Workshop on Seed Dispersal & Frugivory in Asia

January 6-9, 2004 Xishuangbanna, Yunnan, China

ABSTRACTS

Organized by

Xishuangbanna Tropical Botanical Garden, CAS

Sponsored by

National Natural Science Foundation of China

Chinese Academy of Sciences (CAS)

Xishuangbanna Tropical Botanical Garden, CAS

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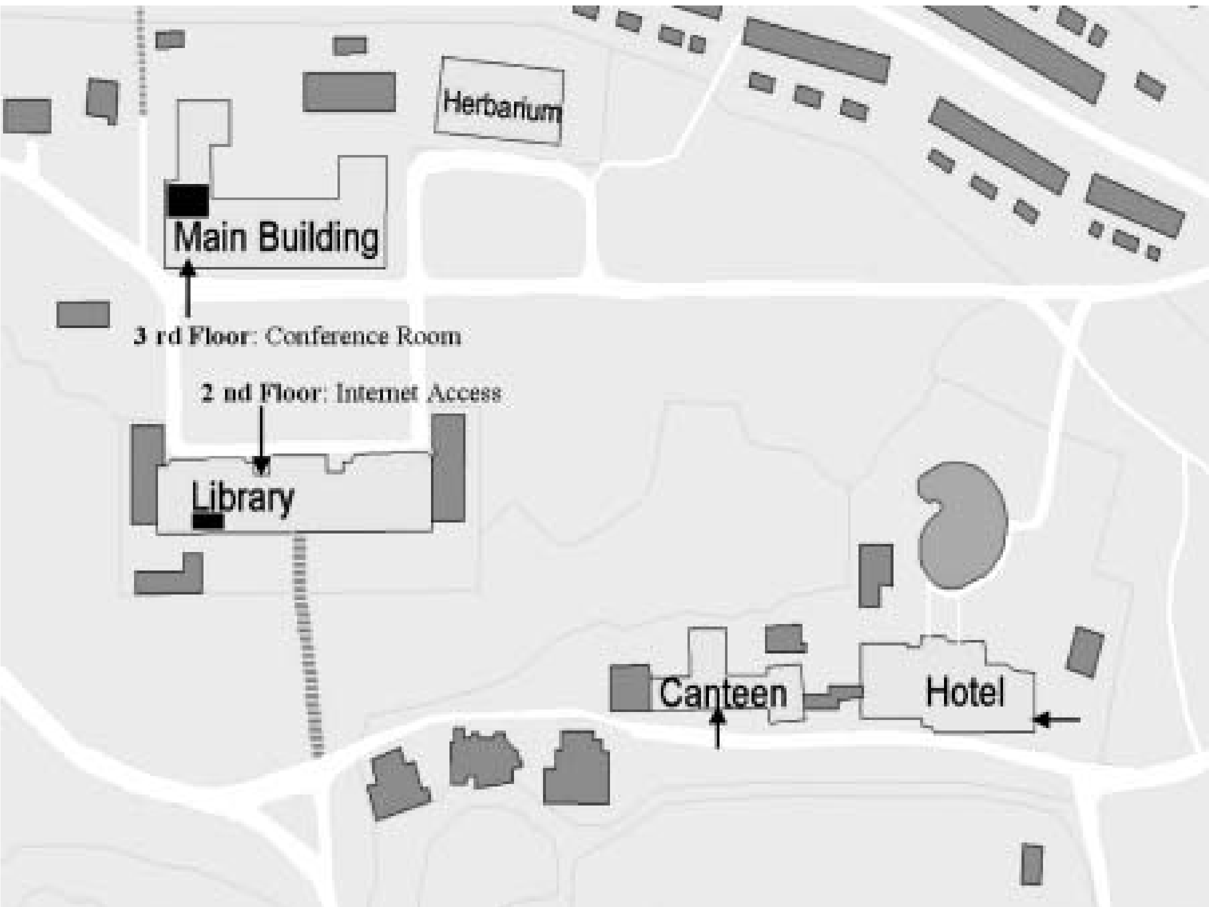

Sketch Map for the Workshop

WORKSHOP PROGRAM

Monday, 5 January 2004

Registration of the Workshop Participants at XTBG Center. Poster Installation at Library Building Hall.

Tuesday, 6 January 2004

08:00-09:30 Tour of the Garden (West Part)

09:30-09:50 Welcome Address

09:50-10:00 Workshop Introduction/Overview

10:00-10:20 Tea Break

Session 1. Frugivory and seed dispersal: ecological perspectives and evolutionary consequences
Chairperson: C. C. Horvitz & S.-Q. An

10:20-11:00

Keynote: Frugivory in the Neotropics: an overview by **T. H. Fleming**

11:00-12:20

C. C. Horvitz: The comparative life histories of ant and bird dispersed Marantaceae

S. Kitamura: Dispersal of Aglaia spectabilis, a large-seeded tree species in a moist evergreen forest in Thailand

F. Chen: Seed dispersal by ants in a tropical perennial herb: *Globba lancangensis* Y. Y. Qian (Zingiberaceae)

S. -B. Ma: Seed dispersals and their influence on geographical distribution of Podophylloideae (Berberidaceae)

Session 1. Continued. Chairperson: M. Cao & D. Westcott

14:00-14:40

Keynote: Characteristics and conservation of wild animals in China by **Z. -G. Jiang**

14:40-16:00

M. Cao: Soil seed banks: a comparison between tropical and subtropical forests in Yunnan, China

H. Zhu: Biogeography of the tropical rain forest in Southern Yunnan

T. Ganesh: Seed predation and seed removal rates in *Myristica dactylodes* in southern India

X. -H. Li: Avian seed dispersal of the Camphor tree (*Cinnamomum camphora*)

16:00-16:20 Tea Break

16:20-18:20

J. Chen: Differences in reproductive strategies and genetic structure in the three species in *Globba* (Zingiberaceae)

R. J. Green: The Other Side of Wallace's Line

Z.-S. Xiao: Testing the classic trade-off theory between seed size and dispersibility: a case from five rodent-dispersed fagaceous species

S.-T. Zhang: Correlates of seed size in a subalpine meadow on the eastward of the Tibet plateau

P. S. Chung: Post-dispersal seed predation in Hong Kong

S. Isnard: Climbing palms from Southeast Asia and America: Biomechanical architecture and the evolution of the climbing habit

19:00-20:00 Banquet hosted by XTBG

Wednesday, 7 January 2004

06:40-08:00 Bird Watching in East Part of the Garden

Session 2. Study on interactions of fruiting plants and frugivorous animals: methodological considerations
Chairperson: A. Dennis & B. D. Hardesty

09:00-09:40

Keynote: Frugivory in the Paleotropics: an overview by **R. Corlett**

09:40-10:40

B. D. Hardesty: Linking dispersers and seeds using molecular techniques: seed arrival, survival and long-distance gene movement in the bird dispersed tree, *Simarouba amara*

Y. -M. Xia: Phylogeny of *Amomum* (Zingiberaceae) revealed by ITS and matK DNA sequence: implicating the importance of fruit traits in classification of Sections

A. Dennis: Seed dispersal at community and landscape scales: incorporating functional classifications of dispersers into the study of an ecological process

10:40-11:00 Tea Break

11:00-12:40

Z. Na: Interspecies variation in the fragrances emitted by ready-for-dispersal fruits of several *Ficus* species

J. Weir: The use of radio-telemetry in seed dispersal studies

H. Xiang: Patterns and correlates of interspecific variation in foliar insect herbivory of four *Ficus* species

L. Zhang: Interspecies variation of morphology and nutritional values of *Ficus* fruits in the Tropics, SW China

S. B. Mikich: The use of the essential oil of chiropterochoric fruits for the attraction of fruit-eating bats and forest recovery

Session 3. Seed dispersal and frugivory: Implications for conservation

Chairperson: R. M. Borges & M. Z. Hussin

14:00-14:40

Keynote: Fruit preferences within guilds of seed-dispersing vertebrates: Substitutable or uniquely keystone species? by **M. Leighton**

14:40-16:00

R. M. Borges: Fruit resource attributes and aggression at fruiting trees in the Malabar giant squirrel *Ratufa indica* within a fragmented cloud forest in India

D. Westcott: Estimation of complete seed shadows for *Ficus* in Australia's tropical rainforests
M. Z. Hussin: Frugivory by birds in primary and logged lowland dipterocarp forest in Sabah, Malaysia

X.-Y. Yang: Seed storage-behavior of several palm plants in Yunnan, China

16:00-16:20 Tea Break

16:20-18:00

J. Vanitharani: Seed dispersal role of (endemic, endangered fruit bat of South India) *Latidens salimalii* in the Southern Western Ghats of India and its conservation status

S.-Q. An: Seed dynamics of tropical montane rain forest in Hainan

Y.-H. Wang: Ornithochory of *Euryodendron excelsum* and its significance in conservation biology

Y. Liu: Physical dormancy in tropical recalcitrant seeds of *Garcinia cowa* (Guttiferae)

Y. Y. Au: Patterns of seed deposition in a degraded tropical landscape.

20:30-22:00 Evening Party. Local music performances and drinks are available.

Thursday, 8 January 2004

Field trip to Bubang Nature Reserve in Mengla County, which is 120 km from XTBG, the typical rainforest which is dominated by *Shorea chinensis* (Dipterocarpaceae, the canopy height may reach 70 m) can be seen. Interpretation in the forest will be provided by Dr. H. Zhu.

Friday, 9 January 2004

08:00-10:00 Discussion on the possibility of regional net-working and cooperation on the study of frugivore-plant interactions (Chaired by R. Corlett & J. Chen).

