

Student projects carried out on TBA courses in Borneo are listed under the following headings. Within each category projects are listed with most recent first, then alphabetical by title. The abstracts follow the index. Click on the date of the paper to go to the abstract. To search, use Ctrl-F.

Index

ECOLOGY	1
HERPETOFAUNA	1
INVERTEBRATES	2
Invertebrates: ants	2
Invertebrates: other	2
PLANT, FUNGI AND FOREST ECOLOGY	3
POLLINATION	3

Abstracts

	5
ECOLOGY	5
HERPETOFAUNA	6
INVERTEBRATES: ants	9
INVERTEBRATES: other	12
PLANT, FUNGI AND FOREST ECOLOGY	16
POLLINATION	21

ECOLOGY

Edge effects and insectivorous birds in Danum Valley, Borneo ([2018](#))

Habitat selection by two size classes of fish and shrimp in the Tambun stream in Danum Valley ([2011](#))

Acoustic niche segregation: Does it happen at Danum Valley? ([2010](#))

HERPETOFAUNA

Home range and microhabitat preferences of *Limnonectes kuhlii* ([2018](#))

Acoustic segregation of frogs in different soundscapes of Danum Valley Conservation Area (Sabah, Malaysia) ([2017](#))

Influences of environmental factors on Rough Guardian Frog (*Limnonectes finchi*) tadpole abundance in the streams of Danum Valley Conservation Area ([2011](#))

Spacing and aggressive behaviour in the Yellow-bellied Puddle Frog ([2011](#))

Interactions between males of tree hole frogs (*Metaphrynella sundana*) in Danum Valley Field Centre area ([2010](#))

Species richness and microhabitat preferences of frog species in Danum Valley Conservation Area ([2010](#))

Adjustment of tree-hole frog (*Metaphrynella sundana*) calling characteristics in relation to tree-hole properties in the field ([2009](#))

Microhabitats of co-occurring tree frogs (*Polypedates* and *Rhacophorus*) around ponds of Danum Valley Field Centre, Sabah, Malaysia ([2009](#))

Tree Hole Frog (Microhylidae: *Metaphrynella sundana* Peters): habitat utilisation and density ([2009](#))

INVERTEBRATES

Invertebrates: ants

Food preferences and species composition of ground foraging ants along a disturbance gradient in Danum Valley, Sabah, Borneo ([2017](#))

What factors elicit anti-herbivore responses in resident ants? A study on the potential myrmecophyte, *Octomeles sumatrana* ([2017](#))

Do ants protect *Korthalsia furtadoana* J. Dransf. against herbivory? ([2011](#))

Foraging ants on the forest floor ([2011](#))

Foraging and recruitment behaviour of *Camponotus gigas* in a Dipterocarp Forest in Danum Valley, Sabah, Borneo ([2011](#))

On the prowl: Why do different ant species use floral and extra floral resources on *Senna alata*? ([2011](#))

A positive relationship between ant biodiversity and predatory function across a disturbance gradient in a SE Asian rain forest ([2009](#))

The recruitment time of ant species in forested and edge habitats at Danum Valley ([2009](#))

Invertebrates: other

The diversity of freshwater macroinvertebrates in the streams of Danum Valley, East Malaysia ([2018](#))

Species diversity and behaviour of Odonata in Danum Valley Conservation Area of Sabah, Malaysia ([2018](#))

Species diversity of butterfly in open and forested area in Danum Valley Conservation Area, Sabah, Malaysia ([2018](#))

Comparison of butterfly bait traps between open canopy and close canopy in Danum Valley Field Centre, Borneo ([2017](#))

Sensing distance of the Tiger leech *Haemadipsa picta* in Danum Valley ([2017](#))

Ecology of water striders (family Gerridae) at puddles in Danum Valley Field Centre ([2011](#))

Differences in fruit feeding beetle communities through the canopy of a primary lowland forest in Malaysia ([2010](#))

Ecosystem engineers: Earthworms in tropical forests: A study from Danum Valley, Malaysia ([2010](#))

Invertebrate drift in the Tambun stream in Danum Valley ([2010](#))

Leech hide and seek: How leech awareness of hosts changes with environment and moisture levels ([2010](#))

The acoustic landscape and cicada call patterns in Danum Valley ([2009](#))

Blood suckers in our midst: Leech (Haemadipsidae) abundance on forest trails and off-trails in the Danum Valley Conservation Area, Sabah, Malaysia ([2009](#))

Diversity and interaction of dragonflies in Danum Valley Field Centre ([2009](#))

PLANT, FUNGI AND FOREST ECOLOGY

A comparison study of biomass changes due to drought event in primary and logged-over forest ([2018](#))

Camouflage success in rainforests: a study case in Danum Valley, Borneo ([2018](#))

Herbivory rate of *Mallotus miquelianus* compared between gaps and understorey in Danum Valley Conservation Area, Borneo ([2017](#))

The structure of a plant-frugivore network in Danum Valley, Sabah, Malaysia ([2017](#))

Anti-herbivory strategy by red young leaves of rainforest tree seedlings ([2011](#))

Is reproductive success in *Calanthe zollingeri* (Rchb.f. 1857) related to distance from the water body and canopy openness? ([2011](#))

Ant predation and herbivore damage on *Mallotus lackeyi* (Euphorbiaceae) in a lowland dipterocarp forest in Borneo ([2010](#))

Different gradients and its influence to recruit of seedlings in primary forest in Danum Valley ([2010](#))

Do epiphytes reach the sky? A study on vertical stratification of *Asplenium* and *Drynaria* on *Parashorea* spp. in Danum Valley ([2010](#))

Seed dispersal ability of *Dryobalanops*, *Dipterocarpus*, *Shorea* and *Parashorea* of Danum Valley Field Station, Sabah ([2010](#))

Ecology of *Pterospermum stapfianum* ([2009](#))

The effect of microclimate in Borneo rains forest on macrofungal communities ([2009](#))

The effect of plant density on insect herbivory in two plant species (*Melastoma malabathricum* and *Clidemia hirta*): A comparison of native and invasive species in Danum Valley Conservation Area ([2009](#))

The effect of seedling density of a shade-tolerant species, *Mallotus miquelianus* (Euphorbiaceae), on herbivory in the tropical rainforest in Danum Valley Conservation Area, Malaysia ([2009](#))

POLLINATION

Investigating environmental factors affecting pollinators in *Etilingera megalocheilos* ([2017](#))

Pollination syndrome as a predictor of primary pollinator and diurnal nectar production trends in *Musa beccari* (Musaceae) in Sabah, Malaysia ([2017](#))

Sexist bees promote greater allocation to male vs. female reproductive function in *Begonia danumensis* ([2017](#))

The relationship between bee abundance and the density of *Melastoma malabathricum* shrubs at Danum Valley, Sabah, Malaysia ([2017](#))

Does nectar production in *Musa beccari* show adaptations to bird pollinators? ([2011](#))

The pollination ecology of *Globba pendula* Roxb. (Zingiberaceae) in Danum Valley, Sabah, Malaysia ([2011](#))

Pollination biology and fruit dispersal of *Alocasia sarawakensis* (M.Hotta) Araceae in a lowland rainforest in Borneo ([2010](#))

Abstracts

ECOLOGY

Edge effects and insectivorous birds in Danum Valley, Borneo

Forest edges differ to the interior core in terms of microclimate, level of disturbance and vegetation structure which can consequently alter faunal species assemblages

Even clearance for roads where one forest edge is nearby to another edge (i.e. roads) is sufficient to have negative consequences on their abundances and distributions

Insectivorous birds are particularly sensitive to habitat disturbance since the typically warmer and drier conditions at the edge negatively affects their invertebrate diet

Distance sampling techniques

Abundance estimates obtained from distance sampling were inconclusive due to large confidence intervals.

