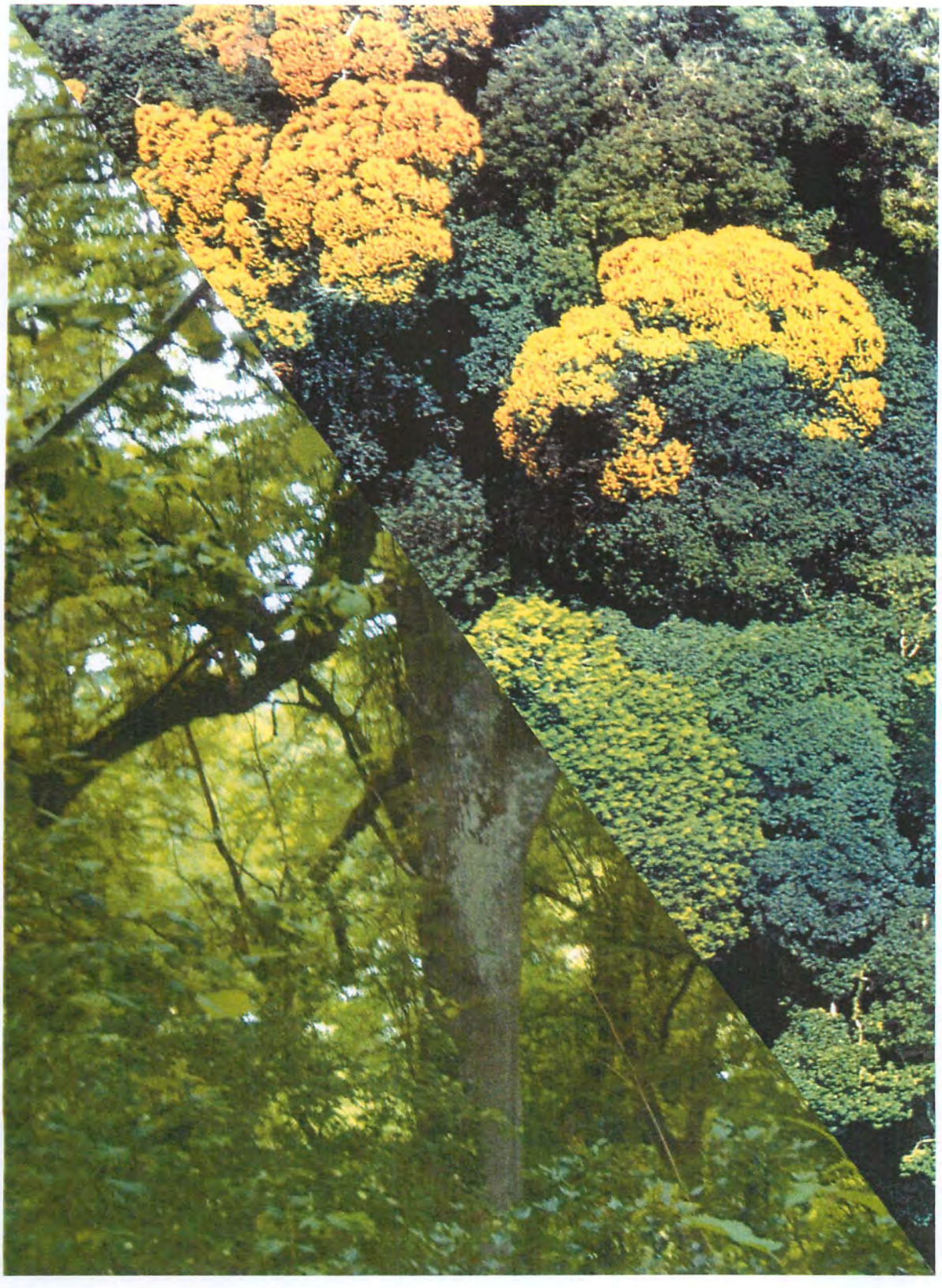

Patterns and processes in canopy science

7th International Canopy Conference

21-26 August 2016 University of Roehampton | London, UK

Plenary speakers

Dr Louise Ashton - Natural History Museum London, UK

Forest Canopy Science: achievements and horizons

Biography

Louise Ashton is a postdoctoral fellow at the Natural History Museum, London. Her research focuses on tropical rainforest biodiversity, climate change impacts on insect communities and understanding the factors shaping community assembly across environmental gradients, primarily using insect herbivores. Recently, her work has focused on ecosystem manipulation experiments to isolate and identify of the drivers of ecological functioning. In the future, Louise aims to use ecosystem manipulation experiments to explore ecological problems, focusing on rainforest canopies and the impacts of human activities.

Professor Gerhard Zotz - University of Oldenburg, Germany

Plants on Plants. Reflections on Canopy-Dwelling Plants

Biography

Gerhard Zotz has been working with plants and animals in tropical forest canopies for more than two decades, addressing a range of questions, particularly on the functional ecology of vascular and non-vascular epiphytes, the importance of canopy plants as facilitators of canopy fauna or large-scale biogeographic issues. Apart from his position at the University of Oldenburg as the leader of the Functional Ecology Group, he is also a Research Associate of the Smithsonian Tropical Research Institute in Panama.

Dr Ben Langford - Centre for Ecology and Hydrology, Edinburgh UK

Revealing the unseen world of biosphere – atmosphere interactions

Biography

Ben Langford is an Atmospheric Scientist based at the Centre for Ecology & Hydrology, Edinburgh. He specialises in the development of micrometeorological techniques to measure the exchange of trace gases and aerosols between the biosphere and atmosphere. His research focuses on understanding the processes that control the emission and deposition rates of reactive chemical species such as volatile organic compounds and aerosols to and from plant canopies and translating the results into improvements in the chemical transport models that underpin UK, European and global policy. His work has taken him from the depths of Borneo, where he investigated the impact of land-use change on regional air quality, to the urban jungle of central London, where his work has helped to highlight gaps in the national atmospheric emission inventory.