10:00-10:20 Tea Break

10:20-11:00 Closing Ceremony

14:00 Departure of Participants

ABSTRACTS

Frugivory in the Neotropics: an overview

Theodore H. FLEMING

Department of Biology, University of Miami, Coral Gables, FL USA

As is the case throughout the tropics, most species of trees and shrubs in Neotropical forests produce fleshy fruits and rely on birds and mammals to disperse their seeds. Nonetheless, because of the Neotropic's geological history, including a long period (> 60 my) of relative isolation from the rest of the tropics, its large area (currently about 5 x 10^6 km^2 of tropical rain forest), and the importance of Andean orogeny over the past ca. 25 my, the evolutionary history of fruit-frugivore interactions in the Neotropics is unique for many reasons. One unique aspect is the sheer number of species of fleshy-fruited plants and frugivorous vertebrates that interact together in Neotropical habitats. In lowland Neotropical forests, up to 300 tree species can co-occur in a single hectare, and the shrub, liana, and epiphyte diversity is equally impressive. Dominant tree families in Neotropical forests include Leguminosae, Palmae, Meliaceae, Sapotaceae, Annonaceae, Guttiferae, and Moraceae. In the understory, three families – Rubiaceae, Melastomataceae, and Piperaceae – dominate. Fruits from these plants support up to 80% of the avian and mammalian biomass in these forests. Important families (or subfamilies) of frugivorous birds in these forests include toucans, trogons, cotingids, manakins, and tanagers. Important frugivorous mammals include phyllostomid bats, cebid monkeys, and procyonid carnivores. Detailed studies indicate that seed dispersal by these animals often plays a critical role in seedling recruitment via three routes: "enemy escape," "directed dispersal," and "colonization of new habitats." Loss of frugivores as a result of overhunting, direct persecution, and habitat destruction threatens to disrupt Neotropical fruit-frugivore interactions, as is the case in the rest of the tropics.

The comparative life histories of ant- and bird-dispersed Marantaceae

Carol C. HORVITZ

University of Miami, Coral Gables, FL 33124, USA.

Demography and light environment dynamics of six bird-dispersed species and three ant-dispersed species were investigated with respect to an hypothesis that bird dispersal is associated with stronger gap dependency. I summarize work on dispersal biology, germination and seedling survival, as well as responses of larger plants. In addition, for one of the ant-dispersed species, I show how demographic and dispersal data can be combined in a new way, utilizing an integrodifference equation model, to determine the relative importance of different reproductive modes to population growth vs. population spread across space. Dispersal was studied by watching animals carry seeds and by marking seeds and later measuring the spatial distributions of established seedlings. Demography was studied both by experiments and by tagging individual plants in study plots and following their fates and reproductive output during 2.5 yrs. Light environment was measured by hemispherical fish-eye photographs. Growth and survival rates differed among species of different dispersal modes as did the effects of light on growth and survival. The species of largest stature was able to take advantage of a gap for a longer period by growing taller. The results imply that different species “perceive” the spatiotemporal heterogeneity in the light environment created by gaps (and gap-phase succession) differently. Population spread across space was more sensitive to demographic transitions involving chasmogamous seeds than it was to demographic transitions involving cleistogamous seeds.

Dispersal of Aglaia spectabilis, a large-seeded tree species in a moist evergreen forest in Thailand

Shumpei KITAMURA[(1)]*, Shunsuke SUZUKI[(2)], Takakazu YUMOTO[(1)], Pilai POONSWAD[(3)], Phitaya CHUAILUA[(3)], Kamol PLONGMAI[(3)], Naohiko NOMA[(2)], Tamaki MARUHASHI[(4)] & Chumphon SUCKASAM[(5)]

(1) Center for Ecological Research, Kyoto University, Kamitanakami-Hirano, Otsu 520-2113, Japan
(2) School of Environmental Science, The University of Shiga Prefecture, Hikone 522-8533, Japan
(3) Hornbill Project, Department of Microbiology, Mahidol University, Bangkok 10400, Thailand
(4) Department of Human and Culture, Musashi University, Nerima, Tokyo 176-8534, Japan
(5) National Park, Wildlife and Plant Conservation Department, Bangkok 10900, Thailand

We investigated the seed dispersal of *Aglaia spectabilis*, a large-seeded tree species in a moist evergreen forest of Khao Yai National Park in Thailand. Although one to one relationships between frugivores and plants are very unlikely, large-seeded plants having to rely on few large frugivores and therefore on limited disperser assemblages, might be vulnerable to extinction. We assessed both the frugivore assemblages foraging on arillate seeds of *Aglaia spectabilis* and dispersing them and the predator assemblages thereby covering dispersal as well as the post-dispersal aspects such as seed predation. Our results showed that frugivores dispersing seeds where a rather limited set of four hornbill (*Buceros bicornis*, *Aceros undulatus*, *Anorrhinus austeni* and *Anthracoceros albirostris*) and one pigeon species (*Ducula badia*), whereas two squirrel species (*Ratufa bicolor* and *Callosciurus finlaysonii*) were not dispersers, but dropped the seeds on the ground. Three mammal species (*Hystrix brachyura*, *Maxomys surifer* and *Callosciurus finlaysonii*) were identified as seed predators on the forest floor. High seed predation by mammals together with high seed removal rates, short visiting times and regurgitation of intact seeds by mainly hornbills lead us to the conclusion that hornbills show high effectiveness in dispersal of this tree species.

Post-dispersal fate of seeds and seedling survival below hornbill nest trees in a tropical forest in Arunachal Pradesh, India

Aparajita DATTA

Wildlife Conservation Society-India Program, Bangalore, India

Nature Conservation Foundation, Mysore, India

During a four year study on the role of hornbills as seed dispersers in a tropical foothill forest in Arunachal Pradesh, north-east India, I found that hornbill seed deposition patterns are clumped around nest sites during the breeding season. However, breeding males and non-breeding adults and juveniles regurgitate and scatter-disperse seeds over a wider area at perch trees during daytime foraging. Although hornbills deposited seeds of 35 rainforest tree species below nest trees, seed deposition patterns are spatially contagious compromising the quality of dispersal due to increased post-dispersal seed predation by rodents and beetles and density dependent mortality. Seed densities at perch trees are much lower than that under nest trees and seed predation rates are also lower suggesting that hornbills play a more efficient role as seed dispersers at perch trees. Though initial seedling density under nest trees is very high, suggesting successful dispersal, there is a high degree of mortality at the seedling stage. The patterns of seedling survival under nest trees are discussed and compared with that under parent trees of hornbill food plant species. The quality of dispersal is relatively poor at nest trees due to the spatially clumped seed rain that results in high seed and seedling mortality. However, possible secondary seed dispersal due to removal and caching of seeds by rodents away from nest trees may also be occurring. This study highlights the importance of examining the fate of seeds and subsequent seedling survival to accurately determine the effectiveness of dispersal by hornbills.

Seed dispersal by ants in a tropical perennial herb: *Globba lancangensis* Y. Y. Qian (Zingiberaceae)

Fan CHEN & Jin CHEN

Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences

Mengla, Yunnan 666303, P. R. China

Myrmecochory is a term referring to the mutualism system in which ants use nutritionally valuable elaiosomes as food, and disperse plant seeds in the process. In this study we aim to understand that how ants affect the seed dispersal of a myrmecochorous plant, *Globba lancangensis* and to explore whether the seed dispersal finally affects the spatial pattern of its seedlings.

G. lancangensis is a small perennial herb of Zingiberaceae mainly distributed in SW Yunnan province. It propagates mainly by seeds and also a small number of bulbils. There are 31.2 ± 2.13 (Mean ± SE, N = 32) seeds in each fruit. The wet weight of the diasporas, seeds and elaiosomes for each fruit is 8.35 ± 0.16 mg, 6.63 ± 0.12 mg and 1.72 ± 0.09 mg respectively (N = 100). The seed are 2 ~ 3 mm in length which bearing a white-color elaiosome.

We conducted an field observation on the seed dispersal of *G. lancangensis* in 2002 and 2003 in its natural habitats in Xishuangbanna, Yunnan province of China (21^{o}59′ N, 100^{o}16′ E, and the elevation is 1 180 m above the sea. The annual mean temperature is 18.3 ℃ and the annual mean rainfall is 1 339 mm). In 2002, a total of 10 species of ants that transport seeds of *G. lancangensis* were recorded and identified. The mean dispersal distance of seeds was 0.47 ± 0.03 m (N = 216), between 0.01 m to 3.35 m. Among all ants, *Odontoponera transversa* (Smith), *Pheidole* sp. and *Pachycondyla luteipes* (Mayr) were the most important species to seed dispersal, with their occurrence frequency to each fruit being of 61 %, 50 % and 28 %, and, the percentage of a total seeds removed being 15.3 %, 43.5 % and 13.0 %, respectively. In 2003, a total of 10 species of ants were recorded and the three species, *Odontoponera transversa* (Smith), *Pheidole* sp. and *Pachycondyla luteipes* (Mayr), were also the most important to seed dispersal. Most of ants transport the seeds to their nests directly. As a whole, ants promote the decrease of aggregation degree of *G. lancangensis* seeds.

To determine whether the elaiosome is responsible for attracting ants for seed dispersal, we conducted field studies on removal of intact diaspores and seeds with elaisomes artificially removed. As a whole, ants removed intact diaspores quicker than seeds without elaisomes. Four species of ponerines included *O. transversa*, *Odontomachus circulus* Wang, *Leptogenys kitteli* (Mayr) and *Diacamma rugosum* (Le Guillou) only removed the seeds with elaisomes and did not remove the seeds without elaisomes. The other species, such as *Pheidole* sp., *Pachycondyla luteipes* (Mayr), *Dolichoderus affinis* Emery and *Aphaenogaster beccarii* Emery, did not show significant differences in remove of seed with elaisomes comparing to seeds without elaisomes. These four species of ponerines, especially *O. transversa*, which have a high occurrence (61 % in 2002 and 22 % in 2003) and great mean dispersal distance (0.60 ± 0.09 m), have bigger body size and can disperse the seeds further than other ants. It suggested that there was a tighter mutualism existed between *G. lancangensis and* ponerines ants especially for ant *O. transversa.*

Exclosure experiments for assessing the relative impact of ants and rodents on dehisced seeds were also conducted in the field. Daytime and nighttime seed-removal frequencies were determined by placing seeds with the following treatments: 1) ants and rodents can access, 2) only ants can access, 3) only rodents can access. Rodents have a great effect in reducing seed pool numbers and mostly at night (84.6 ± 4.6 % in ant exclosure). Ants can removed 70.4 ± 4.3 % and 56 ± 4.8 % seeds in the day and night respectively (in rodent exclosure). It suggested that ants might help seeds of *G. lancangensis* avoid predation by rodents in the night significantly.