Matt Funaki, Auckland University of Technology, New Zealand
Josie Lumley, University of Leeds, United Kingdom
2018

Habitat selection by two size classes of fish and shrimp in the Tambun stream in Danum Valley

The length of animals and the water depth were measured to see variation of habitats in the stream and sizes of fish and shrimp. More than 200 fish individuals and 150 shrimp individuals were caught in the 200 m of the Tambun stream at Danum Valley Field Centre. Our study demonstrated that the size of fish and shrimp varied significantly amongst water depth. Two predation experiments were done. In the first experiment big fish and small shrimp and small fish were collected as prey items. In the second experiment prey items were small fish (live/dead) and shrimp (live, dead). Our study showed that both big shrimp and big fish are predators. Big fish preferred to eat small shrimps. Big shrimp preferred to eat dead prey items.

Kongsy Khammavong, Wildlife Conservation Society, Lao PDR
Malgorzata Bruzio, Warsaw University of Life Sciences, Poland
2011

Acoustic niche segregation: Does it happen at Danum Valley?

Acoustic signals play an integral role in many animals' communication. Acoustic environments can be very complex. Competition for limited acoustic channels and space could drive the partitioning of the acoustic environment resulting in niche segregation. However, few studies have examined the distribution of calls from individuals across different taxonomic groups. This study examines time as a factor by which species across different taxonomic groups segregate into acoustic niches. Birds and cicadas dominated the day while frogs and crickets dominated the night. Within the cicada and cricket group, some species were more specialised in the calling times than others. Acoustic niche segregation by time was found to occur in the primary dipterocarp forests of Danum Valley to a certain degree. However, there was not a clearcut pattern of acoustic niche segregation, suggesting that factors other than time of day might be important.

Chin Lijin, Monash University Sunway Campus, Malaysia
Michal Korniluk, University of Warsaw, Poland
2010

HERPETOFAUNA

Home range and microhabitat preferences of *Limnonectes kuhlii*

The purpose of this study is to gain knowledge about the home range of *Limnonectes kuhlii* and their microhabitat preferences in a dipterocarp rainforest in Sabah, Borneo. We used radio-tracking to get points of their locations during day and night and compared data of maximum distance travelled, distance to closest water bodies, their response to rainfall and the probability of being submerged. The longest distance travelled by one individual was 31.25m. The distance separating a frog from its closest water body did not vary between midday and evening radio tracking events but declined in response to increasing rainfall. Frogs were also more likely to be buried or submerged during daylight.

Anna Jonsson Sundberg (Sweden) University of Edinburgh, United Kingdom
Jennifer Insupp, University of Vienna, Austria
Natasha Woest, Salford University, United Kingdom
2018

Acoustic segregation of frogs in different soundscapes of Danum Valley Conservation Area (Sabah, Malaysia)

Acoustic signalling plays an important role in anuran reproduction, and the structure of advertisement calls is strongly linked to taxonomy. To reveal whether microhabitat and environment factors further determine variation in dominant frequencies across different species, we compared frog calls of nine species recorded from different sites characterised by diverging soundscapes (three pools and forest trails). Sound pressure level (SPL) was measured alongside calls to gauge the ambient noise levels. Dominant frequencies (DF) differed across species which varied in SPL. Moreover, DF and SPL were found to be significantly different across sites. Frogs were calling at higher frequencies in the three pools, with generally lower frequencies found along forest trails. We suggest that forest frogs are more dispersed, leading to less competition between species, whereas higher competition in a pool environment leads to louder calls at overall higher frequencies. For two species (*Rhacophorus appendiculatus* and *Hylarana nicobariensis*), sufficient data were available to investigate the relationship between DF and snout-vent length (SVL). Unexpectedly, larger *H. nicobariensis* tended to call at lower frequencies, whereas larger *R. appendiculatus* called at lower frequencies, however without significant correlation between DF and SVL. Species habitat preference and low sample size may explain these observations.

Nikki Dyanne Realubit, Holistic Education and Development Center (HEDCen), Philippines
Arfah Nasution, Cikananga Conservation Breeding Center (CCBC), Indonesia
2017

Influences of environmental factors on Rough Guardian Frog (*Limnonectes finchi*) tadpole abundance in the streams of Danum Valley Conservation Area

We investigated the distribution of tadpoles of Rough Guardian Frog (*Limnonectes finchi*) related to environmental factors within six streams in Danum Valley Conservation Area. The factors which we examined were tadpole predators, stream size and microhabitat types. These environmental factors were measured and correlations were tested. Streams with high density of leaf litter showed a positive relationship with higher tadpole abundance of the species while streams with a higher proportion of rocks showed the lowest abundance of tadpoles. To have a clearer observation of predator-prey interaction, a predation test was conducted on tadpoles by two predators which were dragonfly larvae (*Macromia* sp.) and diving beetles. Dragonfly larvae results to be the best tadpole predator. The roles

of leaves litter were recognised as protection and food source as previous studies suggested. Hence, prey survival-strategies were further tested with the treatment of leaves litter as protection for tadpoles. Our results showed that leaves litter did not significantly influence the predator efficiency. We concluded that leaves litter may act as food source rather than refuge for tadpole.

Ha Hoang Van (Vietnam), Cleveland Metroparks Zoo, USA
Mung Seng Chua, Universiti Malaysia Sabah, Malaysia
2011

Spacing and aggressive behaviour in the Yellow-bellied Puddle Frog (*Occidozyga laevis*)

There have been no detailed ecological studies regarding the Yellow-bellied Puddle Frog (*Occidozyga laevis*), found in Borneo, to date. Relying on field analysis and pilot observations in a pond located in the Danum Valley Field Centre in Sabah, Malaysia, we hypothesised that *O. laevis* in the pond had a non-random, even distribution and therefore may show territoriality or spacing behaviour. We also considered potential aggressive behaviour between *O. laevis* males as an additional support for our hypothesis. During our study we created 15 density maps which we used to test for non-random distribution. We also performed behaviour trials in the field, matching resident frogs with intruder frogs as well as resident frogs with a negative control (a rock). The Clark-Evans average R value indicated an even and therefore non-random dispersal. We did observe aggressive behaviours during the matches, but there was no significant dominance of the resident over the intruder or vice-versa. Our results suggested that male *O. laevis* show a clear spacing behaviour, likely connected to energetic cost trade-offs. However, given the fluctuations of the occupancy areas and the lack of resident dominance, we cannot infer that *O. laevis* present territoriality.

Bianca Corlett (Canada), Lund University, Sweden
Nicole Ponta (Italy), ETH, Zurich, Switzerland
2011

Interactions between males of Tree Hole Frogs (*Metaphrynella sundana*) in Danum Valley Field Centre area

Males of Tree Hole Frogs (*Metaphrynella sundana*) produce sounds to advertise their presence both to females and to the rival males. The rate of calls of the male frogs might be a good indicator to investigate how the males compete with each other and attract females. This study investigates whether the density of tree hole frogs influences the rate of calls a male makes and whether the distance to the nearest neighbour influences the male calling rate. We show that males in plots with only one individual had a significantly lower calling rate than males in plots with two individuals. These data were corroborated by our playback experiment which shows that the calling rate of males increases after a recording of a different is played. There is no correlation between distance and the rate of calls. For conclusion, our work shows that rate of male calls depends on presence of another calling male, but distance between them does not influence it.