7th International Canopy Conference

Sunday 21st Aug.	Monday 22nd Aug.				Tuesday 23rd Aug.				Wednesday 24th Aug.	Thursday 25th Aug.			
	Symposium	Time	Authors	Title	Symposium	Time	Authors	Title		Symposium	Time	Authors	Title
	Opening Remarks	09:00	Prof Claire Ozanne										
	Plenary	09:15	Dr Louise Ashton	Forest canopy science: achievements and horizons	Plenary	09:00	Prof Gerhard Zotz	Plants on Plants. Reflections on Canopy-Dwelling Plants	Organised visits	Plenary	09:00	Dr Ben Langford	Revealing the unseen world of biosphere – atmosphere interactions
	Coffee break	10.-15-10.40			Coffee break	10.00-10.30				Coffee break	10.00-10.30		
	Arthropod diversity and interactions in forest canopies	10:40	Carl Wardhough	The abundance-distribution of rainforest canopy invertebrates: do bottom-up or top-down forces drive community composition?	Epiphytes: Ecological processes and patterns of distribution	10:30	Glenda Mendieta-Leiva	Directionality in the dynamics of vascular epiphyte assemblages		Cranes, new technologies and experimental manipulation	10:30	Meg Lowman	Climb Up - The Past, Present, and Future of Canopy Science
		11:00	Francisco Emmanuel Méndez Castro presented by Glenda Medieta-Leiva	Islands on the trees: a biogeographic approach to epiphyte dwelling spiders		10:50	Amanda Taylor	Radial distributions of air plants: a comparison between epiphytes and mistletoes			10:50	Akihiro Nakamura	Recent development of canopy science and crane network in China
		11:20	Benjamin Adams, Stephen Yanoviak	Tree crowns act as islands for arboreal and communities		11:10	Juliano Sarmento Cabral, Gunnar Petter, Gerhard Zotz, Holger Kreft	The influence of forest dynamics on structure and dynamics of epiphyte assemblages based on a forest-epiphyte mechanistic simulation model			11:10	Masahiro Nakamura, Moeki Minoshima, Hideaki Shibata, Kentaro Takagi, Tsutom Hiura	Prediction of response of insect-plant interactions to global warming on the correct time scale by using integrating altitudinal gradient study with warming experiment
		11:40	Maurice Leponce, J H C Delabie, P Klimes, J Queiroz, Th Delsinne, J Jacquemin, A Dejean	Ant Mosaics in Tropical Forests		11:30	Gerhard Zotz, Helena J. R. Einzmann, Jaroslaw Puczylowski, Joachim Peinke	Epiphytes and wind			11:30	Philippe Gaucher, Pierre Charles-Dominique & Jérôme Chave	COPAS (Canopy Operating Permanent Access System)
		12:00	Amy Berkov, Lin Li, Timmy Eng, Jhunior Morillo	Plasticity and conservatism in stratification		11:50	Rebecca Hsu	Threat and opportunity: typhoon influence on the vascular epiphyte community in Taiwan			11:50	Andrew Krockenberger	Australian Canopy Crane
		12:20	Jonathan Majer, Harry Recher, Christopher Norwood	Variation in bird assemblages and their invertebrate prey on eucalypt trees across a rainfall gradient in southwestern Australia		12:10	Kevin Burns	Global patterns in epiphyte diversity and community structure			12:10	Christian Wirth	Leipzig Crane
		12:40		As above		12:30	Weyao Liu, Liang Song, Wenzhang Ma, Yuanlin Yao, Chen Ke	Epiphytic bryophyte diversity and distribution patterns along three altitudinal gradients in Yunnan, SW China			12:30	Victoria Tough	Climbing as a key fieldwork skill: The practicalities and considerations when taking research into the canopy
	Lunch	13.00-2.10				12:50	Yi Wu, Liang Song, Huazheng Lu, Wenyao Liu	Diversity and phytogeography of vascular epiphytes of Asian biodiversity hotspots			12:50	Will Koomjian	Review of rope-based access methods for the forest canopy: safe and unsafe practices in published information and a summary of current methods
Registration 2pm	Arthropod diversity and interactions in forest canopies	14:10	Peter Shaw	Edge effects in arboreal Collembola in Richmond Park (UK)	Lunch	13.10-2.10				Lunch	13.10-2.10		
		14:30	Nigel Straw	Canopy matters: an elevated perspective on the spruce aphid in plantation forestry	Epiphytes: Ecological processes and patterns of distribution	14:10	Edicson A Parra Sanchez	Epiphytes: ecological processes and patterns of distribution		Quo vadis epiphyte research	14:10		WORKSHOP
	Small and large scale canopy processes	14:50	Joan Webber	Aerial Phytophthoras and their Interaction with Tree Hosts		14:30	Alfredo Saldaña	Potential for evolutionary responses to the decrease in the rainfall regime in vascular epiphytes' functional traits in the temperate forest					WORKSHOP
		15:10	Tom Bradfer-Lawrence & Daisy H Dent	Bird community development in the canopy and understorey of Neotropical secondary forest		14:50	Claudia Milena Agudelo Palacio, Ana Maria Benavides, Alvara Duque	Functional patterns of epiphyte assemblages across an environmental gradient in the Colombian Andes					WORKSHOP
		15:30	Amanda Matson	Tree-stem and canopy-soil emissions of N_2O in tropical lowland oil palm plantations		15:10	Katrin Wagner, Gunnar Petter, Wolfgang Wanek, Eduardo Sánchez, Gerhard Zotz, Juliano Sarmento Cabral, Holger Kreft	Functional traits in epiphyte ecology					WORKSHOP