To understand whether ants have influences on the spatial pattern of seedlings, we further compared the spatial distribution of seedlings of *G. lancangensis* in natural habitats with that of other two species in *Globba*, *G. barthiri* and *G. racemosa*, and the latter two species propagate mainly by bulbils which are apparently dispersed by abiotic means. Nine plots with 25 × 25 m in size, three plots for each species, were investigated to record every seedling of the *Globba* plants inside of plots. The mean distance to nearest neighbor of *G. lancangensis* was significantly higher than both *G. barthiri* (36.8 ± 1.45 cm *vs*. 29.8 ± 2.70 cm; $t_{73,\,33}$ = 2.11, p = 0.037) and *G. racemosa* (36.8 ± 1.45 cm *vs*. 28.7 ± 3.16 cm, $t_{73,\,31}$ = 2.33, p = 0.022). The Z-value were also employed to describe the clumpy distribution of different populations of the three species and the Z-value of *G. lancangensis* (-1.70 ± 0.19) was significantly larger than the Z-value of both *G. barthiri* (-2.58 ± 0.37, t = 2.36, p = 0.020) and *G. racemosa* (-3.28 ± 0.53, t = 3.54, p = 0.001), indicating that *G. lancangensis* was significantly less clumpy. The results suggested that by interacting with rodent predators, ants might make significant contribution to the increase of the mean nearest neighbor distance and the decrease of aggregation degree of *G. lancangensis* seedlings in the natural habitats.

Biogeography of the tropical rain forest in southern Yunnan

Hua ZHU

Xishuangbanna Tropical Botanical Garden, the Chinese Academy of Sciences

Kunming 650223, P. R. China.

The tropical rain forest in southern Yunnan is similar to the equatorial rain forest of tropical Asia on floristic composition, forest profile, physiognomy and species richness, and therefore is considered to be a type of the tropical Asian rain forest. Compared with the lowland wet evergreen rain forest of equatorial Asia, the rain forest of southern Yunnan has some deciduous trees in the top layer, less richness in megaphanerophytes and epiphytes, but much richer liana plants and the trees with microphyllous leaves. This suggests that the rain forest of Yunnan which occurs at the northern margin of mainland Southeast Asia and controlled by monsoon climate, is affected not only by seasonal dryness of climate, but also by low temperature found in the relatively higher latitude and altitude. The flora of the rain forest of Yunnan consists mainly of tropical floristic elements which contribute about 60% at the family level, more than 80 % at the generic level and more than 90% at specific level to its total flora. The dominant floristic elements of the rain forest of Yunnan at both the generic and specific levels are the tropical Asian distribution, which contributes about 40% of its genera and 75% of its species. This reveals that the flora of the rain forest of Yunnan is of tropical nature with a strong tropical Asian affinity. Most of the dominant families from the rain forest of Yunnan are also dominant in the Indo-Malesian rain forests. The highly floristic and physiognomic similarities between the the rain forest of Yunnan and the Indo-Malesian rain forests suggest that the tropical rain forest of Yunnan is part of the Indo-Malesian rain forests as a marginal type from north of mainland Southeast Asia and still belongs to the Malesian floristic region. The close affinity of the rain forest of Yunnan to the Indo-Malesian rain forests can be explained by the geological history of Southeast Asia.

Seed predation and seed removal rates in Myristica dactylodes in southern India

T. GANESH
Ashoka Trust for Research in Ecology and the Environment (ATREE)
659, 5th A, Main road,Hebbal, Bangalore 560024, India.

Myristica dactyloides is a subcanopy tree in the rain forest of south Western Ghats. It is one of the dominant species in the forest. The tree produces between 400-800 fruits approximately once in two years. The fruits like in other Myristicaceae are dehiscent and arillate. The seeds of the tree genera Myristica are generally dispersed by birds especially large frugivores like pigeons and hornbills. However at the site where this study was done, there are no hornbills and the frugivores assemblage is dominated by seed predators. The seeds of the M.dactyloides are eaten both in the canopy and in the ground. In this study I address 1.What are the primary seed disperser and seed predators of the MD. 2. What is the extent of seed predation and seed removal rates in the species.

Fruiting Myristica dactyloides trees were observed from the ground and from tree tops for visitors. A total of 48 h of observation was made on the trees spanning 8 h per day. The visitors were Nilgiri Langur (Semnopithecus johnii), Malabar Giant Squirrel (Ratufa indica) and the Lion-tailed macaque (Macaca silenus). The langur was a seed predator while the other two only ate the aril and discarded the seeds. Nearly 48% of the visits were from Nilgiri langur and contributed heavily to diurnal seed predation. Among nocturnal species the endemic Malabar spiny dormouse (Platacanthomys lasiurus) was the major seed predator. These are secondary seed predators and Ninty nine % of the seeds in the baited traps were eaten by the mouse. Seed survival and germination was significantly high in areas where the dormouse was not common. It therefore appears that post-dispersal seed predators have a major role in establishment of the species in the forest.

Avian seed dispersal of the camphor tree (*Cinnamomum camphora*)

Xin-Hua LI
College of life sciences, Nanjing Agricultural University
Nanjing, 210095, Jiangsu, China

The camphor tree (*Cinnamomum camphora*), native to China and Japan, is an evergreen broad-leaved tree, very popular and widely cultivated as an ornamental tree, or a timber tree in southern China, mainly in Jiangxi, Fujian, Zhejiang, Hunan, Hubei, Guangdong, Guangxi, Yunnan, Jiangsu and Anhui provinces. Camphor trees are very prolific which produce a large amount of black berries in autumn, and are frequented much by frugivorous birds in autumn and winter. From 1999 to 2001, avian seed dispersal of camphor tree was studied at the southern foot of Zhongshan Mountain, a famous scenic spot located in the east of Nanjing city, Jiangsu province, China. Some results are presented as bellows:

1 Fruit-eating bird species

Totally 12 bird species in 8 genera and 5 families were observed eating the black berries of the camphor tree in autumn and winter (Table 1)

Table 1 Bird species feeding on berries of *Cinnamomum camphora* in Nanjing

	Bird species	Visiting frequency	Note
Phasianidae			
	Phasianus colchicus*	++	resident
Columbidae			
	Streptopelia orientalis	++	resident
Pycnonotidae			
	Pycnonotus sinensis	++	resident
Corvidae			
	Urocissa erythrorhyncha	++	resident
	Cyanopica cyana	++	resident
	Pica pica	+	resident
Muscicapidae			
	Turdus hortulorum	++	winter migrant
	T. merula	+++	resident
	T. naumanni	++	winter migrant
	Garrulax perspicillatus	++	resident
	G. pectoralis	+	resident
	G. canorus	+	resident

Note: +++ most frequent visitor ; ++ frequent visitor; + occasional visitor;
* only on the ground beneath the tree crown.

2 Seed dispersal and seed dispersers

Few intact seeds of *Cinnamomum camphora* were found from the birds' fecal samples randomly collected, because some frugivorous birds, e.g. *Turdus hortulorum*, *T. merula*, and *T. naumanni*, usually regurgitated the seeds soon after they ingested the berries. Hence seeds of the camphor tree were mainly dispersed by birds through regurgitation. Among the 12 fruit-eating bird species, the blackbird (*Turdus merula*) was the most frequent visitor to the fleshy fruits of *Cinnamomum camphora* and may be considered as an important seed disperser of this tree. However, the common pheasant (*Phasianus colchicus*) may be considered as a seed predator of the camphor tree, because the seeds were often destroyed after passing through its digestive tract.

3 Natural regeneration of camphor tree

The camphor tree is a common ornamental tree, which was first introduced and cultivated at the southern foot of Zhongshan Mountain at least about 50 years ago. Now, as a result of bird seed dispersal, naturally regenerated seedlings and saplings of this tree are not difficult to find in the evergreen coniferous and deciduous broad-leaved mixed forest of the Zhongshan Mountain. However, few seedlings of the camphor tree can be found beneath the adult mother trees.

4 Naturalization and invasion of camphor tree as an exotic plant in the world

Outside China and Japan, the camphor trees has been introduced and has been widely cultivated for more than a century as a shade and ornamental tree in the United States, and Australia. It produces numerous bird-dispersed berries and has become naturalized in Hawaii, southern states of the United States, especially in Florida, and Australia. Trees of *Cinnamomum camphora* are quickly invading some disturbed areas and also natural areas, such as Florida's few remaining virgin forests and wetlands. Now the camphor tree is listed on the FEPPC (Florida Exotic Pest Plant Council) that are invading and disrupting native plant communities in Florida.

Differences in reproductive strategies and genetic structure in several species in Globba (Zingiberaceae)

Jin CHEN, Zhi-Qiu LIU, Ling ZHANG, Zhi-Ling BAI, Fan CHEN & Hui-Ping ZHOU
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Mengla, Yunnan 666303, China

Globba plants have a variety of reproductive strategies in their natural population in Southern Yunnan of China. *G. lancangensis* propagated mainly by seeds, while *G. barthei* and *G. schomburgkii* mostly by bulbils, and *G. racemosa* propagated both by seeds and bulbils. The objectives of this study are: 1) To determine the differences of the sexual and asexual reproductions within the several species; 2) To understand whether the differences of reproduction result in the differences in their genetic structure; 3) To explore whether the allocation on the sexual and asexual reproduction responses to different level of soil nutrition.

