PROCEEDINGS OF THE
INTERNATIONAL FIELD BIOLOGY COURSE 2004

Lambir Hills National Park, Sarawak, Malaysia
15 July – 14 August 2004

Edited by Rhett D. Harrison

Center for Tropical Forest Science – Arnold Arboretum Asia Program
Sarawak Forestry Corporation

Preface

The International Field Biology Course (IFBC) 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-aa.org) in collaboration with institutional partners in South and Southeast Asia. The IFBC for 2004 was held at Lambir Hills National Park, Sarawak, Malaysia from 15 July to 14 August and was organised by CTFS-AA and hosted by Sarawak Forestry Corporation (SFC). IFBC 2004 was the fourth such course organised by CTFS-AA, the previous two being held at Pasoh Forest Reserve in Peninsular Malaysia in 2001 and 2003. Next year's course (IFBC 2005) will be held at Khao Chong Botanical Gardens in Peninsular Thailand.

The aim of these courses is to provide high level training in the biology of forests of 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 a strong emphasis on independent projects during the course. Students are also exposed to different ecosystem types, as well as forest related industries, through course excursions.

IFBC 2004 was attended by 20 students from nine countries (Malaysia, Thailand, Philippines, USA, Taiwan, Japan, Singapore, India, and Sri Lanka) and a total of 33 resource staff from a variety of national and international institutions gave lectures and practical instruction. IFBC 2004 was implemented by Rhett Harrison (CTFS-AA), Sylvester Tan (SFC) and Het Kaliang (SFC). Due to their extraordinary 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. We look forward to another successful IFBC in Thailand in 2005.

Stuart J. Davies
Science Director
CTFS-AA Asia Program

Acknowledgements

The IFBC 2004 organisers wish to thank all the resource staff who gave their time to teach on IFBC 2004. Without the commitment of these researchers to see a graduate field biology course in the region succeed, the course at Lambir could never have taken place. We would also like to acknowledge the considerable help of other SFC and CTFS-AA staff who assisted with IFBC 2004 including, Mr. Empenit ak Empawi (SFC), Mr. Hepni Amat (SFC), Ms. Luan Keng Wang (CTFS-AA), and Mr. Paul Sawai (SFC).

We would like to thank the senior SFC and CTFS-AA representatives who made the effort to attend the IFBC 2004 Opening Ceremony and address the participants, in particular Datu Cheong Ek Choon, General Manager SFC, Dr. Lee Hua Seng, Former Deputy Director Sarawak Forest Department, Dr. Stuart Davies, Scientific Director CTFS-AA, Ms. Lucy Chong, Director Forest Research Centre SFC, and Mr. Abang Arabi, Manger Protected Areas and Biodiversity Conservation Unit (Northern Region) SFC.

The organisers would also like to acknowledge the assistance of the National Park staff at Lambir Hills, in particular Mr. Krishnan Kamal, Acting Officer-in-charge. Field trips to Niah National Park and Loagan Bunut National Park were made possible through the help of the Protected Areas & Biodiversity Conservation, Northern Region office in Miri and the Officers-in-charge of the respective parks. We would like to thank Mr Murang for accommodating the course at his lodge at Loagan Bunut and for seeing that we were able to make the most of our visit to the lake.

The excursions to Sarawak Oil Palm and Samling Fibreboard were made possible through the assistance of Mr. John Lu and Dr. Kai Kruse, respectively. The organisers would like to thank them and their staff for hosting IFBC 2004 and giving us such informative tours of their facilities.

Our extended field trip to Mount Kinabalu Park was made possible though the assistance of Sabah Parks, in particular Dr. Jamili Nais, Scientific Director, Sabah Parks, and Mr. Alim Biun, Education Officer, Education and Research Division at Kinabalu Park. We would like to thank them for their time and the considerable efforts they made to make our visit to Kinabalu Park a success.

We would like to thank Dr Tony Lamb for accompanying the course to the *Rafflesia* Centre and Tenom Agricultural Park and Gardens, and especially for his detailed and informative commentary as we toured the gardens. We would also like to acknowledge the assistance given by Mayflower Travel Agency in Kota Kinabalu for arranging and running the excursion to Sabah.

Financial support for IFBC 2004 came from the CTFS-AA Asia program of the Smithsonian Tropical Research Institute and the Arnold Arboretum of Harvard University. The flights of Professor Tohru Nakashizuka, Dr. Michiko Nakagawa, Dr. Koichiro Kuraji, Dr. Kuniyasu Momose and Dr. Yoko Inui were funded by the Diversitas in Western Pacific and Asia program (Japan). We would like to acknowledge this assistance. Dr. Akira Itoh, Mr. Anthony Gonzaga, Ms. Dolores Tongco, Dr. Don Windsor, Dr. Jean-Yves Rasplus, Dr. Jim LaFrankie, Dr. Robert Stallard and Dr. Shawn Lum funded their flights through other sources, and we would like to acknowledge their substantial contribution to IFBC 2004 in this respect. In addition to hosting the course, SFC covered the costs of their employees and facilitated the course in various ways, including providing the use of the 4-wheel drive vehicle, for which we are very grateful.

Thanks to all.
The organizers.

Rhett Harrison (CTFS-AA)
Sylvester Tan (SFC)
Het Kaliang (SFC)

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6 – 10 August	Independent student projects
11 – 13 August	Data analyses and write-up
14 August	Presentations of group and independent student projects. Farewell party.
15 August	Depart Miri airport

16 – 25 July, Lectures and practicals

16 July	14:00	Dr J. V. LaFrankie	Plant identification: 30 Families, 60 species
	19:30	Dr S. Davies	Comparison of CTFS-AA sites
17 July	08:00 14:00	Dr J. V. LaFrankie Dr J. V. LaFrankie	Plant identification: 30 Families, 60 species Plant identification: 30 Families, 60 species
	19:30	Dr J. V. LaFrankie	Tropical forest floras compared
18 July	08:00	Dr J. V. LaFrankie	Plant identification: 30 Families, 60 species
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	19:30	Dr. K. M. Wong	Plant biogeography in Malaysia and Borneo
19 July	08:00	Dr R. Stallard	Geology & Soils
	14:00	Dr K. Kuraji	Forest / Atmosphere exchange
	19:30	Dr I. Das	Amphibians and reptiles (night walk)
20 July	All day	Dr P. Piper	Field trip to Niah National Park
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	19:30	Dr I Fang Sun	Diversity theories
22 July	06:00	Ms L. K. Wang	Bird watching
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	19:30	Dr S. Lum	Molecular ecology
24 July	08:00	Dr M. Azlan	Forest mammals
	14:00	Dr I Fang Sun	Group projects (50 questions)
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25 July	08:00	Dr M. Azlan	Mammal identification
	14:00 19:30	Dr K. Momose Mr Ab. Arabi	Flowering and Pollination Biology National Parks in Sarawak

Mt. Kinabalu and Tenom field trip

26 July	08:00		Flight to Kota Kinabalu
	11:00		Travel to Mt Kinabalu
	18:00	Mr A. Biun	Introduction to Mt Kinabalu
27 July	08:00	Dr J. Nais	Flora of Mt Kinabalu
	18:00	Dr J. Nais	National Parks in Sabah
28 July	08:00		Altitudinal gradient (practical)
	16:00		Travel to Kota Kinabalu
29 July	07:00	Dr A. Lamb	Travel to Rafflesia Centre & Tenom
	14:00		Visit Tenom gardens
30 July	08:00	Dr A Lamb	Visit Tenom gardens
	13:00		Return to Kota Kinabalu
	19:00		Flight to Miri, return to Lambir Hills

31 July – 8 August, Lectures and practicals

31 July	08:00	Dr R. Corlett	Basic statistics
	14:00		Group projects
	19:30	Dr R. Corlett	Comparisons among tropical forests
1 August	08:00	Dr M. Nakagawa	Seed predation
	14:00	Dr R. D. Harrison	Figs
	19:30	Dr R. D. Harrison	Figs and diversity of tropical forests
2 August	08:00	Dr R. Corlett	Seed dispersal
	14:00	Dr D. Windsor	Herbivory
	19:30	Dr P. Ng	Conservation Biology
3 August	08:00	Dr R. Corlett	Seed dispersal
	11:00	Mr A Gonzaga	Diversity of parasitic wasp in Malaysia
	13:00		Travel to Loagan Bunut
4 August	All day	Dr H. Hui	Loagan Bunut National Park
	19:30	Dr J-V Rasplus	Diversity, how many insects are there?
5 August	08:00	Dr Y. Inui	*Macaranga* and ant protection
	14:00 19:30	Dr J-V Rasplus Ms L. Tongco	Parasitoides Diversity estimates
6 August	08:00	Dr Itoh	Habitat specialisation among trees
	14:00		Group projects

Lecture abstracts

Field practical on tree identification
Jim LaFrankie, CTFS-AA, Philippines

Over two days students will go with the course leaders and tree climbers to the 52-ha plot to collect leaf and twig specimens for 60 species of tree representing some 50 families and genera. In the course of their collecting students will make notes on field characters of color, sap, bark, twig and leaf features. To supplement their notes students will receive a booklet that will describe the family, genus and species-level vegetative spot characters as well as the plot distribution map and ecological information derived from the 52-ha plot. Students will keep and study their leaf collections for the duration of the course.

The CTFS-AA Trees of Tropical Asia database
Jim LaFrankie, CTFS-AA, Philippines

The lecture presents a brief introduction to the database compiled through the CTFS-AA network of long-term ecological research plots. The database includes taxonomic and ecological information on thousands of species of trees. It also includes photographs and meta-data from the permanent plots such as tables and distribution maps. The database is organized in FileMaker Pro software which will be explained and demonstrated. This software is well-suited for individual record keeping as well as institutional projects. While the CTFS-AA database is still in its infancy, it is now growing rapidly and should within a year be a useful on-line tool for ecological research and reference.

Plot establishment
Sylvester Tan, Sarawak Forestry Corporation, Malaysia

Plot establishment takes in many designs. It depends on the objective of a study to be carried out. The basic consideration for establishing a plot of any design is that a complete inventory of any particular site is, practically speaking, impossible. The focus will be on producing a comparative procedure which when applied in an identical fashion to different sites or different seasons at the same site, will allow statistical comparisons among data sets. The sampling intensity of any particular design can be increased or decreased in response to range of ecological questions to be answered. Addition of extra activities within the overall design is of course a matter of choice by particular researchers. Any overlap with the designs to be chosen can be carried out in such a way that comparable results are obtained. The designs can readily be modified for application to smaller or larger sites, provided the design adopted can produce useful and representative results. Decisions must therefore be made about the design of the plot to be established with the range of questions that we wish to answer in mind.

Plant Biogeography in the Malay Peninsula and Borneo
Khoon Meng Wong, University of Malaya, Malaysia

Introduction to the region:
Malaysia, megadiversity country; the Peninsular Malaysia and NW Borneo hotspots.
Relative richness of the Malaysian flora.
The concepts of SE Asia, Malaysia and Malesia.
The biodiversity of tropical rain forests: intense species richness, endemism, rarity, series of co-occurring congeners, island-type habitats as special species assemblages.
Basic ideas in plant geography: biological, ecological and geographical approaches.
The process of plant geography: Collection, identification and recording of plants in the field; the basic distributional information; Mapping of plant distributions; Classification of plant distributions; Generation and testing of hypotheses to explain the types of distribution.

Comparing distributions and floristics:
(1) affinities in the distribution of different taxa: the Riau Pocket and other biogeographical elements;
(2) affinities between geographical areas: the Malesian and Australasian floras.
Historical biogeography: changes in distribution with reference to earth history, i.e., geological processes and changes through geologic time.
Continental drift, plate tectonics, sea-floor spreading and "interplate dispersal" of plants.
Climatic change: Pleistocene sea-level changes in the Sunda and Sahul shelf regions (Chicago Field Museum maps, 2000): the Riau Pocket; a savannah corridor through Malaya.
Ecological biogeography: patterns of distribution in relation to prevailing environmental conditions.
Abrupt changes in floristic composition:
(1) demarcation knots and the delimitation of Malesia (van Steenis 1950);
(2) the transition between two forest types at Lambir: *kerangas* on sandy sediments and mixed dipterocarp forest on red-yellow sandy clays.
Disjunctions, isolation and vicariance: historical vicariance and ecological vicariance; endemism; islands.
The significance of closely related forms; habitat heterogeneity in space and time, polyploid complexes, mutations and polytopic evolution.
Centres of origin and diversity: this approach mainly addresses single taxa rather than replicated patterns, and is usually of less interest in historical biogeography. Historical biogeography mainly deals with the recognition of "spatial homology" and areas of endemism, and formulation of hypotheses regarding area relationships.
Biogeographical setting of the Sundaland region: Geographical units: the Malay Peninsula, Perak, the Riau Pocket and NW Borneo hotspot, the Kapuas-Lupar region, the East Coast Sabah subprovince, seasonal Asiatic intrusions. Sharp ecological definitions and isolated environments: high mountains, limestone hills, ultramafic sites, kerangas - peat swamp complexes. High speciation rates in lowland forests (fuelled by competition, biotic pressure or environmental variability?)

Assessment of Hydrology in Small Tropical Catchments

Robert F. Stallard, Smithsonian Tropical Research Institute, Panama & US Geological Survey

A number of forest-dynamics plots being examined and the limited time frame requires a simplified and streamlined approach to studying the interaction of soils and water, involving a mix of fieldwork and modeling. The fieldwork involves measuring soil permeability, gauging streams, measuring rainfall, and monitoring styles and distribution runoff (see Pullen et al, this volume). The modeling will involve implementing simple hydrologic models for each forest-dynamics plot being studied. Input data for the models will involve site-scale and regional data. Site-scale data include the detailed topographic mapping, tree distributions, ongoing meteorological measurements and the soil, hydrologic, and meteorological measurements made in the course of each field campaign. The modeling will be constrained by the field data, some of which will be taken over a short period of time. Campaigns will be two to four weeks. An additional level of model constraint will include stream and rainfall chemistry.

The implementation of hydrologic models is an essential component of rapid assessments of soil-water interactions in small catchments and forest-dynamic plots. The forest-dynamics plots in the CTFS network are topographically mapped on a 5 meter grid, and spaced-based topographic measurements available from NASA are on a 90-m grid. The use of gridded topographic data forms the core of many hydrologic models, such as TOPMODEL. We chose TOPMODEL for its inherent simplicity, bearing in mind that some of the input parameters for TOPMODEL are not easily quantified in the field. At a minimum, TOPMODEL requires knowledge of topography and time series of precipitation and discharge data. With this, and a suitable modeling scheme, such as Monte Carlo simulations, a suite of acceptable solutions can be identified, all of which acceptably predict discharge from precipitation time series. The typical prediction of a wide variety of acceptable models will predict similar hydrologic responses – has been termed "equifinality."

Because of the equifinality problem, our field campaigns are oriented towards measuring parameters that can provide powerful constraints on the hydrologic model. Experiments that have been undertaken using TOPMODEL demonstrate the value of including other data sets in Monte Carlo simulations to provide these additional constraints. Accordingly, we seek to measure properties that can:
(1) relate directly to the suite of soil properties being measured over the whole forest-dynamics plot, such as texture and color,
(2) provide an assessment of the vertical structure of the soil, such as permeability profiles,
(3) provide powerful model constraints, such as the spatial distribution of overland flow, time series of solute chemistry through events, and time series of soil moisture at various depths, and
(4) permit further assessment of the hydrologic dynamics of the landscape, such as characterization of hydrograph recession curves, and the mapping the distribution of wet areas, presence of pipes, and indicators of overland flow.

Long-term micro-meteorological monitoring and some findings in relation to the possible proximate cue of general flowering events in dipterocarp forest, Lambir Hills National Park, Sarawak, Malaysia

Koichiro Kuraji, University of Tokyo, Japan

A long-term micro-meteorological observation has started since January 1999 in Lambir Hills National Park (LHNP, 4°13' N 114° 03' E), Sarawak, Malaysia, where the canopy biology program was initiated in 1991 by collaboration between Malaysian and Japanese Scientists (Inoue et al, 1995). Temperature, humidity, radiation, wind speed and direction, rainfall and soil moisture were measured continuously. One of the target of this observation is to provide baseline data for ecologists and entomologists especially people investigating possible proximate cue required to initiate general flowering events in dipterocarp forests in the South East Asian humid tropics. Periodic droughts, cold snaps and elevated solar radiation have each been hypothesized to be the proximate cue. Recent study based on 10 years monitoring of tree phonology and precipitation around the LHNP suggests that the periodic droughts, defined as consecutive 30 days period whose cumulative precipitation less than 20mm, have higher correlation with the general flowering events than the cold snaps. Drought-induced flowering in Sarawak was already introduced by Brunig (1969) by using the 30 days sliding sum of rainfall.

The intra-seasonal fluctuation of the 30 days cumulative precipitation from 1999 to 2002 was compared with the fluctuation of convective activity using the 5-day mean equivalent black body temperature (TBB) and outgoing long wave radiation (OLR) data from Japanese Geostationary Meteorological Satellite (GMS). The fluctuation of precipitation has similar pattern with the TBB and OLR change. From the analysis of time-longitude sections of TBB suggests that the enhancement of convective activity by Madden-Julian Oscillation (MJO) may play an important role for determining the intra-annual variation in precipitation in this site.

The diurnal variation of precipitation in LHNP has two distinct maximum, i.e. in the afternoon (13:00-15:00) and in the midnight (23:00-2:00) in both northeast and southwest monsoon season (Kuraji et al, 2001). Both intensity and duration of rainfall contributed to the two maximum in the diurnal variation of precipitation. The afternoon maximum of rainfall was observed elsewhere in Sabah and in Kuching, whereas the midnight maximum was observed in Bintulu (Oki and Musiake, 1994). The two-maximum pattern of rainfall in Lambir (12km from the coast) may be explained by a combined effect of mechanism prevailing in each station: Bintulu

(2km from the coast) and Kuching (24.5km from the coast). Houze et al (1981) found that noticeable morning maximum of convective activity over the sea just off Bintulu by radar observation and concluded that the low-level convergence of the land breeze with the northeasterly monsoon wind causes the morning maximum of offshore convection. Ohsawa et al (2001) found a similar maximum even in summer when the prevailing wind blows in the same direction by analyzing the convective activity index calculated by GMS-5 data and he proposed a hypothesis that the land breeze alone can trigger the offshore convection with the morning maximum even without interacting the prevailing wind. The nighttime rainfall observed in LHNP should have some relation with the offshore convective activity in this region.

To understand the mechanism how the periodic drought play a role as the proximate cue to initiate general flowering, decrease in soil moisture during dry spell may be important. The effect of dry spell on transpiration, canopy conductance and the decoupling coefficient was reported by Kumagai et al (2004). Although there are no distinct dry and wet seasons in LHNP, dry (e.g. March – September in 2003) and wet (e.g. September – February in 2002 - 2003) period can be seen in the soil moisture change. In August 2001, soil moisture at all depths is minimum during the four years observation period. This dry condition of soil should correspond with the very low soil water potential and there is a possibility that the trees may detect the strong soil water stress in their roots during this period and then start flowering.

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Niah National Park

Philip Piper, University of Cambridge, UK

Niah Cave comprises a series of enormous caverns in a limestone outcrop of the Gunung Subis on the coastal plain of northern Sarawak, within what is now Niah National Park.

These caverns have produced some of the most important evidence of prehistoric life in Southeast Asia. Alfred Russel Wallace (1823-1914) first drew attention to the archaeological potential of Niah a century ago. However, it was not until 1954, when a short expedition led by the Curator of the Sarawak Museum, Tom Harrisson, that clear evidence of long-term human use of these caves was established. The most notable discovery was made at the West Mouth entrance to Niah in 1958: a human skull, found in the deepest part of the excavation (almost 3m below the ground surface). A radiocarbon date of 40,000 years ago was obtained from this level. It was then and is still today the oldest human remains ever found anywhere in Southeast Asia. At higher levels the archaeologists found further evidence of hunter-gatherers having visited the caves during from the Last Glacial Maximum (21-18,000 years ago) until the early Holocene (about 8,000 years ago): a time when the geography of Southeast Asia was changing significantly. Later still, during the Neolithic period the caves were used more exclusively as a place of burial.

Of all the archaeological remains recovered from Niah the most numerous are fragments of bone, with many probably representing the remains of animals transported to the cave by prehistoric hunters. The identification of the different taxa hunted by people, and the various modifications they made to bones can provide detailed information about hunting strategies and butchery processes, as well as some indications of the type's animals that inhabited the environment around the cave. The assemblage also contains numerous bones of small animals that have accumulated through natural processes, such as bats, rats, swiftlets and lizards. Some of these species have particular environmental tolerances that make them useful indicators of changes in local palaeoenvironmental conditions close to, and within, the cave during the late Pleistocene and early Holocene. Changes in diversity and composition of various animal communities can also be used to determine the impact people have had on their local environment. Furthermore, the identification of different species of animals in the archaeological record is not only important for the interpretation of past human subsistence strategies and palaeoecological reconstruction, but can also have an impact on contemporary biological conservation issues.

Studies on canopy processes in a tropical rain forest at Lambir Hills National Park, Sarawak

Tohru Nakashizuka, Research Institute for Humanity and Nature, Japan

The canopy biological studies in Lambir Hills National Park were initiated in 1992 when Sarawakian and Japanese scientists established the canopy walkway system. The canopy walkway of about 350 m long and two tree towers has been utilized for the researches on phenology and eco-physiology of trees, pollination biology, canopy entomology, and forest meteorology. In March 2000, another canopy facility, canopy crane, was established by the funding from Japan Science and Technology Corporation. The canopy crane with 80 m in height and arm of 75 m long brought us into a new phase of the studies on canopy processes.

The research project now is much concentrated to elucidate the mechanisms of general flowering and canopy-atmosphere interaction in the tropical rain forest. It includes baseline researches on census and phenology of trees, seed/litter traps, periodical trapping of insects (Light and Malaise traps), dynamics of stored substances (starch and sugars) in tree body, meteorological measurement inside forest, and gas flux. The site is also used as the site for the validation site for remote sensing.

Using these data, both proximate and ultimate factors of the general flowering have been tested. The meteorological triggers and eco-physiological condition of trees, which cause the general flowering, has been observed. The pollination efficiency (promotion) and predator satiation hypotheses have been tested as the ultimate factors of general flowering. General flowering is unique in humid tropics in Southeast Asia, and a key for the maintenance of tropical rain forest. The long-term observation will provide crucial information both for ecology and practical sciences.

Carbon and water budget of the tropical rain forest is to be estimated in three ways; direct flux measurement by Eddy covariance, tree enumeration, and integration of eco-physiological processes. The data are particularly important as the first estimation from Asian humid tropic. Three dimensional canopy structure and reflection factor of the canopy have been investigated both from satellite and canopy crane, and the data at a point will be scaled up.

Herpetological studies

Indraneil Das, Universiti Malaysia Sarawak, Malaysia

The high tree species richness in the forests of Borneo is mirrored by that of the herpetofauna, and at present, 154 species of amphibians, 109 species of lizards, 157 snakes, 14 turtles and three species of crocodilians are known from the island.

Amphibians and reptiles have been described as 'modal' vertebrates, for their generally small body size, poikilothermy and generally lacking parental care, and many ecological concepts have been developed through their study. Nonetheless, tropical herpetofaunas remain poorly known, and remarkable new discoveries are being made all the time, although herpetological studies on this island started over a century ago.

Reliable data on amphibians and most reptile species can only be obtained through trapping. Trapping techniques commonly used include pit-fall traps, drift fences, adhesive trapping, noose traps, netting, the use of blow-guns, and hand collection. It is important to collect a voucher series of all unprotected species. It is important to collect the following data for all specimens collected: grid number or position within transect, species, sex, size, reproductive condition, behavior, and any other detail.

Colour photographs of all species and morphs can record variation encountered in the population, besides being useful for talks and publications. Time-constrained searches permit analyses of densities observed, if efforts are replicated. Observations and counts of crocodilians and freshwater turtles can be made from boats, in the case of the former, during moonless nights, using spotlights.

Insect diversity

Fatimah Abang, Universiti Malaysia Sarawak

Insects are the most abundant class of arthropods on land and in freshwater. They are widely distributed and are found almost everywhere on this planet. Approximately 1-10 million different have been named and described (probably a conservative estimate) and some experts believe there may be as many as 10-20 million species, About 7000 new species are described each year an there is no doubt that the numbers yet to be discovered will exceed those now known. The family Curculionidae, or weevils, includes more than 60 000 known species, while the Carabidae, or ground beetles, number about 25 000 kinds. In fact, one in every four animal species on this planet is a beetle.

Insects, because of their astronomical number, are undeniably important in our lives and affect us directly or indirectly in many ways, some are destructive, and many are very beneficial. Because of their abundance and diversity, insects also play a major role in the functioning of the forest ecosystem. About 50% of insects are herbivores and the flowering plants are their main food source.

In general available knowledge about insects in Borneo is limited, especially in comparison with birds and mammals. This is in part due to the vast numbers of species present, their tremendous diversity of habits and their relative small size.

This lecture discusses the classification and diversity of the insect fauna and examples of common species will be illustrated.

Forest dynamics

I Fang Sun, Tunghai University

The big questions

- Why are there so many kinds of tropical trees?
- Why are some species very common and some species so rare?
- Why some species can distribute in many habitats and others have very restricted distribution pattern?
- What are the mechanisms that maintain the coexistence of species?

Why are there so many kinds of tropical trees?

- How many species originate is a mystery of its own
    - Special adaptation to different habitats
    - Reproductive isolation
- How can so many species coexist in one place?

Processes of forest regeneration

- Pollination

Pollination *per se* includes: pollinator attraction; pollen transfer; pollen arrival; fertilization; and development of embryo.

- Seed dispersal

Seed dispersal *per se* includes: developing seeds reach maturity (resources availability and physical environment); advertisement; transfer of seeds; reach suitable environment; avoid been eaten.

- Germination

Germination involves right cues of water and light availability or low temperature; escape from herbivores; competition for light, water, and nutrients with other plants.

- Seedlings establishment and survival of saplings

During this phase the seedlings requires plentiful nutrients to cover the increased amount of energy and metabolites needed for biosyntheses, as well as sufficient water to maintain turgor pressure during rapid elongation growth and cell-wall differentiation.

The loss of progeny during this phase of life is at its highest. The seedling stage is thus the decisive life phase for the survival of the individual plant and for the spread of a population.

- Gap phase dynamics

When a tree falls in the forest, the canopy hole it creates sets in motion a chain of events known as ‘gap-phase regeneration’. Gap disturbances provide the principle or only means by which most tree species can maintain their representation in closed-canopy forests. Such seemingly simple events as tree replacement and gap-phase regeneration are actually complex processes that are still poorly understood. Biology, chance, and history all play a role in the replacement process. Biology plays a role because tree species vary in their ability to disperse seeds, their powers of seed dormancy, their longevity as suppressed saplings in shade, and in their tolerance for gap microclimates. Chance and history also play a role because the precise location of the next gap is unpredictable, so that successful growth and maturation of a sapling may depend as much on being in the right places at the right time as on the species to which it belongs.

How can so many species coexist in one place?

In a spatially uniform and temporally constant world, the most competitive species would come to dominate the community to the exclusion of all others. This is known as the competitive exclusion principle. The reason that most communities contain so many species of plants is that the competitive exclusion principle simply doesn’t work. Environments are neither spatially uniform nor temporally constant.

Explanations of species richness hinge upon whether or not the community is in equilibrium. There are two extreme schools of thought on this, and the truth probably lies somewhere in between. The stochastic school believes that most communities exist in a state of non-equilibrium, where competitive exclusion is prevented by periodic population reductions and environmental fluctuations. The equilibrium school believes that coexistence is possible, even in uniform environments, if certain criteria are met.

Equilibrium explanation

–Niche differentiation hypothesis

–Intermediate disturbance hypothesis

Non-equilibrium explanation
–Enemies hypothesis
–Recruitment-limited hypothesis
–Fluctuating recruitment hypothesis
–Source-sink hypothesis

Niche differentiation hypothesis

- Trade-offs and constraints
- Jack-of-all-trades is master of none
  - Long life vs. early reproduction
  - Photosynthetic rate vs. survival
  - Large seed vs. small seed
- Trade-offs render a degree of specialization advantageous to living things, and represent so many opportunities for different species to coexist
- Habitat heterogeneity enhances tree diversity. Nonetheless, physical factors cannot tell us why there are so many more kinds of trees in a tropical hectare than in a hectare of temperate forest

Intermediate disturbance hypothesis

Species diversity will be maximal at moderate rates of forest disturbance (e.g., treefall disturbances). At low rates of disturbance, light-demanding species are excluded because gaps are rare. At high rates of disturbance, there will be fewer shade-tolerant, mature forest species. Therefore, diversity should be maximal at intermediate rates of disturbance under which the full continuum of life history guilds is maintained.

Enemies hypothesis

Host-specific predators and pathogens cause density-dependent mortality in the seeds, seedlings and small saplings of their host tree species that is sufficiently strong to limit the local adult density of their specific host tree population. If each tree species exhibits negative density dependence, then more species can coexist because no single tree species can become completely dominant.

Recruitment limitation hypothesis

Coexistence is promoted by the failure of species to recruit seedlings in all microsites favorable for their germination, growth and survival, so that many sites are won by default in the absence of a better competitor. Recruitment limitation can facilitate long-term coexistence because it greatly slows rates of competitive elimination; and it can prevent exclusion altogether if there is a tradeoff between dispersal ability and competitive ability to hold a site.

Fluctuating recruitment hypothesis

Asynchronous, fluctuating recruitment in long-lived organisms will result in a frequency-dependent, rare species recruitment advantage, maintaining rare species in the community. The strength of this effect depends on the degree of reproductive asynchrony and the degree to which rare species are not limited by dispersal and maximal fecundity.

Source-sink hypothesis

Many species are not self-sustaining, especially when rare, and these species are locally maintained in a given forest stand only by continual immigration from source populations located elsewhere.

Evidence on these hypothesis

Enemies hypothesis—Strong evidence
Intermediate disturbance hypothesis—Evidence against
Fluctuating recruitment hypothesis—Weak evidence
Source-sink hypothesis—Weak evidence
Recruitment-limited hypothesis—Strong evidence

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Bird community ecology in tropical rain forests

Luan Kheng Wang, University of Washington, USA

Community Structure

Vegetation (dipterocarp forest, secondary forest, etc); Species richness; Number of species found in an area. A consequence of a high species diversity of the bird community in the tropical rainforest is that the majority of species have a low density.

Feeding Guilds

Guilds of birds described in terms of food types, feeding substrates and foraging behaviour. Litter-gleaning insectivores, Foliage-gleaning insectivores, Bark-gleaning insectivores, Fly-catching insectivores, Insectivore-nectarivores, Insectivore-frugivores, Others.

Malaysian Forest

Few undergrowth frugivores, Canopy frugivores common, High diversity in foliage-gleaning insectivores (diversify along size, foraging location and foraging behaviour, specialisation needed for efficient foraging of insects)

Prey density per specialised species is low; thus abundance per species is low (cp fruits, 1-2 trophic levels lower than insects on the trophic web, thus may account for increased total abundance of fruigivores).

Seasonality in the tropics

Constant climate (slight temperature changes, almost constant daylength, rain falls throughout the year, vegetation evergreen), yet breeding seasons of many tropical birds are highly seasonal.

When is the best time to breed? - When it is the best time to raise young?

Food availability: Need to show that peaks in breeding activity within a given species coincide with peaks in food abundance. Correlations are good for insectivores but not fruigivores or nectarivores because protein diet required for feeding young. Lean period in the tropics (when insects are least abundant) = critical period for insectivorous birds. Timing and regularity of lean period results from the consistencies in annual rainfall pattern, which affects primary production and hence insect abundance. Food limits bird populations: Annual cycle of insectivorous birds is organised so that during the lean period, there is a cessation of energetically-demanding activities (moult, breeding, migration). Timing of moult: Determines the timing of breeding - most species have a distinct moult season after breeding; moult is more regular in its timing than its breeding season, implies moult is more "fixed"in its timing, thus constraints the timing of breeding. Overlap in breeding and moult events in tropical birds. High rate of predation (as high as 80% in the Neotropics vs 40-60% in temperate species). Not favourable to terminate breeding in favour of moult. If birds can renest many times, they can increase the probability of nest success.

Field methods

Mist-netting: Most efficient and reliable estimate of relative density and ranging movements of tropical forest understory birds

Line Transect: Used to supplement mist-net data, esp for canopy species, difficult to catch species.

Point Count/Observation

Genetic studies

Shawn Lum, National Institute of Education, Singapore

The field of population genetics contributed to the "New Synthesis" of evolutionary biology. The use of molecular methods to estimate genetic variation and the development of more informative molecular markers have made a staggering impact on population genetics, to the extent that some now work in a field of "molecular ecology".

What are the general aims and methodologies of molecular ecologists, and more importantly, how does molecular ecology fit into the larger context of evolutionary biology? Our brief talk will be an overview of the field as well as a chance to discuss how one might plan a molecular ecology study of tropical forest plants and/or animals.

Mammals of Sarawak

Mohd. Azlan Jayasilan b. Abd. Gulam Azad , University Sarawak Malaysia, Malaysia

Despite the fact that mammal studies are difficult in tropical rain forest, many comprehensive researches have been conducted on large mammals. This is mainly because; they are charismatic and flagship species for conservation of habitat or ecosystem. A total of 221 land mammal species have been recorded in Borneo of which 42% consist of chiropterans. Smaller mammals are much difficult to identify compared to larger mammals. Despite high demand for land due to logging and agriculture, Sarawak has set aside total of 16 protected areas representing a variety of habitat for mammalian species. Some mammals requires pristine habitat while others are resilient to habitat modification. Besides habitat destruction, commercial hunting and conflicts are considered serious threat to most mammals.

Mammals were studied using, live trapping, track counts, interview surveys and direct observations In recent times, with the introduction of infra red sensored cameras, many secretive and cryptic mammals were able to be scrutinized and understood their distribution. Capture techniques on mist nets and camera trapping will be discussed in detail.

Pollination Biology of Tropical Rainforests

Kuniyasu Momose, Ehime University, Japan

Pollination is the process that pollen is transferred from anthers to stigmas. Usually (without some exceptional cases called apogamy), flowering plants cannot produce fruits and seeds without pollination. Unless plants have automatic/active self-pollinating mechanisms, pollen vectors are necessary for pollination. Wind, water, and animals are examples of such vectors.

Almost all outcrossing flowering plants in tropical rainforests are pollinated by animals. Pollination systems in tropical rainforests today are affected both by history and ecological relationships. In the process of pollen transfer, plants are maximizing their fitness in relation with other coexisting organisms in the forests under constraints of their phylogenetic positions.

In order to make this point clear, I introduce historical developments of pollination systems, and ecological backgrounds in which a certain plant chose its pollination system observed today.

Composition of pollination systems in tropical rainforests is considered to have changed since adaptive radiation of angiosperms in the middle Cretaceous in the following ways. 1: (> 120 million years before) Within forests of gymnosperms (wind pollination), the earliest angiosperms, still the rare components, have small animal pollinated flowers with unspecialized morphology. Thus, all visitors are welcome, but flower visiting insects were not abundant. 2: (> 110 m.y.b) Plants of Magnoliales increased in the forest understory, and these flowers were specialized to beetle pollination. 3: (ca. 90 m.y.b) Angiosperms replaced gymnosperms, and animal pollination replaced wind pollination in the tropics. Canopy trees have advanced generalist flowers with nectar glands, and plants in the forest understory tended to have beetle pollinated flowers. Distribution patterns that generalist flowers dominate at forest canopy and specialist flowers at forest understory are also found in tropical rainforest today. This pattern is explained from “advertise effect theory”. 4: Emergence of rich floral resources for animals promoted evolution and diversification of flower visiting insects. Various pollination systems depending on specialist pollinators were derived from advanced generalist flowers. 5: Generalization and specialization of flowers have occurred repeatedly. Size and life span of plants are important factors affecting evolution trends toward generalists or specialists.

Statistics

Richard T. Corlett, University of Hong Kong, China

The availability of user-friendly statistical packages has made statistics too easy: it is no longer necessary to know what you are doing or why. One aim of this session, therefore, is to make the statistical analysis of ecological data as difficult as it should be, by making you aware of issues that the packages don’t always mention. I will also illustrate the range of statistical techniques available for the analysis of standard ecological datasets. The topics covered will probably include: hypotheses and null hypotheses; differences and trends; statistical significance; significance tests; data types; parametric and nonparametric tests; one-tailed and two-tailed tests; testing for differences; testing for trends; confounding effects; observations vs. experiments; non-independence and pseudoreplication.

Comparison among tropical forests: five rainforests

Richard T. Corlett, University of Hong Kong, China

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 since the Miocene, 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 many endemics, 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.

Seed predation

Michiko Nakagawa, Research Institute for Humanity and Nature, Japan

For many plants, seeds are a very important stage for regeneration, however, the stage often represents the period of highest mortality in a life cycle. Among several mortality factors, such as seed predation, fungal attack, desiccation, and germination failure, seed predation is crucial especially for regulating tree regeneration, with losses to seed predators some times as high as 100 %.

One of the most effective systems to protect seeds is to defend them by producing various chemical compounds in their seeds (e.g. total phenolics, condensed tannin, lignin). The physical defense, like a thick and/or hard seed coat, spine, and seed size also contribute to guard them especially against small predators. Masting, annual intermittent production of large seed crops at a population level, is another possible way to protect seeds from various seed predators by satiating them (predator satiation hypothesis) and many reports have examined and tested the saturation of seed predators both at pre-dispersal and post-dispersal stage.

Lowland tropical forests in southeast Asia are characterized by a general flowering, an irregular and multiyear-interval fluctuation of flower and fruit production at the community level. Trees in Dipterocarpaceae are dominant species at upper emergent layer in lowland mixed dipterocarp forests and main components that participate in general flowering. Dipterocarp seeds are eaten by many vertebrates, including birds, small rodents, squirrels, wild pig, and primates, as well as various insects (weevils, scolytids, and micro moths). Populations of small rodents and predation percentages of dipterocarp seeds fluctuate according to the amount of seed production.

How to study seed predation?

1. Identify seed predators· · direct observation, rearing, automatic camera
2. Predation percentages· · direct observation, seed trap

Figs and fig wasps: an intricate interaction

Rhett D. Harrison, Smithsonian tropical Research Institute, Panama

Figs (*Ficus*, Moraceae) are one of the most important plant genera in lowland tropical rain forests. Over approximately 90 M 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 oviposit in some of the flowers. Flowers that receive a wasp egg are induce to form a gall and the fig wasp larvae feeds off the gall tissue. The fig wasps is thus a seed predator – pollinator, and well illustrates the fact that mutualisms are perhaps best understood as mutual exploitation. Approximately, one month later the fig wasp larvae have developed into adults. The wingless males emerge fist and mate with the female while they are still in their galls. The females then emerge and collect pollen, either passively or actively. Meanwhile, the male wasps cut a tunnel through the fig wall and females disperse in search of a receptive fig to begin the cycle again. The adult female wasps live only

1-3 days. The alignment of the reproductive interests of the fig wasp with pollen delivery has led to an incredibly efficient pollination system in figs.

A few days after the emergence of the fig wasps the fig inflorescence softens and ripens into a fruit that is eaten by a variety of vertebrate seed dispersers.

The moneocious system described above is the ancestral system in figs, but in Asia there are many dioecious figs in which the sexual roles have been separated. On female trees the fig wasp enters the inflorescence and pollinates the flowers, but fails to lay its eggs. It, therefore, dies without reproducing and pollination system is best understood as a deceit 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.

In addition to the diversity of breeding systems figs also demonstrate and extraordinary variety of life-histories, far more than any other genus. They include hemi-epiphytes, epiphytes, climbers, small to large trees. Some are pioneers and live only a few years, others such as the huge banyans may live over a 1000 years. Moreover, fig wasp life-histories also vary. They vary tremendously in size. There are day and night flying species. And longevity also varies from a few hours to a few days.

The fig - fig wasp interaction has also been used as a model system for investigating evolutionary theory. The theory of evolution by natural selection is simple in concept but difficult to prove in practice. However, in some special cases it is possible to predict how an animal or plant should behave and then investigate to see whether or not the prediction was correct. Fig wasps have been used to test sexual investment theory such as Local Mate Competition, the evolution of virulence, and co-adaptation and co-speciation.

Figs and the diversity of tropical rain forests

Rhett D. Harrison, Smithsonian tropical Research Institute, Panama

Explaining the diversity of tropical rain forests is a fundamental goal of tropical ecology. One approach to this problem is to examine the biology of characteristic tropical forest species and thereby derive an understanding of the traits that permit the co-existence of so many species. *Ficus* (Moraceae) is arguably the most important tropical plant genus. Figs are diverse. They are found in all lowland tropical rain forests and possess a variety of habits characteristic of tropical rain forest plants. Less well appreciated, however, is the extent to which figs contribute to the diversity of species in tropical rain forests. Here I review 17 tropical lowland florulas (Asia-pacific 7, Africa 4, Neotropics 6) to demonstrate that *Ficus* is invariably one of the most species-rich genera in lowland tropical forest. The variety of plant habits, very low densities and broad ranges of many species have lead to underestimation of fig alpha-diversities in the past. Further examination of florulas from the Asia-Pacific region reveals that (1) *Ficus* exhibits a steep latitudinal gradient, (2) figs are especially important component of regenerating forests, and (3) in highly urbanised and otherwise disturbed environments fig assemblages are impoverished to a greater extent than other genera. In the Neotropics, where relative fig diversity was more variable, figs were most speciose compared to other genera at sites with the highest overall plant diversity. Four basic attributes of fig biology most likely explain their success, (1) *Ficus* is an old pan-tropical genus and has evolved to encompass a phenomenal range of ecologies, (2) small seed size and pre-adaptation to pioneer habits has enabled figs to colonise a broad variety of high energy environments, (3) figs are protected by latex and, especially the inflorescences, suffer low levels of herbivory, and (4) figs possess a highly efficient – long range pollination system, which may enable them to occupy niches untenable to other rain forest plants.

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 (mass 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 behaviors. 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, probably, 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.

Herbivory and Herbivores: The union of Ecology and Evolution

Donald Windsor, Smithsonian Tropical Research Institute, Panama

Herbivores are abundant and their effects are evident yet the world is still Green. Herbivores are unevenly distributed through both time and habitat in the tropics. Herbivory has potentially significant effects on the survival and reproduction of plants, affecting the recruitment curves of many species and playing a role in generating differing levels of plant diversity. Many physical and biotic factors may act to constrain herbivore densities. Additionally, herbivores may be constrained by historical Factors. The ecology, phylogeny and life history strategies of one group of herbivores, tortoise beetles (Coleoptera, Chrysomelidae, Cassidinae), occurring abundantly in both the New and Old World tropics, demonstrates the nature of some of the myriad interactions at work between multiple trophic levels.

Conservation biology in SE Asia

Peter Ng, Raffles Museum, Singapore

So much has been written and said about conservation biology in SE Asia - most of which present despondent predictions and tragic consequences. About how rapid the rate of deforestation is, how many reefs are bleaching and dying, how many species are becoming extinct and all the other terrible things we are doing to a biodiversity hotspot ... But just what exactly do we stand to lose and why? Is poaching and hunting the major culprit, or is logging and fires a more serious threat? Aren't there already enough laws and regulations to ensure our children have enough biodiversity to keep them happy for the 22nd Century? Should our economies slow down to ensure we keep hold of Earth's treasure house of life? Should we not emulate the western economies who appear to have a handle on the situation? The talk will be a wide ranging discussion on these are related issues - and may perhaps answer the question: is there any light at the end of the tunnel?"

Fishes of Loagan Bunut National park – the only natural freshwater lake in Sarawak

Tan Heok Hui, National University Singapore

Freshwater fishes are interesting, with high species numbers, tremendous variety in form, function and habit. They also play important roles in a variety of biogeographic studies. About 10 000 species of freshwater fishes are currently known worldwide and this comprise about 41 % of total known fish species. This diversity of freshwater fishes is impressive due to the fact that freshwater only makes up about 0.01 % of Earth's water supply.

Tropical Asia is estimated to have more than 3000 species of freshwater fish, with Sarawak having about 250 species. A distinguishing feature of the Tropical Asian inland fishes is the high number of families - 121 families, compared with Africa (50 families) and South America (55 families). This is due to the presence of a vast coastline and invasion of rivers by marine species.

The Loagan Bunut lake is part of the Baram River basin, the second largest basin in Sarawak. This lake exhibits periodic drying up due to tidal and seasonal influences. We will examine freshwater fish diversity and several methods of catching the fish.

Parasitoid, parasitoidism and parasitoid communities

Jean-Yves Rasplus, INRA- Centre de Biologie et de Gestion des Populations

Parasitoids are insects whose larvae develop by feeding on the bodies of other arthropods, usually insects. Parasitoidism is restricted to seven orders of insects, but occurs mostly within Hymenoptera and Diptera, with thousands of species. This kind of biology arose at least 20 times independently.

Parasitoids exhibit contrasted biology : ectoparasite *versus* endoparasite, egg - larval - pupal - adult parasitoids, solitary *vs* gregarious, parasite *vs* hyperparasite, but can be divided into two classes koinobiontes which allow hosts to continue to grow and idiobionts which first kill their host and develop on dead bodies. These characteristics can explain most of the biological features show by parasitoids. Some parasitoids have unsual life histories : microtype eggs, polyembryonic, adelpho and heteronomous parasitoids, phoresy.

Finding a host for such tiny wasp appears a formidable task, and parasitoids used a large variety of subtle cues. I will illustrated the three broad categories of stimuli used in lost location: stimuli from host habitats, stimuli indirectly associated with host presence and stimuli from the host.

Soon after the host is located, oviposition take place. The structure of the ovipositor and the way eggs are deposited in the host are discussed. Parasitoid larvae are poorly known but vary considerably in their complexity and external features. At least 14 different first instar forms are recognized. Among which, I shall more thoroughly describe two types of free-roaming host seeking 1st larvae : planidia and triungulins. Parasitoid larvae undergoes hypermetamorphosis, exhibits respiratory adaptations and can produce cocoons.

The adults show series of morphological adaptations to parasitism, that I shall briefly describe : antennal sensillae to detect cues, characters associated with parasitization of host dwelling deep within wood, with norcturnal parasitism or with aquatic hosts.

Host defense are classified into three categories (prevention, behavorial defense and encapsulation) and illustrated by examples. It has been shown that some parasitoids (Braconidae and Ichneumonidae) inject virus into the host (Polydnaviridae). These virus are implicated in suppression of the host immune response.