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	Symposium	Time	Authors	Title	Symposium	Time	Authors	Title		Symposium	Time	Authors	Title
	TEA BREAK	15.50-16.30				15:30	Huazheng Lu, Liang Song, Wenyao Liu, Feihai Yu, Baogui Li, Liqing Sha, Xiaobao Deng, Jiaolin Zhang, Shugang Lu	Effects of aging and fragmentation on performance of clonal epiphytes					
	Lightning Talks (5 minutes per talk)	16:30	Yung-Hsiang Lan	Current study of mature Douglas-fir in Oregon: Relationships between canopy structure, microclimate, and Swiss Needle Cast severity among different ages of Douglas-fir forests	Tea break	15.50-16.30	María Moreno-Chacón, Alfredo Saldaña	POSTER		Tea Break	15.50-16.30		WORKSHOP
			Yung-Hsiang Lan	New canopy access in Taiwan: canopy walkway in Shei-Pa National Park	Epiphytes: Ecological processes and patterns of distribution	16:30	Liang Song, Hua-Zheng Lu, Xing-Liang Xu, Su Li, Xian-Meng Shi, Xi Chen, Yi-Wu, Jun-Biao Huang, Quan Chen, Shuai Liu, Chuan-Sheng Wu, Wen-Yao Liu	Organic nitrogen contributing to N economy of epiphytic bryophytes		Quo vadis epiphyte research	16:30		
			Margaret Lowman and Anthony Ambrose	Penang Hill - New Canopy Exploration in Malaysia		16:50	Alfredo Cascante & Christian Trejos	Rain seasonality and the flowering behaviour of a Neotropical epiphyte					WORKSHOP
Drinks reception 5pm			Margaret Lowman and Michael Barth	Bhutan - Canopy Research Opportunities on the World's Longest Canopy Walkway		17:10	Diane Srivastava	Constancy and contingency in bromeliad food webs					WORKSHOP
			Benjamin Adams, Evan M Gora, Jeff Burchfield, Phillip Bitzer, Matteo Detto, Stephen P Yanoviak	Real-time monitoring of lightning strikes in a tropical forest.		17:30	Helena JR Einzmann, Lisa Döcke, Gerhard Zotz, Carl von Ossietzky	Epiphytes in human-modified landscape					WORKSHOP
			Jennifer Sanger, Stephen Pearce	The Tree Projects – Exploring the canopy of the world's largest rainforest trees		17:50	Holger Kreft, Tim Böhnert, Arne Wenzel, Christian Altenhövel, Likas Beeretz, Sri Sudarmiyati Tjitrisiedirdjo, Ana Meijide, Katja Rembold	Effects of land-use change on vascular epiphyte diversity in Sumatra (Indonesia)					WORKSHOP
			Peter Shaw	Plastic scouring pads as a tool to study fauna of suspended soils		18:10	Hannah Prather, Todd N. Rosenstiel	Assessing Urbanisation Impacts on Canopy Epiphyte Biodiversity and Function in Pacific Northwest (OSA) Forests		CONFERENCE DINNER	6.30 for 7.00pm		

The abundance-distribution of rainforest canopy invertebrates: do bottom-up or top-down forces drive community composition?

Carl Wardhaugh, Biology Center, Czech Academy of Sciences and Faculty of Science, University of South Bohemia

Invertebrates are the most abundant, diverse, and functionally important group of animals in forest canopies. Their distributions have important implications for herbivory, pollination, predation and parasitism, and nutrient cycling. The factors driving variation in invertebrate distributions can be broadly grouped into two categories; bottom-up factors related to host plant traits, and top-down factors mediated by predatory or competitive interactions with other animals. I examined the distributions of various invertebrate groups on five different microhabitats (mature leaves, new leaves, flowers, fruit, and dead wood) across 23 species of canopy trees in an Australian tropical lowland rainforest in order to elucidate the influence of these opposing factors on the abundance-distributions of a variety of invertebrate groups. Most invertebrate groups congregated on those plant microhabitats which provided them with the highest concentrations of their preferred food sources; herbivores were over-represented on new leaves and flowers, while fungivores and saprophages were over-represented on dead wood and fruit. Moreover, significant variation in abundances across tree species suggests that some trees are preferred over others for most invertebrate groups. In contrast to previous studies in other tropical rainforests, I also found significant positive correlations in the abundances of invertebrate groups that are thought to interact antagonistically. These included both potential competitors (ants and spiders, and caterpillars and Hemiptera), and potential predator-prey interacting groups (ants and caterpillars, ants and other invertebrates, spiders and caterpillars, spiders and other invertebrates). It appears then, that the distribution of invertebrate abundances in the canopy is driven primarily by bottom-up forces, where most invertebrates congregate on preferred tree species and microhabitats, with little impact from top-down forces.

Keywords: Feeding-guild; flower-visitor; niche-overlap; interspecific competition

Islands on the trees: a biogeographic approach to epiphyte dwelling spiders

Francisco Emmanuel Méndez-Castro1, Maaike Bader2, Glenda Mendieta-Leiva2, Dinesh Rao1. (1- INBIOTECA, Universidad Veracruzana, Mexico; 2- Faculty of Geography, Univ. of Marburg, Germany)

Spiders establish communities in epiphytic plants. Epiphytes have been compared with islands because the diversity of their inhabiting fauna is positively correlated with habitat size. However, epiphytes are more complex than islands because their geographical position is the result of three dimensional space. We conducted an extensive sampling survey in order to understand the influence of the spatial position of epiphytes over their spider communities. We collected all epiphytes (and their spiders) from three different trees in a shaded coffee plantation of Veracruz, Mexico. We recorded the three dimensional position of plants using a cardinal system at centimetre by centimetre scale. Our results confirmed the influence of habitat size over spider community composition, but also we found evidence of species-isolation processes driving diversity of these communities. According to our results, conservation efforts for epiphyte systems should be focused on preserving larger epiphyte assemblages regardless of their position on the tree.

Keywords: Topology, structure, distance, tridimensional position

Tree crowns act as islands for arboreal ant communities

Benjamin Adams and Stephen Yanoviak, University of Louisville, Department of Biology, Louisville, Kentucky, USA

In the canopies of tropical forests, individual tree crowns are frequently physically isolated due to the phenomenon of crown shyness. For small, non-volant organisms, such as arboreal ants, this isolation can be a barrier to movement within the landscape. Consequently, arboreal ant communities should act similarly to island communities, with species richness and composition in a single tree crown limited by tree size and the degree of isolation. Lianas (large woody vines) are common in tropical forest canopies, provide physical bridges that overcome crown shyness, and differ in density among individual trees. In a tropical forest of central Panama, we investigated patterns of species richness and composition in arboreal ant communities in trees without lianas and trees with a gradient of lianas ranging from one to hundreds of liana stems to determine if individual trees function as islands. Trees with lianas had higher ant species richness and more diverse ant communities (10.2 ± 0.3 species/tree; 92 total species) than trees without lianas (8.5 ± 0.4 species/tree; 58 total species). Furthermore, ant species richness in trees without lianas closely followed predictions of insular species-area relationships, with larger trees hosting more species than smaller trees. This effect disappeared in trees with lianas. Experimental removal of lianas from

tree crowns resulted in a significant decrease in ant species richness compared to non-manipulated trees two years after removal. In combination, these results indicate that liana-free trees function as islands for arboreal ant communities and that connectivity provided by lianas overcomes this isolation.

Keywords: Formicidae, lianas, species-area relationship

Ant Mosaics in Tropical Forests

M. Leponce ([1]), J.H.C. Delabie ([2]), P. Klimes ([3]), J. Queiroz ([4]), Th. Delsinne ([1]), J. Jacquemin ([1]), A. Dejean ([5,6]).