Both *G. barthei* and *G. schomburgkii* mostly depended on bulbils for their reproduction, and the one year aged plants produced 16.46±3.56（mean±SD，N = 60） and 14.25±3.63 （mean±SD，N = 153） bulbils per ramet. No seed set were observed for the two species while by artificial selfing and crossing. The abnormal pollens (> 98% of total pollens observed) in *G. barthei* and low pollen viability in *G. schomburgkii* (<12%) may be ascribable to no seed-set. For *G. lancangensis*, it mainly engaged in sexual reproduction with a seed-set ratios (seed/ovule ratios) of 64.5±12.1% in the field (N =36) and produced relatively few bulbils (2.2±1.4 per ramet, N =184). *G. lancangensis* bear both male and hermaphrodite on same ramets. There were no significant differences for the fruit-set ratios between hand-selfing and hand-crossing, but significant differences of seed-set ratios (seed/ovule ratios), which suggested that this plant might maintain the mechanism of self-incompatibility. Additionally, three species of *Globba* have the ability of clonal reproduction with underground stems. The corolla tuber length of three species differed significantly by the order: *G. barthei* > *G. schomburgkii*> *G. lancangensis.* All pollinators of three *Globba* we observed were definitely honeybees other than butterflies, and the latter was previously suggested by other authors. *Megapis dorstata* was the only pollinator for *G. barthei*, while *M. dorstata*, *Nomia strigata* and *Xylocopa collaris* visited *G. schomburgki*, *M. dorstata* and *N. strigata* were the main visitors for *G. lancangensis.* Three species have much longer corolla tuber comparing with the tongue length of three visitors. Nectar in *G. barthei* during a day can only reach the height of 3/4 corolla tuber length, which may prevent bee with short tongue (e.g., *Nomia strigata*) visiting the flowers. The flowers of *G. schomburgkii* produce large amount of nectar and nectar overflows the corolla tuber after 9:00 A.M., which make bees with different tongue length, can easily suck the nectar. Thus, the visitation of different bees appeared to be influenced by both corolla tuber length and the amount of nectar produced.

The genetic and genotypic diversity of three species of *Globba* populations (*G. barthei*, G. *lancangensis* and *G. racemosa)* were investigated using allozyme. All the three species have relatively high genotypic diversity-- 58.9-67.3% of the loci examined were polymorphic and the mean genetic diversity within populations (He) were 0.294 to 0.334. There is 24.6-32.5% of the total genetic variations were found among populations ($F_{(ST)}$). The differences in the reproduction did not show a significant relationship to the genetic diversity and genetic structure of populations. The correlation between genetic distance and geographic distance of the eight population of *G. racemosa* were not significant.

When treated with high level soil nutrition, both *G. barthei* and *B. schomburgkii* showed a significant increase in asexual reproduction (number of bulbils produced and size of bulbils) while no significant changes were detected for sexual reproduction. Artificially remove the sexual part(flower buds) did not significantly change the asexual reproduction and vise versa in the two speices.

The other side of Wallace's line

Ronda Joy GREEN
Australian School of Environmental Studies, Faculty of Environmental Sciences, Griffith University
Kessels Rd, Nathan Qld 4111 Australia

Australasia's origins in Gondwana, isolated drifting and eventual close approach to Asia have provided us with opportunities for interesting intra-family, intra-genus and even intra-species comparisons of fruit features from areas with different suites of dispersers and seed predators, with implications for evolution of fruit features. This paper presents a survey of Australian fruits which appear to be of importance to particular frugivores or groups of frugivores (including where possible evidence of preferences, of usage in lean seasons, and nutrient content of plants); and frugivores which appear to be of importance to particular plants or groups of plants. The survey includes published and unpublished field and aviary research by the author as well as an extensive literature review. Plant families (of varying importance to frugivores) for special comparison include Arecaceae, Moraceae, Lauraceae, Myrtaceae and Sapindaceae. Differences in fruit features between Australia and Asia are examined as far as possible from existing literature, and suggestions offered for future intercontinental research.

Testing the classic trade-off theory between seed size and dispersibility: a case from five rodent-dispersed fagaceous species

Zhi-Shu XIAO & Zhi-Bin ZHANG
State Key Laboratory of Integrated Management of Pest Insects and Rodents in Agriculture, Institute of Zoology, the Chinese Academy of Sciences, Beijing, 100080, P.R. China

Recently, the hypothesis that dispersibility decreases with increasing seed size has been questioned according to seed dispersal aided by seed-caching rodents. In order to test the classic trade-off between seed size and dispersibility, we traced the seed fates (with coded tin-tags) of five rodent-dispersed fagaceous species (i.e., *Quercus variabilis*, *Quercus serrata*, *Castanopsis fargesii*, *Cyclobalanopsis glauca*, *Lithocarpus harlandii*) with different seed size in two stands (i.e. a primary stand and a secondary stand) over three years in a subtropical evergreen broadleaved forest in Dujiangyan Region, Sichuan Province, China. According to optimal cache spacing model, we develop a dispersal distance model to understand how seed size (and other seed traits as well) affect post-dispersal distributions under the help of scatter-hoarding rodents in relation to primary distributions (i.e., initial dispersal distances by gravity). Our results show that, either in primary stand or in secondary stand, dispersal distances (including distribution range, mean and maximum) of the cached seeds in primary caches and the eaten seeds after dispersal significantly increased with increasing seed size: *Lithocarpus harlandii*, *Quercus variabilis*, *Q. serrata*, *Cyclobalanopsis glauca*, and *Castanopsis fargesii* in descending order. The results support the predictions of dispersal distance model, but reject the classic trade-off between dispersibility and seed size. In addition, large seeds (i.e., *Lithocarpus harlandii* and *Quercus variabilis*) facilitate increasing secondary caching, which can further reduce the relative density among caches and extend the dispersal distances. Our findings indicate that, greater dispersal distances for larger seeds might benefit the evolution of large seed size in a certain range, and scatter-hoarding might ensure their net benefit for both rodent-dispersed tree species and seed-caching rodents. Other seed traits (e.g. nutrient composition, tannin content and seed coat) may modify the evolution of seed size in rodent-dispersed tree species.

Correlates of seed size in a subalpine meadow on the eastward of the Tibet plateau

Shi-Ting ZHANG[1], Guo-Zhen DU[1*] & Jia-Kuan CHEN [2]

[1] State Key Laboratory of Arid Agroecology, Lanzhou University, Lanzhou 730000, China

[2] Bio-diversity Science Institute, Fudan University, Shanghai 200433, China

[*] Corresponding author

We test hypotheses that can account for the variation in seed size in a database of 229 species from a subalpine meadow on the east of the Tibetan plateau. Information on seed mass, plant height, dispersal mode, onset of flowering and family membership is included. We use general linear models to consider not only the primary correlations between seed size and each variable, but also overlap patterns among correlations to determine if each relationship arises as a result of indirect correlations through other variables. The strongest association of seed size is with family membership, and the variation accounted for by family membership overlaps with that accounted for by plant height, dispersal mode, and onset of flowering. Similarly, we find that there are overlaps in the seed-size variation explained both by plant height and dispersal mode, and by plant height and onset of flowering. However, there is no association in the variation in seed size accounted for by plant height and onset of flowering. Family membership, plant height, dispersal mode and onset of flowering have significant associations with seed size independently of the other variables measured. We cannot give a logical explanation for the pattern between seed size and onset of flowering.

Post-dispersal seed predation in Hong Kong

Pik-Shan CHUNG

Department of Ecology & Biodiversity, The University of Hong Kong

Pokfulam Road, Hong Kong, China

A preliminary study suggested that post-dispersal seed predation may be a significant barrier to forest recovery in the degraded landscape of Hong Kong. Seed predation rates on both market seeds (for uniformity) and wild-collected seeds (for naturalness) were therefore compared in the major upland habitat types. Seed predation rates varied greatly between sites, but were generally highest in forest along streams and lowest in dry grasslands. At the sites with the highest predation rates, all seeds disappeared within 24 hrs. Exclosure experiments and camera-traps showed that the major seed predators in all habitats were two species of rats, *Niviventer fulvescens* and *Rattus sikkimensis*, which were also the only species caught in baited cage traps. More rats were caught in sites with higher predation rates. A radio-tracking study showed that both species prefer to nest under rocks near water and that they range up to 100 m from where they were caught. There is no evidence that either species scatter-hoards seeds and their nest sites are unsuitable for germination and growth. However, some very small seeds (e.g. *Melastoma* sp.) were found in droppings, so these rats may play some role in seed dispersal.

Climbing palms from Southeast Asia and America: Biomechanical architecture and the evolution of the climbing habit

Sandrine ISNARD
Botanique et Bioinformatique de l'Architecture des Plantes (AMAP)
UMR 5120 CNRS, TA40/PS2, Boulevard de la Lironde, 34398 Montpellier, France

Biomechanical studies combined with phylogeny have recently led to a better understanding of the evolution of climbing habits within specific families. Most dicotyledonous lianas show a non self-supporting mechanical pattern during ontogeny, resulting in a drop of Young's modulus: a measure of the ability of the material to resist bending forces. Even if this pattern differs in amplitude or rate of change according to the type of liana and the systematic context, these general mechanical patterns leading to flexible old stems, are correlated with deep anatomical changes via secondary growth.

In a recent project we have studied the mechanical architecture of climbing palms belonging to Arecoideae (*Desmoncus* sp.) and Calamoideae (*Calamus* sp) subfamilies to determine how these plants lacking secondary growth are nevertheless capable of developing scandent habits. The climbing palms are particularly interesting from this point of view, since axes can reach incredible lengths (200m), and also because, with 580 climbing species, this growth form seems to be an evolutionary success in the family. Preliminary results will emphasise a particular mechanical architecture in climbing palms where axes are highly stiff and never show a drop of Young's modulus values during ontogeny as observed in dicotyledonous lianas. The mechanical role of the leaf sheath is also compared with the mechanical impact of secondary growth in dicot lianas The hypothesis is presented that in some climbing palms a flexibility mechanism is quite different from dicotyledonous lianas. In such palms the outer sheath can contribute stiffness but under severe loads can fracture and allow bending of the stem inside and thus protect the vital hydraulically conducting part of the stem from stress induced damage.

From the point of view of evolution, the climbing growth form has appeared independently several time in distinct subfamilies (Arecoideae, Calamoideae and Ceroxyloideae) and this convergent evolution seems to have led to specific mechanical architectures related to the phylogenetic affinities of different genera.