In the last part of the lecture, I shall reviews some aspect of parasitic wasp community ecology and diversity as well as the factors affecting parasitoid host range, assemblage size and community structure. I shall illustrate these topics with parasitoid communities associated with leafminers and seedfeeders in the tropics.

Strength and variation of ant defense by Macaranga myrmecophytes

Yoko Inui, Osaka Kyoiku University, Japan

Tree genus *Macaranga* distributed in South East Asia tropics includes many myrmecophyte species. Myrmecophytes (Ant-plants) provide nest space and sometimes food for their partner ant species, and in turn resident ant workers provide a defense service for the plants against herbivores and competitor plants. In *Macaranga* myrmecophytism, *Crematogaster* ants live inside hollow stems of the host plants, and utilize host plant secretions (food bodies) as food.

This mutualistic relationship between *Macaranga* and *Crematogaster* is highly species-specific, and in the obligate myrmecophytes, both parties depend on each other for their survival. Nevertheless, there is variation in intensity and efficiency of the ant defense even among obligate pairs. *Macaranga* species that harbor aggressive ant species suffered from high herbivory, when ants were artificially excluded. On the other hand, *Macaranga* species that harbor less aggressive ants suffered from less herbivore damage when without ants and have tough leaves. Thus, the intensity of ant and non-ant defense is negatively correlated.

Although multiple species of myrmecophytic *Macaranga* species often coexist in a small area, species-specific pairs are maintained. There is chemical barrier to prevent non-partner pairing. Foundress ant queens can recognize host species using contact chemical cues on the stem surface of *Macaranga* seedlings that are species-specific. In addition, ant workers selectively harvest food bodies from host species presumably using surface waxes on food bodies.

I will outline life history of *Macaranga* and ants, and then introduce some examples of defensive traits and chemical barrier, and intraspecific variation in the partnership among different environmental conditions.

Significance of habitat in species coexistence and community dynamics of tropical rain forest trees

Akira Itoh, Osaka City University, Japan

There has been long debate on the significance of habitat in species coexistence and population/community dynamics in tropical rain forests. Does each species has its own habitat within a local community? Or, did their distributions skew to particular habitats only by chance? That is, they are all habitat generalists.

Statistical difficulty is one reason why we could not answer the generality of habitat associations for long time. Recent advance of spatial statistics and the establishment of many large-scale plots enabled quantitative evaluation of habitat associations in various tropical forests. These studies revealed the generality of habitat associations in many tropical forests. However, it is still open to future studies how much proportion of species richness can be explained by the habitat associations in the surprisingly species rich communities, tropical rain forests.

In this lecture, I will show a case study of habitat associations using the data set of the Lambir 52-ha plot. An example of recent statistical methods of habitat association will be explained. The participants would make a trial of the habitat analysis with sample data and ready-made computer programs for better understanding of the method. I would also like to show some evidence that habitats association would affects community dynamics of Lambir trees in relation to El Niño drought.

Field Trips

Niah National Park

Iresha Rajapakse, Prasong Thammapala, Dulip Tillekeratne & Sandra Yap

Participants to the International Field Biology Course 2004 were treated to a series of field trips away from Lambir Hills National Park. The first of these trips was to Niah National Park, about two hours away by bus.

The limestone hills and caves of Niah National Park came from an uplifted ancient coral reef that was weathered into hills. Subsequent exposure to running water dissolved calcium carbonate from these hills that resulted in the formation of a complex of caves, the largest being the Niah Great Cave. The Great Cave is accessible from a 4 km long plank walkway initially cutting through a mixed dipterocarp forest. Along the walkway, we were delighted to witness a multi-species bird flock, otherwise known as a “Bird Wave”. Further down the path, we passed disturbed forest evidenced by the presence of large buttressed *Octomeles sumatrana* trees.

Exhausted students finally reached Trader’s Cave, where zooarcheologist Dr. Philip Piper explained how in the 1950s there was a thriving trading industry bartering goods with edible birds’s nests. These are nests of swiftlets, with a population of more than a million individuals, collected by scaling slim bamboo poles up to the roof of the caves.

Close to some of the poles we saw the excavation trenches initially dug in 1954 by Dr. Tom Harrisson, then Curator of Sarawak Museum, and his team. In 1958, Dr. Harrisson discovered a human skull dated to be about 40,000 years old, making it the earliest dated modern human skull in Asia. Aside from this, Dr. Piper told us that they have collected 162,633 bone fragments, presumed to be from animals hunted by prehistoric men. They had even found fragments of the extinct Giant Pangolin (*Manis* sp.).

One other piece of information from Dr. Piper that did not escape our attention, was about the profuse algal growth presently spreading towards the inside of the cave. The hypothesis is that excessive collection of bat guano, to be sold as fertilizer, has resulted in the decrease of the number of invertebrates. These invertebrates spend part of their life cycle in the guano and presumably eat the algae, consequently regulating its growth. The current worry is that these algae that have gone haywire will spread to the Painted Caves as well.

After lunch at the excavation site, and a tour of the site, we were given the choice to continue walking further on to get to the Painted Cave. This was another long hike on a slippery plank walkway through the dark caverns and connected passages from the Great Cave. However tired, we were delighted get there and view these paintings of so long ago.

Walking back from the Caves, everyone was contemplating on all that was discussed, experienced and seen earlier. Modern methods mapping ancient history, caves as shelter, remains of animals including humans, marks left behind, and man’s influence on nature.

A visit to Sarawak Oil Palm Mill

Jeanmaire Molina, Ling Tseng, Raffae Ahmad & Yen Kheng Chua

As we disembarked from the bus after a long hour ride, we were greeted by the deafening sounds of roaring rotors and a subtle aroma reminiscent of roasted coffee wafting through the air. Thick white smoke billowed from huge chimneys. The plant manager and engineer, John Lu, exuberantly ushered us to an air-conditioned room, apparently oblivious to the irreversible effects of air pollution. We gathered around him to learn how the oil palm industry in Sarawak began. In front was a showcase of the different products resulting from oil extraction. A huge bunch of reddish brown fruits will be subjected to immense pressure and heat in the process. It just seems incredible how the fibrous mesocarp and the rock-hard kernel inside can actually yield pure oil. From biofuels to coffee creamers to scented soaps and moisturizing creams, life seems impossible without this liquid gold.

Elaeus guineensis, the source of this precious commodity, has been imported from West

Africa and was introduced to Sarawak in 1967. The first planting in commercial scale began in 1969. Weevils, the most efficient pollinators, were imported from Africa in 1981, and are artificially reared. Fruits start to develop about 4 months after pollination. At 18 months, the initial fruit yield is artificially aborted to allow for a bigger and better produce in the next fruiting season, about 6 months or more thereafter.

Presently, the number of crude palm oil mills in Malaysia is about 400 (about 70 in Johor, 100 in Sabah and 26 in Sarawak). Mr. Lu expressed concern that profits are currently declining, but overhead costs continue to increase. The industry relies heavily on manual labor especially during fruit harvest. Progress in mechanization is difficult as individual palm trees have varied growth patterns (e.g. variable heights and asynchronous fruiting phenologies). There is pressure to resort to large-scale genetic modification, which is expected to increase fruit yield.

Suitable land area for oil palm planting is getting scarce in Peninsular Malaysia and Sabah, thus expansion of oil palm plantation is now concentrated in Sarawak. Presently Sarawak has 500,000 hectares of oil palm plantation (which is astonishingly larger than any patch of contiguous primary forest in the Philippines, Singapore or Taiwan!). But because man is insatiably selfish, the government aims to expand this area to one million hectares by draining most of their peat swamp forests! Mr Lu appeared to believe that these marshes are but “useless” ecosystems that merely serve as breeding ground for disease-laden mosquitoes. To us zealous ecologists, this was absolute heresy! It is a marvel in itself that peat swamps, despite their acidic, nutrient-poor soils, harbor a myriad of fascinating organisms that have evolved perplexingly complex adaptations allowing them to survive in such a hostile environment. Myrmecophytes (e.g. *Myrmecodia*), insectivorous plants (e.g. *Nepenthes*) and detritus-collecting plants abound in such habitats, each possessing unique morphologies and physiologies that compensate for the nutrient deficiency of the substrate.

We left the compound, perhaps our hearing capacities 5 decibels less following our tour of the plant machinery, and still in utter disbelief about Mr Lu’s heretical comments. As the bus sped away, the unbearable clamour of the machines was drowned with the wind, but the thought of the impending threat to our peat swamps, and ecosystems in general, would reverberate throughout our individual voyages towards biological conservation.

Samling Fibreboard

Endela Tipot, Geetha Nayak & Wendy Clement

Samling Fibreboard was founded in 1997 and is located in Kuala Baram Industrial Park, Miri. This factory is only a small part of the Samling Corporation, which encompasses divisions ranging from logging to furniture production. Samling Fibreboard specializes in integrated wood waste products and processes two million tons of mixed tropical woods a year. The factory consists of a continuous assembly line furnished with world-class equipment producing low emissions making this an environmentally friendly process. Their final wood products are moisture resistant and strong providing materials to make affordable furniture and other wood products such as wood panel flooring for homes.

Our visit to Samling Fibreboard began with an introductory lecture from Dr Kai Kruse, originally from Germany, and a specialist in wood processing. His lecture involved an overview to the Samling Corporation as well as the goals and future direction of the company. Following his talk, we were given a guided tour of the factory grounds where we witnessed the processing of fibreboard beginning with chipping of wood cores left over from the Samling Plywood factory and ending in the laboratory where the quality of the products are inspected. The processing of the wood is fairly straightforward as the wood chips are cleaned with water, and then boiled. Fibre extracted from these chips is compacted into large boards, which are steamed and pressed further. Much of the assembly line process is controlled by computer with manual periodic checks of the equipment by workers throughout the day. These boards can then be cut and packaged into many sizes. Every batch of wood is inspected for moisture resistance and strength, which are produced to exceed the Japanese Industrial Standards. From here, the wood is exported to various countries or it is sent to another Samling factory, which produces finished and unfinished furniture and flooring products. The whole process of plywood production from chipping to end product takes about 90 minutes.

Many questions were raised about the reforestation efforts of Samling. The company uses a selective logging system, which follows the Malaysian rule of Selective Logging Management System. Among the requirements are a minimum diameter cut, protected species and area restrictions. Though some reforestation efforts are made, the amount of logging greatly exceeds the area of land reforested. One problem faced by the industry is that the rate of timber production exceeds consumer demands and so depreciates the value of their products.

Kinabalu Park

Chuti-on Kanwatanakid Savini, Ming- Feng Chuang & Chikako Ishida

The Kinabalu Park is the crown of Sabah, indeed of all of Borneo. It is dominates the skyline, the geology, the weather and the landscape (Beaman et al, 2001). It is the focal point of the oldest park in Sabah. The height of Mt. Kinabalu is 4, 101 m and is South-east Asia's highest peak (Philipps, 1988).

The group flew to Kota Kinabalu by Malaysian Airlines. We arrived in Kota Kinabalu airport around lunch time and proceeded to the park where we attended a presentation by Mr. Alim Biun, the outreach officer from the park, on the first night. The presentation described the history, geology, vegetation, wildlife and park management. The mountain itself was formed less than 1 million years ago, when a hard granite plug forced its way upwards through the overly sandstone rock and shales of the Crocker range. Today, Kinabalu is the youngest non-volcanic mountain in the world and it still growing at the rate of 5 mm a year. The honour of Kinabalu's first climb goes to Sir Hugh Low in 1851. The forests are some of the richest in the world with an estimated number of more than 2,000 flowering plants, and this does not include mosses, ferns and fungi. There are thought to be over 1,200 species of the orchid alone. This park is also a center for the curious pitcher-plants that develop a cup or pitcher-shaped structure at the ends of their leave, which trap insects to supplement the plant's food supply. The abundance of insects and the variety of plants support a rich bird life. About 300 bird species have been recorded from the park.

Our second day involved garden visits. We went to a botanical garden named Mountain garden in the morning and afterwards attended the presentation by Dr. Jamii Nais, Scientific Director of Sabah Parks. He presented some interesting information about vegetation of six altitudinal zones including Lowland, Lower Mountain, Upper Mountain, Ultramafic, Granite boulder and Sub-alpine. He also explained how indigenous people, the Kadazan-Dusun, are involved in the park management for plant and animal conservation. Moreover, *Rafflesia* was described in detail. There are 18 *Rafflesia* species in the world and 5 species have been found Borneo. In the afternoon, we visited the herbarium in the park guided by Mr. A. Biun and the Pitcher-Plant garden.

The third day, everybody started climbing the Kinabalu mountain in the morning. The climb to the top normally takes two days. A road from Park Headquarters takes climbers 5 kms up to the Timpohon Gate at 1,800 m where the Summit trail starts. From here the trail starts to be steep staircase and we started to see Rhododendrons and pitcher-plants. We climbed to different height levels, and the furthest was 4 kms. We left from Kinabalu Park around 2 o'clock.

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Rafflesia Centre

Puan Chong Leong, Siti Nurasmah Abu Samat & Ami Ushihara

Located about 2 hours drive from Kota Kinabalu, the *Rafflesia* Centre is the only place in Malaysia and perhaps in the World that provides comprehensive information on the world's largest flower – the *Rafflesia*. We were lucky to have an introduction about the centre by Anthony Lamb, an experienced plant specialist. The centre has catered the information needs of its visitors with respect to the distribution of different species of *Rafflesia* in Borneo including *Rafflesia pricei*, *Rafflesia tengku-adlini* and *Rafflesia keithii*. The genus *Rafflesia*, comprising 18 species, is one of the rarest plants in Borneo, Sumatra, Java, Peninsular Malaysia, Thailand and the Philippines. The diameter of various species of *Rafflesia* flower ranges from 20-90cm. *Rafflesia* lives as a parasite on a host vine *Tetrastigma*. It has become so specialized as a parasite that the entire plant is but a single flower devoid of leaf, stem or roots.

We were excited to know that blooming occurred at the time of visit. After 30 minutes walk in the hill dipterocarp forest at about 1300m above sea level, we were able to see a blooming of *Rafflesia pricei* and three undeveloped buds emerging from a *Tetrastigma* vine. The flower takes a period of 6 to 7 months to develop into a mature body. It has a brightly-coloured appearance and a meat-like smell, and we were able to see some carrion flies around the flower which apparently acted as main pollinator.

Tenom Agricultural Park & Gardens

Puan Chong Leong, Siti Nurasmah Abu Samat & Ami Ushihara

The objective of the garden is to present tropical flowering plants of horticultural use in a named reference collection for the public. It also constitutes a small gemplasm collection that provides source of seeds, and propagation materials for nurseries or other institutes and parks. With an area of 1,500 acres, the park comprises of an impressive collection of plant species that found locally and abroad. The parks can be generally divided into seven sections based on different concepts.

On the first arrival of the Tenom Agriculture Park, we were glad to have Anthony Lamb again and his kindness in sharing his experiences and knowledge on many aspects of plants. There are a total of 21 ornamental gardens with beautiful landscapes and various garden settings. These include the *Bougainvillea* Court, *Ixora* Garden, *Hibiscus* Garden, Cactus Garden and Shrub Garden.

The following day, we managed to visit the Native Orchid and Hybrid Orchid Garden. Some 150 genera can be found in the garden including the rare and endangered species such as Elephant Ear Orchid, Rat Tail Orchid, and *Paphiopedilum sanderianum*. Following this, we went to displays of suburban gardens and the Evolution Garden. The basic concept of the Evolution garden is to show how plants evolved from the primitive to modern forms depicting their extraordinary ability to adapt to the changing environment of their habitats.

The next visit was to the Honey Bee Centre which is globally recognized as one of the best bee research centres. Here, we had have a chance to learn about various aspects about honey bees including the distribution, extraction of beeswax and honey, as well as the type of research on honeybees. At the Living Crop Museum, more than 400 plant species of economic value are planted systematically based on their uses. This garden is divided into five sections such as scented garden spices and condiments garden, fibre crops, starch crops, fruit and nut trees and medicinal plants. We were so grateful to have the chance to taste some of the fruits.

Loagan Bunut National Park

S. H. Bandumala, Zahid Mat Said & Voradol Chamchumroon

After the lunch on the 3rd August our group proceeded to Loagan Bunut National Park and reached the headquarters by 4.30p.m. Loagan Bunut National Park is located in the floodplain of the Tinjar river, a major tributary of the Baram, and contains Sarawak's largest natural lake called “Loagan Bunut” by the local inhabitants. We reached our destination, which was situated on the other side of the lake by boats. In the evening, we went out on boats on the lake to see traditional fishing techniques. Traditional fishing techniques are a major attraction of the park. Here we could see fishing techniques of cast nets and nets suspended from poles driven into the lake bottom. They also have a unique *Selambau* method of fishing that was developed to harvest migrating fish during times of fluctuating water levels. We looked around until 6.00 pm and went back for a nice swim in the lake. Dinner was marvellous and rich with BBQ fish, brown rice and tom yam soup. After the dinner group members were very happy and enjoy the cool calming environment.

The following morning (4 August 2004) we went the fish market to study about fish. We could observe various kinds of freshwater fish. There was a fish call Glass Perch who can walk on the ground when the water level goes down. Various kinds of cat fish were found and they are the most tasty fish. After the fish were sent to the city market we came back for our breakfast. At mid morning our group left for the Peat Swamp forest on boats. We found darters, egrets, herons and bitterns around the forest. Peat Swamp forest has peat soils, developed on the top of the alluvium. Peat is a soil type with a very high organic content. The dominant trees here belong to *Gonystylus, Dactylocladus* and *Shorea*. A much sought after timber tree in this forest is ramin (*Gonystylus bancanus*). This is a large tree with a cylindrical bole and pale reddish-brown bark. The Kapur paya tree (*Dryobalanops rappa*) is among the tallest and biggest trees in the swamp forest. Many of the large umbrella-shaped crowns, recognizable from a boat crossing Loagan Bunut, belong this species. Away from the rivers, mixed swamp forest is gradually replaced by Alan forest, which is similar in structure but dominated by enormous Alan trees (*Shorea albida*); trees with a girth of up to 6 m, large spreading buttresses invariable support the cylindrical bole. Along the trails, we founded two species of *Nephethes* (*N. ampullaria* and *N. bicalcarata*). Spending after two and half hours in this forest we came back for our lunch. Before returning to the Lambir Hills we visited a traditional Berawan burial platform and longhouse. The chief of this long house is Mr. Maran and situated near to Kampung Loagan Bunut. The longhouse is a typical house in Sarawak. We visited until 16.00 and then returned to Lambir Hills National Park.

IFBC 2004 in Colour

Group projects

Comparison of fruit syndromes among figs

Puan Chong Leong, Siti Nurasmah Abu Samat & Ami Ushihara

INTRODUCTION

Figs (*Ficus* spp.) are a distinctive group of plants that belong to the Moraceae family. A well-known and widespread genus of tropical plants, figs play an essential role in maintaining the ecological balance and providing various values to the society. There are approximately 750 fig species in a roughly pan-tropical distribution (Harrison *et al*. 2003). Hence, *Ficus* is a species-rich genus. There is great diversity of fig species in which each species have developed the ability to coexist in local assemblages. They vary in shape and size which range from shrubs, small to large trees, bole climbers, hemi-epiphytes and true epiphytes. In relation, they colonize a variety of gaps including tree-fall gaps, smaller landslides, and stream sides.

In contrast to the supra-annual general flowering of many species in South-east Asian forests, figs flower continuously. Besides that, figs have two breeding systems, monoecious figs have infrequent and large synchronous crops, while diecious figs tend to have smaller, more frequent crops. This has basically created their essential ecological roles and relationship with other organisms (Harrison & Shanahan *in press*). This includes the species-specific pollinators and other frugivorous mammals as well as birds. All these reasons have made the figs one of the critical components in the forest ecosystem.

This study is intended to identify the different fruit syndromes of figs involving the segregation of the relevant characteristics within the guilds. This paper is begun by providing some background to the study site. The following section deals with the collection of fruits and identification of the relevant characteristics. This followed by analysis of data using Principal Component Analysis. The results was presented in graphical form and further discussed in some detail with respect to different fruit syndromes. Some concluding remarks are made based on the fruit syndromes identified.

METHODS

Study Site

The study site, Lambir Hills National Park, is located about 30 km south of the town of Miri in the northern Sarawak, Malaysia. Approximately 6500 ha in size, the area comprises a relatively small primary lowland dipterocarp forest surrounded by secondary forest, oil palm plantations and shifting cultivation. There is also a small area of kerangas heath forest along the ridge that forms the summit of Bukit Lambir. The area receives 3000 mm of annual rainfall with periodic droughts that occur throughout the year (Lee, H.S *et. al*. 2002).

The figs of Lambir Hills are diverse and represent more than half of the Bornean fig flora. A total of 75 species and 6 varieties have been recorded. There are 46 out of 97 dioecious figs that are endemic to Borneo. There is considerable variation in terms of phenology, flowering frequency, fruit crop sizes, and crop synchrony at Lambir Hills. The monoecious figs are either hemi-epiphytes (*Urostigma* and *Conosycea*) or large trees (*Oreosycea*), while dioecious figs include root-climbers (Rhizocladus and Kalosyce), small understory hemi-epiphytes (*Sycidium*), shrubs or small trees (*Ficus* and *Sycocarpus*), and large canopy trees (Harrison & Shanahan *in press*).

Data collection and analysis

A preliminary survey was done in order to identify the location in which figs can be found. Fruit collection was conducted in three-day visits within the park, including the 52 ha ecological dynamics plot and surrounding areas. Subsequently, a total of 68 fruits of 13 species of *Ficus* were collected. Identification was made on the ground where fruits were collected. Measurement was taken on the diameter of the fruit. The breeding system (whether it is dioecy or monoecy) were recorded based on the fruit dissected. The number of seeds (for female tree) and galls (for male tree) were counted using microscope. The other characteristics recorded were colour, hardness, smell, shape, and the presence of bracts and height of fruit.

All the data obtained were properly checked and a datasheet was prepared. Analysis was conducted by using Minitab. The Principal Component Analysis was performed in order to segregate the fruit characteristics. The first stage of the analysis involved the segregation of female fruits collected from different species in order to examine the fruit characteristics in relation to seed dispersal. While the latter part of the analysis was to examine the fruit characteristics based on sexual dimorphism.

RESULTS & DISCUSSION

In this study, a total of 13 species of *Ficus* was collected which include both monoiecious and diecious figs. However, in only three dioecious species were both male and female fruits collected.

Fig 1 showed the results of Principal Component Analysis for seed dispersal syndromes. From the results, the size, colour of fruit, the height above ground, and crop size appeared to be important in determining, which animals that feed on the fruit. The geocarpic and cauliforous fruits seemed to exhibit similarities in terms of number of seeds, height and diameter of fruit. The geocarpic figs which include *F. geocharis, F. macrophylla, F. uncinata* and *F. treubii* are more likely to be eaten and dispersed by terrestrial mammals while the cauliforous figs including *F. francisci* and *F. schwarzii* are likely to be dispersed by bats. The fruits tend to have small diameter, lower in terms of seed number and height. The geocarpic figs revealed a spectrum of pioneer ecologies, with species segregating according to colonization microsite, light environment and maximum diameter (Harrison & Shanahan *in press*).

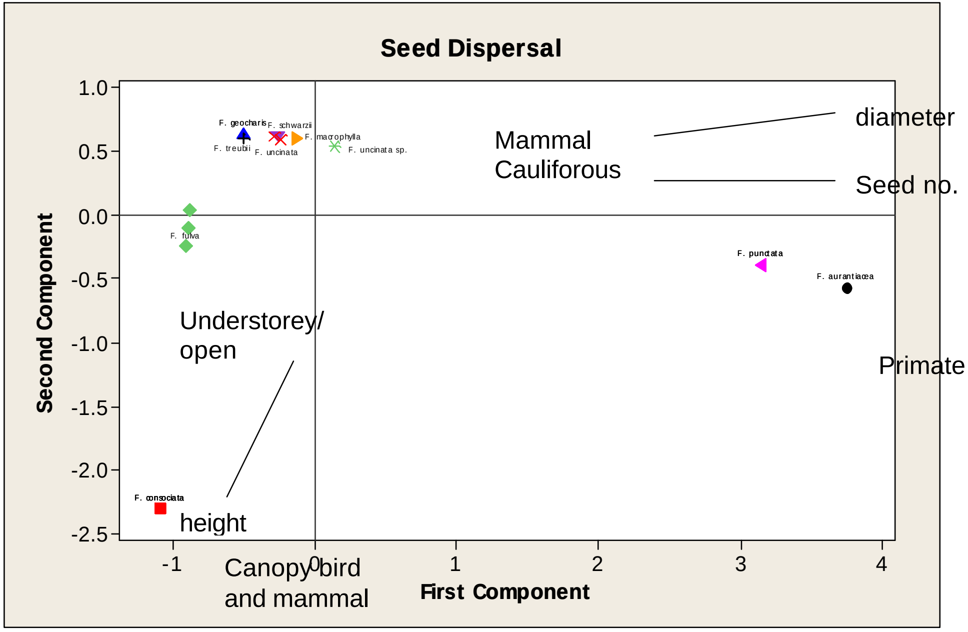

Fig 1 Graph shows seed dispersal syndromes of figs

On the other hand, *F. punctata* and *F. aurantiaceae* are also similar in fruit syndromes. They have a relatively larger diameter and high seed number and height. Primates could be the main disperser of these large fruits. The fruits were smooth and located on the high position of tree and often have bright colour like red and yellow.

Ficus consociata are red in colour, lower in seed number and relatively small in diameter. It can be considered as a canopy species and the fruits are often located high above the ground. The fruits attract the birds and mammals that eat and thus disperse the seeds. Besides that, canopy figs are probably one of the important resources for terrestrial frugivores. This is because there are often large quantities of fruit fall to the forest floor and eaten by animals. Further segregation of species within these broad guilds is evidently possible where the dispersal by canopy birds and mammals may be divided into species with smaller or larger fruit (Harrison and Shanahan *in press*). With medium diameter, hairy and yellow-coloured fruits, *F. fulva* are effective in attracting the open area and understorey birds. Table 1 provides a summary of the fruit characteristics and the relevant frugivores.

Table 1 Characteristics of *Ficus* fruits and the relevant frugivores

Frugivores	*Ficus* sp.	Characteristics of fruits
Terrestrial mammals	*F. geocharis* *F. macrophylla,* *F. uncinata* *F. treubii*	Hairy On the ground White & red in colour Bracts present
Bats	*F. francisci* *F. schwarzii*	Hairy Green Low dispersal
Understorey and open area birds	*F. fulva*	Short White/red/orange Bracts On stalk
Primate	*F. punctata* *F. aurantiaceae*	Big size High tree Smooth Bright color (yellow & red)
Canopy birds and mammals	*F. consociate*	Relatively small High tree Red with white dot

For anlaysis of sexual dimorphism (Fig 2), only three species were included as fruits collected for other species were either male or female. Female fruits of *F. macrophylla, F. schwarzii* and *F. treubii* show some similarity in terms of seed number, diameter size, and height. It seems that female fruits tend to have larger fruits and seed/gall number then male fruits, while the male fruits of the three *Ficus* species mentioned are more likely to have greater height.

CONCLUSIONS

The dispersal of seeds is an essential process for plants in the sense of increasing the chance of germination and survival. While on the other hand, it reduces the competition with mother plant. In tropical rainforests, dispersal by wind is depended on the aerodynamic properties of the seed or fruit, the height and the wind speed during time the seeds are released. However, most tropical forest plants are dispersed by animals. The process might take place either externally or internally. The internal dispersal is most important by far in the tropical forests. Nonetheless, internal dispersal requires that the seeds or fruits are developed with nutritious tissues and are particular attractive to its dispersal agents.

The figs at Lambir Hills demonstrate extraordinary variety of seed dispersal syndromes that attract different frugivores. The relationship between fleshy-fruited plants like figs and seed-dispersal animals is potentially mutualistic for both sides. In the case of figs, different fruit syndromes may be essential for dispersal of seeds. This gradually increases the chance of germination, establishment and growth.

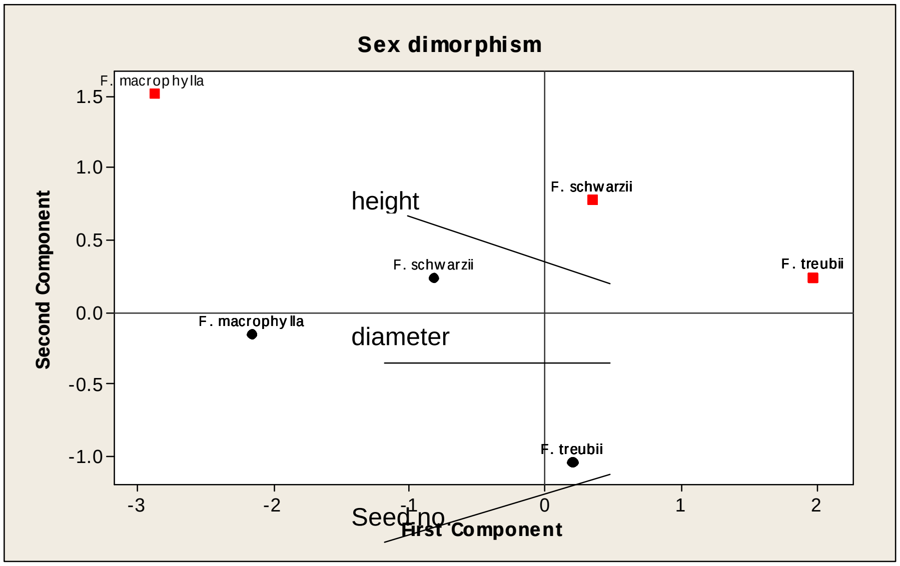

Fig 2 Graph shows sexual dimorphism of figs (black=female, red=male)

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Factors affecting the growth of rattans

S. H. Bandumala, Zahid Mat Said & Voradol Chamchumroon

INTRODUCTION

The physiological basis of growth rates and shade tolerance amongst tropical rain forest tree species until recently remained unknown. Fast growth of pioneer trees results from their high leaf area and high assimilation rates. Relative growth rate (dry weight increase per unit of dry weight) decreases with increasing shade tolerance but is a less basic measure because it changes with age. Rattans are palms. They are major plants in forest floor of tropical rain forest and have high diversity. They have two different growth forms (climber and rosette).

In Lambir Hills National Park there are more than 20 spp. of rattans (*pers. obs.*) Rattans are spiny climbing plants from the sub-family Calamoideae, which also includes tree palms such as *Raphia* and *Metroxylon* and shrub palms such as *Salacca*. There are 13 different genera of rattans that include in all some 600 species. Some of the species in fact do not climb, being shrubby palms of the forest undergrowth. Nevertheless, reproductive features link them with other species that are climbers, and hence they are included in the rattan genera (Uhi and Dransfield 1987). Sarawak boasts as one of the richest rattan floras in the world. The total species number recorded is about 106, slightly higher than the peninsular Malaysia and Sabah (Dransfield 1992). Rattans are very variable plants, juveniles often being strikingly different in size of their parts from adults. Rattans stem may be very short and erect or subterranean, so-called stemless or high-climbing; they maybe solitary or clustered. With habitats ranging from sea level to over 3,000 m elevation, from equatorial rainforest to monsoon savannahs and the foothills of the Himalayas, there is a huge range of ecological adaptation among rattans. However, rattans are predominantly plants of primary rain and monsoon forest. Some species may be adapted to growing in secondary habitats, but these are the exception (Dransfield and Manokaran 1993). Furthermore, rattans entering the world trade are overwhelmingly collected from the wild, with only a very small proportion coming from cultivated sources. Not all rattans are equally useful. Stem diameter varies enormously from 2- 3 mm diameter among the smallest species to 10 cm in exceptionally large species. Within a size class, not all species are equal quality, some being brittle, others of poor external appearance.

Rattans are distributed in tropical and subtropical areas in the Asia –Pacific region and Africa. No rattans are growing naturally in other tropical and sub-tropical areas, or in the temperate regions.

In tropical rain forest, particularly, mixed dipterocarp forest, rattans are prominent species and their distribution and growth studies are very important. This study was carried out to examine the relationship between light condition of the environment and rattan growth. For the purpose of this study we have selected sites from riverbanks and understorey to look at the growth of *Calamus* sp. The two sites were different in term of soil moisture and amount of light received. Within diverse tropical forest, there is growing evidence that variation in soil water and light may contribute to differences in growth performance of some species of tree.

MATERIALS AND METHODS

Species

In this study we only looked at the growth of *Calamus* sp., which is commonly found along the riverbanks and the understorey. There are about 370 species of *Calamus* in the world, distributed from Africa, India, South China, Sri Lanka to southwards through Malay Archipelago to Australia and Fiji. It reaches the centre of diversity in peninsular Malaysia and Borneo with a secondary centre of diversity in New Guinea (Dransfield 1992).

Study site

The field study was conducted in a lowland mixed dipterocarp forest in Lambir Hills National

Park (4^{o} 12’N,114^{o}00’E) is located 24 km south of Miri town, Sarawak, Malaysia. Data collection was made from August 01 to August 05,2004.

Data Collection

Plot establishment- Two sites of different light conditions were selected for this study. One site was situated on a riverside and it received more light than the other site, which was in the understorey. For each site five (10mx10m) plots were established. For this study we selected only rattan plants of genus *Calamus*. In each site light was measured with a Nikon camera and soil samples were taken for soil moisture measurements. Number of rattan plants in each plot, no of rosette plants, climbing plants, and crown area of rattans were recorded.

Light measurement - Light was measured by SLR camera by adjusting a shutter speed and F no (Table 1). We are set camera and measure shutter speed and F number in centre of plots.

Table 1: Light index F stop and shutter speed measurements

Shutter speed	8-15	30	60	60	60	60
F number	3.5	3.5-5.6	3.5	5.6	8	11-22
Light Index	1	2	3	4	5	6

Note: 1=dark, 2= very low light, 3= low light, 4= medium light,
5= more light, 6=over light

Collection of soil samples - We collected a soil sample in the centre of each plot using a soil core (ca. 200 g) and took samples to laboratory for calculate water moisture contents. We measured soil wet weight then oven-dried samples for 24 hours. The weight of the solid phase was measured, and then water phase was calculated by subtracting the weight of solid phase from the wet weight.

Data analysis

We used stepwise regression to investigate the effect of light intensity and soil moisture content on rattan growth. We compared habitats using non-parametric 2 sample t-test.

RESULTS

In ten plots, we founded six species of *Calamus*. Light conditions between the two sites varied significantly, with the riverbanks ranging from very light (Light index 5) to the understory being very dark (Light index 1) (Table 1).

In ten samples from each site, we calculated the percentage soil moisture (Table 2). Soil from the river bank had a sandy loam texture, while soil in the understorey had a clay loam texture. It was shown that there was significant difference of soil moisture between the riverbank (mean 26.04%) and the understorey (mean 17.57%).

Table 2 Soil moisture (%)

Sites	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Mean**	**SE**
River bank	23.94	26.56	33.71	25.31	19.87	26.04	5.05
Understory	20.0	19.05	23.0	10.16	15.13	17.57	4.91

The number of stems, coverage and density, are shown in Table 3. There were fewer stems in riverbank than in understorey, but coverage in the riverbank was more than in understorey (Fig 1). In the riverbank, there were 41 more rosettes than climbers, while in understory there were 129 more rosettes than climbers (Fig 2).

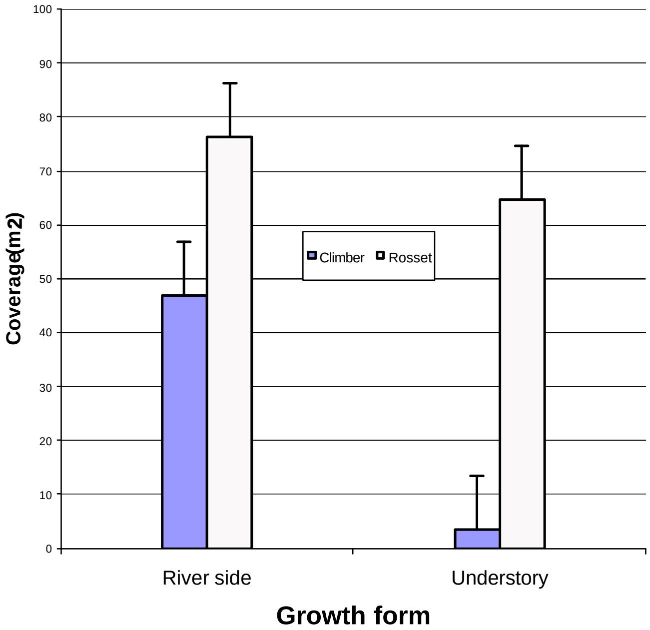

Fig 1 Mean coverage of rosette and climbers of rattan plants in river bank and understorey.

Table 3 Number of stems, coverage and density of rattan in 2 sites

Sites	No. of stems	No. of climber	No. of rosette	coverage	Density
River bank	99	29	70	24.56	0.198
Understory	133	2	131	13.07	0.266

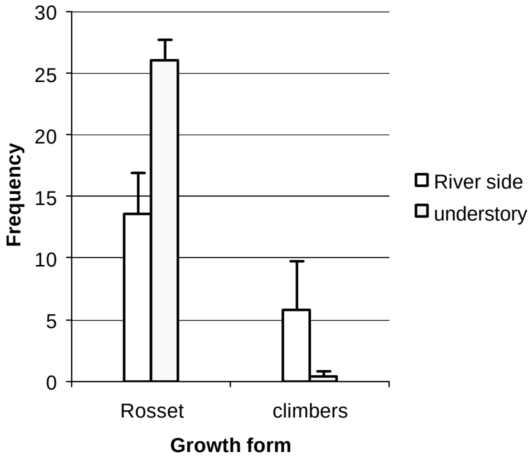

Fig 2 Number of climber and rosette plants of rattan in riverbank and understorey

The number of stems was inversely related to the light index, but it was non-significant. (Pearson correlation of no. of stem and Light = -0.574, *p*=0.08) (Fig 3).

The coverage of rattan was also related to a light index but non-significant. (Pearson correlation of coverage and Light = 0.518 *p* = 0.125) (Fig 4). However, when the different life stages were treated separately a significant relationship with light was obtained (Climbers, r= 0.659, *p* = 0.04; Rosette r = -0.696, *p* = 0.025) (Fig 5).

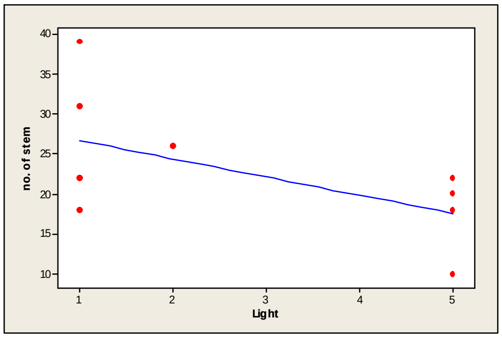

Fig 3 Correlation of no. of stem and light

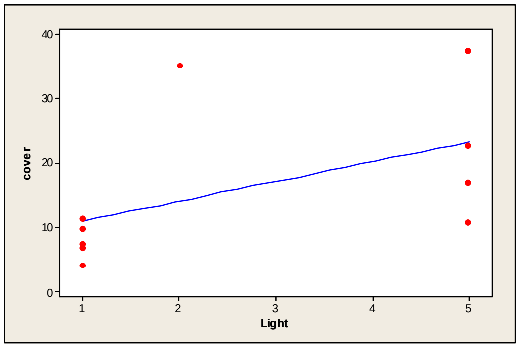

Fig 4 Correlation of coverage and light

Soil moisture was related to number of stem but not significantly (Pearson correlation of no. of stem and moisture = 0.103, *p*= 0.778). Moisture and was related to coverage of rattan but again not significantly (Pearson correlation of coverage and moisture = 0.464, *p*= 0.177) (Fig 6).

When life stages were treated separately the results were also non-significant.

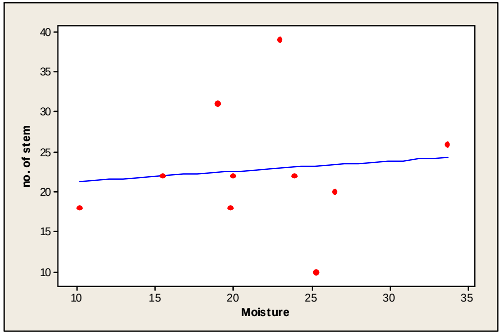

Fig 5 No. stems vs moisture

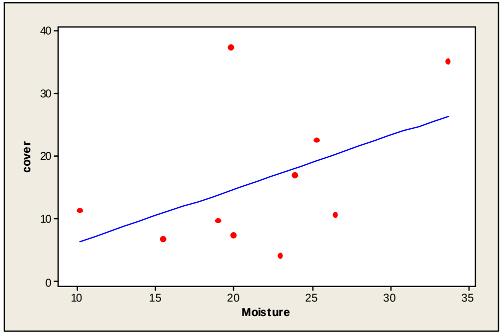

Fig 6 Coverage vs moisture

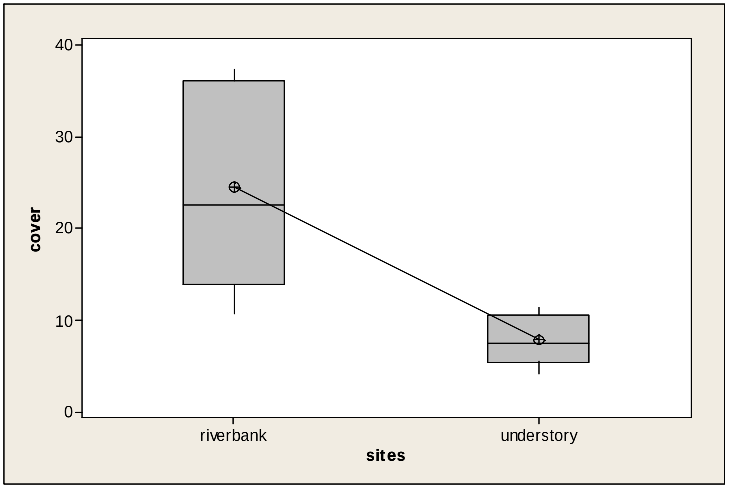

Fig 7 Mean of coverage compared between sites

In our hypothesis, total coverage by rattans in understorey and riverbank were different, indicating a difference in rattan growth in the two habitats. In riverbank coverage was 24.6±5.1 and understory it was 7.89±1.3 (T-Value = 3.15 *p* = 0.034 DF = 4)(Fig 7).

In the case of mean coverage compare by life stage of plants, rosette coverage in riverbank was 15.27±4.4 and in understory was 12.91±3.8 (T-Value = 0.41, *p* = 0.697, DF = 7, Fig 8). Climber coverage in river bank was 9.4±4.8 and in understory was 0.71±0.71 (T-Value = 1.80, *p*= 0.146, DF = 4, Fig 9). Stem number varied from 19.20±2.7 in riverbank and 26.40±3.8 in understory (T-Value = -1.55, *p*= 0.164, DF = 7)(Fig 10).

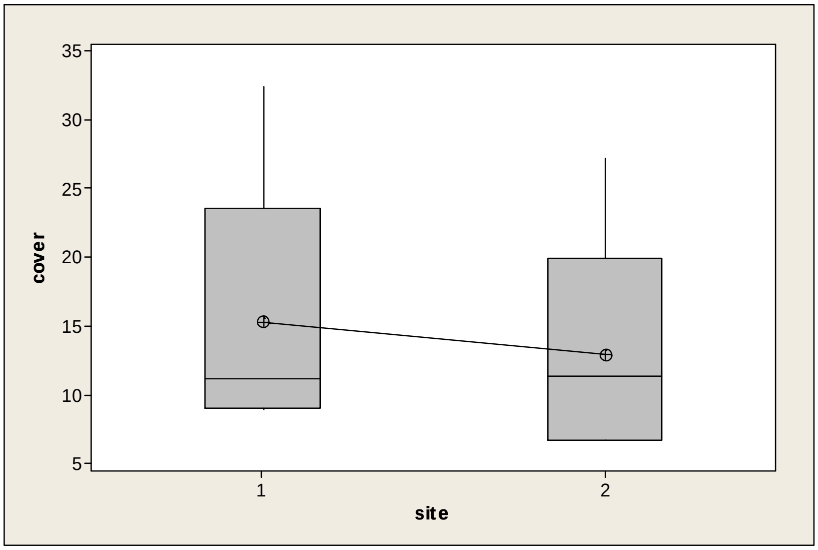

Fig 8 Mean of rosette coverage compared between sites

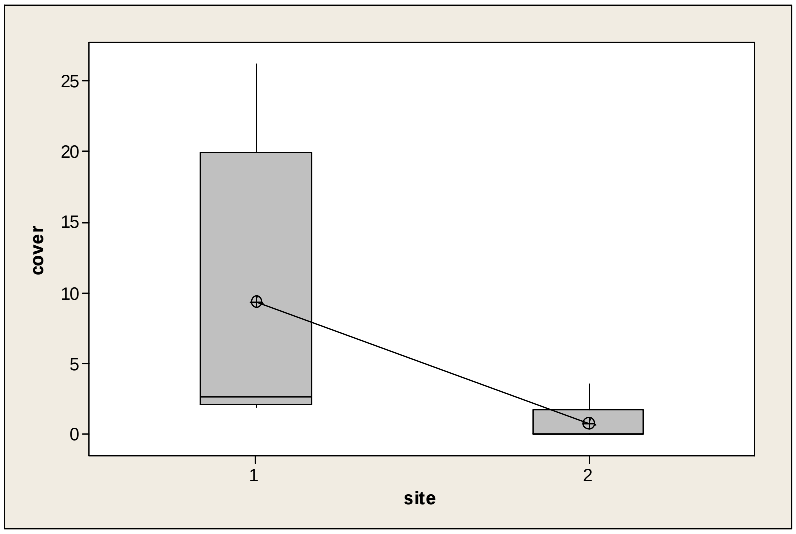

Fig 9 Mean of climber coverage compared between sites

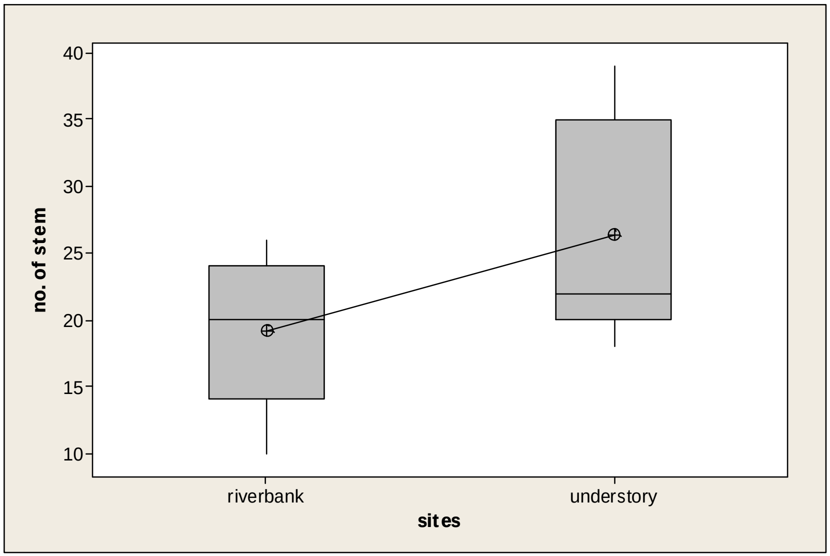

Fig 10 Mean of number of stems in 2 sites

In the case of mean number of stems compared by life stage, number of climbers in riverbank was 5.80±1.7 and in understory was 0.40±0.4 (T-Value = 3.17 *p*= 0.034 DF = 4, Fig 11).