([1])Biodiversity Monitoring & Assessment, Royal Belgian Institute of Natural Sciences, Brussels, Belgium ([2]) U.P.A. Laboratorio de Mirmecologia, Convention CEPLAC-UESC, Brazil; ([3]) Biology Centre of ASCR; Faculty of Science, University of South Bohemia in Ceske Budejovice, Czech Republic; ([4]) Universidade Federal Rural do Rio de Janeiro (UFRJ) ([5]) CNRS - UMR 8172, Écologie des Forêts de Guyane, Campus Agronomique, France; ([6]) CNRS - UMR 5245, Ecolab, 31062 Toulouse, France.

The existence of ant mosaics, or the mutually exclusive distribution of numerically dominant ants (NDA) in tropical tree canopies, has been demonstrated for plantations but remains challenging to study in primary forests due to the difficulty of collecting and observing ants in trees that grow up to 30m in height. Our goal was to overcome this problem and study the three-dimensional distribution of NDA in primary rainforests across four continents. We developed the baitline method allowing us to collect arboreal ants every 5 meters along tree trunks and to conduct aggressiveness tests between ants collected from neighbouring trees. These direct observations allowed us to define ant numerical dominance, species coexistence and to delineate NDA spatio-temporal extension. Ant colonies were mapped in quarter hectare forest plots in French Guiana (Amazonia), Brazil (Atlantic forest), the Democratic Republic of the Congo (RDC), Mozambique, Laos and Papua New Guinea (PNG). Our results indicate that territorial NDA species are found in every lowland forest site investigated. However, there seems to be a gradation in the ant mosaic structure according to the high (e.g. in PNG, RDC), intermediate (e.g. in French Guiana) to low (e.g. in Laos) prevalence of NDA on the trees. In some instances (e.g. in Mozambique or in PNG), *Crematogaster* supercolonies completely dominated the plots. Trees where NDA only forage intermittently can be observed at the border of a large NDA territory (e.g. that of Azteca in French Guiana) and create temporary gaps. Two mutually aggressive NDA are sometimes briefly observed on the same tree (e.g. the vertical segregation of *Crematogaster* and *Oecophylla* foragers along a tree trunk in PNG). These results emphasize the three-dimensional and dynamic structure of ant mosaics.

Keywords: spatial patterns, community dynamics, territorialit

Plasticity and conservatism in stratification

Amy Berkov, The City College of New York; Lin Li, The New York Botanical Garden; Timmy Eng, The City College of New York; Jhunior Morillo, The City College of New York

Dead wood, the substrate for saproxylic beetles, may be more conspicuous on the forest floor—but is also represented by dead branches in the canopy. When similar resources are available at both strata, abiotic conditions are likely to drive stratification. In the old growth rain forest of central French Guiana, the warmest, driest microhabitat is canopy stratum during the dry season, and the coolest, most humid microhabitat is ground stratum during the rainy season. Curculionidae are more abundant in cool, humid microhabitats, while Cerambycidae are more abundant in intermediate microhabitats: ground stratum during the dry season, and canopy stratum during the rainy season. This study explores a proposed continuum of drought-tolerant through moisture-dependent saproxylic beetles, by comparing results from rearing studies in South and Central America. Due to inter-annual variation in rainfall and site-to-site variation in microclimate, stratum associations are expected to be more plastic than host plant associations; nonetheless, some beetle lineages appear to have conserved niches. Adults in drought-tolerant lineages appear to be diurnal, active during the dry season, and preferentially associated with warm, dry microhabitats. Adults in moisture-dependent lineages are generally cryptic, presumably active in low light, and preferentially associated with moist wood. Most global climate models predict substantial rainfall decreases in the Amazon Basin; moisture-dependent lineages are expected to be deleteriously impacted by warmer, drier conditions.

Keywords: Cerambycidae, Curculionidae, moisture-dependence, Neotropics, rainforest

Variation in bird assemblages and their invertebrate prey on eucalypt trees across a rainfall gradient in southwestern Australia

Jonathan Majer (Curtin University), Harry Recher (Murdoch university), & Christopher Norwood Commonwealth department of Agriculture)

Our previous work has shown how invertebrate food resources influences bird usage of tree species. Using data from Western Australian forests, we extend the findings to indicate how the avifauna is influenced by invertebrate food resources at the landscape level. The northern dry sclerophyll forest of southwestern Australia comprises Jarrah (*Eucalyptus marginata*) to the west, with an abrupt replacement by Wandoo (*E. wandoo*) to the east; codominant Marri (*E. calophylla*) trees occur throughout.

Knockdown samples indicated that the canopy invertebrate fauna was highly diverse and more abundant in the Wandoo than in Jarrah. Invertebrates using the trunks of Marri, the species that occurs throughout both formations, were measured along a transect from Jarrah to Wandoo.

Mirroring the canopy, the trunk fauna had high species turnover over short distances. As with the canopy fauna, invertebrate diversity and abundance were higher on Marri situated in the Wandoo zone than in the Jarrah areas.

Abundance and diversity of birds, many of which are wholly or partly insectivorous, were measured at the same sites. Birds were more abundant and there were more species in forests with Wandoo than in those dominated by Jarrah and Marri. In line with the greater abundance and diversity of arthropods on the trunks of Marri, the proportion of bark-foraging by birds increased along the transect from Jarrah dominated forest to sites dominated by Wandoo. Additionally, Wandoo areas had a greater number of species in the bark-foraging guild. It is evident that changes in bird species composition, richness, and abundance are determined on a landscape scale by the abundance and diversity of food resources available to them. Currently neither the patterns of change within forest arthropod faunas nor of their primary vertebrate predators are considered when making decisions on conserving or managing forest communities in Australia.

Keywords: Canopy, Trunk, Invertebrate, Avifauna, Interdependency

Edge effects in arboreal Collembola in Richmond Park (UK)

V Standing & PJA Shaw

A hand-held vacuum was used to sample Collembola from trees in 4 woods in Richmond Park (UK), a site noted for its saproxylic arthropods. Each wood was sampled over 4 seasons, and along a logarithmically-spaced transect from the outside edge to its core. Twenty one species were collected at a mean density of 800 animals m-2, but with considerable seasonal variations (highest in winter). Two common species (*Entomobrya albocincta* and *Orchesella cincta*) showed significant edge effects, with highest densities in the woodland core. There was a positive correlation between Collembola density and depth of crevices in the bark. One of these woods supported the only reliable UK population of the nationally scarce *Entomobrya corticalis*. Elsewhere in London the dominant patterned Entomobrya on tree bark is E. intermedia (apparently scarce in the UK until this millennium), but in Richmond park this species was wholly replaced by the closely related "traditional" species E. nivalis. We suggest that the extensive acid grassland around the Richmond park woods have isolated them, allowing a relic bark springtail community to survive.

