buttresses and examples of cauliflory. The ground vegetation at Cai-yang-he is more abundant compare to other montane forest, for example in Ailao Mountain.

Another unique phenomenon that can found in this forest is the coexistent of north temperate forest genus, *Betula* and the tropical tree genus, *Mastixia*.

Participants having a high view of the evergreen broadleaf forest

360^0 view from the watch tower of the star class hotel

The Indigenous People of Xishuangbanna

Lanka Manojinie Weerasinghe, Daphawan Khamcha and **Arif Setiawan**

XISHUANGBANNA IS A FASCINATING LAND, and is home to several distinct cultural groups. According to historical records, the ancestors of the Dai resided in the Xishuangbanna area more than two thousand years ago. In the Dai language, "Xishuang" means twelve and "Banna" means districts, and there are records of twelve historical districts. Most of the other indigenous groups occupy the highlands. With the development of the Ming and Qing dynasties, people of Hani ancestry and other ethnic groups immigrated to Xishuangbanna in considerable numbers, changing the ethnic composition and natural landscape.

Bamboo houses are the traditional dwellings of the Dai people, and these houses are found in Xishuangbanna, where every household has such a building in an independent courtyard. The Dai bamboo house is square in shape and has two stories. At the center of the living room is a large bamboo matting, on which people eat, rest, or receive guests. They have a separate place for the guest's bed room. There are some strict rules for the guests. If the guest cannot keep to the rules, it is said that, he will become the son in law of that home.

The Dai in Xishuangbanna are most often related to traditional paddy cultivation. More than 2000 years ago, they began by scattering rice seeds on the wetlands near streams, and today the food of the Dai people is still rice. People in Xishuangbanna and some other areas also like to eat polished glutinous rice wrapped in banana leaves. Rice cooked in bamboo tubes is also favoured by Dai people.

The traditional Dai clothes are mostly made of home-spun cloth. The cloth has beautiful patterns. Many Dai women wear a silk girdle around their waists. It is said to be very precious, because it is passed down from mother to daughter from generation to generation. The girdle is actually token of love. If a girl gives the silver girdle to a young man, it means she has fallen in love with him.

Compared to other ethnic minorities in the region, the Dai have the most cultural distinction and integrity because they have their own language. The current Dai language was created over 1000 years ago. It is closely related to the growth of Hinayana Buddhism in the region. In the past, Buddhist scripts were inscribed on Beiye, the tree leaves of an indigenous tropical plant.

A word of thanks to Ms Pao, the interpreter at the museum in XTBG

.

Clockwise from top left; A bed room of a traditional Dai house, Traditional dress of a Dai girl, Some bamboo products, Buddhist scripts written in plant leaves

GROUP PROJECTS

Effect of Bamboo Density on Herbaceous Species Composition

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ABSTRACT

Herbaceous species composition was studied in relation to bamboo density in Ailaoshan broadleaf montane forest. Line transects and complete census was used to sample herbaceous species. Bamboo density had a significant effect on herbaceous community. Bamboo density and elevation were the factors with the strongest effect on herbaceous species composition according to DECORANA. Contrary to our expectation, some species of herbaceous plant benefited from the high density of bamboo growth at Ailaoshan.

Key words: Ailaoshan, broadleaf montane forest, elevation

THE BAMBOOS INCLUDE AT PRESENT ABOUT 45 GENERA and belong to a distinctive group of the family Poaceae (grasses) that are assigned to 13 subfamilies (APG 2003). In addition, bamboos have an extremely wide range of distribution, and grow in different habitats, from open environments to shaded forest. Due to the clonal life history of bamboos, they may optimise light use in their growth by spreading through the area.

Bamboos in temperate and tropical forests appear particularly effective in reducing tree seedlings establishment and development, or inhibiting tree regeneration entirely, because of their rapid growth and high degree of dominance in the understorey (Taylor *et al.* 2004). Thus, understanding the relationship between bamboo and groundcover vegetation is important to determine the factors affecting forest composition and dynamics.

Resource availability is an important factor in the abundance and composition of ground cover vegetation. In the highlands of Ailaoshan, *Sinarundinaria nitida* (Mitford) Nakai is widely distributed and bamboo is dominant. Areas with high bamboos density were found to have some species of tree seedlings, saplings and various herbaceous. However, the presence of bamboo may still affect the composition and abundance of ground cover vegetation. Previous studies in other forests of China have shown that a high level of dominance by dwarf bamboos results in the inhibition of growth among tree seedlings and saplings. But no studies have shown if bamboo density also inhibits the growth of herbaceous species in forest ground cover.

The objective of this study was to determine the effect of bamboo density, topography and light intensity on herbaceous species composition.

METHODS

Ailaoshan is an evergreen broadleaf montane forest. It is located at 24° 32’ N, 101° 01’ E at 2450 m asl. The mean annual rainfall is 1931 mm, the annual temperature is 11°C, while mean air humidity is 83 percent annually. This study was carried out at Xujiaba, Ailao Mountain Ecological Research Station, Jingdong County, Yunnan Province, China. Field work was conducted on 18-20 September 2007.

Ten transects were set up along a slope at 30 m intervals. Each transect had six (2 m × 2 m) quadrates at 20 m intervals. In each quadrate, we identified the plant species and counted the number of individuals (complete census). Light intensity, topography, depth of leaf litter and altitude at each quadrate were also recorded.

DATA ANALYSIS. — We use Detrended Correspondence Analysis, and Pearson’s Correlation Analysis using the R package (R Core group 2007), to see the effect of

different factors (bamboo density, light, leaf litter, slope and elevation) on herbaceous species composition.

RESULTS

After three days of sampling, we were able to identify 36 species of herbs from the total of 60 quadrates. Some plants were identified only until genus level. Twenty three species were documented in quadrates 1 to 30 and thirty species were documented from quadrates 31 to 60, which were on facing slopes. Fig. 1 shows that *Impatiens* species had the highest species abundance captured in quadrates 1 to 30, represented by 235 individuals, followed by *Cauex teinogyra* with 138 individuals and Primulaceae with 42 individuals. Species that were only captured in the first 30 qudrates include *Jasminum* sp., *Tetrastigma obtectum, Rhamnus heterophylla, Zanthoxylum alpinum, Pteracanthus calycinus*.

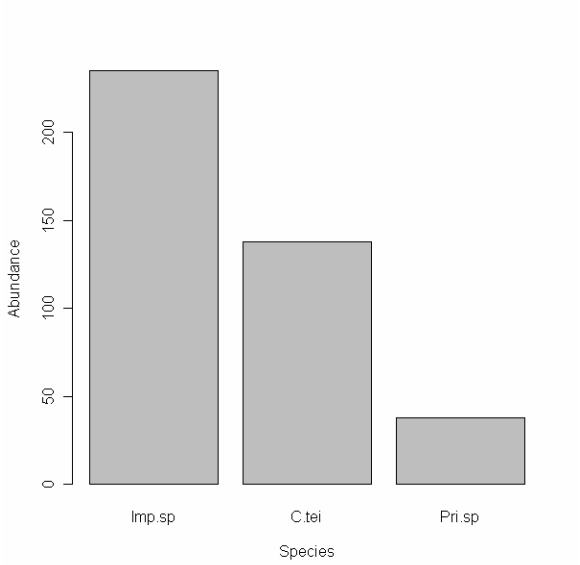

FIGURE 1. Species abundance of herbaceous species with mean value >1 individual recorded in quadrates 1-30.

In quadrates 31 to 60, the most abundant species was *Elatostema obtusum*, represented by a total of 430 individuals (Fig. 2). Species that were only documented in this area include Acanthaceae species, *Berberes dictyophylla, Heterosmilax yunnanensis, Heterosmilax chinensis, Sorbus filipes, Polygonatum kingranum, Ainlicaea henryi, Evonymus vagans, Ligustrum delavayanum, Holboellia latefolia, Briggsia langifolia* and *Styrax grandiflorus.*

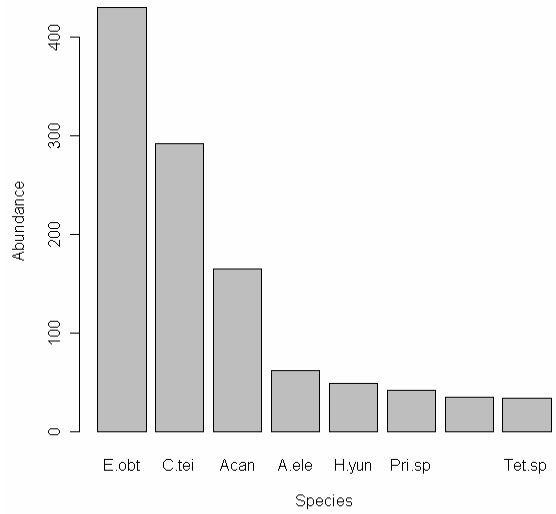

FIGURE 2. Species abundance of herbaceous species with mean value >1 individual recorded in quadrates 31 to 60.

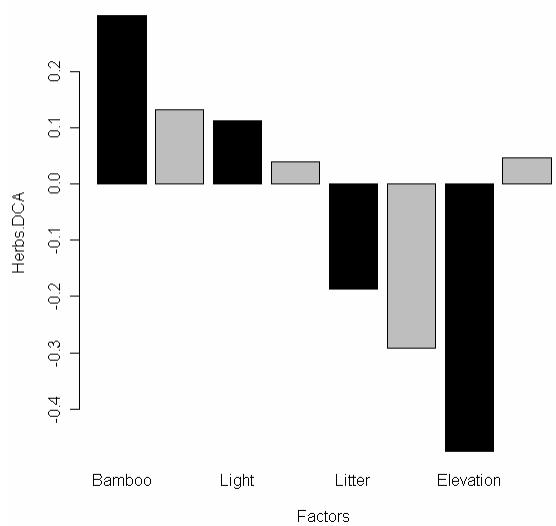

FIGURE 3. Factors influencing herb species composition using DCA1 and DCA2 in Ailaoshan montane forest; black=DCA1, grey=DCA2.

The Eigen value of the first DCA axis is 0.571 meaning that close to 60 percent of the variance in the herbaceous species composition is represented by the DCA axis one. The second axis explained 38 percent of the variance.

We correlated the DCA1 and DCA2 axes scores against bamboo density, elevation, light and leaf litter to herbaceous species richness. The results

showed a positive correlation with bamboo density and light intensity to DCA1. The correlation of bamboo density with herbaceous species composition was significant (P = 0.021), but the effect of light intensity was not significant. However, leaf litter and elevation were negatively correlated with DCA1, which means that the effect of these two factors on herbaceous species composition was in the opposite direction to bamboo density and light. The correlation of elevation with herbaceous species composition was highly significant (P = 0.0001) (Fig. 3).

Bamboo density and light were also positively correlated to DCA2. Though elevation was negatively correlated to species composition in DCA1, it was positively correlated with in DCA2. Leaf litter was also negatively correlated to in DCA2. However, the only factor which had a significant effect on herbaceous species composition using DCA2 was leaf litter (P = 0.023) (Fig. 3).

DISCUSSION

In some plant interactions, one member is a passive player in an interaction that is beneficial to the second member. The protection from direct sunlight afforded by a tall plant to a shorter one is an example. Although solar radiation commonly limits plant growth, many plants cannot thrive if exposed to direct sunlight. All plants need the same resources (water, light and nutrients) for their survival, growth and reproduction (Ewel & Hiremath 2005). However, different species of plants need resources in different quantity. For example, not many herbaceous species can tolerate high levels of light intensity.

Bamboo density seems to be an important factor in determining herbaceous species composition in many forests. Our results revealed that bamboo density, elevation, and leaf litter depth had significant effects on the species composition of herbaceous plants. Bamboo density and elevation were significantly correlated with the DCA1 and leaf litter depth with DCA2.

Bamboo density could influence light intensity in the ground cover. High bamboo density could lower light intensity in the ground cover, which is beneficial to shade loving herbaceous species. Low bamboo density on the other hand could mean higher light intensity to ground cover, which could aid growth of light loving herbaceous plants. With increasing elevation, there was a decrease in the number of species of herbaceous plants. Leaf litter depth may affect herbaceous plant establishment, or could represent an indirect effect of the influence of canopy tree species.

Another factor that seems to influence herbaceous species composition is the orientation of the slope. Though this was not tested, on different slopes we found different herbaceous species composition. Herbaceous species dominance also changed. *Impatiens* species was dominant in the first 30 quadrates but at the other slope was dominated by *Elatostema obtusum*. There were also herbaceous species that were only found in one slope and not the other slope. It might be that the two slopes have different soil characteristics. Though, more information on other possible factors that could explain this result is needed. Thus, we suggest that more parameters such as soil moisture, soil pH, and others should be measured to get a clearer relationship between bamboo abundance and herbaceous species abundance and composition. Unlike with seedlings, wherein bamboo density inhibits seedling growth, bamboo density actually aids the growth of most herbaceous species.

ACKNOWLEDGEMENTS

We would like to express our thanks to the organizers of the CTFS-AA International Field Biology Course 2007 for the opportunity to study in the Ailaoshan montane evergreen broadleaf forest. Our appreciation also goes to Mr. Yang Guoping as our botanist who helped us identify the plants up to the species level.

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Species Diversity and Composition of Ferns from Edge to Interior of a Montane Forest, Ailaoshan Nature Reserve

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ABSTRACT

The effect of edge, which is a consequence of forest fragmentation, on the pteridophyte communities of the montane forests of the Ailaoshan Nature Reserve was investigated. Pteridophytes, which grew on the ground and tree stems up to 2 m, were inventoried from the edge to the interior of the forest. A total of 18 pteridophyte species were recorded during the survey. A total of fourteen species were recorded in more than ten plots, while three species were recorded only once in the study plots. The most common species identified was recorded in around half of the plots surveyed. Significant correlations between fern species richness ($R=0.32$, $P<0.05$) as well as the diversity as Shanon-Weiner diversity index ($R=0.31$, $P<0.05$) and the distance from the edge to the interior of forest were detected. The most common species showed a wide distribution, but its abundance was significantly predicted ($P < 0.05$) by the number of tree stems, based on the results of a General Linear Model. Same analysis found a significant three way interaction ($P<0.05$) between the number of tree stems, canopy height and number of bamboo clumps and the abundance of the most common species.

Key words: abundance, edge effect, fragmentation, pteridophytes

THE INFLUENCE OF ADJACENT NON-FOREST ENVIRONMENT on forest structure and species composition at created edges is now widely recognised. Negative consequences of edge influence have been widely studied and proven for many taxonomic groups (Harper *et al.* 2005, Laurance & Bierregaard 1997).

Ailaoshan is a mountainous area located in the Yunnan province of the People's Republic of China. Ailao Mountains Natural Reserve, which was established in 1981 covers an area of 504 sq. km (Xu & Jiang 1988). The reserve harbours several vegetation types, but subtropical evergreen broad-leaved forests are identified as the major forest type (Qiu 1998). In 1956 in a valley of the Ailaoshan Mountains, a large irrigation tank was established creating an outsized gap. An edge between the forest and open grassland which surrounded lake has been created influencing the microhabitats of the forest along the forest edge.

Ailaoshan Reserve provides an excellent environment for the growth of pteridophytes. However, ferns are a group highly sensitive to environmental changes. Hence, this study was carried out to investigate the responses of the fern diversity and composition of the reserve to the increased edge environment.

We hypothesised that the fern species diversity and composition in the Ailaoshan Reserve changes with the distance from the edge to the interior of the forest.

METHODS

A survey of ferns was carried out for three days from 18 September to 20 September 2007. Nine transects were set from the forest edge to the interior of the forest. Transect lines ran perpendicular to the edge line. All transects were established in an approximately 1.5 sq. km area surrounding the Ailaoshan Forest Ecosystem Research Center. A total of seven sampling plots, each 2m x 2m, were established along each transect. Distances from the edge to each of the seven plots were 0, 5, 10, 20, 40, 80 and 160 m respectively. The edge of the forest was determined as the location of the first tree which was taller than 3m from the grassland. The first sampling plot (Distance = 0 m) of each transect was established just after the first tree on the edge without including the tree.

All the fern species were identified to morpho-species in the field and specimens were collected to make herbarium sheets for later identification using the herbarium collection at XTBG. The number of fern fronds on the ground and up to 2m from the ground on tree stems in each plot was counted. Other parameters recorded were light intensity, slope, canopy cover, understorey cover, ground flora cover, and numbers of saplings, trees, lianas, and bamboo stems in each plot. Light intensity was measured using a lux meter at the middle of the sampling plot. Slope, canopy cover, understorey and ground cover were estimated by the same person in all the plots.

Statistical analyses were done using software R 2.5.1. Pearson's correlation was used to investigate the relationship between the distance from the edge and species richness. The same analysis was performed to find the correlation between the distance from edge and species diversity (Shanon-Weiner diversity index) of ferns. To identify factors that affected the abundance of two most common species, General Linear Models (GLM) with a Poisson distribution of the error term was used. Detrended Correspondence Analysis (DCA) was also used to identify the environmental factors important for the change of fern species composition.

RESULTS

A total of 18 fern species were recorded in 62 sampling plots. The most common species was recorded in 30 of 62 plots and at all distances from the edge. The second most common species occurred in 23 plots. Three other species were recorded in more than ten plots. Other species were relatively uncommon and were observed only in few of the plots. Three species were recorded only once and only one frond was detected in each respective plot on all occasions.

A significant correlation between fern species richness and the distance from the edge was detected (R= 0.32, P< 0.05). Mean number of species per plot changed from minimum of 1.1 species on the edge to maximum of 2.8 species in the interior. Fig. 1 shows the change of the fern species richness as the mean number of species per plot against the distance from edge. As with the mean number of species, mean Shannon-Weiner diversity index for respective plots varied from 0.08 to 0.74 and was significantly correlated with the distance from forest edge to the interior of the forest (R= 0.31, P< 0.05). Fig. 2 shows the change of the fern species diversity as the Shanon-Weiner index against the distance from edge to the interior.

A significant relationship ($P < 0.05$) was found between abundance of the most common species and the number of trees in the plot based on the General Linear Model. A significant three-way interaction (trees, canopy height, and bamboo: $P < 0.05$) was also retained in the most parsimonious model, although the independent effects were not returned. The most parsimonious model for the second most common species recorded returned only a two-way interaction effect of the number of bamboo stems in the plot and slope of the terrain.

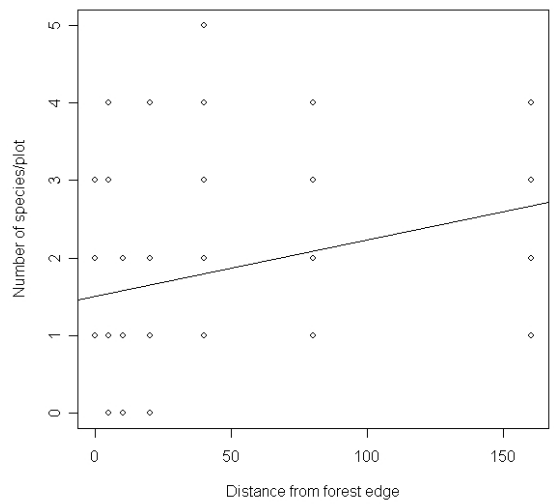

FIGURE 1. Change in the mean number of fern species with distance from edge at Ailaoshan Ecological Research Station.

Results of Detrended Correspondent Analysis (DCA) showed (Fig. 3) that the first component (DCA1) is significantly correlated with the canopy height (R= 0.32, P< 0.05), the number of bamboo clumps in the plot (R= 0.31, P< 0.05), and the distance from the forest edge (R= 0.28, P< 0.05). DCA2 was positively correlated with the canopy height (R= 0.29, P< 0.05), while negatively correlated with the number of lianas (R= -0.25, P= 0.06) and tree stems (R= -0.23, P= 0.07) in the plot though it was only slightly significant.

DISCUSSION

Based on the abundance of the species, only few fern species were found to be dominant in the forest. The most common species recorded during the survey, showed a generalised pattern with the distance from the edge. The significant relationship between abundance of this species and the number of trees in a plot can be explained by the general habitat of the species. This particular species is primarily an epiphytic fern species,

but also grows on the ground when established from fallen branches.

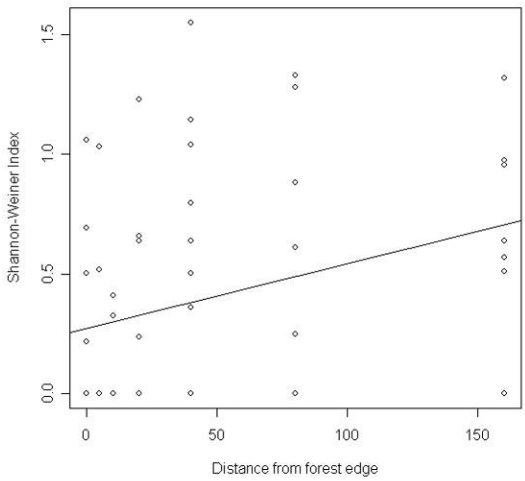

FIGURE 2. Change of Shannon-Weiner index along the edge to the interior of the forest

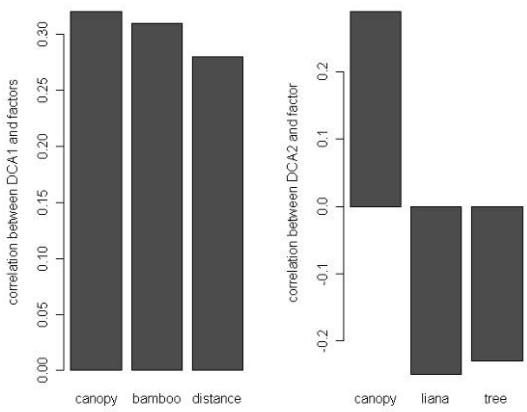

FIGURE 3. The correlation between DCA1 and DCA2 with environmental factors (only significant or nearly significant parameters are shown)

The second most abundant species recorded in the study showed a relationship with the number of bamboo stems and slope of the terrain. Since, this species is primarily a terrestrial pteridophyte, distribution related to the slope and available space on the ground can be expected. However, since no relationship with the any of these parameters independently was detected, making any firm conclusion is impossible. The terrain of the study area was highly heterogeneous; slope and aspect varied greatly. The understorey of the terrain was affected by bamboo growth. Hence, it is important to investigate the correlation among these factors.

The main hypothesis of this study was upheld. Fern species richness and diversity showed positive correlation with the increasing distance from the edge. These results agree with many other studies of fern species diversity and composition in relation to edge effects, from many parts of the world (Paciencia & Prado 2005).

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Variation in Dung Beetle Community across a Grassland to Forest Eco-tone

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ABSTRACT

With biodiversity loss and extinction rates at an all time peak, the need for fast and accurate methods for assessing habitat degradation is becoming a global necessity. Various indicator organisms have been used to assess ecological parameters in the past and more recently anthropogenic impacts on the environment. The Scarabaeine dung beetles, with life histories that are closely associated with mammalian dung, serve as excellent ecological indicators for assessing mammalian abundance. The Ailaoshan region of Yunnan is characterised by tropical montane rainforests, which host a diverse array of mammals. The present study aims to assess the variation in dung beetle diversity and abundance between the Ailaoshan forests and nearby grasslands. We found that among the ten morphospecies trapped, nine were habitat specialists and one a generalist. There was significantly higher biodiversity of dung beetles, as well as dung-feeding flies found in the natural (forest) habitat than in the disturbed (grassland) habitat. The mean body weight of dung beetles was also significantly higher in the forest.

Key words: Ailaoshan, disturbance, diversity and abundance, mammalian abundance, Scarabaeine, tropical montane rainforests

RAPID LOSS OF BIODIVERSITY is one of the major pressing issues around the globe. However, there remains a dearth of suitable biotic, as well as abiotic, indicators to assess biodiversity loss at an equally fast rate. The diversity and abundance of arthropods combined with well worked out life histories are ideal for answering some of the most complex questions in nature. Insects play a variety of key roles in every terrestrial ecosystem and at different trophic levels. Among the insects, the beetles (Order Coleoptera) have diversified the most and the myriad niches they occupy in the environment are evidence for the same.

Scarabaeine dung beetles with their wide global distribution, diversity, abundance, well understood ecological roles and relatively stable taxonomy serve as excellent focal taxa to assess anthropogenic disturbance on large mammal communities (Hanski 1991, Horgan 2005, Nichols *et al.* 2007). Dung beetles play an important role in dung decomposition, facilitating microbial action by breaking down, consuming and moving dung. Their life history is intricately associated with the availability of mammalian dung - a resource which has to be located within a specific habitat and once located has to be defended against other competitors like dung flies. Their diversity and abundance vary according to the availability of resources, which may vary according to habitat quality. Hence dung beetles are considered to be excellent indicator organisms for assessing the effect of disturbance on large mammal communities (Horgan 2005, Nichols *et al.* 2007), whose disappearance from a habitat would then reduce the dung beetle populations within that habitat.

Here we assess and compare turnover in the diversity and abundance of dung beetle communities between grasslands and tropical montane rainforests surrounding the Ailaoshan Field Station.

METHODS

STUDY AREA.— The study was conducted at Ailaoshan Forest Ecosystem Research Station (24º 32' N, 101º 01' E; 2450 m asl), which lies on the northern part of Ailaoshan Nature Reserve in Yunnan province, southwest China. The site is part of the Chinese Ecosystem Research Network (CERN). The annual precipitation is 1931 mm. Annual mean temperature is 11ºC and relative humidity is 83 percent. Under the influence of the southwestern monsoon, the area has

distinctive dry and wet seasons. The forest type is classified as tropical montane rainforest (Zhu 2006). The presence of an artificial lake created as a dam reservoir had led to the formation of several large patches of grasslands. The study was conducted in these two varied habitats.

DUNG BEETLE SURVEY.— We set up three line transects, each 270 m long, perpendicular to the forest edge. Ten pitfall traps (5 located in the forest interior and 5 in the grassland adjacent to the forest at 30m intervals) were set up for each transect. Each trap was baited with pig droppings enclosed in cotton gauze, attached to a stake and left hanging vertically above the rim of the trap. The baits were provided adequate rain protection using pieces of water-resistant plastic covering. The killing solution was made out of liquid soap and salt dissolved in water. To investigate the importance of attractant size, clusters of five traps within a circle of 1m diameter were set up. One cluster was set up in the grassland and one in the forest, for each transect at a perpendicular distance of 30m from the line. The GPS location as well as altitude of each trap was also noted.

The traps were monitored for four days. All of the baits were replaced on the second day. The contents of the traps were filtered through gauze and the collected specimens were preserved in vials containing 75 percent alcohol. The cluster traps were set up on the second day of the study and hence were active for a day less than the single traps. The collected dung beetles were classified by morphospecies. The other main group of insects collected from the traps was the flies (Order Diptera). All the collected flies were classified to the family level.

ANALYSIS.— Analysis of the dung beetle trapping data was performed using the statistics package R 2.5.1 (R Development Core Team 2007). The variation in abundance of the Scarabaeine and Dipteran communities in the two habitats were analysed through an Exact Binomial Test. A Spearman's Rank Test was used to examine species abundance between the two habitats. A community dissimilarity matrix was generated to compare the difference in dung beetle species composition between forest and grassland habitats to the variation within each of the habitats.

RESULTS

Of 44 dung beetles caught in our transects, we found ten distinct morphospecies. Four of these species were found only in the grassland and five were present only in the forest, while one of the species was found in the forest as well as at the forest edge of the grassland. The grassland habitat in Ailaoshan adjacent to the intact forest has a distinctive group of dung beetles (morphospecies 1- 4) with a mean individual biomass of 0.061 g, in contrast to 0.585 g for the species found in the forest (morphospecies 6-10). The distribution of beetles (Fig. 1) combines the total number of individuals found in the three transects. One can clearly see that there is a greater abundance of individuals in the forest than in the grassland. Thirty-one individuals were caught in the traps in the forest and only 13 in the grassland. Based on a null expectation of equal abundance in both habitats, the forest had significantly higher abundance of dung beetles (Exact binomial test, P=0.0096). The abundance of dung flies showed an even greater predominance in the forest habitat (Exact binomial test, P<0.0001) (Fig. 2). A Spearman's rank correlation showed a significantly higher species richness in the forest habitat compared to the grassland (P = 0.01259). A community dissimilarity indices matrix was generated and a randomisation test was conducted by permuting the index values 1000 times. The observed dung beetle community dissimilarity between grassland and forest habitat was found to be significantly larger than within each habitat (P = 0.008).

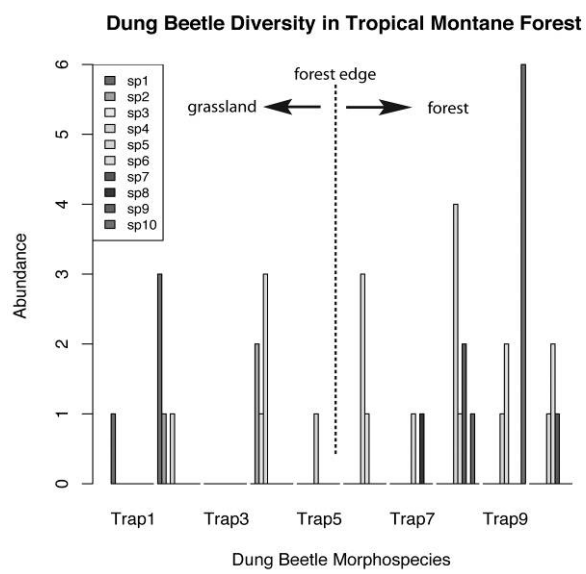

FIGURE 1. Abundance of Scarabaeine Dung Beetles in forest and grassland habitat at Ailaoshan.

DISCUSSION

The natural habitat of Ailaoshan is classified as upper montane forest, and the grassland at the study site can be considered disturbed habitat. The forests are composed of varied mammal communities, ranging from carnivores, such as leopards and viverrids, omnivores such as bears and wild pigs, herbivores such

as sambar and barking deer, and smaller mammals such as shrews, squirrels and mice. Most forest mammals may be inhibited from venturing out on the grasslands due to human disturbances and because of greater exposure to predators in the open grasslands. The mammalian community may contribute to a greater quantity of dung in the forest than in the grassland ecosystem. We expect the pattern we observe in the diversity and abundance of dung beetles between the two habitat types to be primarily linked to the distribution of mammals, but we have not conducted a survey to verify this conjecture. It is likely that more mammals are present in the forest and that most do not venture out into the grasslands, but it is not clear how strong the correlation corresponds to dung beetle abundance. The results however, are very much correlated with the biodiversity of dung feeding flies. As described in the results, there is a significant loss in fly diversity in the degraded habitat. This can probably be explained by the smaller habitat range of the flies. It is unlikely that the flies will venture much outside their normal habitat - the forest. Dung beetles are larger and fly larger distances and can thus probably handle a greater level of disturbance and change of habitat. The flies, however, seem even more sensitive to this change. Yet despite this sensitivity, flies may not be the ideal indicator due to the large number of species and difficulties in identification. Collecting dung beetles is easy, cheap, effective, and does not require a high degree of taxonomic knowledge.