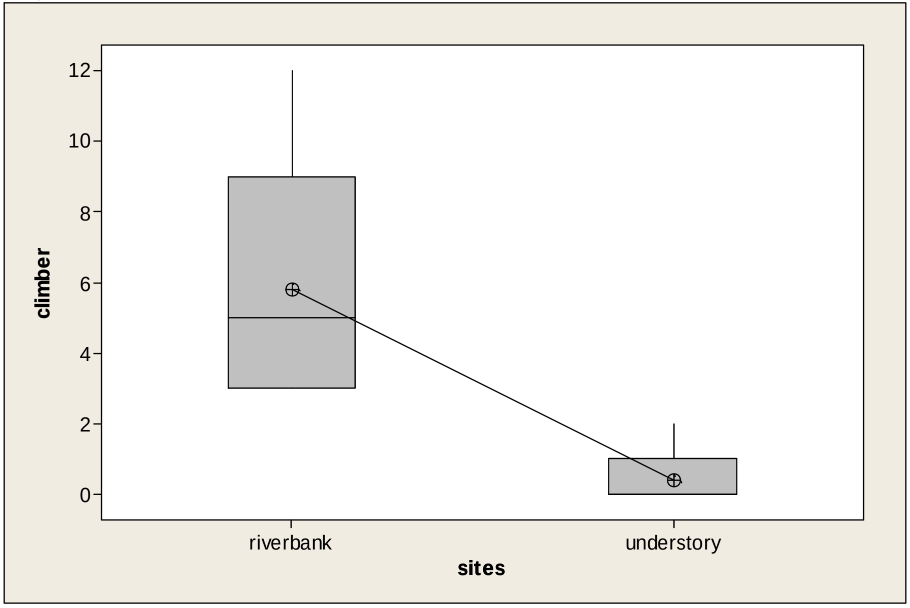

Fig 11 Mean of number of climber compared between sites

Mean number of rosettes in river bank was 13.4±3.3 and understory was 26.0±3.9 (T-Value = -2.46 *p*= 0.043 DF = 7, Fig 12)

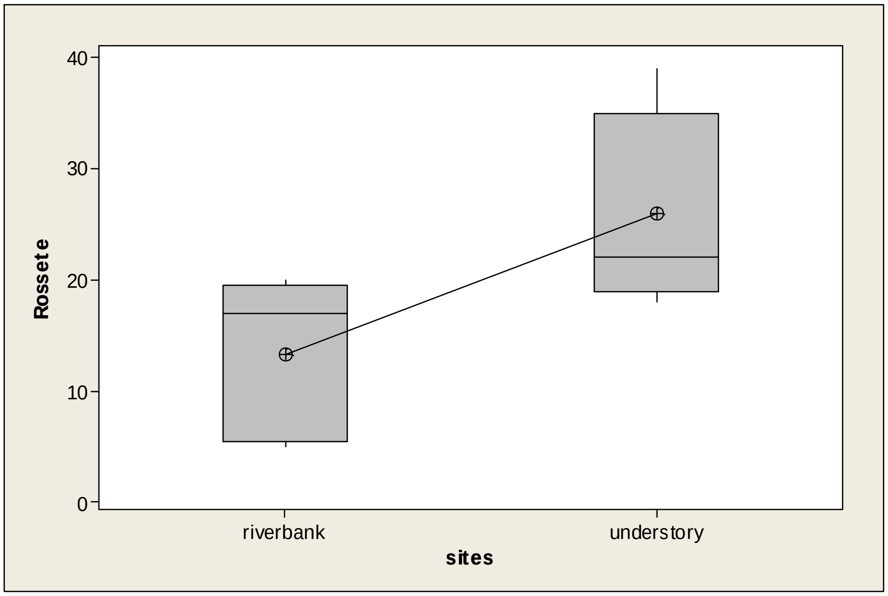

Fig 12 Mean of number of rosette stems compared between sites

DISCUSSION

In the present study growth form of rattan differed between the two sites. The riverside showed significantly higher numbers of climbers than the understorey. The number of rosette plants in two sites was also significantly different, and it was higher in undestorey. Riverside received more light than the understorey. Soil moisture content was also higher in the riverside. These results suggest that rattans need high light or high moisture conditions or both for their growth, but not establishment.

Xu et al. (1993) pointed out that most rattan seedlings grew well in dim illumination, and were damaged by bright light, but over shading hindered clumping habit and stem growth. Full illumination promoted stem growth nodal elongation.

CONCLUSION

In the present study the growth form of rattan differed between the two sites. The riverbank had a significantly higher number of climbers than the understorey. The number of rosettes in the two sites also differed significantly and was higher in understorey. Light conditions and soil moisture were also significant related to habitat.

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Diet Selection in the Green Paddy Frog (*Rana erythraea*)

Chuti-on Kanwatanakid Savini, Ming-Feng Chuang, and Chikako Ishida

ABSTRACT

This study was conducted from 1-6 Aug 2004 at Lambir Hills National Park, Sarawak. We collected 25 individuals of the Green Paddy Frog (*Rana erythraea*) and analyzed the stomach contents. These frogs are sexually dimorphic; females are bigger than males. A total of 83 prey items were found, included 10 orders, most belonging to Isopoda (wood lice) and Hymenoptera (ants). Males ate more ants than females. The prey size and frog body size were significantly correlated overall but not when sexes were treated separately. Prey numbers of males are similar to females.

INTRODUCTION

The herpetofauna of tropical Asia is one of the world's most diverse but it is the least known. They are typically excluded from considerations in habitat management and environment impact assessments (Das 2002). Amphibian and reptiles are an important component of many natural ecosystems, in terms of diversity and contribute significantly to the biomass of many regions. They play a role in the dispersal of food plants, especially their seed.

Frogs are a distinct but relatively uniform taxon. Their distinctive features include: no tail, short body, long hind legs and short front legs, large bulging eyes, and a wide mouth. Frogs also have a large fleshy tongue. Their tongue is generally broad and soft, and unlike the tongue of bird and mammals, is hinged at the front end. Frogs flip the tongue out at prey, and then flip the prey back into the month. Insects and other invertebrates are the usual prey, though large species of frogs may devour other frogs, or small snakes, small birds or mammals. Frogs usually do not feed on plants but they might swallow plant parts accidentally. Other distinctive characteristics of frogs are their complex lifecycle. Their begin life as aquatic larvae, or tadpoles, and change through metamorphosis to become the adult frog (Inger and Stuebing 1977). Frogs depend on water for breeding and survival. The skin of frog is scaleless, so that water tends to pass through quite freely in either direction, so most frogs avoid dry conditions whenever possible.

Frogs occupy a wide variety of fresh water habitats. They occur in all terrestrial and many aquatic environments from the cold edge of the permafrost in the far North to the tips of southern continents. Many frogs live in the grassland, some are able to live in the desert, but the majority live in warm humid forests. Regardless of the habitat, some frogs lay eggs in small rain pools, others in the large ponds or streams. For most species, breeding activity begins with males at breeding sites calling, either single or in groups. Each species has its own distinctive call. Males usually have vocal sacs in the throat which inflate with air to form effective resonating chambers, greatly increasing the volume of sound produced. A gravid female eventually moves towards a calling male, occasionally even bumping into him. Both male and females release gametes and fertilization occurs in the water. After a day or two, the tadpoles hatch and their aquatic life begins.

There are at least 140 species of frogs in Borneo (Inger and Stuebing 1997). Ranidae can be found almost everywhere in the world and it is the largest family in Borneo. *Rana erythraea* is known as Green Paddy Frog. *Rana erythraea* are small to medium-sized with long, muscular hind limbs and a long tapering red snout. This species is bright to dark green on the top of the head, down the back, and along the sides. There is a wide yellow stripe from behind the eyes to the end on each side. The upper surfaces of the limb are light brown with fine dark markings. Usually females are bigger than males, which are 48-75 mm and 32-45 mm, respectively. Green Paddy Frogs prefer to live in disturbed freshwater habitats such as irrigation ditches and flooded rice fields (Inger and Stuebig 1997). They are extremely wary and it is difficult to get close to them even at night. Males do not form calling groups, but may be localized within a small area.

Grass and reeds are the main place for male to perch for food, while females are more often seen on banks. *Rana erythraea* prefer small terrestrial invertebrates, such as small millipedes, crickets, and ants. So it is interesting to understand how frogs select prey.

There are studies showing that prey size of some frogs is not limited by body size, for example, samples taken from the stomachs of five Abbort's Litter Frogs (*Leptobrachium abbotti*) contained crickets, spider and a cockroach, all with average length of 17.5 mm; the average number was only 1.5 prey items. The common Horned Frog (*Megophrys nasuta*) with its impressively wide mouth eats even larger prey (average 32 mm), and is willing to tackle and swallow a 4 cm snail and 10 cm scorpions. The largest prey of all are taken by Giant River Frog (*Rana leporine*), the Mud Frog (*Rana malesiana*) and the Greater Swamp Frog (*Rana ingeri*), some of Borneo's largest species. These eat other frogs, snakes, crabs, forest millipedes, scorpions; almost any small animal passing too close to one of these species is likely to disappear in a single gulp (Inger and Stuebing 1997).

This project was completed during the International Field Biology Course organized by the Center for Tropical Forest Science - Arnold Arboretum and Sarawak Forestry Corporation from 15 July-14 August 2004 at Lambir Hills National Park, Sarawak, Malaysia. The aim of the study was to identify the species and the size of prey items consumed by the frogs. This study investigated the prey consumed under two questions:

1. How do frogs select the prey size?

   H: Frog body size does not relate to prey size.

Explanation: Frogs forage on any thing that moves and can be put into their mouth.

2. Do male and female frogs consume different prey during the breeding season?

   H: The amount of prey (number and size) consumed by females is more than males.

Explanation: Male frogs stay around ponds in the breeding season and they spend most of the time calling to attract females.

METHODS

Study site

The study was conducted around the pond in front of Lambir Hills National Park headquarters. The estimated size of this pond is 0.03 ha and it is surrounded by *Cyperus*. This pond is rather shallow; the depth is about 1 meter (Fig 1).

Fig 1 Study site

Fig 2 *Rana erythraea*

Frog capturing and size measuring

Frogs were captured at the night time around 9.30 pm by netting and catching by hands. Twenty-five live frogs were caught from 1-6 August, 2004. Each frog was kept in the plastic containers until measured. Every individual was sexed and measured. The size dimension used was snout-vent length (SVL), or the length from tip of the snout to the posterior end of the back bone. That distance approximates to the length of trunk (head + body) of a frog.

Identification of stomach contents

The stomach contents were obtained by forcing the frogs to vomit using NaCl solutions. The main reason for using this method was to avoid dissection. However, dissection method was used if regurgitation failed (Fig 3). Frogs were injected water at the first step and waited for 5 minutes before injecting with 5 % NaCl solution. Prey were kept in vials for identification. Each prey species was identified and the body length measured (Fig 4)

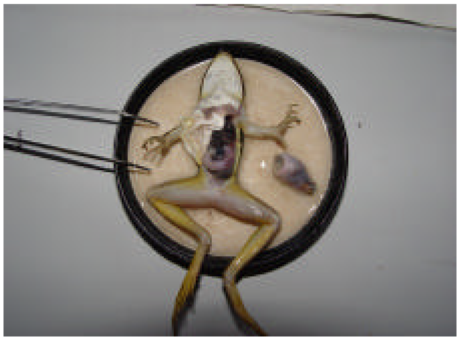

Fig 3 Dissection of frogs

Fig 4 Prey species identification

Data analysis

Two statistical analyses were used to test each hypothesis. Pearson correlation was chosen to investigate the relationship between snout-vent length (SVL) and prey size. T-test was used to test the differences between food consumption of male and female frogs.

RESULTS

Frogs capturing, measuring and sample size

Twenty-five frogs were caught, including 19 males and 6 females. The regurgitation method was successful in only 2 individuals. Fifteen frogs were dissected to identify the stomach contents. Two frogs regurgitated but no food was found in the stomachs.

Frog size ranged between 32.2-64.1mm (Table 1). Females were significantly bigger than males. The average sizes of males and females were 35.8±1.6mm. and 60.1±3.3mm, respectively.

Table 1 Body size of *R. erythraea*

	N	Mean	StDev	SE Mean	T-Value	P-Value	DF
SVL(M)	19	35.76	1.63	0.37	-17.5	<0.001	5
SVL(F)	6	60.08	3.28	1.3			
Total	25	41.6	10.8	2.2			

Food consumption

Eighty- three prey items were identified to family and order. Isopoda was the most common prey found (25.3%), follow by Hymenoptera (24.10%), Hemiptera and Odonata (13.25%), Coleoptera (10.84%), Orthoptera and Arachnida (3.61%), and Collembola (1.2%) (Fig 5). Ants (Hymenoptera) were more common in the diet of males than females.

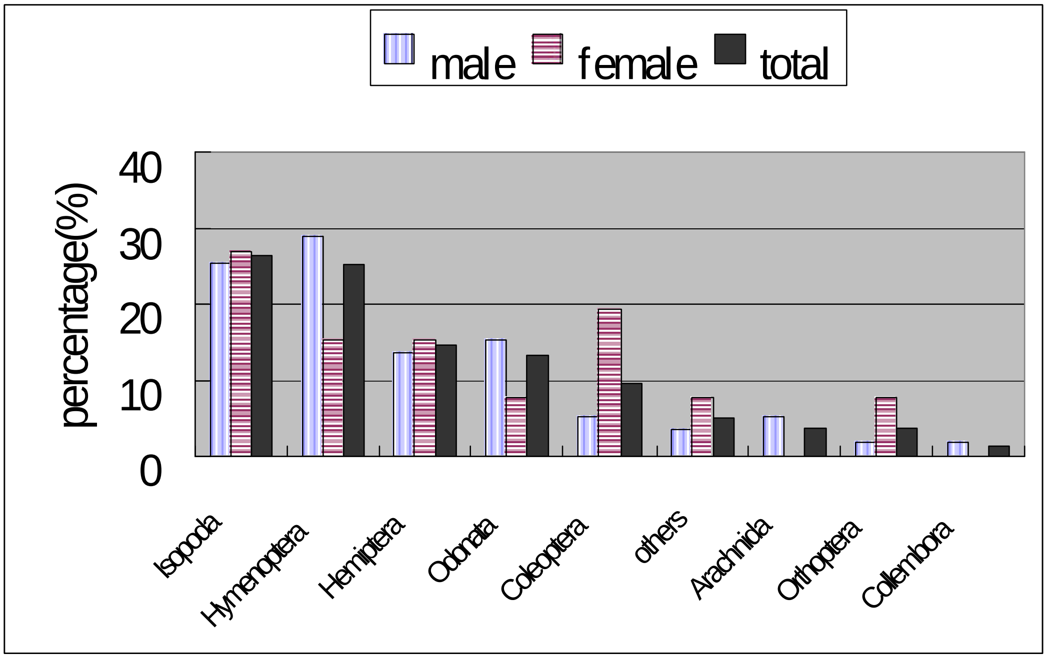

Fig 6 Prey items from the stomachs of *R. erythraea*

Relationship between size of male and female frogs and their preys
The mean prey size was 8.03±4.11 (Table 2), and varied from ants to grasshoppers. There was no significant difference in prey size between males and females (males 6.7±2.77 mm; females 12.88±5.15 mm).

Table 2 Prey size in *Rana erythraea*

	N	Mean	SD	SE Mean	T-Value	P-Value	DF
Prey size(M)	11	6.7	2.77	0.84	-2	0.184	2
Prey size (F)	3	12.88	5.15	3.0			
Total	14	8.03	4.11	1.1			

There was no significant difference in prey number between males and females (Table 3). Average prey number of males was 5.25 ± 3.25 individuals, while for females it was 5.2 ± 3.7 individuals.

Table 3 Prey number in *R. erythraea*

	N	Mean	StDev	SE Mean	T-Value	P-Value	DF
Male	12	5.25	3.25	0.94	0.03	0.980	6
Female	5	5.20	3.70	1.7			
Total	17	5.24	3.27	0.79			

DISCUSSION

Prey taxa in stomachs of frogs

Nine different prey species were found in frog stomachs. Six insect groups were identified (Fig 5). The major prey group was Isopoda in both male and female frogs. The results showed non significant different of food consumption between male and female frogs. Isopoda is a small order in tropical arthropods and play a major role in the decomposition of dead trees. Prey species were surveyed around the pond. Woodlice could be found in the top soil and under leaves. Green Paddy Frogs were shown to be generalists. As the rule, generalists tend to eat larger prey and to ingest fewer prey per meal (Inger and Stuebing 1977).

Food preferences between male and female

The results showed that males and females do not have different prey species or quantity of prey items, and the diet similarity between male and female was 72.2%. However, our hypothesis was that they have a different prey composition. This can be explained into two points. Firstly, the male frogs of *R. erythraea* do not call so often, so have opportunities to take whatever prey that pass by. Secondly, these frogs have special characteristic to forage. They usually sit and wait for the prey so take mostly the common smaller prey species. As a consequence, woodlice and ants were the most common items in their diet.

Frogs have succeeded in exploiting almost every imaginable nook and cranny of Borneo's forests, and use in one way or another essentially all the insects or other invertebrates found there (Inger and Stuebing 1997). Furthermore, the species making up this rich fauna divide and share resources of space and food, forming a critical part of the complex structure of the tropical rain forest.

ACKNOWLEDGEMENTS

First of all, we would like to thank CTFS-AA and Sarawak Forestry Corporation for arranging International Field Biology Course. As for this study, we would like to thank Dr. J-V Rasplus, the great entomologist and instructor, for his kindness and insect identification. Special thank to Dr. Rhett Harrison, course coordinator and the Japanese laboratory at Lambir Hills National Park for providing equipment.

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Host Specificity of *Asplenium*

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ABSTRACT

Epiphytic plants derive physical support from different phorophytes. The Bird's Nest Fern, *Asplenium* sp., was studied to determine if it had any preference for bark texture. Chi square test result gave a *p* value of 0.215, indicating no significant relationship. Data also show a significant relationship between the size of *Asplenium* and with both point of attachment (*p*=0.006) and dbh (*p*=0.003).

INTRODUCTION

A typical tropical rain forest is characteristically abundant in epiphytes. In wet tropical forests, such as South-east Asia's many lowland dipterocarp forests, as much as 35% of all vascular species found may be epiphytes, accounting for more than half the total number of individuals of vascular plants (Castro et al 1991).

Epiphytes are symbiotically related to other plants (phorophytes) to which they are rooted for structural support (Fatland 1996). Epiphytes in varying heights in the forest canopy live deprived from nutrients available in the ground. Thus, they have adapted to this environment by deriving nutrients from atmospheric sources and organic matter accumulated in canopy soils.

Epiphytic ferns are particularly successful epiphytes because they can withstand low supplies of water and light by having finely divided and thick root systems that provide a greater surface area for water and mineral acquisition. Furthermore, some epiphytic ferns arrange their leaves in a whorl forming a bowl that collects humus and is highly capable of retaining water and nutrients (Fatland 1996). An example of an epiphytic fern with this morphological adaptation is the *Asplenium.* It is a common epiphytic fern widespread in South-east Asia (Martin, et al. 2004; Ellwood, et al. 2002).

Asplenium, as in other epiphytic ferns, has very small spores that can easily be borne by wind. Dispersal of the spores into the forest canopy lands the spores on to trees with different morphologies. As in all of nature, the right conditions must be present to allow germination and subsequent growth processes. In this study, we investigate if *Asplenium* has a preference in bark texture, which may account for the presence of *Asplenium* on some trees and absence on others. We also attempt to determine other factors affecting the growth of *Asplenium* on its selected host tree.

MATERIALS AND METHODS

Study site

The study site was the 52 ha Forest Dynamics Plot at Lambir Hills National Park. The 500 x 1020 m plot covers a section of the national park's lowland dipterocarp forest. It receives a mean annual precipitation of approximately 2700 mm, with infrequent minor droughts and occasional severe droughts during El Niño events (Harrison, 2003). We randomly surveyed the area along the main trail, extending to both sides until reaching streams. We also inspected a second path perpendicularly traversing the plot midway. The area covered consisted of slopes, ridges, landslip areas and areas near streams.

Data collection

Fieldwork was performed over 3 days (July 31, August 2 and 6, 2004). All individuals of *Asplenium* were measured for the following: (1) size (classified into 3 classes: 0-20 cm, 21-50 cm and greater than 50 cm); (2) amount of light received (classified according to readings from a camera light-meter: 1- <4, 2- 4, 3- 4.5, 4- 5.6, 5- 8, 6- 11, 7- 16, 8- 22 and 9- >22); and (3) height of attachment, measured using a range-finder. Presence of moss and position of colonization was also recorded.

For the host trees, tag numbers were recorded and data on the species and dbh were obtained from the plot dataset. Bark texture of the host trees were scored as 1= smooth, 2=scaly (rough), 3=flaky (peeling off), 4=fine to medium fissured, 5=deeply fissured and 6=with spines or other projections. One hundred trees were randomly chosen and scored for bark texture to show the frequency of each bark texture.

Data analysis
Chi-square test was performed to test for bark texture preference. To test for significance in other variables, one-way ANOVA was used.

RESULTS

Bark texture and the frequency of Asplenium *plants*

Out of the 45 plants in the sample, *Asplenium* plants were found on each category of bark texture, except for category 6 (with spines). Most plants were found in the trees with a scaly bark and the least number of plants were found in trees with a smooth bark (Fig 1). From the random study of the abundance of trees with each bark type, it was revealed that there were more trees with scaly and flaky barks in the study area of the 52-ha plot where the study was carried out. Considering these facts there was no significant relationship between the bark texture and the frequency of *Asplenium* appearance in the plot (the chi square test showed a non-significant *p* value of 0.215).

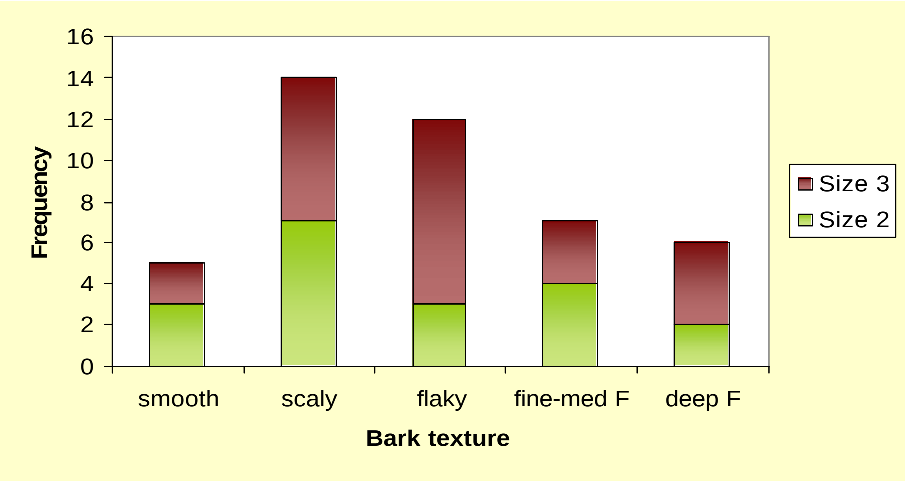

Fig 1 Frequency of *Asplenium* plants on each bark texture type

Host tree preference of Asplenium

The 45 *Asplenium* plants were distributed across 19 host families. Nine of the host individuals were dipterocarps, with a total of 13 *Asplenium* attached to them. Otherwise only Leguminosae had more than one individual with an epiphyte. Every other family had only one host individual tree with one, two or three *Asplenium* sp. plants on them (Table 1).

The distribution pattern of Asplenium *in the area of study*

The distribution pattern of *Asplenium* in the study area was plotted (Fig 2). The study was carried out in the area marked on the map. The trees with *Asplenium* are plotted in the map. The soil type and elevation is marked in the map. Majority of the *Asplenium* plants were found on trees growing in soils with clay over shale. The ferns were also located mostly on trees which were very close to lowland areas along streams, or at least within 20-30 meters from the streams. The number of *Asplenium* found in high elevations was lower than in the found in lower topographies. It was noted though that, even close to streams, the smaller and younger *Asplenium* plants were very rare in the plot.

Table 1 No of trees from each family hosting *Asplenium* ferns

Family	# *Asplenium* hosts
Anacardiaceae	1
Annonaceae	1
Apocynaceae	1
Burseraceae	1
Celastraceae	1
Dipterocarpaceae	9
Ebenaceae	1
Kiggelariaceae	1
Kiggelariaceae	1
Lauraceae	1
Leguminosae	2
Myristicaceae	1
Myrtaceae	1
Rubiaceae	1
Rutaceae	1
Sapindaceae	1
Sterculiaceae	1
Thymelaeaceae	1
Verbenaceae	1
Total	28

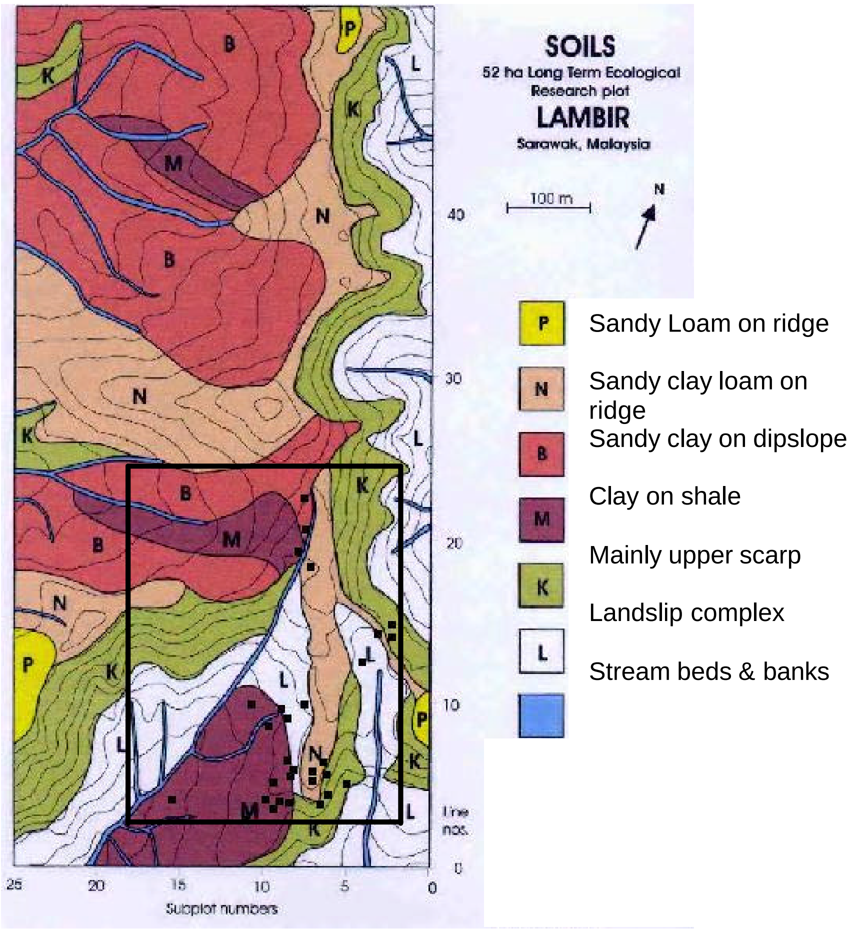

Fig 1 Distribution of *Asplenium* in the study area with the elevation and soil type

Factors affecting size of Asplenium

The size-class of the *Asplenium* plant was estimated and the distribution tested against the point of attachment and DBH of the host tree. The bark texture was plotted against the size of the *Asplenium* plants to establish any correlation or effect on the growth of *Asplenium* on a tree. The point of attachment had a positive correlation with the size of the plant. Larger *Asplenium* (>50cm) were found when they were attached to points more than 15m high. On the other hand the plants attached to the lower heights of the trees were much smaller. The value of *p* is 0.006, showing a significant relationship between the size of *Asplenium* with point of attachment (Fig 3).

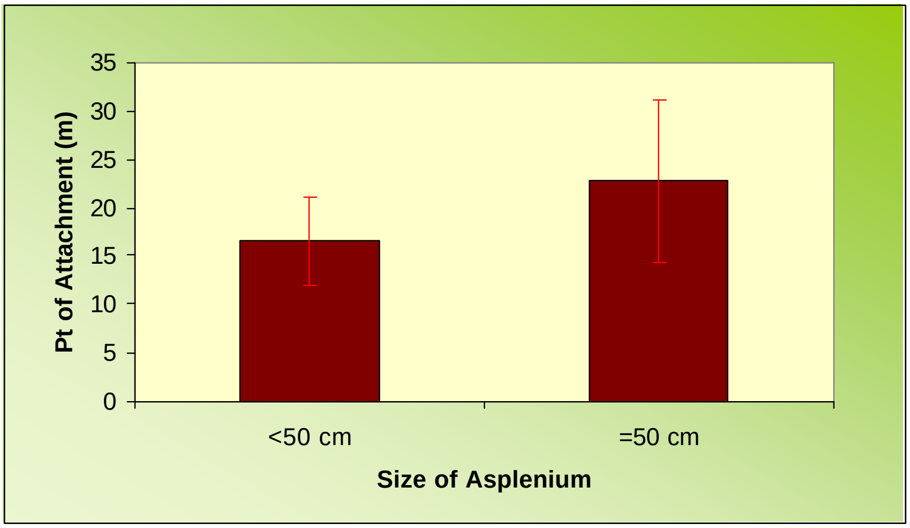

Fig 3 Height of attachment *Asplenium*

The size of the *Asplenium* fern increased with an increased DBH of the host tree. Chi Square test gives a *p* value of 0.003. Only smaller ferns were found in trees with smaller DBH. The range of host dbh for size class 2 is 151-823 cm and 322-1232 cm for size class 3 (Fig 4).

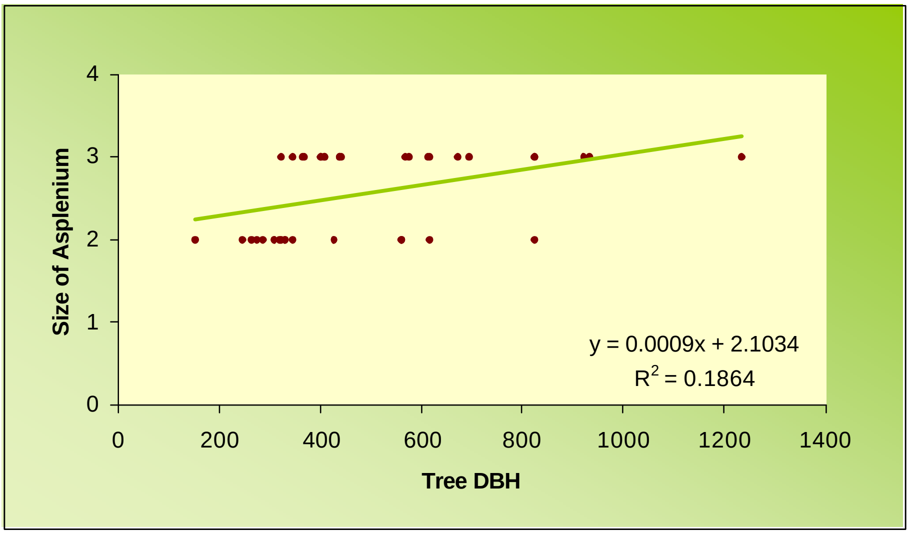

Fig 4 Size of *Asplenium* and host DBH

DISCUSSION

This study was carried out to determine if there is bark texture specificity in the *Asplenium* fern. *Asplenium*, being an epiphyte, does not have any parasitic tendencies toward the host plant. It only obtains physical support from it. Hence it would be very important for the fern to be able to obtain water and other nutrients while being attached to the host tree. This increases the plant's requirements for surviving in such a difficult environment (Fatland 1996). For this reason the *Asplenium* plant would profit if the host species supports the growth of the fern. As the fern is attached to the bark of the host tree, the bark is the most important surface that reacts with the fern. Consequently the hypothesis was formed that the bark texture of the host tree would be the most important factor for the establishment of the fern. The study revealed that the bark texture of the host tree did not affect the presence of *Asplenium.* According to the random study the majority of the trees in our study area in the 52 ha plot had either scaly or flaky barks. Naturally the number of flaky or scaly barks with *Asplenium* should be higher than any other bark type. The results indicated that there was no relationship between the abundance of *Asplenium* with the bark type of the host. Majority of the trees in the plot are dipterocarps (22.6% for trees with dbh>15cm). As a result dipterocarps constituted 31.7% of the *Asplenium* host trees.

Being an epiphyte the *Asplenium* fern occupies a severe micro-habitat. Hence the distribution of the *Asplenium* fern could be more affected by environmental factors, such as temperature, amount of light and humidity. Though the study was not carried out in the entire 52-ha plot, the area covered by the survey would enable us to suggest that *Asplenium* plants prefer areas that are low elevation and along streams, which would increase the humidity of the surrounding areas. Furthermore, especially for ferns, water is an important resource for the dispersal of gametes. Hence, as its reproductive process is involved, it is apparent that the plant will be very particular about being able to obtain this resource.

Larger *Asplenium* plants were found on trees with greater DBH. The average DBH was 50.7cm. This could be explained by the utilization by *Asplenium* of the greater surface area for attachment. This allows them more space to grow wider and larger. Water could also be more plentiful if the fern grows wider because it can catch more rain trickling down the tree's bark. The same explanation can be said for observing bigger ferns attached higher up on the host tree. Furthermore, the closer they get to the water source, the more water it can catch. Organic matter can also be collected from falling leaves, and still, the closer they are to the tree crown, the more leaves they collect. A noteworthy point is the low number of small *Asplenium* plants found. It can be inferred there is a decrease in the establishment of *Asplenium.* Perhaps population growth is affected by the infrequent minor and severe droughts brought about by recent El Niño events that the forests experienced (Harrison et al. 2002). A more thorough looking at this perceived trend is suggested. It is also recommended that studies on epiphytes up in the forest canopy be performed where the plants occur. Researchers can make use of Canopy Walkways or Canopy Cranes.

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Effects of height and wing area on seed dispersal in *Shorea* and *Dryobalanops*

Wendy Clement, K. Geetha Nayak & Endela Tipot

ABSTRACT

This study investigates the effects of height and wing area on seed dispersal of various species of Dipterocarpaceae. The hypothesis is that larger wing area will decrease the rate of fall such that the chances of dispersing further from the mother tree increase. We predict that increased wing area and increased height will confer a decrease in the rate of fall and increase the distance the seed lands from the mother tree. Our results show no correlation between height dropped and distance from the mother tree, however, a significant relationship among time and height dropped was found. We also found differences among the effectiveness of different wing arrangements. Although height does not significantly affect the dispersal distance of a seed, other abiotic factors not investigated in this study, such as wind, are suggested to play an important role in Dipterocarpaceae seed dispersal.

INTRODUCTION

In tropical rain forests, seeds are dispersed primarily by animal vectors and by wind. Few plant families are exclusively wind dispersed, however, one example is Dipterocarpaceae. In this family, wind dispersal is facilitated by the outgrowth of wings from the bottom of the seed.

Dipterocarpaceae is one of the most important timber families that dominate much of the undisturbed lowland tropical rainforest in Sarawak, Malaysia. The family consists of more than 250 species comprising nine genera. The external appendages of the seeds in Dipterocarpaceae differ among the genera. Although there are many differences in the construction of the seeds, many genera have five wings and the relative size of the wings vary from species to species. For example, many species of *Shorea* have three long wings and two short wings. However, in *Anisoptera*, *Dipterocarpus*, *Vatica*, *Cotylelobium* and *Hopea*; just the opposite arrangement is found where two of the wings are longer than the other three wings. The genus *Dryobalanops* displays five equally long wings (Ashton 1968). It has been hypothesized that seeds will disperse further if they fall slowly, from high altitude, or in the presence of strong winds. It might follow that greater wing area in combination with light weight would increase the time the seed remains in the air, improving the probability of the seed being dispersed further. The effect of wing construction in Dipterocarpaceae on the rate of fall and the distance the seed is dispersed from the tree has not been investigated.

Although much of the lowland tropical rainforest in Malaysia is dominated by Dipterocarpaceae, few studies have considered the seed dispersal of these plants. This study aims to quantify differences among seeds of different wing area and arrangement among Dipterocarpaceae species. We tested the effect of height and wing area on *Dryobalanops aromatica*, *Shorea curtisii*, *Shorea parviflora*, and *Shorea* sp. We assumed that the longer the seed remains in the air, the greater the chance the seed will be dispersed further from the mother tree. Our hypothesis is that increased wing number and increased wing area will allow the seed to remain in the air longer, thus increasing the distance the seed will fall from the mother tree.

MATERIALS AND METHODS

This study was conducted with seeds collected from *Dryobalanops aromatica*, *Shorea curtisii*, *Shorea parviflora*, and *Shorea* sp. *Dryobalanops aromatica* is widely distributed in Sarawak but is commonly found on ridges and hilly areas. It produces large wind-dispersed, one-seeded fruits with five equally long wings (Itoh *et al*. 2003). In contrast, *Shorea* species (*S. curtisii* and *S. parviflora*) are common in low altitude especially in northern part of Sarawak and produce three long wings and two short wings.

To prepare for our experiment we first collected fresh or nearly fresh seeds from Dipterocarpaceae trees found along the trails of Lambir Hills National Park. We collected ten seeds from three individuals of *D. aromatica*, and ten seeds from one individual each of *S. curtisii*, *S. parviflora*, and *Shorea* sp. Seeds were either collected from the ground or removed directly from the tree. The following measurements were made on each individual seed; weight with wings (g), weight without wings (g), number of wings, and total area of wings (mm^2). Each seed was given a unique number to distinguish them during the experiment. The seed dropping experiment was conducted on August 6, 2004 at the crane site at the Lambir Hills National Park. All individuals were dropped from 20 m, 35 m, and 60 m. The fall time, or the time the seed took to reach the ground, was recorded as well as the distance the seed landed from the crane (which represents the mother tree). We performed manipulations on all three individuals of *D. aromatica* by removing two of the five wings and dropping these seeds at 60 m. We again recorded the fall time and distance the seed landed from the crane. Also at 60 m, we removed all of the wings from all seeds used in the experiment and recorded the fall time. These data will be used in conjunction with the fall time of seeds with all wings to better compare across species.

To analyze our data we compiled descriptive statistics of the initial measurements of the seeds (weight, area, etc). We then conducted a series of correlations and statistical analyses to compare the effect of height on fall time and distance from mother tree, as well as compare the differences among species. All statistical analyses were performed with Minitab Release 14.

RESULTS

Variation in weight, wing area, and wing loading was apparent among all species (Fig 1, 2, and 3), with a large amount of variation among different individuals of the same species, in *D. aromatica*.

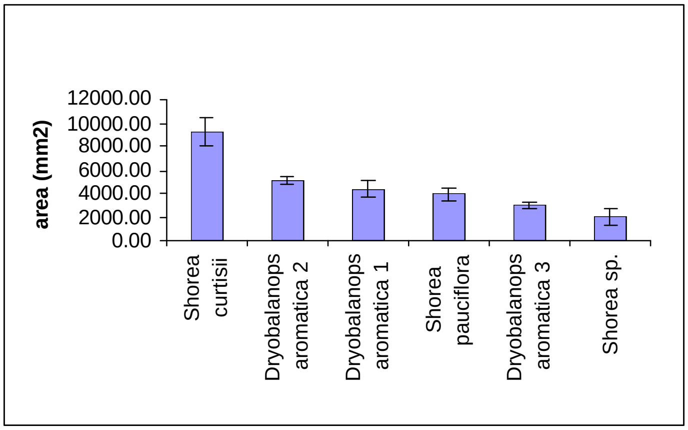

Fig 1 Variation in mean area across species

Effect of height on distance and fall time

To test the effect of height on the fall time and distance from the mother tree for each set of seeds, we used Pearson's correlation test (Table 1). We found no significant relationship between height and distance except for *S. parviflora*. However, there was significant positive correlation for the height and fall time in all species.

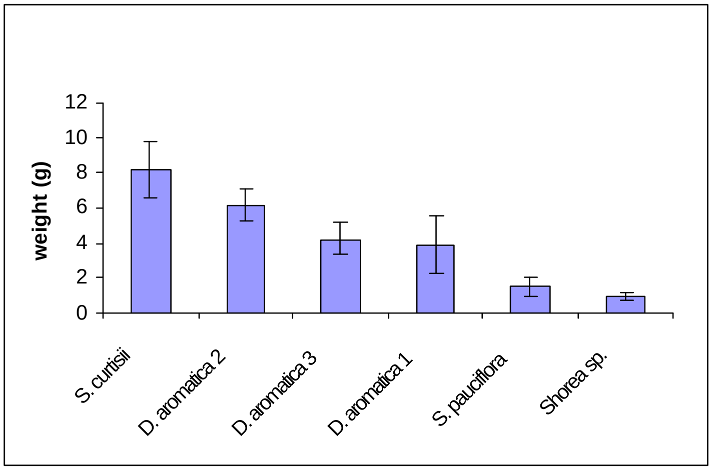

Fig 2 Variation in weight across species

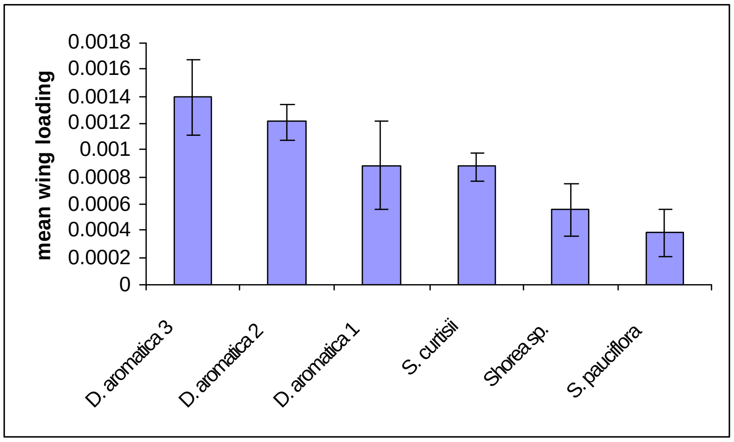

Fig 3 Variation in wing loading across species

Table 1 Correlations between height with fall time and distance

	Time		Distance	
	Pearson's correlation	p-value	Pearson's correlations	p-value
*Dryobalanops aromatica*1	0.538	0.002	0.133	0.499
*Dryobalanops aromatica*2	0.893	0.000	0.014	0.944
*Dryobalanops aromatica*3	0.713	0.000	0.306	0.100
Shorea curtisii	0.909	0.000	0.116	0.541
Shorea parviflora	0.864	0.000	0.572	0.001
Shorea sp.	0.790	0.790	0.458	0.019

Comparison of fall time with wings and without wings across species

We compared the fall time in species with and without wings (Fig 2). The result clearly shows the wing removal reduces the fall time in all species we studied. Moreover the seeds which dropped without wings cracked as it fell on the ground. So, the wings not only aid in reducing the fall time but also protect the seed.

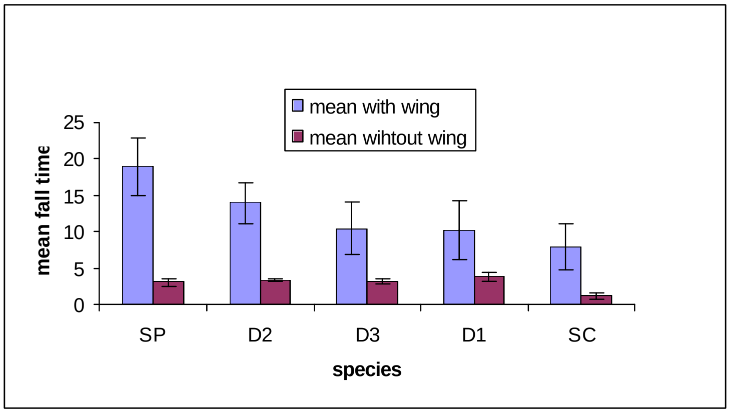

Fig 4 Comparison of mean fall time with and without wings in all species

Wing loading and rate of fall

Another factor which may influence the fall time is the wing loading of the seed. We plotted the wing loading against the rate of fall (this value is extracted from regression line for height and time which is expressed in m/s). The rate of fall was lowest in *Dryobalanops* 1, and *Shorea curtisii* followed by *Dryobalanops* 3. The fall time in *Dryobalanops* 2 and *Shorea parviflora* was almost the same even though there was difference in the wing loading.

DISCUSSION

The height and distance of seed fall are only one a combination of the many factors which affect seed dispersal of Dipterocarpaceae. There was no significant relation between the height and distance of seed fall in our study, which may be due to other confounding variables such as wind. Other factors not measured in this study, such as the location of the trees such on ridges and slopes (Itoh et. al *unpublished data*) must also be considered to better explore this relationship.

The height and fall time was highly correlated, as expected, which indicates that taller trees have a higher probability of the seed remaining in the air. The time the seed spends floating in the air is critical, for the longer is it airborne, the more chance there will be for wind to pick up the seed and disperse it further. This of course also needs to be considered in conjunction with wind speed and direction. The study on recruitment of *D. aromatica* seeds by Itoh et. al (*unpublished data*) shows that the distance the seed is dispersed from the mother tree is relatively short (approx. 20-40m). As a result, the overcrowding of seed under the mother tree is a common phenomenon among most Dipterocarpaceae species.