Keywords: Collembola, Arboreal, edge effects, seasonality

Canopy matters: an elevated perspective on the spruce aphid in plantation forestry

Nigel Straw, Nick Fielding & David Williams

Green spruce aphid *Elatobium abietinum* (Walker) is the most important defoliator of Sitka spruce plantations in the UK and in other countries of north-west Europe. Severe infestations of the aphid, which develop after mild winters and warm springs, have a significant impact on spruce growth and stand productivity. Quantifying this impact is not straight forward however, and requires an understanding of how aphids are distributed in the canopy and how they interact with canopy structure. Long-term impacts may also depend on the response of invertebrate predators and other natural enemies to increasing spruce aphid populations. Invertebrate predators cause secondary cycles in spruce aphid populations and they are a major cause of mortality after peak years, but their influence is modulated by stand structure, especially tree density, size and variability. This interaction presents problems for sampling and investigating the interplay between predators and aphid populations, but it also provides opportunities for managing the spruce aphid by manipulating its silvicultural environment.

Keywords: defoliation, *Elatobium abietinum*, Sitka spruce

Aerial Phytophthoras and their interaction with Tree Hosts

Joan Webber, Forest Research, Alice Holt Lodge, Farnham, Surrey, UK

Plant pathogens are biotic agents that cause disease in plants, reducing plant productivity and at their worst causing mortality associated with significant socioeconomic and ecological impacts. The genus *Phytophthora* includes some of the world's most destructive plant pathogens, and many of the species are highly damaging to trees and also cause widespread environmental damage to natural ecosystems. Until relatively recently most Phytophthoras were considered to be root-attacking with much of the damage inflicted on tree roots underground and out of sight. However, in the last 20 years many previously unknown invasive *Phytophthora* pathogens have emerged, apparently spread via the international plant trade although their native origins are often obscure. A significant number are aerial pathogens which attack the above ground parts of trees and show particular behaviours suited to this aerial lifestyle in the tree canopy. Their spread and distribution are strongly influenced not only by the host but by changing weather conditions and climate. One of the most damaging recent introductions, *Phytophthora ramorum*, is the cause of Sudden Oak Death in the USA but in Britain it has become a significant pathogen of the conifer *Larix* (larch) which is often grown in plantations as a commercial forestry species. These large areas of densely planted forest appear to be an ideal environment for aerial spread and allow the pathogen to operate on a landscape scale, infecting trees over many hectares. Once introduced, these invasive *Phytophthora*

species usually prove impossible to eradicate and have impacts that are likely to continue over many decades and shape the forest landscape of Britain into the future.

Keywords: Tree pathogens, *Phytophthora*, invasives, landscape impact

Bird community development in the canopy and understorey of Neotropical secondary forest

Tom Bradfer-Lawrence[1,2] and Daisy H. Dent[1,2].

[1.] The University of Stirling, Scotland

[2.] The Smithsonian Tropical Research Institute, Panama

Secondary forest habitats are increasingly recognised for their potential to conserve biodiversity in the tropics. However, faunal assembly varies according to habitat quality and species-specific traits, and there are still many questions regarding the rate, direction and extent of faunal community development in secondary forests. Previous research examining birds in this context has been almost exclusively ground-based, and hence is biased towards species in lower levels of the forest. This talk will present results from the first study to give equal attention to all forest strata by conducting simultaneous surveys in both canopy and understorey, and hence provides a more nuanced picture than ground-based studies. This study was undertaken in a chronosequence of secondary forests in central Panama, at sites of 60, 90 and 120 years old, and old-growth forest. Bird community development varied according to both habitat age and isolation, but these effects were weaker in the canopy compared to the understorey. Guild proportions and body mass patterns did not vary with habitat age, but were significantly different between strata. Canopy bird communities were characterised by higher species diversity, and greater variation in both dietary breadth and body mass, relative to understorey communities. The results highlight that secondary forests may offer critical refugia for many bird species, particularly specialist canopy-dwellers. These findings contribute to the growing understanding of the factors influencing bird colonisation and community assembly in secondary forest.

Keywords: Birds, Community, Conservation, Reassembly, Secondary

Tree-stem and canopy-soil emissions of N_2O in tropical lowland oil palm plantations

Amanda Matson a, Evelyn Hassler a, Kara Allen ab, Syahrul Kurniawan ac, Marife D. Corre a, Edzo Veldkamp a Affiliations: a Soil Science of Tropical and Subtropical Ecosystems, Büsgen Institute, Georg-August-Universität Göttingen, Büsgenweg 2, Göttingen, Lower Saxony, Germany; b Department of Ecology, Evolution and Behaviour, University of Minnesota, St.

Paul, USA; c Department of Soil Science, Faculty of Agriculture, University of Brawijaya, Jl. Veteran 1, Malang, Indonesia

Soils in the humid tropics are an important global source of nitrous oxide (N2O), yet in quantifying this source, inventories using top-down estimates and bottom-up estimates do not always correspond. This may be partly explained by processes occurring in the canopy, which are not included in bottom-up approaches. Using oven-bag chambers and soil incubation to quantify N2O fluxes, we investigated whether tree stems and/or canopy soil from oil palm plantations in Jambi Province (Sumatra, Indonesia) contributed to the emission of N2O to the atmosphere. Results show that both oil palm stems and canopy soil were a source of N2O, and that in both locations fluxes were sensitive to moisture and N availability. Using 15N as a tracer, we were able to show that added N fertilizer can be traced directly to tree-stem N2O emissions. Initial upscaled estimates show that emissions from tree stems (330 g N2O-N ha-1 yr-1) and canopy soil (10.7 g N2O-N ha-1 yr-1) are low compared to ground-soil fluxes (1-9%), but considering the increasing area of oil palm plantations in our study area, total fluxes could be substantial.

Keywords: stem fluxes, canopy organic matter

Current study of mature Douglas-fir in Oregon: Relationships between canopy structure, microclimate, and Swiss Needle Cast severity among different ages of Douglas-fir forests

Yung-Hsiang "Sky" Lan, Department of Forest Ecosystems & Society, Oregon State University

Swiss Needle Cast (SNC) is a foliar disease afflicting Douglas-fir (*Pseudotsuga menziesii*) trees, caused by the fungus *Phaeocryptopus gaeumannii*. SNC is causing growth loss in forests across coastal Oregon and Washington, and is thought to be one of the largest threats to Douglas-fir plantation management in these regions. The fungal reproductive structures, pseudothecia, emerge from within the needle and subsequently grow into the stomata. This fungus blocks gas exchange, thereby reducing photosynthetic rates and productivity of Douglas-fir trees.