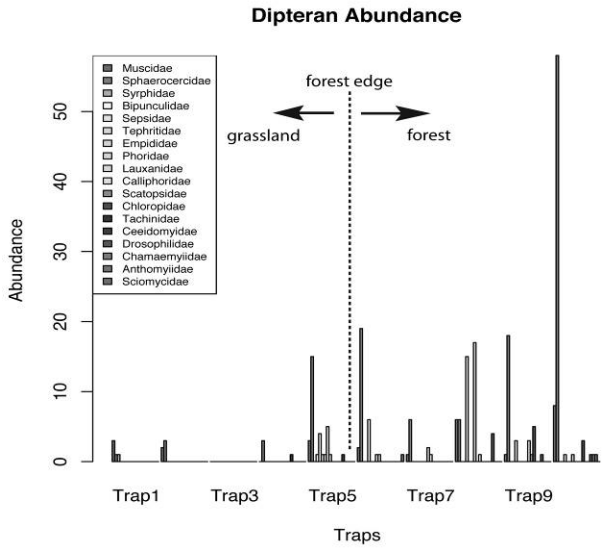

FIGURE 2. Abundance of Diptera in forest and grassland habitat at Ailaoshan.

It has been shown that dung beetles are highly sensitive to environmental disturbances and that larger species, which are more efficient in dung removal, are more extinction prone (Larsen *et al.* 2005). Although limited by trapping time, our data confirmed this trend: the largest among the beetles, morphospecies 8, was trapped only once and was found in the forest habitat. In the light of our findings, we conclude that dung beetle diversity and abundance appear to be closely associated with habitat type and quality. The results confirm the potential of dung beetles for being an indicator taxon for ecosystem and mammalian community assessment. On a broader scale, the pattern seen here also indicates that it may be critical to target the requirements of the most sensitive species in order to maintain ecosystem integrity.

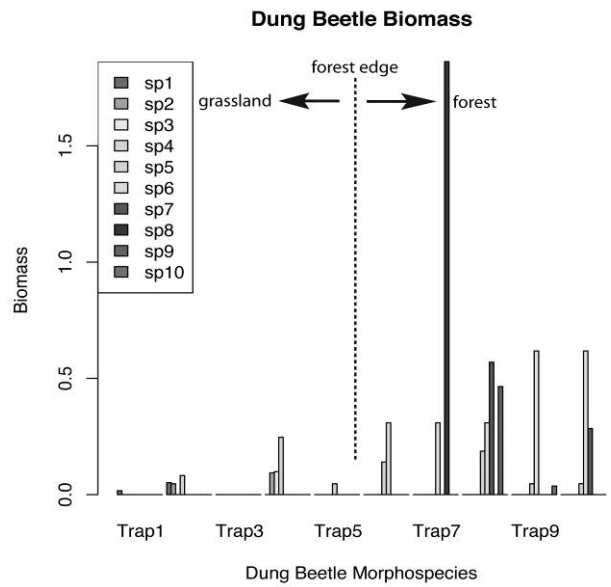

FIGURE 3. Biomass of Scarabaeine Dung Beetles in forest and grassland habitat at Ailaoshan.

Measuring dung beetle abundance will not in itself provide information on habitat quality, but the dynamics of dung beetle diversity over time can provide information on the flux of abundance of the mammalian population. We recommend conservation groups and scientific biodiversity and ecosystems groups to integrate regular monitoring of the dung beetle community as a cheap and simple means to test for mammalian abundance in threatened ecosystems.

ACKNOWLEDGEMENTS

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Aquatic Invertebrate Species Composition in Different Stream Microhabitats in a Montane Forest in South China

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ABSTRACT

Freshwater courses maintain a large number of aquatic invertebrates, such as insects, worms, crustaceans, and shellfish. In this study, we compared two habitats, forest and grassland, and two microhabitats, moving water and pools, within streams. Samples were collected using an aquatic net and sorted to morpho-species. Six streams with ten sampling points (five pools and five riffles) were surveyed. Using analysis of similarity (ANOSIM in R) we found a significant difference in species composition among habitats, although variance within habitats was high. However, we failed to detect any significant differences among microhabitats, based on a rapid survey. Most species were caught too infrequently to contribute meaningful information on habitat preferences. Discriminant correspondence analysis on streams showed that stream number 1 was distinct from others in terms of species composition.

Key words: Ailaoshan, habitat, moving water, pools

AQUATIC INVERTEBRATES CAN BE FOUND in any aquatic habitat from small temporal pools to streams, lakes, and rivers. Different species use different parts of the habitat to varying degrees. Aquatic invertebrates can live in extreme habitats such as polluted or saline waters (Dudgeon 2000). As a result of the diversity of aquatic invertebrates, they are often used as an indicator for monitoring water quality and different species have different tolerances to a variety of water pollutants.

Some aquatic invertebrates are intolerant of pollution and can only be found in pure water or in specific habitats such as running water (Malmqvist 2002). Usually when the water becomes polluted these organisms will be the first group to disappear.

Ailaoshan tropical montane broadleaf forest is located in the high lands of Yunnan, (>1,600 m asl, elevation) and has a unique geographical setting and vegetation community that includes forested habitat and grassland habitat. We postulated that species or groups of aquatic invertebrates would change according to stream characteristics in different habitats or microhabitats within streams.

The objective of this study was to investigate the composition of aquatic invertebrates in two different habitats (forest and grassland) and two microhabitats within streams (pool and moving water). We hypothesised that a greater aquatic invertebrate diversity would be found in forested habitat and moving water.

METHODS

STUDY SITE.— This study was conducted in six streams at Ailaoshan in tropical montane evergreen broad leaf forest. To compare between two habitats, three forest streams and three grassland streams were selected. Each stream was classified into two microhabitats, "pool" and "moving water".

COLLECTION.— Along each stream, five pool stations and five moving water stations were sampled using an aquatic net for one minute. The width and depth of each sample station were measured. Samples were sorted at both the sampling station and at laboratory. All samples were identified to the Order and were grouped into morpho-species.

RESULTS

Six streams were surveyed in three days in Ailaoshan Mountain and 40 aquatic invertebrate morphospecies were recorded. Analysis of similarity (ANOSIM) was used with a Jaccard Dissimilarity index, to detect difference in ecological composition among habitats and microhabitats (Fig. 1 & Fig. 2). Variance in aquatic invertebrate composition between habitats was significant (Fig. 1), although variance within habitats especially forest was also large. However, between microhabitats pool (P) and moving water (M) within streams there was no significant difference in community composition (Fig. 2).

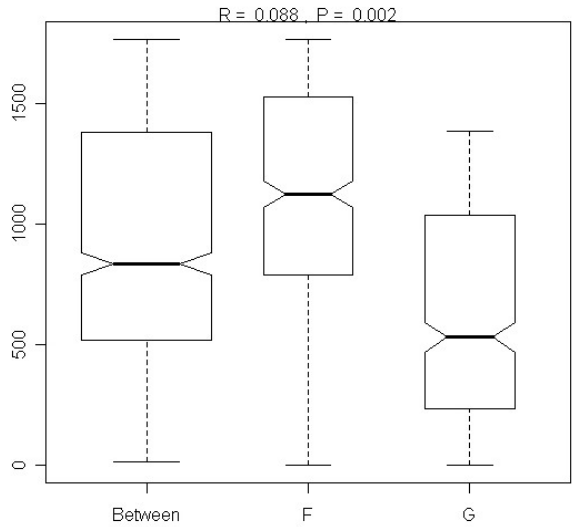

FIGURE 1. Boxplot of similarities of aquatic invertebrate community composition between streams in forested habitat and streams in grassland habitat at Ailaoshan

A Discriminant Correspondence Analysis on streams showed that a wide variation in stream composition largely masked the between habitat differences in composition (Fig. 3). Stream number 1 was distinct from others in terms of species composition

DISCUSSION

We observed substantial differences in faunal composition in headwater streams of Ailaoshan. Based on our analysis of similarity the compositional difference between habitats was significantly greater than within habitats (Fig. 1). However, the variation in composition between microhabitats was not significantly greater than variance within microhabitats (Fig. 2). Streams in Ailaoshan have had minimal disturbance, and may therefore support similar species of aquatic invertebrates, although grassland patches represent an anthropogenic habitat. Most of our species were caught too infrequently to contribute meaningful information on species habitat preferences.

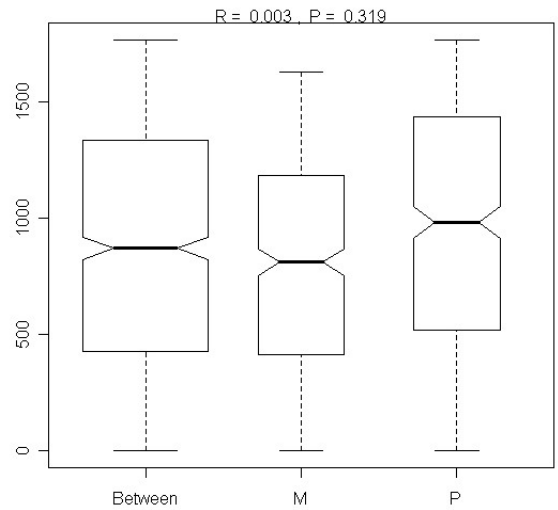

FIGURE 2. Boxplot of similarities of aquatic invertebrate community composition between microhabiat moving water (M) and pool (P) in both forest habitat and grassland habitat

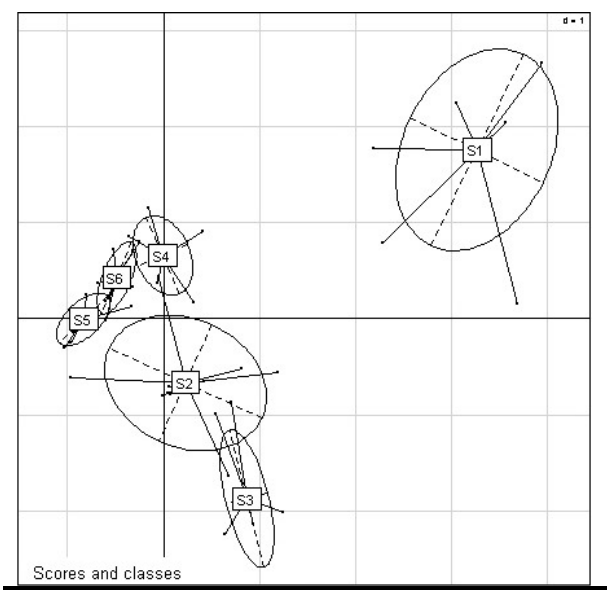

FIGURE 3. Discriminant correspondence analysis of species composition in six streams. Streams S1, S3 and S4 were in forest habitat, and streams S2, S5, and S6 were in grassland.

Some of the aquatic invertebrates can be used as water quality indicators. According to Compin and Cereghino (2003), insect orders such as Ephemeroptera and Diptera constitute indicators of good water quality. We did not look at the presence and absence of indicator species in our study, but only species composition. However, this would be an interesting area for further investigation.

ACKNOWLEDGEMENTS

We wish to thank CTFS-AA 2007, especially Dr. Rhett Harrisson for guidance, John Harting for help on similarity index using "R", Ailaoshan research station staff and other participants in this course - a "giant thanks" for you all.

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Factors Affecting Seedling Abundance of Four Tree Species in a Subtropical Mossy Forest in Ailaoshan, Southern China.

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ABSTRACT

In a short study carried out in the Ailaoshan mossy forests of Yunnan Province, China, seedlings of four dominant tree species - *Lithocarpus jingdongensis*, *Castanopsis watti, Litsea* sp., and *Schima wallichii* were inventoried using line transect and quadrat sampling. We investigated the following questions: Does the high bamboo density inhibit seedling abundance in the four species? Do some seedlings have a preference for light gaps and edges in the forest? Are locations where seedlings establish influenced by the extent of slope? Low bamboo density played a role in the seedling survival in *Lithocarpus* sp. and *Litsea* sp. Light and slope seemed to have an interactive effect on *Schima* sp.

Key words: bamboo density, *Castanopsis watti*, dominant trees, light gaps, *Lithocarpus jingdongensis, Litsea* sp, *Schima wallichii*

THE SUB-TROPICAL MONTANE FORESTS of southern China are dominated by plant families Theaceae, Fagaceae, Lauraceae and Magnoliaceae. A characteristic feature of the mossy forests in this region is the presence of a single canopy layer and a bamboo rich understorey. We investigated the seedling densities of the dominant tree species in a mossy forest of Ailaoshan Nature Reserve – *Lithocarpus jingdongensis*, *Castanopsis watti* (Fagaceae), *Litsea* sp. (Lauraceae) and *Schima wallichii* (Theaceae). Our hypothesis was that high bamboo densities in the understorey would inhibit the establishment of seedlings of the dominant trees. We also expected some seedlings such as the Fagaceae and Theaceae members to have a preference for light gaps or edges. The availability of light is a fundamental determinant of tree seedling growth and survival in forests (Pearson *et al.* 2003). We also asked if a given species' seedling had a preference for flat, medium or steep slopes.

METHODS

STUDY SITE.— The study site is the mossy forest of Ailaoshan (24˚32' 384" N, 101˚01'632" E) at an elevation of 2400 m and the study lasted 4 days. Fifty two quadrats of 5 x 5 m were laid at intervals of 30 m along 5 transects in the mossy forest. We wished to analyse the distribution of the seedlings of the four species in response to three factors; slope, amount of light on the forest floor, and the density of bamboo in the quadrat.

Seedlings of the four species were counted, as were the bamboos in the quadrat. We assigned slope as a categorical variable measured qualitatively with three levels; Flat, Gentle and Steep. For light measurements, we used an assessment of canopy openness. The canopy was photographed from the forest floor with a wide-angle lens. The image pixels were analysed and converted to amount of white light using R 2.5.1 (pixmap Package).

Since our data comprised of counts of seedlings, we fitted a generalised linear model in R 2.5.1 with a poisson or quasipoisson distribution of the error term, to identify the most important factor(s) influencing individual seedling density of each species. We also generated plots and barplots to explain the patterns of seedling abundance in relation to the factors that emerged as most significant.

RESULTS

LITHOCARPUS SPECIES.— The minimal model we obtained with a quasipoisson distribution of the error term did not reflect a significant individual or interactive effect for any of the factors. When plotted against bamboo density, *Lithocarpus jingdongensis* seedling abundance apparently showed a slight preference for low bamboo densities.

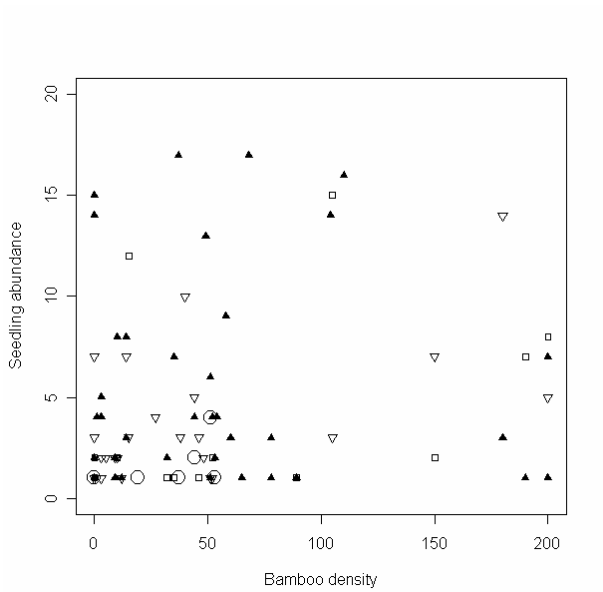

FIGURE 1. Seedling abundance of *Lithocarpus* sp. (▽), *Castanopsis* sp. (o), *Litsea* sp. (▲) and *Schima* sp. (□) plotted against bamboo density.

CASTANOPSIS SPECIES.— We recorded a very low seedling count of *Castanopsis watti* - six in 52 quadrats. The minimal model with a quasipoisson distribution did not reveal any significant individual or interactive effects

SCHIMA SPECIES.— We simplified a linear model with a quasipoisson distribution of the error term from the maximal model including bamboo density, light, and slope (Table 1). Only slope was retained in the minimal model. *Schima wallichii* seedling density was highest in flat quadrats (p=0.0035). A barplot also showed a slight preference of *Schima* seedlings for low bamboo density quadrats (Fig. 1).

LITSEA SPECIES.— The data was fitted to a generalised linear model with a quasipoisson distribution of the error term, and the most parsimonious model revealed a highly significant effect of light (p=5.22 e-07), slope (p= 4.34 e-05) and the two way interaction between slope and light (p = 9.39 e -05) (Table 2). Most *Litsea* seedlings were recorded in medium slopes (Fig. 3) and a moderate light intensity (Fig. 2).

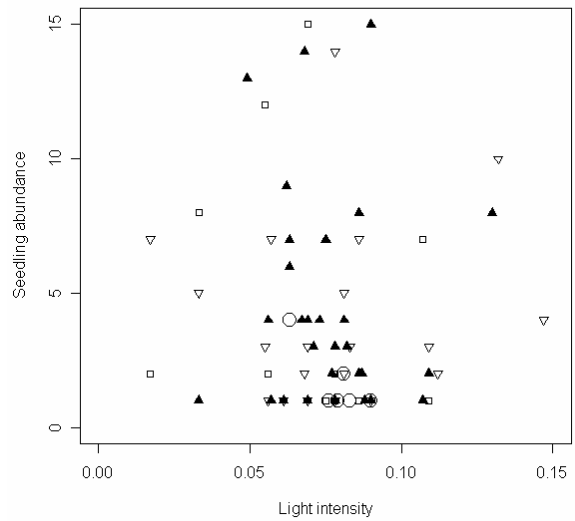

FIGURE 2. Seedling abundance of *Lithocarpus* sp. (▽), *Castanopsis* sp. (o), *Litsea* sp. (*Litsea* sp. (▲)) and *Schima* sp. (□) plotted against light intensity

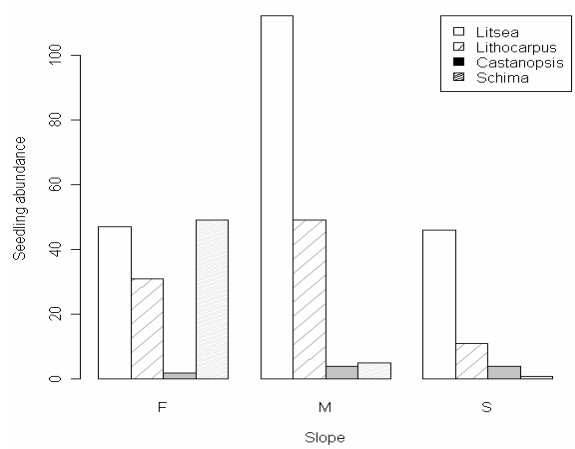

FIGURE 3. Barplot of number of *Lithocarpus* sp., *Castanopsis* sp., *Litsea* sp. and *Schima* sp. seedlings plotted against slope (F=Flat, M=Medium, S=Steep)

DISCUSSION

The understorey in the mossy forests of Ailaoshan is bamboo dominated; this and the fact that there was an extremely low number of Fagacaeae seedlings provoked us to hypothesise that bamboo density has a negative impact on seedling survival of canopy tree

species. A study in western China revealed that more seedlings established in plots with low bamboo densities (Taylor *et al.* 2004). Several tropical forest tree saplings are known to do better in canopy gaps and edges with higher light intensity. In light gaps, the probability of seedling survival was enhanced for all the nine species studied in a lowland forest in Barro Colorado Island, Panama (Augspurger 1984). Our study also suggests that seedlings of *Litsea* have a preference for light gaps above 60 percent. Further studies on dispersal distances and monitoring long term seedling survival studies would be required to establish mode of recruitment in this species.

The current study provides no evidence that seedlings of any of the species have a preference for low bamboo density quadrats. For *Lithocarpus* and *Castanopsis watti* the low number of seedlings recorded meant the power of our models were very low. It was extraordinary how few seedlings of these important canopy species were recorded, and suggests the forests at Ailaoshan may have unusual recruitment dynamics. While *Schima wallichii* was most recorded in gently sloped quadrats with no apparent preference for light, *Litsea* showed a preference for medium slopes and moderate light intensities.

It should be remembered that *Lithocarpus* and *Castanopsis*, as do many species of Fagaceae, display general flowering and mast seeding. Tropical trees have unique mechanisms and strategies to escape predation and reproductive successfully. 'Low' fruit set or 'low' seedling survival needs to be seen in the perspective of a long lived tree. Detailed, long term studies are the appropriate approach to examine mechanisms that play a role in seedling survival in the forest community at Ailaoshan.

TABLE 1**.** *The minimal generalised linear model (with a quasipoisson distribution) from the formula called for Schima seedling abundance at Ailaoshan ~ slope * light * bamboo density.*

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	3.5000	0.6941	5.043	6.68e-06 ***
Slope M	-3.3077	0.8609	-3.842	0.000351 ***
Slope S	-3.4167	1.0216	-3.344	0.001588 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.597 on 49 degrees of freedom
Multiple R-Squared: 0.2571, Adjusted R-squared: 0.2268
F-statistic: 8.48 on 2 and 49 DF, p-value: 0.000688

TABLE 2. *The minimal generalised linear model (with a quasipoisson distribution) from the formula called for Litsea seedling abundance at Ailaoshan ~ slope * light * bamboo density.*

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	3.5254	0.4115	8.567	< 2e-16 ***
slope.L	3.4318	0.8394	4.089	4.34e-05***
slope.Q	0.9101	0.5581	1.631	0.1030
Light	-33.0361	6.5835	-5.018	5.22e-07***
slope.L:Light	-53.1836	13.6167	-3.906	9.39e-05***
slope.Q:Light	-20.6091	8.6392	-2.386	0.0171*

Signif. codes 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Null deviance: 270.97 on 45 degrees of freedom, Residual deviance: 229.12 on 40 degrees of freedom; AIC: 343.53

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Distribution of Non-Bryophyte Epiphytes in Relation to Mosses in Ailao Montane Forest, Yunnan, China

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ABSTRACT

The relationship between moss thickness and the diversity and abundance of non-bryophyte epiphytes in the montane moist evergreen broad-leaved forest at Xujiaba, in the Ailao Mountain of Yunnan was studied. Our study focused on determining the different environmental factors including diameter-at-breast height, elevation, moss thickness, and moss water content that may be influencing the growth of non-bryophyte epiphytes on mosses. *Lepisorus scolopendium, Polypodium amoemum, Asplenium planicaule* and *Elatostema* sp. were recorded and found growing on moss with thicknesses of 0.1 to 0.8 cm. *Polypodium amoemum* had the highest number of individuals recorded at 237. With 66 individuals, *Elatostema* sp. was the rarest of the non-bryophyte epiphyte recorded. A general linear model revealed that moss thickness was an important factor affecting the abundance of non-bryophyte epiphytes.

Key words: abundance, diversity, montane moist evergreen broad-leaved forest, moss thickness

BRYOPHYTA (MOSSES) GROW IN MOIST ENVIRONMENTS, especially on the surface of rocks, soil, bark and branches. Epiphytic Bryophyta are one of the dominant plant groups in subtropical moist evergreen broadleaf forest. They gather dust and water from air to form a thin soil on the bark. Bryophyta can hold soil tightly and, because they generally grow densely, they tend to form a suitable environment for the growth of other non-moss epiphytes.

Non-moss epiphytes are plants that grow above the ground surface, using other plants or objects for support. They are not rooted in the soil nor are they parasitic (*i.e.* they do not directly harm the host plant). By growing on other plants, non-moss epiphytes can reach positions to obtain maximum light. Epiphytes are particularly common in some groups of plants, such as ferns, Bromeliaceae and Orchidaceae.

Most epiphytic seed plants and ferns are found in tropical and subtropical rainforests because they require high humidity. Areas rich in epiphytes are the montane rainforests at altitudes of over 1500 m (Anon 2007). The trees provide many habitats with different temperature, exposure and illumination conditions.

Water is especially important in plant growth as it influences stomata opening and closing, which in turn affects the photosynthetic rate. Silvola (1990) found that the decrease in photosynthesis is very steep towards lower water contents and less steep towards higher water contents. It was found that water content was negatively correlated with air temperature but positively correlated with the relative humidity of the air (Juhász *et al.* 2005).

The Ailao montane forest is classified as subtropical moist evergreen broadleaf forest. Fagaceae family is abundant, with *Lithocarpus* and *Castanopsis* being the dominant genera. Preliminary observations revealed that some trees had epiphytes growing with mosses, while some trees did not have epiphytes although mosses were present. Previous studies in Ailao Mountain have shown that there was no significance relationship between epiphytic species and host tree species (Xu & Liu 2005). Therefore, our study focused on the different environmental factors, such as diameter-at-breast height (dbh), elevation, moss thickness, and moss water content that might influence the growth of non-bryophyte epiphytes on moss covered trunks. Our hypothesis was that the abundance of non-bryophyte epiphytes should increase as the abundance and water content of mosses increase.

METHODS

The study site was located at 24°32' N, 101°01'E with an elevation of 2491 m above sea level in an evergreen broadleaf forest in Ailao Mountain, Yunnan. Average annual temperature is 11°C and annual rainfall volume is 1800 mm.

Quadrates were established within an elevation range of 2371 m to 2425 m. Eight 30 m transect lines were established with a meter tape. Transect lines were established at 20 m intervals. Two 10 x 10 m quadrates were set on each 30 m transect with an interval of 10 m. GPS readings were recorded at each quadrate. Diameter-at-breast height (dbh) of trees more than 5 cm was measured using a diameter tape and trees with or without non-bryophyte epiphytes were recorded. Moss thickness was measured on trees that had more than fifty percent of their bark covered with moss. The number of non-bryophyte epiphytes on trees to a height of 2 m was counted and the species identified.

Seven moss samples from trees with and without non-bryophyte epiphytes were collected. Fresh weight of each sample was recorded. They were then packed into paper bags and dried in an oven at 70 °C for 24 hours. The dry weight was recorded.

Water content (%) = (Fresh weight – Dry weight)/Fresh weight x 100

These two sets were analysed with Wilcoxon Test. Data were analysed with general linear model (GLM) using R 2.5.1 (R Development Core Team, 2007).

RESULTS

SIZE CLASS OF TREES.— There were 390 trees sampled in a total of 1600 m^2. The size class which had the highest number of trees was at 20 to 30 cm dbh with 98 trees (Fig. 1). Tree density was 244 individuals per hectare.

ABUNDANCE OF NON-BRYOPHYTE EPIPHYTES.— Moss thickness was found to be a significant factor for all species except *Elatostema* sp (Table 1). For *Polypodium amoemum* and *A. planicaule* other factors also had significance effects. For *Elatostema* sp. only the interactive effect of elevation and dbh was significant.

Lepisorus scolopendium had the highest number when moss thickness was 0.7 cm, followed by *P. amoemum* at 0.3 cm moss thickness, *A. planicaule* at 0.3 cm and *Elatostema* sp. at 0.4 cm. The general linear models indicated that the effect of moss thickness was more important for *L. scolopendium* and *P. amoemum* as compared to *A. planicaule* and *Elatostema* sp. (Fig. 2).

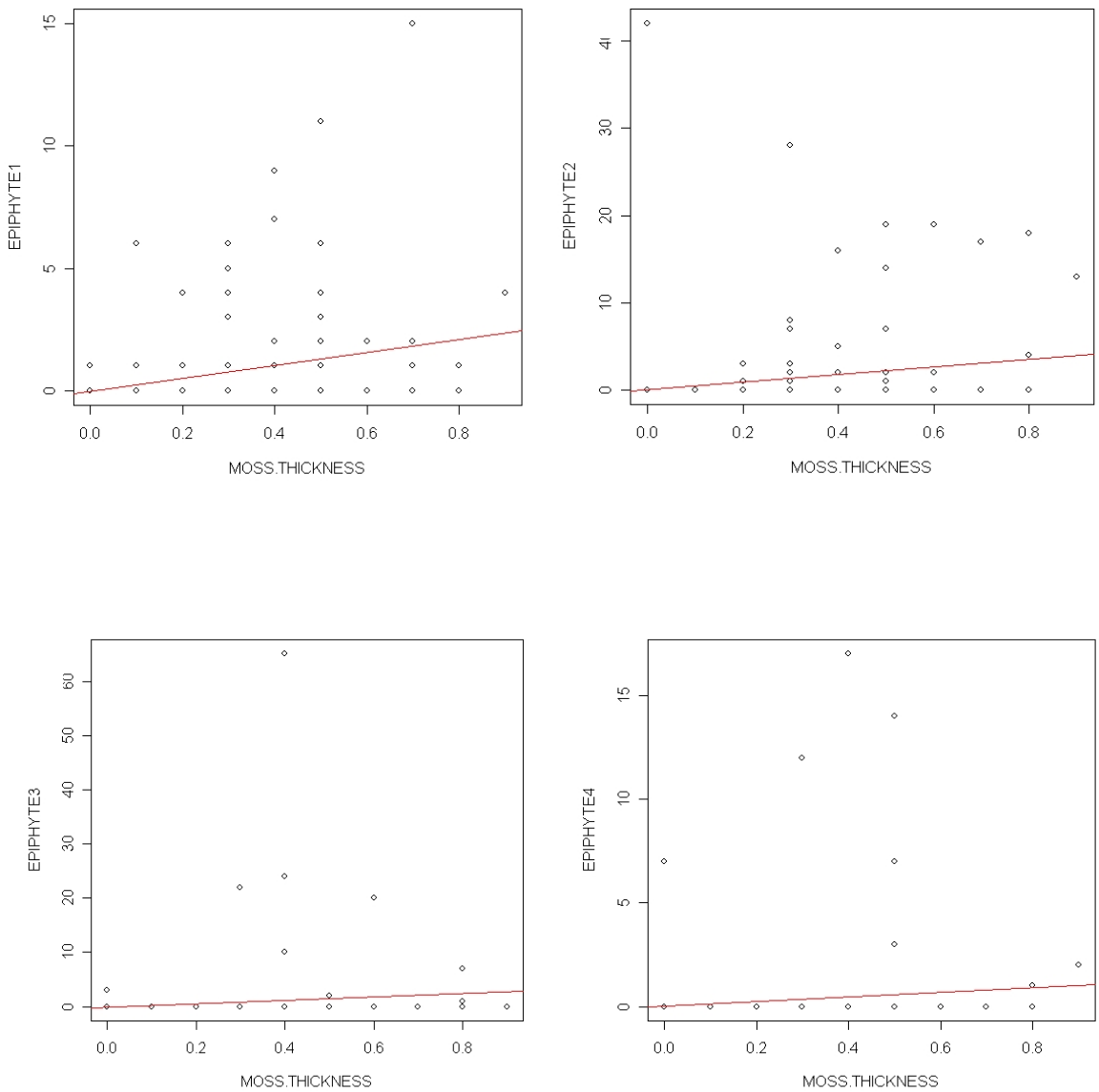
Lepisorus scolopendium had 138 individuals growing on mosses, *P. amoemum* with 237 individuals and 161 and 66 individuals of *A. planicaule* and *Elatostema* sp. respectively.