When we compared the fall time of the seed from the wing removal experiment we found that the wings aid in increasing the fall time as well as protect the seed from damage during its fall. An ambiguous result was the relationship between wing loading and fall time. The five equal winged *D. aromatica* 1 and three large two short winged *Shorea* had somewhat similar wing loading and rate of fall suggesting other factors may also be responsible for selecting different wing designs. Many of the planned manipulations to test the effect of wing removal of the seed were not performed because many of the seeds were destroyed upon impact. However, performing these manipulations may give insight into the tradeoffs between various wing constructions that this study was only able to suggest.

CONCLUSIONS

Seed dispersal in Dipterocarpaceae is a combination of various factors such as tree height, topography, wind speed, and direction. Wings obviously aid the process, but the presence of variation in size and number of wings in regard to seed dispersal needs to be studied further.

Our original hypothesis was that increased wing area would allow the seed to remain in the air longer, thus increasing the distance the seed will fall from the mother tree. Because we found no correlation between distance and height the seed was dropped, but a strong significant correlation between height and fall time in all species used in the study, we conclude that other static abiotic factors not quantified in this study are extremely important in seed dispersal of *Dryobalanops* and *Shorea*. Experiments simulating various abiotic conditions are needed to explore what factors are most important in dispersing seeds far from the mother tree. Although *Dryobalanops* and *Shorea* may rely on chance wind gusts to disperse their seeds, it is evident from the present composition of lowland dipterocarp forest that these species have been very successful using wind as a seed dispersal mechanism.

ACKNOWLEDGEMENTS

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Varying leaf morphologies (juvenile and adult) in *Scaphium macropodium* (Miq.) Beumee ex heyne (Malvaceae)

Raffae Ahmad, Yen Kheng Chua, Jeanmaire Molina & Ling Tseng

ABSTRACT

Scaphium macropodum is a canopy tree that exhibits different leaf forms throughout its life history. As a very young sapling, it has entire leaves, that are gradually replaced by leaf forms that increase in lobe number and surface area as the tree matures. Upon reaching the canopy, leaves become smaller and entire again. We tested investigated the evolutionary importance of these adaptations. All lobed leaves had significantly greater surface area than adult leaves, possibly adaptation to the diminished light levels in the understorey. Stomata number increased from understorey to canopy. Water flow rates from leaf surfaces were not significantly different among the various lobed forms, although confounding factors, such as leaf surface area. The evolution of larger lobed leaves in juvenile *S. macropodum* is an important adaptation to the light-deprived environment of the understorey, as it maximizes light capture and allows light transmittance to the lower leaves.

INTRODUCTION

Generally, canopy and emergent tree species have varying leaf morphologies at different stages of their life histories. Light availability is an important resource in the tropical rainforest that may have strongly influenced the evolution of these different leaf forms. Understorey saplings tend to have larger leaves, but as the trees mature, especially when they reach the sun-scorched canopy layer, new leaves tend to be smaller. This smaller leaf size may be an adaptation to the intense light exposure in the canopy, and allows the leaves to dissipate heat more rapidly. The juvenile leaf form, on the other hand, due to the diminished light levels in the understorey of closed canopies (0.2-6.5% of incidence light, Montgomery et al. 1992), is often larger to increase the light absorptive surface area of the leaf for photosynthesis. Understorey plants have a highly dynamic light environment, receiving a high proportion of light in the form of sun flecks (Chazdon et al. 1991), unlike the canopy layer, which receives a continuous and more or less steady dose of sunlight throughout the day. Hence, the forest microclimate changes vertically, which influences crown morphology as well. A young tree may be monopodial, but upon reaching the canopy, it gradually changes into a sympodial architecture**.**

Scaphium is a genus of large deciduous trees of the canopy and emergent strata in Malaysian rainforests. It has wind-dispersed fruits with a boat-shaped wing derived from a dehiscing follicle (Ashton 1998). It is easily identifiable due to its unique leaf shapes and crown forms (Yamada and Suzuki 1996). *Scaphium macropodum* has palmately-lobed juvenile leaves and entire, relatively small adult leaves. It is an orthotropic species (having a 3-dimensional leaf arrangement, as opposed to plagiotropic, i.e. planar arrangement) and among understorey saplings this form has larger leaves and longer petioles than plagiotropic species (King 1999).

In this study we propose three hypotheses concerning the evolution of the two leaf forms in *S. macropodum*. The immature form is often lobed, varying from 2 to as many as 7, but a few may also be entire. Lobing presumably increases the surface area of the leaf to capture more sunflecks in the understorey. A 3-lobed leaf may encompass the area of 3 adult leaves, and this intuitively reduces the energetic cost of producing additional petioles. Moreover, lobing permits light transmittance to the lower leaf layers. As there is decreased light availability in the understorey, we surmise that an increased leaf surface area would have greater stomatal count, which is positively correlated with photosynthetic efficiency. There is perhaps a need for these shade leaves to evolve a more efficient photosynthetic machinery to compensate for the light deficit, and this we intend to measure by stomatal count. We also speculate that lobing equips the leaf with additional drip tips that may expedite the draining process and consequently reduce epiphyll or fungal growth that can hamper photosynthesis.

METHODS

Study site: Our samples were collected from a permanent plot of 52 ha (1040m x 500m) established at Lambir Hills National Park (4o12'N,114o00'E). The plot was divided into 1300 subquadrats of 20m x 20m and all trees equal to or larger than 1cm DBH (diameter at barest height) had been tagged with an aluminium tag, identified, measured and mapped. To aid us in getting to the right species, the data set from the plot was used to locate adult and juvenile *Scaphium macropodum* on the plot.

Field collection: We collected two leaves each from 21 young trees and 3 adult trees, with the help of a tree climber. Heights of trees and total number of leaves on young saplings were noted. If leaves on a sapling differed in the number of lobes, the proportion of each of these was also noted.

Measurements: The surface areas of both the juvenile and adult leaves were measured by tracing the leaf margins on graph papers. For stomatal counts, four 1 cm x 1 cm sections were randomly chosen from each lamina to obtain a mean stomatal density for a particular leaf. We applied transparent nail polish on these sections to obtain a clear imprint of the stomata. The imprint was then carefully peeled off the lamina for examination under a light microscope. Stomata within the microscope's field of view were counted with a hand tally counter.

Drainage efficiency of each leaf was measured by taking note of the time it took to drain 500 ml of water over its surface. Each leaf was attached to a tripod at a fixed angle, pointing down, and water was allowed to drip from a mineral water bottle with a punctured base at a constant height. The time taken for a leaf to complete drainage is determined at the point when no further water droplets are formed at the drip tips.

Analysis: We used ANOVA test and LSD comparison to compare stomata number, surface area and draining efficiency in different lobed leaves.

RESULTS

Stomata number: According to ANOVA and LSD comparison, there was a significant difference among the 3 groups ($p < 0.001$)(Fig 1). The first group comprised the adult leaves, and they had the highest stomata number. The second group included the 7-lobed juvenile leaves. The third group was composed of the 5-lobed, 3-lobed and entire juvenile leaves, and they had the lowest stomata number. This suggests that stomata number increases with tree age.

Surface area: In juvenile leaves, the surface area was also positively correlated with the number of lobes ($p < 0.001$)(Fig 2). However, the surface area of the adult leaves was not significantly different from that of the entire juvenile leaves.

Draining efficiency: Flow rates among the different juvenile leaf forms were not significantly different ($p = 0.103$)(Fig 3). The average time was 119 seconds per leaf.

Juvenile leaf form: The number of lobes was positively correlated with tree height. Treelets with heights less than 2 m would have leaves with 3 lobes or less, whereas at heights greater than 2 m leaf forms would have greater than 3 lobes. ANOVA and LSD comparison were used for this analysis ($p < 0.001$)(Fig 4).

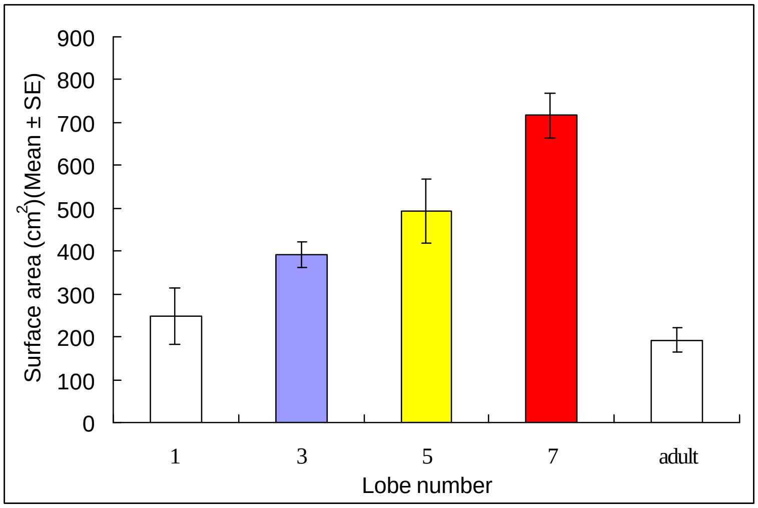

Fig 1 Stomata numbers in different juvenile leaf forms

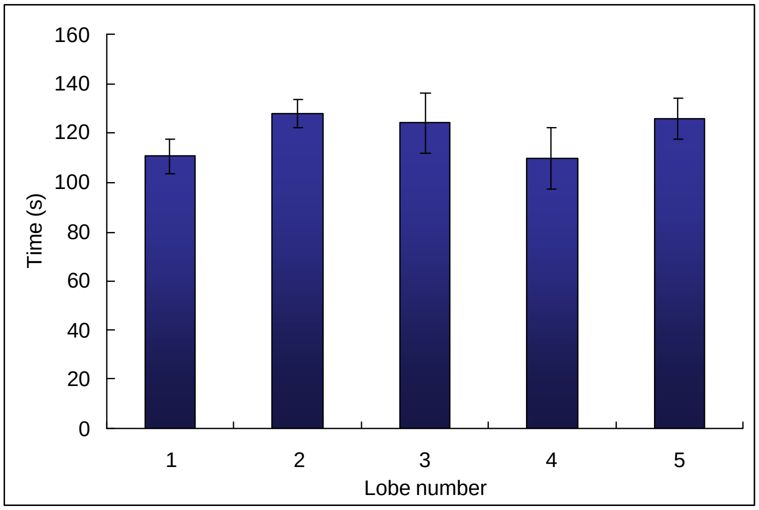

Fig 2 Surface area in different juvenile leaf forms

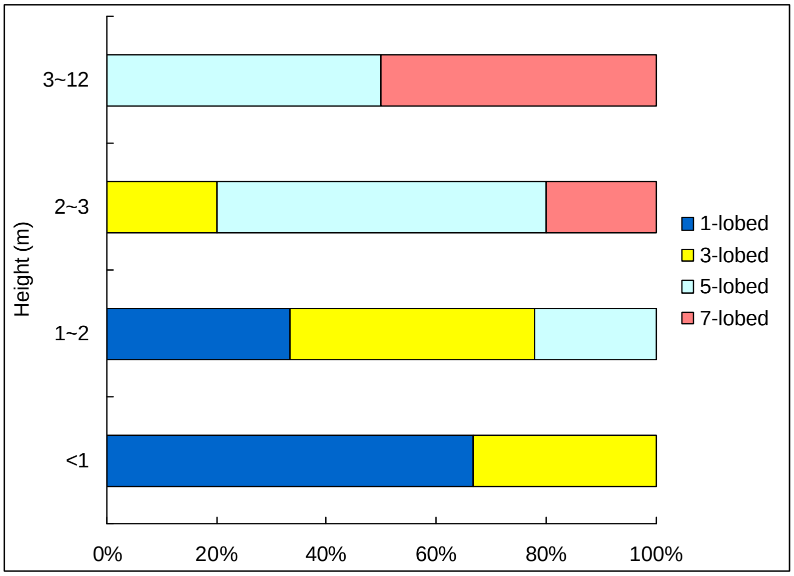

Fig 3 Flow rates among the different juvenile leaf forms

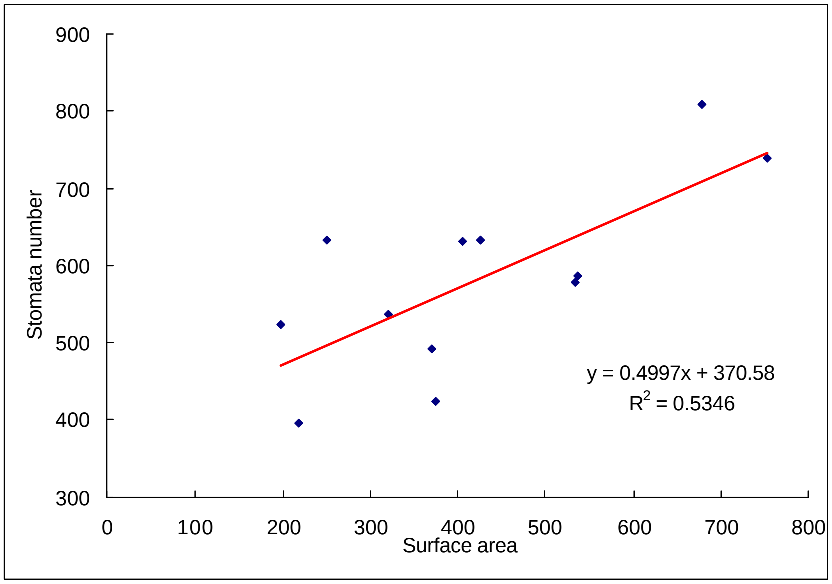

Fig 4 Number of leave lobes against tree height

DISCUSSION

Contrary to our prediction, this study has demonstrated that stomatal count is inversely proportional to the number of lobes (Fig 1), with the adult leaf having the greatest number of stomata, hence the greatest photosynthetic rate. The juvenile forms (1-, 3-, 5- and 7-lobed) had significantly fewer stomata than adults, but the 1-, 3- and 5-lobed leaves did not significantly differ from each other. Stomata number increases from the youngest to the most mature leaves.

Sack et al. (2003) asserted that juvenile plants in shaded understoreys in Southern Spain have moderate or low stomatal densities and this was what we observed in juvenile *Scaphium* leaves. However, despite lower stomatal counts, Poorter et al. (1995) have shown that shade species in a Costa Rican tropical forest, have higher absorption in lower light levels. Lee et al. (1990) alleged that shade-adapted taxa had significantly lower specific leaf weights, synthesized less chlorophyll per unit area and used less chlorophyll for capturing the same quanta for photosynthesis. A lower specific leaf weight allows the plant to allocate energy for the efficient production of surface for quantum capture. So if we were to compute for the specific leaf weight of the juvenile leaves of *S. macropodum,* it is highly likely that we will obtain a lower value compared to the leaves of a sun-adapted adults. The decreased chlorophyll production in shade leaves, as shown by Lee et al. (1990), could perhaps explain the lower stomatal count in the young leaves. Küppers et al. (1996) have shown that the utilization efficiency of light flecks by leaves increases with decreasing duration of light flecks. Moreover, shade leaves maintain a higher photosynthetic induction state over longer periods in dim light than sun leaves. This means that shade leaves can still activate their photosynthetic machinery even in diminished or fluctuating light levels, but they may not be performing as much photosynthesis as the sun-exposed leaves.

Clark et al. (1993) has also shown that short-term height and diameter increment are correlated with PAR (photosynthetic active radiation). This may explain why *Scaphium* saplings appear to be etiolated. But as light availability is augmented upward, overall plant biomass also increases. Sack et al. (2003) have also demonstrated that shade-tolerant juvenile trees of tropical rainforests allocate more belowground than do light-demanders, which increases capture of soil resources. Hence, it is probable that *Scaphium* saplings have greater root mass allocation to compensate for the photosynthesis deficiency in the understorey, but this is highly speculative, and warrants testing. Yamada et al. (1997) have studied the distribution of the three *Scaphium* species in the 52-ha plot of Lambir, and observed that *S. macropodum* is a habitat specialist that is associated with sites lower than 180 m altitude, where clay rich soils predominate.

Increased number of lobes in juvenile leaf was demonstrated to be positively correlated with surface area (Fig 2). Mature leaves had the lowest surface area, followed by the entire juvenile form, and then the lobed immature forms, with the 7-lobed leaf having the greatest dimensions. Adult leaves were not significantly different from the entire juvenile form, but the lobed forms tested (3-, 5- and 7-lobed) were all statistically different with respect to surface area. Montgomery et al (2002) had shown that in tropical tree seedlings, there is a positive relationship between light availability and growth, with total biomass increasing as light levels increased. Hence in *S. macropodum* the number of lobes and inevitably surface area increase as the sapling grows taller since light levels also increase.

We also found that stomatal number is not correlated with surface area, but considering only juvenile leaves (Fig 3), there is a positive relationship between number of lobes and stomatal count. Among juveniles, the 7-lobed leaves have greatest stomatal count, but maximal count is attained in the entire canopy leaves, where light levels are optimal for photosynthesis.

In the understorey, there is minimal exposure to sun and wind, compared to the canopy stratum. Hence the understorey is more humid. Given this, we tested our hypothesis that lobed leaves may also equip the leaf with additional drip tips that facilitate rapid runoff to preclude epiphyll and fungal growth. However, based on our results, there was no correlation between lobing and flow rate (Fig 4), and it may even be true that the smaller entire adult leaves drain water faster, as dictated by physical laws, and this we failed to consider. It is possible that there may be an underlying trend for this experiment, but due to our small sample size and failure to control the area of the different lobed leaves tested, this pattern did not emerge.

We also observed that the number of lobes was positively correlated with the height of the sapling or treelet (Fig 5). The leaf could not be expanded indefinitely because the weight of petiole per blade increases with leaf size (Yamada 1998). Below 2 m, leaves tended to be entire, and as the tree matures, this form is gradually replaced by the lobed forms, with the subcanopy treelets attaining the greatest number of lobes (i.e. 7). Hence, the 7-lobed form is the last juvenile leaf form. Beyond the subcanopy, leaf form reverts to an entire and smaller morphology. King et al. (1991) had shown that in a wet forest in Costa Rica, tree species that are more or less shade-tolerant increased biomass allocation to leaves when light is suppressed. Additionally, he found that two species with orthotropic branching had lower relative growth rates in shade, but had the highest leaf allocation. This may explain the bigger leaves of the immature *S. macropodum*, which is shade-tolerant.

In conclusion, lobing in *S. macropodum* is an adaptation to the reduced light availability in the understorey. It amplifies the leaf surface area for maximal light capture, and at the same time, allows light penetration to the lower tiers of leaves. Yamada (1998) found that in LHNP, light intensity increased gradually upward until 12 m, and remains nearly constant between 12 to 18 m. He believed that *S. macropodum* is adapted to this light environment. The monoaxial tree is lower than 12 m could thus increase the amount of light with vertical elongation, and the branched trees higher than 12 m could increase it by means of lateral extension of crown area (Yamada 1998).

ACKNOWLEDGMENTS

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Independent projects

Characterizing differences among closely related dioecious fig species

Wendy Clement & Ami Ushihara

ABSTRACT

With approximately 750 species, figs represent a diverse genus of plants that are found in the tropics throughout the world. Although figs have been well studied as a result of their unique pollination system, the mechanism driving their success in speciation remains unknown. This study focuses on three species pairs and one species complex to identify morphological characters that differ between them. Male and female reproductive as well as vegetative characters were analyzed. We found many significant differences between closely related species, but were not able to identify a common suite of characters in the four groups studied. However, consistent differences in seed size were observed suggesting that speciation might be due to characters other than those involved in the fig-fig wasp mutualism.

INTRODUCTION

The figs of Lambir Hills are a remarkably diverse group of plants representing more than half of the Bornean fig flora (Soepadmo and Saw 1999). To date, 75 species and six varieties have been documented in this area (Harrison and Shanahan *in press*). Figs are an essential part of the forest and are intricately linked to many of its organisms due to the fig's seed dispersal mechanisms and pollination syndrome. Figs are an important food source for many vertebrate frugivores as figs flower and fruit asynchronously throughout the year providing a reliable food source. In turn, the figs depend on these arboreal and terrestrial frugivores, such as birds, bats, squirrels, primates, and wild boars to consume and subsequently disperse the seeds. The various growth forms of figs and size of the fig fruit foster this connection with a wide range of fruigivores (Harrison and Shanahan *in press*).

Fig pollination has been documented as a well known example of an obligate mutualism. Fig flowers are embedded within an enclosed inflorescence known as a syconium which can only be accessed by highly specific fig wasp pollinators. Figs are represented by both monoecious and dioecious species. In dioecious figs, female trees have inflorescences with long, thin-styled flowers which are not accessible for fig wasps to lay eggs. Instead, the female wasp pollinates the flowers. However, male trees bear inflorescences with short-styled 'female' flowers (gall flowers) in which fig wasps can oviposit, and so these figs are dedicated to the reproduction of the fig wasp. As the new generation of fig wasps emerge, the male flowers become receptive and the emerging fig wasps carry pollen with them to the next fig.

With over 750 species of figs, a simple yet complex question is what is responsible for the success of speciation in this genus? One hypothesis concerns the obligate mutualism and species-specific relationship between the fig and the fig wasp. However, recent evidence suggests that there may in fact be more than one pollinator specific to one fig species. This would suggest that the fig wasps can be preadapted to changes in fig biology, and so reproductive characters may not be responsible for speciation. There are many non-pollinating wasps also associated with the fig, and its evolutionary trajectory maybe to deter occupation from non-pollinating wasps. It is also possible that characters independent of the mutualism or reproductive biology may be more prominent or subject to natural selection in a changing environment. After all, the figs do exhibit a plethora of growth forms ranging from small climbers to trees to hemiepiphytes and stranglers, while reproductive structures remain relatively conserved among species.

The goal of this study is to characterize differences among closely related species of figs in Lambir Hills. Our aim is not to determine what characters are driving speciation, but simply to explore the degree to which morphological characters vary among closely related figs. We have chosen three species pairs and one species complex of figs to investigate. This study will focus on quantifying differences in male and female reproductive characters as well as vegetative characters.

METHODS

Selection of species pairs

Three species pairs and one group of species were chosen for this study (Table 1). From the subgenus Sycomorus section Sycocarpus we chose two species pairs (*F. schwarzii* and *F. lepicarpa*, and *F. cereicarpa* and *F. francisci*) and one species complex (*F. geocharis*, *F. beccarii, F. megaleia, F. stolonifera, F. treubii, F. uncinata*, and *F. lambirensis*; Berg 2004). From the subgenus Synoecia section Kalosyce we chose one species pair (*F. punctata* and *F. aurantiacea*; Berg 2003).

Study site and fig collection

Lambir Hills National Park is located 30 km south of the town of Miri in northern Sarawak, Malaysia. This site is approximately 6500 ha and is a relatively small island of primary lowland dipterocarp forest surrounded by secondary forest, oil palm plantations and shifting cultivation.

We collected male and female figs and leaves from thirteen species. Collections were made from the canopy walkway, trails, secondary forest, and disturbed forest in or near the national park, as well as the 52 ha long-term Ecological Dynamics Plot in Lambir Hills (Table 1).

Table 1. List of the species of fig leaves and fruits collected and location collected.

	Leaves	Male figs	Female Figs	Location
Section Sycocarpus				
Ficus schwarzii	yes	yes	yes	disturbed forest
Ficus lepicarpa	yes	yes	no	secondary forest
Section Sycocarpus				
Ficus cereicarpa	yes	yes	yes	disturbed forest
Ficus francisci	yes	yes	no	disturbed forest
Section Kalosyce				
Ficus punctata	yes	yes	yes	national park trai
Ficus aurantiacea	yes	no	yes	canopy walkway
Section Sycocarpus (geocarpic figs)				
Ficus lambirensis	yes	yes	yes	52ha plot
Ficus geocharis	yes	yes	yes	national park trai
Ficus beccarii	yes	yes	yes	national park trai
Ficus uncinata	yes	yes	no	national park trai
Ficus megaleia	yes	no	yes	secondary forest
Ficus stolonifera	yes	no	yes	52ha plot
Ficus treubii	yes	yes	yes	secondary forest

Measurements

To compare closely related species of figs, we chose to measure the following characters; (male characters) gall length, style length, number of galls per syconium, length and width of syconium, (female characters) seed length, style length, number of seeds, length and width of syconium, (vegetative characters) leaf length, leaf width, petiole length, stipule length, and twig diameter.

Gall and flower size and style length were measured using a dissecting microscope and an ocular ruler. From both a male and female fig of one species, 30 galls or seeds were measured, and fifteen styles were measured. To count the number of seeds or galls in a syconium, we weighed the entire fig and the part of the fig from which we counted the flowers. Three figs per species were used to count the number of galls or seeds. This data was used to extrapolate the total number of galls or flowers in the syconium. The length and width of the syconium, as well as the vegetative characters were measured using callipers. These measurements were made on as many leaves and figs as were available to us.

Analysis

Statistical tests including two-tailed t-test (for species pairs) and ANOVA (for species complex) were used to test for significant differences in each character measured. Three principal components analyses were performed to understand how well the characters measured were able to separate the species complexes. These analyses grouped 1) male reproductive characters, 2) female reproductive characters, and 3) vegetative characters. All statistical analyses were performed with Minitab Release 14 and Systat vs 9.

RESULTS

Male reproductive characters

Male reproductive characters were not able to separate the various species complexes analyzed in the PCA analysis (Fig 1). All species with the exception of *F. cereicarpa* were grouped together. However, there are many significant differences among individual characters between the various species groups. Style length of the male flowers was significantly different in all species groups except *F. schwarzii* and *F. lepicarpa*. The other characters differed in their ability to significantly differentiate the species from one another (Table 2).

Female reproductive characters

Female reproductive characters were able to separate *F. punctata* and *F. aurantiacea* from the geocarpic figs (Fig 2). However, we were not able to analyze all species pairs because data was not available for *F. lepicarpa* and *F. francisci* female figs. When the characters were analyzed separately, we found that seed size and length of syconium significantly differentiates the geocarpic figs, whereas style length significantly differentiates *F. punctata* and *F. aurantiacea* (Table 3). We were not able to test all comparisons between *F. punctata* and *F. aurantiacea* because we did not have enough samples.

Vegetative characters

Vegetative characters were able to separate *F. punctata* and *F. aurantiacea*, but were unable to differentiate any other species pair from one another (Fig 3). When analyzed individually, the characters measured significantly differentiate all species groups except for the geocarpic figs (Table 4). Within the geocarpic figs, only *F. megaleia* was consistently different from the rest of the group according to these characters.

Table 2 Results of variation among male reproductive characters. Reported are the mean and standard deviation for all measurements made on male reproductive characters. A t-test was use to test for significance among the pairs, and a p-value less than 0.05 is considered significant. ANOVA was used to test for significant differences among the geocarpic figs. Instead of p-values, groups of species that were not significantly different from one another were assigned the same letter. Analyses were not performed on species with too few samples to compare or where figs were not available (n/a).

	Gall Size			Style length			No. of galls per syconium			Length of syconium			Width of syconium		
	mean	st. dev	p-value	mean	st. dev	p-value	mean	st. dev	p-value	mean	st. dev	p-value	mean	st. dev	p-value
Section Sycocarpus															
Ficus schwarzii	1.50	0.22	0.000	0.46	0.03	0.479	592.60	64.84	0.399	21.45	1.37	0.173	25.55	1.13	0.004
Ficus lepicarpa	1.22	0.10		0.45	0.04		2331.50	1781.20		20.25	1.28		22.75	2.25	
Section Sycocarpus															
Ficus cereicarpa	2.12	0.11	0.287	0.68	0.05	0.000	1881.86	134.70	0.024	46.00	9.01	0.001	59.33	7.94	0.001
Ficus francisci	2.09	0.14		0.57	0.05		579.35	319.57		22.38	1.41		24.63	1.77	
Section Kalosyce															
Ficus punctata	1.70	0.10	n/a	0.90	0.07	n/a	n/a	n/a	n/a	68.60	4.83	n/a	54.80	5.54	n/a
Ficus aurantiace	n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a	
Section Sycocarpus (geocarpic figs)															
Ficus lambirensis	1.71	0.10	b	0.38	0.03	a	765.30	256.10	a	24.40	2.19	ab	29.40	4.45	ab
Ficus geocharis	1.27	0.10	a	0.46	0.04	b	1289.18	131.94	b	20.13	1.46	abc	24.25	2.60	abc
Ficus beccarii	1.35	0.24	ac	0.42	0.04	c	1707.00	384.81	b	20.83	3.43	ab	26.50	2.43	a
Ficus uncinata	1.60	0.04	n/a	0.45	0.03	n/a	1599.22	n/a	n/a	24.00	n/a	n/a	39.00	n/a	n/a
Ficus megaleia	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ficus stolonifera	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ficus treubii	1.41	0.12	c	n/a	n/a		366.92	68.43	a	15.44	1.33	bc	15.22	0.67	bc

Table 3 Results of variation among female reproductive characters. Reported are the mean and standard deviation for all measurements made on male reproductive characters. A t-test was use to test for significance among the pairs, and a p-value less than 0.05 is considered significant. ANOVA was used to test for significant differences among the geocarpic figs. Instead of p-values, groups of species that were not significantly different from one another were assigned the same letter. Analyses were not performed on species with too few samples to compare or where figs were not available (n/a).

	Seed size			Style length			Non.			Length of syconium			Width of syconium		
	mean	st. dev	p-value	mean	st. dev	p-value	mean	st. dev	p-value	mean	st. dev	p-value	mean	st. dev	p-value
Section Sycocarpus															
Ficus schwarzii	1.15	0.08	n/a	1.14	0.12	n/a	1245.49	735.04	n/a	20.38	0.52	n/a	24.63	0.92	n/a
Ficus lepicarpa	n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a	
Section Sycocarpus															
Ficus cereicarpa	0.94	0.09	n/a	2.21	0.30	n/a	4831.34	3276.80	n/a	34.90	3.98	n/a	44.40	6.24	n/a
Ficus francisci	n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a	
Section Kalosyce															
Ficus punctata	1.17	0.08	0.554	1.06	0.05	0.011	22480.00	n/a	n/a	58.00	n/a	n/a	57.00	n/a	n/a
Ficus aurantiacea	1.17	0.07		1.33	0.12		17793.86	8345.45		53.50	4.95		65.00	1.41	
Section Sycocarpus (geocarpic figs)															
Ficus lambirensis	1.06	0.07	a	0.93	0.10	bc	2305.04	570.47	c	16.77	2.17	c	21.85	2.23	c
Ficus geocharis	0.88	0.12	b	1.02	0.10	ac	1195.44	253.58	ab	19.97	1.25	b	20.10	1.51	b
Ficus beccarii	0.61	0.05	c	1.03	0.07	ac	1516.39	111.39	ab	13.20	1.01	a	14.00	0.85	a
Ficus uncinata	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ficus megaleia	0.88	0.06	b	1.00	0.11	abc	4974.16	326.40		23.45	1.63	d	34.73	3.69	d
Ficus stolonifera	0.73	0.05	d	1.21	0.10	d	619.93	116.60	bd	12.33	0.98	a	15.00	0.74	a
Ficus treubii	1.02	0.09	e	0.99	0.15	abc	840.67	90.77	abd	17.27	1.62	c	14.82	0.60	a

Table 4 Results of variation among vegetative characters. Reported are the mean and standard deviation for all measurements made on male reproductive characters. A t-test was use to test for significance among the pairs, and a p-value less than 0.05 is considered significant. ANOVA was used to test for significant differences among the geocarpic figs. Instead of p-values, groups of species that were not significantly different from one another were assigned the same letter. Analyses were not performed on species with too few samples to compare or where figs were not available (n/a).

	Leaf length			Leaf width			Petiole length			Stipule length			Twig diamete		
	mean	st. dev	p-value	mean	st. dev	p-value	mean	st. dev	p-value	mean	st. dev	p-value	mean	st. dev	p-value
Section Sycocarpus															
Ficus schwarzii	16.60	2.86	0.919	5.56	0.98	0.014	0.46	0.07	0.001	1.13	0.21	0.646	0.17	0.06	0.024
Ficus lepicarpa	16.74	3.81		7.35	2.02		2.06	0.57		1.07	0.06		0.33	0.06	
Section Sycocarpus															
Ficus cereicarpa	55.30	4.73	0.000	26.38	1.18	0.000	18.18	1.77	0.000	5.85	0.07	0.043	1.40	0.14	0.068
Ficus francisci	18.36	4.11		6.49	1.55		2.36	0.58		1.40	0.42		0.35	0.07	
Section Kalosyce															
Ficus punctata	2.17	0.35	0.002	1.03	0.32	0.002	0.19	0.07	0.000	0.15	0.07	0.030	0.10	0.00	n/a
Ficus aurantiacea	2.69	0.53		1.36	0.25		0.47	0.12		0.56	0.12		0.24	0.07	
Section Sycocarpus (geocarpic figs)															
Ficus lambirensis	22.53	4.09	bd	6.58	1.01	bce	1.09	0.35	bcf	2.75	0.21	n/a	0.30	0.00	a
Ficus geocharis	18.42	3.27	bd	4.85	1.04	bc	0.59	0.17	abcef	2.54	0.84	n/a	0.86	1.04	a
Ficus beccarii	18.08	3.25	a	3.47	0.53	a	0.45	0.08	abe	2.30	0.57	n/a	0.10	0.00	a
Ficus uncinata	25.62	1.71	d	7.09	0.54	ce	0.98	0.16	bcef	2.15	0.35	n/a	0.20	0.10	a
Ficus megaleia	41.15	4.85	c	15.58	1.85	d	2.10	0.45	d	1.20	0.00	n/a	0.45	0.07	a
Ficus stolonifera	15.14	1.86	a	5.83	0.60	bc	0.65	0.16	abef	0.55	0.07	n/a	0.17	0.06	a
Ficus treubii	17.06	1.91	a	5.31	0.63	bc	0.80	0.13	bcef	0.82	0.40	n/a	0.25	0.07	a

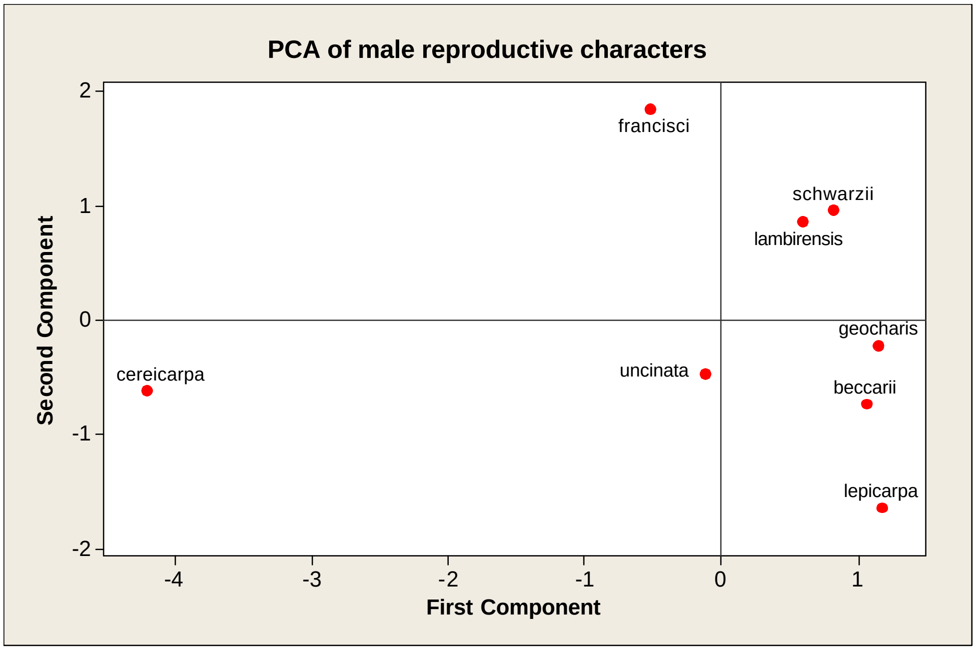

Fig 1 Principle component analysis of male reproductive characters

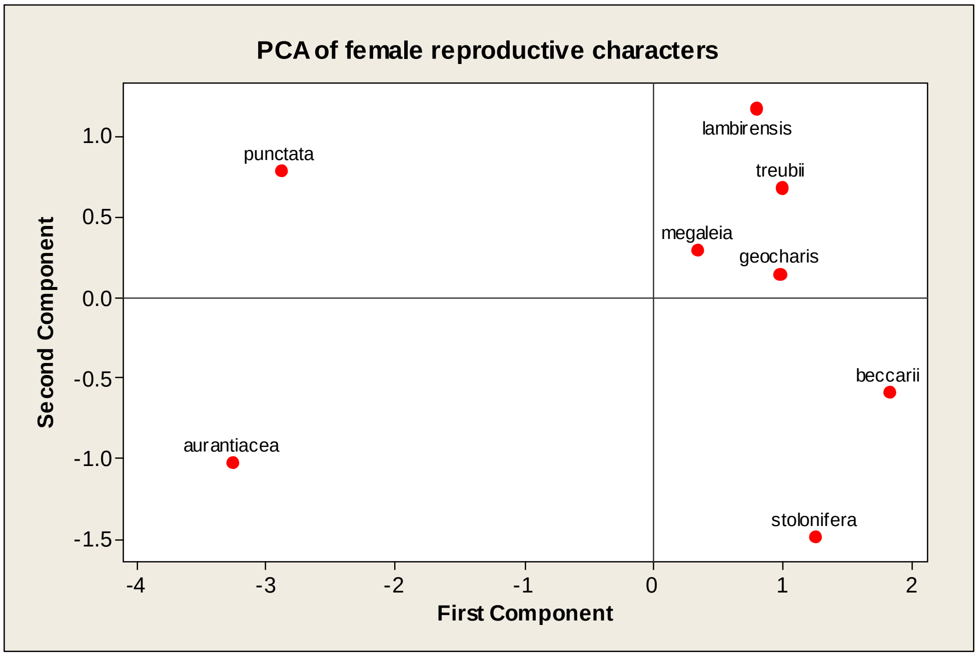

Fig 2 Principle component analysis of female reproductive characters

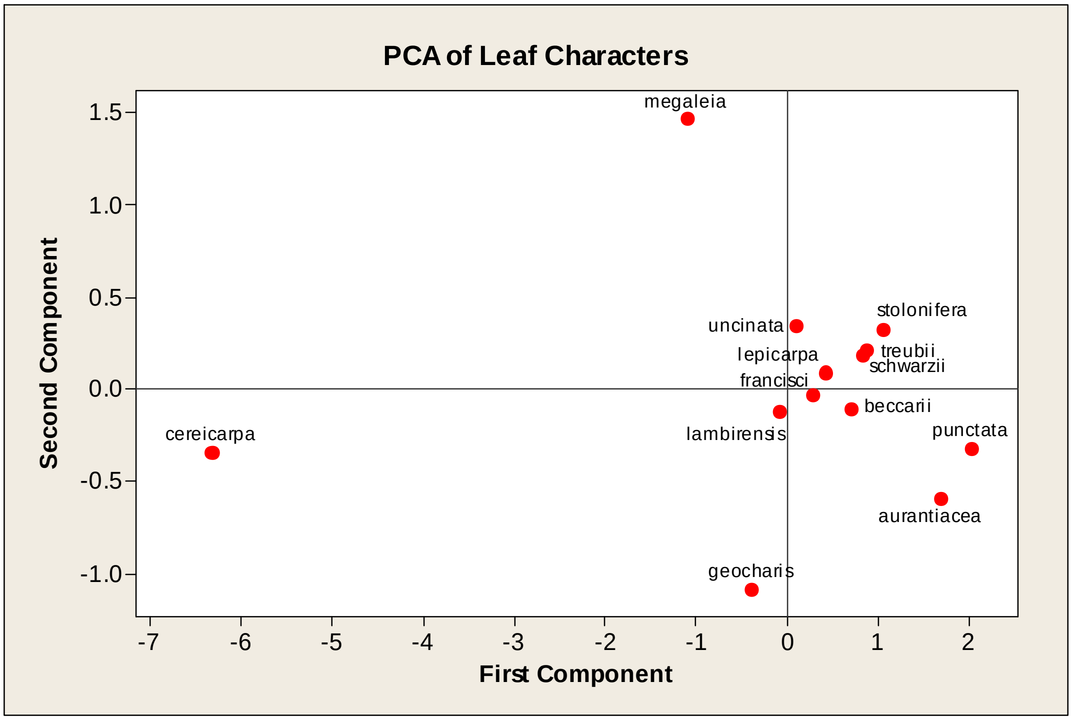

Fig 3 Principle component analysis of leaf characters

DISCUSSION

Many characters can be used to differentiate a fig given the many niches a fig can occupy. One can always identify a fig due to the presence of its distinctive inflorescence and fruit. Vegetatively figs are united by the presence of stipules, latex, stipule scars, and trinerved leaves. Within the genus, growth forms of figs, such as hemiepiphytes or stranglers provide a basis for splitting the genus into more manageable sections (Berg 2003).

In this study, we examined the relationship among figs within these larger sections such that growth form and position of the fig was uniform. We purposely chose to work with closely related species to begin to understand what characters differentiate similar species of figs. For the remainder of this section we will discuss each species pair individually and then make concluding remarks on any patterns evident across these species groups.

Ficus schwarzii and *Ficus lepicarpa*: The appearances of the figs from both of these species are very similar. Both have a yellow-green color when ripening lacking bracts and hair on the outside of the syconium. However, distinguishing these species is simple since *F. schwarzii* is cauliflorous and the figs of *F. lepicarpa* are in the axils of the leaves and branches. Although the figs are very similar in size and shape, we did find significant differences among them. The width of the syconium and the size of the galls are significantly different. The latter suggests that the pollinators are of two different sizes, and the taxonomy of the pollinator is conventionally considered in understanding the taxonomy of the figs. We are unable to compare female reproductive characteristics as we could not find female *F. lepicarpa* in flower. Our analysis found significant differences in leaf width, petiole and twig diameter, suggesting that some vegetative characters are different from one another.

Ficus cereicarpa and *Ficus francisci*: Although closely related and both grow in the form of trees, morphologically these two individuals are very distinct from one another. Both are cauliflorous, however *F. cereicarpa* is an extremely large plant in comparison to *F. francisci*. Also, *F. cereicarpa* has partly hairy figs with bracts that are brown with yellow-green patches on the fig. The figs of *F. francisci* are glabrous, without bracts, and brown in color. As a result, we found that all leaf characters differ significantly between the species. Many of the male reproductive characters differ significantly from one another with the exception of gall size. This suggests that their pollinators are similar in size. However, the style length differs significantly suggesting that the ovipositor length among the pollinators varies and could easily relate to different species. Again, female reproductive characters are not compared because female figs of *F. francisci* were unavailable.

Ficus punctata and *Ficus aurantiacea*: *F. punctata* and *F. aurantiacea* are both climbers but exhibit differences in the way they ascend a host tree. *F. punctata* will climb straight up the side of a tree sending out adventitious roots and branches which it uses to clasp to the tree, and eventually branches out sending its leaves out away from the trunk of its host. *F. aurantiacea* will densely cover the bark of the tree with its leaves staying close to the trunk, never branching far away from its host (Harrison *personal communication, pers. obs*). The leaves are virtually indistinguishable from one another, but we found that *F. aurantiacea* consistently has slightly larger leaves than *F. punctata*. The female figs are very different from one another as *F. punctata* produces large pair shaped figs which are tan to orange in color, and *F. aurantiacea* produces red figs with orange-yellow spots. The style and seed morphology is very similar and distinct from the section Sycocarpus. The seed shape is a long thin oval, and the style of the flower is forked. All aspects of the female reproductive characters were significantly different from one another, although the differences in the size of the figs were only marginally significant. It is worthwhile to note that strong differences in the female character may infer evolution independent of the pollination syndrome. In this case, male figs of *F. aurantiacea* were not available for study.

Geocarpic figs: The position of the figs, as is obvious from their name, unites this group of species. Most of these species are small trees often occurring on water edges on or on forest edges very often in sloped or steep topography. The leaf shape of these figs is very similar, with an obtuse margin and often hairy surfaces. However, the size of the leaves can vary dramatically within and among species. For example, *F. megaleia* is much larger than all of the other geocarpic species examined. With the exception of *F. megaleia*, leaf characters did not vary significantly. Our observations suggested that we should have seen more significant differences in leaf characters, and perhaps using leaf area may have been more representative of this difference. The overall morphology of the fig is also similar; most of these figs are hairy with bracts that turn to red to brown color when ripe. Exceptions to this include the pink to whitish figs of *F. beccarii* and *F. lambirensis*, and *F. treubii* which has no bracts. One interesting finding is that the female figs of *F. lambirensis* are glabrous whereas the male figs of this species are hairy. Seed size and size of syconium differed strongly across all of the geocarpic fig species. Gall size, style length, and gall count were also significantly different among the species, however, fewer species were compared because of the unavailability of many of the male figs.

CONCLUSION

Although many significant differences among closely related species were found as a result of our study, no consistent trends of significantly varying characters were found across all groups. Also, our data show that male, female, or vegetative characters alone cannot explain the morphological differences among species. Instead we are seeing a mix of characters varying across species. One interesting trend was the importance of seed size which significantly differed in both the Kalosyce and Sycidium sections suggesting that this character may play an important role in speciation.

The results of this study suggest that there are many significantly different varying characters across fig species pairs. Future studies should include more species pairs, and denser sampling within species. For instance, we were only able to count seeds in three figs. A larger sample size would confer stronger statistical interpretation. Also, other growth forms, such as hemi-epiphytes, should be included. Increasing these data may help elucidate more trends in the variation of closely related fig species.

ACKNOWLEDGEMENTS

The authors thank R.D. Harrison and J.Y. Rasplus for their help collecting figs for this study as well as their guidance in the development of this project.

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Floral Structure and Pollinator Visitation in *Melastoma malabathricum*

Jeanmaire Molina & Sandra Yap

ABSTRACT

Melastoma malabathricum exhibits heteranthery with two whorls of stamens: a set of six pink, longer stamens and six yellow, shorter stamens. We tested the effects of the removal of either whorl of stamens on pollinator visitation. Results show a decrease in visitation for flowers with excised stamens. We also observed that black *Trigona* bees tended to forage more on the yellow stamens, which they possibly perceives to be more visually attractive or perhaps to avoid encounters with the larger, more aggressive brown *Trigona* that preferred to forage on the pink stamens. Removal of petals on the flowers with excised stamens increased the strength of this pattern. We suggest that staminal removal reduces attractiveness of the flower. Visitor tendencies may be attributed to spatial partitioning in resource acquisition.