The structural complexity of canopies is well known to have differences in microclimate and nutrient allocation depending upon position in the canopy. As forests mature, vertical and structural complexity increase, and diversity of biota inhabiting canopies increases. However, disease patterns in canopies are poorly understood. What does SNC look like on young and mature Douglas-fir trees? SNC has been well studied in young stands, but SNC data from mature and old-growth forests is rare, and therefore understanding of the disease ecology in older forests is not well known. We are involved in studies exploring the relationship between disease severity of SNC, canopy position and microclimate in young, mature and old-growth forests. These studies will provide a database for mature and old-growth trees serving as background information for future research, especially for those studies regarding issues of climate change.

Keywords: SNC, microclimate, canopy structure, Douglas-fir

New canopy access in Taiwan: canopy walkway in Shei-Pa National Park

Yung-Hsiang "Sky" Lan, Department of Forest Ecosystems & Society, Oregon State University

For most canopy research in Taiwan, especially for old-growth conifer canopies, researchers usually climb trees by Single Rope Technique (SRT). SRT is useful and efficient to access canopies, however, it is limited in providing opportunities for the public to experience canopy ecosystems on their own. In Shei-Pa National Park, researchers built a canopy walkway between two woody platforms in adjacent superba trees (*Schima superba*) in 2014. By using these platforms, walkway, and rope systems, scientists access broadleaf tree canopies, and study invertebrate communities, phenology of vascular epiphytes, and breeding of birds. Additionally, these facilities are used for public education. Shei-Pa National Park serves many activities through these canopy facilities, like tree climbing and overnight camping on canopy platforms, providing experience and information for the public to learn more about canopy ecosystems.

Keywords: Taiwan, canopy walkway, 2014

Penang Hill - New Canopy Exploration in Malaysia

Margaret Lowman, California Academy of Sciences and Anthony Ambrose, University of California – Berkeley

Penang Hill, just outside the city of Penang, Malaysia, is the site of The Habitat, a new canopy initiative scheduled to open in 2017. Privately funded, this site will contain an extensive canopy walkway, biological field station, and seed funding for innovative biodiversity and rain forest canopy research. In a unique partnership of business, local and global scientists, and eco-tourism, this site is available for long-term research on the canopies of primary Malaysian tropical rain forests. This project also creates an innovative model of sustainable rain forest research, using ecotourism to fund science and using science to inspire visitors.

Keywords: Malaysia, tropical rainforest ecotourism, Dipterocarps

Bhutan - Canopy Research Opportunities on the World's Longest Canopy Walkway

Margaret Lowman, California Academy of Sciences and Michael Barth, The King's Challenge (Bhutan)

Bhutan, a country where the environment is protected by her constitution, has over 70% remaining primary forest. In addition, the King of Bhutan operates his government according to the GHI (gross happiness index), not the GDP (gross domestic product) as do most countries. Given this unique legacy of nature and leadership, Bhutan is launching a series of forest sustainability initiatives. One of the first projects, led by the current King, is the construction of a canopy walkway in Royal Manas National Park in southwestern Bhutan. Close to the border with India, this park has one of the world's largest densities of tigers as well as extraordinary intact forest canopy. A walkway up to 5 kilometers long is planned within park boundaries, along with accommodation for researchers and a limited number of adventurous ecotourists. This site will offer opportunities for long-term canopy research on the subtropical forests of Bhutan, including elevational gradients into Himalayan landscapes. The biodiversity of Bhutan is relatively unexplored.

Keywords: Bhutan, subtropical rainforest, canopy walkway

Real-time monitoring of lightning strikes in a tropical forest.

Benjamin Adams[1], Evan M. Gora[1], Jeff Burchfield[2], Phillip Bitzer[2], Matteo Detto[3], and Stephen P. Yanoviak[1,3]

[1]Department of Biology, University of Louisville
[2]Department of Atmospheric Science, University of Alabama in Huntsville
[3]Smithsonian Tropical Research Institute, Balboa, Panama

Lightning is an important source of tree damage and mortality in tropical forests. However, quantifying the short-term ecological effects of lightning is very challenging because the damage often is inapparent and difficult to locate. To overcome this problem, we are using a combined camera and lightning sensor network to record cloud-to-ground lightning flashes in real time in the forest canopy of Barro Colorado Island, Panama. We locate flashes by comparing synchronized, time-stamped images from multiple surveillance cameras mounted on towers extending >10m above the forest canopy. These images enable field biologists to visit the strike site via triangulation within hours or days of the event. This time scale provides unprecedented opportunities to collect replicate data concerning the immediate and long-term effects of lightning on tree condition, insect

activity, and other ecologically relevant parameters. Data from electronic sensors (e.g., field mill and field change meter) enable us to correlate the ecological parameters with flash intensity (as peak current), polarity, and duration. This system enabled us to locate damage from multiple strikes in 2014 and 2015, and could be implemented at other forest sites worldwide.

The Tree Projects – Exploring the canopy of the world's largest rainforest trees

Steven Pearce and Jennifer Sanger, The Tree Projects

The Tree Projects are innovative photography projects which draw focus on some of the worlds' most significant rainforest trees and the unexplored realms of their canopies. The centrepiece of the Tree Projects is a high-resolution photographic portrait of a giant rainforest tree. When these trees are viewed from the ground, the majority of the tree and its canopy are often obscured from view and it can be impossible to get a sense of the full size of these trees. We use innovative arboreal rigging techniques to take hundreds of photos from different perspectives, which are stitched together to create a complete image of a giant rainforest tree without visual distortion. With climbers in the tree as a scale reference, these images highlight for the first time how grand these trees are and highlights the complexities of their canopies. One of the main aims of the Tree Project is to promote canopy exploration, which we achieve by capturing powerful imagery of the canopy using the latest of technologies, such as virtual reality, hyper-lapse and 3D videos. All content is show-cased in state-of-the-art museum exhibitions which will help promote the conservation of these globally significant trees and help foster an appreciation and understanding for the rainforest canopy. The team completed the New Zealand Tree Project in 2015, have just completed the Tasmanian Tree Project (April 2016), and will be conducting a Bornean Tree Project in 2017.