TABLE 1. *General linear models with abundance of different epiphyte species as the dependent variable and moss thickness, dbh, and elevation as independent variables in Ailao Mountain*

	Estimate	Std. Error	t value Pr(>|t|)
Lepisorus scolopendium			
Moss.Thickness	5.149730	0.641316	8.030 1.18e-14 ***
Polypodium amoemum			
Moss.Thickness	3.591e+00	1.540e+00	2.331 0.02025 *
Elevation:Dbh	5.114e-06	2.449e-06	2.089 0.03739 *
Asplenium planicaul			
Moss.Thickness	-1.088e+03	2.781e+02	-3.912 0.000108 ***
Moss.Thickness:Elevation	4.556e-01	1.160e-01	3.928 0.000102 ***
Moss.Thickness:Dbh	7.506e+00	1.904e+00	3.943 9.58e-05 ***
Moss.Thickness:Elevation:Dbh	3.126e-03	7.943e-04	-3.935 9.87e-05 ***
***Elatostema* sp.**			
Elevation:Dbh	1.145e-05	1.862e-06	6.150 1.93e-09 ***

Signif. Codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(a) **(b)**



(c) **(d)**

FIGURE 1. Number of epiphytes in relation with moss thickness in Ailao Mountain, Yunnan, China: (a) *L. Scolopendiumin,* (b) *P. Amoemum*, (c) *A. Planicaule*, and (d) *Elatostema* sp

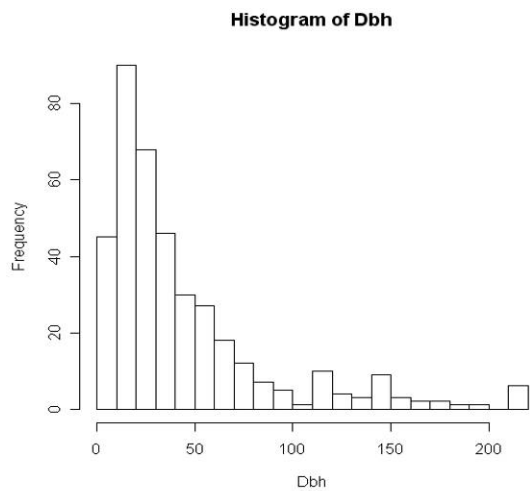


FIGURE 2. Size class distribution of trees of more than 5 cm dbh in Ailao Mountain, Yunnan, China

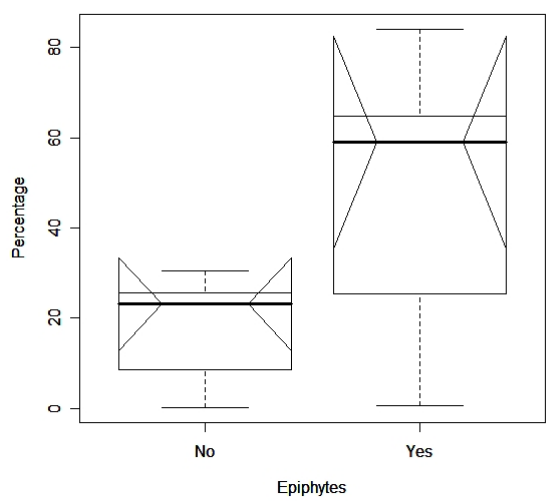


FIGURE 3. Water content of mosses in Ailao Mountain, Yunnan, China with non-bryophyte epiphytes (Yes) growing among them and mosses with no non-bryophyte epiphytes (No) growing among them.

WATER CONTENT.— Samples of mosses with and without non-bryophyte epiphytes showed that mosses with non-bryophyte epiphytes had a higher water content compared to mosses without non-bryophyte epiphytes (Fig. 3) (Wilcoxon Rank Sum test P = 0.02960).

DISCUSSION

Studies by Zotz and Vollarath (2003) and Moran *et al*. (2003) found that dbh and elevation were not important factors in determining the distribution of epiphytic fern species. However, height and light availability may be important factors affecting the abundance and distribution of non-bryophyte epiphytes, as higher numbers were observed on the upper parts of tree trunks.

In our study, three of four non-bryophyte species found growing on moss were fern species, indicating that moss may be an important factor affecting the abundance and distribution of fern species. Moss thickness was the most consistent factor influencing the abundance and distribution of *L. scolopendium, P. amoemum* and *A. planicaule.* However, the interactive effect of dbh and elevation was significant for *P. amoemum* and *Elatostema* sp. While the two-way interactive effects of elevation and dbh with moss thickness, and the three-way interactive effect were significant for *A. planicaule*.

A study by Atwood and Krannitz (2000) demonstrated that soil beneath thick moss did not receive light rain shower but soils beneath lichens did. This shows that thick moss has the capability of absorbing water. They further explained that water loss was reduced if the area surrounding microbiotic crust contained thick moss (Atwood & Krannitz 2000). The water holding capacity of epiphytes in a semi-humid evergreen broad-leaved forest in Karst Region was high, reaching 5.5 to 9.7 times of its dry material (Xu *et al*. 2006). Therefore, although non-bryophyte epiphytes on tree trunk do not depend on this capability of mosses, they may gain some benefit from growing with them.

Lepisorus scolopendium and *P. amoemum* were common species in this study. All non-bryophyte epiphytes were found growing on moss with thickness of 0.1 cm to 0.8 cm. Moss thickness had a significant effect on three out of four non-bryophyte epiphyte species distributions and abundances, but the strength of the response differed among the non-bryophyte epiphyte species.

ACKNOWLEDGEMENTS

We would like to extend our appreciation to the field staff of Ailao Ecological Field Station, especially to Yang Guoping, Yang Xiaodong of Xishuangbanna Tropical Botanical Garden and Rhett D. Harrison of CTFS-AA, without whom this project would not have been completed.

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The effect of distance from edge on seed predation in two Fagaceae fruits (*Lithocarpus* and *Castanopsis*)

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ABSTRACT

Twenty fruiting trees (L*ithocarpus* and *Castanopsis*) and twenty-four 1 x 1 m experimental plots were surveyed in order to test how density, distance from forest edge, and fruit traits related to predation rate. We found a weak correlation between predation rate and density and distance in the natural observations. The predation rate between *Lithocarpus* and *Castanopsis* was similar in natural conditions, but there was a significantly higher predation rate on *Lithocarpus* fruit in the experimental plots. Based on significant value in the minimal model, gap, distance from edge, density and adjacent fruiting tree were consequently considered, while no suitable model in experimental condition was suggested.

Key words: density, experiment, interior forest, predation rate

FAGACEAE IS ONE OF THE MOST ABUNDANT in ailao mountain, and *Lithocarpus* and *Castanopsis* are the dominance genera. Many organisms depend on the seeds of these plants for food. Sometimes predated fruits are dispersed by the predators and can germinate. However, fruits that are severely damage, cannot germinate. predation rate at forest edge is presumably higher than those in intact forest (Yahner 1988, Lopez-Barrera *et al.* 2005).

However, different result in predation pattern is possible by various factors, e.g. behavior of predator (Zhishu and Zhibin 2006) and microhabitat (Yahner 1988). Fruit density is one common factor that relate to predation rate (Janzen 1970). High density can lead to high predation rate (Janzen 1970). Concept of predator satiation is then derived and explained by huge amount of available fruit in masting year in order increase survival rate of seed (Janzen 1970, Sun, Chen *et al.* 2007). Fruit traits are good evidences of co-evolution between fruit and predator. In this study, we wished to examine three hypotheses that relate to the predation of these oak groups. (i) Highest predation rate will occur near forest edge and gradually reduce as the distance from the edge increases. The lowest predation rate will occur in interior forest. (ii) According to density dependence concept, higher fruit density will result in higher predation rate, and lastly (iii) Smooth-shelled *Lithocarpus* fruits suffer higher predation rate than spiny *Castanopsis* fruits.

METHODS

STUDY SITE.— The study was carried out at Ailao Mountain subtropical montane forest, SiMao, Yunnan, China (24°32´ N, 101°01´ E), 2,450 msl. in elevation, in September 2007. There are two dominant genera (*Lithocarpus* and *Castanopsis*) belonging to the oak family in our study area.

Twenty four 1x1m quadrates were set in four 200 m line transects running from grassland through the forest edge into the interior forest. *Lithocarpus* or *Castanopsis* fruits were scattered in quadrates according to the following treatments; high density (20-30 fruits) and low density (10 fruits). All quadrates were checked at 24 hr and 4 days after setting up. We recorded number of fruit that had been destroyed, and the number of fruit that showed signed being eaten by investigating the teeth-marks or other marks on fruit shell.

We investigate predation rates under fruiting trees based on the ratio of predated fruit and whole falling fruit within 3 m radius circular plots. Ecological variables such as elevation, undergrowth, canopy gap

size, slope, and the presence of adjacent fruiting trees were noted down. Coordinates were collected in order to estimate distance from the forest.

Correlation between predation rate and distance from the forest edge and fruit density were examined and compared between experiment and natural observation. Surrounding parameters- rank of canopy continuity, under growth density, and slope, and the presence of adjacent tree were noted in field. Canopy continuity, undergrowth, and slope were noted in rank, from one (lowest) to three (highest). All parameters were considered in null predation model. Model selection was then based result from General Linear Model (GLM) function in by using R statistical program.

RESULTS

We collected 9064 fruits (3122 *Lithocarpus* and 5942 *Castanopsis*) from twenty different fruiting trees, ten for each genus. 2,442 out of 3,122 *Lithocarpus* fruits were predated (78.22%) where 3,543 out of 5,942 in Castanopsis (59.63%) in natural observation. In experimental treatments, based on pooled number from all treatments, *Lithocarpus* fruit suffered higher predation rate (57 predated fruits, 31.67%) than *Castanopsis* (34 predated fruits, 18.89%). However, as we aimed to test these predation rates with other factors, the summaries were statistically tested.

PREDATION RATE AS A FUNCTION OF DISTANCE FROM THE FOREST EDGE AND FRUIT DENSITY.— We found a weak correlation between predation rate and density, and distance from the edge in these natural observations (Fig. 1 & Table 1). Predation rate in *Lithocarpus* and *Castanopsis* was similar in natural conditions, but a significantly higher predation rate on *Lithocarpus* than on *Castanopsis* fruits was detected in the experimental plots (Table 1). We examined all the ecological variables around fruiting trees in a general linear model with predation rate as the dependent variable. However, we did not obtain any model that retained significant factors.

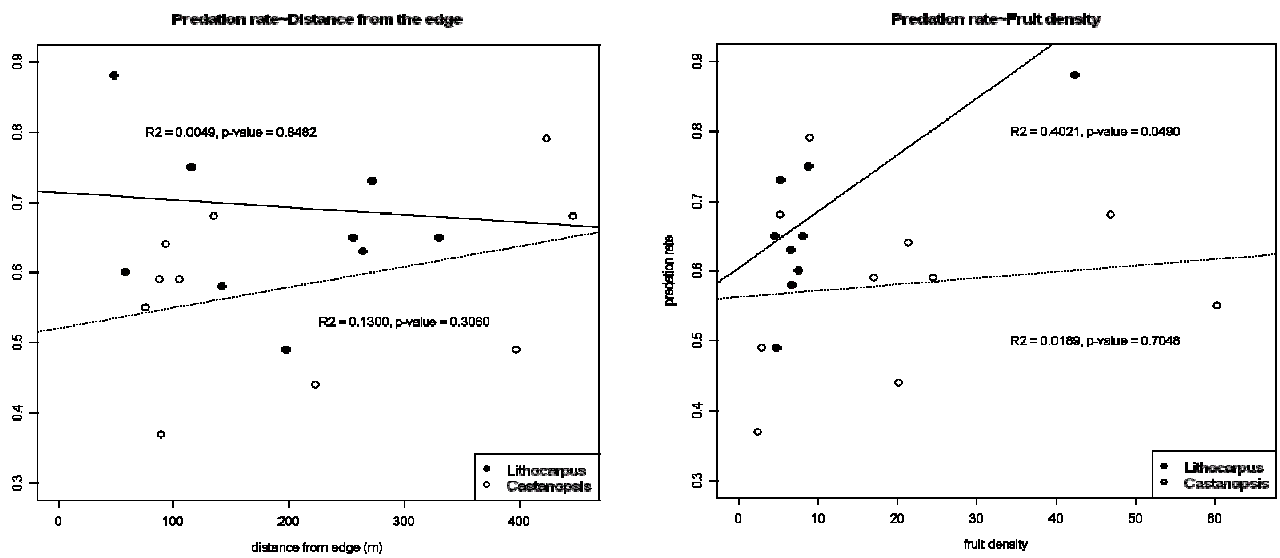

FIGURE 1. Correlation between predation rate and distance from the forest edge and fruit density in natural condition.

TABLE 1. *Predation models from natural observation and experiment*.

	Effects	df	t-value	p-value
Obsevation	density		-0.440	0.6656
	density*slope		-1.447	0.1661
Experiment	distance		1.741	0.0998
	distance*adj. tree		2.051	0.0560

DISCUSSION

Our results from both experiment and observation reveal that predation rate on both oak fruits are not significantly related to distance from the forest edge, it was not following our hypothesis. The plant phenology of particular trees causes variation in fruit density under the fruiting trees. Hence, our inability to detect any significant factors possibly was partially due to these limitations. However, one of our predictions was borne out. We argued that *Lithrocarpus* fruit should be preferred by predators because of their smooth fruit case. Although predation rate in natural conditions between two genera were similar, we detected a significant difference in our experiment plots. One treatment plot with *Lithocarpus* fruit was completely predated under a large fruiting *Castanopsis* tree within one day. Fruit trait can be one factor that makes predation rate on these oak fruits different, although we cannot conclude what specific fruit trait causes this difference.

This study was conducted under various constraints. Insufficient time led to a very small sample size. A lack of basic information on area, for example plant phenology and the distribution of fruiting trees, added to the difficulties of this study.

One possible reason that might explain the homogeneity of predation rates would be the guild, number, and distribution of seed predator species. Territorial species for example, might eat a constant number of fruits regardless of fruit density, species may locate fruits in a stochastic manner, and predator species may be wary of the forest edge; all of which would produce results contrary to our predictions. Unfortunately, no data are available on the seed predators in the study area.

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INDEPENDENT PROJECTS

The Macrofauna of Water-filled Tree Holes and Bamboo Stumps in XTBG

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ABSTRACT

Tree holes and bamboo stumps are phytotelmata openings or cavities in plants capable of holding water permanently or ephemeral. We investigated the macro-organisms of water-filled tree holes and bamboo stumps in Xishuangbanna Tropical Botanical Garden (XTBG) and correlated tree hole characteristics to the macrofaunal diversity. Ecological roles within these phytotelmata were identified. Results indicated that macrofauna diversity and abundance is not strongly influenced by the size of opening or volume of tree holes and bamboo stumps. The cluster analysis indicated differences in species composition between the two phytotelmata, suggesting that tree holes and bamboo stumps support distinct faunal communities.

Key words: abundance, community, diversity, phytotelmata, microcosm

A PHYTOTELMATA IS AN AQUATIC MICROCOSM which is formed by a plant (Srivastava *et al.* 2004). Phytotelmata are usually filled with a small volume of stagnant water and have low primary productivity, but there is spatial variation in amount of dissolved oxygen, the carbon dioxide concentration, and pH of phytotelmata (Laessle 1961). Tree holes are one kind of phytotelmata and are usually very common in tropical forests (Yanoviak 2001). Tree holes are filled with a small volume of water from rainfall and form a microhabitat for various organisms to breed in and inhabit (Yanoviak 2001, Srivastava *et al.* 2004). Bamboo stumps, like tree holes, are often used by various macro-organisms as breeding sites (Sunahara & Mogi 2002). Bamboo stumps are formed artificially, unlike tree holes which form naturally. These microcosms are considered powerful model systems for ecological studies (Srivastava *et al.* 2004), and therefore an enhanced understanding of the community composition and physical characteristics of such microcosms will contribute to various applications in ecology. Although there are many studies about the macrofauna of water-filled tree holes, relatively few studies are reported from tropical Asian forests.

In this study, we determined the community structure of macro- organisms in water-filled tree holes and bamboo stumps in the Xishuangbanna Tropical Botanical Garden (XTBG), and correlated tree hole and bamboo stump characteristics to the macrofaunal diversity. We also identified the ecological roles of different macrofauna based on taxonomy within these phytotelmata. We hypothesised that 1) macrofauna diversity and abundance increase with the size of opening and volume of phytotelmata, and 2) macrofauna diversity are similar between tree holes and bamboo stumps of similar size.

METHODS

We conducted this study from 4 - 9 October 2007, in Xishuanbanna Tropical Botanical Garden (XTBG), China. We surveyed the distribution of water-filled tree holes and bamboo stumps. We marked the coordinates using a GPS and identified tree species with water-filled tree holes and bamboo species with water-filled bamboo stumps. The tree holes and bamboo stumps with water depth >1.5 cm were recorded. We measured tree hole and bamboo stump variables, including the maximum internal diameter of opening, the depth, the height from the ground, water volume, distance from other tree holes or bamboo stumps, pH, and water and air temperature. The pH was measured using litmus paper. We drained the water from tree holes and bamboo stumps using a siphon and then measured the volume and collected the macrofauna. Identification of the macrofauna was done in the laboratory. Functional roles of taxa were determined from the literature (Yanoviak 2001) and direct observations of feeding behaviour.

Data were analysed with DCA (Detrended Correspondence Analysis) using R 2.5.1 (R Development Core Team, 2007) to examine the parameters that influence the composition of macrofauna in phytotelmata. This method ordinate the species composition to orthogonal axes and other parameters can be correlated against these. A cluster dendrogram was used to investigate the similarity in species composition in the microhabitats.

RESULTS

Fourteen water-filled tree holes, which were formed in nine tree species (*Pterocarpus sp.*, *Ficus oligodon*, *Ficus callosa*, *Ficus benjamina*, *Senna floribunda*, *Cinnamomum camphora*, *Litsea sp.*, *Senna floribunda*, and *Psidium guajava*) were found. Twenty bamboo stumps, formed from two bamboo species (*Dendrocalamus albostrictus* and *Dendrocalamus asper*), were recorded in the bamboo garden in XTBG. The mean height of tree holes from the ground, the mean maximum diameter of tree holes, the mean depth and the mean volume of tree holes was greater than that of bamboo stumps (Table 1). Most water in tree holes (86.7 %) and bamboo stumps (85 %) was slightly acidic (pH). Water temperature of tree holes and bamboo stumps varied with air temperature.

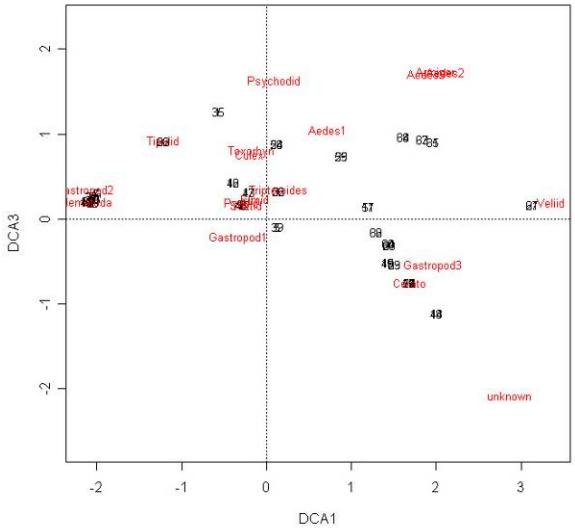

FIGURE 1. Detrended Correlation Analysis of the Species of macrofauna in Tree holes and Bamboo Stumps

Eighteen macrofaunal taxa were identified. Thirteen taxa were recorded in the tree holes and 14 taxa were recorded in the bamboo stumps (Table 2). The dominant Order among the macrofauna was Diptera and included 11 species (Table2).

Most were omnivores, but some were predators, detritivores and herbivores. One species (Diptera sp.10) was widely distributed in both the tree holes and bamboo stumps. A Nematode (sp. 1) and *Tripteroides* sp. (Diptera) were distributed only in the tree holes. Diptera (sp.9) and *Aedes* sp.1 (Diptera) were widely distributed in the bamboo stumps, but only occasional in tree holes.

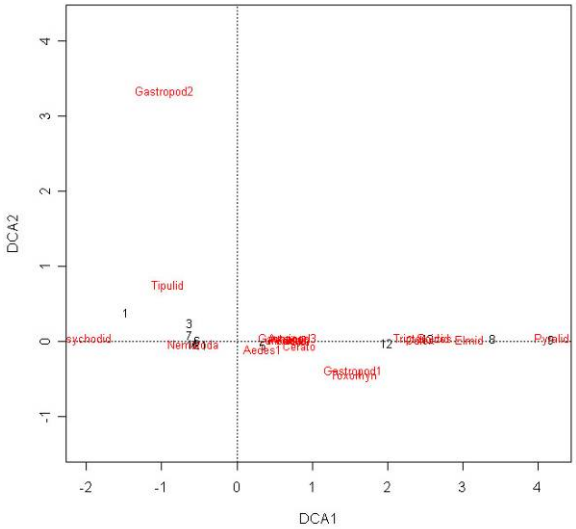

FIGURE 2. Detrended Correlation Analysis Matrix of Species of macrofauna in Tree Holes.

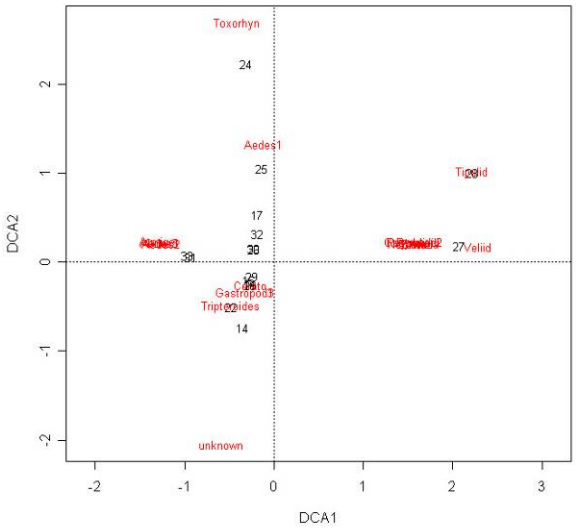

FIGURE 3. Deterended Correlation Analysis Matrix of Species of macrofauna in Bamboo Stumps

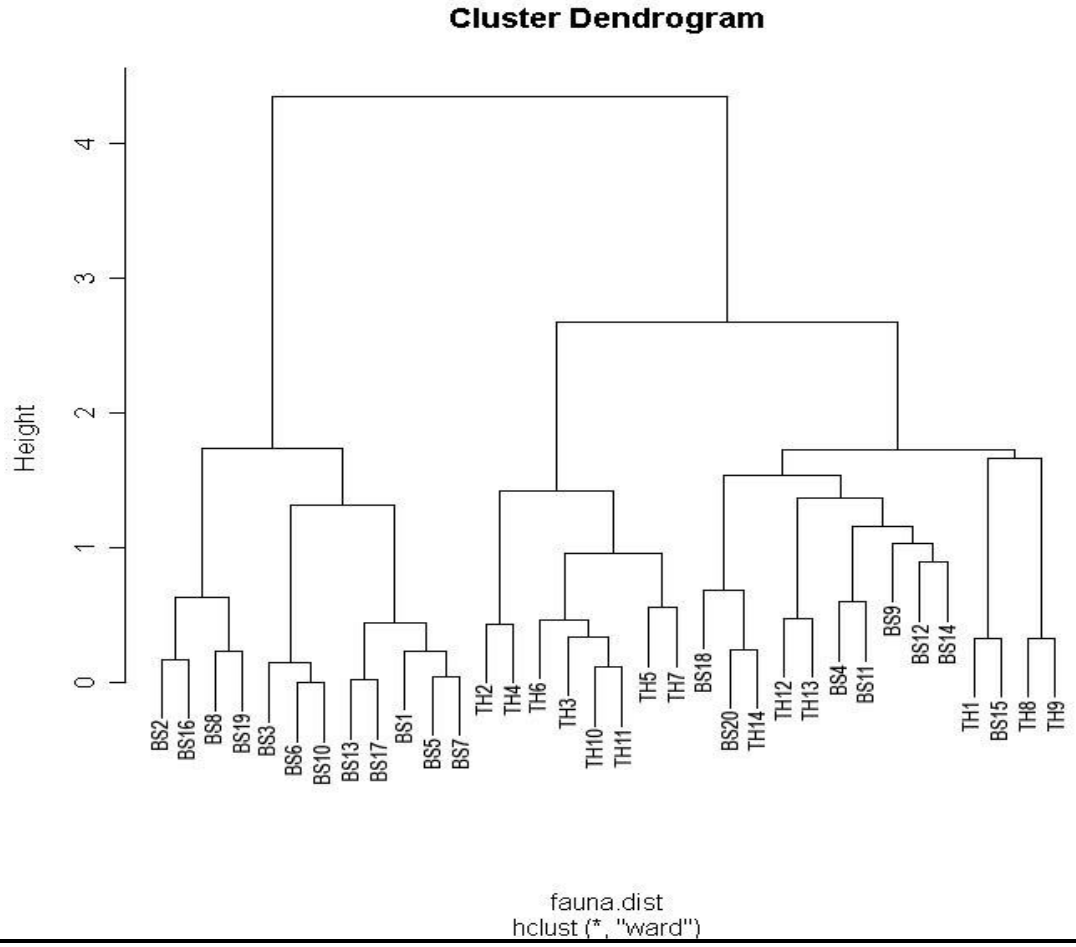

FIGURE 4. Cluster Dendrogram of the Phytotelmata (TH= Tree Hole, BS= Bamboo Stumps).

TABLE 1. *Physical characteristics of tree holes and bamboo stump*

Phytotelmata	N	Height (cm)	Maximum diameter (cm)	Depth (cm)	Volume (ml)	Temperature (^{o}C)	
						Air	Water
Tree hole	14	128 ± 56.2	8.9 ± 3.9	8.8 ± 9.7	632.5 ± 1724.2	22.4 ± 0.5	22.7 ± 0.8
Bamboo stump	20	27.9 ± 13.8	3.7 ± 2.5	7.3 ± 2.9	52.8 ± 72.9	22.4 ± 0.9	22.5 ± 0.8

All data are represented with means ± SD

TABLE 2. *Functional roles of taxa and the percent of phytotelmata containing taxa.*

Taxon	Functional roles	The percent of phytotelmata containing following taxa (%)	
		Tree holes	Bamboo stumps
Class Nematoda			
Sp.1	uncertain	71.4	0
Class Gastropoda			
Sp.2	uncertain	14.3	5
Sp.3	uncertain	7.1	0
Sp.4	uncertain	0	5
Class Insecta			
Coleoptera			
Scirtidae			
Sp.5	detritivore	35.7	0
Elmidae			
Sp.6		7.1	0
Hemiptera			
Veliidae			
Sp.7	predator	0	10
Diptera			
Tipulidae			
Sp.8	detritivore	35.7	15
Psychodidae			
Sp.9	detritivore	7.1	5
Ceratopogonidae			
Sp.10	predator, omnivore	78.6	90
Culicidae			
Toxorhychites sp.		21.4	10
Aedes sp.1	predator	14.9	90
Aedes sp.2	omnivore	0	15
Aedes sp.3	omnivore	0	5
Armigeres sp.	omnivore	0	10
Culex sp.	omnivore	14.3	5
Tripteroides sp.	omnivore	64.3	20
Unknown sp.	omnivore	0	5
Lepidoptera			
Pyralidae	uncertain		
Sp.11	herbivore	14.29	0
Total species		13	14

Fig. 1 shows the distribution of species composition along two axes (DCA1= 0.9326; DCA3 = 0.5226), suggesting a gradient that separates the species in the matrix. Correlation with different abiotic parameters reveals a weak relationship species composition. A DCA of tree holes alone (DCA1=0.8806; DCA2=0.10673) (Fig. 2) found no distinct polarity of the faunal species. In contrast, for bamboo stumps (DCA1= 0.8718; DCA3=0.4086) there was a clear gradient separating the species (Fig. 3). Using the cluster dendrogram, species similarity of the different tree holes and bamboo stumps are presented. Numbers 1 to 11 and 28 represents the tree holes, while the rest are bamboo stumps (Fig. 4). Several of the bamboo stumps cluster within the tree holes, but most cluster separately. Thus, while there is some overlap, tree holes are clearly compositionally different from bamboo stumps.

DISCUSSION

The dominant macrofauna of water-filled tree holes in XTBG were the Diptera, and this is similar to the results of a study in Neotropical forests (Yanoviak 2001). Most species were omnivores, which again is similar to macrofauna of water-filled tree holes in Neotropical forests (Yanoviak 2001).

The survey revealed that almost all water held in tree holes and bamboo stumps is slightly acidic. Moreover, water temperature varied with air temperature. These results indicated that the abiotic conditions are similar across tree holes and bamboo stumps despite their obvious differences in size. Fincke (1999) indicated that oxygen content, pH, and water temperature of tree holes could not predict species occupancy, when tree holes were of different sizes. The cluster dendrogram of the different tree holes and bamboo stumps revealed a difference in the species composition between the two phytotelmata. Therefore, increasing bamboo stumps artificially probably does not increase the habitat available for species that breed or live in tree holes.

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Foraging behaviour of *Apis cerana* on *Turnera subulata* (Turneraceae)

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ABSTRACT

The foraging behaviour of *Apis cerana* was observed in a patch of *Turnera subulata* at the Xishuangbanna Tropical Botanic Garden, Yunnan, China. To determine bee activity and factors affecting bee activity, observations of bee visitation rates were made from 09:30h to 13:30h, during which time the flowers were open. Results showed that bee activity was reduced by high temperature (>33°C). Peak activity was seen from 10:00h to 11:00h almost immediately after the beginning of anthesis and the activity dropped towards the afternoon as the temperature rose. Results also showed that *Apis cerana* was able to visit all the flowers an average of almost fifty times each in a 78 m^2 patch of flowers during the four hours in which the flowers were open. Thus, *Apis cerana* is an efficient pollen forager of *Turnera subulata,* and even at relatively low rates of pollen transfer should be an efficient pollinator.

Key words: Bees, pollination, visitation, Yunnan

BEES ARE THE DOMINANT AND MOST IMPORTANT pollinator for many floral species, especially in the tropical rainforests (Liow *et al.* 2001; Samejima *et. al* 2003). Many plant species rely on bees as their main pollinator and have adapted their flower morphology to suit bee foraging preferences. *Turnera subulata,* or the white alder, is an important food source for bees as well as other insects. A study in North-East Brazil, where this plant is a native, showed that 46 species of bees visit the flowers of this plant (Schlindwein & Medeiros 2006). Because the flowers are open all year, it is a reliable food source for bees. Social bees, such as *Apis* spp., have year round colonies, which compel them to forage the entire year (Kajobe 2006). A plant like *Turnera subulata* would therefore be highly appealing to honeybees. Rewards from this plant are also easily accessible, since the flower morphology does not limit the type of insect that can gather resources from it and no specialized morphological requirement is needed to gather food resources from the plant (Schlindwein & Medeiros 2006).