INTRODUCTION

A plant's reproductive biology defines its success in creating the next generation. This results in the importance plants put on the design of their flowers, consequently showcasing a great variability in floral morphologies. These are specially adapted to different pollination environments (Harder and Barrett 1993). Various characteristics are developed to increase chances of pollination. Flowers can be monoecious or dioecious; be wind-dispersed or animal-dispersed; be pollinator-specialists or pollinator-generalists. In contrast to flowers that are wind-pollinated, animal-pollinated flowers must be structurally specialized to cater to a suite of pollinators that vary in morphology and behavior. In very rare cases, there is no need for pollinators (autogamy). Less rare are geitonogamous (vector-mediated selfing) flowers (Renner 1989).

Harder and Barrett (1993) suggested maximized pollen dispersal of animal-pollinated plants occurred by restricting pollen removal by a single pollinator and instead distributing pollen to all possible pollinators. Poricidal anthers effectively perform this function. Poricidal anthers enclose the pollen allowing release through one, two or several pores, in different sizes and varying positions. This is found usually in stamens exhibiting heteranthery (dimorphic anthers) (Gross and Kukuk 2001).

Most of the members of the family Melastomataceae are characterized by poricidal anthers. Cymose inflorescences have 4- or 5-merous flowers, mostly perigynous or epigynous with a cup-shaped hypanthium, bearing on its rim the calyx lobes, petals and stamens (Renner 1989). In *Melastoma malabathricum*, the dimorphic stamens come in two sets of six. The six antepetalous stamens are longer and of the same pink-color as the petals, while the other six antesepalous stamens are shorter and colored a contrasting yellow. Both forms of anthers have only a single pore at the tip. *M. malabathricum* is also described as a pollen-only flower because it only offers pollen as a reward (Renner 1989).

Pollen, being encased in the poricidal anther, is not released without a vector. The usual vectors are bees that buzz the anthers with vibrations of around 420 Hz or higher. This is the most widespread pollination system in Melastomataceae, occurring in 120 species in 31 genera (Renner 1989).

In this study, we investigate if the removal of either of the staminal whorls affects the visitation rate of the pollinators. We also attempt to determine anther preference of different foragers.

MATERIALS AND METHODS

Study site

The chosen study site was a 5m x 5 m section of an open area near the headquarters of Lambir

Hills National Park. It is also only about 500 meters away from the edge of a lowland dipterocarp forest. About six *Melastoma malabathricum* treelets are clumped amongst *Nephrolepis, Dicranopteris* and *Lygodium* thickets, along a road connecting several residential buildings. It is bordered on the other side by a shallow stream.

Treatments

Field experiments ran from August 8 to 11, 2004. Three treatments were designed for the study. The first set-up was unmanipulated, retaining both sets of anthers, serving as a positive control. A second set-up, NO PINK, had the pink anthers removed and the third set-up, NO YELLOW, had their yellow anthers removed.

Three sets of observation periods were scheduled, each 40 minutes long, each day. Observations began at 8 am when the flower buds started to open and ended at 11 am. Excluding the flowers used in the first observation period, all flowers assigned for succeeding observations were bagged to prevent the visitation of foragers on these flowers.

For each set-up, the following data was gathered: (1) visitors (2) frequency of visits per visitor and (3) number of stigma touches.

A different manipulation was performed on the fourth day of observations. Petals were removed from the three set-ups and the same information on visitations was recorded as in the previous experimental design.

Data Analysis

One-way ANOVA was used to test for any significant relationships between visitation rates and treatments. The same test was used to compare visitation rates per visitor species per treatment. Pearson correlation was performed to compare visitation with stigma touches.

RESULTS AND DISCUSSION

Varying pollination syndromes have allowed an extremely diverse array of floral morphologies to evolve, but not one is perfect and there are inherent tradeoffs for each. For animal-pollinated systems there is selective pressure to develop male gametophytes that will permit efficient pollen dispersal (Harder and Barrett 1993). Heteranthery, as exemplified in melastomes, has probably been evolutionarily advantageous since its inception in the Cretaceous, as it is manifested in about 172 plant families. However, the basis for its evolution has not been resolved (Gross and Kukuk 2001). The poricidal anthers also seem to work well in melastomes since this feature has been preserved in the evolution of the family. Harder and Barrett (1993) suggested that this system restricts immediate pollen removal by visitors to allow more pollinators to benefit, thus enhancing pollen dispersal.

In this study we wanted to investigate the function of this staminal dimorphism, and we tested the hypothesis that removal of either whorl of stamens would diminish the appeal of the flower and hence, accordingly, reduce visitation.

Fig 1 and Fig 2 show individual tendencies of each visitor for a setup as measured by their visitation frequencies. For both ‘petal’ and ‘no-petal’ setups, black *Trigona* seemed to forage more on yellow stamens, while the brown *Trigona* preferentially foraged on pink anthers. The trend was more apparent (i.e. significant) in the ‘no-petal’ setup, which may imply that the presence of petals confounded our results.

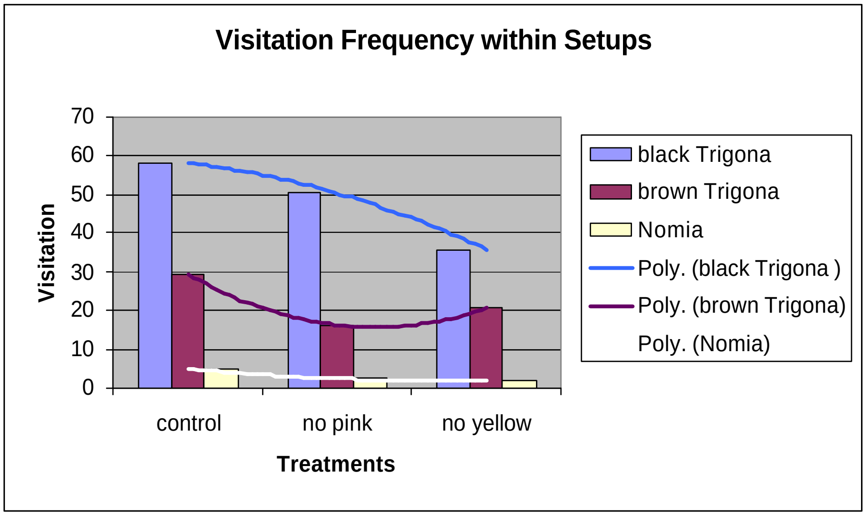


Fig 1 Petals present: Visitation frequencies of each bee within a setup in the first 3 days. Control received the most number of visitors. Between the manipulated setups, black *Trigona* preferred yellow stamens more than pink; brown *Trigona* was the reverse. *Nomia* sp. also foraged more on yellow (*p*=0.467 for black *Trigona*; *p*=0.289, for brown; *p*=0.264 for *Nomia).*

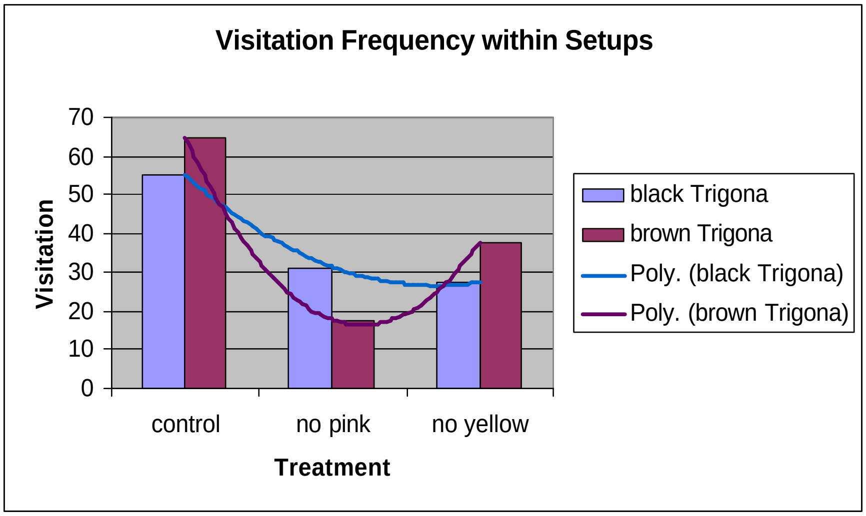
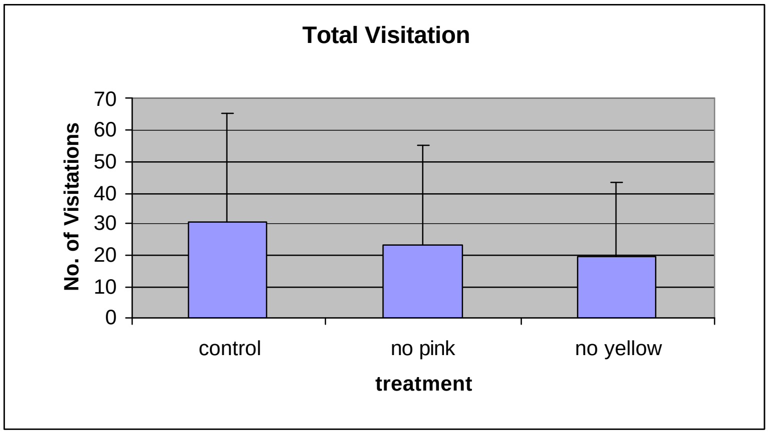


Fig 2 No Petals: Same pattern as Fig 1, but more significant. Presence of petals seemed to confound the results. There was no *Nomia* data for the 'no-petal' setup (*p*=0.140 for black *Trigona*, *p*=0.006 for brown).

Petals were eliminated on the fourth day after we realized that presence of the pink corolla seem to confound our results. Unfortunately, it was too late for us to have more replicates, given the time constraint imposed on us. We observed that the petals alone can attract visitors. It is possible that visitors come to the flowers, initially lured by the pink petals, without actually knowing that one of the anther whorls is missing, until they start to move about inside the flower. Renner (1989) described some sweet odor emanating from the petals, and petals do act as "secondary attractants" in melastomes. Gross and Kukuk (2001) found that emasculated flowers still appealed to *Amegilla*.

Fig 3 compares total visitation within the three setups. For the 'petaled' treatment, there was higher visitation for the yellow anthers than the pink setup. The reverse was true for the 'no-petal' treatment. We are inclined to believe in the trend exhibited in the 'no-petal' treatment, since we think that it reveals the real tendencies of each visitor. It seems likely that pink anthers attract more visitors than yellow anthers. Even if the short anthers were excised, they still appear to be intact due to the illusion that the yellow ends of the pink anthers impart. However, this conjecture is premature and additional observations are necessary.



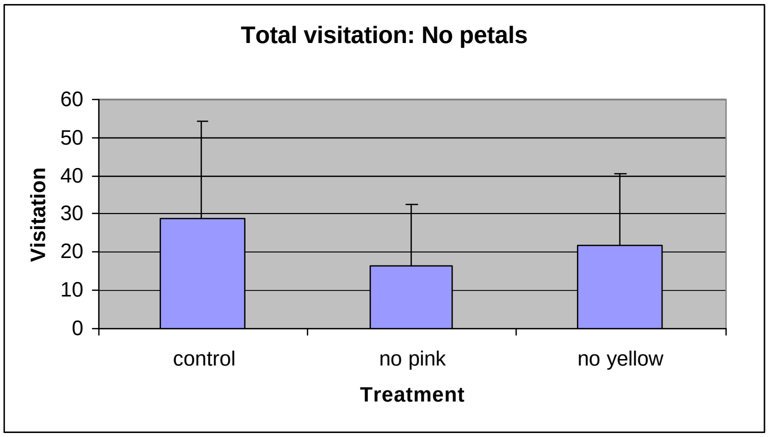


Fig 3 Total visitation in each setup. For 'petaled' setups, between the manipulated treatments, there was more visitation in the yellow setup more than pink (p=0.376). Reverse was true for the 'no-petal' setup (*p*=0.105).

In Gross and Kukuk's (2001) experiment on a closely related species, *Melastoma affine*, *Amegilla anomala*, its bee pollinator, preferred the long pink stamens more than the short yellow ones, perhaps due to the former's greater pollen content, which they previously assessed.

In *Pontederia cordata*, a tristylous plant, Harder and Barrett (1993) found that more pollen was also removed from the exserted anthers. This was true for one of our visitors, the brown *Trigona*, which we observed to favor the longer pink stamens (Fig 1-3). This result was strongly significant (*p*=0.006) for that treatment where both petals and yellow stamens were removed (Fig 2).

During the first three days, the black *Trigona* seemed to scavenge more on yellow stamens. Also whenever they landed on a setup where there were only pink stamens, they would not immediately chew on the anthers, but interestingly walk down the filament to seek out the yellow stamens, which of course, had been eliminated. The yellow bases of the pink anthers (Fig 8) seem to deceive these bees. "It is uncertain if the visual cues provided by the yellow connective appendages elicit pollen collecting behavior (Renner 1989:p. 510)."

Nomia sp. were inclined to visit yellow stamens. This was also observed by Gross and Kukuk (2001) in the pollinating *Nomia* species of *M. affine* in Australia.

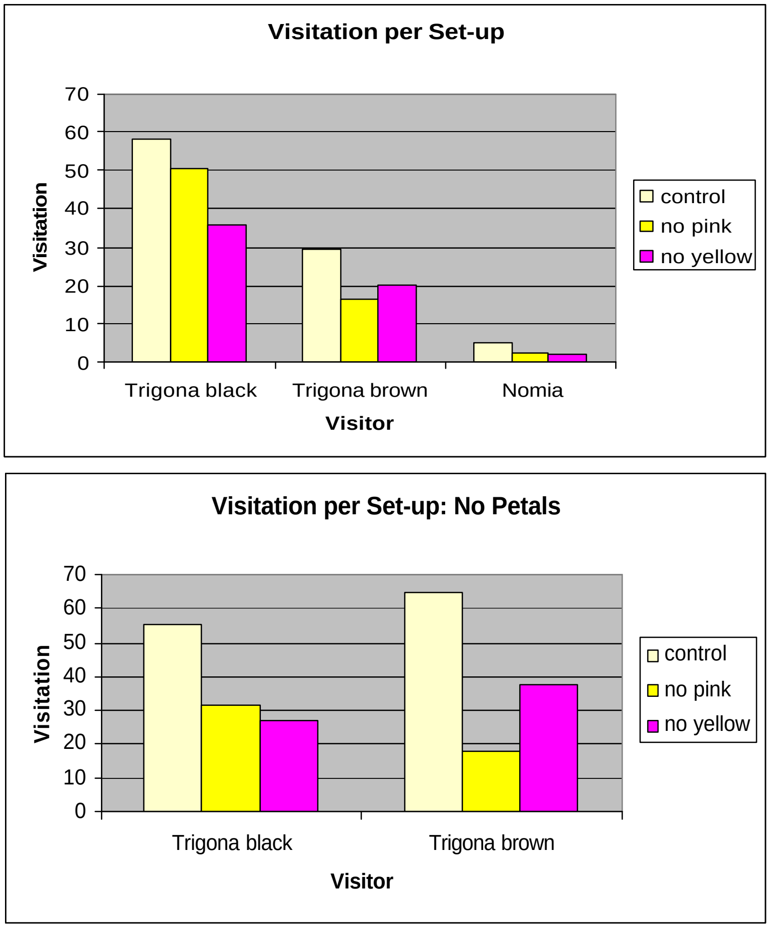


Fig 4 Spatial resource partitioning in both 'petal (upper)' and 'no-petal (lower)' setups. Similar trends were obtained for both, but it was more significant in the 'no-petal' setup. The black smaller *Trigona* species seemed to prefer yellow stamens, while the brown *Trigona* species was more attracted to pink anthers. There was no *Nomia* data for the 'no-petal' setup.

The black *Trigona* may have also preferred to forage on yellow stamens to avoid the more aggressive and larger brown *Trigona* species, which more often scavenge on pink stamens. Nagamitsu and Inoue (*in press*) described aggressive behavior in stingless bees. More aggressive species would "monopolize clumped and rich resources, whereas the less aggressive species are excluded and forage on poor resources." They also proposed that "early-arriving, less aggressive species are temporally replaced by late-arriving more aggressive species (p. 56)." It seems probable that there is some spatial resource partitioning involved in the foraging behavior of the two *Trigona* species as seen in Fig 4. However, this pattern is not very distinct, which may mean that in flowers without the brown *Trigona*, black *Trigona* will still forage. The long pink anthers may be selected by the brown *Trigona* since they have more pollen (though we have not assessed this, but this may be supposed since *M. affine* is closely related to *M. malabathricum*).

Though it was predicted that the more aggressive species would later displace the more docile species, we did not observe such temporal partitioning (Fig 5). The population of the black *Trigona* significantly increased (p=0.002) across the observation period (8-11 AM), whereas the brown *Trigona* slightly decreased in number at 9 AM and increased marginally thereafter. It may be possible that 3 hours per day was not enough to observe the temporal behavior of these bees. We may predict a decline in the visiting population of the black *Trigona* later in the day**,** as the brown *Trigona* increases in number. Aggression was displayed by the larger brown *Trigona* by grappling the smaller species.

It has long been postulated that the inner showy stamens of melastomes serve as feeding anthers, while the long more obscure ones are involved in pollen dispersal (division of labor hypothesis). However, there is no strong evidence to support this (Renner 1989; Gross and Kukuk 2001). Gross and Kukuk (2001) described heteranthery in *Melastoma affine* as a "seemingly inefficient situation (p. 174)," because they found that *Amegilla* ironically preferred to buzz the long anthers more than the yellow ones, though buzzing the latter increases the chances of the pollinator contacting the stigma and thus depositing pollen. They also discovered that removal of the short stamens decreased fruit set because without these stamens, *Amegilla* would rarely contact the stigma as it buzzes only the long anthers. However, if both stamen types were present, *Amegilla* would vibrate the short stamens, while the long anthers, arched over the bee, also released pollen and deposit it onto the bee's dorsum. Because the pollen is unlikely to be groomed off from the bee's back, they are then carried off to potentially pollinate the next flower.

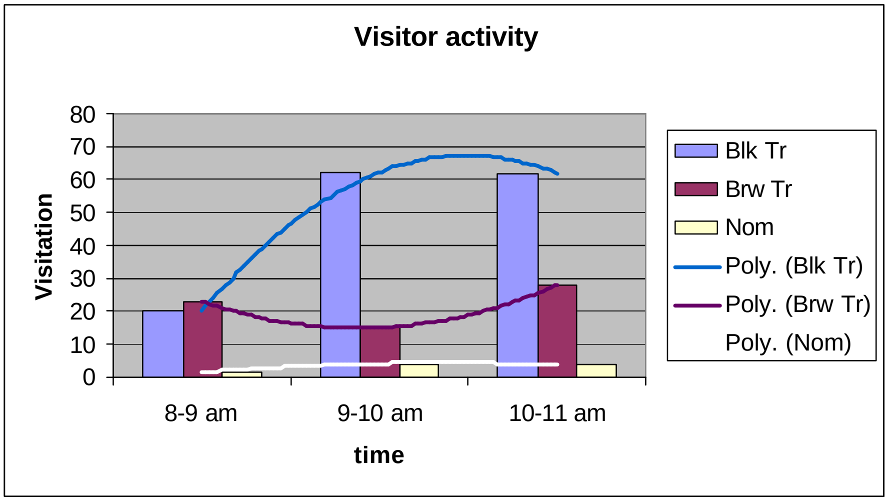


Fig 5 Visitation was most active from 9-11 AM

In Fig 6 it is shown that there was more stigmatic contact in flowers that only had yellow stamens compared to the treatment where only pink ones remained. This was also previously demonstrated by Gross and Kukuk (2001) in *M. affine*. Correspondingly, with more stigma contact, more fruit set was observed compared to setups where the inner whorl was removed. *Melastoma affine* is self-compatible, but it is herkogamic (i.e. spatial separation of stigma and anthers) to prevent selfing. An animal vector is also necessary to self-fertilize (i.e. geitonogamy) (Renner 1989).

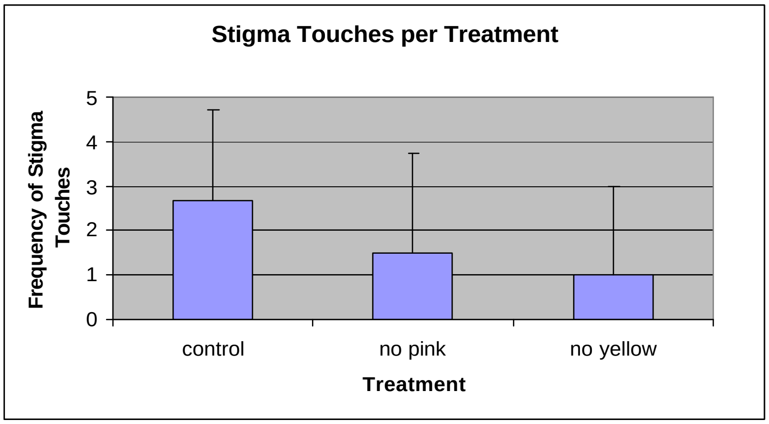


Fig 6 Stigma touches within a setup. Setup with only yellow stamens had the most stigma contact

The number of stigma contacts was positively correlated with the number of visits by the three bees (Fig 7). However, *Trigona* was more of a pollen thief for *Melastoma*, because it scavenges pollen without normally touching the stigma (Momose et al. 1998), but in rare cases where it does, *Melastoma* may be pollinated. Large visitors like *Xylocopa* are the preferred pollinators for the big flowered melastomes, since these bees can grasp and buzz several stamens simultaneously as their pollen-dusted bodies gyrate over the stigma (Momose et al. 1998).

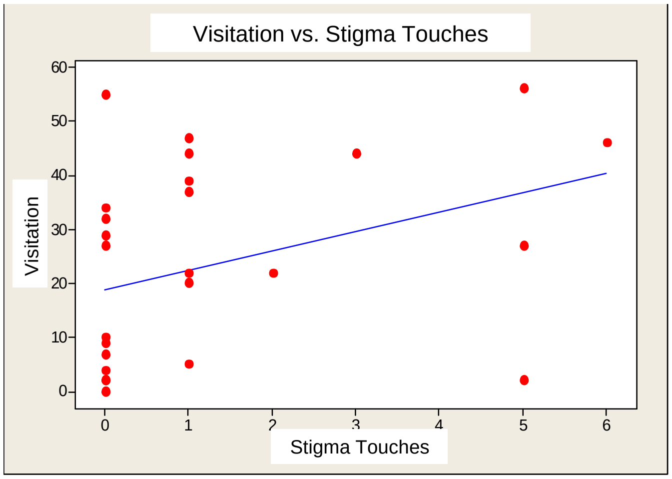


Fig 7 Visitation was positively correlated with number of stigma touches (*p*=0.062; Pearson coefficient=0.364)

In our study, we failed to observe *Xylocopa* in any of our setups within the 4 day period. Though we would see them come near the plant, they would only buzz the highest flowers. We collected some flowers that were visited by *Xylocopa* for observation and noticed that the styles turned green, in contrast to styles that were not visited by *Xylocopa* (Fig 9). We think that pollinated stigmas become green due to some chemical reaction triggered by pollen contact with the stigma, but this warrants more observation. It impressed upon us that the melastome plants that we were observing were pollen-limited due to the very few fruits that we saw on its branches, and despite the great number of flowers that bloom each day. We seldom noticed pollinators other than *Nomia* and *Xylocopa,* which were much fewer in number compared to the *Trigona* spp. *Melastoma malabathricum* flowers June-August and, a considerable number of fruits should have developed but were not observed.

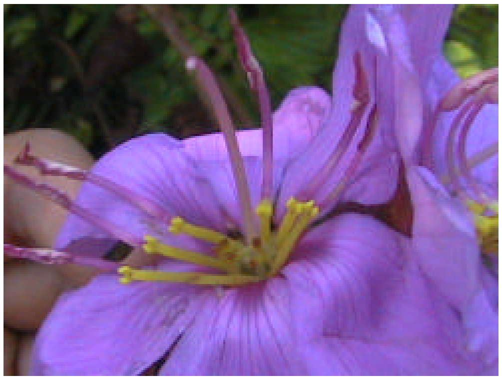


Fig 8 Yellow bases of the outer whorl of the longer pink anthers

Fig 9 Difference in color between *Xylocopa*-pollinated (above, green) and non-pollinated (below, pink) styles

Gross and Kukuk (2001) proposed that for pioneer plants, like *Melastoma,* "a system that allows selfing is a good insurance policy, but once the population is large, outcrossing could become an important component of the mating system (p. 175)." As they have observed in *M. affine,* the exserted stamens contain more pollen. In conjunction with the 'division labor hypothesis,' this greater pollen content is necessitated in these "pollinating anthers" to maximize outcrossing more than selfing. Since *Amegilla* can harvest more pollen from the exserted anthers, it prefers this stamen type, which likewise, benefits the plant, since more pollen are sonicated off, deposited and dispersed to other plants.

Harder and Barrett (1993) believed that "stamens do not play a role in pollinator attraction (p. 1060)," but do affect pollen removal and dispersal. However, in the case of melastomes, stamens may enhance visual attractiveness since they are dimorphic, with the inner whorl bright and showy and the outer, elaborately structured due to the prolonged connective. Nonetheless, in all systems, anther structure and placement must be precise so as to maximize pollen deposition on the pollinator. In our study, we confirmed that visitation is affected by removing either of the staminal whorls. This may be attributed to two possible causes, as we have observed—reduction in aesthetic appeal and spatial partitioning in resource acquisition to prevent aggressive encounters among foragers.

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Comparison of insect diversity and abundance on different tree barks

Puan Chong Leong & Ming-Feng Chuang

ABSTRACT

This study was carried out on the 8-10 august 2004. A total of 1141 specimens of 21 orders of arthropods were collected from different types of tree barks. Hymenoptera, Thysanura and Araneae were most dominant. There was no significant difference between the diversity, group richness, and individual abundance against bark texture. However, the composition of certain arthropods (Diptera, Acari and Phalangida) varied among different tree barks. The community similiarity between smooth and fissured bark was 0.763, and 0.813 between smooth and flaking bark, 0.893 between fissured and flaking bark. There was a positive and significant relationship between the individual abundance and tree size. The results support the equilibrium theory of island biogeography as applied to tree-trunks-as-islands.

INTRODUCTION

The tropical lowland forest is among the most diverse ecosystems in the world comprising a diversity of flora and fauna. As the biodiversity increases, different species of organisms have the ability to coexist in local assemblages and occupy different niches. Unlike temperate counterparts, the tropical plants exhibit a variety of leaf, flowering and fruiting phenologies. All these factors are essential in determining the abundance and diversity of animal communities that depend on the forests for food and shelter.

Insects are abundant and successful organisms that occur in a wide range of habitats. Every surfaces of a tree may provide microhabitats to various insects and other arthropods. The forest physiognomy has direct influences on the insect composition. These includes features like the height of the canopy, the distribution of large tree trunks, leaf area, the occurrence of free space and in particular the tree architecture that includes height, biomass, size and abundance of leaves, flowers, seeds, etc (Basset et al. 2003).

Animal communities vary between different kind of habitats. Referring to the equilibrium theory of island biogeography (MacArthur & Wilson 1963; MacArthur 1967), the number of species on an island will be affected by the arrival of new species and continuously depleted by extinctions The rates of immigration is defined as the rate of arrival of new species on an island. Rate of extinction is the rate at which species went disappear from an island. Immigration and extinction rates will be specific to the island (as well as to the taxon), with higher immigration rates for closer, more accessible islands and lower extinction rates for larger islands that can support larger populations. As in the case of animals that live on tree barks, a large tree is expected to have more species as attributed by lower extinction. Other than this, the existence of animal communities are also depended on other factor such as niches availability, complex habitats that could offer more food sources, shelters and different niches for animals in a uniform size of area.

This study is intended to examine the relationship between species composition and complexity of their habitat by examining the bark insects and other arthropods. Comparison was made on the diversity and abundance of arthropods on different bark textures and tree sizes.

METHODS

Study Site

The study was conducted at Lambir Hills National Park which is located about 30km south of the town of Miri in the northern Sarawak, Malaysia. Approximately 6500 ha in size, the area comprises of primary lowland dipterocarp and kerangas heath forest along the ridge. The forests are surrounded by secondary forest, oil palm plantations and area disturbed by shifting cultivation. The area receives 3000mm of annual rainfall with periodic droughts that occur throughout the year.

Data collection and analysis

A preliminary survey was conducted in order to identify the trees with three types of bark textures: smooth, fissured and flaking. A total of 30 trees from four genera were selected, with each bark texture type represented by ten individuals. Table 1 showed the tree species selected based on the different types of bark selected in the study.

Table 1 Four genus selected based on different bark types

Bark type	Tree genus
Smooth	Kompassia sp. Artocarpus sp.
Fissured	Shorea sp.
Flaking	Dryobalanops sp.

The bark spray method was used in the study in which insecticide was sprayed on the tree bark. The diameter at breast height (dbh) of the tree was measured. The area sprayed was about 100 cm x 100 cm. Smaller tree was sprayed higher and *vice versa*. The insects were collected using a cloth that placed around the base of the tree. The insects were put into an alcohol filled bottle for further identification in the laboratory.

The insects were sorted in order to identify and classify the insects into their respective order. The abundance and diversity index, the Shanon Diversity Index, species richness, individual abundance and community similiarity were calculated for each sample or tree. The correlation analyses were performed to examine the relationship between the abundance and diversity against bark texture and tree size.

RESULTS AND DISCUSSION

Table 2 provides a summary of the total specimens collected according to taxon and bark types. A total of 1141 specimens were collected within three days from 3 broad classes (Arachnida, Chilopoda and Insecta) and 21 orders. From the total number of specimens collected, Hymenoptera, Thysanura and Araneae were the dominant groups occupying about 41.3% of the collection. This is followed by Acari (9.0%), Orthoptera (8.2%), Diptera (8.0%), Phalangida (6.8%), Blattodae (6.7%), Coleoptera (6.5%), and Collembola (5.5%).

Comparison of specimen composition by bark types

Shanon diversity Index, species richness and individual abundances are reported in Table 3 (also Appendix 1). The estimates were quite similar for smooth and flaking bark while the value for fissured bark was unexpectedly lower. The diversity indices, species richness and individual abundance range from 2.37 to 2.54, 14.9 to 18.6 and 32.7 to 41.1 respectively. In addition, the results of the ANOVA analysis were non-significant. This might be due to the small sample size as the estimates of diversity may be influenced by sample size (Schulze & Fiedler, 2003).

It should be highlighted that the distributions of certain groups including Diptera, Acari and Phalangida were quite distinctive across different types of bark (Table 2). In the case of smooth bark, Diptera was among the dominant groups, but not for fissured or flaking bark. In contrast, less dominant groups, like Acari, on smooth bark turned out to be more dominant for fissured or flaking bark. This implies that certain taxa tend to select or prefer certain bark texture. The composition of communities on flaking bark was intermediate to the smooth and fissured bark. This was further supported the similarity in terms of specimen composition between three types of bark texture (Table 4). The high similarity of 81.30% was obtained between the flaking bark and the fissured bark. This is expected as both bark types exhibited relatively high complexity.

Table 2 Total number of specimens collected according to taxon and bark type

Taxon	Group	Smooth	Fissured	Flaking	Total
Chelicerata					
Arachnida (3 orders, 3 groups)					
Acari	mites	13	42	48	103
Araneae	spider	33	34	40	107
Phalangida	havestmen	16	39	23	78
Uniramia					
Chilopoda (1 order, 1 group)					
Centipede	centipedes	1	-	1	2
Insecta (17 orders, 21 groups)					
Blattodae	cockroaches	23	24	30	77
Coleoptera	beetles	27	17	25	69
	weevils	1	1	3	5
Collembola	springtails	21	16	26	63
Dermaptera	earwigs	4	4	1	9
Diptera	flies	62	8	6	76
	Mosquitos	5	4	6	15
Embioptera	embiids	-	-	1	1
Hemiptera	bugs	3	2	18	23
Homoptera	cicadas	3	6	1	10
Hymenoptera	ants	71	38	55	164
	wasps	8	8	8	24
Isopoda	termites	2	2	12	16
	woodlices	-	1	1	2
Lepidoptera	moths	7	5	6	18
Mantodae	mantis	1	-	1	2
Neuroptera	lacewings	3	1	-	4
Orthoptera	crickets	36	23	34	93
Psocoptera	psocides	1	-	3	4
Thysanura	silverfishs	62	52	62	176
Total 21	24	403	327	411	1141

Table 3 Shanon diversity Index, species richness and individual abundance by bark texture

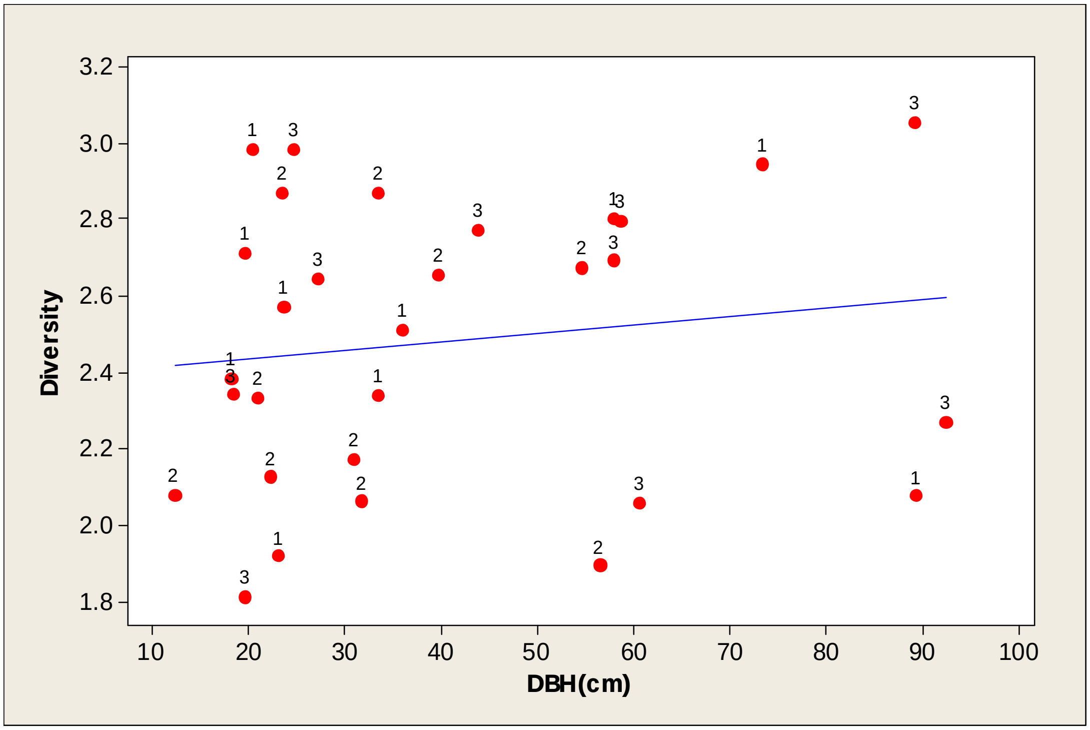
	Smooth	Fissued	Flaking	P-value
Diversity	2.52±0.35	2.37±0.36	2.54±0.41	0.549
Group richness	17.6±5.8	14.9±4.7	18.6±6.8	0.357
Individual abundance	40.3±20.5	32.7±13.8	41.1±20.6	0.544

Table 4 Community similiarity between different tree bark textures

	Smooth	Fissured	Flaking
Smooth	-		
Fissured	0.763	-	
Flaking	0.813	0.873	-

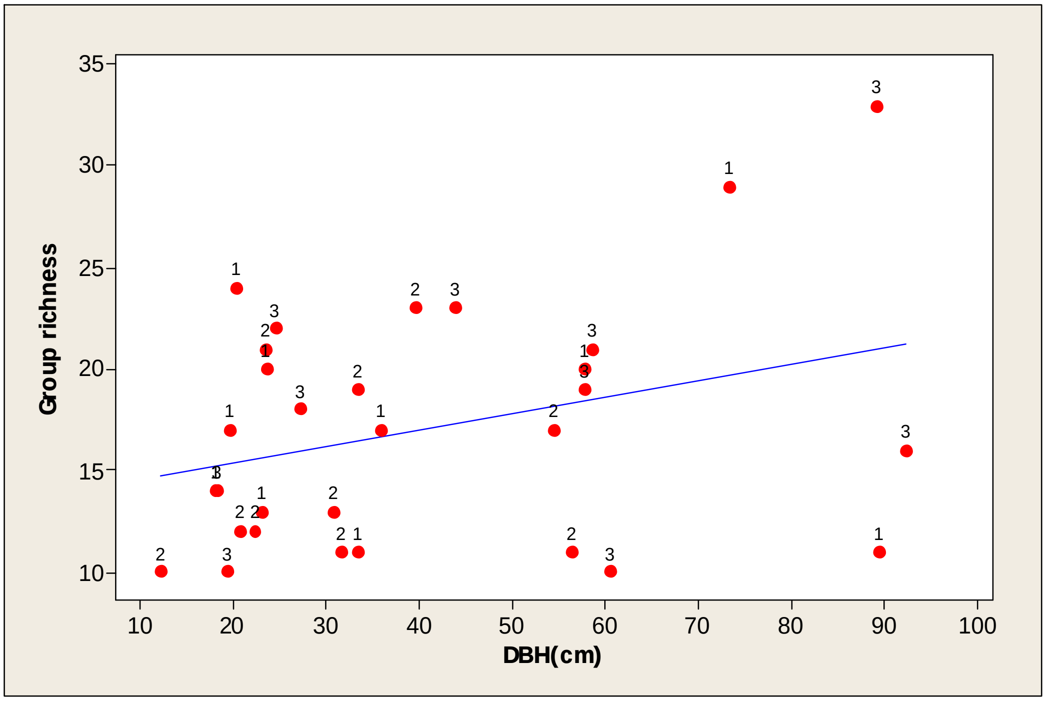
Comparison between diversity indices and tree size

Correlation analysis was performed on the indices obtained against the dbh of the tree. Referring to Fig 1, there was a weak and non-significant relationship between the diversity indices and tree dbh. However, the stronger trends were obtained for species richness and individual abundance as shown in Fig 2 and 3 respectively.



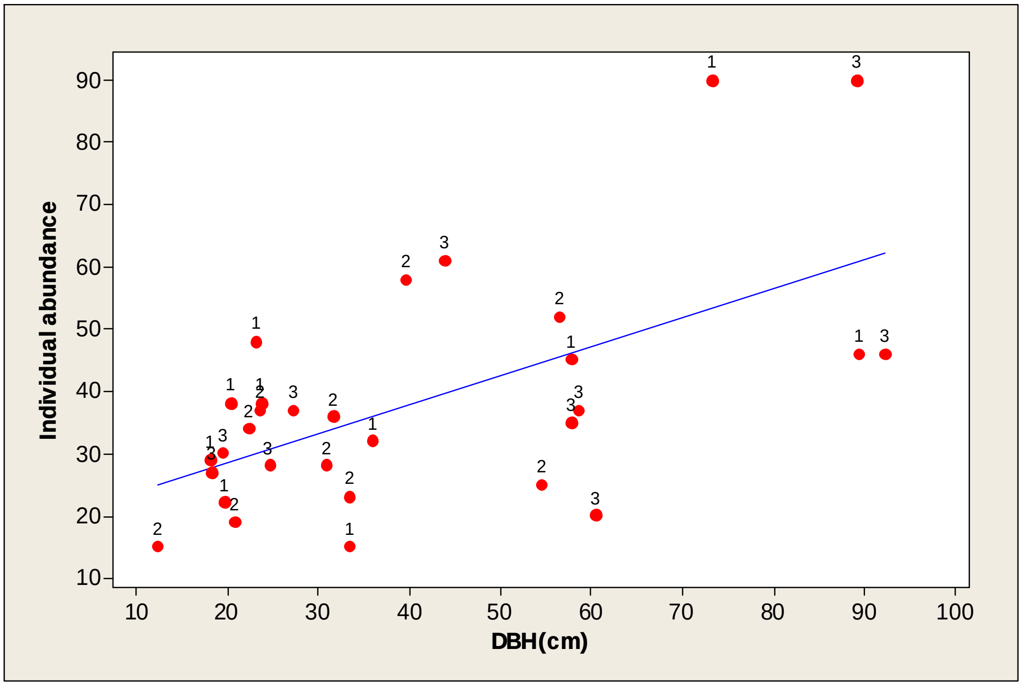
Note: Pearson correlation of DBH (cm) and diversity = 0.137
P-Value = 0.470

Fig 1 Relationship between diversity indices and dbh of tree



Note: Pearson correlation of DBH (cm) and group richness = 0.321
P-Value = 0.084

Fig 2 Relationship between group richness and dbh of tree



Note: Pearson correlation of DBH (cm) and individual abundance = 0.590
P-Value = 0.001

Fig 3 Relationship between individual abundance and dbh of tree

As indicated in Fig 2, there is a positive relationship between the group richness and dbh (*p*=0.10). This explained that the more species tend to be found on larger trees. The larger trees provided more habitat for a wider range of organisms. Fig 3 showed the relationship between individual abundance and dbh of trees. From the results, there is a positive and significant relationship between the individual abundance and dbh of the tree (p<0.01). This explained that the number of individual organisms increases as the diameter of the tree increases. The results support the equilibrium theory of island biogeography (MacArthur & Wilson 1963; MacArthur 1967) in which the number of species increases as the area increases.

Subsequently, correlation analysis was also performed separately with respect to different bark texture. However, weak and non-significant relationships were obtained for all three types of bark. The small sample size might explain the results.

In short, there is a significant relationship between individual abundance and diameter of the tree. The results also indicated that several arthropods prefer certain type of bark. The fissured and flaking tend to have higher similarity than either with smooth bark in terms of composition of arthropods.

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Appendix 1

Summary of diversity index, group richness and individual abundance by different tree barks

No.	Tree species	Bark type	DBH (cm)	Diversity	Group richness	Individuals
1	Dryobalanops sp.	3	60.6	2.06	10	20
2	Dryobalanops sp.	3	19.5	1.81	10	30
3	Dryobalanops sp.	3	58.6	2.80	21	37
4	Dryobalanops sp.	3	27.2	2.65	18	37
5	Dryobalanops sp.	3	57.9	2.69	19	35
6	Dryobalanops sp.	3	24.6	2.99	22	28
7	Artocarpus sp.	1	20.4	2.99	24	38
8	Artocarpus sp.	1	73.2	2.95	29	90
9	Shorea sp.	2	12.2	2.08	10	15
10	Dryobalanops sp.	3	92.4	2.27	16	46
11	Artocarpus sp.	1	18.2	2.38	14	29
12	Artocarpus sp.	1	23.6	2.57	20	38
13	Kompassia sp.	1	57.8	2.80	20	45
14	Shorea sp.	2	23.5	2.87	21	37
15	Shorea sp.	2	30.9	2.17	13	28
16	Shorea sp.	2	33.4	2.87	19	23
17	Shorea sp.	2	39.6	2.65	23	58
18	Shorea sp.	2	22.3	2.12	12	34
19	Shorea sp.	2	31.7	2.06	11	36
20	Shorea sp.	2	20.9	2.33	12	19
21	Shorea sp.	2	54.5	2.68	17	25
22	Kompassia sp.	1	33.4	2.34	11	15
23	Kompassia sp.	1	89.3	2.08	11	46
24	Shorea sp.	2	56.4	1.89	11	52
25	Dryobalanops sp.	3	89.2	3.05	33	90
26	Dryobalanops sp.	3	43.8	2.77	23	61
27	Dryobalanops sp.	3	18.3	2.34	14	27
28	Artocarpus sp.	1	23.1	1.92	13	48
29	Artocarpus sp.	1	36.0	2.51	17	32
30	Artocarpus sp.	1	19.6	2.71	17	22
	Average		40.4±23.3	2.48±0.37	17.0±5.9	38.0±18.3

Note: 1 indicated smooth bark, 2 indicated fissured bark & 3 indicated flaking bark

Relation of shape and position of *Nepenthes* pitchers to trapping efficiency

Voradol Chamchumroon & Prasong Thammapala

INTRODUCTION

The pitcher plants comprise seven genera, which are distributed throughout parts of America, Asia and Australia. Of the five American genera, two are bromeliads (one species of *Catopsis* and at least one species of *Brocchinia*), while the remainder all belong to the family Sarraceniaceae. The monotypic *Cephalotus* (Cephalotaceae) grows only in south-western Australia, whereas the largest genus, *Nepenthes* (Nepenthaceae), is distributed from northern Australia throughout South-east Asia to southern China. Outlying species of *Nepenthes* occur in Sri Lanka, India, the Seychelles, Madagascar and New Caledonia, while the vast majority occurs on the islands of Borneo and Sumatra (Clarke 1997).

Most *Nepenthes* species produce two types of pitchers. On young stems, short, squat pitchers are produce, which usually rest on the ground. These are called terrestrial or lower pitchers. On climbing stems, narrower, funnel-shaped pitchers, called aerial or upper pitchers, are produced. The great variation in pitcher morphology, even within individual *Nepenthes* species, has caused much of confusion in identification. The main body of the pitcher is variable in shape and size, although the lid and the peristome are usually fairly uniform in structure. Lower pitchers sometime contain large quantities of fluid. The funnel-shape upper pitchers are often smaller and less colourful than the lower ones. The most likely reason why upper pitchers are funnel-shape is that they need to be very light, as the plant could not support squat pitchers in the climbing stage. By having a narrow base, the amount of fluid they can accommodate is small. The attachment to the tendril is also much stronger.

The aerial pitchers catch more flying prey than terrestrial pitchers, as expected. However, the trapping efficiency may derive from many factors. Aerial pitchers may be intrinsically more attractive to insects than terrestrial pitchers. We examined the major factors playing a role in trapping efficiency.

METHODS

Study Site

Our study site was at Lambir Hills National Park, in secondary forest and on the edge of the forest. Field work was conducted from August 7-10, 2004. We found three species of *Nepenthes*: *N. ampullaria* Jack, *N. gracilis* Korth and *N. mirabilis* (Lour.) Druce and we selected two widespread species (*N. ampullaria* and *N. gracilis*) for this study. They are commonest in lowland swamp forest and are sometimes found in open areas, where they scramble among low bushes, occasionally climbing to 3 m or more. *Nepenthes gracilis* can also be found in many roadside ditches in western Borneo. Although most plants produce plain green pitchers, several forms with red lower pitchers and green upper pitchers are known, and there is one very attractive form with dark purple pitchers.

Data collection

We selected *Nepenthes gracilis* and *N. ampullaria* from two sites (secondary forest and edge of forest) and collected insects in the pitcher (80 individual pitchers: 50 aerial pitchers and 30 terrestrial pitchers belonging to *N. amphullaria* and *N. gracilis*) and identify species in laboratory. We measured the size of pitchers (diameter of lip, diameter of pitcher; length of pitcher; color). For criteria of terrestrial pitchers and aerial pitchers, we set a height above ground of less than 0.50 m as terrestrial pitchers, more than 0.50 m as aerial pitchers.