Keywords: Environmental education, Rainforest trees, Photography

Plastic scouring pads as a tool to study fauna of suspended soils

PJA Shaw, University of Roehampton

Canopy arthropod communities habitually contain multiple species of "soil-dwelling" groups (Collembola, acari, myriapods, Isopoda) living in the suspended soils arising from leaf litter accumulation in natural traps. The species involved are often uncommon in the local soil, and hard to collect because of the tiny volumes of soil involved and the physical problems of access. I report a cheap, replicable way to collect these fauna without causing habitat damage by use of inert plastic scouring pads. Once placed in contact with a suspended soil these are rapidly colonised by the local arthropod community, and easily removed for extraction in a Tullgren apparatus. Small-scale trials on the Collembola of bark crevices and suspended soils in the UK suggest that standard scouring pads collect a representative mix of the local species, and allow rapid non-destructive surveying of

suspended soil communities. By attaching plastic pads to rope loops around high branches, Collembola (notably *Willowsia platani*) have been collected from tree bark at 5m elevation, without the researcher having to leave terra firme. This is a cheap simple technique suitable for many different project designs involving multiple arthropod taxa.

Key words: arboreal collembola acari 'artificial habitats'

Directionality in the dynamics of vascular epiphyte assemblages

G Mendieta-Leiva & G Zotz, University of Marburg & University of Oldenburg

Differentiating the contribution of determinism and stochasticity in the assembly of communities is a hot topic in ecology. Field work on the subject is currently highly biased due to an almost exclusive focus on trees. Structurally dependent life forms such as lianas or vascular epiphytes, may provide us with a different point of view.

Unlike most natural systems for which sampling grains are mostly arbitrary, vascular epiphytes as structurally dependent plants allow us to distinguish distinct and ecologically meaningful spatial scales. Thus, the observed scale-dependence of the structure and dynamics of vascular epiphyte assemblages (VEAs) is arguably not arbitrary, but reflects their ecology. Moreover, there seems to be a consensus in epiphyte ecology that assembly and structure of VEAs are greatly affected by the vertical stratification of the forest as a proxy of abiotic factors, which highlights the influence of deterministic processes in community assembly in this particular system.

Here, we report the long-term changes of a VEA in a lowland forest in Panama over one decade. We analysed this globally unique dataset using different ecological scales in order to search for directionality and convergence in the dynamics of VEAs. Such a finding would back the notion that VEAs are largely driven by deterministic processes.

The dynamics of VEAs showed clear directional changes in their composition at different ecological scales although convergence was shown only for a particular host species.

Keywords: community assembly, dispersion, directionality, dynamics

Radial distributions of air plants: a comparison between epiphytes and mistletoes

Dr. Amanda Taylor, Georg-August University of Göttingen

Vertical gradients of light and humidity within forest canopies are major predictors of air plant distributions. Although this pattern was first recognized over 120 years ago, few studies have considered an additional axis of resource availability, which exists radially around the trunks of trees. Here, we explored the radial distributions of mistletoes and epiphytes in relation to gradients of light and humidity around the trunks of their south- temperate host trees.

Additionally, we correlated microclimate occupancy with plant physiological responses to shifting resource availability. The radial distributions of mistletoes and epiphytes were highly directional, and related to the availability of light and humidity, respectively. Mistletoes oriented northwest, parallel to gradients of higher light intensity, temperature, and lower humidity. Comparatively, epiphytes oriented away from the sun to the southeast. The rate of CO_2 assimilation in mistletoes and photochemical efficiency of epiphytes was highest in plants growing in higher light and humidity environments, respectively. However, the photosynthetic parameters of mistletoes suggest that they are also efficient at assimilating CO_2 in lower light conditions. Our results bridge a key gap in our understanding of within- tree distributions of mistletoes and epiphytes, and raise further questions on the drivers of air plant distributions.

Keywords: air plants, radial distributions, south-temperate

The influence of forest dynamics on structure and dynamics of epiphyte assemblages based on a forest-epiphyte mechanistic simulation model

Gunnar Petter1, Gerhard Zotz2,3, Holger Kreft1 & Juliano Sarmento Cabral1,4* 1 Free Floater Research Group Biodiversity, Macroecology & Conservation Biogeography, University of Göttingen, Göttingen, Germany. 2 Functional Ecology Group, University of Oldenburg, Oldenburg, Germany. 3 Smithsonian Tropical Research Institute, Panama City, Panama. 4 Research Group of Ecosystem Modeling, Center of Computation and Theoretical Biology, University of Würzburg, Würzburg, Germany.

Vascular epiphytes live in a three-dimensional, highly dynamic, and heterogeneous habitat that is the forest canopy. Knowledge about how forest structure and dynamics influence the spatio-temporal distribution of epiphytes is still limited owing to difficulties in accessing the forest canopy and a lack of long-term observations. In this study, we present a coupled forest-epiphyte model that is three-dimensional, spatially-explicit, niche-, and individual-based. The model considers species-specific light requirements and simulates individual dispersal, recruitment, growth, and mortality. By coupling spatiotemporal distribution of trunks and branches obtained from a functional-structural forest model with our epiphyte model, we first assess whether the model results satisfactorily match real-world data, then address how differences in long-term natural forest dynamics, selective logging, and the size of forest fragment influence epiphyte assemblages. The model generated vertical distributions of individuals and species and rank-abundance distributions that were comparable with field data from lowland forests in Panama and Ecuador. Higher forest dynamics had complex effects on epiphyte assemblages, with stable forests having generally high abundances, low extinction rates and highest saturation. Selective logging of larger trees resulted in lower abundances, species numbers, and saturation levels of epiphytes. Strikingly, a slight reduction in minimum harvested tree size from 45 to 40 cm DBH had a catastrophic effect on the epiphyte assemblage and led to a near complete extinction of epiphytes. Increasing fragment size decreased species extinction rates. Our demonstrated that the average abundance and biomass of epiphytes can be strongly influenced by forest dynamics. We concluded that modelling approaches that

explicitly account for forest dynamics and epiphyte demography provide valuable insights on epiphyte assemblages, with potential applications for assessing long-term impacts of human-induced changes.