Documented frequent visitors of *Turnera subulata* in Brazil are *Apis mellifera*, *Trigona spinipes* and *Frieseomelitta doederleinii*. There is even one species of bee (*Protomeliturga tumerae* that is entirely dependent on *T. subulata* as a food source and for reproduction, but *T. subulata* does not seem to be dependent on this species of bee for pollination. Bees that were found to be effective pollinators of this plant are the eusocial bees like *Apis mellifera*, polylectic solitary species like *Centris* and *Xylocopa* and one oligolectic species (*P. turnerae*) (Schlindwein & Medeiros 2006). Our observations at the Xishuangbanna Tropical Botanical Garden indicate that *Apis cerana* was by far the most common flower visitor.

The objective of this study was to document the foraging activities of *Apis cerana* on *Turnera subulata* in response to temperature, humidity and time of day, and to determine the rate of visitation throughout the day. In addition, we wished to determine how effective the bees were at foraging pollen on the entire flower patch we observed.

METHODS

Xishuangbanna Tropical Botanical Garden (XTBG) is situated in Xishuangbanna,Yunnan, China (21º54'N, 101º46'E, 580m asl). Xishuangbanna has a monsoon climate with annual precipitation greater than 1500 mm and 80 percent relative humidity (Zhu 2006). XTBG has a large collection of plants from different areas of the world. One of these is *Turnera subulata* (Turneraceae), which is a shrub with funnel-shaped ephemeral flowers. The flower has white petals with dark violet to black nectar guides at the base. *Turnera subuluta* have distylic flowers: thrum type, which has short styles and the pin type, which has long styles (Schlindwein & Medeiros 2006; Swamy & Bahadur 1984), although we only observed the thrum type in our flower patch and elsewhere in XTBG.

The two types of flowers usually produce almost the same number of pollen grains. The pin flowers usually produce 14,040 pollen grains per flower, while the thrum flowers produce 14,805 pollen grains per flower. *Turnera subulata* is self-incompatible but cross compatible between the two types of flowers (Swamy 1984). The flowers found at XTBG may not be producing any viable seed, as only one (the thrum type) flower type was found. The flower has a diameter of 4.0-6.0 cm. There is an orifice between the base of the filaments and the petals, which allows easy access to the nectaries. Nectar is usually produced at the beginning of anthesis at small quantities (0.8 µL to 1.0 µL per flower) with mean sugar concentrations of 28 percent to 32 percent. Pollen of this flower is characterised by the abundance of pollenkitt, which makes the pollen sticky and orange in colour, allowing it to adhere to the insect bodies (Schlindwein & Medeiros 2006).

Three 1.5 m x 2 m quadrats were set up to observe the number of bees (*Apis cerana*) that were foraging in a patch of *Turnera subulata*. One-minute observations at ten-minute intervals from 09:30h to 13:30h were conducted at each quadrat to determine the number of bee visitors. This was the time that the flower was open and receptive to pollinators and pollen foragers. A focal *Apis cerana* individual was then observed for one minute to determine the number of *Turnera subulata* flowers that it visited. This was repeated throughout the day.

To determine if the bees can visit all the flowers in the patch, twelve 1 m^2 quadrats were set up and we calculated the mean number of flowers in each quadrat. The area of the flower patch was then measured, to determine the total number of flowers within the flower patch. Temperature and relative humidity were recorded throughout the day to determine if these factors had an influence on the foraging activities of the bees.

RESULTS

Bee visitation rates changed significantly throughout the day, dropping off as the temperatures rose. The peak of bee foraging activity was between the hours of 10:00h and 11:00h, when the flowers were already fully open but the pollen had not yet been completely foraged (Fig. 1). Foraging activity was only measured during the period the flowers were open. The flowers were closed until 9:30h and only stayed open until 13:30h. Before and after these times, foraging activity was zero. The reduction in foraging behaviour was strongly related to temperature. Fig. 2 shows how foraging activity dropped as soon as temperatures rose above 33º C.

The flower density ranged from 41 flowers/ m^2 to 96 flowers /m^2, with a mean value of 75 flowers/ m^2 ($\overline{\eta} = 75.17 \pm 4.88$). The number of flowers found on the entire patch (A = 77.7 m^2) was thus estimated to be 5840 flowers ($\mathrm{A} \times \overline{\eta} = 5841 \pm 379$).

The flowers stayed open for a period of four hours from 9:30h to 13:30h (t = 240 min.). During this entire period, the number of bees found on the patch varied significantly, but the feeding rate (γ) per bee remained constant. Each bee was found to visit 7 flowers per minute (γ = 7.2 ± 0.4). The bees were foraging for pollen. Therefore, it is theoretically possible for only four bees ($N_{B\min} = 3.38 \pm 0.03$) to gather at least some pollen from all of the 5840 flowers over the four- hour period if they foraged continuously.

$$N_{B\min} = \frac{\overline{\eta} \times \mathrm{A}}{t \times \gamma}$$

Similarly, a single bee can visit 420 flowers within an hour were it to forage continuously.

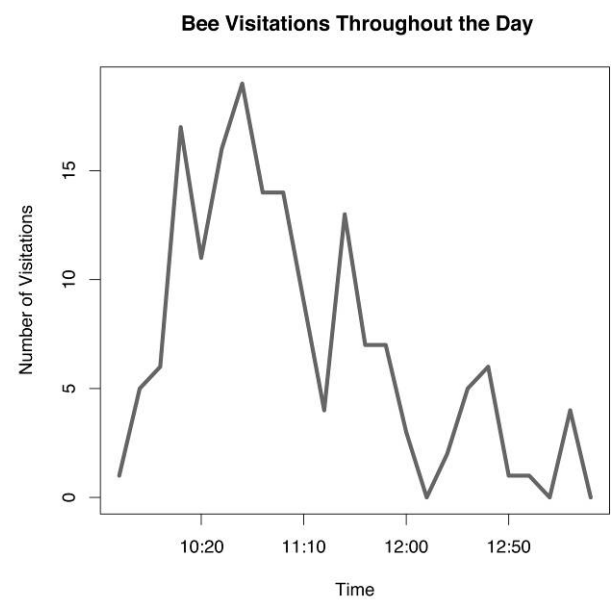

FIGURE 1. *Apis cerana* visitations throughout the day per square meter to flowers of *Turnera subulata* at Xishuangbanna Tropical Botanical Gardens in Yunnan.

We measured bee abundance throughout the day for one-minute intervals every ten minutes to calculate total flower visitations (V) on the 77.7 m^2 flower patch. $\overline{\beta}$ is the mean number of bees found in one square meter of the three quadrats observed during a one minute interval ($\overline{\beta} = 7.35 \pm 0.79$). n is the number of ten minute intervals measured (n = 24). The summation of the means is multiplied by ten to estimate

the total number of bees during the entire four-hour period. The result was then multiplied by the total area (A) and the visitation rate (γ) to obtain the total number of flower visitations in the patch examined. The estimate of the total number of flowers visited (V) for the entire patch during the four-hour period was over 300,000 ($V = 307692 \pm 2998$).

$$V = \mathrm{A} \times \gamma \times 10 \times \sum_{i=1}^{n} \overline{\beta}_i$$

The total number of flower visitations is much higher than the total number of flowers in the patch, signifying that most flowers must be visited several times throughout the day. A simple calculation shows that each flower was visited 50 times on average throughout the day (52.7 ± 7.9). Alternatively, the bees have the ability to visit all flowers within the entire 77.7 m^2 patch within six minutes at average visitation rates.

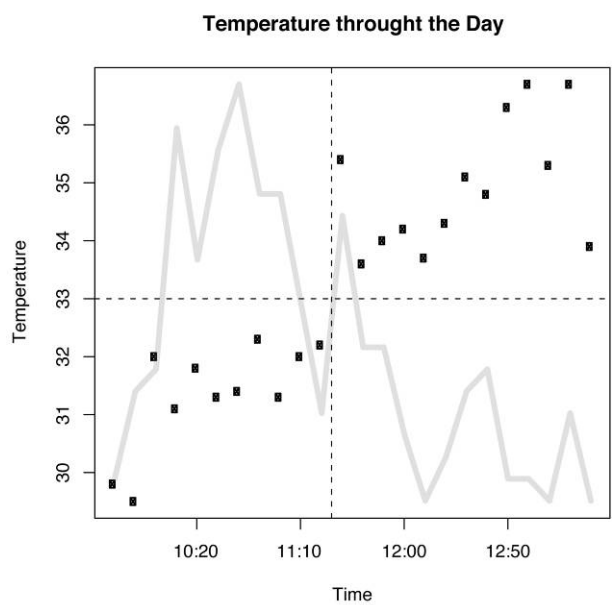

FIGURE 2. Temperature throughout the day combined with *Apis cerana* visitations at Xishuangbanna Tropical Botanical Gardens in Yunnan. The vertical line marks the time at which temperatures rose and foraging activity reduced. The horizontal line marks the temperature at 33º C.

DISCUSSION

It is clear from our results that *Apis cerana* is an efficient pollen forager at *Turnera subulata*, but the question still remains as to its effectiveness as a pollinator. The greater the number of visitations by *Apis cerana*, the higher the chances that some of the pollen gathered will be deposited on the female flower part and will aid in pollination. Until a study is conducted on the successful fertilization of *Turnera subulata*, the effectiveness of *Apis cerana* as a pollinator remains a conjecture. However, we can expect that out of the 300,000 flower visits per day, some portion will be deposited and will aid in fertilization even if the rate of accidental pollen deposition is very low.

Plants can be visited by different species of pollinators that have different foraging behaviour and resource preferences (Kunin 1993). During the sampling, we were able to observe different possible pollinators of this plant, in addition to *Apis cerana.* They included wasps, butterflies and other species of bees. The wasps were predating on *Apis cerana*, as well as feeding on extra floral nectaries found at the base of the leaves.

Apis cerana was found to be the dominant pollinator of *Turnera subulata*. Other bees, beetles, and butterflies also visited the flower patch, but at much lower rates. *Apis cerana* was found to be mostly gathering pollen from the anthers of *T. subulata*, feeding only on the nectar in the afternoon when foraging activity was greatly reduced. They have hairy bodies that help them gather pollen from many flowers before returning to their hive. Like other social bees, they also have pollen baskets on their first tarsal segment. These are enlarged structures, covered with hairs and found in both hind legs, for pollen carrying.

Apis cerana visited seven flowers per minute on average, but did not gather all the pollen present on the anthers of each flower. Bees that spend too much time on a single flower are possibly more vulnerable to predation by the wasps, which forces them to only gather a small quantity of pollen from each flower before moving on to the next. We were able to observe a wasp capturing a bee during the sampling, but further observations of this behaviour need to be made to confirm if any evolutionary pressure is exerted on bee behaviour by predatory wasps.

Weather also probably had an effect on *Apis cerana* foraging behaviour. Our data shows that at higher temperature, bee activity was reduced. In good weather conditions, bee activity peaks during the early morning, which might be because during this time, temperature does not reach more than 33° C. However, the pollen content of the anthers might also be a factor for the reduction in bee activity later in the morning and in the afternoon. Flowers at this time seem to have less pollen. Measurements of pollen content throughout the day would aid in confirming this conjecture.

Rain also reduced bee activity significantly. During the rain, even when it was slight, bee activity, as well as the activity of other insects, essentially dropped

to zero. Even after the rain subsided, bee activity did not increase rapidly. Flowers that had water droplets on the petals had far less bee visitations as compared to flowers that were relatively dry. Rain essentially prevented much of the foraging activity by the bees, even after it subsided. Despite the rain reducing the visitations by the bees, the effectiveness of *Apis cerana* as a forager still will guarantee flower visitations and may be the only significant visitor during rainy weather conditions.

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Effects of Plantation Diversity on Ant Community Composition

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ABSTRACT

The tropical rainforests are being denuded to make way for cash crop plantations at an alarming rate. In such times of rapid biodiversity loss, it is helpful to have suitable indicators, which can be easily utilized to determine the causes or aftermaths of such events. The present study looked into the effect of plantation type on the ant community composition, within Xishuangbanna Tropical Botanical Gardens, Yunnan, China. The study used ants as indicators and leaf litter characteristics as the major environmental factor affecting their community structure. Fifteen morpho-species of ants were captured in pitfall and aerial traps. We found that leaf litter characteristics, such as dry weight and litter depth, were highly significant determinants of ant community composition. The results also showed that plantations support a higher diversity and abundance of ants than secondary forest. The study also indicates the existence of clear demarcations within the communities, which might be a result of niche partitioning at the micro-habitat level.

Key words: diversity and abundance, leaf litter, rainforest, rubber, tea

TROPICAL RAINFORESTS ARE KNOWN to be the most diverse terrestrial ecosystems and they serve many important ecological functions. Despite this fact they are rapidly being depleted and, in Asia, replaced by rubber and oil palm plantations due to the high short-term economic values of these crops (Bickel & Watanasit 2005).

Ants are good models for examining the impacts of land-use change on ecosystem functioning and serve as a focal taxon, especially in agro-ecological research (Philpott & Armbrecht 2006). This is attributed to the wide range of ecological functions they perform as predators, herbivores, detritivores and pollinators. Ants were chosen for this study because they are known to respond to micro-environmental gradients, and they are suitable for surveying over shorter time periods (Underwood & Fisher 2006). Pitfalls and aerial baited traps were used to assess differences in the community structure of ants. Baiting offers an appropriate technique for sampling dominant species, since the abundance of ant foragers at baits may indicate ecological and behavioural dominance among foraging species (Bestelmeyer *et al.* 2000).

There have been many studies on ants in coffee plantations due to their shaded environment. And studies have shown that plantations have more biodiversity value than is commonly believed (Parrotta *et al.* 1997). The objective of this study was to assess the difference in ant community composition among various plantations and in a secondary rainforest. We looked mainly at leaf litter characteristics to account for the changes in ant community structure. We hypothesised that the diversity and abundance of ant communities would decrease as leaf litter depth and weight increase.

METHODS

STUDY SITES.— The study site was located within the Xishuangbanna Tropical Botanical Gardens (21°41’ N, 101°25’E , 570 m asl), in Yunnan, China. The gardens are spread over 900 hectares and consist of a substantial collection of tropical and sub-tropical plants. The landscape which makes up much of the garden today is composed of old rubber plantations established in the early 1980’s. Although some of the rubber plantations still remain, they have mostly been replaced by other crops like tea and coffee planted along the same stretch. This makes it ideal to compare the ant communities of different plantations with a similar history and a secondary forest without having confounding environmental variables.

This short term study was carried out for 5 days and focused on a tea (*Camellia sinensis*) plantation, a rubber (*Hevea brasiliensis*) plantation, a plantation mixture of rubber and tea, a plantation of rubber with several different crops, and a patch of

natural secondary rainforest, which were all within the garden.

LEAF LITTER SAMPLING. — Three transects were established within each plantation type and the rainforest. Plant species diversity and litter depth were recorded, and leaf litter samples collected along each transect. Sampling was done within five 1 m × 1 m quadrates placed along each transect in the simple plantations and three 5 m × 5 m quadrates placed along each transect in the mixed crop plantation and rainforest.

In each 1 m × 1 m quadrate a 25 cm × 25 cm sub-quadrate was established to collect leaf litter. Whereas in each 5 m × 5 m quadrate three 25 cm × 25 cm sub-quadrates were established to collect leaf litter. All the leaf litter samples collected were dried in an oven for 48 hours at 75°C. Each leaf litter sample was weighed prior to and after drying in order to calculate the moisture content, which was measured as a percentage of the leaf litter dry-weight.

ANT SAMPLING.— The diversity and abundance of ants were determined along replicated transects. Three transects were established at each plantation and the rainforest. Five pitfall traps were placed at equal intervals along each of the three transects, in addition to four randomly placed traps within each habitat type; thus taking the total number of traps to 19. Ten aerial traps, baited with cotton soaked in sugar syrup and processed fish were also set up within each habitat type. They were placed equally along each transect line. The pitfall traps were active for four days and the aerial traps for two. The captured ants were identified to their morphological species.

DATA ANALYSES.— Species richness, abundance and community composition were analysed using R 2.6.0 (R Core Team, 2007). Species abundance barplots were constructed to visualise the patterns in ant distribution in the various habitat types. General linear models (GLM) were used to examine differences in species composition, with the abundance of the most common ant species as the response variable and litter characteristics such as leaf litter depth, moisture and weight as the independent variables. Variation in morphospecies diversity across habitats was also calculated using the Shannon diversity index for each type of traps separately. Species accumulation curves were also drawn to assess the changes in species composition across habitats. The extrapolated species richness for both trap types was calculated to estimate the number of un-observed species. To visualise differences in community turnover between the habitats, cluster dendrograms were constructed using the Chao index, clustering the habitat types. The ant morphospecies captured in aerial and pitfall traps were treated separately for constructing the dendrograms, due to the variable capture rates in the different trap types.

RESULTS

HABITAT VARIABLES. — Mean number of plant species in three plantations were similar. As expected there is a big leap in diversity from plantations to the rainforest, with the mixed crop plantation and the rainforest having eight and 14 plant species respectively (Table 1). Although there was a large difference in the mean leaf litter weight between forest and plantations, the mean leaf litter moisture content only differed by ± 5 percent. The general linear models (Table 2) showed that the abundance of the most common species caught in each trap type was highly significantly predicted by leaf litter characteristics, like litter dry weight and litter depth.

The number of ants caught in the pitfall traps was substantially lower in the rainforest compared to the plantations. The aerial traps in the tea plantation captured 506 individuals, a significantly high number compared to the mixed crop plantation, which had the lowest captures of only 62 individuals. The tea plantation had the highest number of ants caught in both the traps and was the habitat with the highest leaf litter weight and moisture among plantations.

ANT COMMUNITY COMPOSITION.— A total of 15 morphospecies of ants were identified across the five habitats. There were 744 individuals of ants from 14 species caught in the pitfall traps and 1076 individuals of ants from 13 species caught in the aerial traps, accounting for a total of 1820 individuals. The tea plantation had the highest number of ants with 757 individuals from 11 species and the least was from the rainforest with 118 individuals from eight species (Fig. 1). The rubber- tea plantation had the highest species-richness with all 15 species present.

The Shannon diversity index (Fig. 2) showed contrasting results for the two trapping methods. Based on the pitfall trap data, the tea plantation is the most diverse habitat followed by the rubber-tea plantation and the rainforest. But the tea plantation is the least diverse habitat according to the aerial trap data, with the mixed crop plantation and rubber plantation being the most diverse. The species accumulation curves (Fig. 3) show a steady increase in the number of observed species across the habitats. This result is supplemented by the calculated extrapolated species richness (Table 3), which shows that the number of unobserved species was very few (<3) for either trapping method.

SPECIES TURNOVER BETWEEN HABITATS. — The dendrogram for the aerial trap data (Fig. 4) showed clear clustering of habitat types according to the ant communities present in them. We see two main clusters, the first being formed by the mixed crop and rainforest and the second being formed by the rubber and tea plantations. For the pitfall data (Fig. 4) the clustering patterns were different. The two main clusters seen are the ones formed by tea and rubber-tea, and rubber and rainforest. These results show that variation in ant species diversity and abundance occurs across the habitats.

TABLE 1 *Habitat variables and ants caught in two types of traps between four plantations and a rainforest in Xishuangbanna, Yunnan, China.*

	Mean Leaf Litter Weight (g)	Mean Leaf Litter Moisture (%)	Mean Number of Plant Species	Number of Ants in Pitfall Traps	Number of Ants in Aerial Traps
Rubber	54.7	40	3	111	83
Rubber-Tea	75.1	43	3	209	349
Mixed Crop	153.3	45.1	8	131	62
Rainforest	212.7	50.4	14	42	76

TABLE 2. *General linear model with a Poisson distribution of the most common ant species in aerial (Sp 10 and Sp 11) and pitfall (Sp 3 and Sp 4) traps and the most correlated habitat variables*

	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**
Aerial traps				
Sp 10				
Weight	-0.027253	0.007559	-3.606	0.000312 ***
Depth	0.216773	0.060556	3.580	0.000344 ***
Sp 11				
Weight	-27.952	4.707	-5.938	2.89e-09 ***
Moisture	-131.514	22.397	-5.872	4.31e-09 ***
Depth	230.557	38.950	5.919	3.23e-09 ***
Pitfall traps				
Sp 3				
Weight	-0.020573	0.003345	-6.149	7.78e-10 ***
Depth	0.153706	0.027935	5.502	3.75e-08 ***
Sp 4				
Weight	-0.008993	0.004131	-2.177	0.0295 *
Depth	-0.009178	0.036213	-0.253	0.7999

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

TABLE 3. *Extrapolated species richness across the habitats, for the pitfall and aerial traps*

Trap	**Species**	**Habitats**	**Chao**	**SE**	**Jack.1**	**SE**	**Jack.2**	**Boot**	**SE**
Pitfall	14	5	16	3.74	15.6	1.13	16.35	14.78	0.83
Aerial	13	5	14.5	2.29	15.4	1.88	15.85	14.25	1.20

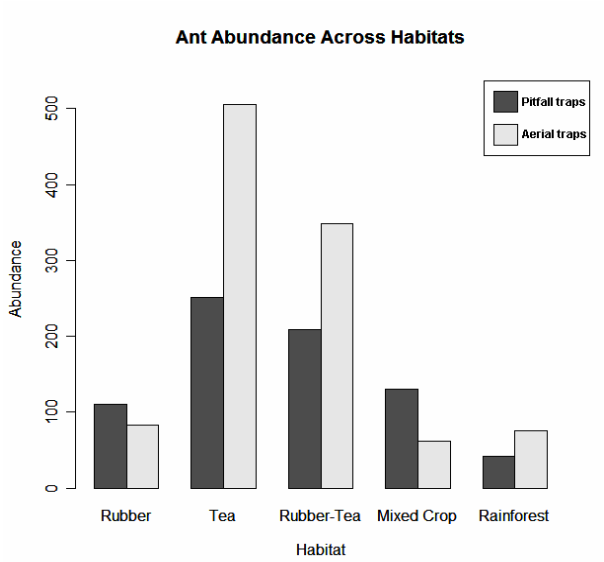

FIGURE 1. Ant abundance across plantations (rubber, tea, rubber-tea, and rubber-multicrop) and rainforest habitats according to pitfall and aerial traps in Xishuangbanna, Yunnan

Species 1 is present across all habitats except the rubber plantation. Species 3 and 4 occurred across all five habitats sampled but appear abundant where rubber plants are present (rubber, rubber-tea, and mixed-crop). Species 11 was found in all the plantations but was absent in the rainforest. With 409 individuals caught in the aerial traps at the tea plantation, they were the highest contributor to the ant community in the tea plantation.

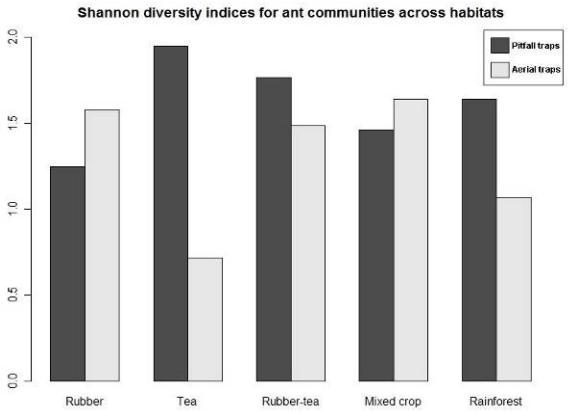

FIGURE 2 Shannon diversity indices for the ant communities across habitats, with the pitfall and aerial trap data treated separately.

Species 1 was caught in the pitfall with small numbers but was abundant in the aerial traps at the rubber-tea plantation with 162 individuals. Species 3 and species 4 were caught in high abundance in the pitfall traps with 280 and 160 individuals respectively (Fig. 5). The rainforest was the only habitat where species 4 was caught in the pitfall traps.

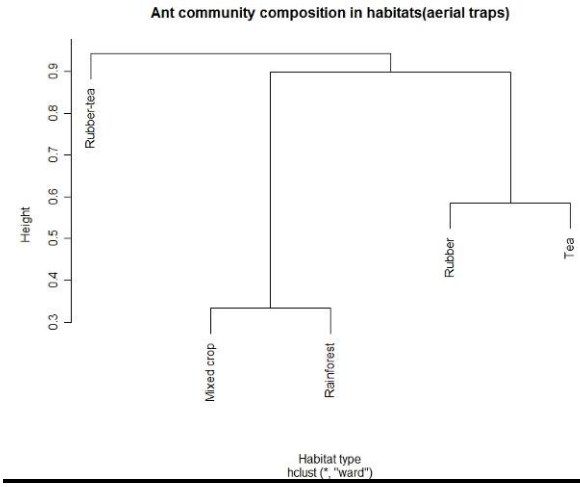

FIGURE 3. Ant community distributions across habitats based on aerial trap data, in Xishuangbanna, Yunnan

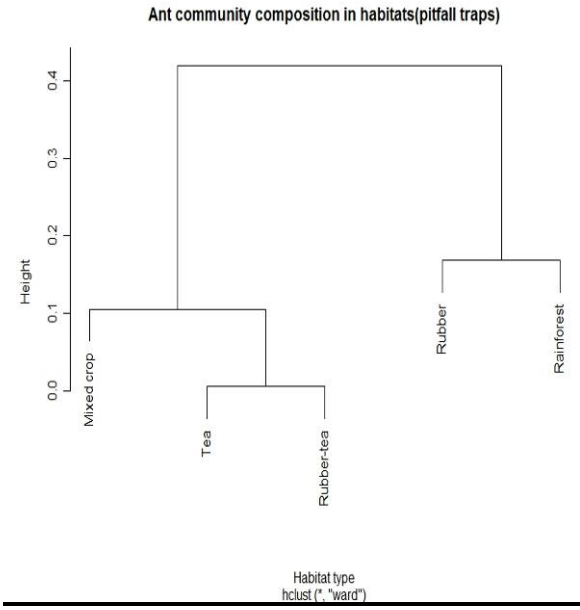

FIGURE 4. Ant community distributions across habitats based on pitfall trap data, in Xishuangbanna, Yunnan

Species 11 was found in both the pitfall and aerial traps. Species 13 with 92 individuals only occurred in the aerial traps at the rubber-tea plantation and was not found in any other habitats.

DISCUSSION

The rainforest had the highest leaf litter depth and plant species diversity compared to all the other habitats, as expected. A substantial difference in the ground ant communities in the plantation compared to the forests was apparent, (Bickel & Watanasit 2005).

The complexity of the foraging surface influences ant community structure and productivity. Leaf litter is a factor that inhibits ant movement efficiency when foraging (Andersen 2000). Some species of ants have come to adapt to the dense leaf litter in the forest floor by occupying the tree barks and branches as their foraging ground.

The tea plantations had thicker leaf litter as compared to the rubber plantations. Ants in the tea plantation generally forage on the tea plants, possibly because these provide some shade. Ants prefer more shaded environment as they are better protected from dehydration and predation (Biological Conservation Newsletter 2006). A study in India by Senapati *et al.* (2002) indicated that ant abundance in tea plantations were the same as in the forest and disturbed tea areas. This comes to show that disturbance is not a main factor affecting ant communities at least in some plantation habitats.

Monocultures will not have the biodiversity value of a natural or secondary forest but their values are not negligible (Sayer *et al.* 2004). With time monoculture plantations in the tropics can acquire many of the structural attributes of intact forest (Kanowski *et al.* 2003) indicating possible re-colonisation by ant communities and other biota.

During this study a total of 15 morphospecies of ant species were identified across five habitats. There were 744 individuals of ants from 14 species caught in the pitfall traps and 1076 individuals of ants from 13 species caught in the aerial traps, accounting for a total of 1820 individuals. The species richness of ants showed a negative correlation with plant diversity across the habitats. Leaf litter characteristics such as depth and weight, however, were found to be contributing factors in determining ant abundance between plantations and the rainforest.

The diversity as measured by the Shannon index showed contrasting results. The tea plantation was the most diverse according to pitfall trap data, but *vice versa* according to the aerial trap data.

The other plantations were more or less similar in their diversity values for each trapping method. The species accumulation curves also showed a trend of steady increase in the number of species as the habitat types varied. The extrapolation of species richness to estimate the number of unobserved species showed that very few species were missed by each trapping technique.

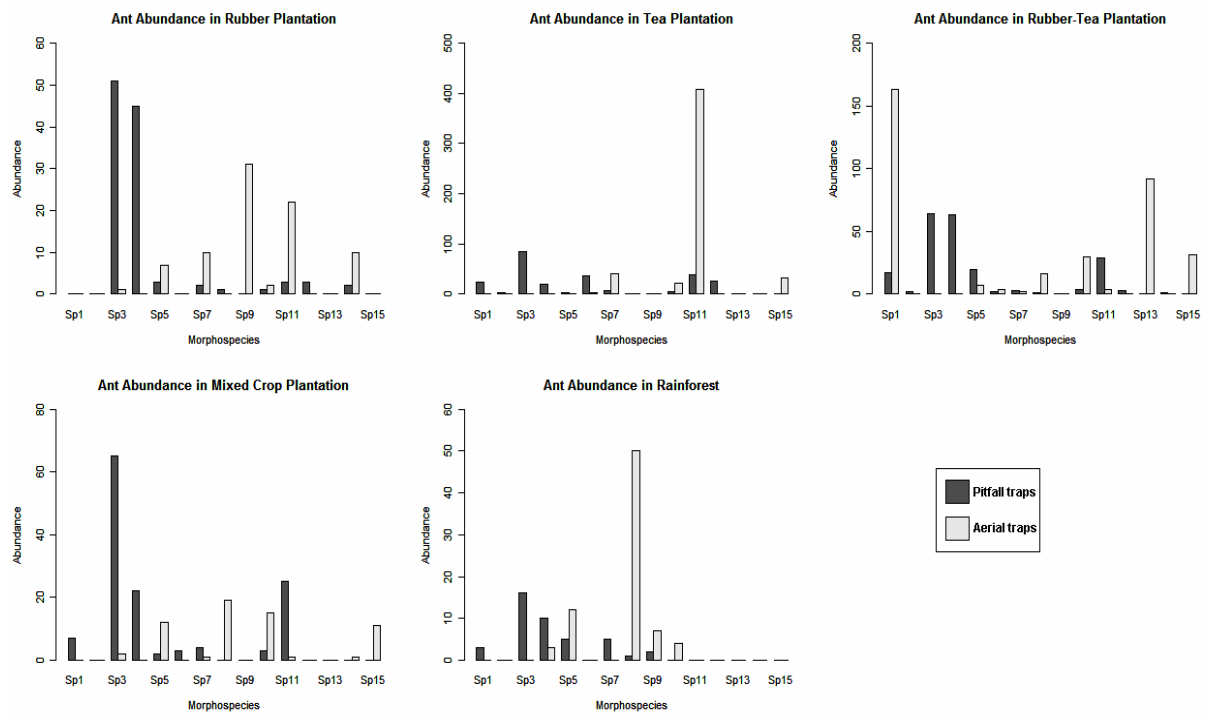

FIGURE 6. Ant morpho-species abundance and diversity in plantations (rubber, tea, rubber-tea, and rubber-multicrop) and forest habitats according to pitfall and aerial traps.