Experiment

We inversed the position of pitchers (placed aerial pitchers in a terrestial position and terrestrial pitchers in an aerial position) for 3 days, and then collected and identified the insects in the pitchers. We selected 50 individuals (25 aerial pitchers switched to terrestrial position and 25 terrestrial pitchers switched to aerial position). We examined the correlation between diameter of pitcher and height of pitcher above a ground, and tested hypothesis by chi-square tests and t-tests.

RESULTS

Prey spectrum of Nepenthes ampullaria and N. gracilis

From the pitchers of 80 individuals of *Nepenthes gracilis* and *N. ampullaria* it was found that flying insects were only captured in the aerial pitchers. Pitchers caught a diverse range of prey, including mites, termites, bug, thrips, and flies. The number of ants individuals captured was 1336, more than 90% of the prey (Table 1).

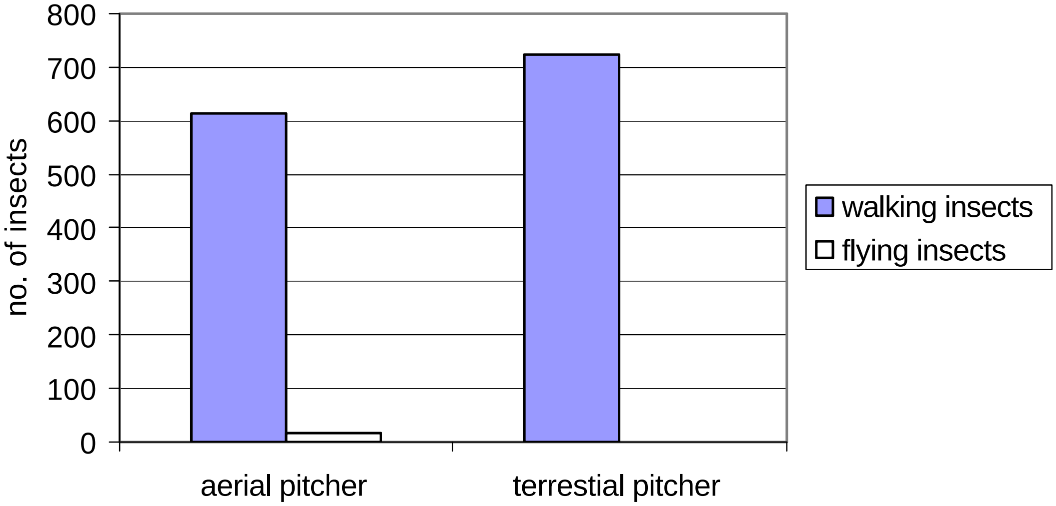

Fig 1 Number of insects in aerial pitcher and terrestrial pitcher

Table 1 Insects founded in pitchers

	Order	Number of individuals
	Hymenoptera	
1	Formicidae (Ants) *Componotus* sp.	1221
2	*Polyrachis* sp.	115
	Isoptera	
3	Termites	16
	Hemiptera	
4	Bugs	1
	Thysanoptera	
5	Thrips	1
	Diptera	
6	*Chironomus* sp.	2
7	UK1.	2
	Orthoptera	
8	Grasshoppers	1
9	Other Mites	
	Zwickea sp.	1

Shape, position and a volume of fluid

The measurements of size support hypotheses that aerial pitchers have to less weight than terrestrial. The correlation of volume of fluid and pitcher length was highly significant (Fig 2; r^2=0.490, n=80, *p*=0.0001). The correlation of volume of fluid and pitcher diameter was highly significant (Fig 3; r^2=0.338, n=80, *p*=0.002). The negative correlation of volume of fluid and height was highly significant (Fig 4; r^2=-0.284, n=80, *p*=0.01).

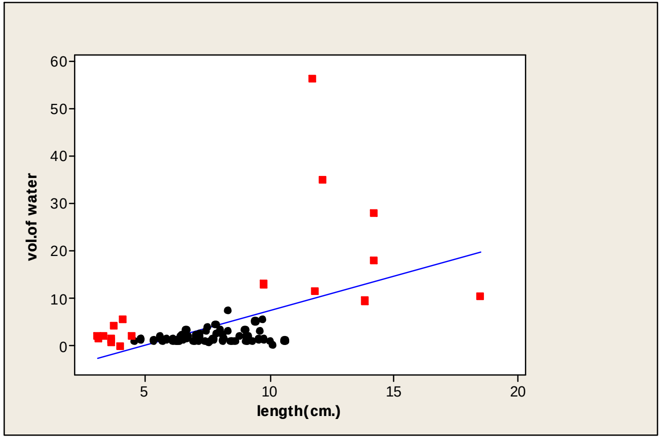

Fig 2 Correlation between volumn of fluid (ml) and pitcher length (cm)
• *N. gracilis*🟥 *N. ampullaria*

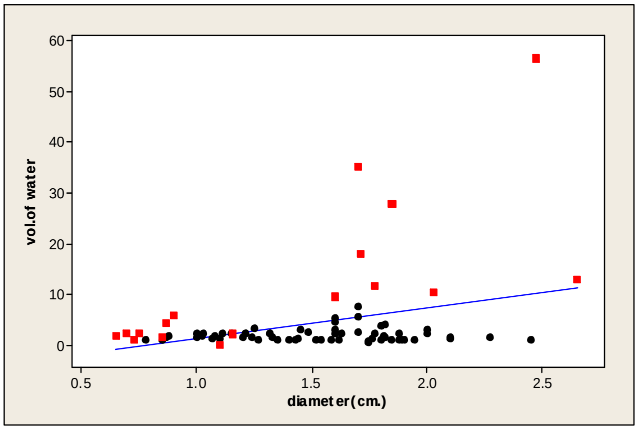

Fig 3 Volumn of fluid vs pitcher diameter (cm) • *N. gracilis*🟥 *N. ampullaria*

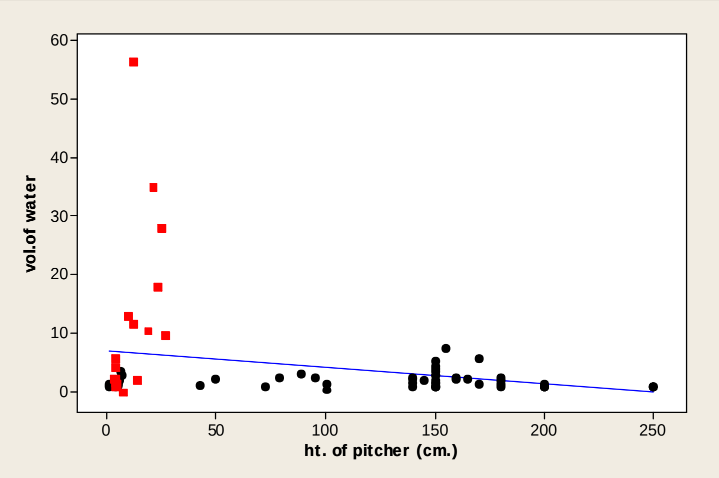

Fig 4 Volume of fluids (ml) vs pitcher height (cm) • *N. gracilis*■ *N. ampullaria*

In case of *N. ampullaria*, they have a rosette habit, meaning the volume of fluids depends on the size of pitchers, but for *N. gracilis*, which have a climber habit, the pitcher cannot carrry a high volume of fluids. In Fig 4 the volume decreased with increasing height, because they have to reduce size of pitcher as it grows on a tree.

Variation of size of pitchers
N. gracilis occurred in both study sites and we tested variation of diameter and length of pitchers by t-test. In the case of diameter, in forest edge (1) mean diameter=1.306±0.064 and in secondary forest(2) mean diameter=1.724±0.05 (N=63, *p*= 0.0001; Fig 5)

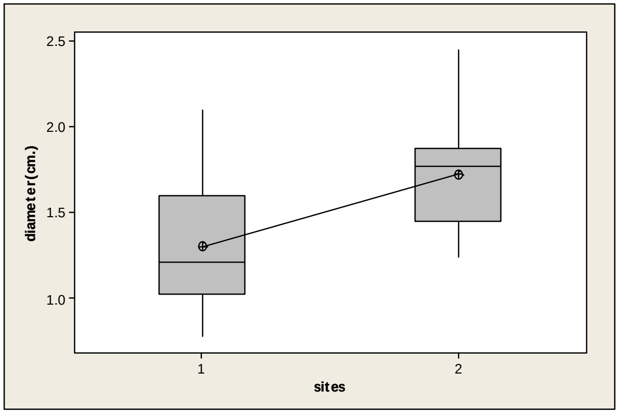

Fig 5 Boxplot of pitcher length (cm) in *N. gracilis* by sites

For pitcher length in *N. gracilis* forest edge (1) =7.10±0.28 cm and in secondary forest (2)= 8.08±0.22 cm (n=63, *p*=0.008; Fig 6).

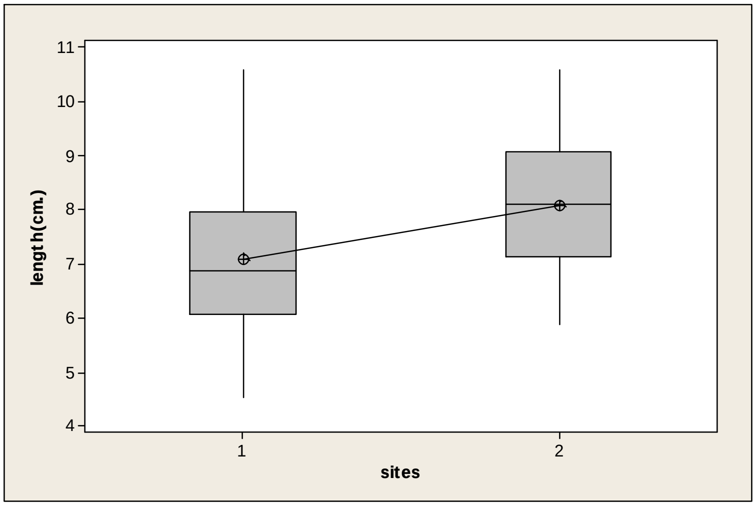

Fig 6 Boxplot of pitcher length (cm) in *N. gracilis* by sites

Efficiency of trapping
For our hypothesis that flying insects occur more in aerial pitchers, the results were highly significant (Table 2). It means the type of insects caught were different between aerial pitcher and terrestrial pitcher.

Table 2 Chi-Square test for compare capturers between aerial pitcher and terrestial pitcher

		Walking insects	Flying insects	Total
Aerial pitcher	Observed	614	16	630
	Expected	620.25	9.45	
Terrestrial pitcher	Observed	0.094 722	6.942 2	724
	Expected	714.38	9.62	
		0.081	6.040	
Total		1336	18	1354

Chi-Sq=13.157, DF=1, *p*=0.0001

The diameter and length of pitcher were not, or only marginally, significantly correlated with number of flying insects (diameter, r=0.235, *p*=0.04, Fig 7; length 0.291, *p*=0.687, Fig 8). But the height of pitcher show highly significant correlation (r=0.291, *p*=0.001, Fig 9).

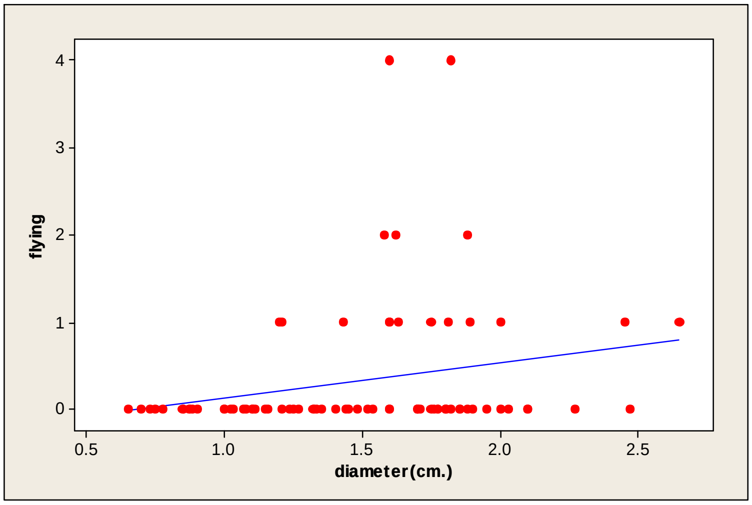

Fig 7 Correlation between number of flying insects and diameter of pitcher

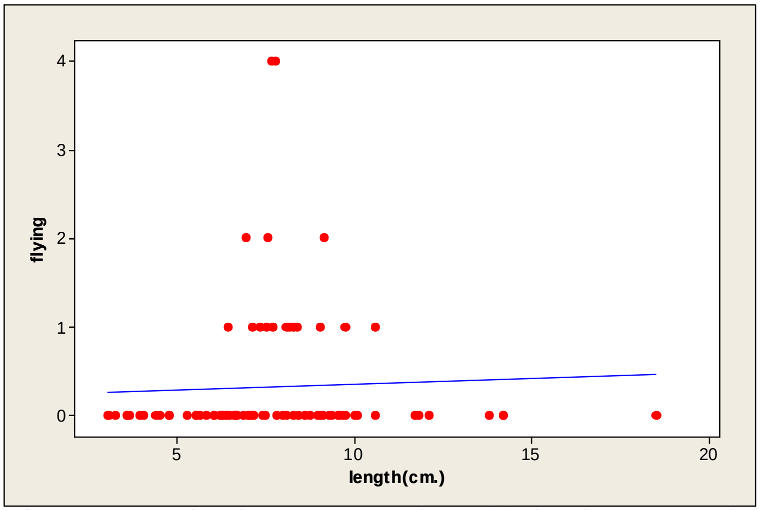

Fig 8 Correlation between number of flying insects and length of pitcher

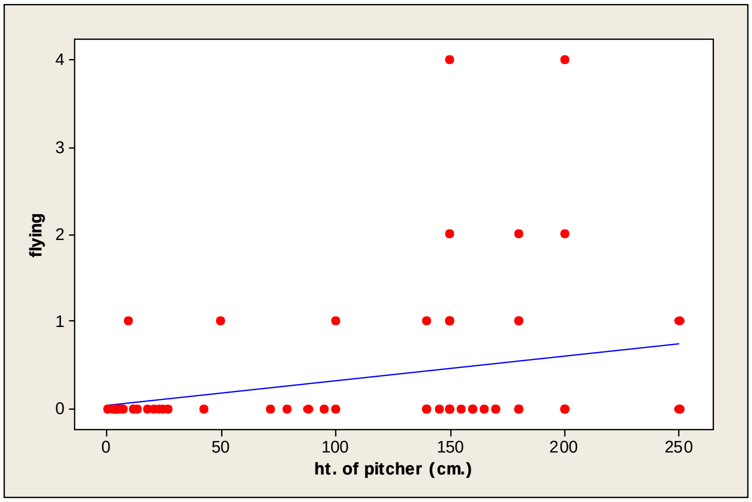

Fig 9 Correlation between number of flying insects and height of pitcher

In the experiment inversing the position of pitchers, we founded only ants in both types of pitcher (mean number 1.88±0.4; 3.0±2.4). The number of insects was not significantly different between treatments (T-Value=-0.53 *p*=0.609, Fig 10).

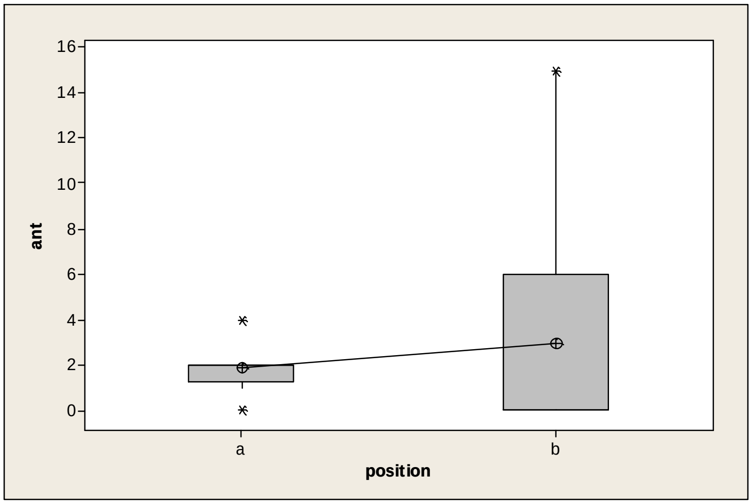

Fig 10 Mean number of insects (all ants) by treatment

Mosquito not a prey in pitcher

Mosquito and midge larvae which habitat pitchers usually lay their eggs in newly opened pitchers. Aerial pitchers caught more flying insects, but mosquitoes lay eggs in both pitchers (Fig 11). The height of pitcher was not correlation to number of Mosquito larvae (r=0.151, *p*= 0.180).

DISCUSSION

In general, *Nepenthes* plants are vines with thin stems and long, narrow leaves. The stems are usually unable to support the full weight of the plant, and depend on adjacent plants for support. When growing on open ground, the stems are usually decumbent, but will attempt to climb whenever they come into contact with any object that might support them. Stems may attain lengths of over 20 m, but most tend to be 2-5 m on mature plants. The stems vary substantially in form among different species, being cylindrical, winged, or even square in cross-section. Stems may be hirsute or glabrous, and any shade between light green and drake red in colour. The leaves are produced singly, never in whorls. Just above the point where each leaf joins the stem is a node. This contains a dormant meristem, which may be activated if the stem above is broken off. The dormant state of the nodal meristem is governed by negative feedback processed in most plants, in which the apical meristem produces hormones which inhibit the activity of other nodes lower down the stem. This phenomenon is referred to as apical dominance. When apical dominance is removed, the hormones which prevent meristematic activity in the nodes are no longer produced, and the nodes become active. A dormant node appears as a small nodule in shallow crevice on the stem, usually up to 1 cm above the leaf base on most mature *Nepenthes.*

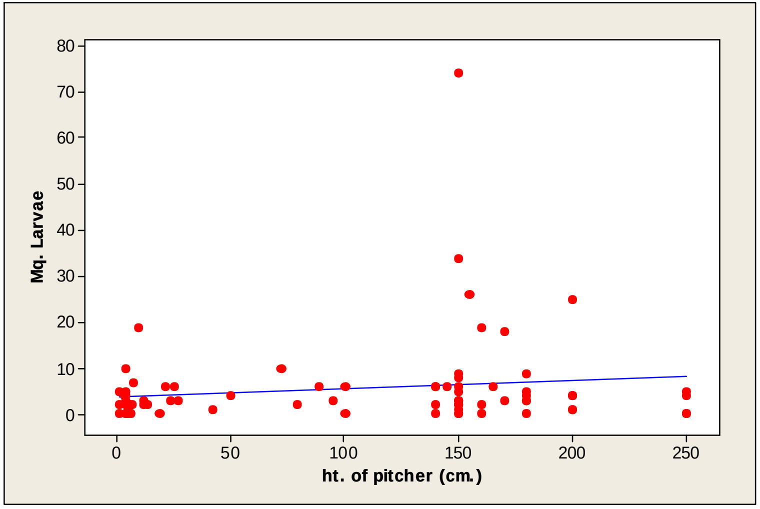

Fig 11 Correlation between number of Mosquito larvae and height of pitcher (cm)

Not all *Nepenthes* plants grow in exactly the same way. Two different strategies have evolved. Mature plants of many species have one or more main shoots, with no active nodes below the apex. Occasionally, new shoots are produced at the base of the plant which, in turn, may develop into large stems. Only if a large stem is broken, becomes very long or is damaged, will any of the sub-apical nodes become active. An alternative strategy, which is best observed in *N. ampullaria*, is for many nodes around the base of the stem to become active, producing very small leaves and clusters of pitchers (Jebb 1991; citied to Clarke 1997). Sometimes, nodes higher up the stem may do the same, resulting in occasional clumps of pitchers suspended beneath the forest canopy. Fully-developed leaves tend to be produced only on large stems, and few of these bear pitchers. Once again, the nodes which produce clumps of pitchers tend not to progress any further unless the apex on the main stem is damaged or removed for some reason.

In this study, the number of flying insects in aerial pitchers was significant different from terrestrial pitcher, meaning position is a major factor in determining trapping efficiency. If we concentrate on ants, species such as *Camponotus* sp. and *Polyrhachis* sp. were found in aerial pitchers more than terrestrial pitcher. Itino (1995) found *Camponotus* sp. and *Polyrhachis* sp. were more active in the understory than on the forest floor. Hence, pitcher position explains the difference in captures.

Moran (1996; cited to Clarke 1997) suggested aerial pitchers are more attractive to insects than are terrestrial pitchers because of two attributes, fragrance and ultraviolet patterns. In our opinion, these factors are less important than position because terrestrial pitchers are not different in these factors.

Although *Nepenthes* pitchers all share the same basic structure, they vary a great deal in size, shape and colour. This diversity is useful in identifying different *Nepenthes* species. At the top pf the pitcher is the lid. These come in a variety of different shapes and perform two main functions. The first is to assist in attracting insects to the pitcher. This is achieved using various combinations of bright colour and nectar-producing glands. The lid is often the first part of the trap that flying insects come into contact with. It is important not only in attracting them, but inducing them to browse over other parts of the pitcher, and increase the chances of them being caught. The second function of the lid is to cover the pitcher mouth, so that rainwater does not dilute the pitcher contents. Without a lid, many *Nepenthes* pitchers would soon overflow with rainwater, losing the valuable nutrients in the pitcher fluid. There are however, a few species that have unconventional methods of obtaining their nutrients. In most *Nepenthes*, there is a spur at the junction of the lid and the neck of the pitcher. Its function (if any) is not know, but in some species it has a distinctive shape, making it a useful taxonomic character (Clarke 1997). Below the lid is the mouth of the pitcher. In nearly all *Nepenthes* species, there is a ridge of hardened tissue which runs around the mouth; called the peristome. This is often cylindrical in cross section, and consists of a large number of corrugations and teeth. The teeth point downwards into the pitcher, while the outer side of the peristome may be expanded or simply recurved. The development of the peristome varies greatly among species, and can be a useful distinguishing character. One role of the peristome is to trap potential prey items to enter the pitcher. It is very smooth and has nectar glands at the base of each tooth, which entice browsing insect to its inner edge, placing them in a precarious position. However, the main function of the peristome is to prevent captured prey from escaping from the pitcher. The overhanging teeth form a barrier to animals crawling up the pitcher walls, making escape difficult. The main body of the pitcher comes in a variety of shapes and sizes. Although the lid and the peristome are usually fairly uniform in structure, regardless of whether lower or upper pitchers are being produced, pitcher shape is generally variable. Lower pitchers are usually ovate or squat, and rest on the ground. They sometime contain large quantities of fluid. The funnel-shape upper pitchers are often smaller and less colourful than the lower ones. The most likely reason why upper pitchers are funnel-shape is that they need to be very light, as the plant could not support squat pitchers in the climbing stage. By having a narrow base, the amount of fluid they can accommodate is small and the attachment to the tendril is much stronger. Some *Nepenthes* plants produce intermediate pitchers during the transition in production from lower to upper pitchers. Intermediate pitchers, as there name suggests, are intermediate in shape and structure between upper and lower pitchers. They may have wings, be less funnel-shape than the former, but more funnel-shape than the latter, and have the tendril inserted at the side. However, the point of insertion of the tendril cannot be used when distinguishing between pitcher types. Some *Nepenthes* plants have one or both types of pitchers in which the tendril is always inserted at the side. Furthermore, the tendril is forced to the side sometimes when pitchers are produced in confined spaces, such as between rocks or against branches of trees. The fluid body usually occupies the lower 30% of the pitcher. Much of the fluid is secreted by the walls of the pitcher while it develops. An insect which loses its foothold on the surface above falls into the fluid. It is thought that wetting agents are secreted by the plant, helping to prevent struggling prey from swimming through the fluid and making it sink. Many struggling insects quickly become exhausted and drown, but others are able to reach the side, and climb the walls of the pitcher. Many of these are unable to ascend further, as they cannot traverse the overhanging rim to the peristome. Eventually, they fall back into the fluid and drown. Other insects, notably some ants, have no difficulty escaping from pitchers. Feeding from the nectarines around the pitcher rim and lid, they often fall into the fluid, but within seconds they climb up the walls, over the rim and continue feeding.

CONCLUSION

1. A relation between pitcher shape and position was demonstrated. Upper pitchers were usually cylindrical shape while lower pitcher must be oval shape.
2. Aerial pitchers were more efficiency than terrestrial pitcher at trapping flying insects, because they have highly chances to attracting flying insects.
3. Most prey were ants (more than 90%) because ants feeding on the nectarines around the

pitcher rim and lid often fall into the fluid.

4. Mosquito larvae were found in all pitchers, but no mosquitoes were caught in pitchers. Some mosquitoes and flies are apparently able to climb the walls without any difficulty.

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Sustratum specificity in fungi

Shirmilee Iresha Rajapakse & S.H. Bandumala

INTRODUCTION

Lowland rain forests in South East Asia enjoy a warm and humid climate through out the year. The diversity of fungi is one of the most spectacular elements of these forests. Fungi breakdown the dead wood and fallen litter allowing the recycling of both simple and complex compounds, which is vital to the ecology of the rain forest and to any plant community. Many fungi are economically important and on the forest floor form an intimate relationship with the roots of many trees to the extent that one cannot exist without the other. This relationship is known as micorrhizal association (Pegler 1997). However, fungi remain amongst the most poorly known elements. Estimates suggest there are as many as 1,600,000 species of which only five percent are described (Pegler 1997).

Fungi comprise either cell-units or, the vast majority, branching filaments. These filaments, called hyphae, bore through the substrate, secreting enzymes and decomposed products are re-absorbed. The hyphae lengthen and branch to produce mycelium. Reproductive hyphae grow upwards forming a fructification or fruitbody on which spores are produced. From these spores haploid hyphae grow and may give rise to asexual sporangia, which produce spores eventually. When haploid hyphae from two different fungal organisms meet sexual reproduction occurs through cell fusion.

Most fungi are saprophytes, feeding on dead and decaying material, or parasitic, feeding on living organisms without killing them (http://www.ucmp.berkeley.edu/fungi/fungilh.html). As fungi are dependent on dead or decaying material or other organisms, they may have evolved to very specialised growing surfaces. Species of fungi may grow on leaves, roots, fruits, twigs, trunks or on dead wood, leaves or on soil.

In this study substrate specificity of fungi was investigated. We examined the hypothesis that fungi are substrate specific; 1. specific to different substrates with respect to weight, 2. show colour variations with respect to habit; and 3. specific to certain status of substratum.

METHODOLOGY

Study site

Our study site was Lambir Hills National Park (LHNP, 40 º 20’ N, 1130 º 50’ E, 150-250 m a.s.l.), located 30 km south of the town of Miri in Northern Sarawak, Malaysia (Harrison R. D. *et al*, 2003). Lambir Hills National Park is approximately 6,500ha and consists two thirds of primarily lowland dipterocarp forest. The climate is perhumid with a mean annual precipitation of approximately 2700 mm, and monthly average precipitation ranging from 168 mm in July to 328 mm in November with infrequent minor droughts (Harrison R. D. *et al* 2003).

Data collection

Data collection was made from 07th August to 10th August 2004. We surveyed the area along the main trail to the waterfall from park headquarters. In addition two areas, approximately 300m^2 under the canopy was surveyed. The area covered included areas close to the stream. All individuals observed were recorded, (1) fungi species were identified or collected for identification using “The Larger Fungi of Borneo” by David N. Pegler; (2) size of the fungi (height and width); (3) weight and (4) the colour was noted. For each substrate the following data were recorded, (1) substratum as 1-live trees, 2-leaves, 3-logs, 4-twigs and 5-soil; (2) status of substratum scored as 1-starting to decay, 2-moderately decayed, 3-heavilly decayed, 4-clay, 5-leaflitter/organic matter or loam, and 6-sandy; and (3) size of the host (circumference of the host approximately).

RESULTS AND DISCUSSION

Two hundred and nineteen individuals were recorded and 113 species were found. Fungi were divided into seven groups as club fungi, fleshy fungi (agarics), bolets, puff balls, polyporus fungi, shelf fungi and cup fungi according to the fruit bodies they produce. The species that could not be identified were placed under the above mentioned groups with a reference number. Most species belonged to fleshy and poliporus groups (Fig 1). Abundance of species in different fungi groups decreased in the order club, cup, boletes, puff and shelf.

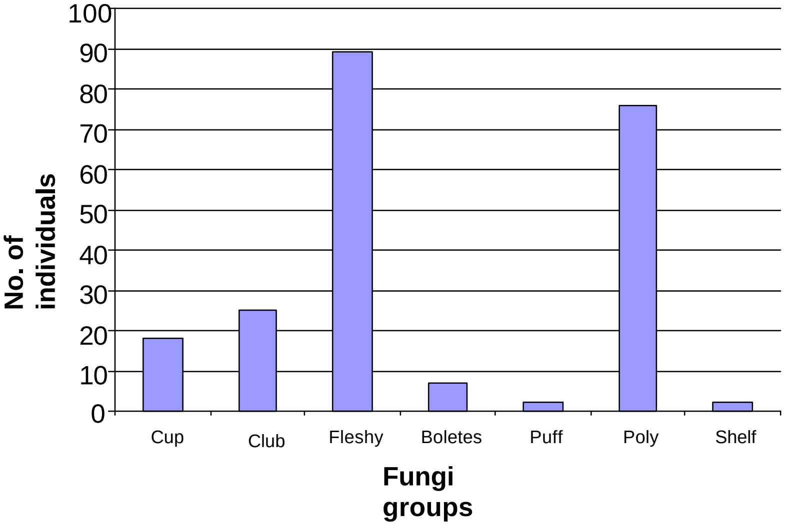

Fig 1 Distribution of individuals among fungi groups

The distribution of fungal groups on different substratums showed that different fungal groups preferred certain substrates (Fig 2). Fleshy and poliporus fungi occurred on all the substrates in abundance. Cup fungi were present in all the substrates, except live trees. Shelf and club fungi were restricted to two substrates, whereas puff fungi were found only on soil.

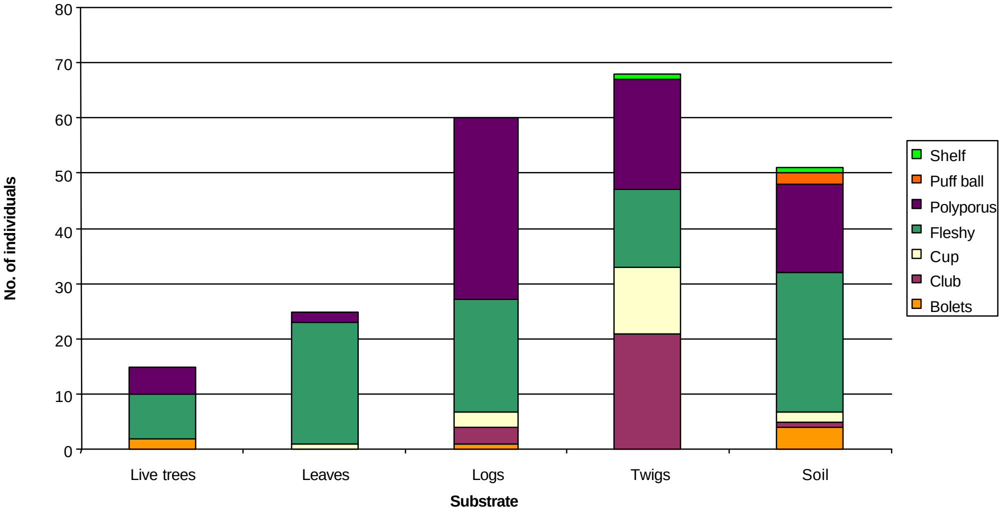

Fig 2 Distribution of fungi groups on different substrates

Considering species, most club fungi were mainly found on twigs (Fig 3).

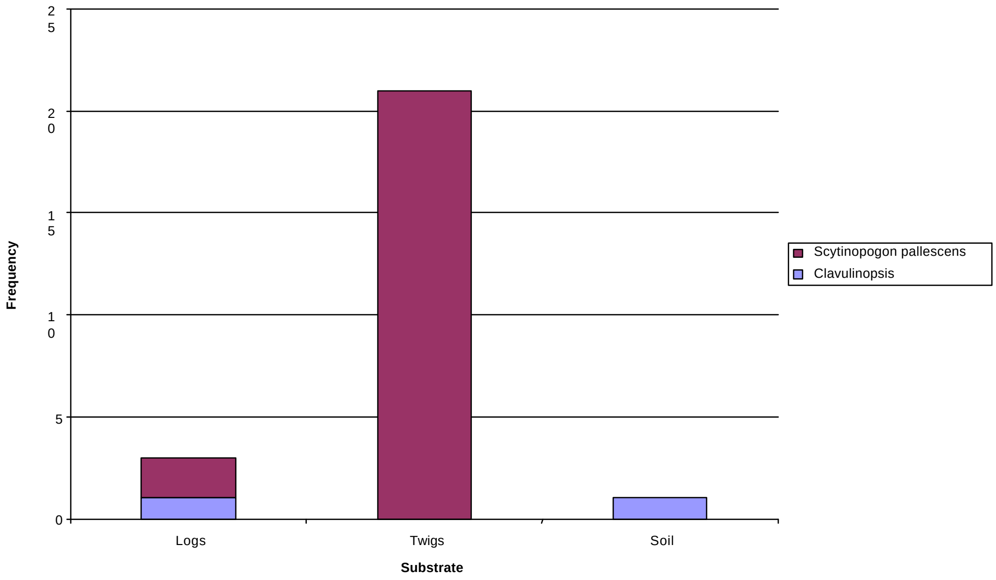

Fig 3 Substrate specificity among club fungi

Fleshy fungi were widely distributed on every substrate (Fig 4). Some species like *Marasmius crinisequi* were found exclusively on leaves. Generally fleshy fungi were more abundant on soil followed by leaves, logs and twigs.

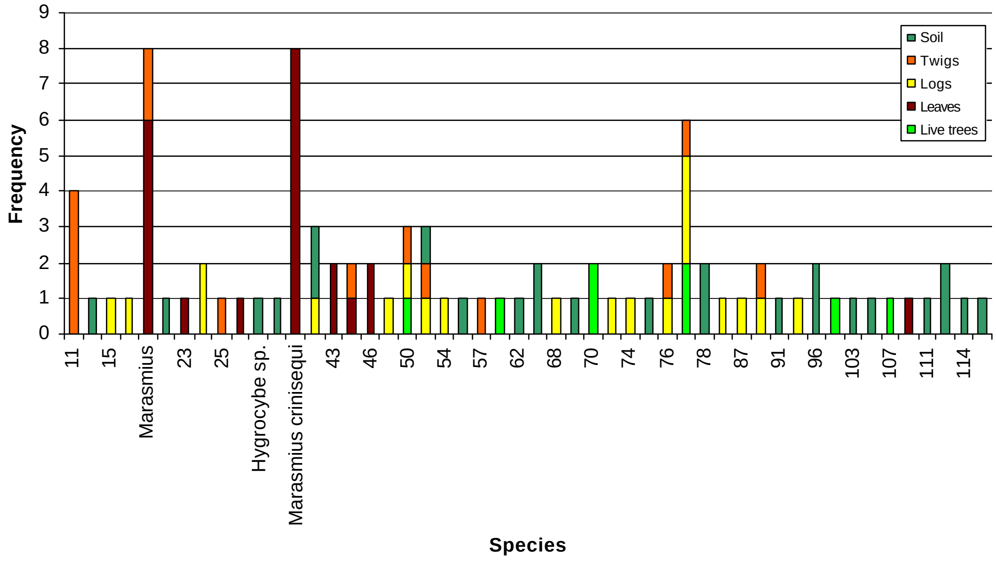

Fig 4 Substrate specificity of fleshy fungi

Most bolets were found on soil (Fig 5).

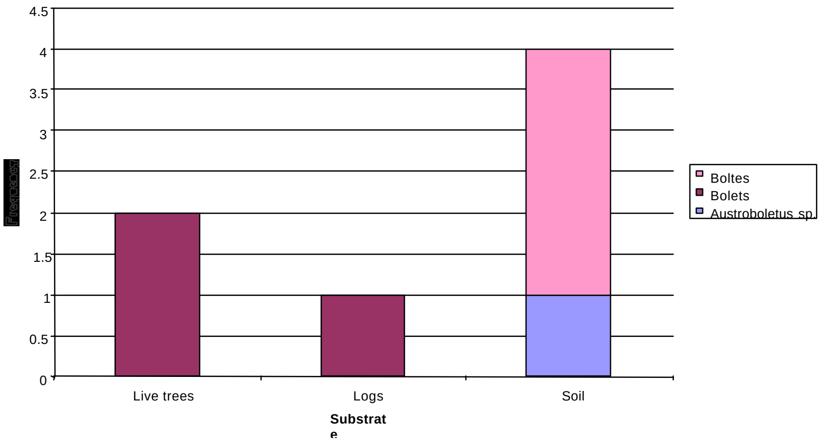

Fig 5 Substrate specificity of bolets

Regarding polypores (Fig 6), *Amauroderma perplexum* was found only in soil, living on buried roots. *Microporus xanthopus* was specific on twigs, mostly on moderately decayed twigs.

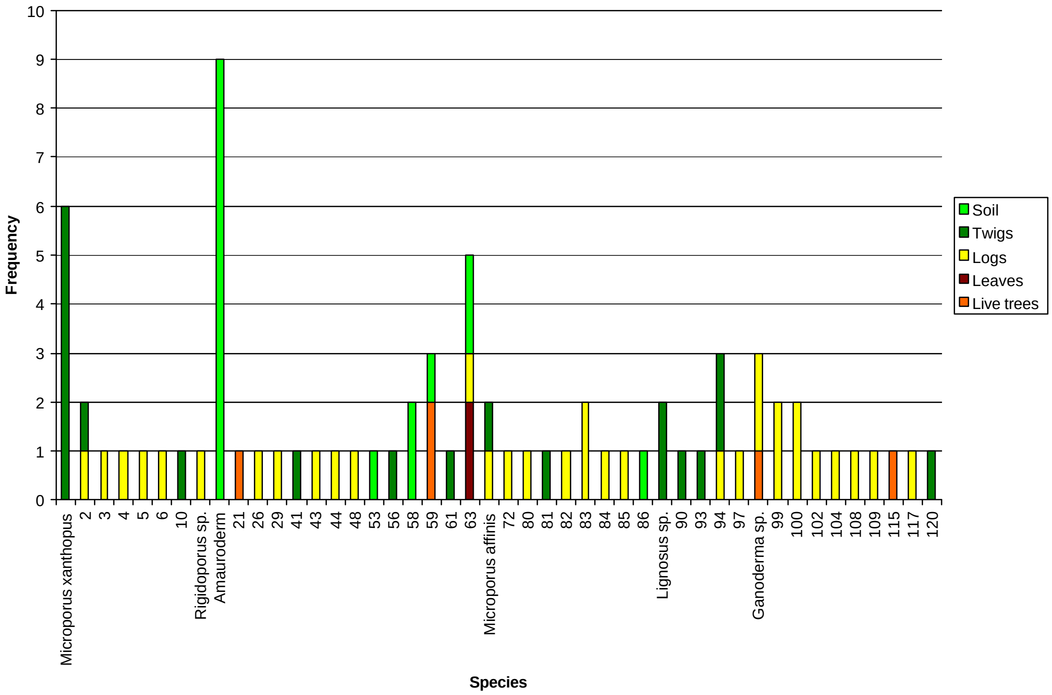

Fig 6 Substrate specificity of polyporus fungi

Cup fungi were mainly found on twigs, especially *Cookeina* which were found on moderately decayed twigs (Fig 7).

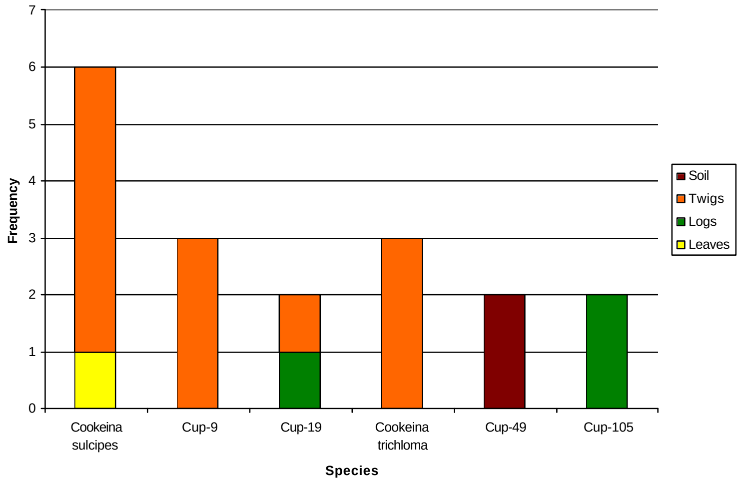

Fig 7 Substrate specificity of cup fungi

Weight

The weight distribution of fungi clearly shows that different fungi groups are specific on different substrates (Fig 8). The polypores which are heavier were dominant on live trees and logs, where fungi with lower weight were specific on leaves and twigs.

The polypores have developed an alternate means of overcoming desiccation in a land based environment unlike club, fleshy, bolets and puff balls, which produce simple short lived fruit bodies. They are able to survive for several years producing a new layer of spore producing surfaces. They have evolved in such a way to elevate themselves above ground level guaranteeing a continuous supply of food material (Pegler 1997). Our results clearly support Pegler's views on polyporus fungi.

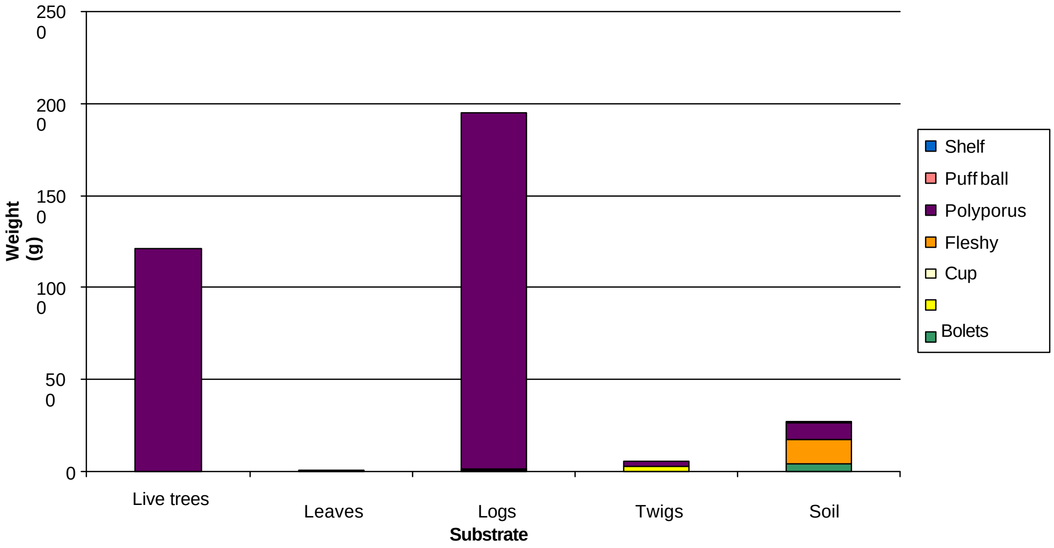

Fig 8 Weight distribution of fungi on different substrates

Colour

It was observed that the predominant colours of fungi are of shades of brown, orange and red. The above coloured fungi were present in all substrates (Fig 9). Even though a relationship between substrate specificity and colour of fungi was not proven, colouration may be due to attraction of insects for spore dispersal.

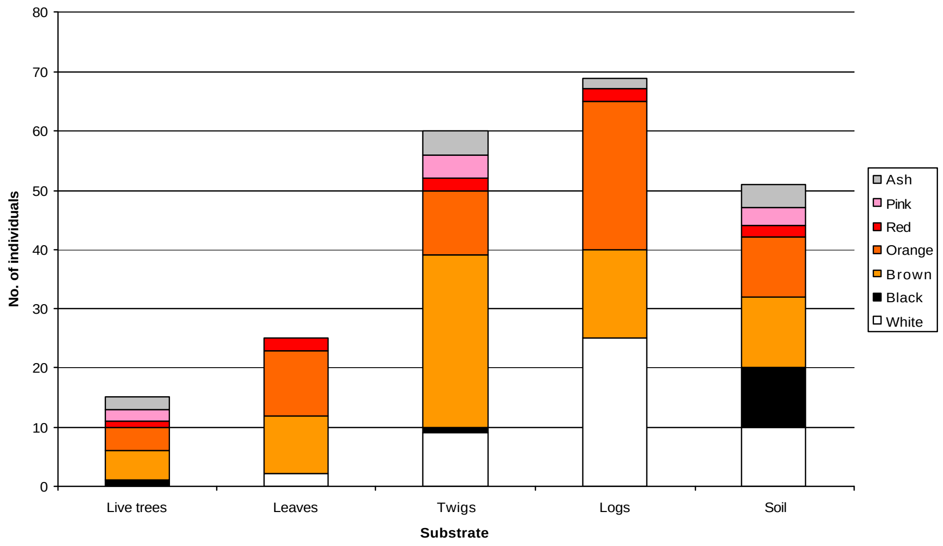

Fig 9 Colour variation in fungi population

Status of substratum

It was evident that most fungi prefer moderately decayed substratums, followed by heavily decayed (Fig 10). Puff balls were restricted to clay/loamy soil.

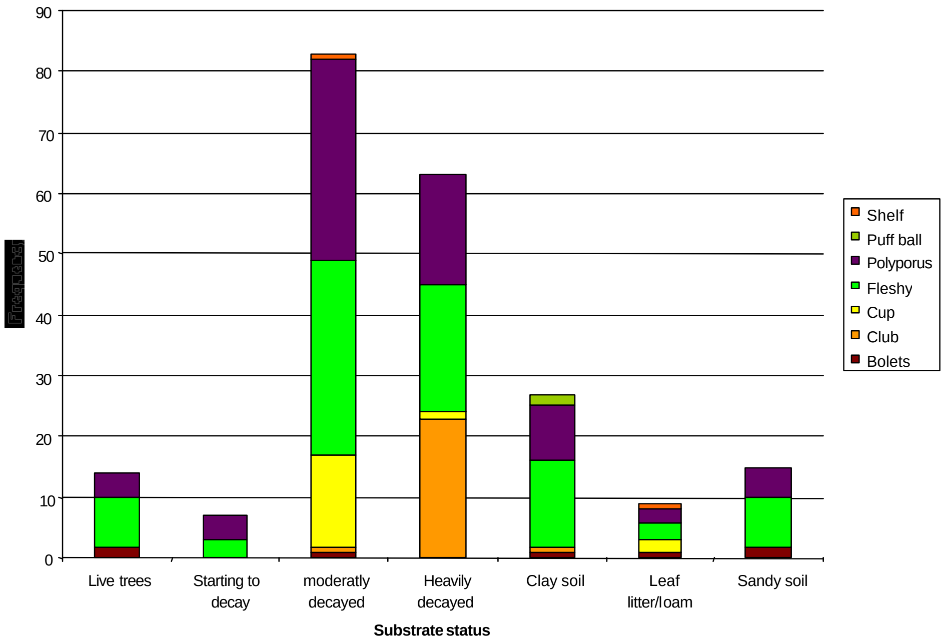

Fig 10 Specificity of fungi on substrate status

CONCLUSION

In this study we found 219 individuals belonging to 113 species, out of which 9 were identified to species level and 11 to generic level. In the rain forest, it is unlikely that more than one in ten species of the larger fungi can be recognised by name (Pegler 1997).