Frugivory in the Paleotropics: an overview

Richard T. CORLETT
Dept. Ecology & Biodiversity, The University of Hong Kong, Pokfulam Road, Hong Kong, China

The Paleotropics is defined here to include tropical Asia and Africa, which have been connected since the Miocene and share many frugivore families, but not Madagascar, New Guinea and Australia, which have remained isolated. Ripe fleshy fruits in the Paleotropics are consumed by numerous invertebrates and by fish, reptiles, mammals and birds, but mammals and birds are responsible for the great majority of seed dispersal. Although most species of mammals and birds eat some fruit, field observations of fruiting trees suggest that most fruits are removed by apes (Hominidae and, in Asia, Hylobatidae) and Old World monkeys (Cercopithecidae, particularly Cercopithecinae), fruit bats (Pteropodidae), civets (Viverridae), squirrels (Sciuridae), and members of fifteen bird families; barbets (Capitonidae), hornbills (Bucerotidae), parrots (Psittacidae), pigeons (Columbidae), mousebirds (Coliidae; Africa only); turacos (Musophagidae; Africa only), leafbirds (Irenidae; Asia only), crows (Corvidae), Old World orioles (Oriolidae); thrushes (Turdidae), starlings (Sturnidae), flowerpeckers (Dicaeidae; Asia only), bulbuls (Pycnonotidae), white-eyes (Zosteropidae) and babblers (Timaliidae).

All these animals disperse at least some seeds, except probably most parrots, colobine monkeys and squirrels, and some pigeons. In addition, terrestrial herbivores – including elephants (Elephantidae), rhinoceroses (Rhinocerotidae), bovids (Bovidae), chevrotains (Tragulidae), and, in Asia, deer (Cervidae) – consume fallen fruits and are major dispersal agents for some plants. Some rodents scatter-hoard some fruits and seeds, but their role in seed dispersal is unclear. Seed-dispersal guilds among plants are most obvious for species with fruits dispersed largely by primates, by fruit bats, and by terrestrial mammals, with bird fruits apparently partitioned largely by size. Conversely, the diversity of fruits recorded in the diets of well-studied animal species suggests a general lack of specialization among Paleotropical frugivores.

Frugivory in the Paleotropics differs from frugivory in the Neotropics in: the larger size of many fruits and frugivores; the presence of megaherbivores; the willingness of many forest frugivores to cross open areas; the presence of seed-spitting monkeys with cheek pouches; and the rarity of some fruit acquisition and processing techniques that are common in Neotropical birds, including taking fruits on the wing and mashing fruits to remove seeds before swallowing. Only the squirrels, barbets, parrots, pigeons, corvids and thrushes eat fruit in both the Old and New World tropics, and *Turdus* is the only genus that is important in both.

Seed dispersal studies in the Paleotropics have concentrated almost entirely on the seed removal stage, i.e. frugivory. Studies of seed deposition are in their infancy, very little is known about seed dispersal distances, and almost nothing about post-dispersal seed fates. These gaps in our current knowledge make is impossible to link patterns of frugivory with patterns of plant regeneration, and thus impossible to predict the impacts of the disruption of plant-disperser interactions by human activities.

Linking dispersers and seeds using molecular techniques: seed arrival, survival, and long distance gene movement in the bird dispersed tree, *Simarouba amara*

Britta Denise HARDESTY

Unit 0948, Smithsonian Tropical Research Institute, APO AA 34002-0948, The Republic of Panama

Seed dispersal is a fundamental process that shapes plant communities at local and large scales in both space and time. From the animal perspective, researchers assess disperser movement patterns, generally addressing seed deposition without empirical evidence of seed fate. From the plant perspective, ecologists have traditionally relied on seed traps and other indirect measures of determining seed shadows and dispersal curves. Recent advances in molecular techniques now permit analyses of gene flow via seed dispersal using maternal tissue from seeds, and enable us to determine genetic relationships among large numbers of individuals and populations of plants at widespread geographic scales in contemporary and historical time.

Using microsatellite genetic markers developed for the vertebrate-dispersed dioecious tropical tree, Simarouba amara, I inferred the parentage of seeds and seedlings in the Barro Colorado Island 50 ha plot and related this to fine-scale spatial genetic structure and successful seed arrival and survivorship near and far from the parent plant. The spatial distribution of parents and their offspring, coupled with field measures of floral and fruit production, crown area and tree height, was used to calculate relative reproductive success and the frequency of long-distance seed and pollen movement. The dispersal dynamics examined here provide insight into a demographic filtering stage that is critical for generating forest structure. This study assesses the relative importance of gene flow via pollen versus seed with respect to distance, thus gaining insight to the role of frugivores in structuring plant communities at a forest characterized by high species richness and tree density.

Phylogeny of Amomum (Zingiberaceae) revealed by ITS and matK DNA sequence: implicating the importance of fruit traits in classification of Sections

Yong-Mei XIA[1], W. John KRESS [2,4] & Linda M. PRINCE[2,3]
[1]Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Mengla, Yunnan 666303, China;
[2] Botany, MRC-166, United States National Herbarium, National Museum of Natural History, Smithsonian Institution, PO Box 37012 Washington, District of Columbia 20013-7012;
[3]Current address: Rancho Santa Anna Botanic Garden, 1500 North College Avenue, Claremont, California 91711-3157;
[4] Author for correspondence. (e-mail: kress.john@)nmnh.si.edu)

Comparative sequencing of the nuclear ribosomal Internal Transcribed Spacer (ITS) and the chloroplast *mat*K coding and non-coding regions was used to examine the evolutionary relationships among 53 accessions representing 13 genera of the Zingiberaceae, including 31 accessions of *Amomum* (Alpinioideae). Phylogenetic analyses of the ITS and *matK* sequences alone and in combination using maximum parsimony methods produced a moderately supported topology within Alpinioideae. Our results indicated that *Amomum* as currently defined is polyphyletic with three major groups of species that do not correspond with any previously recognized sectional classification of the genus. Our analyses also identified *Paramomum* as sister to *Elettariopsis*, which are both embedded within one group of *Amomum*. The other two groups of *Amomum* share common ancestors with additional genera of the Alpinioideae. ITS and *matK* sequences provide new data for inferring relationships within *Amomum* and allow fresh interpretations of morphological characters (such as anther appendage and fruit type) that may be of value in future classifications.

Seed dispersal at community and landscape scales: incorporating functional classifications of dispersers into the study of an ecological process

Andrew DENNIS[*] & David WESTCOTT
CSIRO Sustainable Ecosystems and the Rainforest CRC, P.O. Box 780, Atherton, 4883 Australia

The dispersal of seeds in tropical rain forests can involve a shifting array of potentially hundreds of species in a process that is fundamental to ecosystem behaviour. Unfortunately, this abundance and complexity complicates any attempt to describe and understand seed dispersal processes at the community scale. An approach that derived and described functional groups of fruits and dispersers by recognising similarities between participants would reduce the number of interactions that need to be considered. It would also provide a coherent set of attributes for recognising functional groups that could be applied at a variety of scales and locations. The lack of such an approach impedes our ability to describe seed shadows in complex communities and to predict the outcomes of seed dispersal processes at community and landscape scales in tropical forests. In addition, this lack diminishes our ability to manage these systems sustainably in the face of global change and its impacts at the process level.

In this paper we outline a functional classification of frugivores that has general utility in describing and predicting the outcomes of seed dispersal processes at community and landscape scales. We outline the traits of dispersers that are likely to influence the outcome of their interactions with fruit and derive a classification of the frugivores of the wet tropics region of Australia. Traits include movement patterns, gut passage times, fruit sizes swallowed, foraging strata, carrying method, deposition pattern and patterns of visitation. We designed the classification to be used at a range of levels from broad divisions for the study of complex and spatially large systems to divisions at much finer levels for studying simpler systems. The resulting analyses for Australia's wet tropics reduced 61 species of frugivores and granivores to 15 functional groups.

Interspecies variation in the fragrances emitted by ready-for-dispersal fruits of several *Ficus* species

Zhi NA & Jin CHEN

Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Mengla, Yunnan 666303, China

With about 800 species, distributed worldwide in tropical and subtropical zones, the genus *Ficus* (Moraceae) is one of the largest genera of woody plants. Although the importance of figs as keystone resources for many frugivores is increasingly recognized, systematic study of characteristics of fig fruit and how they relate to the animal that eat the fruit and disperse their seeds is largely unexplored, especially the ecological correlates of chemical signaling by ripe (ready-for-dispersal) figs. In this study, the fragrance released by ripe figs from 8 tropical *Ficus* species have been investigated *in situ* using adsorption-desorption headspace technique. On each day of measurement, collection of volatile compounds was done in the two periods, i.e. from 0900 to 1900 and from 2200 to 0800 the following day, respectively. GC-MS analyses of the headspace samples resulted in the identification of 172 compounds. The compounds are mainly terpenoids, aliphatic and benzenoids compounds.

We hypothesized that ripe fruits of female or monoecious *Ficus* species might emit particular volatiles in the night in order to attract their nocturnal mammal seed disperser. Thus, volatiles released by female ripe figs should significantly differ from those released by male figs and the volatiles collected in the night might also differ from those collected in the day. Our preliminary results in this study did not support the hypotheses.