This also confirmed that the sampling effort was efficient enough at picking up the most common species in each habitat.

There was great variation in the capture rates and diversity between the two trapping methods across the habitats. Clustering the habitats according to the species diversity and abundance showed which habitats shared similar ant communities. Hence we see a pattern where the habitats with highest leaf litter weight (mixed crop plantation and the rainforest) and the one with the lowest (rubber-tea plantation) form distinct clusters for the aerial trap data. The same is true for the pitfall data where we see a clear difference between the communities that occur in habitats with moderate levels of leaf litter (tea, rubber-tea and mixed crop plantation) and the ones with highest (rainforest) and lowest (rubber). The existence of such clear demarcations within the communities across habitat boundaries, that are closely related to litter characteristics, might be a result of niche partitioning at the microhabitat level.

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The Effect of Canopy Openness on Soil Properties and Species Richness of Soil Macrofauna in Xishuangbanna Tropical Rain Forest

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ABSTRACT

Canopy openings can change the resource availability in the forest floor, by changing the amount of light entering to the forest floor, which in turn affects the biological and physical properties on the forest floor. This study was carried out to investigate the effect of canopy openness on soil properties and on soil macrofaunal species richness in Xishuangbanna Tropical Botanical Garden. Samples from ninety subquadrates in thirty 1m x 1m quadrates were collected. The analysis was done using linear models in R 2.5.1. The results revealed a highly significant relationship between canopy openness and species richness of macrofauna.

Key words: forest floor, light, resource availability, species richness

FOREST CANOPY OPENNESS varies from large canopy gaps due to death of the dominant and co-dominant trees over an extended area to very small size openings from branch falls. By changing the amount of light reaching the forest floor, canopy openings can change the resource availability on the forest floor, which in turn affects the biological and physical properties of the forest floor.

Soils are a key piece in the picture of how an ecosystem works. Soil is a living entity, comprising an inseparable mixture of solid, liquid and gaseous phases, and a diverse fauna and flora; the below ground biodiversity. The simplest functional division of soil fauna is on the basis of body size, into micro-, meso- and macrofauna (Anderson 1981). The macrofauna, by convention, consists of animals longer than 4 mm or wider than 2 mm, which are easily located by the naked eye, and includes arthropods, molluscs and earthworms. Soil macrofauna plays an essential role in the initial comminuting and degradation of organic matter entering the soil environment (Lavelle & Spain 2001).

Species richness is the simplest measure of biodiversity and is simply a count of the number of different species in a given area. Species richness is a critical variable for biodiversity management that has been used for decision making and prioritisation of conservation efforts. (Pimm *et al.* 2001).

The shading and insulation afforded by the canopy buffers temperature extremes at the ground surface. The canopy also alters hydrological conditions by redirecting precipitation and removing soil water through transpiration. The canopy also alters the chemical composition of precipitation; as rain passes through the canopy, concentrations of nutrients such as N, P, K and Ca may increase or decrease (Sollins *et al.* 1980).

The objective of this study was to investigate the effect of canopy openness on soil properties and on soil macrofaunal species richness in Xishuangbanna Tropical Botanic Garden. We hypothesised that soil properties and soil macrofaunal richness will change with the canopy openness.

METHODS

STUDY AREA AND PERIOD.— The study was carried out in Xishuangbanna Tropical Rain Forest for five days. Xishuangbanna has a typical monsoon climate with three distinct seasons: a humid hot rainy season (May–October), a foggy cool-dry season (November–February), and a hot-dry season (March–April) (Cao *et al.* 2006). Tropical seasonal rain forest is one of the principle forest types in Xishuangbanna (Zhang & Cao 1995, Zhu *et al.* 2006).

COLLECTION OF SAMPLES AND OBTAINING REQUIRED MEASUREMENTS.— Thirty quadrates with the extent of 1 m x 1 m were set randomly in the Xishuangbanna Tropical Rain Forest. In each quadrate, three sub-quadrates with the extent of 15 cm x 15 cm were set up. One sub quadrate was set at the centre of each 1m x 1m

quadrate and the other two quadrates were set in opposite corners. In each sub-quadrate, the light intensity was measured using light meter, soil pH and soil moisture measurements were taken using the Kelway soil tester, and the soil temperature was measured using a soil thermometer. In each sub-quadrate, all the leaf litter was collected. The macrofauna of soil leaf litter and soil layer up to 10 cm depth were collected separately. The sorting of the macrofauna was done both in the field and the laboratory, and morpho-species were identified.

DETERMINING CANOPY OPENNESS.— Photographs of the canopy were taken in the centre point of each quadrate, mounting the camera on the ground. For this, a Nikon Cool pix 6.0 megapixel camera with the zoom setting of X10 was used. The percentage canopy openness was calculated using pixmap package of R 2.5.1 version. This provides an objective index of the canopy openness rather than an absolute measure.

DATA ANALYSIS.— We conducted linear models using the R version 2.5.1 (R Core group 2007) to investigate the effect of canopy openness on the soil moisture, soil pH, soil temperature, leaf litter moisture, and species richness.

RESULTS

There were 30 quadrates established randomly in the study site. Most of the macrofauna could only be identified up to order and were subsequently classified as morphospecies. There were 16 orders of macrofauna recorded. The number of macrofauna morphospecies found in the leaf litter was high, with 40 species, compared to soil, which only 10 species. The most common order was Hymenoptera (Table 1). There were no clear distribution patterns of macrofauna among the quadrates. All macrofauna were widely distributed. However, earthworms and Geophylomorpha (centipede) were found only in the soil. Canopy openness was a significant predictor of species richness of macrofauna. (P= 0.006295), but the canopy openness was not significantly related to any of the other variables.

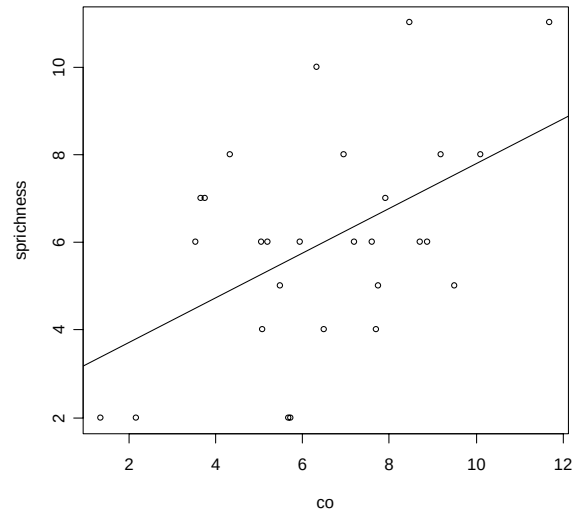

FIGURE 1. The plot between macrofauna species richness (y-axis) with canopy openness (co)

TABLE 1. *List of macrofauna orders occur in leaf litter and soil*

Taxon	No. of morphospecies	
	Leaf Litter	**Soil**
Araneida	10	01
Coleoptera		
Coleopteralarvae	05	01
Dermaptera	01	01
Diptera	01	00
Earthworm	-	01
Geophilomorpha	-	01
Hemiptera	04	-
Hymenoptera	09	02
Isopoda	02	01
Isoptera	01	01
Lithobiomorpha	01	01
Millipede	02	01
Orthoptera	04	01
Slug	01	-
Snail	01	-
Total	**40**	**18**

TABLE 2. *Linear Model to show the canopy openness and species richness of soil macrofauna (lm(formula = sprichness ~ canopy-openness, adjusted R^2 = 0.2249, $F_{26,1}$ = 8.834 P = 0.006295)*

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	2.6939	1.1185	2.272	0.0316
Canopy openness	0.5101	1.1716	2.972	0.0063

DISCUSSION

Our results showed an increase in macrofauna species richness with canopy openness. There was a positive correlation between canopy openness and species richness of soil macrofauna. Previous studies have shown that the number of species increases with the light intensity to some point, after which it decreases. We did not find this, which may be due to the fact that the quadrates did not represent a sufficiently wide range of variation in canopy openness. According to Sollins *et al.* (1980), the soil properties, such as moisture content and temperature, are also affected by the canopy openness but in this study, we did not find any relationship. This may be due to the heavy rains during the study period, and the saturated condition of the soil.

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Feeding preferences of two sunbird species on varieties of *Hibiscus rosasinensis*

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ABSTRACT

Sunbirds are small birds that feed mainly on nectar of flowers. *Hibiscus rosasinensis* is a famous garden plant, which is grown in the tropical areas. Many varieties of this species are grown in the Xishuangbanna Tropical Botanic Garden (XTBG). We hypothesised that the Sunbirds show a preference for particular varieties of *Hibiscus* grown in the garden. Flower morphology was analysed by measuring nine morphological parameters. Seven morphological parameters related to the trees of each variety were also recorded. Observations of bird visitation to the flowers of selected trees were made from 0800h to 1800h each day for seven days. A total of 741 records of flower visitations by sunbirds and butterflies were obtained during 23 hours of observation. Mean time spent on a tree and mean number of flowers visited by sunbirds and butterflies were high for two varieties. A General Linear Model revealed a highly significant preference of sunbirds for these two varieties. However, when the two sunbird species were considered separately, only the Ruby Cheeked Sunbird showed a strong preference for one of the two varieties. There was also a significant correlation between number of flowers visited by sunbirds and the number of flowers on the trees. Nectar robbing by sunbirds on *Hibiscus* flowers was proven, as only 11 percent of feeding efforts were through the corolla tube of the flower.

Key words: Crimson sunbird, flower visitation, Foraging, *Hibiscus* varieties, nectarivores, Ruby cheeked sunbird

THE SUCCESS OF POLLINATION DEPENDS ON MANY FACTORS. One important factor is the morphology of flower (shape, colour, scent and structure) to attract their pollinator. The shape, size and amount of nectar can influence the number of both insects and birds that visit (Hargreaves *et al*. 2004, Nicolson & Fleming 2003). White flowers are widely visited by insects (Zych 2006), as birds prefer red or orange colours (Nicolson & Fleming 2003). In addition, the flower visitors vary in their preference for different numbers of flowers in a display and on location of a plant (Nagamitsu *et al*. 1999). However, not all the flower visitors are pollinators.

Flower species are often specialised for certain pollinator species, while other flower visitors are nectar robbers (Fenster *et al*. 2004). The particular matching between a flower and its pollinators is obvious in many ornithophilous pollinated plants, which have tubular corollas matching the long slender bills of sunbirds (Old World) or humming birds (New World).

Sunbirds belong to the family Nectariniidae, which comprises 126 species in the old world (BirdLife International 2007). Sunbirds are characteristically small birds, which have long slender curved bills and a tube like tongue. Sunbirds have both morphological (Cheke *et al*. 2001) and physiological adaptations (Lotz 2000, Roxburgh & Pinshow 2000) for exploiting nectar as an energy source. They are primarily nectar feeders and rarely feed on insects.

Flowers are usually exploited from a perch but many sunbirds will also hover briefly, if this is necessary to access nectar (Corlett 2004).

Chalcoparia singalensis (Ruby Cheeked Sunbird) is a small (10 cm) colourful bird. *Aethopyga siparaja* (Crimson Sunbird) is a medium sized (13 cm) and bright coloured sunbird. Both are common resident species in South and West Yunnan (MacKinnon & Phillips 2000). Both species are found in forest edges as well as human habitations and gardens. These two species are commonly found in the Xishuangbanna Tropical Botanic Garden (XTBG).

Hibiscus rosasinensis commonly referred to as 'Tropical hibiscus' or 'Chinese hibiscus' belongs to family Malvaceae and is a popular garden plant in the tropics, as well as some temperate regions. More than a thousand varieties are available, differing in bloom size, colour, and other aspects. The bloom can be single, semi-double, or double, depending upon the variety. Also many colours are available in a single, double or

multi-shades including white, yellow, orange, red, pink, salmon, purple, and so on (www.floraskolkata.com).

Many nectar feeding birds are reported to obtain nectar of flowers by making perforations at the base of the corolla tube or using a hole already made by insects (Navarro 1999). This type of feeding pattern does not effect the pollination of the flower and therefore called nectar robbing. Sunbirds are recorded as feeding on various types of flowers, and it is known that some of these are robbed by puncturing a hole at the base of the corolla (Ali 1932).

The above mentioned two sunbird species were observed feeding heavily at the *Hibiscus* flower garden of the XTBG. Preliminary observations raised the general question of whether the two species of sunbirds prefer some varieties among the large number of varieties of the *Hibiscus rosasinensis* planted in the garden. The main objective of this study was therefore, to investigate the preferences of the Crimson sunbird and Ruby cheeked sunbird to different flower varieties of *Hibiscus rosasinensis*. The main hypothesis of the study was that sunbirds prefer flower varieties of *Hibiscus rosasinensis* with red colour, tubular shape and higher nectar volume over others.

METHODS

The study plot was located in the Xishuangbanna Tropical Botanical Garden (XTBG). A newly established collection of *Hibiscus* species was selected for the study. Different *Hibiscus* species and many varieties of *Hibiscus rosasinensis* are grown here as separate patches in around a 0.5 ha area. Six varieties of *H. rosasinensis* were selected for the study (Table1). Observations were made from 4 to 10 October 2007.

Five trees from each variety were selected for the study. Three levels of parameters were selected for investigation: characters related to host trees, flower morphology, and observations of visitation by sunbirds and butterflies.

Following parameters related to the selected trees were measured, (1) Number of flowers on the tree, (2) Distance to the nearest tree, (3) Variety of the nearest tree, (4) Height of the tree, (5) Number of main branches, (6) Distance to the nearest tree over 2m height.

All the selected trees were marked with a coloured flag for the easy observation from a distance. All the parameters except the number of flowers on the tree, were measured before start the observations. The numbers of flowers on the selected trees were counted each day.

Ten flowers from each variety were collected and measured for the flower morphology. Flowers were collected between 11.00h and 12.00h, and measured immediately. Length and width of the display, length and width of the corolla, lengths of the stigma and stamens, style length of the portion which stamens are attached, were all measured. All the measurements were done using a vernier calliper, which had a precision of 0.05mm. Colours of the petals (display), stigma and stamens were also recorded. For all the varieties, flower openness at full bloom (open or close), petal complexity (simple or complex), odour of the flower (odour or odourless), damage to the petals (damaged or not) were noted. Nectar was extracted from each flower using a micro capillary tube of 20µl volume, and the nectar volume recorded. The percentage of simple (sucrose-like) sugars in the nectar was measured using a refractometer.

Observations on the bird and butterfly visitations were conducted from 08:00 h in the morning to 18:00 h in the evening. Seven time blocks of one hour each were considered for the sampling throughout the day. In each time block, trees of three varieties were observed for bird and butterfly visitations. Observations for one variety were done for 15 minutes in each time block. Light intensity was measured using a Luxmeter twice during the 15 minutes survey sessions. All the observations were done at least 10 m away from the target trees. Binoculars of 8 x 42 were used for the observations. For bird visitations following parameters were recorded. (1) Sunbird species, (2) Number of flowers visited, (3) Number of flowers feed on, (4) Number of flowers visited on the display, (5) Time spent on the tree, (6) Feeding behaviour (whether perching or hovering).

The number of butterflies visiting the selected trees, and the numbers of flowers visited by butterflies in each tree were also recorded.

Statistical analyses were conducted using software R 2.5.1 (R Core team 2007). Linear Discriminant Analysis was done to identify the main parameters, which are important to identify different varieties. To assess the preferences of Sunbird species general linear models (GLM) with a Poisson distribution of the error term was used, with visitation as the dependent variable. A Kruskal-Wallis test was done to compare the visitation of sunbirds on each variety.

RESULTS

Based on the results of the Linear Discriminant Analysis, it was observed that the selected six varieties differentiated in to six groups. It also clearly distinguished small flower varieties in to one major group and larger flower varieties in to another. It also showed that the main factors differentiating the varieties were display length and the display width (Fig.

1). Among the smaller flower varieties, variety 4 was differentiated from the varieties 3 and 5 by the lower nectar volume and sugar concentration. Moreover, from the morphological measurements, one can appreciate that varieties 3 and 5 are tubular shaped flowers.

Observations were made over seven days completing a total of 23 hours. This included 92 sessions of 15 minutes. A total of 741 observations of flower visitations by sunbirds and butterflies were obtained during this period. Visitation rate was calculated as number of flowers visited per hour per tree (Table 2). Time spent on a tree per hour by sunbirds was also calculated (Table 3).

Mean flower visitation against the time period is given in the Fig. 2. Mean number of visitations by sunbirds and butterflies against the different varieties are shown in Fig. 3. Varieties 3, 4 and 5 received more visits by Crimson sunbird and varieties 1, 2 and 6 received more visits by Butterflies.

From the general linear model (GLM), using a Poisson distribution of the error term and flower visitation as the dependent variable, variety was found to have a highly significant effect, with varieties 3 and 5 receiving significantly more visits than other varieties ($P<0.0001$). Modelling revealed a good fit. Comparing these two varieties separately using a Kruskal-Wallis test, Crimson sunbirds showed no significant preference for either variety, but Ruby Cheeked sunbird showed significant preference ($P< 0.015$) for variety 3.

Flower visitation by sunbirds was highly significantly correlated ($P< 0.001$) with the number of flowers on the tree. Results showed that the variety 3 and variety 5 had the highest number of flowers.

TABLE 1. *Six study varieties of Hibiscus rosasinensis*

Variety	Colour	Shape of flowers	Corolla Length/width ratio	Ave. no. flowers on tree	Nectar Vol. (µl.)	% of sugar
1	white	Saucer shaped	0.23	43	0.28	6.37
2	red	Saucer shaped	0.40	5	2.46	7.48
3	red	Tubular	0.53	124	3.95	11.18
4	pink	Saucer shaped	0.26	11	5.69	9.14
5	pale pink	Tubular	0.25	86	1.70	11.70
6	red	Complex	0.30	4	2.28	12.53

TABLE 2. *Visitation rate for Hibiscus varieties as Number of flowers visited per hour*

	Variety 1	Variety 2	Variety 3	Variety 4	Variety 5	Variety 6
Crimson Sunbird	1.143	2.4	57.867	9	44.25	0
Ruby Cheeked Sunbird	0	3.2	47.2	3.25	6.25	0
Butterflies	1.143	4.267	3.733	1.5	4	2.75

TABLE 3. *Time spent on trees by sunbirds*

	Variety 1 Sec hr^{-1}	Variety 2 Sec hr^{-1}	Variety 3 Sec hr^{-1}	Variety 4 Sec hr^{-1}	Variety 5 Sec hr^{-1}	Variety 6 Sec hr^{-1}
Crimson Sunbird	120.05	35.04	397.17	123.45	497.84	0
Ruby Cheeked Sunbird	0	0	393	62.63	177.52	0

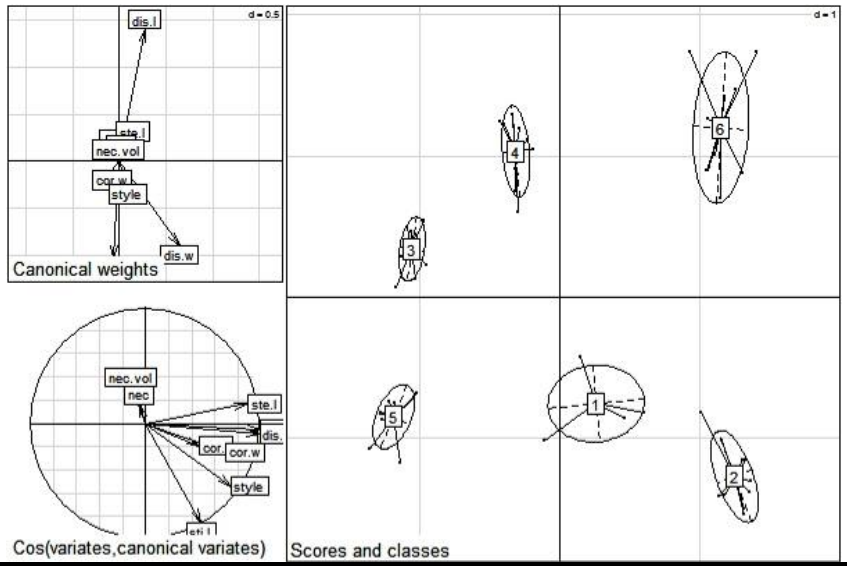

FIGURE 1. Linear Discriminant Analysis for the different flower varieties

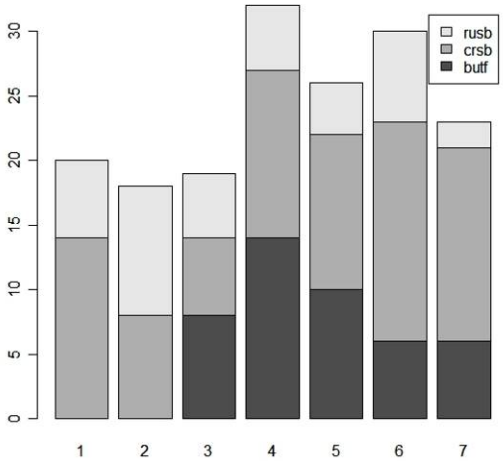

FIGURE 2. Flower visitation in different time blocks from 0800h to 1800h. (butf: Butterflies, crsb: Crimson Sunbirds, rusb: Ruby Cheeked Sunbird).

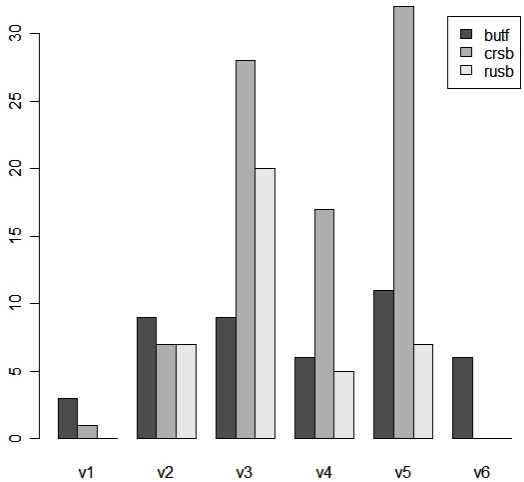

FIGURE 3. Visitation of sunbirds and butterflies for different varieties as mean number of visits per variety (butf: Butterflies, crsb: Crimson Sunbirds, rusb: Ruby Cheeked Sunbird, V1: Variety 1, V2: Variety 2, V3: Variety 3, V4: Variety 4, V5: Variety 5, V6: Variety 6)

Only 69 observations (11.22%) of feeding by sunbirds on the display of the flower were obtained. However, majority (54) of these observations were on the variety 3, which is a small tubular flower. Varieties 2 and 4 which are open at full bloom showed only eight and three feeding efforts on the display respectively. Usually the sunbirds pierced the base of the corolla tube, avoiding the display.

DISCUSSION

Results suggested that two sunbird species preferred the smaller flowers and those that had a higher nectar volume and sugar content. Although varieties 3, 4 and 5 are small flowered, only variety 3 and 5 are tubular shaped, thus another factor that affects flower preference of sunbirds is the shape of the flower. When

the colour of the flowers was considered, no significant preference was obtained over a single colour. Variety 3 and 5 which showed high visitation rate, were different in colour. Visitation rate was higher in variety 3, which has red colour, than variety 5, which has pale pink colour. However, the lesser visited varieties 2 and 6 were also red coloured. Hence, it can be concluded that the colour of the flower is not a significant factor for sunbird preference in XTBG. Our main hypotheses were proven correct by these results.

When considered separately, Crimson sunbird showed more generalised preference for the two varieties, while the Ruby cheeked sunbird showed higher preference for the variety 3.

The correlation between number of flowers visited and the number of flowers present on the tree can be easily explained by the energy budget of the birds. When number of flowers on the tree is higher, energy expenditure for moving between flowers is reduced. It can be identified as a possible triggering factor for the preference for variety 3 and 5. Both species of sunbird showed the same response to the number of flowers on the tree when considered separately.

Most flowers pollinated by sunbirds are bilabiate, tubular, or, in a few cases, brush-shaped (Corlett 2004). Both the preferred varieties showed the tubular shape and smaller size, agreeing with the above statement. Fenster *et al.* (2004) showed that a higher visitation rate does not necessarily provide better pollination. Findings of this study indicate a similar result, since 89 percent of the feeding visits by both species of sunbirds involved nectar robbing. Contribution to the pollination of these *Hibiscus* plants by sunbirds must be nominal.

ACKNOWLEDGEMENTS

We would like to thank Dr. Rhett Harrison and Mr. John Harting for their comments and support on statistical analysis. We are also grateful to Mr**.** Charlie D. Heatubun for sharing his expert knowledge in field botany with us.

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Variation in Orthopteran and Homopteran Community Acoustic Signatures across Two Habitats in Xishuangbanna Tropical Botanic Garden, Yunnan Province, China

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ABSTRACT

Insect song recordings from a secondary rainforest and an open habitat in the premises of XTBG were used to identify acoustic species belonging to Orders Homoptera and Orthoptera. I generated song spectrograms and obtained dominant frequency values. The species composition in the two habitats was distinctly different with an overlap of only one species. There was a higher representation of Homopterans in the rainforest, while the open habitat was dominated by Orthopteran songs. I also analysed the effect of temperature and humidity on song frequencies in a habitat. This study demonstrates that the diversity of insect songs can be used as a measure of Orthopteran and Homopteran species richness and abundance.

Key words: acoustic species, dominant frequency, insect songs, species composition

AMONG INSECTS, MANY ORTHOPTERA (crickets, katydids and grasshoppers) and Homoptera (cicadas) have established systems of acoustical communication mostly for mate finding. Signals are species-specific in temporal pattern, and often also in carrier frequency (Otte 1992) and have been used to identify even cryptic closely related species. Larger active calling ranges reach more females, and selection is therefore expected to act on males to produce increasingly loud signals until the benefit of increased loudness is balanced by energetic or predation costs. Temperature and humidity are known to play a role (developmental and evolutionary) in the sound characteristics of an insect song. High humidity causes absorption loss in sound waves, while high temperature increases pulse rates and carrier frequencies (Walker 1974).

It has been suggested that calling behaviour is energetically disadvantageous in colder and more humid environments, and selection may have restricted it to warm and less humid habitats. I used song types to identify acoustic species in XTBG. I hypothesised that habitats with higher temperatures and lower humidities would harbour a greater number of singing insects with higher mean carrier frequencies. I also sought to compare song types across two habitats in XTBG in an effort to get a measure of species composition of these often cryptic animals. Many Orthoptera are sensitive indicator species for habitat quality in temperate and tropical ecosystems. Since every habitat has its typical composition of signalling insect species, biotic sound can be used for the characterisation of the habitat (Nischk & Reide 2001). I focussed on Homopteran and Orthopteran songs since recording these is easier. Orthopteran families such as Katydids were omitted since their songs are in the ultrasonic frequency range and cannot be recorded with a microphone.

METHODS

This study was conducted in the Xishuangbanna Tropical Botanical Garden (21˚55’ N, 101˚15’ E). Song recording visits were made to the open habitat (Garden area) and the secondary rainforest at dawn (6:00 - 7:45 hrs), mid-day (12:30 – 14:00 hrs), dusk (18:30 – 20:00 hrs) and night (22:30 – 1:00 hrs). I used a Digital Voice recorder (Pentastic MP3 pro) and Sony microphone to record any insect sounds heard during the time. The sampling method involved recording every song heard, excluding those of birds and frogs.

SONG ANALYSIS.— From a total sample of 126 songs recorded, 54 clear recordings were used for generating spectrograms. Each distinct sounding song was treated as an acoustic species and where possible identified to the level of Order or Family. In instances with more than one recording a type of song, the mean dominant frequency was computed. These were treated as the carrier frequency estimate for that individual. The frequency composition of the calling songs was analysed with the R 2.5.1 signal analysis package Seewave (Sueur *et al*. 2006) with a 22.05 kHz sample rate and 8-bit resolution. The spectrogram was used to generate the mean dominant frequency of each song. Spectrograms of closely resembling songs were compared using the Raven Lite software (Cornell Lab of Ornithology).

STATISTICS.— I used a randomisation test to avoid the problem of non-independence. I shuffled the habitats in which each of the song frequencies were found and calculated a deviation statistic based on the mean dominant frequency in each habitat type: S[(Randomized ÿ Expected)2 / Expected]. The statistical significance of observed mean difference of frequency between the two habitats was assessed by permuting the grouping vector to obtain the empirical distribution of the mean difference of frequency under a null-model. F test for comparing variances was used to look at dominant frequency types at four time slots – dawn, day, dusk and night. The habitat preference of Homopteran and Orthopteran families was tested using a Pearson's Chi-squared test with Yates' continuity correction.

RESULTS

A spectrogram was generated for each insect song and the value of dominant frequency was extracted from it; this value was used for all comparisons and correlations (Fig. 1 & 2).

TIME OF SINGING.— A boxplot of the dominant frequencies of the different songs plotted against time of day revealed a greater range of dominant frequencies during the night (Fig. 3). Songs at dawn were of a higher dominant frequency than other parts of the day. Song frequencies at dawn were significantly different from those at dusk, day and night, all tested separately using F test (p-value < 2.2e- 16). I generated a barplot depicting the larger number of Homopteran and Orthopteran acoustic species calling after dusk and during the night. No Orthopteran songs were recorded during the day visits (Fig. 4).

EFFECT OF TEMPERATURE AND HUMIDITY.— The dominant or carrier frequencies of all the fifty-four songs were plotted against temperature at the time of recording (Fig. 5). There was a greater range of dominant frequencies in recordings made at a higher temperature. The frequencies were also plotted against relative humidity. There was a greater range of dominant frequencies in recordings made at a lower humidity (Fig. 5).

HABITAT ASSOCIATIONS.— Of the total fifty-four songs analysed, twenty three distinct acoustic species were sorted out. Nine of them were recorded exclusively from the open habitat - 4 Tettigonidae (Orthoptera), 1 Gryllidae (Orthoptera), 2 Hompterans, 2 uncertain Orthopterans. Twelve songs were heard only in the rainforest – 8 Homopterans, 2 Tettigonidae (Orthoptera), 2 uncertain Orthopterans. One Gryllotalpidae (mole cricket family, Orthoptera) member was found common to both habitats. A barplot shows higher representation of Homopterans in the rainforest and a higher representation of Orthopterans in the open habitat (Fig. 6). The number of Homopteran and Orthopteran families found in the two habitat types was subjected to a Pearson's Chi-squared test with Yates' continuity correction and was found to be significantly different (p value = 1.850e-05).