The fungal groups (club, fleshy/agarics, bolets, puff balls, polyporus, shelf and cup fungi, classified according to the fruit bodies) were found on different substrates as live trees, leaves, twigs, logs and soil. According to the study, fleshy fungi were the most abundant group, followed by polypores. Abundance of shelf and puff fungi were minimal. The study showed that fungi prefer certain substrates, such as puff fungi on soil, *Amauroderma perplexum* in soil living on buried roots, *Microporus xanthopus* specific on twigs, and *Marasmius crinisequi* exclusively on leaves.

The weight distribution of fungi clearly showed a correlation to different substrates. The polypores which are heavier were dominant on live trees and logs, where fungi with lower weight were specific on leaves and twigs.

A relationship between substrate specificity and colour of fungi was not evident, but colouration may be due to attract insects for spore dispersal.

Most fungi preferred moderately decayed substratums, followed by heavily decayed.

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Comparison of recruitment in *Macaranga* and *Musa* in fire and tree-fall gaps

Raffae Ahmad & Zahid Mat Said

INTRODUCTION

Lambir Hills National Park is a small fragment of primary forest set in a matrix of palm plantations and slash-and-burn cultivation (Harrison 2001). From January to April 1998, northern Borneo suffered a very severe drought linked to the El Nino Southern Oscillation event of 1997–1998. During this drought fires entered the edge of the forest from the roadside (Harrison 2001). All saplings up to approximately 20 cm diameter were killed from the scorch damage ringing the bases of the trees. Larger trees also burnt, especially if a rotten root or split trunk provided fuel to ignite the trunk but most large trees were not affected. The area has since been invaded by self-seeding banana plants (Harrison 2001).

The condition of the forest understorey is normally damp, so that in primary forest areas, fires are only associated with the most severe drought. Major disturbances such as forest fires leave a big impact and form a big gap in the forest and tropical forest species differ in the extent to which gaps are required for successful regeneration. In reality, the canopy is in a continuous state of flux, with gaps developing from many causes, and varying in size from tiny to huge (Whitmore 1991). The ensuing differences in light, moisture and temperature between undisturbed forest and the newly created gap environment play a crucial role in influencing species establishment.

Pioneer species germinate from seed after gap creation and the seeds may be dispersed after the gap formation, or may already present in the soil. Symington (1933) reported an experiment that he had placed some forest soil in the open and observed germination of pioneer species from it. Keay (1960) repeated the same experiment and found the same results. Indeed, wherever a soil seed bank has been sought under a lowland rain forest one has been found.

Seed physiologists have discovered that pioneer species have seeds that can withstand desiccation and then become dormant. They have called this behaviour ‘orthodox’ (Whitmore 1991). The dormancy of the seeds of tropical pioneer species has been shown to be broken by one or two features of gap microclimates. As reported by Whitmore (1991), species are triggered to germinate by exposure to light in which the energy of the red (660 nm) wavelength exceeds the far-red (730 nm) and some species have seeds triggered to germinate by either high temperature, or by alternating high and low temperature. Whitmore (1991) also mentioned that in parts of the Neotropics, stands of *Ochroma lagopus* develop where burning has followed forest clearance. It has been shown that the seeds of *Ochroma* have impermeable layer in the testa, which is ruptured by heat to allow the seeds to imbibe water and germinate. Whitmore (1991) also pointed that he expected germination in response to high irradiance or to a pulse of nitrate, both known from temperate species. Like prolonged white light or high temperature, these cues are also likely to be provided by gaps.

Soil seeds banks normally contain many species, small samples (2 m^2 x 50 mm deep) from six different forest in Ghana contained from 17 to 38 species each, nearly all of them pioneers (Whitmore 1991).

Pioneer species are called light-demanders with reference to their seedling requirements for high solar radiation. Sometimes they are also called secondary species because they form secondary or regrowth forest on cleared surfaces. A big gap is sometimes simultaneously colonized by pioneers of different mature height, for example in Central America *Cecropia*, *Ochroma* and *Trema* may colonize with *Cedrela*. To start with the small species dominate but as they die the bigger long-lived pioneers come to dominate (Whitmore 1991).

Pioneer species, as a class, have a whole syndrome of characters, which fit them to their ecological niche. Pioneer species have an aggressive lifestyle. They produce a large volume of low density wood by fast growth, with open-branched crowns whereby they rapidly pre-empt competition by filling a large space. They start to reproduce early and produce copious seeds frequently, which are small and easily dispersed. Growth is opportunistic. Leaves are short-lived and, as their efficiency diminishes with age, their nutrients are recycled to fresh flushes, so there is no need to invest in mechanical and chemical protection against herbivores.

There are also speculations of how pioneer species coexist in gaps by specializing to different facet of the regeneration niche, thus avoiding direct competition. For example *Trema tomentosa* in Penang, Malaysia establishes preferentially on root plates (Raich 1987). It has also been shown that different species successfully establish seedlings in different parts of the gaps, the crown, trunk or butt regions (Brandani *et al.* 1988)

The objective of this project was to investigate the succession of *Musa* and *Macaranga* in the fire and tree-fall gaps at the Lambir Hills National Park.

METHODOLOGY

The field survey was conducted in a lowland mixed dipterocarp forest in Lambir Hills National Park (4° 2'N, 113° 50'E, altitude 60 m), Miri, Sarawak. A site from behind the Japanese laboratory to the canopy walkway and a site just before the entrance to the 52-ha plot, by the road side, were chosen as fire gaps and three tree-fall gaps around the Canopy Biology Plot, with different size and age were chosen. The data collection was made from 7 to 11 August, 2004. For each gap three transects were laid out. We also laid out transects in primary forest at one site. Further sites were not possible due to the time constraint. Soil samples were collected at three points along the transect (20 cm x 10 cm x 5 cm). The soil samples were taken back to the laboratory and number of seeds of *Macaranga* and *Musa* were counted. The number of saplings (below 1m height) and adult *Macaranga* and *Musa* along the transect (30m long and 2m width) were counted. Data were analyzed using a Minitab 14 (Two Sample T-Test)

RESULTS

The total number of *Macaranga* seeds found in fire gaps was 59 compared to 67 of *Musa*. The mean value for *Macaranga* was 6.56 and mean value for *Musa* is 7.33 (Fig 1). The analyses showed that there is no significant difference (p = 0.614) in the number of seeds of these taxa in fire gaps. However, in tree-fall gaps there was a significant difference (*Macaranga* mean 9.11 seeds and *Musa* mean 3.56 seeds, $p < 0.01$). The seed comparison of *Macaranga* and *Musa* in the primary forest without gap was also not significant.

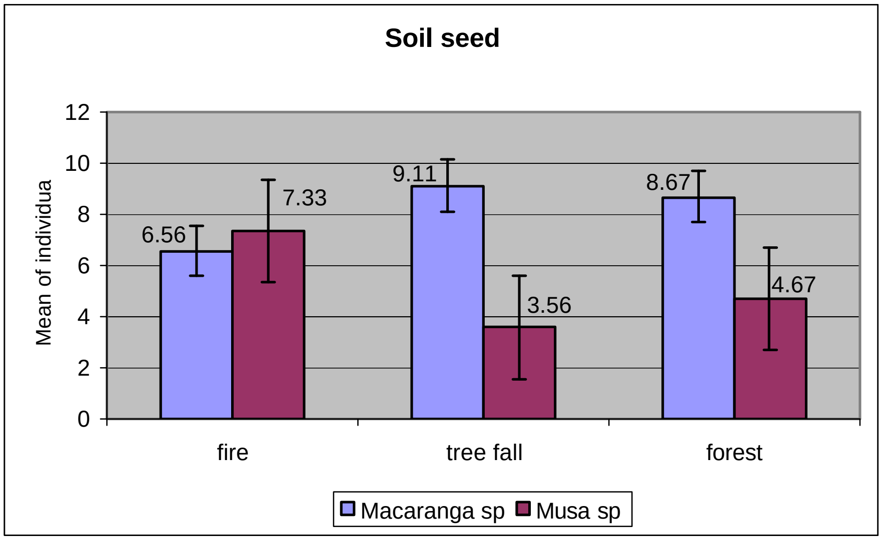

Fig 1 Number of seed in different types of gap and primary forest.

Fig 2 shows the number of *Musa* and *Macaranga* saplings in the three habitats. Fire gaps had more *Macaranga* saplings, 230 individuals *vs Musa* with only 61 individuals. Mean number of saplings for *Macaranga* was 25.6 and for *Musa* was only 6.8. The difference was significant (*p* < 0.011). In tree-fall gaps, the number of *Macaranga* sapling was 131 and *Musa* saplings was 31. The mean number of *Macaranga* saplings was 15.67 and the mean number of *Musa* saplings was 3.44. Again the result was significant (*p* < 0.002). In the primary forest without gap only two *Macaranga* and one *Musa* saplings were found. Again, this data was obtained from only one site.

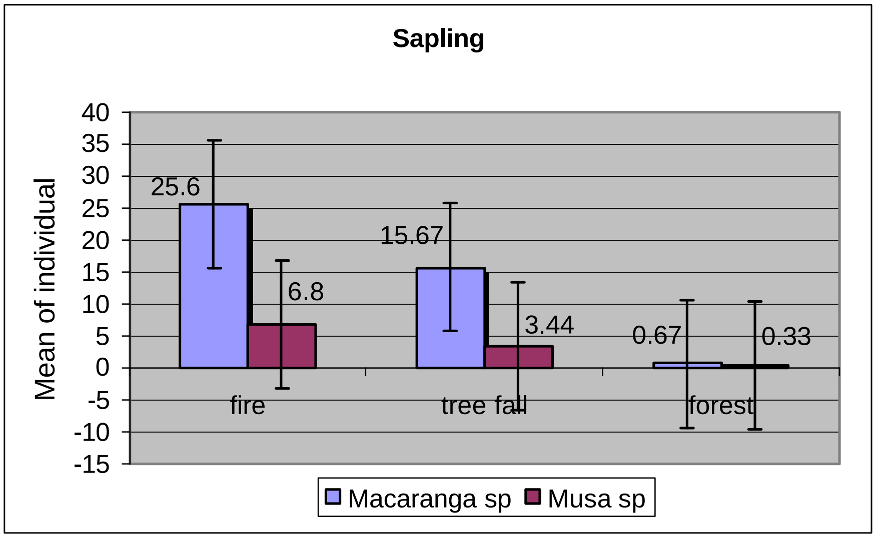

Fig 2 Number of sapling in different types of gap and primary forest.

In fire gaps the number of *Musa* adult plants was higher than the *Macaranga* adults, with a mean value for *Musa* of 16.33 and for *Macaranga* of 14.13. However, this was not significantly different (*p* = 0.536). In tree-fall gaps, the number of *Macaranga* adults was almost three times more than *Musa*. The mean number of *Macaranga* adults was 2.56 and of *Musa* adults was 0.67 (*p* = 0.001). In the primary forest without gap, we still found *Macaranga* and *Musa* adults, although numbers were low.

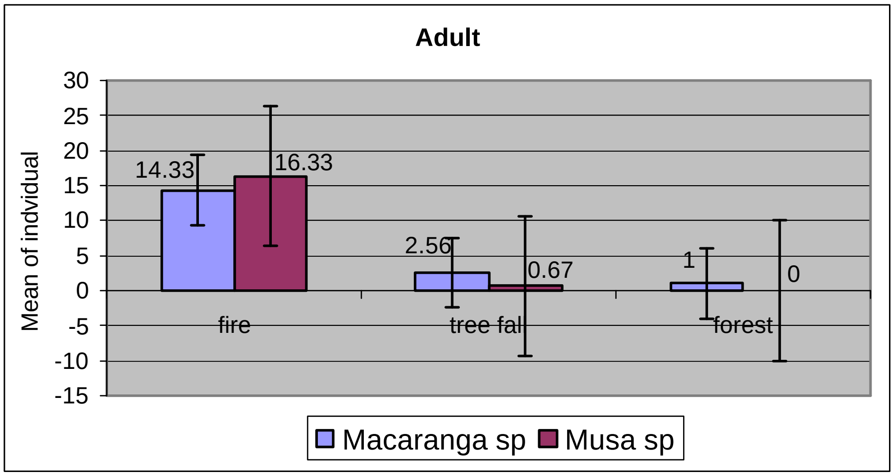

Fig 3 Number of adult in different types of gap and primary forest.

DISCUSSION

Our result showed that there is no limitation in the seed dispersal of *Macaranga* and *Musa* i.e. their seeds are found almost everywhere in the forest, and not only in the gaps, and both *Macaranga* and *Musa* had a large number of seeds in the soil seed bank. However, the number of viable seeds from the soil seed bank remains unknown. The soil seed bank is also a good record or archive of pioneer trees that formerly occupied the site. Despite good adaptation to dispersal many seeds are likely to fall below or near the parent tree. There was no significant difference in the number of *Macaranga* and *Musa* seeds in the fire gap. This could be due to the fact that the number of adult plants of *Macaranga* and *Musa* were almost the same. The primary forest floor also harboured a number of *Macaranga* and *Musa* seeds, although the number of *Macaranga* seeds was just slightly higher than that of *Musa*. However, the limited number of transects in the primary forest restricts our discussion. The seeds of *Macaranga* and *Musa* are only few millimetres diameter, with *Macaranga* seeds being round and *Musa* seeds irregularly shaped. Both seeds were covered with hard testa, being a typical seed's of pioneer species.

The numbers of *Macaranga* and *Musa* saplings were significantly different in fire gaps. *Macaranga* had more saplings compared to *Musa* in the fire gap. This is an interesting result given that the number of seeds and adults of both species were not significantly different. One possibility is that the site condition is no longer conducive for the growth of *Musa* saplings. We could speculate that *Musa* has not recruited many new seedlings when compared to *Macaranga*, and this could also mean that the population of *Musa* is not being maintained and that *Macaranga* should dominate the fire gap in years to come. However, in the tree-fall gap, the number of *Macaranga* saplings was also much higher than the *Musa* (p= 0.002). This would mean that *Macaranga* is more successful as a pioneer in the tree-fall gap compared to *Musa*. This is not surprising because it is already known that *Macaranga* is a very successful and dominant in tree-fall gaps due to adaptation and good strategy as a pioneer species (Davies 1998, Fiala *et al.* 1999, Hatada *et al.* 2001). The numbers of *Macaranga* and *Musa* saplings in the primary forest were not significantly different, although this result may be questionable, as neither *Macaranga* nor *Musa* survive in deep shade conditions in primary rain forest, although some species of *Macaranga* are known to be shade tolerant. We may have chosen a site that is not a typical of primary rain forest, with some light penetrating to the forest floor and promoting the growth of *Macaranga* and *Musa* saplings.

The number of adult of *Macaranga* and *Musa* in the fire gap was not significantly different, even though the number of *Musa* was slightly higher than *Macaranga*. This would be expected if there were the early colonization of *Musa* in the fire gap. The number of *Macaranga* adult plants was significantly higher than *Musa* in the tree-fall gap. This is again telling us the success of *Macaranga* compared to *Musa* as pioneer in the tree-fall gap. However, the number of adult *Macaranga* in the tree-fall gap is lesser than in the fire gap. This may be because of the greater magnitude of gap in the fire gaps than tree-fall gaps. The availability of other species seed and sapling is much higher in tree-fall gaps because they are surrounding by primary forest. The adults plant of *Macaranga* and *Musa* in the primary forest could be misleading information due to fewer transects compared to other sites. Normally it is not possible to see adult *Macaranga* and *Musa* in the primary rain forest without gap disturbance.

As for the succession in the fire gap, we could see other evidence that *Macaranga* is going to dominate and the *Musa* population decreasing, such as *Macaranga* overtopping *Musa*. We observed in some cases that *Macaranga* had grown taller and formed a canopy and below the canopy either the old *Musa* clumps were dying or no *Musa* saplings were observed. The biology of *Musa* also will not allow it to make a successful pioneer for a longer time. We, however, could not speculate on the why *Musa* being so dominant at the early succession of fire gap but not in the tree-fall gap? Several hypotheses could be drawn such as *Musa* seeds germinate after fire, or *Musa* seeds are not killed by fire but *Macaranga* seeds are. We also could speculate that the germination of *Musa* needs a severe disturbance such as a large gap, heat and other harsh conditions.

CONCLUSION

There is no seed dispersal limitation of *Macaranga* and *Musa* in the forest. *Macaranga*, although not dominant at the early stage of succession in the fire gap is becoming vigorous. There is lower sapling recruitment of *Musa* in the fire gap and the population is not being maintained.

ACKNOWLEDGEMENTS

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Comparison of medicinal plants among forest types

Endela Tipot & Siti Nurasmah Abu Samat

INTRODUCTION

Most of today's indigenous people in Borneo descend from later immigrants arriving from Cambodia-Vietnam area, around 10,000 years ago even though the earliest evidence of human beings in Borneo dates back 39,000 years (Chin et al. 1991). They were hunters and gatherers and only more recently did they settle down as shifting cultivators. Some form of primitive agriculture or selective use of plants leading to 'wild gardens' is believed to have existed in Borneo for the last 5,000-6,000 years (Hutterer 1948). Indigenous people possess and practice their own unique traditional knowledge to utilize and maintain the forest and are highly dependent on various types of plant for fulfilling the needs of their daily lives. These plants come from the primary forest, young and old secondary forests, rice fields and home gardens.

Plants have been recognized as a major component in traditional medicine. One of the reasons is that plants are readily available and are much cheaper compare to pharmaceutical medicines. In the early days, plants were used by medicine men, midwives and also religious men to treat sick people. In Malaysia, particularly in Sarawak, vast numbers of plants are used for medicinal purposes. Species commonly used for traditional medicines are from the families such as Zingiberaceae, Menispermaceae, Lauraceae, Rubiaceae, Annonaceae, Leguminosae, and Clusiaceae. It is generally assumed that Sarawak's many indigenous cultures possess a great diversity of ethnobotanical knowledge (Christensen 2002). Medicinal plants study is very interesting as it connects the study of pure biological science to human socio-economy. However, this subject has been seen as most ignored in plant studies.

This study was carried out as a project assignment for International Field Biology Course (IFBC) 2004, which was held at Lambir Hills National Park (LHNP). LHNP is located between 4^{o}10'N, 113^{o}57'E and 4^{o}15'N, 114^{o}6'E and has an area approximately 6800 ha. The area is dominated by lowland Mixed Dipterocarp Forest with an altitude between 150-250 m a.s.l. Prior to this study, there was no record of medicinal plants and their uses from LHNP despite the many detail studies on plants being carried out in the park. The main objective of this study is to evaluate the frequency of occurrence of medicinal plants and types of uses in different vegetations of LHNP. Our expectation is that there are more medicinal plants in the secondary forest in terms of species number and uses.

METHODS

Study site

Two longhouses, namely Rh Aji Ak Keriong and Rh Bundan Ak Limpeng, were visited in order to record the plant names and their uses. The longhouses are located approximately 15 minutes drive from the park headquarters. Rh Aji consists of 72 doors while Rh Bundan has 58 doors. These two longhouses belong to Iban communities. Most of the people living in Rh Aji and Rh Bundan are farmers. They practice subsistence shifting cultivation, wet rice fields and other agriculture activities and they utilize the secondary forest near the park. From our observation, they are most likely still adhering to traditional practices, in which many activities and occasions are still closely related to the nature and unseen spirit.

Field surveys were conducted around Rh Aji and LHNP. Rh Aji is surrounded by mixed garden, grassland and open vegetation, young and old secondary forest and a small patch of primary forest.

Data collection and analysis

Six elders were interviewed in our visits to Rh Aji and Rh Bungan. In addition two knowledgeable staff at LHNP were also interviewed. Every plant mentioned in our interviews was recorded including local name, habit, habitat, uses and part of the plant used. A field survey at the longhouse area was carried out for one afternoon with one of the knowledgeable elders of Rh Aji as our key informer. Some of the plants that were mentioned in the interview were identified and recorded. Plant surveys were also carried out along the trail to Latak Waterfall and around the park headquarters area. In the trail areas both side of the trail of approximately 10m distances on each side were surveyed. All species of medicinal plants observed were recorded. All the data recorded were keyed into and analysed using Microsoft Excel 2000.

RESULTS AND DISCUSSION

A total of 91 species of medicinal plants from 47 families were recorded (Appendix 1). Most of the medicinal plants mentioned in the interviews were identified up to species level, except for *Alocasia* sp., *Garcinia* sp., *Gigantochloa* sp., *Cissus* sp., *Bauhinia* sp. and *Uncaria* sp. Our identification was made easier because there are similarities among the species used by many Iban communities in Sarawak. Leguminosae contribute the greatest number of species (9 spp.) followed by Dilleniaceae and Zingiberaceae (4 spp. each). The family Leguminosae was also used for more types of sickness including chest pain, cough, fatigue, gastrointestinal problem, mouth ulcer, skin problem, tooth problem and wounds. Twenty-two families had only one species recorded as being used as a medicinal plant.

Habitat

We used the term primary and secondary for plants found naturally in the primary and secondary forests while term cultivated was used for cultivated plants either at the house compound or garden. Plant habitat was divided into 6 categories namely primary, secondary, cultivated, primary and secondary, secondary and cultivated and finally primary, secondary and cultivated (Table 1). Twenty-six species or 28.57% of the total medicinal plants recorded were found only in secondary forest (19 families), 17 species or 18.68% cultivated (16 families) while only 10 species or 10.98% were recorded only from primary forest (11 families). Twenty-eight species or 30.77% were recorded to occur in both primary and secondary forest, 6 species or 6.59% were recorded from secondary forest and cultivated while only 4 species or 4.4% were recorded from primary, secondary forest and are cultivated.

Table1 Number of families, species, uses, habit and parts used for medicinal plants in different forest types

Habitat	Family	Species	Uses	Habit	Part used
Primary	11	10 (10.98%)	9	4	5
Secondary	19	26 (28.57%)	10	6	8
Cultivated	16	17 (18.68%)	11	6	7
Primary& secondary	15	28 (30.77%)	14	6	8
S’dary & cultivated	6	6 (6.59%)	4	3	3
Primary, secondary & cultivated	3	4 (4.4%)	2	2	3

Uses

Various types of sickness were recorded where different parts of plants were used. We grouped the uses of plants according to types of sickness they are used for and put them into 23 categories (Table 2). A total of 27 (29.67%) species of plants are used for treating gastrointestinal problem, followed by 11 (12.09%) species used for treating wounds and 8 species (8.79%) for the treatment of skin problems. Most of plant parts were also used for the treatment of gastrointestinal problem and skin problem. Certain sicknesses require a very specific plant. Only 1 species of plant was recorded as being used for the treatment of blood circulation, cancer, chest pain, hernia and urinating problem.

Table 2 Comparison between number of species and number of plant parts used for different categories of sickness (uses)

Category of used for	No. of species	%	No. of part used
Afterbirth treatment	5	5.49	4
Antidote	3	3.30	2
Asthma	2	2.19	3
Blood circulation	1	1.10	1
Cancer	1	1.10	1
Sting & bite	2	2.19	2
Chest pain	1	1.10	1
Cough	2	2.19	1
Energy	1	1.10	1
Eye treatment	5	5.49	3
Fatigue	5	5.49	2
Fever	4	2.19	2
Gastrointestinal problem	27	29.67	6
Headache	6	6.59	4
Hernia	1	1.10	1
High blood pressure	3	3.30	3
Internal bleeding	2	2.19	2
Mouth ulcer	2	2.19	2
Skin problem	8	8.79	6
Sprain	3	3.30	3
Tooth problem	4	4.26	4
Urinating problem	1	1.10	1
Wounds	11	12.09	4

Table 3 Comparison between numbers of species, uses and plant habit for plant parts that are being used

Plant part	No. of species	No. of uses	No. of habit
Flower	1	1	1
Whole plant	3	3	3
Fruit	4	3	3
Cabbage	5	5	3
Sap	7	5	3
Stem	10	7	2
Bark	13	7	1
Root	24	13	5
Leaves	30	15	6

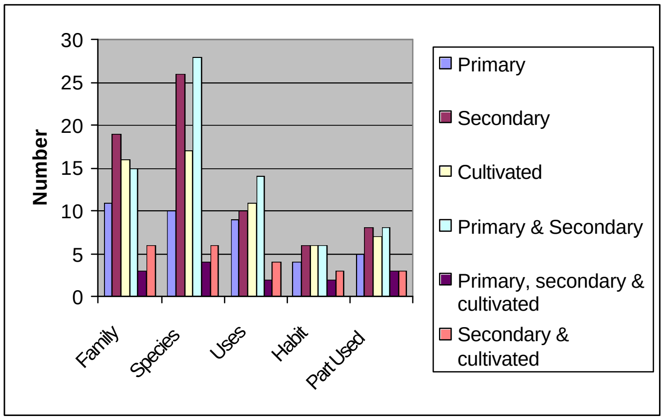

Fig 1 Number of family, species, uses and plant part in each habitat

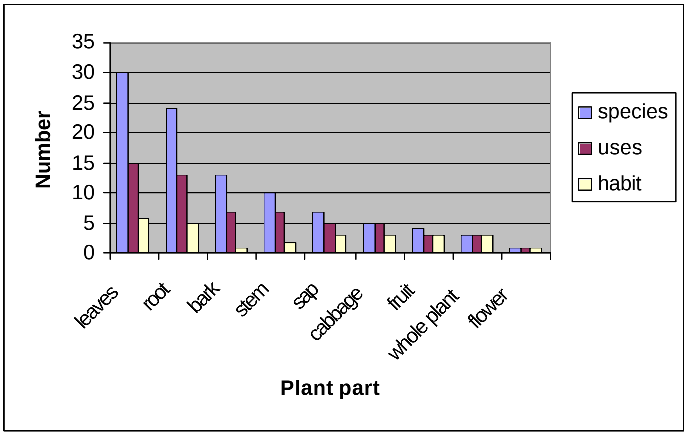

Fig 2 Number plant part used for species, uses and plant habit

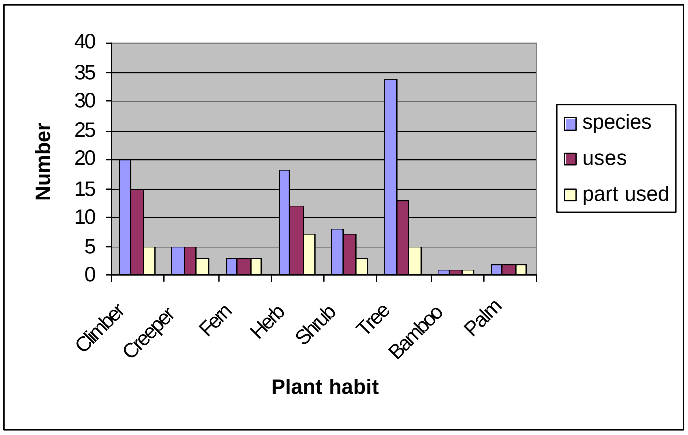

Fig 3 Number of species, uses and part of plant used for every plant habit.

Plant part

Plant parts were divided into nine categories namely flower, fruit, cabbage, sap, stem, bark, root, leaves and whole plant. Leaves were the most commonly used plant part as shown in Table 4. Leaves of 30 species of plants were used to treat 15 types of sickness and they are from various types of habitat. The most uncommon plant part used is the flower. The flower was only used for the treatment of skin problems from one species of plant i.e *Hanguana* sp. Our record also shows that mostly stem and whole plant are used in climbers, creepers and herbs.

CONCLUSIONS

From this study, we found that a relatively high percentage of medicinal plants species are found in the secondary forest compare to primary forest. However, a high percentage of medicinal plants species are also occur in both primary and secondary forest. There were no records of medicinal plants occurring only in primary forest that are being cultivated. Most of the cultivated medicinal plants are primarily planted for other uses such as fruit trees e.g *Nephelium lappaceum*, *Psidium guajava* and *Carica papaya*, spices and food flavours such as *Zingiber officinale* and *Etlingera elatior*, and vegetable such as *Ipomea batatas*.

Gastrointestinal problem is the most common ailment that is recorded as being treated by plants. They includes flatulence, diarrhoea, constipation and gastric. Plants used for the treatment of blood circulation, cancer, hernia and urinating problem are among the most uncommonly recorded. It was also found that most of the medicinal plants are used for treating simple ailments such as wounds, headache, stomach ache and skin problem. A number of species were also recorded for afterbirth treatment.

More species of medicinal plants could be recorded if we included the other few longhouses that are found near the park area. Medicinal plants study is a subject that needs detail and long observation where degree of information gathered are very much depend on the willingness of the key informers to reveal their knowledge during the interview.

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Appendix 1 List of family with number of species, habit, their type of habitat, uses and part of the plant that are used

Family	No. of species	Plant habit	Category of uses	Part used
Acanthaceae	2	he, sh	vi,xx	Le
Acoraceae	1	he	xiii	Ro
Agavaceae	1	he	xi	Ro
Annonaceae	4	cl, sh, tr	i,xi,xiii,xx	ro, le, st
Apocynaceae	3	cl,tr	xiii,xix,xxi	ro, sa, ba
Araceae	2	he	vi,xxiii	sa,ba
Arecaceae	2	pa	xiii,xviii	fr,ca
Asteraceae	2	sh,tr	i,xxiii	wh,le
Bignoniaceae	1	tr	xix	Fr
Blechnaceae	2	fe	i,xix	le,sh
Bromeliaceae	1	he	xiii	Sh
Caricaceae	1	he	xiv	Le
Clusiaceae	1	tr	xxiii	Ba
Convolvulaceae	1	cr	xiv	Le
Cyperaceae	1	he	vi	wh,le
Dilleniaceae	5	cl,tr	iii,viii,xiii	st,ba
Ebenaceae	1	tr	iii	ba,ro
Euphorbiaceae	4	tr	x	ro,sa,le,ba
Flagellariaceae	1	cl	xii,xix,x	le,sh,ca
Gesneriaceae	1	he	xiii	Le
Hanguanaceae	1	he	xix	Fl
Hypoxidaceae	1	he	I	Ca
Lauraceae	3	tr	xiii,xx	ba,le
Lecythidaceae	1	tr	xii,xiii	Ba
Leeaceae	1	tr	xix	Ba
Leguminosae	9	tr,cl,cr,sh	vii,viii,xi,xiii,xviii,xix,xxi,xxiii	sa,st,wh,le,ro
Lycopodiaceae	1	cr	xxiii	Le
Melastomataceae	2	sh,tr	v,xxiii	Le
Meliaceae	1	tr	xiii	Ba
Menispermaceae	3	cl	Ii,iv,xiii	ro,st
Moraceae	2	tr	xi,xvii	le, ro
Myrtaceae	1	tr	xii,xiii	Le
Oxalidaceae	1	tr	xvii	Ro
Piperaceae	3	cl,cr	x,xiii,xix	Le
Poaceae	3	he,ba	ii,xiv,xxiii	ro,le,st
Polypodiaceae	1	fe	xxi	Ro
Rubiaceae	3	cr,cl,tr	ix,xv,xx	le,st,ro
Rutaceae	1	tr	xix	Fr
Sapindaceae	2	tr	xiii,xxiii	le,ba
Schizaeaceae	1	cl	xiv	Le
Simaroubaceae	1	sh	iv	Ro
Solanaceae	1	sh	Xiii	Ro
Symplocaceae	1	tr	X	Sa
Ulmaceae	1	tr	I	Le
Verbenaceae	3	tr	xii,xiii,xiv,xxiii	le,ba
Vitaceae	1	cl	I	Le
Zingiberaceae	5	he	iv,xiii,xiv,xx	ca,ro,fr

Plant habit: cl=climber; cr=creeper; fe=fern; he=herb; sh=shrub; tr=tree; ba=bamboo; pa=palm. Category of sickness: i=afterbirth treatment; ii=antidote; iii=asthma; iv=blood circulation; v=cancer; vi=sting&bite; vii=chest pain; viii=cough; ix=energy; x=eye treatment; xi=fatigue; xii= fever; xiii=gastrointestinal problem; xiv= headache; xv=hernia; xvi=high blood pressure; xvii=internal bleeding; xviii=mouth ulcer; xix= skin problem; xx=sprain; xxi=tooth problem; xxii=urinating problem; xxiii= wounds. Part used: le=leaves; ca=cabbage; st=stem; ro=root; ba=bark; sa=sap; fr=fruit; fl=flower; wh=whole plant.

Comparison of plant physical defences against herbivory

K. Geetha Nayak & Chikako Ishida

INTRODUCTION

Herbivory is the consumption of live plant biomass. Ecologically this is regarded as costly to the plants leading to the loss of photosynthetic area, and in turn the productivity. Herbivory has a potential influence upon the phenological development of plant tissues especially the timing of budding and leaf expansion. The diversity of plant defences which deter the herbivores in tropics is enormous (Coley and Aide 1991).They have physical, chemical, mutualistic and phenological defences to limit the ability of herbivores to exploit plant biomass. Some physical defences are presence of spines, latex, trichomes, hairs, silica content and strong odor. The aim of this study was to compare herbivory damage in plants with various types of physical defense. We tested the following hypotheses.

1. The amount of herbivory damage is correlated to total leaf area.
2. There is a relationship between the size of the leaves and kind of physical defense plants possess.
3. Physical defences of plants reduce the amount of damage sustained by a leaf.
4. There is a difference in the types of damage sustained by the plants with smooth leaves and plants with physical defense such as latex, smell and hairs.

METHODS

The first consideration in the field survey was to collect the plants with specific physical characters such as leaves with latex, hairs, smooth, smell belonging to several species across various families. This minimizes the confounding effects of species-specific attributes. Plants with various physical defense were chosen from the plant key Malesian seed plants- spot-characters (Van Balgooy 1997).

Ten leaves were randomly collected from plant species and the characters noted down. They were grouped into 4 categories: smooth, latex, hairy and odourous. The plants species were identified later by Voradol Chamchumroon or with tag number.

The leaf area was traced on graph sheet along with the damage (hole damage and marginal damage). Later the number of squares (cm) was counted in the whole leaf area and damaged area. These values were noted down for further analysis.

Study site

The study site was Lambir Hills National Park, (LNHP) in Sarawak (4 º20'N 113º50' E 150-450 m asl). This region is situated in humid tropics and the vegetation here is classified as primary evergreen forest, dominated by dipterocarps. Some of the sampling was done in a 52-ha plot in LHNP.

Data analysis

The Pearson’s rank correlation test was used to see the correlation between amount of herbivory damage and total leaf area. Here the leaf characters such latex, hairs, smell and smooth were not considered as we wanted to test our prediction the larger the leaf, the more area available for herbivorous insects, hence the higher damage. Here, the data on mean leaf area (cm^2) of 31 plant species was correlated with mean damaged area (cm^2).

One-way ANOVA was performed to see if there was difference between;

1. Leaf characters and the size of the leaves
2. Physical defense (leaf character) of the leaves and amount of damage.
3. Type of physical defense and amount of hole and marginal damage in the leaves.

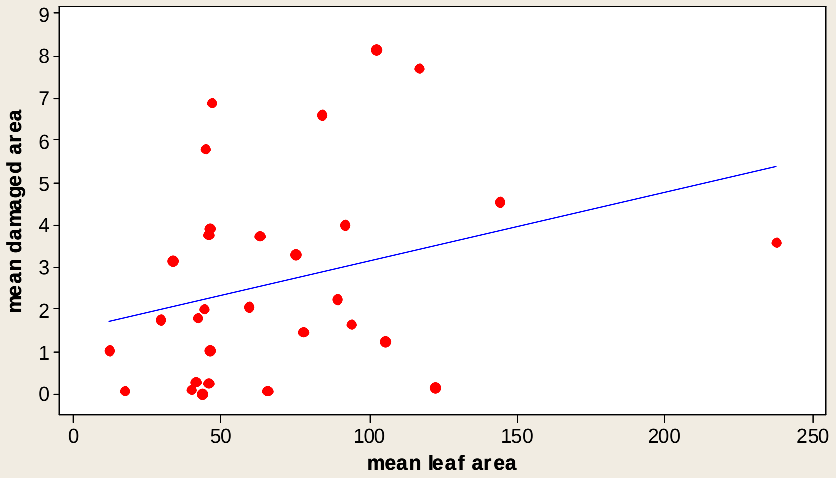
The statistical analysis on the data was performed using MINITAB 14.

RESULTS

Amount of herbivory damage and total leaf area:

The Pearson correlation of mean leaf area and mean damaged area in 30 plant species we studied (Appendix I) showed no significant relation (Pearson correlation, r=0.301, *p*=0.100) (Fig 1). This indicates that as the leaf area increases there may not be an increase in the herbivory damage. The quality or quantity of plant defense is needed to determine the extent of herbivory.

Figure 1 Scatterplot of mean damaged area vs mean leaf area



Size of the leaf and physical defense

There were significant differences in the leaf area in the 4 types of physical defences plants possessed (ANOVA, F=17.22, d.f.=3, *p*=0.000). Smooth leaves had the lowest leaf area compared to the others. The odorous leaves had highest leaf area followed by latex and hairy leaves (Fig 2).

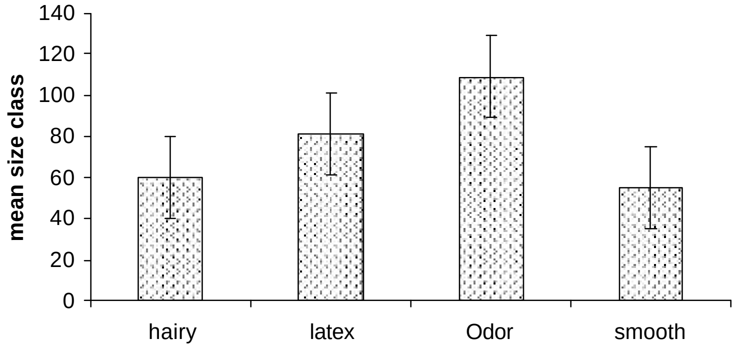


Figure 2. Plant physical defense and mean size class

Plant physical defences and amount of damage

The null hypothesis that the physical defense of plants would make no difference in the amount of damage sustained by the leaf was tested by employing one-way ANOVA. The difference in the amount of herbivory was highly significant (ANOVA F=30.42, df=3, *p*=0.000). The leaves with latex and hairs had lowest damage and odourous leaves had the highest. Smooth leaves also had slightly higher amount of damage (Fig 3).

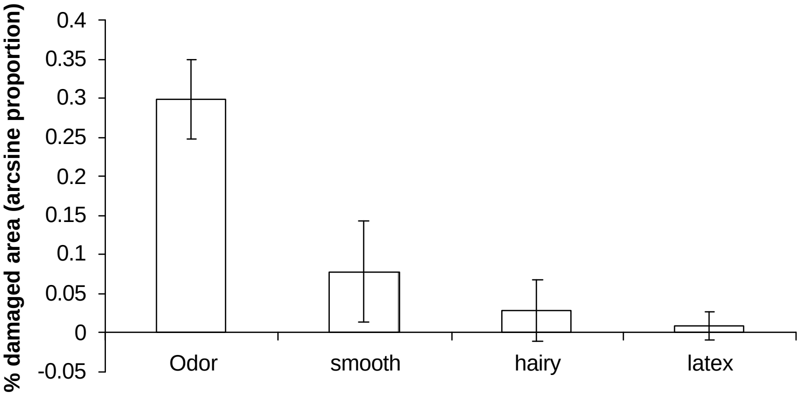


Figure 3. Plant physical defense and % damaged area

Type of damage and physical defences in plants

The type of damage was classified into two categories based on the area damaged. One was marginal damage from the edges of the leaves and the other was hole damage. Then we tested for significance between differences in hole and marginal damage in various types of defense plants possessed (ANOVA hole - F=10.61, df=3, *p*=0.000 and marginal - F=17.67, df=3, *p*=0.000). The smooth leaves had both marginal and hole damage that was higher compared to all other groups. The mean hole damage in all other types was lower than marginal damage (Fig 4).

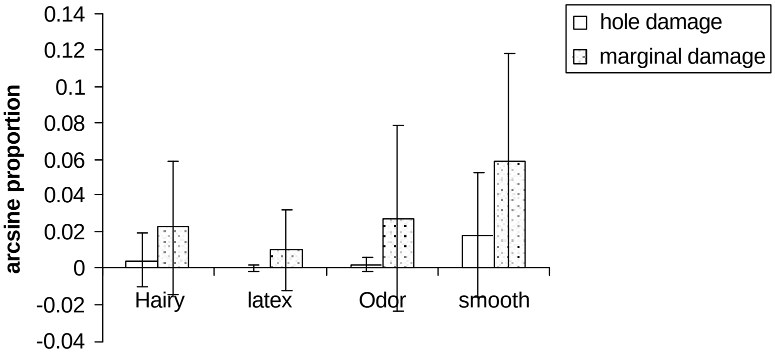


Figure 4. The comparison of hole and marginal damage in leaves with various physical defense

DISCUSSION

Herbivory damage and leaf area

One of our first predictions that as the leaf area increases there is an increase in herbivory damage, as there is greater area available for the insects to exploit, was not found to be true. Size of the leaves was not the factor influencing the amount of damage. It is largely a factor of plant defense.

Size of the leaves and physical defense
In the present study, we show the mean size class of smooth leaves was lower than the other which had hairs or latex. It may be costly to the plants when larger leaves are not defended efficiently. As the cost of producing the larger leaf is higher and damage to such leaves represents a greater reduction in future productivity (Coley and Aide, 1991). On the other hand, plants may not necessarily invest in small or short-lived leaves. It is advantageous to the plants to defend the larger leaves with strong physical and chemical defense.

Amount of damage and physical defense
It is evident form the results that among the four categories of physical defense that we considered, presence of latex considerably reduces the herbivory damage whereas smooth leaves are more prone to damage. But the odorous leaves had higher damage than the hairy leaves and ones with the latex. This may indicate presence of species specific herbivores specialized to exploit the odorous leaves. However, this needs to be confirmed with larger sample size and information on such specialist herbivores.

Type of damage and physical defense
Some of the herbivores may be specialized to feed on some of the selected plant parts such as phloem and xylem sap-suckers, xylem and phloem borers, gall formers, leaf miners, and in each category, there may be myriad number of insects exploiting the resources. Here we considered two types of damage, hole and marginal and results showed that the leaves with latex, hairs and odor are mostly damaged from the margin. The smooth leaves had both marginal and hole damage. There may be more herbivores insects utilizing the smooth leaves than the other types. Moreover there may be many other factors such as presence of secondary metabolites in certain areas of the plant parts may limit the resource utilization.

CONCLUSIONS

It is difficult to separate physical effects from possible chemical effects in plant defense. In the present study the leaves were categorized merely by physical characters. These leaves may be associated with some other factors too. The results presented here show that there is a significant difference in the damage suffered by leaves with various kind of physical defences.

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APPENDIX I

Family	**Plant species**	**Mean**	**SD**	**physical defense**
Meliaceae	*Aglaia cordata*	59.45	13.09	Hairy
Alangiaceae	*Alangium*	46.20	17.97	Smooth
Anisophyllaceae	*Anisophylla*	47.10	9.51	Smooth
Anonaceae	*Annonaceae spp.*	17.55	4.27	Hairy
Moraceae	*Antiaris toxicaria*	122.37	22.25	Latex
Moraceae	*Artocarpus lakkoocha*	41.70	10.00	Latex
Burseraceae	*Burseraceae spp*	89.11	22.84	Smell
Guttiferae	*Calophyllum inophyllum*	105.35	11.14	Latex
Burseraceae	*Canarium* c.f *denticultum*	46.20	17.97	Hairy
Burseraceae	*Dacryodes incurvata*	63.39	17.72	Smooth
Dilleniaceae	*Dillenia*	77.65	18.23	Hairy
Compositae	*Eupatorium*	43.90	9.33	Hairy
Ulmaceae	*Gisronniera*	46.10	8.44	Hairy
Anacaridaceae	*Gluta* spp	237.57	76.10	Smell
Myristicaceae	*Gymnacranthera forbesii*	54.00	17.98	Smooth
Myristicaceae	*Horsifieldia glabra*	102.35	43.87	Smell
Rubiaceae	*Ixora glomerulifera*	33.95	7.80	Smooth
Rubiaceae	*Ixora javanica*	31.73	5.74	Smooth
Myristicaceae	*Knema* spp	46.05	9.97	Latex
Melastomataceae	*Melastona malabathricum*	12.42	4.16	Hairy
Melastomataceae	*Memecylon* spp	44.10	9.72	Hairy
Euphorbiaceae	*Ostodes*	42.20	13.83	Smooth (no latex)
Rubiaceae	*Pavetta* spp.	92.10	30.84	Hairy
Rubiaceae	*Porterandia*	65.81	6.06	Hairy
Sapindaceae	Rambutan-ake	84.30	15.77	Smooth
Euphorbiaceae	*Sapium*	94.15	35.55	Latex
Dipetrocarpaceae	*Shorea*	116.90	23.38	Smooth
Lauraceae	*Litsea*	144.65	46.5492869	Hairy
Tiliaceae	*Microcos*	44.7	11.63376312	Smooth
	Unknown3	46.32	10.06	Hairy

Time budget and social structure of Tree Sparrows (*Passer montanus*)

Chuti-on Kanwatanakid Savini and Ling Tseng

INTRODUCTION

Many common species of birds have not been well studied. Tree Sparrows are a common species that have a broad geographical range, and are generally found throughout Europe, east into Asia and the pacific coast of Russia and south to Indonesia. Eurasian Tree Sparrows (*Passer montanus* Linnaeus) are similar to house sparrow (*Passer domesticus*). Both sexes are similar, with a rich chestnut-brown head and nape, a clear black spot on white cheeks, and a white collar. The voice consists of various chirps and cheeps, which are of a higher pitch than those of house sparrow.