Piotr Kuterba, Jagiellonian University, Poland
Rizka Apriani Putri, Universitas Gadjah Mada, Indonesia
2010

Species richness and microhabitat preferences of frog species in Danum Valley Conservation Area

Resource partitioning allows the co-existence of various species as it reduces competition. Our aim was to find out if there is habitat and microhabitat partitioning among frog species in Danum Valley. Two artificial ponds, two natural ponds, and one stream section were sampled. Our results show that

species richness in the stream is higher than in the ponds. Frog species have certain microhabitat preferences but they also occur in less preferred microhabitats. The same microhabitat can support more than one species. Thus, we concluded that the main factor allowing the presence of different species in the same place is the ability of sharing the microhabitat.

Ninda Lara Baptista, University of Lisbon, Portugal
Nurul Silva Lestari, Dipterocarps Research Centre, Indonesia
2010

Adjustment of Tree-hole Frog (*Metaphrynella sundana*) calling characteristics in relation to tree-hole properties in the field

Previous studies have indicated that male Bornean Tree-hole Frogs (*Metaphrynella sundana*) change their call frequencies to tune in to the resonant frequency of their cavity under laboratory conditions. We carried out a field study at Danum Valley Field Centre, Sabah, Borneo to investigate the correlation between call frequency and volume of water in natural tree cavities under field conditions. We recorded the calls of 19 frogs before and after adjusting the water volume in steps of 5 and 10 ml in the cavity. We found a significant relationship between the mean call frequency and air column volume. Continuous recording of an individual frog over a 32 minute period, as we added water, also showed an increase in frequency with increasing air column volume. Call frequency in response to changes in volume varied among individual frogs in cavities with different resonance properties. Although the laboratory evidence could not directly be translated into the field, we demonstrate that tree hole cavities influence the ability of *M. sundana* to vary its call.

Björn Johansson, Linköping University, Sweden
Stephen Hyland, National University of Ireland, Galway, Ireland
2009

Microhabitats of co-occurring tree frogs (*Polypedates* and *Rhacophorus*) around ponds of Danum Valley Field Centre, Sabah, Malaysia

Six tree frog species, *Polypedates leucomystax*, *P. macrotis*, *P. otilophus*, *Rhacophorus appendiculatus*, *R. pardalis* and *R. dulitensis* were observed to use the same ponds for breeding in around the Danum Valley Field Centre (Sabah). We investigated whether these six species shared the same ecological niche, or whether different microhabitats could be defined. For one week, the location of every individual encountered around three ponds was recorded every night. We found that the frog species occurred at different heights; *P. leucomystax* was different from all other species by occurring close to the ground at a maximum of 1 m. Seventy percent of all individuals were located within 0.50 metres from the water. *Rhacophorus pardalis* and *R. dulitensis* showed a preference for herbs over trees. All species were distributed randomly around the ponds. *R. dulitensis* was the main species in the temporary pond after heavy rain, which is an indication of a difference in breeding pattern.

Lieneke Bakker, Wageningen University, The Netherlands
Cheryl Cheah, Universiti Putra Malaysia, Malaysia
2009

Tree Hole frog (Microhylidae: *Metaphrynella sundana* Peters): habitat utilisation and density

We investigated patterns of habitat use and density in the Tree Hole Frog *Metaphrynella sundana* in the Danum Valley Conservation Area, Sabah Malaysia. We recorded a total of 46 calling sites in five 10 x 100 m transects. When calling from tree holes, *M. sundana* showed no preferences for specific tree diameter at breast height (dbh), tree height, canopy cover, litter depth or slope. Tree hole diameter and hole height (a preference for small holes close to the ground), as well as the height of trees (frogs

preferred smaller trees compared to reference samples) affected the frog's occurrence. The density of calling males was lower after heavy rainfall, and there is strong evidence that frogs regularly move between tree holes. Our result suggests that the density of *M. sundana* populations vary temporally and spatially, meaning that environmental heterogeneity is important for conservation management and should not be overlooked.

Phuong Thi Thanh Sam, Nature and People Reconciliation, Hanoi, Vietnam
Robin Lim, Danum Valley Field Centre, Sabah, Malaysia
2009

INVERTEBRATES: ants

Food preferences and species composition of ground foraging ants along a disturbance gradient in Danum Valley, Sabah, Borneo

The tropics are especially affected by land-use change, increasing the contact areas between disturbed areas and pristine forest habitats. This leads to heavy changes in habitat structure, in turn influencing organisms inhabiting those sites. Ants are commonly used to assess biodiversity, because they respond to changes in nutrient availability caused by variation in habitat structures. The aim of this study was to investigate food preferences and species composition along a disturbance gradient. Therefore, three transects were established near the Danum Valley Field Centre, Sabah, Borneo, leading from disturbed areas into pristine lowland rainforest. Five different baits, containing either lipid, salt, sugar and protein sources, as well as water were placed along these transects and observed for 90 minutes, while recording species and number of ants and present on each bait. Ants were classified into a total of 30 morphospecies. Species compositions in disturbed areas were relatively similar, whereas no patterns could be observed for edge and forest habitats. Concerning food preferences, both sugar and tuna were preferred across all habitat types, while oil was more heavily utilised in forest habitats than in disturbed areas.

Johannes Hausharter, University of Vienna, Austria
Silvan Rossbacher, ETH Zürich, Switzerland
2017

What factors elicit anti-herbivore responses in resident ants? A study on the potential myrmecophyte, *Octomeles sumatrana*

Ant-plant mutualisms have been studied extensively in tropical regions. These interactions involve reciprocal fitness enhancement between a host-plant and its resident ant community. Our study focused on a previously undescribed potential ant-plant (myrmecophyte), *Octomeles sumatrana*. We aimed to investigate the extent to which this can be considered a myrmecophyte, by analysing the degree of host-defence by resident ant species. Moreover, we aimed to disentangle the stimuli that induce a defensive response in symbiotic ants. We asked whether this signal is host-plant or herbivore derived by experimental introduction of herbivores to host leaves, and/or the mechanical damage of the leaf surface. Our results indicated that neither mechanical damage, nor herbivore presence, alone were enough to instigate a significant response. However, in combination, these factors were sufficient to elicit significant defensive behaviour. This indicates that it is the active damage to leaves, combined with the presence of a herbivore, that induces the ants to protect their host in natural systems. This, alongside observations of ants living in hollowed-out stems and the presence of possible extrafloral nectaries, we conclude that *O. sumatrana* is a transitional myrmecophyte.

James Johnston, University of Cambridge, United Kingdom
 Meg Griffiths, University of Oxford, United Kingdom
 2017

Do ants protect *Korthalsia furtadoana* J. Dransf. against herbivory?

Many plants are known to host ant colonies for protection against herbivores. *Korthalsia furtadoana* is a common rattan in Borneo that has very simple domatia as ant-housing structures and hosts many different species of ants. This study tested the effectiveness of the resident ants in protecting the host rattan against herbivory and whether this differed between ant species. The time of response of different ant species to two different types of herbivore was measured: the chewer herbivores (e.g. caterpillars) and the sucker herbivores (e.g. scale insects). The time of response and ant activity were compared with the leaf damage and number of herbivores identified in the plant during day and night observations.

Our results show that *Korthalsia furtadoana* does not have a mutualistic relationship with the host ants; however some interesting observations in *Myrmicinae* sp. 2 might suggest a possible mutualistic relationship still in evolutionary progress.