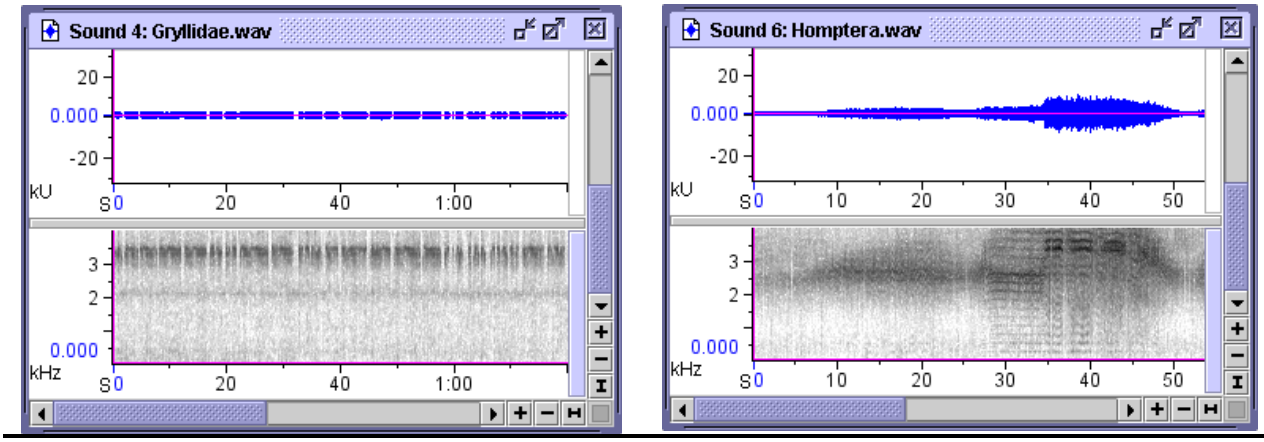

FIGURE1. Spectrograms generated using Raven Lite software, (left) of a Gryllidae (Orthoptera) with a pulsated high frequency distribution, and spectrogram (right) of a rainforest Homopteran composed of a dominant frequency (high pitched) and a fundamental (lower) frequency.

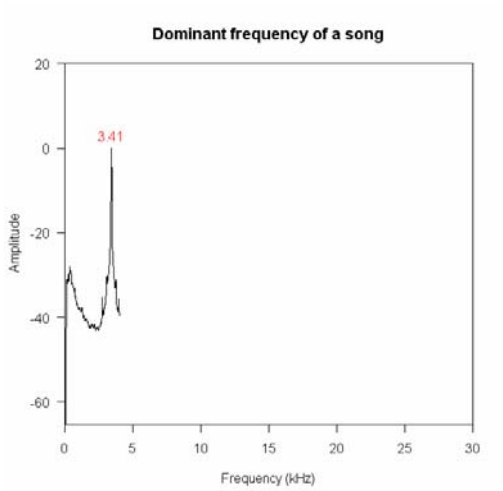

FIGURE 2. Mean frequency spectrum generated using R (seewave package), showing the dominant frequency of a Tettigonidae song.

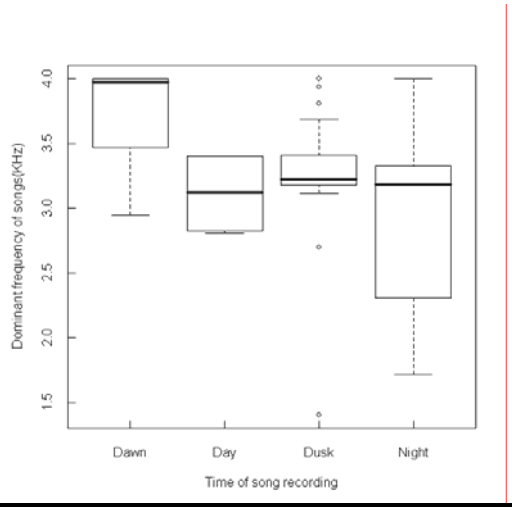

FIGURE 3. A boxplot of the dominant frequencies of all the 54 recorded songs plotted against time of day; song frequencies at dawn were significantly different from those at dusk, day and night, all tested separately using F test (p-value < 2.2e-16).

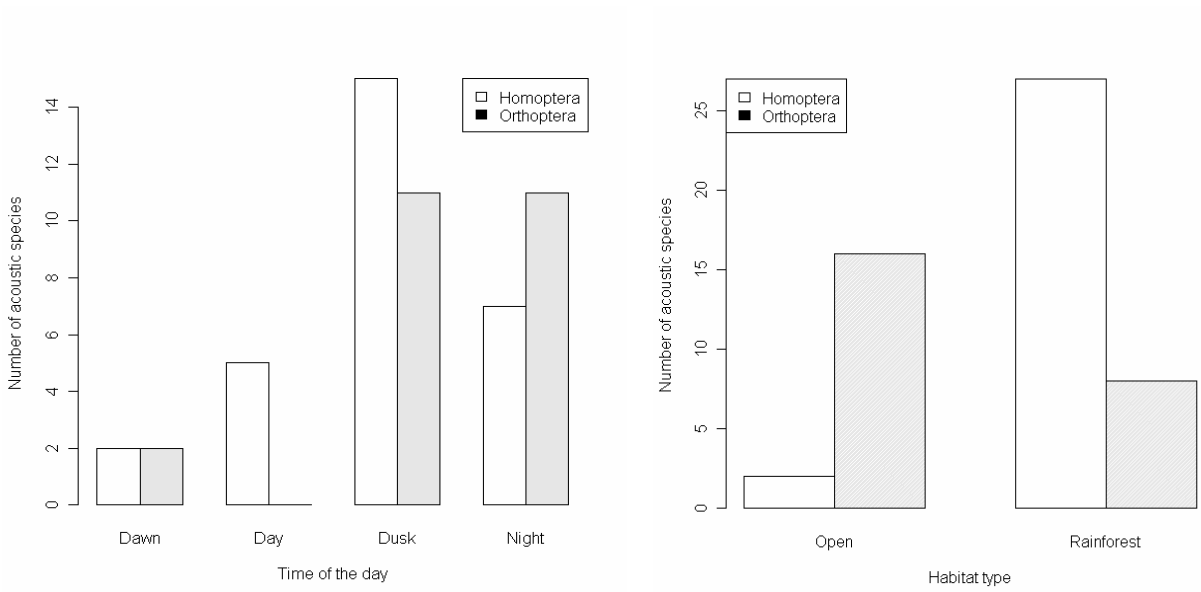

FIGURE 4. (Left) Barplot showing the concentration of Homopteran and Orthopteran songs at dusk and during the night, and (Right) higher incidence of Homopteran songs in the rainforest and more Orthopterans in the open habitat

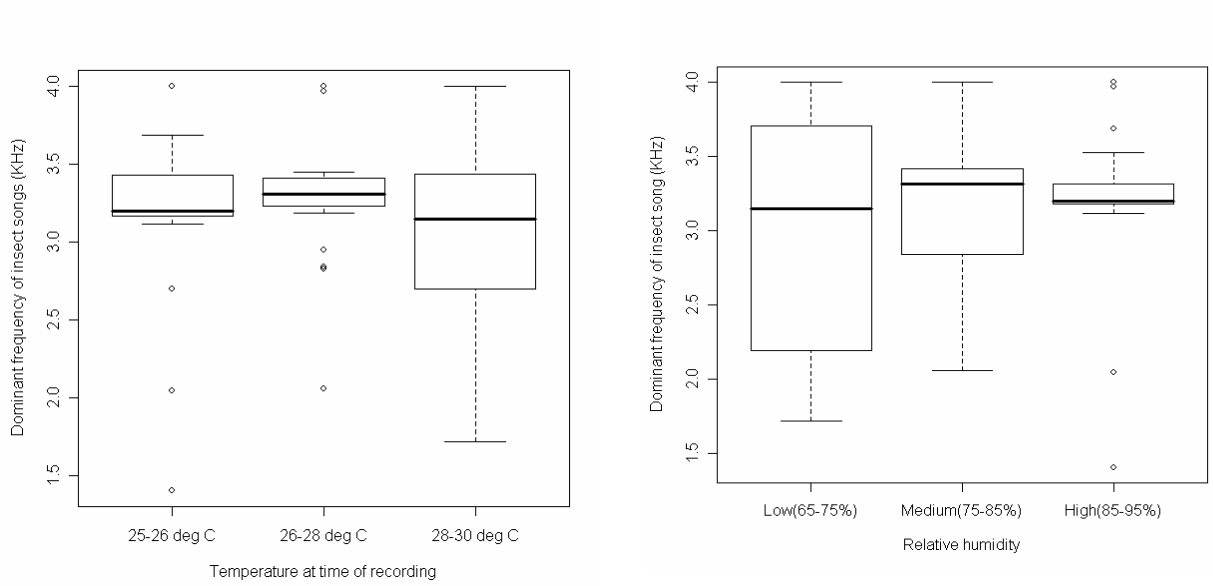

FIGURE 5. Range of dominant frequencies of insect songs (KHz) under different levels of temperature and humidity.

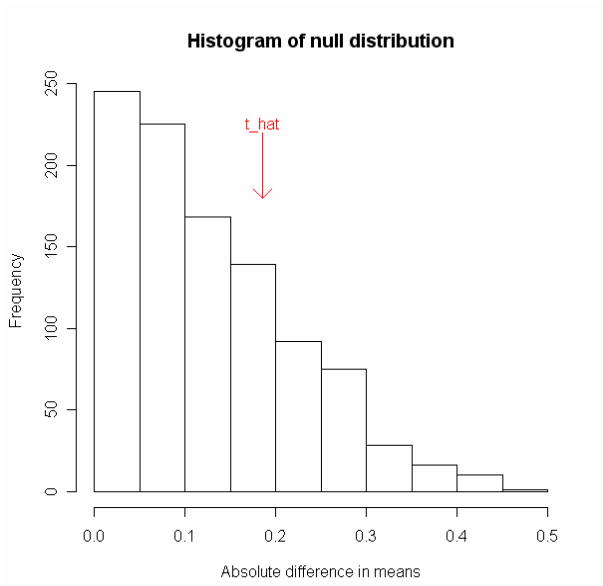

FIGURE 6. Histogram of randomised data with the observed (t-hat) value. P-value = 0.255, indicating that the observed difference in mean dominant frequency between habitats is not significantly greater that the expected.

The randomisation test for comparing mean dominant frequency between the two habitats revealed no significant difference in the mean dominant frequency (p value = 0.255).

Lower carrier frequencies (2-3 KHz) in the rainforest were produced by Homopterans and higher frequencies (3- 4 KHz) seemed to be a characteristic feature of Tettigonidae (family of long horned crickets). Most songs fell under the 3- 4 KHz class of dominant frequency (Fig. 7).

DISCUSSION

Signal evolution in insects is known to have evolved under the influence of sexual selection as well as environmental constraints such as temperature (Forrest 1994). I expected insects with higher carrier frequencies to be common in the open habitat where temperatures are higher. Similarly humid environments absorb sound and thus most singing insects evolved to sing in less humid conditions. There was no drastic variation in temperature and humidity between the two sites and even when there was a fluctuation, it was similar in both habitats. Thus my predictions were not borne out. However, I found Orthopterans (with a higher carrier frequency) more common in the open habitats and Homopteran songs were more common in rainforests.

Habitat associations of songs have been studied in detail in several Orthopteran species. Many field crickets for instance, occupy open, non-forested habitats or disturbed areas, with some species

associated with particular moisture regimes or soil types (Harrison *et al.* 1995)

In the absence of taxonomic expertise, songs are excellent features for classification of recognisable taxonomic units (RTUs), which can be used to measure Orthopteran and Homopteran diversity (Riede 1992), although this would be effective with an overlapping with a taxonomic survey using morphological traits. All the songs with their analyses will be deposited at the library or entomology archive at XTBG for any further reference for future researchers.

ACKNOWLEDGEMENTS

Dr Rhett Harrison's interest and suggestions made this project materialise. I wish to thank Dr Klaus Riede of the Zoological Research Institute and Museum, Bonn, Germany for his invaluable and timely help in identifying the insect songs and for the 'long-distance supervision'. Thanks to Martin Stenflo for generously offering his microphone and MP3 recorder, to John Harting for being the ever-patient statistical crisis-solver.

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The Importance of Accessory Bracts *of Mussaenda erythrophylla* in Attracting Lepidopteran Flower Visitors

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ABSTRACT

Experiments were carried out to test the effect of bract colour and bract area of *Mussaenda erythrophylla* (Rubiaceae) in attracting butterfly visitors. A total of 31 hours of observation was carried out in Xishuangbanna Tropical Botanical Garden. Six Lepidopteran species of *M. erythrophylla* flower visitors were recorded. Bract area was determined to be important in attracting Lepidopteran flower visitors at both long- and short- distances. Second to the natural bract, the artificial orange bract was also shown to be a comparably effective visual signal to the butterflies.

Key words: artificial bract, artificial flower, flower scent, pollinator, Rubiaceae.

ANIMAL - POLLINATED FLOWERS DEVELOP many ways to attract pollinators, including distinct smell, large inflorescence or colourful flowers. Bracts are nonfloral showy structures associated with inflorescences. Where they are colourful or enlarged, they are generally thought to enhance plant reproductive success by attracting pollinating insects and are, therefore, often associated with small and inconspicuous flowers. Studies have shown that the white bracts of *Mussaenda frondosa* (Rubiaceae) attract both long-ranging pollinators, such as the birdwing butterfly *Troides minos*, and short-ranging territorial butterflies to visit the low-density small flowers (Borges *et al.* 2003). The contrast between white bracts and green leaves of *M. frondosa* presents a strong visual signal to flower visitors. *Mussaenda erythrophylla* (Rubiaceae) on the other hand, has showy red bracts. There are a number of reports describing the relationship between coloured stimuli and certain behaviour patterns of butterflies. Pioneering work (Ilse & Vaidya 1955) showed that foraging *Papilio demoleus* (Papilionidae) spontaneously visited artificial flowers coloured blue and purple. *Pieris napi* (Pieridae) was shown to feed on artificial flowers of certain colours; the preferred colour varied among individuals. In this study we investigate the importance of the red bracts of *M. erythrophylla* in attracting flower visitors, and the effectiveness of other colour contrasts between bracts and leaves of *M. erythrophylla* using artificial bracts. The role of the flower in attracting flower visitors was also investigated. Our hypotheses were: a) *M. erythrophylla* flowers with reduced bract area are less efficient in attracting flower visitors; b) natural leaf-bract colour contrast is more efficient than other colour contrasts, and c), scent of *M. erythrophylla* plays a role in attracting flower visitors.

METHODS

STUDY SITE AND STUDY ORGANISM.— Xishuangbanna Tropical Botanical Garden (XTBG) (21º 55' N, 101º 15'E) is located at Menglun county in Yunnan Province, southwest China. *Mussaenda erythrophylla*, originally from West Africa was introduced to the garden as an ornamental plant. In *M. erythrophylla*, usually four flowers per inflorescence (*i.e.* the terminal flowers of the lower four partial inflorescences) bear brightly red coloured enlarged calyx lobes (bracts); the other flowers only have small, (sub) equal calyx lobes. The *M. erythrophylla* flowers in XTBG open at around 09:30 h and close around 18:00 h. They are, therefore, only visited by diurnal pollinators. Six different species of butterflies, *Menelaides noblei, Menelaides helenus, Menelaides memnon, Menelaides polytes, Menelaides nephelus, Hebomoia glaucippe*, were recorded to visit the flowers.

FLOWER VISIT EXPERIMENT. — Three bushes of *M. erythrophylla* were located in Xishuangbanna Tropical Botanical Garden (XTBG) for observation over five days. On each day each of the two observers was randomly assigned to a bush, except on two days when one bush had to be avoided due to the high tourist

traffic. A portion of the bush with 21 inflorescences was selected every day for focal observation from 10:00h to 17:30h in 30-minute sessions. A total of 31 hours of observation was done over the five-day period. Our experiment had six treatments and one control. There were three replicates each, and each inflorescence was randomly assigned with a treatment or as a control. The six treatments were bract area treatments, including 100 percent reduction and 50 percent reduction, and bract colour treatments, including blue, orange, and white, and an artificial flower treatment. Bract area reductions were attained by covering the bracts with *M. erythrophylla* leaves. Bract colour changes were achieved by pinning colour cloths to cover the upper surfaces of the *M. erythrophylla* bracts. Artificial flowers made of cloth resembling the real *M. erythrophylla* flowers were fixed to the inflorescences without any flower. Each inflorescence was standardised to have four bracts and one flower. Each flower visitation by butterflies within the focal watch area was recorded.

BUSH VISIT EXPERIMENT.— To test the density effect of *M. erythrophylla* bracts in attracting butterflies at long distance, one bush was chosen and divided into two halves for control and treatment respectively. The two sides of the bush were maintained for equal density and number of inflorescences (30 inflorescences on each side, of which nine had one flower only and the rest no flower). On the treatment side of the bush all bracts were covered with *M. erythrophylla* leaves to attain 100 percent bract area reduction. For each butterfly visiting the *M. erythrophylla* bush, the side where the butterfly first landed was noted and the number of flowers visited on each side was counted.

STATISTICAL ANALYSIS.— Data were analysed using R 2.5.1 (R Development Core Team 2007). The number of visitations was changed to a proportion of visits over each half-day period per bush to accommodate the large fluctuations in abundance of flower visitors. The proportions were then Arcsin transformed. A linear model was used to assess the effects of different treatments on the visitation rate to *M. erythrophylla* flowers by butterflies. Tukey Honest Significant Difference Test was used for pairwise comparisons between the means of the control and all the treatments. An Exact binomial test and Wilcoxon rank sum test were carried out on the bush treatment result.

RESULTS

The total visitations by butterflies to *M. erythrophylla* flowers are shown in Fig. 1. The Arcsin transformed proportional visitation data have a normal distribution therefore a linear model was used to evaluate the effect of each treatment (Table. 1). All the treatments had lower visitation rates than the control (base for the comparison), although the half bract area reduction (treatg 50, p-value = 0.033878) and orange bract (treato, p-value = 0.009947) had relatively higher visitation rates (Fig. 1, Table 1). Tukey Honest Significant Difference Test showed that the pairwise differences between these two treatments and the control were not significant, but all others were significant (Table 2).

Out of the 50 visitations by butterflies to the *M. erythrophylla* bush treatment, 42 first landed on the control side of the bush showing a higher attraction compared to the side of the bush with all bracts covered (Exact binomial test, p-value = 0.0009105). The number of flowers visited on the control side was also significantly higher (Wilcoxon rank sum test, W = 476.5, p-value = 0.001261).

DISCUSSION

The large red bract of *M. erythrophylla* was shown to be effective in attracting butterflies. This is not surprising as red colour has long been considered a 'butterfly colour' (Kearns & Inouye 1993). During our experiment we noticed that the some butterflies that visit *M. erythrophylla* flowers are also frequently attracted to a red jacket hanging nearby. It is also expected that reducing the bract area by half reduced the visitation frequency, but still attracted more flower visitors than 100 percent bract area reduction. As suggested by this study, white and blue did not serve as good visual signals to the six butterfly species that visit *M. erythrophylla*. Interestingly, white coloured bracts naturally occur in other *Mussaenda* species, *e.g. M. frondosa* and *M. flava*, and have been shown to be effective in attracting butterflies and it was suggested that this may have to do with the bract's ultraviolet (UV) absorbing attribute (Borges *et al.* 2003). It is not clear whether the white artificial bract used here absorbs UV. Orange colour appeared be a strong visual cue for butterflies (Fig. 1, Table 1 & 2). Spectral reflectance tests of all the artificial colour treatments may be able to shed more light in this aspect. *Mussaenda erythrophylla* inflorescences with artificial flowers were able to attract butterflies to hover around but recorded very few landings.

There are two possible reasons: a) butterflies can easily detect the morphological difference between a real flower and a fake flower at a short distance, or b) the mild sweet scent of *M. erythrophylla* flowers plays an important role as a short distance signal. Further studies should be designed to separate the effect of flower scent.

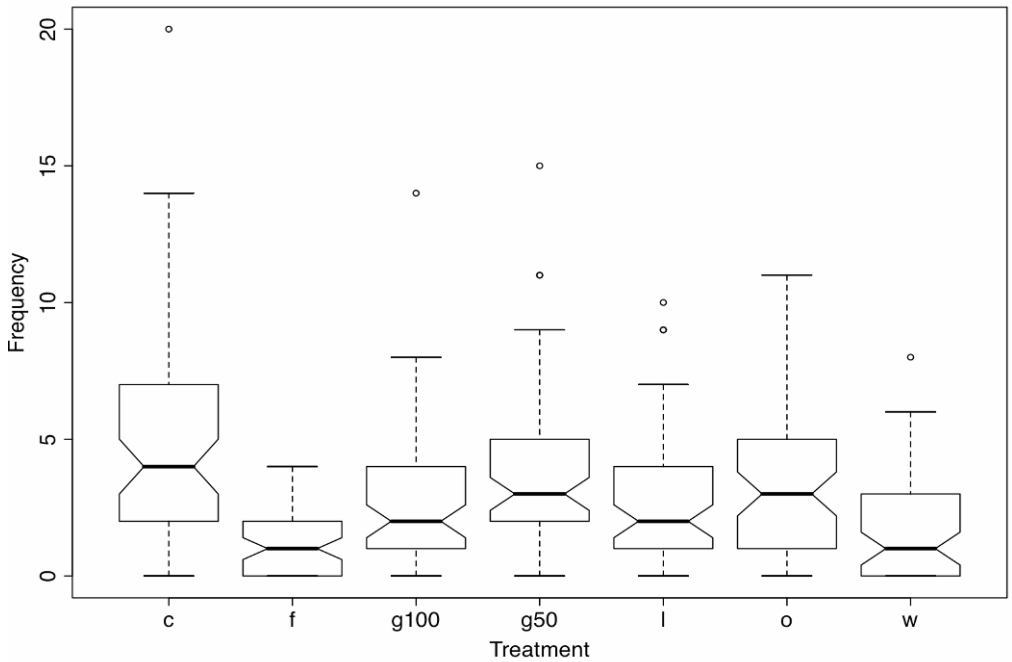

FIGURE 1. Comparison of total visitation frequency by butterflies to M. erythrophylla control and treatment flowers

TABLE 1. *Linear modelling for effects of different treatments on visitation to M. erythrophylla flowers by butterflies. treatf: artificial flower; treatg100: 100% bract area reduction; treatg50: 50% bract area reduction; treatl: blue bract; treato: orange bract; treatw: white bract.*

Residuals:				
Min	1Q	Median	3Q	Max
-0.083654	-0.022449	-0.004952	0.020284	0.096203
Coefficients:				
-0.083654	-0.022449	-0.004952	0.020284	0.096203

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.23684	0.01691	14.007	6.49e-16 ***
treatf	-0.18695	0.02391	-7.818	3.47e-09 ***
treatg100	-0.08182	0.02391	-3.422	0.001600 **
treatg50	-0.05280	0.02391	-2.208	0.033878 *
treatl	-0.10217	0.02391	-4.273	0.000141 ***
treato	-0.06518	0.02391	-2.726	0.009947 **
treatw	-0.16895	0.02391	-7.065	3.15e-08 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.04142 on 35 degrees of freedom
Multiple R-Squared: 0.7208, Adjusted R-squared: 0.673
F-statistic: 15.06 on 6 and 35 DF, p-value: 1.964e-08

The bush treatment indicated that a higher density of red bracts of *M. erythrophylla* attracts the butterflies to land on the bush. This should facilitate pollen dispersal by attracting long-ranging butterflies (Borges *et al.* 2003).

This study was limited by availability of *M. erythrophylla* (only 3 bushes) and weather conditions (most of the 5 mornings were rainy). Due to high variation in counts across different time periods and locations we used the frequency proportions instead of counts in our model. However, this covers up the effects of bush and time. Considering the spatial scale of this study, the population of butterflies that visit our flowers is expected to be small (we were able to recognize several individuals). Butterflies have been shown to have short-term learning ability (Stanton 1984, Goulson & Cory 1993) and hence the results may contain a certain degree of individual bias.

TABLE 2. *Pairwise comparisons of means between all treatments*

Tukey multiple comparisons of means
95% family-wise confidence level
Fit: aov(formula = mussprop.lm)

$treat	diff	Lwr	upr	p adj	
f-c	-0.18694931	-0.26169821	-0.112200415	0.0000001	***
g100-c	-0.08181838	-0.15656728	-0.007069487	0.0243098	*
g50-c	-0.05280254	-0.12755143	0.021946363	0.3171245	
l-c	-0.10216934	-0.17691824	-0.027420445	0.0024628	**
o-c	-0.06518401	-0.13993291	0.009564886	0.1215955	
w-c	-0.16894596	-0.24369486	-0.094197065	0.0000006	***
g100-f	0.10513093	0.03038203	0.179879826	0.001732	**
g50-f	0.13414678	0.05939788	0.208895676	0.0000486	***
l-f	0.08477997	0.01003107	0.159528869	0.0177312	*
o-f	0.1217653	0.0470164	0.196514199	0.0002275	***
w-f	0.01800335	-0.05674555	0.092752248	0.9878863	
g50-g100	0.02901585	-0.04573305	0.103764747	0.8842205	
l-g100	-0.02035096	-0.09509986	0.05439794	0.9773581	
o-g100	0.01663437	-0.05811453	0.09138327	0.9920073	
w-g100	-0.08712758	-0.16187648	-0.012378681	0.0137388	*
l-g50	-0.04936681	-0.1241157	0.02538209	0.3949606	
o-g50	-0.01238148	-0.08713037	0.062367421	0.9984121	
w-g50	-0.11614343	-0.19089233	-0.04139453	0.0004554	***
o-l	0.03698533	-0.03776357	0.111734228	0.715451	
w-l	-0.06677662	-0.14152552	0.007972277	0.1057068	***
w-o	-0.10376195	-0.17851085	-0.029013053	0.002039	**

Overall our study has confirmed the importance of the red showy bracts of *M. erythrophylla* in attracting butterflies for pollination at both long and short distances. Second to the natural red colour, orange colour is shown to be a relatively effective visual signal to the butterfly species that visit *M. erythrophylla*. The mild scent of *M. erythrophylla* flowers is also potentially a short distance cue for butterflies.

ACKNOWLEDGEMENTS

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Density-Dependent Herbivory in a Native Understory Herb, *Alocasia macrorrhiza* (Araceae)

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ABSTRACT

Herbivores may be one of the main top down controls on the population dynamics of native plant species. The aroid, *Alocasia macrorrhiza*, produces latex upon attack, while the leaf beetle, *Aplosonyx*, makes trenches before feeding to evade the plant's defenses. I surveyed 30 *A. macrorrhiza* clumps in the secondary forest at Xishuangbanna Tropical Botanical Garden to investigate the importance of density-dependent effects. Mean number of trenches per individual varied from 2.7 to 164 and averaged 35.3 ± 8.0 (mean ± SE) among clumps. The intensity of herbivory in *A. macrorrhiza* was best predicted by the minimum distance to the nearest two clumps, but not by number of individuals in a clump. *Alocasia macrorrhiza* can reproduce asexually by rhizomes and few insects can feed on its latex-producing leaves, so it has potential to be invasive plant in alien environment without the leaf beetles *Aplosonyx*.

Key words: aroid, herbivore, leaf beetle, invasive species

THE POPULATION DENSITY OF A PLANT SPECIES may be constrained by it natural enemies. Herbivores are one of the principle enemies given their huge number and biomass. Plants develop various responses such as thorns or poisonous chemicals to resist the herbivores. However, specialist herbivores can evade the host plant defense through specialised digestive organs or feeding behaviour. This may result in reciprocal evolution between specialist herbivores and their host plants. *Alocasia* (Araceae) and the leaf beetle, *Aplosonyx* (Chrysomelidae), is a good example of this phenomenon (Darling 2007).

Alocasia is an important component of the understory herb layer in tropical forest of Southern China and Vietnam. The leaves of *Alocasia* have laticifers, which produce latex and the cut leaves and stems have a stronger smell of cyanide (Darling 2007).

Aplosonyx adults cut circular trenches from the undersurface of the leaves using their mandibles prior to feed on the leaf tissues of *Alocasia*. The cuts initiate the release of latex from the undersurface of the leaves. Then, the beetle consumes the tissues enclosed by the trench. Near perfectly circular holes are formed in the leaf surface after the remaining small pieces of leaf tissue within trenches wither and fall off. Previous anecdotal observations found that leaves of *Alocasia macrorrhiza* in high-density clumps have many holes, while scattered individuals appeared to have only a few holes. Hence, here I address the question: Do *A. macrorrhiza* in high density clumps suffer more severe herbivory than in low density clumps?

METHODS

STUDY SITE.— This project was conducted in the Xishuangbanna Tropical Botanic Garden (21º55' N, 101º15' E), Mengla County, Yunnan Province, China. The annual mean temperature is 21°C, with the hottest month at 24.6°C, and the coldest month at 15.2°C (Zhu *et al.* 1998); the annual precipitation is 1532 mm, with 282 mm in the dry season (November to April), and 1250 mm in the wet season (May to October) (Zhu *et al.* 1998).

STUDY ORGANISM.— *Alocasia macrorrhiza* (Araceae) occurs naturally in the understory of tropical forests below 1100m altitude in Yunnan Province. It also occurs in India, Laos, Sri Lanka, Thailand, Cambodia, Vietnam, and Philippines (Kunming Institute of Botany 2007). *Alocasia macrorrhiza* is a massive perennial with huge elephant-ear shaped leaves, 0.9-1.8 m in length and 0.6-1.2 m wide, borne on petioles 0.6-1.2 m long. The petioles emerge from a stout upright trunk that can stand up to 1.8 m tall. In the typical form, the leaves are glossy medium green with paler veins. The greenish spathe and spadix stands 20.3-25.4 cm tall and is not particularly showy. Flowering time is from April to July (Kunming Institute of Botany 2007)

DATA COLLECTION.— I defined a clump as a group of individuals which can be spatially separated from other groups (clumps) by a minimum distance of 5 m. I surveyed 30 *A. macrorrhiza* clumps occurring in Xishuangbanana Tropical Botanical Garden and recorded the location of each clump with a GPS

(Megellan explorist 400, Thales Navigation). In each clump, I counted the number of individuals and measured the minimum distances to the nearest three clumps. For each individual within a clump, I counted the number of circular trenches in each leaf from the oldest to the youngest. For large clumps, I counted holes on 7 to 10 individuals selected randomly.

DATA ANALYSIS.— I calculated the mean number of circular trenches per individual in the clump. Because the circular trenches mainly occur in the first two mature leaves, I also calculated the mean number of trenches in the first and second leaves in a clump and used as another indicator for plant herbivory intensity. After the log-transformation, the variables were normally distributed. I used the linear model (lm) with herbivory intensity as the dependent variable and plant density as the independent variable. I used number of individuals in the clump (clump size) and the minimum distances to nearest three clumps as indicators for plant density (log transformed). The analyses were carried out using R Package (R Development Core Team, 2007).

RESULTS

A. macrorhhiza usually has three to five leaves. The mean number of circular trenches on the first leaf was 19.1 ± 2.2 (mean ± SE), with 13.9 ± 1.7 on the second leaf, 5.8 ± 0.9 on the third leaf and only 2.0 ± 0.4 on the fourth leaf. For individuals, the number of trenches varied from 0 to 334 and averaged 40.3 ± 4.5 (mean ± SE). Mean number of trenches on the first two leaves per individual varied from 2.7 to 164 and averaged 35.3 ± 8.0 (mean ± SE) among clumps.