Tree Sparrows are in Family Ploceidae, Order Passeriformes. Tree Sparrows feed mainly on plant matter, including seed, buds, shoots, berries and flowers. They also take invertebrates such as grasshoppers, beetles and spiders when available. The young are fed entirely on invertebrates in their first week. The breeding season is between mid April and early August. They build nests in holes, roofs or occasionally in old nests of larger birds. Two to three broods can be produced a year, each containing 2-7 eggs. Both parents share the incubation duties. After 11-14 days the chick hatches and fledging occurs after a further 15-20 days (Spittle, 1949).

Tree sparrows are a rapidly declining species that were once widespread throughout in many countries. They have dropped in numbers by over 80% in the last 20 years. Understanding the behavior and social structure of Tree Sparrows will help conserve their population decline. This report was done during the International Field Biology Course organized by Center for Tropical Forest Science - Arnold Arboretum (CTFS-AA) and Sarawak Forestry Corporation during 15 July-14 August 2004 at Lambir Hills National Park, Sarawak, Malaysia.

The objectives of this study are to explain whether certain physical factors affect the behaviour of Tree Sparrows and to understand some of their behaviours. We tried to answer two main questions: why do they forage in groups even though they are monogamous, and what factors influenced Tree Sparrow activities.

Our first hypothesis is that Tree Sparrows are more active in the morning than afternoon. Second, temperature influences Tree Sparrow activities. Third, there is more competition when foraging in groups than in pairs. The study was conducted at Lambir Hills National Park, Sarawak, Malaysia. Two study sites, canteen and guard house were selected to observe Tree sparrow activities.

METHODS

Two animal behavior observation methods were used, focal and scan observations at five minutes interval. The observations were conducted 3 times per day (6.00-8.00, 11.00-13.00, 16.00-18.00). Temperature and rainfall were recorded at the beginning and the end of each observation period. Two observers had the previous practice before starting the data collection. A list of animal behavior list and their definitions and assumptions were categorized as shown in Table 1.

Data analysis

The results were analyzed by Minitab 14 Program and SYSTAT version 9. Three statistical tests were selected for data analyses; one-way ANOVA, LSD comparison and linear regression.

Table 1 List of behaviors and its definition

List of behaviours	Definitions
1.Pecking	Feeding with bill
2.Receiving food	Receiving food from bill to bill
3.Feeder	Giving food from bill to bill
4.Hopping	Jumping from the grown at same position
5.Walking	Stepping with legs while changing the position
6.Calling	Having sound from the throat
7.Flying	Moving from the grown with wings
8.Mating	Male stay on Female
9.Playing	Two individuals using bill to attach each other less than 5 seconds
10.Flapping	Moving 2 wings up and down but stay on the ground
11.Chasing	Using part of the body to against others when they come close
12.Being chased	Individual is chased by other when they come close
13.Fighting	Two individuals using bill to attach each other less than 5 seconds
14.Displacement	One individual replaces the other one
15.Carrying nest materials	Carrying materials with mouth
16.Courtship	Moving wing very fast but stay on the ground
17.Grooming	Cleaning feather with bill
18.Searching	Moving head up-down or left-right
19.Resting	Do not move more than 5 seconds
20.Out of site	Can not see focal individual within 5 minute focal observation

Assumptions
1. Consider 1 behavior when object changes the behaviour
2. Consider second behavior when object continue doing the same behavior more than five seconds
3. Pair activities are considered whatever each individual has the same activities at the same time

RESULTS

To determine the time budget of each behavior, we first grouped all the sixteen behaviors into 8 main behaviors (Table 2). Only six main behaviors were presented, as nesting behavior was not observed while mating behavior had very few observations. A total of 262 observations in 24 hours were made over 4 days by 2 observers. Numbers of observations are 85 and 177 for the focal observation and scan observation respectively.

Table 2 List of grouped behaviors

Grouping	Behaviors
Feeding	Pecking, Receiving food, Feeder
Foraging	Hopping, Walking, Flying, Searching
Competition	Chasing, Being chased, Fighting, Displacement
Calling	Calling
Grooming	Flapping, Grooming
Resting	Resting
Mating	Mating, Courtship
Nesting	Carrying nest materials

Canteen
Number of individuals ranged between 1 and 18, average 4.94±3.42. Juvenile Tree Sparrows appeared mostly in this area. Feeding of juveniles by adults was observed occasionally.

Guard house
Number of individuals ranged between 1 and 12, average 3.02±2.25. There was at least 1 pair that stayed around the guard house all the time. One nest location under the guard house roof was discovered on the first observation day. Two adults carried food into the nest as soon as they found some insects or warms.

Physical factors
The physical factors investigated were temperature and rainfall. Unfortunately, there was no rainfall in the 4 day observation period but there was a clearly change of temperature. Fig 1 shows there is significant differences of whether in the morning, afternoon and evening (*p*=0.001).

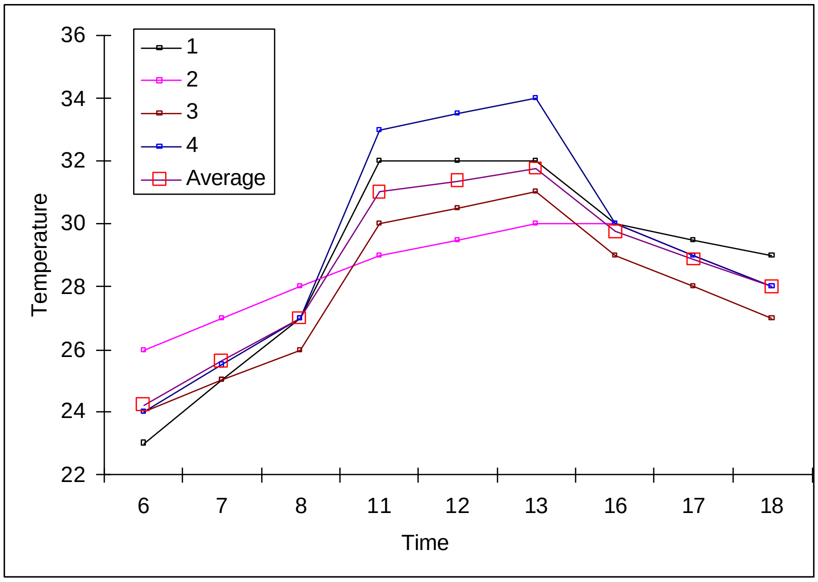

Fig 1 Changes of temperature during four-day observations

Comparison between time budget and activities
Fig 2 and 3 show the activities of groups and pairs. Frequency of feeding, foraging and competition, but not calling, grooming or resting, were significantly different according to the time of day for the group activities observed at the canteen, whereas frequency of all behaviours, but competition, were significantly different for pair activities. Table 3 summarizes the behaviour results.

Table 3 Results (*p* value) for differences among daily observation periods for different behaviors in group and pair observations over 4 days

Behaviors	Group	Pair
Feeding	<0.001	0.001
Foraging	0.001	<0.001
Competition	0.001	0.145
Calling	0.177	<0.001
Grooming	0.465	<0.001
Resting	0.847	<0.001

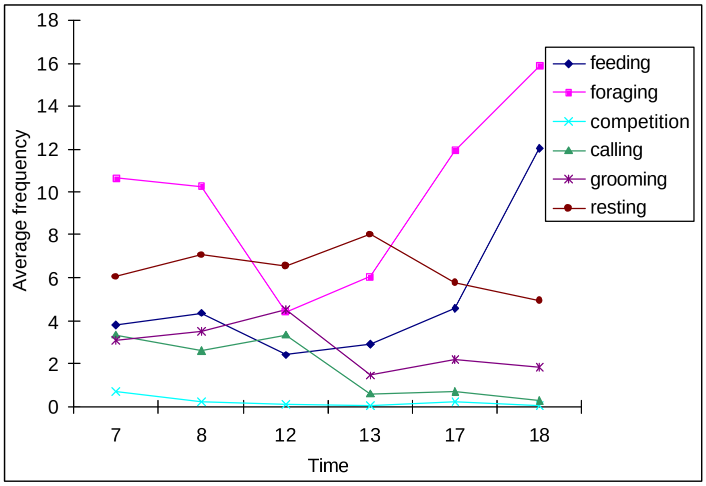

Fig 2 Average frequency of 6 main behaviors of group activities during the day

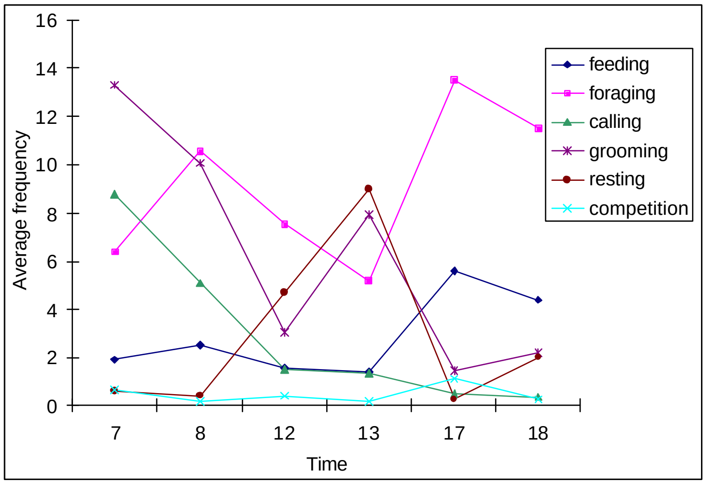

Fig 3 Average frequency of 6 main behaviors of pair activities during the day

Relationship between physical factors and behaviors

The clearest trend was the relationship between feeding frequency and temperature (Fig 4). Due to the short time observation, we could not see a significant relationship between temperature and feeding frequency within 4 days (*p* = 0.123).

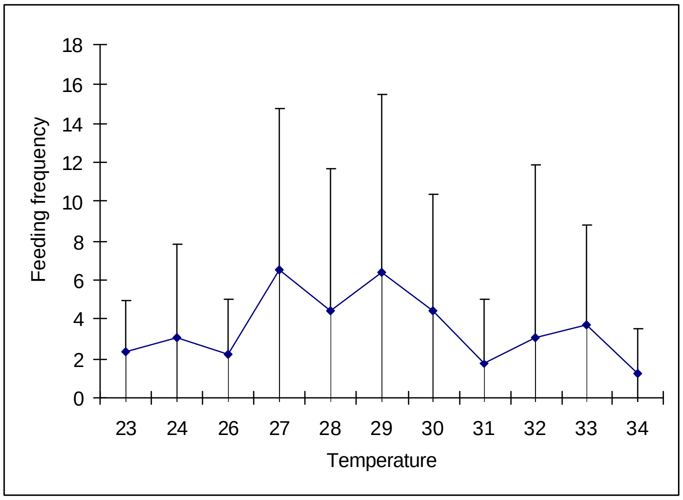

Fig 4 Feeding frequency in different temperatures

Activeness

The active activities were all activities other than grooming and resting. Fig 5 and 6 show that Tree Sparrows were active in the evening more than morning and afternoon respectively for the pair and group observations (p<0.001).

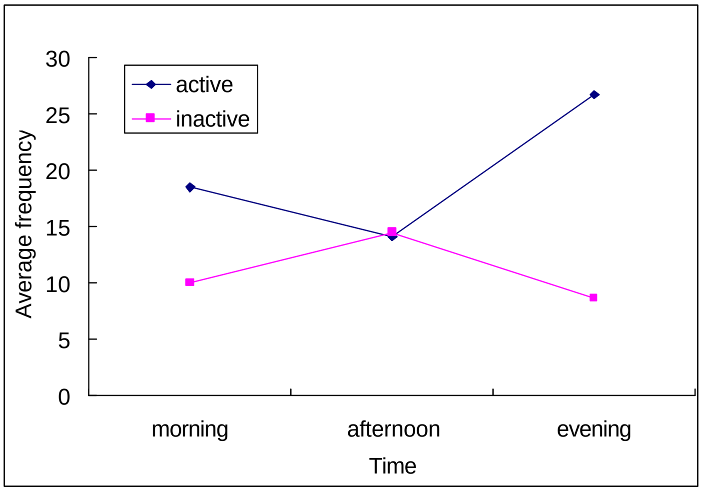

Fig 5 Average frequency of group active behaviors in different time of the day

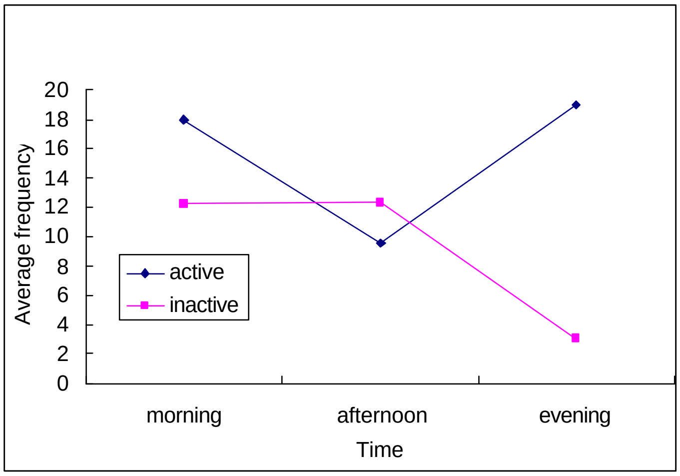

Fig 6 Average frequency of group active behaviors in different time of the day

DISCUSSION

The two selected sites for Tree Sparrow observations, canteen and guard house, are represented by different activity patterns. Differences in the patterns among each of the eight behaviours would be clearer with long term data collection. The canteen and guard house represented group and pair activities patterns, respectively. Most Tree Sparrows at the canteen were juveniles but there were adults mostly at the guard house. As a consequence, there are more observations of feeding from adults to juveniles at the canteen than at the guard house. Food abundance may explain juveniles gathering at the canteen more than guard house. It is easier for juvenile to find at this area as there is food availability from human activities. By contrast, the guard house surrounded by big trees and there is no feeding from humans. However, there is at least one pair that is always there, as they have nests on top on the roof.

Temperature

Temperature during four days observation fluctuated but we can see that the temperature in the afternoon (11.00-13.00) was higher than evening and morning. It might have high standard error caused from the short duration of observations. However, temperature trend can be suggested as the physical factor influencing some behaviors.

Factors influencing Tree Sparrow activities and their activeness

The frequency of main behaviors fluctuated among different time periods. Even though competition was infrequent compared with other behaviors (feeding, foraging, calling and grooming), it varied significantly among time periods. There were also significant trends for feeding, foraging, calling and grooming. The adult pairs had higher grooming and resting frequency, than the juveniles that foraged at the canteen. Table 3 shows some significant and non-significant behavior results. The different *p* value can be explained as being because of the short time for observations. We expected significant results will occur in every behavior over a longer time observation.

The effect of temperature on feeding frequency was non-significant, as the standard deviation was high. It is the consequence of the short term data collection.

Activeness

Fig 5 and 6 show the activeness and inactiveness during morning, afternoon and evening. The active behaviors of group and pair observations show highly significant difference between times of day. This result can be explained in several reasons. Firstly, the temperature in the morning is relatively cold (23-26^{o}C). Cold weather might effect to some behaviors such as feeding and foraging. Secondly, food abundance might be low in the morning and afternoon. It is supported by the temperature result in Fig 1 shows the highest temperature in the afternoon, more than morning and evening, so it might influence the active of insects.

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Nesting behaviour and provisioning pattern in *Bembix*

Dulip Tillekeratne and Chua Yen Kheng

ABSTRACT

The nesting behaviour and provisioning pattern of *Bembix* sp. found in the sandy area opposite the Latak Waterfall at Lambir Hills National Park were studied. We also examine the nest structure and the ability of the wasp in relocating its nest when the surrounding surface is disturbed.

INTRODUCTION

The genus *Bembix* belongs to the family Sphecidae, which includes a great majority of large predatory wasps, in the tribe Bembicini, part of the big subfamily Nyssoninae. They are solitary in habit and construct nests in the soil, and as such, are commonly known as sand or “digger” wasps. As in most Bembicids, *Bembix* provision their larvae with adult Diptera. They are excellent hunters, capturing flies on the wing, paralysing them with venom in mid-air and carrying them back to the nests. Provisioning is practised progressively, in which females capture a great number of prey items over subsequent days during larval growth.

Females work solitarily, creating a somewhat J-shaped burrow about 20 to 50 cm long at a slanting angle to the sand surface. Each burrow leads to a cell which holds only one egg.

The main questions addressed in this study are: (i) what is the composition and quantity of the dipteran preys captured by the females for their larvae? (ii) do the females recognize their way back to the nests if the area around them has been manipulated?

METHODS

Study site

The field survey was conducted in the sandy area of about 135 m^2 opposite the Latak Waterfall in Lambir Hills National Park from 7 August- 11 August 2004, during the International Field Biology Course (IFBC). The waterfall is about 1 km from the National Park’s office and is well frequented by visitors, especially over the weekends. To protect the nests being studied from visitor disturbance, we demarcated a 5 m x 5 m plot in a least frequented corner and focused our observations on marked female wasps over the weekends. As the number of nests was limited within the plot, we continued our observation on the rest of the sandy area on the following weekdays when the place received fewer visitors.

In a single morning of observation (10 August), we tagged a total number of 36 active nests created by female *Bembix*. This is only a rough estimate of the female population and as we noted new nests being built after the observation period, a more realistic estimate would be about 50. We noted that the distribution of female nests in the135 m^2 study site is influenced by the degree of human disturbance on the sand. Most of the nests occurred in areas that were slightly disturbed but with the top layer unturned. There were only 3 nests in the area that was heavily disturbed by visitors with much overturned soil layer. No nests occurred in compacted sandy area and area covered by a substantial layer of leaf litter.

Provisioning pattern and prey composition

Within the 5 m x 5 m study plot, the activities of nesting females were observed for two days during their active period (0730-1630h). The frequency of individually marked wasps bringing preys back to their nests was recorded. As we were unable to keep track of all the individuals simultaneously and may have missed counts of some of their returns, the total number of preys in each nest was only determined when we excavated the nests at the end of the observation period. Larvae or pupa in the cell chamber were also collected and the body size and mandibles of larvae measured.

We employed two methods of collection: (i) by excavating with a shovel around the entrance, after putting a bamboo stick through the burrow as a guide to arrive at a proximal depth to the chamber; (ii) by introducing liquid paraffin into the burrow and opening the solidified matter to obtain the contents in the chamber. A few numbers of preys were also netted from the grasp of female wasps returning to their nests.

Sixty-four dipteran prey were collected and sorted to the family level. A great proportion of the preys came from the family Calliphoridae and these were sorted into 6 morpho-species. We believe, however, that we may have misrepresented the number of different species hunted by the wasps as some of the species exhibit sexual dimorphism. Meanwhile, our collection awaits for an entomologist more familiar with Diptera to determine the correct number of species present.

Nest specificity and recognition

Seven adult females were caught when they were emerging from their nest and they marked with paint markers either on their wings or mesoscutum. Three adult males were also marked for observation. The nests were observed from 0800-1600 h. After confirming that the wasps did return to their nests, we proceeded to manipulate the site to find out if they relied on any visual cue from the nests surroundings for nest location. All possible landmarks around the nests, such as fallen leaves, sticks and sand piles were removed or shifted. Observations of any returning females to those nests that had been excavated were also made

RESULTS

Basic morphology of Bembix

Bembix exhibits sexual dimorphism by having difference in body colours and band patterns on their gaster segments. These bands are slightly wavy and on the females are of black, greenish-yellow and dark grey colours, whereas those in males are of black, light blue, dark grey and light grey colours. On the second, third and fourth gaster segments of the females, the single black band has a triangle joined at the median point, with two black dashes ("- -") on each sides of the triangle, thereby creating a mask-like icon on each segment. The triangle is replaced by a semi-circle in the males and it only occurs in the second gaster segment. The mouthparts of the adults reveal that they do not feed on their captured dipteran prey but nectar and maybe plant exudates.

The wasps excavate their nests with their forefeet, which are specially adapted to include a marginal row of long, stiffed, flattened bristles, known as pectin, on the lateral margin of the fore tarsus; especially the basitarsus.

General observations on activity pattern

The first sighting of *Bembix* at the site was noted to be after 0730h. The number of wasps emerging from their nests peak in the period from 0830h to 0900h and decreased sharply after that. Fig 1 below shows our observation on the time of emergence of 73 wasps in two consecutive mornings.

Provisioning was observed to be more active between 1100h to 1430h in 7 individuals (see Table 1). There was an exception where a female wasp brought a prey to its nest at 0815h one morning and covered herself inside the nest for some time. However, we were not successful in tracking her later. As the sample size is too small and we must have missed counts of some of the returns, we are unable to determine exactly the most active time of the day and the frequency in which the wasps were provisioning their larvae.

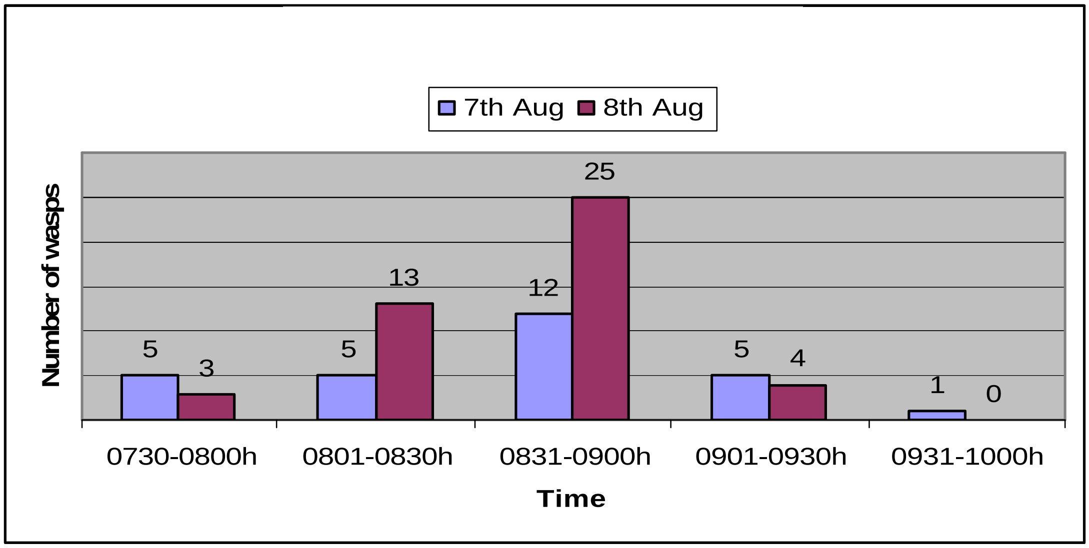

Fig 1 Time of emergence from nests of 73 wasps

Table 1 Frequency of provisioning by 7 marked wasps in half hour periods

	Individual							
	C7	A1	A12	A9	A3	D19	D15	Total caught in each period
Time period								
0730-0800h								
0801-0830h								
0831-0900h							2	2
0901-0930h								
0931-1000h								
1001-1030h				1				1
1031-1100h				1				1
1101-1130h				2				2
1131-1200h		1			3			4
1201-1230h				2	1		1	4
1231-1300h		2		2	1			5
1301-1330h	1			1				2
1331-1400h					1			1
1401-1430h	1		2	1	1			5
1430-1500h	1			1		1		3
1501-1530h								
1531-1600h	1							1
Total no. of preys =31	4	3	2	11	7	1	3	

Generally, most females did "housekeeping" from around 08.00h to 10.00h, where they remove extra sand particles and/or flies remnants from the cell chamber to the surface. This activity is not restricted to the morning though. We had also noted there was a decrease in wasps' activities in the afternoon between 13.00h and 14.30h. An interesting observation was made one afternoon of many male wasps re-opening shallow nests randomly or excavating new ones in the soil to enter.

Observation on nesting behaviour

The wasps excavate their nests with their forefeet and throw the excess sand behind them from beneath their body. After completing their nests, we observed that not all wasps would close their nests before taking their flight. Those that do close their nests with sand were also seen to destroy the evidence of their nest construction by burying the darker sand unearthed by their digging with paler sand from the surface layer.

Nest structure

We discovered from the solidified paraffin nest extractions that females of *Bembix* create J-shaped burrows that are elongated and deep. The wasp will first create the burrow at a slant of 15^0 to 40^0 from the sand surface and as it burrows deeper, it increases the angulation a little along the way. After digging in this direction for about 11 to 23 cm, it will make a change and continue to dig for about 11 to 26 cm in a different direction, but maintaining the same range of angulations. The ratio between the first and second part of the burrow is almost equal, as observed in 5 samples (Table 2). A single cell chamber is created at the end of the second part of the burrow.

Table 2 Measurements of burrows

Sn	First part (cm)	Second part (cm)	Total length (cm)
1	23	21	44
2	22	25.5	47.5
3	15	19	34
4	11	11.5	22.5
5	14	20	34

Nest specificity and recognition

All of the seven marked adult female wasps were observed to return to their respective nests showing nest specificity as well as the ability to locate their nests. The marked male wasps, however, did not return to the nests, suggesting that there was no nest specificity in the males.

When possible landmarks such as leaves or sticks were removed from the surrounding of various nest sites, their respective owner was still able to locate their nests without much difficulty. We observed that when the sand around the nests was disturbed with the sand, the females were still able to arrive at the proximity of their nests, where they then began to search for the nests by digging slightly in the sand at various points. Even after the nests were excavated, it was evident that the wasps were able to return near their nests. When there were difficulties in locating a nest, especially in badly disturbed sites with much overturned soil surface, wasps had been observed in several occasions to forsake their preys while searching.

We had also observe that on the completion of a new nest, the females perform a special flight pattern (Fig 3) around the nests before flying away from the site. Females were assumed to be constructing new nests by the longer time they took to dig at a site, and the fact that they did not leave the nest or brought back any prey during the study period. This observation may shed lights to the question of how the wasps are able to locate their nest. The wasps start by moving in small loops, each time returning back to the nests, as indicated in the diagram. This primary flight is observed to be no more than 15 cm above the ground. In the secondary and tertiary flights, they fly progressively away from the nests in bigger loops and at a higher level of up to 1 m from the ground. During this flight process, a few observations were also made of females landing close to the nest and reaching the nest by repeating the primary flight. This may be an attempt of the wasps to reinforce its familiarity to the nest location.

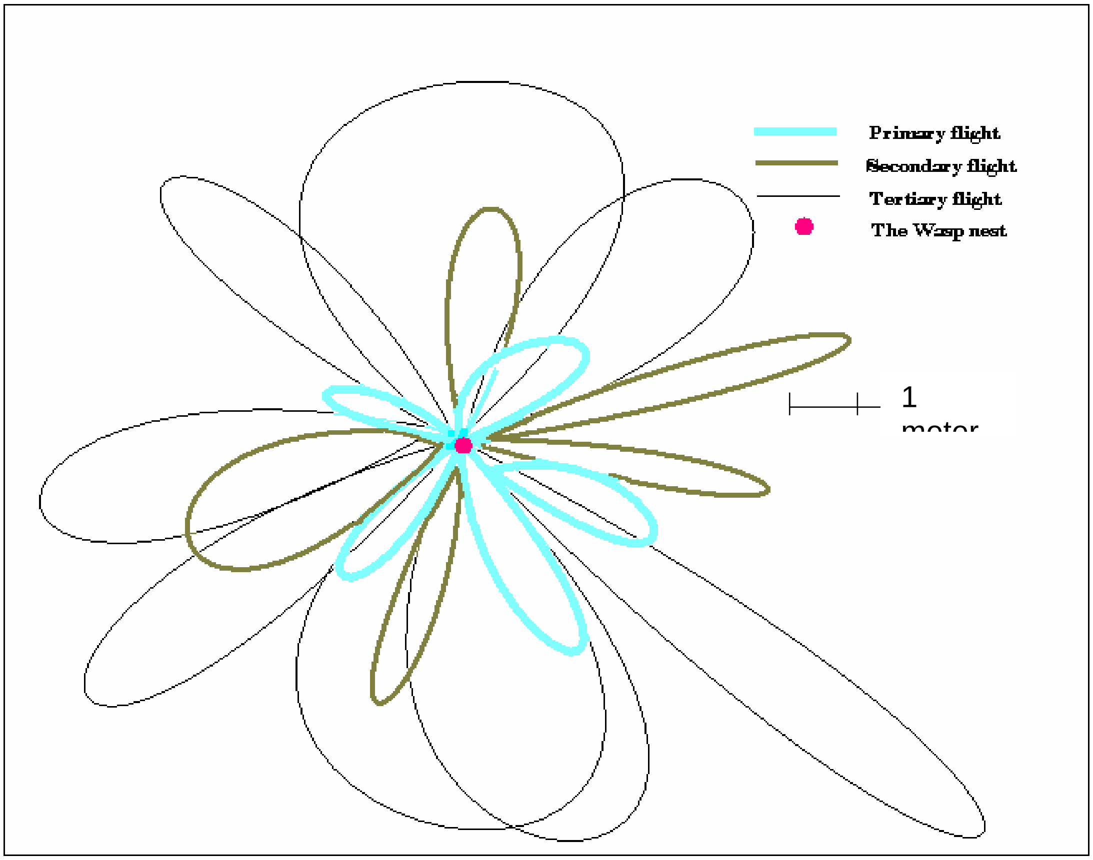

Fig 3 The flight pattern followed by females making new nests

Prey Composition

Bembix shows prey specificity to adult Diptera and prey on flies from various habitats to feed their larvae. We recorded 12 species of flies from six different families: Tabanidae, Tachinidae, Bombylidae, Syrphidae, Stratiomyidae and Calliphoridae. The results are summarized in Table 3 below.

Table 3 Dipteran preys of *Bembix* A

Family	Species	Number
Tabanidae	-	4
Tachinidae	Species A	1
	Species. B	2
Bombylidae	*Anthrax* sp.	1
Syrphidae	-	1
Stratiomydae	-	2
Calliphoridae	Species A	21
	Species B	25
	Species C	2
	Species D	3
	Species. E	1
	Species. F	1
		64

DISUCUSSION

This study has shown that *Bembix* built elongated nests that are constructed at a slanting angle to the surface with a change in orientation underground. The species may possibly build multicellular nests because of their burrow length and depth.

Compared to the excavating method, the paraffin method is more accurate in reaching the chamber of an observed individual at the end of the curving burrow. By directly digging into the nest, we had either missed the chambers or reached adjacent nests with empty pupa and flies remnants. The paraffin method, however, does not allow easy retrieval of fly and larva specimens. Specimens can be destroyed or distorted with the introduction of fire when melting the solidified paraffin. Then, it is a good way to uncover the nest structure for examination; though at times, attempts to obtain a complete replica with the cell chamber at the base were hampered when a burrow was blocked by sand that had accumulated along with the flow of liquid paraffin into the nest.

Although our field observation period is limited, we discovered many interesting aspects about the nesting behaviours, activity pattern and provisioning of *Bembix*, which can be further investigated. For example, males were seen to emerge from their nests earlier than the females but we are unable to quantify our observation as many of the wasps emerged almost at the same time and took to the air too quickly for us to discern the colour differences of the two sexes. Also, as the sample size is too small and we must have missed counts of some of the returns, we are unable to determine exactly the most active time of the day and the frequency in which the wasps were provisioning their larvae. More accurate data on the provisioning activities may demonstrate whether the active period has any relation to time of prey availability and also the larval stage of the wasps.

And why do some wasps close their nests before leaving their nests while others do not? *Bembix* grasp their prey in both mid and hind legs while in the air, and are able to carry the prey with only the mid legs while scraping the entrance to a closed nest. Other species that held its prey by the mandibles will either need to put down their prey first or choose not to close their nest. The latter practice will increase the chances of attack of the larvae by parasitoids. However, in the case of *Bembix*, we observed that most of them do not close their nests when they went hunting for their prey. The difference may be related to the larval stage, where more developed larva might be less susceptible or immune to parasitoid attacks, even though we found 3 nests that were not closed with small larvae.

From a nature educational point of view, the *Bembix* population, at the popular visitor site has great potential for formulating an outreach programme for the public, who has a common misperception of wasps being dangerous. Female *Bembix*'s sting can inflict a painful wound in defense, but in general they do not pose any threat to humans.

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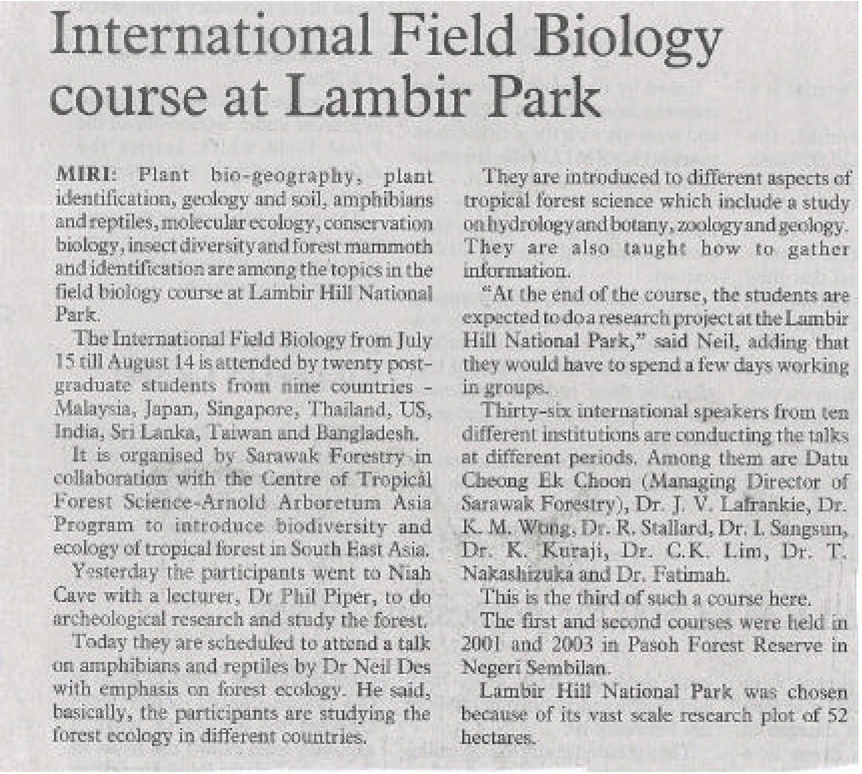
IFBC 2004 in the news

Borneo Post, Wednesday 21 July 2004



International Field Biology course at Lambir Park

MIRI: Plant bio-geography, plant identification, geology and soil, amphibians and reptiles, molecular ecology, conservation biology, insect diversity and forest mammoth and identification are among the topics in the field biology course at Lambir Hill National Park.

The International Field Biology from July 15 till August 14 is attended by twenty post-graduate students from nine countries – Malaysia, Japan, Singapore, Thailand, US, India, Sri Lanka, Taiwan and Bangladesh.

It is organised by Sarawak Forestry in collaboration with the Centre of Tropical Forest Science-Arnold Arboretum Asia Program to introduce biodiversity and ecology of tropical forest in South East Asia.

Yesterday the participants went to Niah Cave with a lecturer, Dr Phil Piper, to do archeological research and study the forest.

Today they are scheduled to attend a talk on amphibians and reptiles by Dr Neil Des with emphasis on forest ecology. He said, basically, the participants are studying the forest ecology in different countries.

They are introduced to different aspects of tropical forest science which include a study on hydrology and botany, zoology and geology. They are also taught how to gather information.

"At the end of the course, the students are expected to do a research project at the Lambir Hill National Park," said Neil, adding that they would have to spend a few days working in groups.

Thirty-six international speakers from ten different institutions are conducting the talks at different periods. Among them are Datu Cheong Ek Choon (Managing Director of Sarawak Forestry), Dr. J. V. Lafrankie, Dr. K. M. Wong, Dr. R. Stallard, Dr. I. Sangsun, Dr. K. Kuraji, Dr. C.K. Lim, Dr. T. Nakashizuka and Dr. Fatimah.

This is the third of such a course here.

The first and second courses were held in 2001 and 2003 in Pasoh Forest Reserve in Negeri Sembilan.

Lambir Hill National Park was chosen because of its vast scale research plot of 52 hectares.

STRI News 23 July 2004

Opening of the CTFS-AA field course at Lambir Hills, Sarawak, Malaysia. Apertura del Curso de Biología de Campo del CTFS-AA en Lambir Hills, Sarawak, Malasia.

CTFS-AA field course

The Center for Tropical Forest Science-Arnold Arboretum (CTFS-AA) Asia Program annual International Field Biology Course 2004 (July 16-Aug 16) was opened by Datu Cheong Ek Choon general manager of the Sarawak Forestry Corporation (standing, left of center) at Lambir Hills National Park, Sarawak. Twenty graduate students from nine countries (India, Sri Lanka, Singapore, Malaysia, Thailand, Taiwan, Japan, Phillipines and the USA) are participating in this course, focused on frontiers in research on tropical forest biology, and spans a diversity of fields including taxonomy of plants and animals, biogeography, hydrology, molecular ecology, zoology, chemical ecology and plant ecology. Thirty six specialists including CTFS and STRI researchers will serve as instructors. The course includes field trips to neighboring national parks, such as Mount Kinabalu in Sabah, and independent student projects. This year's course, hosted by Sarawak Forestry Corporation, was organized by STRI postdoctoral fellow Rhett Harrison.

El Curso de Biología de Campo Internacional anual del Programa de Asia del Centro de Ciencias Forestales del Trópico y el Arboreto Arnold (CTFS-AA) de 2004 (julio 16-agosto 16) fue inaugurado por Datu Cheong Ek Choon, administrador general de la Corporación de Forestería de Sarawak (de pié a la izquierda del centro) en el Parque Nacional Lambir Hills, Sarawak. Veinte estudiantes graduados de nueve países (India, Sri Lanka, Singapur, Malasia, Tailandia, Taiwan Japón, Filipinas y los EU) están participando en este curso que enfoca las fronteras en investigación de biología forestal tropical y cubre una variedad de campos incluyendo taxonomía de plantas y animales, biogeografía, hidrología, ecología molecular, zoología, ecología química y ecología vegetal. Treinta y seis especialistas incluyendo investigadores del CTFS y STRI serán los instructores. El curso incluye trabajo de campo en parques nacionales cercanos como Monte Kinabalu en Sabah y proyectos independientes para los estudiantes. El curso de este año, patrocinado por la Corporación Forestal de Sarawak, fue coordinado por el becario posdoctoral de STRI, Rhett Harrison.

Pledge to create an endowed chair in Paleontology

STRI received a pledge of $3.5 million from the 1923 Fund to create an endowed Chair in Paleontology, on June. This gift allows STRI to offer an opportunity to an outstanding scientist to work in one of the world's most fascinating locations for paleontology research. The Isthmus of Panama—as a land bridge connecting two continents and an ocean barrier separating Caribbean and Pacific—holds an extraordinary and unique record documenting the creation of two oceans; the merger of two distinct land faunas and floras from North and South America; the impact of humans on tropical vegetation as they first colonized the new world around 15,000 years ago; and the saga of prehistoric humans who used the isthmus as a corridor for migration. Of special note, this generous gift also establishes the first endowed position in science at the Smithsonian. We are grateful to the 1923 Fund for its extraordinary support, and look forward to filling the position by the end of the year.

STRI recibió un fideicomiso por $3.5 millones del Fondo 1923 para crear una posición en Paleontología, el pasado mes de junio. Este fondo permite que STRI ofrezca una oportunidad a un científico de alta graduación para trabajar en uno de los lugares más fascinantes en investigaciones paleontológicas. El Istmo de Panamá, un puente natural que conecta dos continentes y una barrera oceánica que separa al Caribe del Pacífico, tiene un registro extraordinario y único que documenta la creación de dos océanos; une dos faunas y floras distintas de Norte y Suramérica; el impacto de los primeros seres humanos en la vegetación tropical al colonizar el nuevo mundo hace cerca de 15,000 años y la saga de humanos prehistóricos que usaron el istmo como corredor migratorio. Como nota especial, esta generosa donación también establece la primera posición dotada para ciencias en el Smithsonian. Agradecemos al Fondo 1923 por su extraordinario apoyo y esperamos llenar esta posición lo más pronto posible.

Berita Harian, Monday 19 July 2004

25 penuntut sembilan negara sertai kursus biologi

KUCHING: Seramai 25 penuntut dari sembilan negara mengambil bahagian dalam Kursus Lapangan Biologi Antarabangsa 2004 ketiga yang diadakan di Taman Negara Lambir Hills di Miri, mulai Jumaat lalu.

Penuntut asing itu akan mengikuti kursus anjuran Sarawak Forestry Corporation (SFC) itu selama sebulan sehingga pada 15 Ogos ini.

Jurucakap SFC berkata, seramai 36 pakar biologi dari 10 negara akan memberi syarahan kepada penuntut berkenaan mengenai pelbagai tajuk.

Katanya, antara tajuknya ialah mengenai biogeografi tumbuhan di hutan Malaysia dan Borneo, mengenalpasti jenis tumbuhan dan hidupan liar, tanah, ekologi molekular dan pemuliharaan kepelbagaian biologi serangga.

"Mereka juga dijadualkan melawat Taman Negara Niah, Loagan Bunut, kilang pemprosesan kayu dan kilang minyak sawit berdekatan," katanya dalam kenyataan di sini semalam.

Kursus hasil kerjasama SFC dengan Pusat Sains Hutan Tropikal (CTFS) di Institut Penyelidikan Tropika Smithsonian dan Program Asia Universiti Harvard.

Ia bertujuan mendedahkan penuntut dengan pengetahuan asas berkaitan biodiversiti dan ekologi alam dan hutan tropika di Asia Tenggara.

Beliau berkata, Taman Negara Lambir Hills dipilih untuk kursus itu berikutan keunikan dan kekayaan alam semula jadinya.

Ia terletak di kawasan seluar 52 hektar dan diliputi dengan 1,192 spesis yang sudah dikenal pasti dan dikaji pelbagai pihak selama ini.

Katanya, taman itu juga mempunyai banyak kemudahan penyelidikan termasuk kren kanopi, jambatan gantung dan kanopi sistem pemerhatian.

Sebelum ini, dua kursus itu pernah diadakan di Hutan Simpanan Pasoh di Negeri Sembilan pada 2001 dan 2003.

SFC sedia bantu kajian alam sekitar

KUCHING: Sarawak Forestry Corporation (SFC) akan memberi sokongan kepada mana-mana pihak yang ingin mengadakan kajian dan kursus mengenai kekayaan biodiversiti dan alam semula jadi yang ada di negeri ini.

Pengarah Urusannya, Datuk Cheong Ek Choon, berkata SFC bersedia bekerjasama dengan sesiapa termasuk syarikat swasta, universiti dan badan penyelidikan asing.

Beliau berkata, SFC mempunyai kemudahan lengkap, lokasi khas dan program menyeluruh untuk tujuan berkenaan.

Katanya, usaha mereka yang berminat untuk membuat kajian di hutan Sarawak amat dialu-alukankan memandangkan SFC juga komited dalam melindungi dan pemuliharaan kekayaan biodiversiti di negeri ini.

"Kami memberikan galakan kepada organisasi terbabit terutama untuk menjana kesedaran di kalangan generasi akan datang," katanya ketika merasmikan Kursus Lapangan Biologi Antarabangsa 2004 di Taman Negara Lambir Hills di Miri, Sabtu lalu.

Utusan Borneo, Wednesday 21 July 2004

6 MASYARAKAT UTUSAN BO

Kursus biologi libatkan sembilan negara, 10 institusi antarabangsa

Oleh **Mary Francis**

MIRI, 20 Julai: Bio-geografi tumbuhan, pengenalan tumbuhan, geologi dan tanah, amfibia dan reptilia, ekologi molekul, biologi pemuliharaan, kepelbagaian serangga dan hutan besar dan pengenalannya adalah antara topik yang diperbincangkan dalam kursus bidang biologi di Taman Negara Lambir, di sini, baru-baru ini.

'Bidang Biologi Antarabangsa' yang diadakan dari 15 Julai lalu dan akan berakhir 14 Ogos ini telah dihadiri oleh 20 pelajar bekas graduan dari sembilan negara iaitu Malaysia, Jepun, Singapura, Thailand, Amerika Syarikat, India, Sri Lanka, Taiwan dan Bangladesh.

Kursus sebulan ini telah dianjurkan oleh Jabatan Perhutanan Sarawak dengan kerjasama Pusat Sains Hutan Tropika-Program Arnold Arboretum Asia Program.

Antara lain tujuan ia diadakan adalah untuk memperkenalkan biodiversiti dan ekologi hutan tropika di Asia Tenggara melalui sampel tumbuhan dan serangga hinggalah ke ekologi molekul.

Kelmarin, para peserta telah berkunjung ke Gua Niah bersama pensyarah Dr Phil Piper untuk mengkaji penyelidikan arkeologi dan hutan.

Hari ini pula, mereka diberi taklimat berhubung amfibia dan reptilia oleh Dr Neil Des yang menekankan mengenai ekologi hutan.

Menurut Dr Neil, secara asasnya para peserta mengkaji ekologi hutan di pelbagai negara berlainan.

Mereka jelasnya, diajar dan diperkenalkan kepada aspek berbeza sains hutan tropika yang melibatkan penyelidikan hidrologi dan zoologi botani serta geologi.

Mereka juga diajar dan diperkenalkan dengan setiap subjek dan teknik bidang mengenai cara mengumpul maklumat, jelasnya lanjut.

"Pada penghujung kursus, para pelajar dijangka melakukan projek penyelidikan di Taman Negara Lambir," kata Dr Neil sambil menambah bahawa para pelajar harus meluangkan masa beberapa hari bekerja dalam kumpulan mengenai projek tersebut yang mirip projek mini-saintifik, seperti yang telah dipelajari oleh mereka sejak beberapa hari lalu.

Tiga puluh enam penceramah antarabangsa dari sepuluh institusi berlainan di seluruh dunia telah dijemput mengadakan taklimat pada waktu-waktu tertentu, antaranya Datu Cheong Ek Choon (Pengarah Urusan Perhutanan Sarawak), Dr. J. V. Lafrankie, Dr. K. M. Wong, Dr. R. Stallard, Dr. J. Sengsun, Dr. K. Kuraji, Dr. C.K. Lim, Dr. T. Nakashizuka dan Dr. Fatimah.

Kursus ini merupakan yang ketiga pernah dianjurkan dan kali pertama dianjurkan di Miri di mana kursus pertama telah diadakan pada tahun 2001 dan kursus kedua tahun lepas, kedua-duanya di Hutan Simpan Pasoh, Negeri Sembilan.

Dalam pada itu, Taman Negara Lambir terpilih kerana keluasan plot penyelidikan melibatkan 52 hektar dengan kepelbagaian spesis terkaya di dunia.