The use of radio-telemetry in seed dispersal studies

Jacqueline WEIR
Department of Ecology & Biodiversity, The University of Hong Kong, Pokfulam Road, Hong Kong, China

Seed dispersal patterns can be predicted from the movement patterns and gut passage times of frugivores. In contrast to molecular techniques, this approach identifies the pathways as well as distances of seed movement. Studying disperser rather than seed movements is especially useful where a few dispersal agents are responsible for most seed dispersal, as in Hong Kong. It also provides information on frugivore ecology which may be used to encourage dispersal into degraded areas. Radio-tracking allows a single animal to be followed for extended periods of time even when it cannot be located visually. The smallest transmitters currently available weigh 0.35 g, have a battery life of around 14 days, a minimum range of 80 m, and can be used to track birds or bats weighing as little as 10 g. Larger frugivores can carry heavier transmitters with longer battery life and range. Transmitters are attached to small birds by gluing or on a harness, and to bats by gluing or on a collar. Tracking accuracy is affected by how close it is possible to approach the subject, the vegetation cover (which reduces effective signal range), and signal reflection produced by rough topography. Simultaneous bearings from three or more angles allow error estimation. Gut passage times cannot usually be estimated for free-flying animals, so the realism of measurements on caged animals cannot be assessed. The measured times can be affected by the length of captivity of the animals, the experimental set-up, diet, age, stress, season, and even diurnal variation, and must be standardized for comparisons between animal or fruit species. The problems and potential of the use of radio-telemetry in seed dispersal studies will be illustrated by a study of the Chinese Bulbul, *Pycnonotus sinensis,* in the rugged and heterogeneous landscape of upland Hong Kong.

Patterns and correlates of interspecific variation in foliar insect herbivory of four ficus species

Hui XIANG[1,2] & Jin CHEN[1]

[1] Xishuangbanna Tropical Botanical garden, Chinese Academy of Sciences, Mengla, Yunnan, China

[2] Present address: Institute of Plant Physiology and Ecology, Shanghai Institute for Biological Science, Chinese Academy of Sciences, 300 Fenglin Road Shanghai, China

To understand the defensive characteristics of interspecies varieties and their responses to herbivory damage, four species of *Ficus* plants (*Ficus altissima*, *F. auriculata*, *F. racemosa*. and *F. hispida*) were studied. They were similar in life form, but differed in successional stages. Of these, *Ficus altissima* is a late successional species, *F. hispida* is a typical pioneer and *F. auriculata* and *F. racemosa* are intermediate successional species.

Herbivory damage was measured in the field on randomly planted seedlings of the four species of the same age. Defences to herbivory were also tested by feeding leaves of the four species to larvae of *Asota caricae* in the laboratory. A total of 14 characters such as water content, thickness, toughness, pubescence density on both sides, leaf expansion time, lifetime and the contents of total carbon (C), nitrogen (N), phosphorous (P), potassium (K), magnesium (Mg) and calcium (Ca) were measured. An artificial herbivory treatment was used and leaf calcium oxalate crystal (COC) density, total Ca and N content, leaf toughness and height were measured to investigate induced responses to herbivory among the four species.

Herbivory damage in the four studied species varied greatly. The pioneer species, *F. hispida*, suffered the most severe herbivory damage, while the late successional species, *F. altissima*, showed the most defensive characteristics and least damage. A combination of several characteristics such as content of N, Ca, P and leaf toughness, lifetime and C:N ratio were associated with interspecific defferences of herbivory defence. The late successional species, *F. altissima*, might also incorporate induced defence strategies by means of an increase in leaf COC and toughness.

Interspecies variation of morphological characters and nutritional values of 20 figs species in the Tropics, SW China

Ling ZHANG & Jin CHEN

Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Mengla, Yunnan 666303, China

Figs are essential for many animals in many tropical regions. Previous analyses have indicated that figs are low quality, sugary fruits, with minimal nutritional value. To determine their nutritional value and interspecies variation with different morphological characters, we analyzed 20 fig species from Xishuangbanna, SW China, for fiber, lipids, protein, total sugar, titratable acidity and minerals. Fig fruits consisted of restively high content in total sugar (32.36±8.32%, cv=25.72%, range from 22.43 to 50.4%); they also contained 7.54±2,90% proteins and 7.51±2.84% lipids. The amount of minerals in fig fruits is as follows: potassium (1.97±0.06%), calcium (0.76±0.39%), magnesium (0.21±0.08%), sodium (111.00±27.9mg/kg), phosphorus (0.23±0.06%) and iron (75.7±36.4mg/kg). The content of total sugar was positively correlated with fruit weight. The content of protein had positive relationship with N, Mg and Zn content, and lipids had positive relationship with seeds per fruit and zincum, and negative related with calcium content.

When divided all figs into three groups according to their fruit position, axillary figs had higher percentages of proteins, titratable acidity, fiber, magnesium and calcium; cauliflorous figs had much more liquids and total sugar; and rhizocarpous figs contained higher iron, sodium, zincum, and copper. We also used fruit size to separate these figs into three groups: small (<2cm), medium (2-4cm) and large (>4cm). The results showed that big figs contained higher lipids and total sugar, but had lower proteins, calcium, magnesium, iron, copper and sodium, medium size figs had higher proteins, K, Mg, Fe, Zn, Cu and Na, small size figs had very high calcium level.

We also found that leaf size had positive relationship with fruit size in these 20 fig species, which imply the phylogenic component could be one of the major factors to be ascribe to the variation of fruit size in fig plants

Our further work will try to incorporate the phylogenic tree of the study figs and field observation on frugivores on the those fruiting fig plants and try to explore to what extend the variations of the characteristics could be ascribed to the interaction of figs and their frugivores.

The use of the essential oil of chiropterochoric fruits for the attraction of fruit-eating bats and forest recovery

Sandra B. MIKICH[a,b] Gledson V. BIANCONI[c,d] Beatriz Helena L. N. S. MAIA[e] & Sirlei D. TEIXEIRA[e,f]

[a] Embrapa Florestas, Estrada da Ribeira km 111, C.P. 319, 83411-000 Colombo – PR, Brasil

[b] Mater Natura, Rua Desembargador Westphalen 15, 16º andar, 80010-110 Curitiba – PR, Brasil

[c] Mülleriana, C.P. 1644, 80011-970 Curitiba - PR, Brasil

[d] Programa de Pós-graduação em Biologia Animal, UNESP, Rua Cristóvão Colombo 2265, 15054-000 São José do Rio Preto - SP, Brasil

[e] Departamento de Química, UFPR, Caixa Postal 19081, 81531-990 Curitiba - PR, Brasil

[f] FACIPAL, C.P. 221, 85555-000 Palmas - PR, Brasil

Based on previous studies which demonstrated that fruit-eating bats can be attracted by the essential oils of mature chiropterochoric fruits, we believe that essential oils can be used to attract seed dispersing bats to degraded land, improving seed rain and forest recovery. To test this hypothesis field tests were performed in an agricultural matrix that surrounds a 354 ha Semideciduous Seasonal Forest remnant previously studied[1] in southern Brazil. Ten mist-nets (12 x 2,5 m), divided in two sets of five nets, were set 50 m apart from the forest and parallel to its edge. The sets were 50 m apart from each other and were used to test if the essential oils would produce a significant difference in bat capture when applied exclusively to one set, considering that both sets held mimetic fruits made of floriculture foam. Essential oils of mature fruits were extracted through hydrodistillation, using a modified Clevenger, for 4 hours and stored with water in vials kept refrigerated. We performed six trials, with two days and 6 hours each, in July, August, September and November 2002, and January and April 2003 using essential oils of *Piper gaudichaudianum* (three trials), *P. crassinervium* – Piperaceae (1 trial) and *Ficus insipida* – Moraceae (two trials). By the end of the study, 115 frugivorous bats were captured, being 102 *Artibeus lituratus*, two *A. jamaicensis* and two *A. fimbriatus*, specialists in the consumption of *Ficus* spp., three *Sturnira lilium*, specialist in *Solanum* spp. – Solanaceae, and one *Chiroderma villosum* a supposed predator of *Ficus* seeds. *A. jamaicensis*, *A. fimbriatus* and *C. villosum* were captured mainly or exclusively in nets with the oil of *F. insipida*. *A. lituratus* was significantly attracted to nets with *F. insipida*, as expected, but also to nets with *P. gaudichaudianum.* We believe the pepper attractiveness was caused by the absence of fruits in the habitat sampled, since when the same species was tested inside the forest remnant, where fruits of several species were available, *A. lituratus* was not attracted to its oil. Even though the experiment was performed very close to the forest remnant, we believe the reported results are valid for larger distances, since bats can fly huge distances in a single night and in the fragmented landscape studied we observed bats flying in and out forest remnants all the time. We conclude that the essential oils of mature chiropterochoric fruit can be used to attract frugivorous bats to specific places in very disturbed habitats, potentially improving seed rain and habitat restoration.

Fruit preferences within guilds of seed-dispersing vertebrates: Substitutable or uniquely keystone species?

Mark LEIGHTON
Great Ape World Heritage Species Project, Inc., c/o Peabody Museum, Harvard University, 11 Divinity Ave., Cambridge, MA 02138, USA

Presumably rainforest plants eventually go extinct without effective seed dispersal. But perhaps vertebrate agents that overlap in the plants they visit are redundant, so that plant extinction would be prevented if at least one guild member serviced the plant. Fruit preference data for Bornean guild members are compared to examine this hypothesis. The results indicate that for at least some guilds, seed-dispersing species are not redundant, and most or all must be conserved to prevent extinction of the full range of plant species serviced by the guild. Therefore, to conserve plant diversity, forest habitat fragments must be large enough to support viable populations of all guild members.

Fruit resource attributes and aggression at fruiting trees in the Malabar giant squirrel *Ratufa indica* within a fragmented cloud forest in India

Renee M. BORGES[*], Subhash MALI & Hema SOMANATHAN
Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560 012, India

The Malabar giant squirrel *Ratufa indica* is a major arboreal frugivore and seed predator in many Indian forests. Although it feeds preferentially on fruit, it will consume other plant resources when fruit is unavailable. It is solitary and territorial, each squirrel confining itself to a patch of trees of varied species composition. Based on tree location and tree phenology, there is variation in fruit availability across several scales in the forest. Squirrels make territorial excursions (forays outside their territories) in order to access fruit resources that are unavailable within their own territories. We examine the variation in fruit availability across squirrel territories and its impact on aggression between individual squirrels at fruiting trees. We ask whether this aggression is related to the nutrient content of the fruit, the availability of fruit at micro- and meso-scales, and the location of fruiting trees in relation to the edges of the forest fragments. We examine aggression at fruiting trees in relation to overall aggression at food resources, and ask whether the nutritional and spatio-temporal attributes of fruit relative to those of other food resources could contribute to the patterns observed.