TABLE 1. *Linear model of the number of trenches per individual predicted by the minimum distances to the nearest two clumps of Alocasia macrorrhiza at Xishuangbanna Tropical Botanical Garden.*

	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
Intercept	16.6230	4.9209	3.378	0.00231 **
log(min.dist1)	-3.8268	1.4235	-2.688	0.01236 *
log(min.dist2)	-3.3580	1.4628	-2.296	0.03002 *
log(min.dist1):log(min.dist2)	0.9035	0.3860	2.341	0.02720 *

Note: Significance. codes: 0.001 '**' 0.01 '*'
Adjusted R-squared: 0.2772
F-statistic: 4.708 on 3 and 26 DF, p-value: 0.009365

TABLE 2. *Linear model of the number of trenches on the first two leaves predicted by the minimum distances to the nearest two clumps of Alocasia macrorrhiza at Xishuangbanna Tropical Botanical Garden.*

	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
Intercept	17.4208	5.1546	3.380	0.0023 **
log(min.dist1)	-3.9718	1.4911	-2.664	0.0131 *
log(min.dist2)	-3.7373	1.5323	-2.439	0.0219 *
log(min.dist1):log(min.dist2)	0.9706	0.4043	2.400	0.0238 *

Note: Significance. codes: 0.001 '**' 0.01 '*'
Adjusted R-squared: 0.2129
F-statistic: 3.615 on 3 and 26 DF, p-value: 0.02639

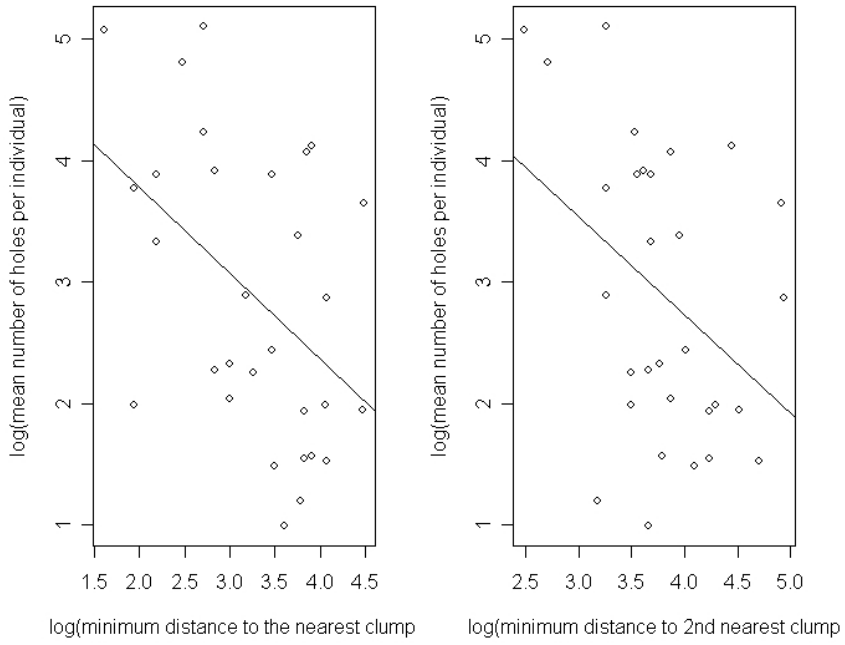

FIGURE 1. The mean number of trenches per individual predicted by minimum distance to the nearest clump and second nearest clump, in *Alocasia macrorrhiza*.

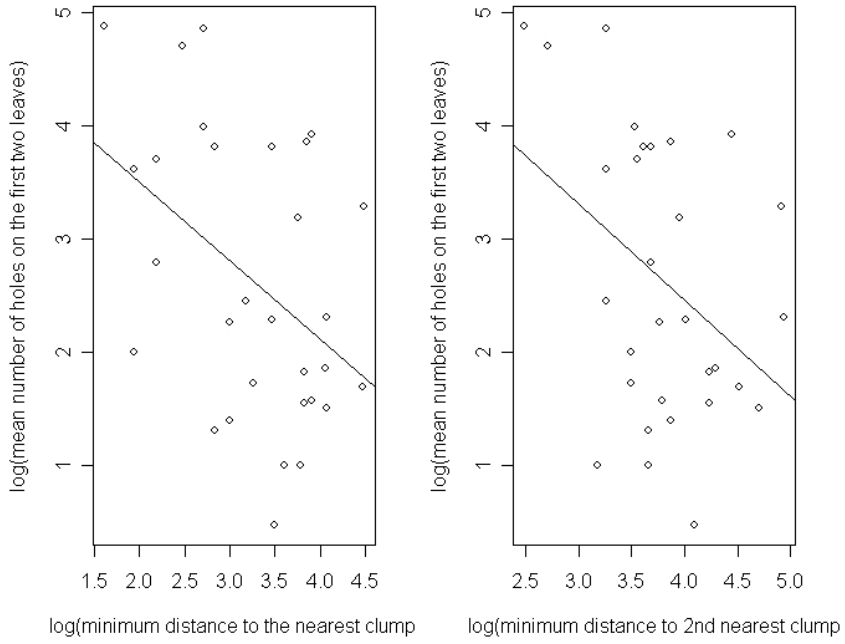

FIGURE 2. The mean number of trenches on the first two leaves predicted by minimum distance to the nearest clump and second nearest clump, *Alocasia macrorrhiza*

The clump size varied from 2 to 125 individuals. The common clump sizes were from 7 to 29 individuals and the mean clump size was 26 ± 5.7 (mean ± SE) individuals. The minimum distance to the nearest clump ranged from 5 m to 89 m and averaged 34 ± 4.1 m (mean ± SE). The second nearest distance was from 12 m to 140 m and averaged 53 ± 5.9 (mean ± SE) m. The third nearest neighbor distance was from 15 m to 166 m and averaged 70 ± 6.5 (mean ± SE) m.

Using a linear model, the mean number of trenches per individual among clumps was best predicted by the minimum distance to the first and the second nearest neighbor clumps (Table 1; Fig. 1), but not by clump size or the minimum distance to the third nearest neighbor clump. The mean number of trenches on the first two leaves could also be predicted by the minimum distance to the first and second nearest neighbor clump (Table 2; Fig. 2). Again, clump size and the minimum distance to the third nearest neighbour clump were not significant predictors of the herbivory on the first and second leaves.

DISCUSSION

Herbivory intensity in *A. macrorhhiza* was best predicted by the minimum distance to the nearest and second nearest clumps, but not by the number of individuals in the clump. Thus, clump density rather than clump size was a better predictor of the intensity of herbivory. In a certain area, the more clumps there were, the more severe herbivory.

Severe herbivory can greatly reduce the leaf area and consequently reduce the photosynthetic products, which is the energy source of plants. The circular trenches in the leaves may also facilitate the infection by fungus and bacteria. For example, I often observed yellow spots around the holes made by leaf beetles. Leaves with many holes were also easily torn up by wind. So, the growth of *A. macrorrhiza* is probably greatly affected by the leaf beetles. As a result, the leaf beetle, *Aplosonyx,* may have a substantial effect on population dynamics of *A. macrorrhiza* by density-dependent herbivory.

Population dynamics of many herb species is comparatively stable in their native habitat. One of the reasons is that herbivores or other enemies constrain the population growth through density-dependent effects. Many alien species become invasive in new environments because there have few natural enemies, especially herbivores, in the new environment. For example, water hyacinth (*Eichhornia crassipes* Pontederiaceae), one of the worst weeds in the world, is a native aquatic herb in South America. In South America, there are more than 200 species of insects feeding on it and it is not an ecological problem. However, since its introduction or escape to other continents, it has become an invasive species. Without its herbivores, water hyacinth populations can double its population in 12 days (Center for Aquatic Plants, IFAS, University of Florida, 2007) and as a consequence it has caused ecological disasters in many parts of the world. *Alocasia macrorrhiza*, given its large size and the ability to reproduce asexually by rhizomes, has the potential to become invasive species in alien environments. More importantly, it can produce poisonous latex, protecting it from generalist herbivores. *Alocasia macrorrhiza* is also an important ornamental plant; care should therefore be taken when introducing *A. macrorrhiza* to alien habitats.

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Comparative study of stem hydraulic properties in four tropical gymnosperm species with significantly different leaf sizes

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ABSTRACT

Larger leaves must consume more water transported by stem xylem. In this study, the stems hydraulic properties of four species trees of Podocarpaceae with different single leaf area were measured. I found that the hydraulic conductivity positively correlated with Huber value and specific conductivity negatively correlatively with sapwood density. However, there was no significant variation in hydraulic properties across the four species. The main reason may be that the total leave area per branch was not significantly difference across the four species.

Key words: hydraulic conductivity, leaf specific conductivity; Podocarpaceae, sapwood density, specific conductivity

IN GYMNOSPERMS, the water transport conduits are tracheids. Compared to the vessels of angiosperms, tracheids are smaller in diameter and shorter in length and have much higher resistance to water transport. Thus, gymnosperms usually have very small leaves due to their less effective water conducting xylem (Gibson 1985, Li 2000). However, in some, particularly tropical species, broad leaves have evolved. How these species can support the transpiration from large leaves is an unresolved ecophysiological question.

In this study, we studied the stem hydraulic properties of four gymnosperm tree species of the same family (Podocarpaceae). Two species had relatively broad leaves comparable to the leaves of most angiosperms, while the other two species had small leaves similar to most other gymnosperms. I hypothesised that the broad-leaved species would have stems with higher hydraulic conductivity compared to species with small leaves.

METHODS

STUDY SITE — This study was conducted in Xishuangbanna Tropical Botanic Garden, Yunnan province, SW China (21°08′N-22°36’N, 99°56′E-101°50′E). It receives a mean annual rainfall of 1500 mm and has a distinct dry season from July to October and a rainy season from November to May. The annual average temperature is 21°C and the temperature ranges from 11.2°C to 33.5°C with a relatively constant day length.

Four species of plants of Podocarpaceae in XTBG were selected, which have different leaf area (Table 1). All the species were growing in the same garden environment. Nine branches per species taken from different individuals were collected early in the morning and transported to the laboratory immediately. Stem hydraulic properties, including hydraulic conductivity (*Kh*), specific conductivity (*Ks*), leaf specific conductivity (*Kl*), and Huber value (*LA/SA*) were measured (Tyree and Ewers 1991). Hydraulic conductivity (K_h; kg m s^{-1} MPa^{-1}) was calculated as:

$$K_h = J_v / (\Delta P / \Delta L)$$

Where J_v is the flow rate through the segment (kg /s) and $\Delta P/\Delta L$ is the pressure gradient across the segment (MPa /m) (Li 2000). Huber value (*LA/SA*) was calculated as:

$$HV = A_{sw} / A_l$$

Where A_{sw} is the sapwood area (mm^2) and A_l is the total leave area on a branch (cm^2). Specific hydraulic conductivity (K_s; kg m^{-1} s^{-1} MPa^{-1}) was calculated as the ratio of K_h to A_{sw} and leaf-specific hydraulic conductivity (K_l; kg m^{-1} s^{-1} MPa^{-1}) was calculated as the ratio of K_h to A_l.(Li 2000). Sapwood density was calculated as:

$$\rho_{wood} = D_m / V$$

Where D_m is the dry mass of sapwood (g) and the V is the volume of sapwood (mm^3) (Li 2000). Linear model regression and ANOVA was performed using R 2.6. 0.

RESULTS

The average leaf sizes of *Podocarpus nagi* and *Podocarpus fleuryi* were significantly larger than those of *Podocarpus manii* and *Podocarpus macrophyllus* ($F_{1, 32}$ = 84.312, P < 0.01). But contrary to the average increase in leaf sizes, the total area of leave on a branch was not significantly different across species (R^2=0.703, P=0.104, N= 36). The Huber value (LA/SA) did not significantly differ across species (R^2 = 0.714, P=0.1, N=36). Contrary to expectations, there were no significant correlations in K_h, ρ_{wood}, K_s and K_l with the average leaf size (R^2=*0.831*, P = 0.058; R^2 = 0.074, P=0.382; R^2= 0.641, P = 0.128; R^2= 0.354, P = 0.246, respectively, N =36) (Table 2)

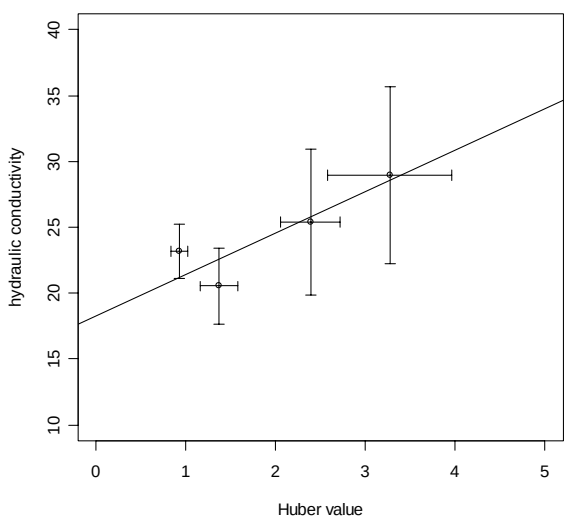

FIGURE1 The relationship between the hydraulic conductivity and Huber value across four species of Podocarpaceae at XTBG (R^2 = 0.669, P = 117, N = 4)

However, the *Kh* values increased with the *LA/SA*, and the *Ks* values decrease with the ρ_{wood} across the four species (Fig. 1 & 2)

DISCUSSION

Although the average leaf area is significantly larger in *Podocarpus nagi* and *Podocarpus fleuryi*, the total area of leaf on a branch was not significantly correlated with the average leaf area across the four species. The leaf area allocated to unit stem sapwood area was also not found to be significantly different across species. These results may largely explain the similarity in stem hydraulic properties across the four species.

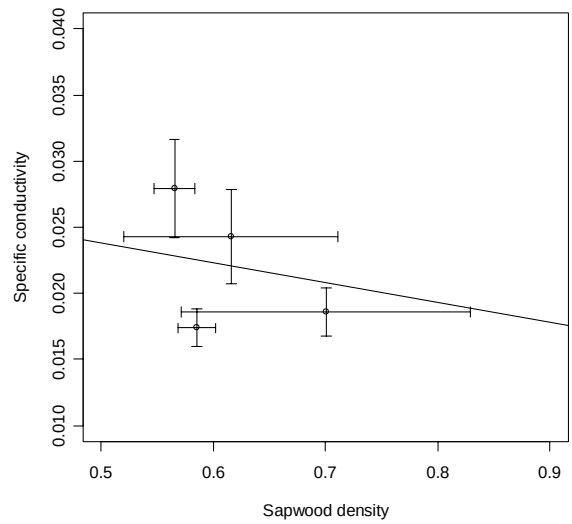

FIGURE 2 The relationship between specific conductivity and sapwood density across four species of Podocarpaceae at XTBG (R^2 = -0.116, P = 0.494, N = 4).

However, there was a positive correlation between hydraulic conductivity and Huber value, and a negative correlation between specific conductivity and sapwood density, although the latter correlation was not significant.

The bigger the Huber value, the more water that needs to be transported per unit stem sapwood area, assuming a similar transpiration rates in the leaves of different species.

Species with higher Huber value thus require more conductive sapwood to support transpiration (Tyree 1991). However, I did not measure the transpiration rate, which would be required to firmly establish this relationship. Lower sapwood density in these species was found to be related with bigger tracheids (Li 2000), which may result in the negative correlation between sapwood densities and stem hydraulic conductivity.

Although *P. mannii* and *P. macrophyllus* have relatively small leaves, they have a large number of leaves on a branch, which compensates for their small size. This explains the similarity in hydraulic properties across the four species.

TABLE 1. *Four species of Podocarpaceae used in this study and their leave size*

Species name	Average leaf area (Mean±SD)
Podocarpus nagi	32.91±2.5
Podocarpus fleuryi Hickel	19.4±1.9
Podocarpus macrophyllus (Thunb.) Sweet	4.76±0.8
Podocarpus manii	3.65±0.7

TABLE 2. *The comparison of LA/SA, Kh, Ks and Kl across four specie*

Tree species	*Total area*	*LA/SA*	ρ_{wood}	*Kh*	*Ks*	*Kl*
Podocarpus nagi	2116	2.386	0.565	25.400	0.027	1.274
Podocarpus fleuryi	1362	1.364	0.693	20.530	0.018	1.492
Podocarpus macrophyllus	1213	3.269	0.615	28.940	0.024	1.012
Podocarpus manii	3066	0.922	0.585	23.185	0.017	1.938

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Effect of Distance from Water on the Diversity of Leaf-Litter Amphibians and Reptiles in Xishuangbanna Tropical Rain Forest, XTBG, China

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ABSTRACT

The effect of distance from water on the diversity of leaf-litter amphibians and reptiles was studied in Xishuangbanna tropical rainforest, XTBG, China. Sample plots were established at 0 m, 20 m, and 40 m from water. The field survey was conducted in a forest stream, and a pool, a relatively open habitat. We found 57 individuals belonging to 11 species, five genera in five families of amphibian, and three species in three genera of three families of reptiles. Analysis of similarity (ANOSIM) failed to identify any significant difference in species composition with distance in both pool and stream habitat. However, a General Linear Model detected that habitat had a significant effect on the abundance of leaf-litter amphibians and reptiles. The diversity of species decreased with distance from water in the pool habitat, but showed the opposite pattern in the stream habitat.

Key words: abundance, habitat, pool, species composition, stream

THE XISHUANGBANNA TROPICAL RAIN FOREST is one of the plant landscapes in Xishuangbanna Tropical Botanic Garden (XTBG). As part of the garden's ex-situ collection, it is a good habitat for amphibians and reptiles. Amphibians and reptiles play a major role not only as secondary consumers, but also as prey for various predators (Watanabe *et al.* 2005). Amphibians and reptiles are susceptible to environmental changes, their diversity is influenced by environment factors, such as temperature, gradient elevation, vegetation cover and humidity (Huang & Hou 2004). The objectives of our study were to determine diversity of leaf-litter amphibians and reptiles according to a gradient of distance from water in two habitat sites; a stream inside the forest and pool representing a relative open habitat. We hypothesised that leaf-litter amphibian and reptile diversity would decrease with distance from water.

METHODS

The survey was conducted from 4 – 8 October 2007. Sampling plots were situated in the Tropical Rain Forest at XTBG, with twenty-four plots at the pool site, and 30 plots at the stream site. Each 5 x 5 m^2 plot was sited on a transect of 0, 20 and 40 meters from water edge. We collected all the litter amphibians and reptiles in the plots, measured them, and identified them. We measured the temperature and humidity in each plot. We also sampled 1 x 1 m plots for seedlings in the middle of each plot. To compare diversity we used the vegan package in R 2.5.1 to calculate Shannon-wiener diversity index. A general linear model (GLM) was performed using a quasipoisson error distribution, because of over-dispersion, to examine the relationship between habitat and distance from water on the abundance of litter amphibians and reptiles. A Student's t - test also was used to compare plant species composition in different habitats. All of these calculations were performed in R 2.5.1.

RESULTS

Our results from the survey revealed that environmental factors, temperature (23.20°C-28.10°C) and humidity (80%-97%) did not significantly differ between pool and stream sites (Wilcox. test, $p>0.05$). We measured the density of seedling plants. The stream habitat had higher numbers than the pool site (21 plants /m^2 and 19 plants /m^2, respectively, but this was not significantly different ($W = 343$, p-value = 0.7733).

We recorded 57 litter amphibians and reptiles from 54 plots (Table 1). These included 11 species from 8 families. We used the Shannon-Wiener index to measure species diversity in the different habitats (Table 2). The diversity of amphibians and reptiles

increased with increasing distance from water in the pool habitat. However the stream habitat showed the opposite trend.

The GLM indicated that there was no significant relationship between distance and amphibian and reptile abundance, there was a significant effect of habitat. The amphibian and reptile community composition was also not significantly correlated with distance from water using Analysis of Similarity (R= -0.028, p= 0.594) (Fig 1).

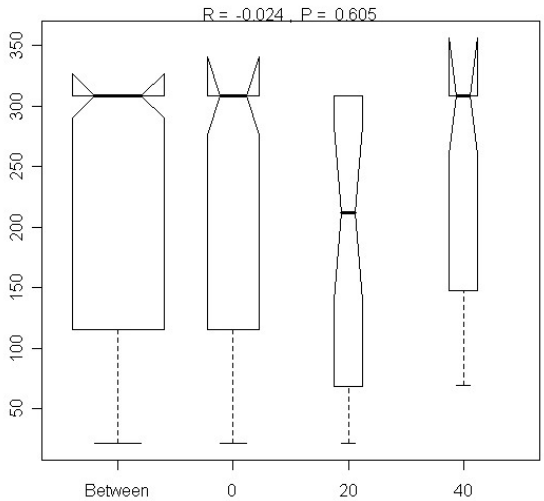

FIGURE 1 Analysis of similarity on the community composition of amphibians and reptiles at different distances from water

TABLE 1. *Litter amphibian and reptiles which found in Xishuangbanna Tropical Rainforest.*

Sl. No.	Species	Family	Pool	Stream
	Amphibians			
1	*Bufo melanosticus*	Bufonidae	+	
2	*Calluella yunanensis*	Microhylidae	+	+
3	*Polypedates leucomystax*	Rhacophoridae		+
4	*Rana limnocharis*	Ranidae	+	
5	*Rana sp2*	Ranidae		+
6	*Rana andersonii*	Ranidae		+
7	*Rana sanguinea*	Ranidae		+
8	*Microhylla hemonsi*	Microhylidae		+
	Reptiles			
9	*Trimeresurus sp*	Viperidae	+	+
10	*Japalura sp*	Agamidae	+	+
11	*Scincella monticola*	Scincidae	+	

TABLE 2. *Shannon-wiener index diversity of litter amphibians and reptiles in different habitats and different distance from water.*

Diversity	**Distance**			**Density (ind/m2)**
Habitat	**0 m**	**20 m**	**40 m**	
Pool	1.475076	1.332179	0	0.022
Stream	1.161187	1.087761	1.329661	0.025

DISCUSSION

We recorded 11 species belonging to eight families of amphibians and reptiles during the four-day survey in Xishuanbanna Tropical Rainforest. In both pool and stream sites, we noted that the densities of amphibians and reptiles were very low. From our general linear model, the only significant effect on abundance of amphibians and reptiles was habitat. Diversity also varied with distance from water. There were zero species at 40 m distance in the pool habitat. This follows our hypothesis that diversity will decrease according with distance from water.

However, in the stream habitat the diversity on gradient was in the opposite direction; furthest distance from water (40 m) with the highest diversity. In this study, we did not measure the leaf – litter depth. It is possible that this factor affects the diversity of amphibians and reptiles. None of the parameters we measured (temperature, humidity and seedling density) had a significant effect of amphibian and reptile diversity. Soil pH is another factor that could potentially have an effect on the diversity and abundance of leaf-litter amphibian and reptiles (Huang & Hou 2004).

According to our Analysis of Similarity the species composition in both habitats (pool and stream) did not vary with distance from water (Fig. 1). However, there were some species that were only found in pool habitat, such as *Bufo melanosticus,* and *Scincella monticola*. In contrast, there were other species that were only found in the stream habitat, such as *Rana andersoni, Rana* sp2*, Rana Sanguinea, Microhylla hemonsi* and *Polypedates leucomystax.* The low sample size we obtained may explain the lack of a significant result. According to Lee *et al.* (2006), species richness in the area fluctuates according to the season because of variation in the detection probability of different species. Based on our observation in the field, *Calluella yunanensis* often hid underneath leaf litter or soil. They have camouflaged skin that resembles dry leaves. Other examples, particularly in the genus *Rana* are fast moving species and very shy. They may be able to make a long leap out from the plot and it is difficult to catch them.

In summary, the leaf-litter amphibians and reptiles are very interesting animals to study in relation to environmental changes. In this study, we may have omitted some parameters that could affect amphibian and reptile diversity. Microenvironment factors such as leaf litter thickness and soil pH may affect amphibian and reptile diversity. The relatively short period of observation was a consraint for our study given the low capture rates we obtained.

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Lantana Fruit Removal by Birds in Xishuangbanna Tropical Botanic Garden, China

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ABSTRACT

I conducted observations in the four lantana patches, two sites located in central areas of the garden and other two located in remote areas. Patch characteristics in all sites were described but were not compared quantitatively. However, some differences were drawn quite clearly. Number of fruit per inflorescence, total fruit in remote sites, and fruit density were higher in the remote area than in central area. Three species of frugivorous birds, Red-whiskered bulbul (*Pycnonotus jocosus*), Sooty-headed bulbul (*P. aurigaster*), and white-eyes (*Zosterops* spp.), were recorded. Unsurprisingly, they were recognised as common dispersal agents for *Lantana* in the region. *P. aurigaster* visited *Lantana* bushes with highest frequency (15 times) and White-eyes visited the bush in larger groups (median=3, range from 1-8 birds) than Bulbuls. However, both differences in patch characteristics and birds did not affect visitation or fruit removal rate as was suggested by the model. I found no suitable fruit removal model. I discuss from the garden management point of view, that the invasion in the areas is not a big problem when compared to the ecological benefits to the garden ecosystem. Associations among Lantana bushes and birds, insects and small mammals were found along this study.

Key words: Bulbuls, frugivore, invasive plant, *Lantana camara,* removal rate, White-eyes

LANTANA (*LANTANA CAMARA* L.) IS WELL RECOGNISED as a wide-spread invasive plant in many countries. It is listed as the world's 100 worst invasive alien species by Invasive Species Specialist Group (IUCN 2000). The keys to their success are human activities and their distinctive characteristics (Sharma *et al.* 2005). Due to their various colourful flowers and, in some cases, their ability to provide high number of available fresh fruit to frugivores, *Lantana* is commonly contributed into landscapes by human agents and animals. Moreover, their fitness homeostasis, phenotypic plasticity, dispersal benefits from destructive foraging activities, widespread geographic range, vegetative reproduction, fire tolerance, better competitive ability compared to native flora, and allelopathy are the biological keys of their success (Sharma *et al.* 2005). It is a fact that it has low germination rate but large number of fresh-fruit with long exposure period to disperser, almost throughout the year (Sharma *et al.* 2005, Corlett 2005, Gosper & Vivian-Smith 2006), and low mortality rate can offset low germination rate of seed (Sharma *et al.* 2005). The germination rate can be increased by passage through animal gut (Mandon-Dalger *et al.* 2004). Therefore, the invasion is essentially caused by high effective seed dispersing-process. *Lantana* seed is mostly dispersed by birds (Bhatt & Kumar 2001, Corlett 2002, Feare 1975). Bulbuls (*Pycnonotus* spp.) and White-eyes (*Zosterops* spp.) are the most common functional groups that feed on *Lantana* in disturbed area (Bhatt & Kumar 2001, Corlett 1998, Feare 1975, Chimaera 2004, Gosper & Vivian-Smith 2006). Positive interactions between invasion of exotic birds and frugivory on *Lantana* fruit have been documented (Corlett 1998, Mandon-Dalger *et al.* 2004, Pimentel 2000). The consequence of this change is declining population of native plants and birds (Eguchi & Amano, 2004). Many ideas of invasive species control involved frugivores and the importance of observation on interactions between birds and invasive plants in management practices has been highlighted (Buckly *et al.* 2006, Gosper *et al.* 2005). To provide some basic information on interaction between birds and *Lantana* bushes, I conducted this study in the Xishuangbanna Tropical Botanical Garden (XTBG), China, with aims to investigate (1) species diversity of dispersal agents, (2) the patch visitation and the fruit removal rate among difference birds, and (3) habitat. I hypothesised that visitation and fruit removal rate among all birds and habitats present lower disturbance by tourists in remote sites leading to higher number of bird, visitation and fruit removal rate.

METHODS

STUDY SITE. — This study was conducted in Xishuangbanna Tropical Botanical Garden (XTBG), which was founded in 1959. The garden is located at 21º55' N, 101º15' E, covering an area of 900 ha. Over ten thousand species of tropical plants are well

preserved in its 34 living collections. I conducted observations in four *Lantana* patches, two sites located in central area and two located at a distance from XTBG.

PATCH CHARACTERISTICS. — I recorded general characteristics of focal bush in order to compare between two difference locations, in central and remote area. Moreover, these patch characteristics were important to be considered in the fruit removal model. Characters noted down were patch size, number of ripe and total fruit, proportion of ripe fruit to total fruit, and fruit density. Patch size was estimated by the radius. Total and ripe fruit estimation was based on total count in small patches, and by partial count and extrapolation in larger patches. I assumed that fruits were distributed uniformly across the whole bush.

BUSH OBSERVATION. — Each patch was observed during 0830- 1130 and 1330- 1730 h. Bush scanning was conducted in every 10-minute interval. Species identification was made to species level, with an exception in white-eyes (*Zosterops* spp.). They were identified to generic level. The fruit removal rate was based on focal sampling. When a new bird was seen at the bush, its exact arrival time was recorded. A focal bird was picked up in every 10-minute interval, after scanning. Total fruit removed by the focal bird was noted down during the period that bird spent in the bush. Fruit removal rate was then calculated by total number of removed fruit divided by the duration.

DATA ANALYSIS.— Patch characteristics of each study site was described, so was the group size of bird from scanning the bush. Visitation pattern among focal bird species was compared based on similarity of total birds in two periods, the morning and afternoon period. Number of removed fruit, duration in the bush, and fruit removal rate were compared among focal bird species and among the habitats - central and remote sites, by using R 2.6.0 (R Development Core Team, 2005). Finally, fruit removal model was tested by accounting patch characteristics - proportion of ripe fruit to total fruit, patch size, and fruit density.

RESULTS

PATCH CHARACTERISTICS. — Patch characteristics from 4 selected patches were described. However, due to small number of patches, I do not compare these characters across the sites, only basic descriptions are made (Table 1). Mean size of selected *Lantana* bushes was 13.62±1.96 m2. Mean fruit density was 121.01±36.13 fruits/m2 with some bushes exposing ripe fruit that were 0.05±0.02 fruits/total fruit. Each inflorescence consisted of 25.06±3.22 fruits.

VISITATION AND FRUIT REMOVAL RATE. — In four observation days, I recorded 31 visitations made by three frugivorous, Red-whiskered bulbul (*Pycnonotus jocosus*), Sooty-headed bulbul (*P. aurigaster*), and white-eyes (*Zosterops* spp.). The highest number of visits was made by *P. aurigaster*, 15 visitations, while *P. jocosus* and White-eyes were equal (9 visitations). White-eyes generally visited the *Lantana* bushes in significantly larger groups than *P. aurigaster* (Kruskal - Wallis test, df= 2, $p<0.05$; Fig. 1). However, number of fruit that were removed by focal birds, as well as duration that focal birds spent in the *Lantana* bushes, and removal rate were neither significantly different among focal bird species nor between habitat types (Table 2).

TEMPORAL DISTRIBUTION OF VISITATION. — Owing to the constraint of small number of birds in a particular scan, the comparison among numerous interval periods was not possible. I looked at number of birds visiting in the morning and afternoon periods within each focal species and compared these rough patterns among species. The result revealed that number of birds was not significantly different between these two periods in all bird species (Table 3).