Patricia Dos Santos (Portugal), Royal Botanic Gardens Edinburgh, UK
 Edith Sabara, Bogor Agricultural University, Indonesia
 2011

Foraging ants on the forest floor

Ants are very species rich, especially in the tropics. To be species rich ants have developed coexistence strategies to deal with competition. This study looked at several characteristics that might be able to explain the coexistence of several genera using the same resources. The study was carried out in primary rainforest in Danum Valley Conservation Area in the period 18-25 October 2011. Bait was placed on 30 random plots. For each ant genera arrival time, recruitment time and distance to the nest were measured. A total of five genera of ant were identified in the study. Results showed differences among the ant genera for arrival time, recruitment time and distance to the nest. Main differences were between *Myrmicinae* and *Camponotus* with the main difference but none of the variables could clearly explain species coexistence. Observation showed large variation in social organisation and foraging behaviour of the present ant genera. Smaller ants have shorter arrival and recruitment times and distance to the nest compared to larger ants. Larger ants take bait usually immediately after arrival. Larger ants on the other hand are stronger and seem to have a more individualistic social organisation. Species specific social organisation could be a good explanation for explaining scavenging species coexistence.

Nico de Koning, Wageningen University, Netherlands
 Thomas Haege Mogensen, Aarhus University, Denmark
 2011

Foraging and recruitment behaviour of *Camponotus gigas* in a dipterocarp forest in Danum Valley, Sabah, Borneo

Ants represent a large amount of biomass in tropical ecosystems and demonstrate complex foraging and recruitment behaviours. We studied the behavioural and foraging ecology of *Camponotus gigas* at the Danum Field Valley Centre in October 2011. We recorded foraging activity at 14 nests and performed an experiment, where we varied the size of bait and recorded the recruitment behaviour. We also observed 7 nests at dusk and recorded changes in activity within 30 minutes. We found that *Camponotus gigas* mainly forages alone and only rarely in groups. We found no effect of bait size on recruitment. However, even though the results were not significant we observed a trend - that ants

recruit more conspecifics when more bait is available. Further, we found a significant increase in foraging activity at dusk. Additionally, we found that Temperature had a positive effect on the numbers of foraging ants at dusk. Our results are consistent with previous studies on the foraging behaviour of *Camponotus gigas* and generated several new interesting observations. Although *C. gigas* is largely known to be a nocturnal species, we found that some workers forage during the day and are able to recruit high numbers of conspecifics, when lots of food is available. The ecological impact of *Camponotus* on the rainforest is thus not solely restricted to night time.

Miranda A. Strubel, University of Leeds, UK
Joel O. Baumann, University of Berne, Switzerland
2011

On the prowl: Why do different ant species use floral and extra-floral resources on *Senna alata*?

A key factor in triggering ant-plant interactions is the provisioning of food by the host plant. Extra-floral nectaries in *Senna* are regarded as an important innovation for symbiotic relationships in this genus. Despite the fact that *Senna alata* does not have extra-floral nectaries, high numbers of different ant species were observed on inflorescences and stipules. It was the aim of this study to investigate the patterns of ant resource use on *S. alata*, a plant with the phylogenetic and physiological potential to develop ant mutualisms. Ants of different species show an increase in activity as a result of the addition of sugar and mashed buds to the inflorescence stems. The ants show no change in activity if access to the flowers or stipule like “bract” structures of the host plant is denied. It can therefore be assumed that ants obtain resources from these structures, opening up new perspectives in ant-*Senna* evolution.

Amy Munro-Faure, University of Cambridge, UK
Agnes Dellinger, University of Vienna, Austria
2011

A positive relationship between ant biodiversity and predatory function across a disturbance gradient in a SE Asian rain forest

Human modification of pristine habitats almost always leads to the local extinction of a subset of the species present. This means that the ecosystem processes carried out by the remaining species may change. It is well documented that particular species of ants carry out important ecosystem processes. However, while much work has been carried out to investigate the link between biodiversity and ecosystem functioning in other taxa, this has received relatively little attention for ant communities. Here we investigate the impacts of anthropogenic disturbance on ant-mediated predation, using bait removal rates as a surrogate measure. We found that although ant species richness, diversity, biomass and rates of bait removal did not change systematically across the disturbance gradient, the rate of bait removal was related to both ant species richness and biomass. Sites with a higher species richness and biomass of ants experienced a faster rate of bait removal. If these results are applicable at larger spatial scales for a wider range of prey items, then loss of ant species could lead to changes in the way that ecosystems function.

Tom M. Fayle *et al.* (class exercise)
2009

The recruitment time of ant species in forested and edge habitats at Danum Valley

Ants recruit nest mates to a food source through the use of chemical trails. This study aimed to determine the differences in recruitment times for ant species in two different habitats. A four day study was carried out on the recruitment times and abundances of ants in edge and forested habitats. The abundance of each ant species was recorded every minute over a 30-minute period. Recruitment time is defined as the time difference between the first arriving ant and the arrival time of the second ant of the same species. The abundance in forest ant species was negatively correlated with recruitment time. The same significant relationship was found with edge ant species. However, no significance difference in species diversity, species richness or abundance was found between the two habitat types. Qualitative observations of competitive interactions were also recorded and examined.

Adam D. Earl, University of Sussex, UK
Judy F. Walsh, Trinity College Dublin, Ireland
2009

INVERTEBRATES: other

The diversity of freshwater macroinvertebrates in the streams of Danum Valley, East Malaysia

A large proportion of the world's freshwater is found within the tropics. However, our current understanding of the diversity of freshwater macroinvertebrates in Malaysia is incomplete, with many species unknown to science. This study focused on how the family diversity and abundance of freshwater macroinvertebrates varied with substrate type and rate of water flow in three streams in Danum Valley Conservation Area, East Malaysia. There was minimal variation in the number of families as flow rate and substrate type altered. However, the families present varied, particularly between substrates, with most families inhabiting one or two substrate types. This is likely due to the energetic cost associated with evolving the necessary locomotive, feeding and breathing apparatus for the varied substrate types. Variation in families present with flow rate was much less distinct, likely due to the limited difference in the flow speeds across the streams.

Caroline Johnson, University of Cambridge, United Kingdom
Samantha Liza Durit, Universiti Putra Malaysia
2018

Species diversity and behaviour of Odonata in Danum Valley Conservation Area of Sabah, Malaysia

Odonata have always fascinated the nature lovers and conservationists. They are huge and colourful, making their behaviour somewhat easy to observe. In addition, they have been extensively used as indicators of environmental quality in aquatic ecological units. The objectives were to evaluate the Odonata species diversity, species richness and behaviour, especially *Camacinia gigantea*. Data collecting was carried out 9.00 am – 12.00 midday and 1.00 – 4.00 pm in two different ponds by scan for all species and focus observation for *Camacinia gigantea*. The light intensity and temperature were measured in every kind of the observation. The diversity of species of Odonata each location was measured by Shannon Weiner index (H'). The relationship between the Odonata community and the environmental variables was done through canonical correspondence analysis. All analyses were conducted with the computer program PAST program 3.0. There were 23 species of Odonata in which Libellulidae and Coenagrionidae were the most dominant families. The diversity and richness of species of Odonata were higher in the shade pond

than in open pond. The presence and abundance of some Odonata species were related to temperature, and lux. Sitting and flying behaviours of all Odonata species, including *Camacinea gigantea* can be observed since 9.00 am to 3.30 pm. Playing can be observed from 9.00 am. until 2.00 pm, while mating and laying eggs can be observed from 9.00 am to 10.45 am. Sitting behaviour was the most activity during the daytime, alternatively with a short time flying to balance their body temperature.