Estimation of complete seed shadows for Ficus in Australia's tropical rainforests.

David WESTCOTT* & Andrew DENNIS
CSIRO Sustainable Ecosystems and the Rainforest CRC, Australia

In plant life history seed dispersal represents one of the few opportunities for individuals movement within a landscape. Seed dispersal plays a crucial role in structuring plant populations and communities. Therefore, describing seed shadows, or the frequency distribution of seeds relative to their parental trees, is important in understanding the scale and outcomes of these processes. In tropical rainforests seed dispersal is predominantly an animal-vectored process, something which has greatly complicated seed shadow estimation. This has reduced most published seed shadows to those produced by one or a few of the total number of disperser species of focal plant species. In this paper we describe complete seed shadows, i.e. seed shadows that incorporate the service provided by all vertebrate dispersers, for *Ficus* in the rainforests of north-eastern Australia. Plants in the genus *Ficus* are demonstrably one of the critical resources contributing to the maintenance of frugivore diversity and abundance in many tropical forests around the world. To estimate complete seed shadows we identify the dispersers visiting *Ficus spp.* and the disperser functional groups they represent. For each disperser functional group we then combine data on *Ficus* seed gut passage rates and on disperser movement patterns to estimate the seed shadow produced. The seed shadows produced by each disperser functional group are then combined to produce the complete seed shadow for the genus *Ficus*. In Australian rainforests plants in the genus *Ficus* are visited by nearly all frugivorous vertebrates and regularly receive dispersal over spatial scales of tens to hundreds of metres. Dispersal distances of over 1 km are provided as infrequent but not rare events by others. The suite of dispersers visiting a tree, and hence the exact proportions of seeds dispersed any particular distance, is highly variable in both space and time. Despite this, our results suggest that for *Ficus* dispersal of hundreds of metres is common, and, that this is likely to represent one of the scales at which population and community processes relevant to the genus operate.

The frugivorous bird assemblage and seed dispersal in a fragmented rainforest landscape in subtropical Australia.

C MORAN[1, 2], C P CATTERALL[1, 2], R J GREEN[2], M F OLSEN[3]

[1] Rainforest Co-operative Research Centre
[2] Environmental Sciences, Griffith University, Nathan, QLD 4111AUSTRALIA
[3] Landscape Assessment, Management and Rehabilitation, Brisbane AUSTRALIA

The abundance of frugivorous birds may change in the remnant and regrowth habitats available following forest clearing. These changes may cause differences in seed dispersal between forested and fragmented areas. We compared the abundance of 23 frugivorous bird species between extensive tracts, remnants and regrowth patches of rainforest in subtropical Australia. There were five species that showed much lower abundance in remnants and/or regrowth than in extensive forest ("decreasers"), five that showed higher abundance in remnants and/or regrowth than in extensive forest ("increasers") and 13 whose abundance did not change substantially between the three habitat types ("tolerant" species). The "decreasers" included three fruit-specialist rainforest pigeons from the genus *Ptilinopus*. The "increasers" were largely mixed-diet bird species, many of which also use non-rainforest habitat. We discuss likely changes in seed dispersal between forested and fragmented landscapes using data collected on seed-grinding behaviour, and the gape width and frugivory level of each frugivore.

Seed dispersal by birds in primary and logged lowland dipterocarp forests in Sabah, Malaysia

Mohamed Zakaria HUSSIN
Department of Forest Management, Faculty of Forestry, University Putra Malaysia
43400 UPM Serdang, Selangor, MALAYSIA

This study examined the effects of logging on dispersal of seeds by frugivorous birds. Previous studies on bird observations at fruiting trees have shown that species composition of frugivorous birds remains the same in logged forest. However, most of these species particularly specialised frugivores were less often observed feeding on fruits in logged forest compared to primary forest. Only the small size generalised frugivores such as bulbuls were frequently observed feeding on fruits in logged forest.

Seed dispersal experiments were conducted simultaneously in primary and logged forests. Results from the seed-traps show that fewer seeds particularly of large size were collected in logged forest. More large size seeds are being dispersed in primary than in logged forests. These results imply that many trees that are being regenerated in logged forest are secondary species that bearing small-seeded fruits. Therefore, logged forest may still regenerate naturally, but the rate is slower for primary forest species. If the next logging cycle is too short, the forest may not be able to fully regenerate.

Seed dispersal role of (endemic, endangered fruit bat of South India) *Latidens Salimalii* in the Southern Western Ghats of India and its conservation status

J. VANITHARANI [1], V. CHELLADURAI[2], M. J. PEARCH[3], P. J. J. BATES[3], & D. L. HARRISON[3]

[1] Bat Research Laboratory, Department of Zoology, Sarah Tucker College,Tirunelveli – 627 007, South India.

[2] Survey of Medicinal Plants Unit-Siddha (Central Council for Research in Ayurveda and Siddha) Govt. of India Palayamkottai - 627 002. South India .

[3] Harrison Institute, Centre for Systematic and Bio diversity Research, Bower wood House, St. Botolph's Road, Sevenoaks, Kent, TN13 3AQ, Great Britain.

According to IUCN Red List Criteria Version 3.1, in India we have 13 species of Megachiropteran bats (Frugivorous bats) of which the only one Megachiropteran 'endemic and endangered fruit bat of South India' is *Latidens salimalii.* Recently the author and her student in the Southern Western Ghats of Tirunelveli district of Tamil Nadu have reported a new record of distribution and roosting. Three populations of Salim Ali's fruit bat, one at an altitude above 1000 metre in Courtallam hill range and two roosting caves above 1400 metre altitude in Agasthyamalai hill range of Kalakad Mundanthurai Tiger Reserve, Tirunelveli have been located. This study area is included in two of the 200 WWF Global Eco regions, which have been selected for their outstanding biodiversity (no 20: South Western Ghats Moist forests: and no 171: Western Ghats Rivers and streams). Agasthyamalai or Ashambu hill range and Courtallam hill range are internationally recognized for its natural richness and for high levels of faunal and floral endemism. The ongoing studies on the foraging behaviour of this bat species revealed they forage fruits from relatively taller trees of evergreen forests of these hill range. The fresh remnance of these fruit bats (ejected fruit pellets, unconsumed, half eaten fruits etc.,) suggests these bats play a major role in the seed dispersal of some of the fruit trees, which is endemic to Southern Western Ghats of India, and also they help in replenishing the forest eco system in an altitude above 1200 metre height. The conservation status about these very sensitive bats are threatened because of the human interference in their roosting sites for hunting and collection of edible gums from the nests of swift birds (the birds use thick saliva to fix their nests on the walls of the rocks) who inhabit along with this bat species.

Physical dormancy in tropical recalcitrant seeds of *Garcinia cowa* (Guttiferae)

Yong LIU, Jin CHEN, Ling ZHANG, Zhi-Lin BAI
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Mengla, Yunnan 666303, China

The breaking of dormancy and the storage behaviours of *Garcinia cowa* seeds were investigated in this study. Because of their low tolerance to desiccation, remarkable chilling sensitivity and relatively short life span, *G. cowa* seeds should be classified into the tropical recalcitrant category. Intact seeds of *G. cowa* failed to germinate after being sown at 30 °C for 120 d and the mean germination time (MGT) of seeds cultured in a shade (50% sun) nursery was 252 d. The most effective method of breaking dormancy was to remove totally the seed coat, which reduced the MGT to 13 d. Germination was also promoted by partial removal of the seed coat by physical scarification (excising the hilum and exposing the radicle) and chemical scarification (emergence in 1% H_2O_2 for 1 d). Experiments showed that seed coats are impermeable to water and gases (O_2, CO_2 and air). Study of the anatomy of the seed coat revealed that it can be divided into three layers: the first layer has vascular bundles, a complex of which resembles a sponge; the second layer contains decussate-structured bundles and its mucilaginous components might add to the impermeable nature of the seed coat; and the third layer of the seed coat is thick. The ecological implications and ideas on storing recalcitrant seeds are also discussed.

Patterns of seed deposition in a degraded tropical landscape

Yuet-Ying AU
Department of Ecology & Biodiversity, The University of Hong Kong, Pokfulam Road, Hong Kong, China

Seed input – both number and diversity – is likely to be a major factor limiting the rate of vegetation recovery in degraded tropical landscapes. We used 120 seed traps to measure the composition of the seed rain in the major upland vegetation types in Hong Kong – secondary forest, shrubland and grassland – and also under isolated trees and shrubs in the grassland. The number of seeds deposited per square metre per year declined in the order isolated shrubs > isolated trees > shrubland > forest >> grassland, while the number of seed species declined in the order shrubland > forest > isolated trees > isolated shrubs > grassland. The relatively low seed rain in forest partly reflects the smaller number of seeds per fruit in this community. Seeds were concentrated under isolated trees in grassland throughout the year, but isolated shrubs only attracted seeds when they were fruiting. A total of 83 plant species were identified in the seeds traps, of which all but 4 wind-dispersed species are dispersed by animals. A total of 79 species are known or suspected to be dispersed by bulbuls (*Pycnonotus* spp.) and none are definitely dispersed by bats.