FRUIT REMOVAL MODEL. — I considered patch characteristics, proportion of ripe fruit per total fruit, patch size, and fruit density, in the model. I found no model where any factor was significantly related to fruit removal rate (Table 4).

TABLE 1. *Patch characteristics across four study sites*

Characters	**Study Site**		
	Both	Remote	Central
	Mean ± SE (n)	Mean ± SE (n)	Mean ± SE (n)
No. of Fruit / Inflorescence	25.06 ± 3.22 (18)	31.50±5.81 (6)	21.83±6.46 (12)
Ripe / Total fruit	121.01 ± 36.13 (24)	0.65±0.05 (12)	0.04±0.02 (12)
Patch size (m^2)	13.62 ± 1.98 (4)	11.14±4.25 (2)	16.11±3.70 (2)
Fruit density (fruit/ m^2)	121.01 ± 36.13 (n)	186.2±77.25 (2)	55.77±7.21 (2)

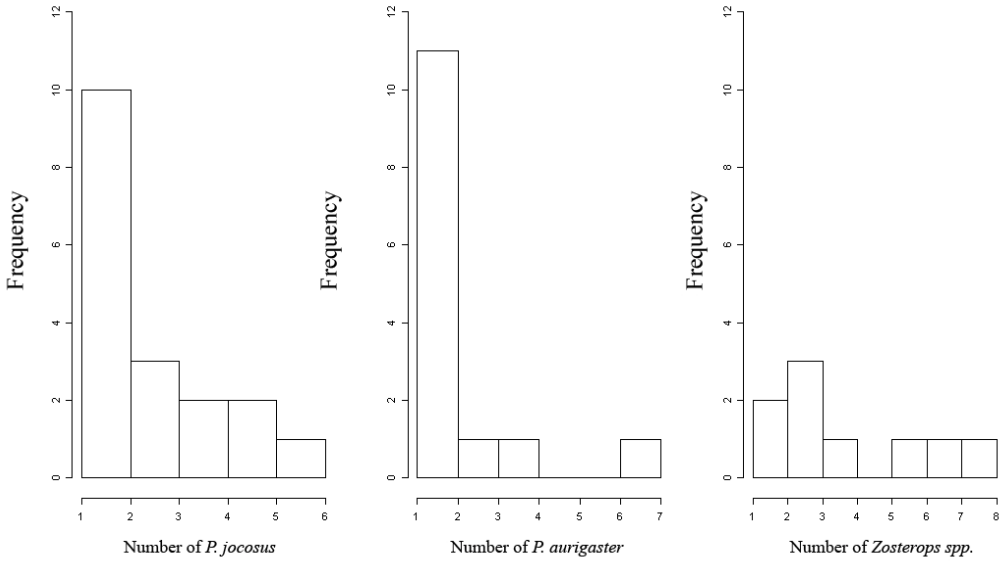

FIGURE 1. Number of birds in each scan

TABLE 2. *Number of removed fruit, duration in Lantana bushes and fruit removal rate by focal birds*

Focal bird species	No. of fruits removed Mean ± SE	Duration Mean ± SE	Removal rate Mean ± SE
All remote site	4.47 ± 2.48 (17)	241.41 ± 2.48 (17)	0.02 ± 0.04 (17)
All central site	1.75 ± 1.27 (16)	95.31 ± 55.78 (16)	0.05 ± 0.07 (16)
All both sites	3.15 ± 1.43 (33)	170.58 ± 75.81 (33)	0.03 ± 0.03 (33)
P. jocosus	5.11 ± 4.88 (9)	281.11 ± 280.08 (9)	0.02 ± 0.01 (9)
P. aurigaster	3.07 ± 1.59 (15)	107.60 ± 60.51 (15)	0.06 ± 0.07 (15)
Zosterops spp.	1.33 ± 1.09 (9)	1651 ± 68.68 (9)	0.01 ± 0.01 (9)

TABLE 3. *Mean number of birds by scan sampling in the morning and afternoon*

Bird Species	Morning	Afternoon
P. jocosus	2.46 ± 0.78 (13)	3.00 ± 2.22 (5)
P. aurigaster	1.38 ± 0.56 (8)	1.38 ± 2.00 (6)
Zosterops spp.	3.86 ± 0.93 (7)	5.00 ± 4.24 (2)

TABLE 4. *Summary fruit removal model which patch characteristics were considered; Rp: Proportion of ripe fruit to total fruit, Fd: Fruit density and Pt: Patch size*

	Estimate Std.	**Error**	**z value**	**Pr(>|z|)**
(Intercept)	-8.579785	13.707093	-0.626	0.531
Rp	21.129613	94.303239	0.224	0.823
Fd	0.001377	0.036122	0.038	0.970
Pt	0.273472	0.631869	0.433	0.665

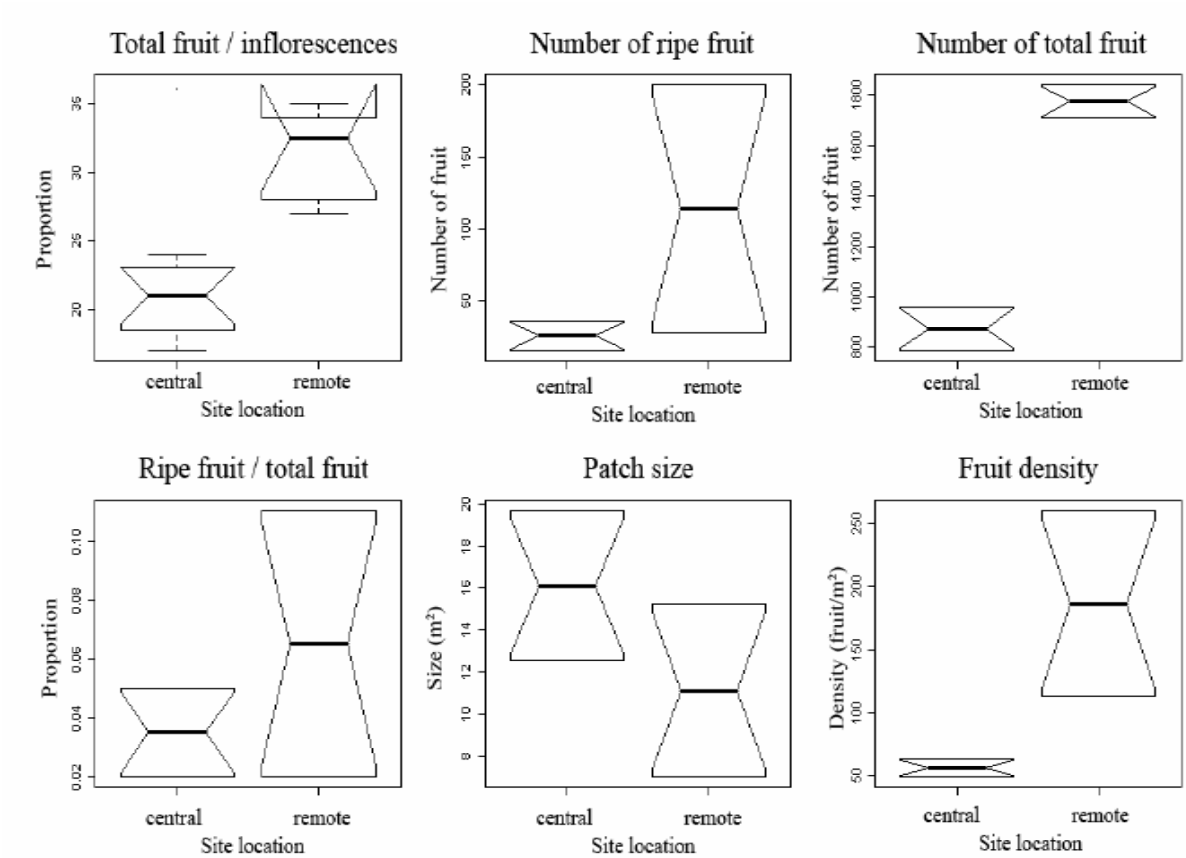

FIGURE 2. Patch characteristics across four selected *Lantana* bushes

DISCUSSION

Patch characteristics in all sites were described but no quantitative comparisons were done. However, some differences did emerge. Number of fruit per inflorescence, total fruit in remote sites, and fruit density were higher in remote site than in central site (Fig. 2). Based on four days of observation, three frugivoruous bird species were recorded across four *Lantana* patches - Red-whiskered bulbul (*Pycnonotus jocosus*), Sooty-headed bulbul (*P. aurigaster*), and white-eyes (*Zosterops* spp.). They are previously known as Lantana seed dispersal agents in this region (Bhatt and Kumar 2001, Mandon-Dalger *et al.* 2004). All of them are medium and small gape birds living in between middle and lower canopy. I did not encounter another existing bulbul, the black-crested bulbul (*Pynonotus melanicterus*) on the *Lantana* bush, probably due to it being a canopy species. Moreover, remarkably, another common middle-storey frugivorous species - flower peckers (Nectariidae), were also never seen. Although white-eyes visited the *Lantana* bushes in larger groups, but did not significantly result in higher removal rate than others. Nevertheless, white-eyes seem to have higher potential in fruit removal as they often form large groups, up to fifty birds in group. But possibly due to their foraging behavior, following them in a bush was always difficult. Feeding events were also relatively less detectable than bulbuls which are more than two times bigger. I compare number of birds in morning and afternoon, and the results suggested that all birds visited the bush. However, looking at temporal distribution of visitations, bulbuls appear in clumped distribution, while white-eyes' visitation seemed uniform (Fig. 3). Finally, as a note on landscape management, as this study was conducted in a well-organised botanical garden landscape, the invasion of *Lantana* was not seen as a problem. In four observation days, I found plenty of animals associated with *Lantana* bushes, e.g. four shrews, more than five species of butterflies, diurnal moths, and other insectivorous birds. Facts confirm that under proper management *Lantana* can be more than an ornamental plant, it can be a food source and habitat for animals in a human-dominated landscape.

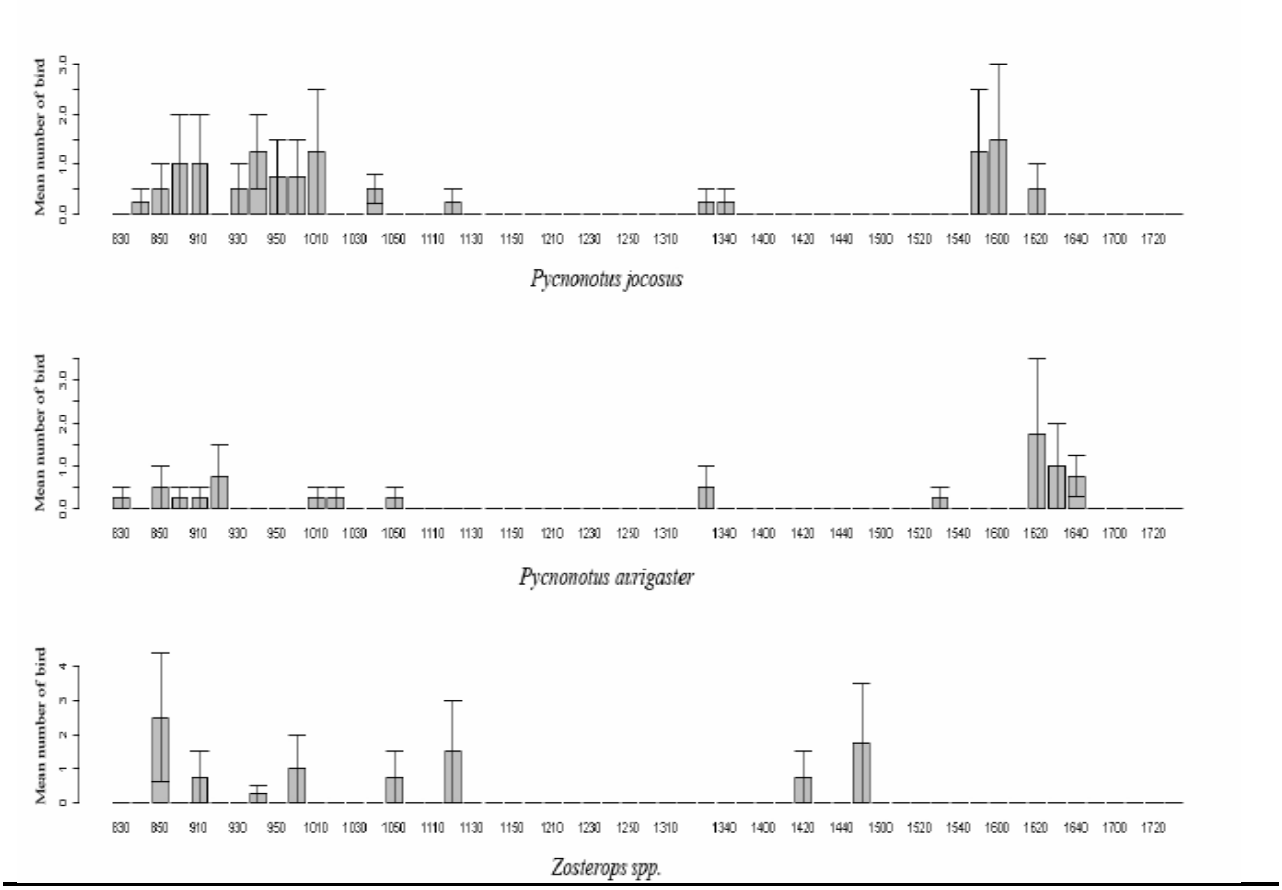

FIGURE 3. Mean number of bird during the day by scan sampling

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A Survey of Tourist Preferences for Plant Landscapes that are aimed at Species Conservation in Xishaungbanna Tropical Botanical Garden, China

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ABSTRACT

A survey of tourist preferences to different plant landscapes was conducted with the aim to look for a balance between public recreation and species conservation in a botanic park. I compared the popularity of different gardens, and analysed the relationship between popularity and the age and education degree of respondents, and the garden area and species number. The results indicate that most tourists are aware of conservation issues. Young people and people with a high education had a higher conservation sense. Local plant landscapes were popular with tourists. Decision-makers should develop local plant landscapes directly, including useful plants, together with a holistic approach towards plant conservation. Unnatural plant landscapes were not popular with the public. The size of area and species number had no direct relation with garden popularity, but if managed well, a large area and a high diversity of species can be attractive to the public.

Key words: aesthetics, age, education, holistic approach, local plant, social culture, questionnaire

GARDENS PLAY MULTI-FUNCTIONAL ROLES, including economic, cultural and social. Not only do they provide aesthetic environments for public recreation, but are also key sites for conserving species (Niemela 1999). However, conservation is often inconsistent with the public recreation (Maunder *et al.* 2001.).

As we know that the development of botanic gardens and species conservation need public support, especially in the hard economic reality of developing countries. So it is necessary to understand tourist preferences in order to know how to meet these duel aims. We also cannot ignore the fact that individual, family, and community life shape the landscape, and the landscape reflects public sense culture (Jacobs & Mann 2000). So a questionnaire about tourists and their preferences for different plant landscapes is a suitable method to study public attitudes towards gardens.

In general, a larger area and higher number species is better for protecting more species, but one question stands out: is a garden with a large area, and high species number popular with the public? In order to understand how to balance public preferences and species conservation, I choose the area and number species of every garden in Xishuangbanna Tropical Botanic Garden as two factors to analyse in relation to preference.

The aim of this study was to survey the public to understand how public recreation and species conservation could be balanced in a botanic garden. I started out with the following hypotheses; (i) younger people, (ii) with a higher education would preference more natural gardens and be more interested in conservation aspects of the garden, because of the increasing awareness of conservation issues in China. The popularity of a garden is positively correlated with (iii) the garden area, and (iv) the number of species.

METHODS

STUDY SITE.— My survey was undertaken in Xishuangbanna Tropical Botanical Garden (XTBG). Xishuangbanna is located in southwest China, with about 5000 species of vascular plants (about 18% of China's flora), but only occupies 0.2 percent of the total area of China, and is therefore one of the richest areas in biodiversity in China. XTBG, as the only botanic garden in the region, is an important site for plant conservation.

QUESTIONNAIRE.— I used a questionnaire to interview the public visiting XTBG (Table 1). The questionnaire was designed to assess the degree of tourist satisfaction to 19 XTBG gardens, and to test the expected degree to six potential plant landscapes for XTBG. Because garden characters often overlap, it is difficult to separate the 19 gardens into different groups. However, some gardens can be grouped, so depending on a garden's character I separated the 19 gardens into seven groups and divided the six potential plant landscapes into four groups (Table 2).

ANALYSIS (PREFERENCE ANALYSIS).— Preference (%) = n/N*100, where n = the number of tourists who most

like, most expect, or medium like, medium expect, or dislike, not expect that plant landscape; N: the total number of tourists corresponding to different age stage, education degree. (See table 2). For example, if 156 tourists most like palm garden, the total tourist number is 253, then preference for the palm garden = 156/253*100 = 61.7%.

ANALYSIS (CORRELATION ANALYSIS).— I divided the total number of tourists into six age groups and five education degree groups (excluding young people under 18 year old) (Fig. 1). I conducted linear regressions with preference as the dependent variable and age or education as the independent variable. I performed a correlation analysis (Spearman Rank Correlation) between preference and garden area and species number. I conducted linear regressions with preference as the dependent variable and garden area, species number as the independent variable.

RESULTS

COMPARISON OF GARDENS.— Comparing the garden groups with each other, the most popular was the tropical natural rainforest (57%) and the exotic gardens ranked second (52%). The special collection garden was not very popular (34.6%), but the degree of satisfaction was highest for the palm garden (62% of respondents said it was their favourite). The national trees and flowers garden in social culture group ranked fourth (51%).

TABLE 1. *The information of tourists composition*

Tourists composition	Number
Chinese that do not live in Yunnan	124
Local people in Yunnan outside Xishuangbanna	57
Local people in Xishuangbanna	33
People from American and European countries	27
Field course students from tropical Asian countries	12

Endemic species ranked highest (71.1%), more flower gardens (56%) ranked second, plants useful to humans was third (42%), and man-made landscapes ranked lowest (24%) (Table 2).

THE CORRELATION OF PREFERENCE FOR PARTICULAR GARDENS WITH AGE.— There was a significant positive relationship between age and preference for Palm Garden (R^2 =0.8464, *P*=0.0059), Arboretum Garden (R^2 = 0.7196, *P*=0.0205); and a significant negative relationship for plant in Greenhouses (R^2 =0.6635, *P*=0.0301), Endemic species (R^2 =0.8655 *P*=0.0045); slightly negative relationship for Aromatic Garden (R^2 =0.4860, *P*=0.0749) and Unnatural plant landscape group (R^2 =0.5035, *P*=0.0694) (Table 2, Fig. 1).

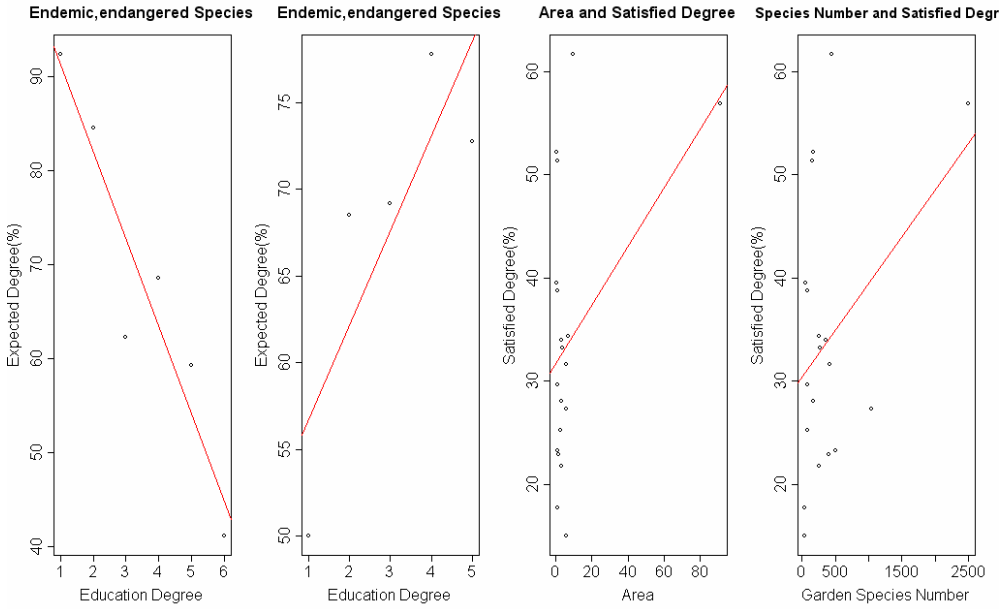

FIGURE 1. The relationship of preference with tourist age, education degree; and garden area, species number Age stage: 1, <18; 2, 18-30; 3, 31-40; 4, 41-50; 5, 51-60; 6, >60. Education degree: 1,Primary; 2, Middle;3, University;4, Master;5,Docter.

TABLE 2. *Preference degree comparison of different gardens with different area, species number*

Code	Plant landscape	L/E	Medium	Not L/E	Area	Species
	Garden groups in XTBG					
I	Tropical rainforest	56.9	12.3	0.8	91.1	2494
II	Exotic garden	52.2	13.4	2.8	0.8	168
III	Social culture	39.5	25.7	2.4		
	National trees and flowers Garden	51.4	22.9	0.8	1.3	162
	The Ethnic Culture Garden	34	21.3	1.6	3.4	361
	Celebrity Garden	33.2	32.8	4.7	3.7	269
IV	Special collection garden	34.6	22.1	1.6		
	Palm Garden	61.7	15.0	0.4	9.8	450
	Ficus Garden	38.7	26.9	1.6	1.2	86
	Bamboo Garden	34.4	20.2	0.8	7.0	253
	Dracaena Collection	29.6	20.9	1.2	1.1	85
	The Cycas Garden	25.3	27.3	2.8	2.9	87
	Dipterocarps Collection	17.8	22.1	2.4	1.3	40
V	Different habitats garden	28.2	19.1	2.8		
	Aquatic Plant Collection	39.5	15.4	2.4	0.5	49
	Shade Plant Collection	23.3	20.2	2.4	1.0	512
	Vine Garden	21.7	21.7	3.6	3.4	256
VI	Arboretum (Integration)	27.3	21.3	2	6.1	1050
VII	Gardens useful to human	24.4	20.7	2.6		
	Tropical Fruit Tree Garden	31.6	15.8	1.6	6.1	417
	Aromatic Plant Collection	28.1	18.2	0.4	3.4	165
	Medicinal Plant Garden	22.9	24.5	2	1.7	400
	Artificial rubber and tea community	15.2	24.1	6.4	5.7	40
	Potential gardens					
A	Endemic species	71.1	8.3	1.6		
B	More flower plant	55.7	12.6	1.2		
C	Plant useful to human	41.5	18.4	4.6		
	Local vegetable	46.2	15.8	4.7		
	Local crop	36.8	20.9	4.3		
D	Unnatural plant landscape	24.3	21.7	10.5		
	Topiary plant	25.7	18.6	12.6		
	Plant in greenhouse	22.9	24.9	8.3		

Note: Separate 19 gardens into seven groups from I to VII codes. Divide six potential plant landscapes into four groups from A to D codes. L/E: tourists who most like some garden, or most expect some potential plant landscape, occupied the percentage (%) of the total tourists; Medium: the percentage (%)of medium like, or expected; Not L/E: the percentage (%) of dislike, or unexpected. In the questionnaire, some tourists left blanks corresponding to gardens in the sheet, so the percentage of L/E+ Medium+Not L/E is not equal to 100. Area, ha; Species, species number.

TABLE 3. *Correlation analysis*

Variable1~ Variable 2	p-value	R^2	cor
Age stage ~ L/E			
Plant in greenhouse	0.0301	0.6635	-0.8549
Endemic species	0.0045	0.8655	-0.9447
Unnatural plant landscape	0.0694	0.5035	-0.7764
Palm Garden	0.0059	0.8464	0.9365
Arboretum Garden	0.0205	0.7196	0.8807
Aromatic Garden	0.0749	0.4860	-0.7673
Age stage ~ Not L/E			
Topiary plant	0.0137	0.7689	0.9028
Unnatural plant landscape	0.0539	0.5579	0.804
Exotic Garden	0.0084	0.8181	-0.9244
Education degree ~ L/E			
Palm Garden	0.0836	0.5800	0.8276
Bamboo Garden	0.0101	0.8918	-0.9586
Dracaena Collection	0.0018	0.9653	-0.9869
Aromatic Plant Collection	0.0003	0.9904	-0.9964
Artificial rubber and tea community	0.0531	0.6836	-0.8733
Gardens useful to human	0.001	0.9759	-0.9909
Endemic species	0.0877	0.5678	0.8221
Local vegetable	0.072	0.6171	-0.8443
More flower plant	0.0198	0.8319	-0.9348
Plant in greenhouse	0.0379	0.7443	-0.899
Unnatural plant landscape	0.0521	0.6872	-0.8749
Education degree ~ Not L/E			
Tropical rainforest	0.0411	0.7307	0.8933
Exotic Garden	0.0464	0.7093	0.8843
More flower plant	0.0746	0.6086	0.8405
Topiary plant	0.0783	0.5967	0.8352
Area ~ L/E (19 gardens)	0.0623	0.1421	0.4356
Species number ~ L/E (19 gardens)	0.1029	0.0987	0.3857

Note: L/E, Not L/E meaning refers to the note of Table 2; R^2 is adjusted R-squared; cor means correlation coefficient; education, age refer to the note of fig. 1.

There was a slightly positive relationship between age and the degree of dislike for Unnatural plant landscape group (R^2 = 0.5579, *P*= 0.0539), significantly positive relationship for Topiary plants (R^2 = 0.7689, *P*= 0.0137), and a significantly negative relationship for Exotic Garden (R^2 = -0.8181, *P*= 0.0084) (Table 2. Fig. 1).

THE CORRELATION OF PREFERENCE WITH DIFFERENT EDUCATION DEGREES.— There was a slightly positive relationship between education and favourite for Palm Garden (R^2 = 0.5800, *P*= 0.0836), Endemic species (R^2 = 0.5678, *P*= 0.0877); and a significant negative relationship for Greenhouses (R^2 = 0.7443, *P*= 0.0379), Gardens useful to human (R^2 = 0.9759, *P*= 0.001); and a slightly negative relationship for Unnatural plant landscape group (R^2 = 0.6872, *P*= 0.0521). (See table 2, Fig. 1.)

THE CORRELATION BETWEEN PREFERENCE AND GARDEN AREA AND SPECIES NUMBER.— The public satisfied degree has no direct relation with garden area (R2= 0.1421, p-value: 0.06227) or species number (R2= 0.0987, p-value: 0.1029) (Table 2, Fig. 1).

DISCUSSION

Most tourists are aware of conservation issues. Young people have higher conservation consciousness than older people, and people with a higher degree of education have higher conservation awareness than the people with lower education. Gardens that conserve species well can also contribute to education about conservation. A positive feedback cycle forms, and so public conservation awareness will improve in the future. Decision-makers should enhance the species conservation function of botanic gardens.

People's expected degree to endemic species in the garden was the highest (71.1%), and young people expected the garden to conserve more endemic and endangered species (R^2 =0.8655 *P*=0.0045) than older people. People with more education have higher conservation awareness (R^2 = 0.5678, *P*=0.0877), the pattern was stronger for Chinese tourists alone (R^2=0.8251, P=0.02102).

It is necessary to take on a holistic approach to conserve plants in a public garden, integrating ecological theories, social culture, and aesthetics.

Few people (1.2%) did not hope to see more flowers in garden. It is clear that the public have aesthetic expectations of the garden. Few people disliked the exotic garden (2.76%). The public have a psychology of searching for novelty, so introducing more species into garden and developing effective ways to increase the public attention, will win both ways.

The public liked the social culture gardens, especially national trees and flowers Garden (51.4%). Culture is an effective way to conserve species (Hongmao *et al.* 2002).

Local plant landscapes were popular with tourists, but not always, so careful development of the local landscape together with aesthetics is required. Most people liked the palm garden (61.7%) and tropical natural forest community (56.9%). In the exotic garden, a local species, the dancing herb, attracted most people. This indicates that local landscapes are the most popular with the public.

People hope to see palms in the botanic garden and think of palms as exotic; it is common that palms are popular to the public (Maunder *et al.* 2001.). But according to the garden officials, there are several palm gardens in China, while only the palm garden in XTBG is a favourite with the public. The reason is that palm garden is landscaped with aquatic plant garden well, which makes the palm garden look especially beautiful. So decision-makers should conserve and develop local plant landscapes directly together with aesthetic considerations for the best result.

Conservation should include useful plants, not just ornamental species. The preference of useful plants was low, especially the Tropical Fruit Tree Garden (31.6%), and artificial rubber and tea community (15.2%). There is not enough time to cover the whole botany garden in several hours, so guides do not lead tourists to some gardens, and most tourists follow the guide routes. So this influences the scores of preference to some gardens including Tropical Fruit Tree Garden and Artificial rubber and tea community. In the potential garden group, the tourist's expected degree to plant landscapes useful to human (41.5%) was not low, especially tropical vegetable (46.2%).

To conservation biologists, it can often seem that agriculture species conservation conflicts with wildlife conservation, but simplistic agriculture reduces not only wild species diversity, but also agriculture species diversity. Currently many agriculture species are endangered, and need emergent protection (Argenta & Brackmann 1996; Banks 2004; Sunwar *et al.* 2006). Useful plant conservation and garden popularity will benefit mutually.

Unnatural plant landscapes are not popular with the public. Decision-makers should cut down the unnatural landscape budget. Few people like unnatural landscapes (24.3%), older people dislike unnatural landscape (R^2 = 0.5035, *P*= 0.0694) more than younger people. For example, more people did not want a topiary landscape (R^2= 0.7307, P= 0.0137). Though young people also do not much appreciate unnatural landscapes (30.8%), they are more sensitive to novelty, so prefer the aromatic garden (R^2 = 0.4860, *P*= 0.0749) and exotic garden (R^2= 0.8181, P= 0.008356); more hope to get knowledge from greenhouse plants (R^2 = 0.6635, P= 0.0301). People with higher education also tend to dislike unnatural plant landscapes (R^2 = 0.6872, P= 0.05212).

The size of garden and species number were not direct factors influencing the public appreciation, but if managed well gardens with a large area and high species number can be popular. A large area and high species number can conserve more species in a garden in general, but the results indicate the popularity was not directly related with garden area (R2=0.1421, P= 0.06227) or species number (R2=0.0987, P= 0.1029). Though the exotic garden had a small area (0.8ha) and low species diversity (168), it ranked the third, while the arboretum with a large area (6.1ha) and high species diversity (1050) ranked 13th.

However, the tropical rainforest with a large area (91.1) and high species diversity (2494) ranked second, so if managed well, large areas with high species diversity can be balanced with garden popularity and objectives of conserving more species (Table 2, Fig. 1).

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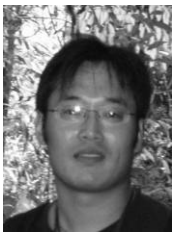

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