Agus Suroto, Indonesia
Sahat Ratmuangkhwang, Thailand
2018

Species diversity of butterfly in open and forested area in Danum Valley Conservation Area, Sabah, Malaysia

Butterflies are a taxon that is highly sensitive to habitat disturbance and most of them are threatened by forest modification. Understanding the species diversity of butterflies is crucial for monitoring the status of butterflies in an area. Passive sampling using baited traps and active sampling using butterfly nets was done in forested and open areas of Danum Valley Conservation Area (DVCA). The open area was found to have a higher species diversity and abundance compared to forested areas. There were 35 species found in total, seven of them are shared in both open and forested areas, six were only found in the forest whereas the remaining 22 species were found only in the open area. Butterflies prefer areas with more sunlight and a higher temperature mainly to regulate their body temperature and generate energy. It is evident that certain species were habitat specific and can only be found in the forested area but not in the open area and vice versa. It is important to identify the species and abundance of butterflies in DVCA for future management and habitat protection purposes.

Pyae Phyo Kyaw, Wildlife Conservation Society Myanmar
Sze Ling Tee, University Putra Malaysia
Vivienne Pei Wen Loke, University of Nottingham Malaysia
2018

Comparison of butterfly traps between open canopy and close canopy in Danum Valley Field Centre, Borneo

Over the years, butterflies are used in studies because of their sensitivity to alterations in their habitat. There are different ways in monitoring the abundance and diversity of butterflies but in this study we used baits to identify their species composition in an open and close canopy of the tropical rainforest of Danum Valley Conservation Area. The study took four days of observation on 20th to 24th October, 2017. ANOVA was used to test the significance between the baits among the four sampling sites. The mean preference of butterfly individuals between the baits were not significant, however, there is significant in the number of insects attracted to the baits.

Grace Luke, The Papua New Guinea University of Technology, Papua New Guinea
Salmah Widayastuti, Institut Pertanian Bogor, Indonesia
2017

Sensing distance of the Tiger leech *Haemadipsa picta* in Danum Valley

Leeches are thermosensitive predators with a worldwide distribution. However, their predatory behaviour is still poorly understood. By using unmoving human bait, this study is aimed to test the sensing distance of the tiger leech *Haemadipsa picta* in Danum Valley (Sabah, Borneo) in the absence and presence of DEET repellent. We further collected data on weight increase after blood meals. All individuals can sense their prey from up to 25 cm (most individuals reacted from 5 cm and

less), with no apparent effect of the repellent treatment. Furthermore, leeches show an up to tenfold weight increase after a blood meal.

Hong Pham, Hanoi University of Science - Vietnam National University
Jenny Panziera, University of Lausanne, Switzerland

2017

Ecology of water striders (Family Gerridae) at puddles in Danum Valley Field Centre

Water strider is the one interesting aquatic insect. They are capable of skating on the water surface, including in puddle habitat. Twenty-eight puddles (large, medium and small puddles) were surveyed in seven days from 18th to 27th October, 2011. This research aims to measure relationship between puddle size and number of Gerridae. It also collects information about behaviour and prey taken by Gerridae. Our results showed a significant relationship between size of puddles and number of Gerridae. Large puddles are important habitats for Gerridae while small puddles may be too short lived to support individuals for long. Gerridae activity types differed significantly from one another. Gerridae use puddles for feeding – largely flies and ants and small insects and even fruit. They also use the puddle habitats for breeding, even though Gerridae also predate on eggs from the same species.

Fauziah Syamsi, Andalas University, Indonesia
Lan Ho Thi Kim, Wildlife At Risk, Vietnam

2011

Differences in fruit feeding beetle communities through the canopy of a primary lowland forest in Malaysia

Vertical stratification has been shown to have an influence on the communities of insects in the rainforest canopy. Here we studied the community composition of fruit feeding beetles through the rainforest canopy at Danum Valley Conservation Area, Sabah, Malaysia. 42 morphospecies from 7 families were recorded from three different canopy heights: 1 m, 10 m and 20 m. The community was dominated by the family Nitidulidae but there were differences in the canopy layers with more families including Staphylinidae being found at ground level. The species richness and diversity of fruit feeding beetles did not differ between canopy layers. The abundance of beetles however differed significantly; particularly samples from 1 m differed significantly from 10 and 20 m. The complexity of the immediate environment in terms of canopy cover held no relationship with species richness, diversity or abundance. It is likely that the difference in abundance is related to the high abundance of ripe fruit on the forest floor dropped from the tree and opened by large mammals.

Felicia Lasmana, University of Padjadjaran, Indonesia
Jasmine King, University of Nottingham, United Kingdom

2010

Ecosystem engineers: Earthworms in tropical forests: A study from Danum Valley, Malaysia

The forest floor of Danum Valley in Sabah, Malaysia, is densely covered with thousands of miniature tower-like soil structures. This study investigated the role of earthworms, which were found to be the creators of these towers, in nutrient retention and soil turnover in tropical forests. Results showed these small earthworms are potentially major ecosystem engineers in tropical forest ecosystems, which turn over and process huge amounts of soil per year (over 88 kg per m²). The worm casts were found to have significantly higher levels of nitrate and conductivity than surrounding soils. It is well known that tropical forests are scarce in nutrients, particularly nitrate. This makes the activity of earthworms potentially crucial for retaining nutrients within the ecosystem and preventing loss through leaching. Soil moisture

content was found to be an important factor determining the distribution of earthworms. The implications are especially significant for dry degraded forests where our study showed that the presence of earthworms was lower than in primary and intermediate forests.

Sarah Johnson, University of Salford, UK
Arshiya Bose, University of Cambridge (UK), India
2010

Invertebrate drift in the Tambun stream in Danum Valley

The invertebrate drift is the main food source of stream fish, but do the fish eat just the aquatic animals or do they also eat the terrestrial animals that drop down into the water? The drift composition was measured and fish gut contents were examined in the Tambun stream (Danum Valley, Sabah, Borneo). The results show that invertebrate drift in the Tambun Stream accounted for 41 million potential food particles drifting down the Tambun Stream each 24 hours. The numbers of aquatic animals drifting were greatest at night. The reason may be that the animals are minimising risks of being eaten by fish, which are visual predators. Also, the fish guts content showed that the fish prefer terrestrial and aquatic animal to exuviae. The terrestrial animals drop accidentally into the water and flounder. They are not adapted to the water environment and are therefore more vulnerable to predation in water. The aquatic animals are adapted to living and surviving under these conditions through structural and behavioural adaptation. One of those adaptations could be the voluntary drift during the night, when they are not visible to fish. Such controlled drift allows redistribution with minimum risk.

Anita Bousa, Wildlife Conservation Society, Lao PDR
Chiara De Cesare, University of Innsbruck (Austria), Italy
2010

Leech hide and seek: How leech awareness of hosts changes with environment and moisture levels

Leeches are parasitic organisms that take blood meals, most commonly from warm blooded mammals. A wide range of leech species exist and are widely distributed around the world, however the largest proportion of leech species is found in the tropics. In order to assess changes in leech activity and density across the forest at Danum Valley Field Centre, four habitat types were selected and sampled in two main areas. Samples were taken at different times of day and after different time periods had elapsed since heavy rainfall. Field observations showed no difference in leech density across habitat type or across levels of rainfall, however further experiments in the lab concluded that leech activity and awareness is increased after spending time in a wet environment.

Jenny Mason, University of Liverpool, UK
Sysomphane Sengthavideth, Wildlife Conservation Society, Laos
2010

The acoustic landscape and cicada call patterns in Danum Valley

Cicadas are a dominant feature of the acoustic environment in the tropics and are known to have species-specific calls making them useful subjects for investigating acoustic niches. Cicadas in Sabah, Borneo however, have been relatively poorly studied. This study described the daily acoustic landscape of Danum Valley by measuring sound pressure levels, humidity and temperature along a transect, together with recording the dominant calling animals. The presence/absence of eight 'sound species' of cicadas was scored to investigate potential partitioning in their acoustic behaviour. The acoustic landscape was shown to have a daily cyclical pattern, clearly dominated by cicadas. Cicada calls were found to be partitioned amongst other animal groups as well as between cicada sound

species. This partitioning was found to occur temporally and by call frequency and call pattern. Observations also found spatial location influenced partitioning. Avoidance of interspecific competition seems to be the most likely driver for species occupying different acoustic niches.