List of Participants

Australia

Dennis, Andrew Dr.
Cooperative Research Centre,
CSIRO Sustainable Ecosystems and Rainforest CRC
Maunds Road, Atherton 4883, Australia
Tel. 07 4091 8800
Fax. 07 4091 8888
E-mail: Andrew.Dennis@csiro.au

Green, Ronda J.
Faculty of Environmental Sciences
Australian School of Environmental Studies, Griffith University
Nathan, Qld 4111, Australia
Tel. 07 3875 5101(intl: 61 7 3875 5101
Fax. 07 3875 7459 (intl.61 7 3875 7459)
E-mail: ronda.green@griffith.edu.au

Westcott, David Dr.
Tropical Rainforest Research Centre
CSIRO-Sustainable Ecosystems & Rainforest CRC
P. O. Box 780, Atherton, Australia
Tel. +61 7 4091 8800
Fax. +61 7 4091 8888
E-mail: David.Westcott@csiro.au

Brasil

Mikich, Sandra Bos
Embrapa Florestas, Estrada da Ribeira km 111
C.P. 319, 83411-000 Colombo, Brasil
Tel.
Fax.
E-mail: sbmikich@cnpf.embrapa.br

China

AN, S. Q. Dr. & Prof.
Nanjing University, Nanjing 210093, China
Tel.
Fax. 025-3596252
E-mail: anshq@nju.edu.cn

Au, Yuet Ying Student
The University of Hong Kong
Room 3N-20, the Kadoorie Biological Sciences Building

Pokfulam Road, Hong Kong, China
Tel.
Fax.
E-mail:

Cao, M. Dr. & Prof.
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
88 Xuefu Road, Kunming, Yunnan 650223, China
Tel.
Fax. +86-871-5160916
E-mail: caom@xtbg.ac.cn

Chen, F. Student
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
Menlun,Mengla, Yunnan 666303, China
Tel.
Fax. +86-691-8715070
E-mail:

Chen, J. Dr. & Prof.
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
Menlun,Mengla, Yunnan 666303, China
Tel. +86-691-8715457
Fax. +86-691-8715070
E-mail: biotrans@bn.yn.cninfo.net

CHUNG, Pik-Shan Student
The University of Hong Kong
Room 3N-20, the Kadoorie Biological Sciences Building
Pokfulam Road, Hong Kong, China
Tel.
Fax.
E-mail:

Corlett, Richard Dr.& Asso. Prof.
The University of Hong Kong
Room 3N-20, the Kadoorie Biological Sciences Building
Pokfulam Road, Hong Kong, China
Tel.
Fax.
E-mail: corlett@hkucc.hku.hk

Gao, X. M. Student
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
Menlun,Mengla, Yunnan 666303, China

Tel.   0691-8715471
Fax.   0691-8715070
E-mail: gaoxuem@yahoo.com.cn

Gao, X. X. Student
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
Menlun,Mengla, Yunnan 666303, China
Tel.   0691-8715471
Fax.   0691-8715070
E-mail: gaoxx456@sohu.com

He, Y. L. Student
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
88 Xuefu Road, Kunming, Yunnan 650223, China
Tel.   +86-(0)871-5142055
Fax.   +86-(0)871-5160916
E-mail: hyl@xtbg.ac.cn / yunlinghe@yahoo.com.cn

Huang, S. Q. Dr.
College of Life Sciences, Wuhan University
Wuhan, 430072, China
Tel.   027-87682869(0); 13554060071.
Fax.
E-mail: sqhuang@whu.edu.cn

Jiang, Z. G. Dr. & Prof.
Beijing Institute of Zoology
Beijing, China
Tel.
Fax.
E-mail: jiangzg@panda.ioz.ac.cn

Li, X. H.
School of Life Science, Nanjing Agricultural University
Nanjing 210014, China
Tel.
Fax.
E-mail: lxinhua@jlonline.com / xinhuali@yahoo.com.cn

Liu, Y. Assistant Prof.
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
Menlun,Mengla, Yunnan 666303, China
Tel.
Fax.   +86-691-8715070

E-mail: liuyong@xtbg.org.cn

Ma, S. B. Prof.
College of Life Science, Yunnan University
Kunming, Yunnan 650091, China
Tel.
Fax.
E-mail: masb6599public.km.yn.cn

Na, Z. Dr.
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
Menlun ,Mengla, 666303 Yunnan, China
Tel.
Fax. +86-691-8715070
E-mail: nazhi@xtbg.org.cn

Song, Q. H. Student
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
Menlun,Mengla, Yunnan 666303, China
Tel. 0871-5160904 / 0691-8716475
Fax. 0871-5160916
E-mail: sqh@xtbg.ac.cn / qinghai973@sohu.com

Wang, X. Student
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
88 Xuefu Road, Kunming, Yunnan 650223, China
Tel. +86-(0)871-5142055
Fax.
E-mail: wx@xtbg.ac.cn

Wang, Y. H. Dr. & Prof.
College of Life Science, Yunnan University
Kunming, Yunnan 650091, China
Tel.
Fax.
E-mail:

Weir, Jacqueline, Student
The University of Hong Kong
Room 3N-20, the Kadoorie Biological Sciences Building
Pokfulam Road, Hong Kong, China
Tel.
Fax.
E-mail:

Xia, Y. M. Associate Prof.
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
88 Xuefu Road, Kunming, Yunnan 650223, China
Tel.
Fax. +86-871-5160916
E-mail: xiaym@xtbg.ac.cn

Xiang, H.
Institute of Plant Physiology and Ecology
Shanghai Institute for Biological Science, Chinese
Academy of Sciences
300 Fenglin Road,Shanghai, China
Tel.
Fax.
E-mail: huihuiboo@yahoo.com.cn

Xiao, Zhishu
Institute of Zoology, Chinese Academy of Sciences
Beisihuanxilu 25, Haidian District, Beijing 100080, China
Tel. +86-10-62554027
Fax. +86-10-62565689
E-mail: xiaozs@panda.ioz.ac.cn

Xu, H. Q. Student
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
88 Xuefu Road, Kunming Yunnan 650223, China
Tel. 0871-514205
Fax. 0871-5160916
E-mail: maxsea201@yahoo.com.cn

Yang, X. Y. Dr. & Asso. Prof.
Kunming Institute of Botany, Chinese Academy of Sciences
Heilongtan, Kunming, Yunnan 650204, China
Tel. +86-871-
Fax. +86-871-
E-mail: xy04km@public.km.yn.cn

Yu, Y. Student
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
Menlun,Mengla, Yunnan 666303, China
Tel. 0691-8716852
Fax. 0691-8715070
E-mail: yuyang@xtbg.ac.cn

Zhang, D. Y. Dr.& Prof.

Institute of Ecology, College of Life Sciences, Beijing Normal University,
Beijing 100875, China
Tel. 6210-9889
Fax. 6210-7721
E-mail: zhangdy@bnu.edu.cn

Zhang, L. Asso. Prof.

Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
Menlun,Mengla, Yunnan 666303, China
Tel.
Fax. +86-691-8715070
E-mail: Zhangl@xtbg.org.cn

Zhang, S. T. Dr.

Nanjing University
Nanjing 210093, China
Tel.
Fax.
E-mail: zhangst@nju.edu.cn

Zhou, H. P. Student

Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
Menlun,Mengla, Yunnan 666303, China
Tel.
Fax. +86-691-8715070
E-mail: pingse77@163.com

Zhu, H. Dr. & Prof.

Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences
88 Xuefu Road, Kunming, Yunnan 650223, China
Tel.
Fax. +86-871-5160916
E-mail: Zhuh@xtbg.ac.cn

France

ISNARD, Sandrine

Botanique et Bioinformatique
TA 40 / PS2, Boulevard de la Lironde, 34398 Montpellier cedex 5, France
Tel. (+33) (0)467617553
Fax. (+33) (0)467615668
E-mail:

India

Borges, Renee M. Dr.Assistant Professor

Centre for Ecological Sciences, Indian Institute of Science
Bangalore 560 012, India
Tel. 91-80-3602972
Fax. 91-80-3601428, 3341683
E-mail: renee@ces.iisc.ernet.in

Ganesh, T. Dr.
ATREE
659, 5th A main, Hebbal, Bangalore, India
Tel.
Fax. 91-080-3530070
E-mail: tganesh@atree.org

Vanitharani,Juliet, Dr.& Prof.
Dept. of Zoology, Sarah Tucker College, TVL - 7
Sarah Tucker College, Tirunelveli - 627007, India
Tel.
Fax.
E-mail: juliet@sancharnet.in / jvanitharani@yahoo.co.in

Japan

KITAMURA, Shumpei Dr.
Center for Ecological Research, Kyoto University
Kamitanakami-Hirano, Otsu, Shiga, 520-2113, Japan
Tel.
Fax.
E-mail: shumpei@ecology.kyoto-u.ac.jp

Malaysia

Hussin, Mohamed Zakaria Dr. & Asso. Prof.
Faculty of Forestry,University Putra Malaysia
43400 Serdang, Selangor, Malaysia
Tel.
Fax. 603-8943 2514
E-mail: zakariahussin@hotmail.com

Panama

Hardesty, Britta Denise, Dr.
Unit 0948, Smithsonian Tropical Research Institute
APO AA 34002-0948, Panama
Tel. 507 212 8835
Fax.
E-mail: hardesty@dogwood.botany.uga.edu

Thailand

Wangpakapattanawong, Prasit Dr.
Department of biology, Faculty of Science,
Chiang Mai University

Chiang Mai, Thailand 50202
Tel. 66-53-943-346 ext 1113
Fax. 66-53-892-259
E-mail: prasit.w@chiangmai.ac.th, pwangpak@hotmail.com

Ngonjun, Pattamavadee Miss
Department of biology, Faculty of Science
Chiang Mai University
Chiang Mai, Thailand 50202
Tel.
Fax.
E-mail:

Sanitjan, Sawat Mr.
Department of biology, Faculty of Science
Chiang Mai University
Chiang Mai, Thailand 50202
Tel.
Fax.
E-mail: s_sanitjan@yahoo.com

USA

Horvitz, Carol C. Dr.& Prof.
Department of biology, Miami University
Coral Gables, FL 33124, USA
Tel.
Fax.
E-mail:

Fleming, T. F. Dr. & Prof.
Department of biology, Miami University
Coral Gables, FL 33124, USA
Tel. 305-284-6881
Fax. 305-284-3039
E-mail: tedfleming@miami.edu

Leighton, Mark, Prof. & Dr.
Peabody Museum, Harvard University
11 Divinity Ave. Cambridge, MA 02138, USA
Tel.
Fax. 001-617-496-8041
E-mail:

Workshop Organizers

CHEN Jin

LI Liming

YIN Shouhua

HU Huabin

ZHANG Jian

WANG Jian

FANG Chunyan

ZHANG Ling

Author Index

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