Emma Ligtermoet, Charles Darwin University, Australia
 Stefanie Weigl, Ludwig Maximilian University, Germany
 Ana Filipa Palmeirim, University of Lisbon, Portugal
 2009

Blood suckers in our midst: Leech (*Haemadipsidae*) abundance on forest trails and off-trails in the Danum Valley Conservation Area, Sabah, Malaysia

Danum Valley Conservation Area (DVCA) is exceptionally rich in both flora and fauna. Forming part of this richness, DVCA has two species of terrestrial leeches, the Tiger Leech (*Haemadipsa picta*) and the Brown Leech (*Haemadipsa zeylanica*). Our study looked at the composition and abundance of leeches in trails and off-trails in three sites in the forest. We tested the hypothesis that leech abundance would be greater in the trails than off-trails mainly because more animals use trails for foraging. The results showed no significant differences between species composition and abundance of leeches overall. However leeches were more abundant in one trail system when we tested for differences between sites. We also found no significant correlation between the abundance of leeches in relation to temperature and humidity.

Legi Sam, University of Papua New Guinea, Papua New Guinea
 Dwi Susanto, Bogor Agricultural University, Indonesia
 2009

Diversity and interaction of dragonflies in Danum Valley Field Centre

This study investigated diversity and interaction of dragonflies around the Danum Valley Field Centre. Six days samplings were conducted (18th-23rd October 2009) in different locations which included two ponds (114 m², 28.98 m²) and a wet-grass area (486.3 m²). Twenty two species were recorded in three study sites. Different types of interaction within two particular species of dragonflies were observed during different times of the day. Apart from gathering information on diversity and interaction, data collection on behaviour is also included in this study.

Sithisack Paninhuan, Wildlife Conservation Society (WCS), Lao Program, Lao
 Kai Lin Ling, Institute for Tropical Biology & Conservation (ITBC), Borneo, Malaysia
 2009

PLANT, FUNGI AND FOREST ECOLOGY

A comparison study of biomass changes due to drought event in primary and logged-over forest

Extreme weather events such as drought affect the ecosystem services of primary and logged-over forests. This study aims to assess recovery capability of primary and logged-over rainforests using above ground live tree biomass (AGB, t/ha) and its change related to drought and non-drought years. This study used three plots from Danum Valley Conservation Area (DVCA) and Innoprise-Face Foundation Rainforest Rehabilitation Project (INFRAPRO), respectively to represent primary forest and logged-over forest. In October 2018, trees were measured in plots of 0.1 ha size. AGB was modeled to compare the rate of change in AGB throughout different periods following a drought event that was identified between year 2015-2016. Primary forest plots have a higher total biomass than logged-over forest plots. However, the speed of biomass recovery is not significantly different

between the two forest types. This implies that logged-over forests carry similar value regarding carbon storage as primary forest.

Chigusa Renate Keller, University of Zurich, Switzerland
 Gabriel Paul Hibberd, University of Bangor, United Kingdom
 Maliwan Namkhan, King Mongkut's University of Technology Thonburi, Thailand
 Mohd Ashraf bin Abdul Mutalib, Universiti Putra Malaysia, Malaysia
 Shia Kang Ping Amanda, HUTAN-KOCP, Malaysia
 2018

Camouflage success in rainforests: A study case in Danum Valley, Borneo

Camouflage efficiency is an important factor influencing prey-predator interactions and survival success. Selection of coloration in animals seem to be dependent on the environmental conditions found in different habitats. This study tested the detection success of mammals with unicolor, spotted and striped patterns. Participants were asked to spot mammal figures hidden in different vegetation densities during a limited time and restricted movement. Results showed that unicolor pattern was the most successful camouflage strategy. Vegetation density did not influence the detection success of distinct colouration patterns; and high light intensity decreased the detection success of different camouflage strategies. Unicolor pattern might be absorbing light in shady areas while reflecting it in open sites, leading to high camouflage effectiveness. Striped patterns seemed to perform better in open areas, whereas dotted patterns were less effective across all vegetation densities and light intensities.

Amael Hinojo Antille, University of Lausanne, Switzerland
 Lourdes Martínez-García, Lund University, Sweden
 Vincent Grognez, University of Fribourg, Switzerland
 2018

Herbivory rate of *Mallotus miquelianus* compared between gaps and understorey in Danum Valley Conservation Area, Borneo

The study was conducted in tropical lowland forest in Danum Valley Conservation Area, Borneo. The objective was to identify potential differences of herbivory between gaps and the understorey. The herbivory rate was assessed by sampling leaves of *Mallotus miquelianus* (Euphorbiaceae) in gaps and the surrounding understorey. This is a shade-tolerant tree that is commonly found both in understorey and around tree fall gaps. Both representative and intact leaves were collected to determine the relative loss of area and weight. Soil moisture, soil temperature, air temperature, seedling density and canopy cover were recorded as environmental factors. Between gaps and understorey, there was no difference in the herbivory. However, the consumed biomass is higher in gaps, as the leaves are bigger and heavier. The leaf area of the individuals is very variable. This study is important to assess growth processes in gaps and to investigate the ecology of species and their variances during the succession.

Charlotte Kohns, Universität Koblenz-Landau, Germany
 Arvid Lindh, Lunds universitet, Sweden
 Amelia Joyce Philip, Universiti Malaysia Sabah, Malaysia
 2017

The structure of a plant-frugivore network in Danum Valley, Sabah, Malaysia

To understand the plant-frugivore network in the surroundings of Danum Valley Field Centre we observed seven species of fruiting plant species namely *Mangifera caesia*, *Lagaestromia speciosa*, *Grewia laevigata*, *Glochidion rubrum*, *Heynea trijuga*, *Crateva religosa* and *Clidemia hirta* and the frugivores visiting them. The observed plant species had a variety of fruit-sizes to include as many

potential frugivores as possible. One invasive species, *Clidemia hirta* was included in the observations to see if this plant shares utilisers with other fruiting plants. The study observed five fruit eaters. Two different networks were made for the study, one for all the visitors to the plants and one for visitors that are frugivores. The interaction networks from our study shows a complex system with a relatively high level of nestedness. For both networks we can see a high specialisation level which show that there are few generalists in the network.

Grace Pounsing, Maliau Basin Conservation Area, Yayasan Sabah
Rachman Bogor Agricultural University
Ulrika Erwander, University of Göteborg Sweden
2017

Anti-herbivory strategy by red young leaves of rainforest tree seedlings

Delayed greening and presence of anthocyanin provide adaptive advantages to developing young leaves. Among the many hypothetical functions of leaf reddening, its potential defensive value against herbivory was examined among seedling of *Hopea nervosa* and *Pentace laxiflora*. Herbivory was examined in green phenotypes and red phenotypes of both species based on proportion of damaged leaves and leaf area lost to herbivory. Levels of foliar damage were significantly lower for red phenotypes than for green phenotypes in *Hopea nervosa*, suggesting a successful antiherbivory strategy. In *Pentace laxiflora*, protection against insect damage was only observed in red young leaves but did not persist in matured green leaves.

Shen Nyan Leong, Wildlife Conservation Society, Malaysia
Naing Lin, Wildlife Conservation Society, Myanmar
2011

Is reproductive success in *Calanthe zollingeri* (Rchb.f. 1857) related to distance from the water body and canopy openness?

Fruit production in many orchid species is low and, as light is a key factor for terrestrial orchid distribution, we studied the influence that distance to the water and canopy openness have on the reproductive success of the terrestrial orchid *Calanthe zollingeri* in Danum Valley Field Centre. We measured attributes of the vegetative and reproductive structures of each plant as well as canopy openness and distance from the closest water source. Results show that fruit production is resource limited. Even though we could not observe any variations in pollination level due to spatial factors, the reproduction success was positively related to light availability and negatively related to distance from the water. Thus we suggest that a temporal difference in pollination success during the 2011 flowering schedule occurred.

Sophak Sett, Royal University of Phnom Penh, Cambodia
Ambra Tosto, Camerino University, Italy
2011

Ant predation and herbivore damage on *Mallotus lackeyi* (Euphorbiaceae) in a lowland dipterocarp forest in Borneo

We did predation experiments using 600 termite baits and 200 plasticine caterpillar baits placed on 30 *Mallotus lackeyi* (Euphorbiaceae) trees with varying degree of herbivore damage. There was no statistically significant relationship between the herbivory damage and the predation rate on the termite baits. However, we found significant correlation between the herbivore damage and the rate of ant attacks on the plasticine caterpillar baits. This result suggests that the artificial plasticine caterpillars may be more suitable for assessing ant predation activity than live termites used as baits.

Hla Naing, WCS, Myanmar Program, Myanmar
Chris Dahl, New Guinea Binatung Research Centre, Papua New Guinea
2010

Different gradients and its influence to recruit of seedlings in primary forest in Danum Valley

Seedling recruitment was examined across a topographical gradient of the lowland dipterocarp forest in the Danum Valley Field Centre. Difference between number of recruits, species, and location were tested in three sites. Eighteen sample plots were set up and seedlings were counted and identified. The results indicated that most of the new seedlings are from the dipterocarp species, accounting for 86 per cent of the total seedlings. In addition, the number of old seedlings is very small, only accounting for 4 per cent of the total seedlings. Moreover, statistical tests show that there is no difference between the number of recruits and its locations; but there is a difference in term of species and its gradient.

Ngoc Thang Nguyen, WWF Greater Mekong - Vietnam Program, Vietnam
Hoeun Seanglay, Royal University of Phnom Penh, Cambodia
2010

Do epiphytes reach the sky? A study on vertical stratification of *Asplenium* and *Drynaria* on *Parashorea* spp. in Danum Valley

In this study, we examine whether there is vertical stratification in big epiphytic ferns of the genus *Asplenium* and *Drynaria* on *Parashorea* spp. Measuring the epiphyte occurrence on these trees together with a study on the abundance of epiphytes gives us a clear picture of how the epiphyte world looks like in the forest. The large epiphytes are mainly found in the canopy, only two were found at lower heights, less than 30 metres, on the trunks of the trees. There is a significant difference between the heights at which the *Asplenium* and the *Drynaria* grow. The *Asplenium* is not more abundant compared to the total of all other species of epiphyte in forest. However it does take up a large proportion of the present epiphyte community.

Chau Phing Ong, Massey University, New Zealand
Els Ton, Wageningen University, the Netherlands
2010

Seed dispersal ability of *Dryobalanops*, *Dipterocarpus*, *Shorea* and *Parashorea* of Danum Valley Field Station, Sabah

In this study we worked on the question whether dipterocarp seeds of different species differ in their dispersal abilities. Moreover we were interested in the morphological features of the seeds which mostly determine this issue. Since we took an experimental approach as well as observations in the forest to investigate our question we also wanted to know whether our experimental based findings can be applied for natural environment.

In both approaches we could find significant differences in seed dispersal among the different species. Moreover correlation tests showed that the seed weight and wing area are mostly responsible for the flying abilities of the seeds. Comparing our two approaches we found out that general trends of dispersal ability that we gained in our experiment can also be seen in natural patterns.

Felix Steinmeyer, University of Regensburg, Germany
Sentiko Ibalim, New Guinea Binatung Research Centre, Papua New Guinea
2010

Ecology of *Pterospermum stapfianum*

Pterospermum stapfianum is usually found growing along riverine primary lowland forest. The effect of proximity to the river and canopy cover on this plant was examined. Six plots were established along two rivers and measurements on adult tree and seedling for this species were collected. Results showed, the distribution of adult tree was related to the distance from the river. This suggested, their distribution were affected by disturbance from river, presumably flood. The density of seedlings was affected by the canopy cover, and seedlings were found in areas with less canopy cover than adult trees.

Huaimei Yong, Universiti Malaysia Sabah, Malaysia
Phouthakone Luangyotha, Wildlife Conservation Society, Lao
2009

The effect of microclimate in Borneo rains forest on macrofungal communities

Understanding the ecology of fungi is of great importance due to their relevance to questions of biodiversity and to the role they play in regulating populations of other organisms. This study was conducted in Danum Valley Conservation Area to investigate the effect of microclimate on the occurrence, density and state of host decay on the fruiting macrofungi. Macrofungi were recorded at relative humidities between 85.20 - 97.20 %; temperatures between 27.5 - 31.0 °C; and a substrate moisture content of 31.40 - 77.62 %. Different macrofungi groups showed a tendency to prefer different states of decay (measured by bark characteristics). The density of fruiting bodies was not influenced by abiotic conditions. These results suggest that further work on the succession of macrofungi on different substrates would help understand their diverse microhabitats and role in ecosystem function.

Bruno Herlander Martins, University of Lisbon, Portugal
Mui Ching Tan, Universiti Putra Malaysia, Malaysia
2009

The effect of plant density on insect herbivory in two plant species (*Melastoma malabathricum* and *Clidemia hirta*): A comparison of native and invasive species in Danum Valley Conservation Area

The effect of plant density on insect herbivory was examined in two plant species. It was expected that with increasing density higher levels of herbivory would be sustained. A native melastome, *Melastoma malabathricum*, and *Clidemia hirta*, a non-native from the same family, were compared. Under the enemy release hypothesis any effect of density would be expected to be more severe in the native species. Five measures of density were used in order to test which aspect of plant distribution was the best predictor of herbivory. Light availability was measured to assess the impact of growth rate. Finally herbivory types were recorded so that any differences between the two species could be analysed. There was no difference between mean herbivory levels in the two species. For *C. hirta* height provided the best model and was a significant predictor of herbivory levels showing a negative relationship. For *M. malabathricum*, volume provided the best model but none of the terms were significant. Herbivory type differed between the two species in number and frequency. These results suggest that density measures are not the best predictors of herbivory levels in *C. hirta* and *M. malabathricum* and that *C. hirta* is not becoming abundant as a result of the release from natural enemies.

Alexandra Davey, Oxford University, UK
Sebastian Kepfer Rojas, Lund University, Sweden
2009

The effect of seedling density of a shade-tolerant species, *Mallotus miquelianus* (Euphorbiaceae), on herbivory in the tropical rainforest in Danum Valley Conservation Area, Malaysia

Mallotus miquelianus is a shade-tolerant shrub (Euphorbiaceae) which is usually found in both primary and secondary forest. This paper reports the results of a study on *M. miquelianus*. There was no relationship between seedling density and herbivory. This may be insects feeding on the plant species are generalist species. The study also showed that younger leaves exhibit more herbivory level than the mature leaves, which could be explained in terms of the nutritional value where young leaves mean higher nitrogen concentrations. Herbivory levels were not related to seedling height and the distance to the nearest neighbour. This could be because the insect types that feed on the plant are mobile and not restricted to localised feeding areas (dense seedlings). There is a significant negative relationship between the number of parent trees nearby and seedling density. Our study also showed *M. miquelianus* seedlings prefer high canopy cover compared with open canopy areas. Shaded areas may be the optimum condition where seedlings are high in number. Herbivory is influenced by a range of factors all occurring simultaneously and a better understanding of this very important concept would be to look into these various factors insect herbivores, florist composition and the abiotic factors.

Agus Wahyudi, Dipterocarp Research Centre, Indonesia
Francesca F. Dem, New Guinea Binatang Research Centre and UPNG, Papua New Guinea
2009

POLLINATION

Investigating environmental factors affecting pollinators in *Etlingera megalochelios*

The relationship between environmental factors and number of pollinators of *Etlingera megalochelios* were studied. Our main aims were to see whether light intensity and spatial arrangements of inflorescences affect number of pollinators. We did 71 observations in six days in two different study areas (Danum 1 and Danum 2). We used R version 3.4 to establish the relationship between the factors tested. We found that neither light intensity nor spatial arrangements of the inflorescences show any existence of relationship. Our results could be the basis for more studies on the genus *Etlingera* (Zingiberaceae) in Danum valley, Borneo.

Phonesouk Chanthavong, Wildlife Conservation Society, Lao PDR
Alfred Kik, New Guinea Binatang Research Center, Madang, PNG
2017

Pollination syndrome as a predictor of primary pollinator and diurnal nectar production trends in *Musa beccari* (Musaceae) in Sabah, Malaysia

Pollination syndromes can provide useful predictors of the primary pollinators for flowering plants based on morphological specialisation, and therefore offer evolutionary insight to pollination ecology. *Musa beccari*, a species of wild banana native to the Sabah region of Borneo, offers a good example of pollinator-mediated specialisation whereby the flowers exhibit an ornithophilous (erect red inflorescences) pollination syndrome adapted for bird pollination. This study investigated the reliability of the pollination syndrome by identifying the floral visitors received by *M. beccari*, and whether trends in nectar production correspond to pollinator activity. To achieve this we conducted observations of floral visitors throughout the day and collected nectar samples, measuring volume

and sucrose concentration, for flowers sampled at regular intervals and for flowers bagged for 24 hours to establish a standing crop. We found that rate of nectar production ($\mu\text{l/hr}$) peaks between dawn and midday and this coincides with observed bird visitation. This suggests the pollination syndrome of *M. beccari* predicts primary pollinators and *M. beccari* is able to prioritise resource allocation by varying its diurnal rate of nectar production to encourage bird visitation. Furthermore, we observed a number of other floral visitors not adapted to the pollination syndrome, the diversity of which also peaked with nectar production suggesting these visitors are nectar robbers. Hence, our results support the prediction that *M. beccari* is primarily bird-pollinated but also receives other visitors that aim to benefit from the nectar resources.

Fiona Plenderleith, University of Edinburgh, UK

Connie Turton, University of Nottingham, UK

2017

Sexist bees promote greater allocation to male vs. female reproductive function in *Begonia danumensis*

Many *Begonia* species are pollinated by deception: their female flowers offer no reward but deceive pollinators into visiting them by mimicking their reward-providing male counterparts. In contrast to Neotropical species, relatively little is known about the reproductive ecology of Bornean *Begonia* species. We investigated whether *Begonia danumensis*, a species endemic to the Danum Valley Conservation Area, is pollinated by deception and, if so, whether relative floral sex allocation and visitation between male and female flowers is similar to observations made for similar Neotropical *Begonia* species. Female *B. danumensis* flowers were found to contain no nectar or other floral resources and are therefore likely pollinated through deception. The floral sex ratio was significantly biased, with 9.88 ± 4.57 male flowers for every female. Male flowers were also visited significantly more frequently than females, receiving 1.165 and 0.153 visits per hour, respectively. This indicates that male function is a more important determinate of reproductive fitness at this stage of the fertilisation process. This is likely driven by frequency dependent selection in favour of increased male function as a means to increase visitation to female flowers. As many *Begonia* are habitat specific, narrow endemic species, they are particularly sensitive to disturbances such as logging and mining, more detailed information regarding their reproductive biology may be invaluable for the conservation of rare and threatened species.

Annie Armstrong, University of St. Andrews, Scotland

Joshua Whitehead, University of New England (UNE), Australia

2017

The relationship between bee abundance and the density of *Melastoma malabathricum* shrubs at Danum Valley, Sabah, Malaysia

We studied the relationship of pollinator bee abundance with the number of open flowers, density of stems, area occupied by plants and the distance to closest clump of *M. malabathricum* along the road around Danum Valley Field Centre. Thirty three clumps with 162 flowers of *M. malabathricum* were surveyed over 6 days from 8:00 AM to 12:00 PM. Four families of eight species of bee and a total of 233 individuals were recorded. A Generalised additive model (GAM) related all parameters and showed that the number of open flowers (p -value= 0.0537) and the number of plants in a clump (p -value = 0.0675) were strong influences on the abundance of bee species. While these two parameters had relationship with each other, number of flower is assumed to be attracting bees for pollination. Shade or sun light may not affect the detection of bee even though study area occupied

under canopy or exposed to sun light, the detection of bee by be affect by variety of behaviour among species.

Mao Khean, Wildlife Conservation Society, Cambodia Program
Aung Ye Tun, Wildlife Conservation Society, Myanmar Program
2017

Does nectar production in *Musa beccari* show adaptations to bird pollinators?

We studied diurnal patterns of investment of wild banana *Musa beccari* into nectar volume and sucrose concentration in male and female flowers. We also measured the final volume of nectar produced by flowers that experienced nectar removal throughout the day and flowers that did not. We found no effect of nectar removal on final volume of nectar. Volume of nectar produced by both male and female flowers declined sharply before the night, when bird pollinators are not available. Sucrose content on the first day of anthesis dropped before night in male, but not in female flowers.

Katarzyna Mikolajczak (Poland), University of Edinburgh, UK
Xaysompheng Sengkhamyong, Integrated Ecosystem & Wildlife Management Project, Lao PDR
2011

Pollination biology and fruit dispersal of *Alocasia sarawakensis* (M.Hotta) Araceae in a lowland rainforest in Borneo

This study investigated the reproductive ecology of *Alocasia sarawakensis* in Danum Valley Field Centre. Nothing is known about the pollination and dispersal biology of this species. Our investigation reports the first thermogenesis measurements and also observations on pollinators (Diptera, Drosophilidae). In addition, unique spathe movements within this genus were recorded and are believed to act as a pollinator management device. Dispersal observations indicate that seeds of this species are exclusively dispersed by birds. A total of nine bird species were observed removing fruits, indicating *A. sarawakensis* is an important food resource for many species in lowland rainforest. Spiderhunters (Nectarinidae, Arachnothera) dominated in visitation rates and total seed removal. This may be due to the characteristic beak morphology of the genus allowing easy removal of often relatively inaccessible fruits, or possibly territorial exclusion of other species.

Conor Redmond, Trinity College Dublin, Ireland
Florian Etl, University of Vienna, Austria
2010

The pollination ecology of *Globba pendula* Roxb. (Zingiberaceae) in Danum Valley, Sabah, Malaysia

The pollination of *Globba pendula* is poorly known to science. This study aims to document the fruit set variation between the opened and closed forested areas. Sixty plants were tagged, measured and observed (for 28 hours 45 minutes) in open and closed forested areas. Floral visitors were also observed on video cameras. The light density did not have any effect on the fruit set of *Globba pendula*. The number of floral visitors was highly related to the number of opened flowers and with the time of day. The study suggests that the main pollinator for *Globba pendula* could be *Anthophora* bees (Anthophoridae) regardless of whether the flower is in the open or closed forested areas.

Billy Bau, University of Papua New Guinea, Papua New Guinea
Chhin Sophea, Royal University of Phnom Penh, Cambodia
2011