Keywords: assemblage, dynamics, epiphyte, model, simulation

Epiphytes and wind

Gerhard Zotz, Helena J. R. Einzmann, Jaroslaw Puczylowski, Joachim Peinke

Epiphytes live at the interface of vegetation and atmosphere and may thus be particularly susceptible to physical disturbance by wind. There are at least 20 reports in the literature that document serious damage inflicted on epiphyte communities, mostly during tropical storms in the Caribbean, but a rigorous analysis of the physical forces is missing: neither the drag imposed by wind nor the forces necessary to dislodge an individual epiphytic plant have ever been studied quantitatively. We determined these forces in the field and in a wind tunnel for five epiphytic bromeliad species from the lowlands of Panama. As expected, the drag experienced by these epiphytes increased with wind speed and plant size. Surprisingly, however, even at the highest tested wind speeds in the wind tunnel of 50 m s-1 the developing forces would not suffice to pull these plants off their substrate (with one exception, i.e. very large individuals of the broad-leaved tank bromeliad, *Vriesea sanguinolenta*). We discuss the frequent reports of damage to epiphytes in hurricane regions in the light of our results. The surprisingly high resistance to drag may suggest that the biomechanics of the host tree branches are at least as important as the strength of the connection between epiphyte and host to the survival of epiphytes during storms.

Key words: bromeliads disturbance hurricanes wind drag

Typhoon influence on the vascular epiphyte community in Taiwan

Rebecca C.-C. Hsu, Taiwan forestry research institute

Jan H.D. Wolf, IBED, University of Amsterdam

Despite having immense plant diversity, Taiwan may be considered relatively poor in epiphytes. There have been ca 350 species of vascular epiphytes reported for Taiwan, comprising only eight percent of the total vascular flora, which is less than the worldwide level of 10 percent. Epiphytes are also poorly represented on tropical islands of the Caribbean, which has been attributed to geographical isolation and large-scale disturbances by tropical cyclones. Here, the typhoon disturbance was defined as the frequency of historical typhoons. Recorded traces and eyes of typhoons from 1958 to 2006 were plotted as circles with radii of Beaufort scale 7 and 10, and the accumulated numbers of typhoons per cell were calculated. To establish whether typhoon

influenced the distribution of epiphytes, we performed an ordination analysis, and found that typhoons have a significant influence on the distribution of epiphytes, independent of the temperature- and humidity-related variables. The two typhoon intensities that we analysed (scales 7 and 10) had largely opposing effects on the epiphyte community. Whereas powerful typhoons can be damaging to epiphytes, moderate typhoons are likely less damaging or may even promote epiphyte proliferation because of the significant accompanying precipitation. Moreover, typhoons exert varied degree of influence on epiphyte sub-categories. Hemiepiphytes, such as strangler figs and aroids, seem relatively resistant to direct wind-blow in terms of their tightly-attached adventitious roots on hosts.

Keywords: disturbance hurricane island Pacific-Asia vascular-epiphyte

Global patterns in epiphyte diversity and community structure

K C Burns

Global patterns in terrestrial plant diversity have been studied for decades. Even though epiphytes constitute approximately 10% of the total number of vascular plant species on earth, global patterns in epiphyte diversity have never been studied and are completely unknown. In an attempt to bridge this gap, I compare epiphyte diversity and community structure between a temperate rainforest on the North Island of New Zealand and a similar latitude forest on Vancouver Island, British Columbia, Canada. Vascular epiphytes were common at both sites. However, several key differences were observed. First, the majority of vascular epiphytes in New Zealand were 'obligate', meaning they were nearly always found growing epiphytically. On the other hand, the majority of epiphytes in British Columbia were 'accidental', meaning they commonly grew in the forest floor. Second, epiphyte community structure in New Zealand was 'nested' meaning epiphyte species composition among host trees was highly predictable. Conversely, community structure in Canada was stochastic. While far from bridging the gap in our understanding of global patterns in epiphytic plants, results provide a tantalising first-glimpse in how interesting latitudinal gradients in epiphyte diversity and community structure might be.

Keywords: epiphyte macroecology ecological networks diversity

Epiphytic bryophyte diversity and distribution patterns along three altitudinal gradients in Yunnan, SW China

Weyao Liu[1], Liang Song[1], Wenzhang Ma[2], Yuanlin Yao[1], Chen Ke[1]

[1]Key Laboratory of Tropical Forest Ecology, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Kunming, China

[2]Key Laboratory for Plant Diversity and Biogeography of East Asia, Kunming Institute of Botany, Chinese Academy of Sciences, Kunming, China;

On a larger scale, there is still relatively poor understanding of species composition, biomass and distribution patterns of epiphytic bryophytes along the altitudinal gradients in different forest areas. Species composition and cove of bole bryophytes of three protected forests were investigated along different altitudinal gradients in three representative forest areas in sub-montane (800–1400 m), montane (2000–2600 m) and sub-alpine (3200–3800 m) in Yunnan, SW China. The three protected forests in Yunnan harboured 226 epiphytic bryophyte species belonging to 101 genera and 46 families, which were essential components of biodiversity of the entire forest ecosystem. In total, 99% of bryophyte species (224 species) showed varying degrees of local rarity. Smooth mat, fan and turf dominated in the sub-montane, montane and sub-alpine forests, respectively. Significantly lower bryophyte species richness was detected in the sub-montane area, which may be partly attributed to higher temperature, limited water availability and more frequent human disturbance. Epiphytic bryophytes exhibited a hump-shaped species richness pattern with increasing altitude. Peak richness coincided with highest moisture levels at ca. 2600 m. Based on the presence of a high diversity of bryophytes and a high percentage (99%) of locally rare species growing on tree boles, this study emphasizes the importance of conserving these forests in Yunnan. Additionally, the regional pattern of lower epiphytic bryophyte diversity in warmer, drier areas shown in this study reveals how emerging climate change threatens Yunnan's epiphytic bryophytes.

Key Words: Altitude; Epiphyte; Bryophyte; Life form; Species richness

Diversity and phytogeography of vascular epiphytes of Asian biodiversity hotspots

Yi Wu, Liang Song, Huazheng Lu, Wenyao Liu

Epiphytes are important structural components of tropical forests, however, they have been given insufficient attention because of inaccessibility. Unlike their terrestrial counterparts, they are under-represented in regional-scale diversity and biogeographic analysis. This is the case for Asian biodiversity hotspots.

In the present study, we carried out an analysis to provide an overview of species richness and phytogeography among several paleotropical epiphyte floras by adopting the uniform classification and eliminating species that do not fall within the definition of Zotz (2013). Our database comprised three islands from equator tropical (Singapore) to northern limited (Hainan) then to tropical-subtropical transition (Taiwan), as well as the inland of tropical Asian (Xishuangbanna).

The epiphyte quotient (i.e., percentage of epiphyte species in the total flora) per locality ranged from 6.3-14.1 % (mean: 9.9 %). Xishuangbanna represented the most species diverse locality (486

species). At the family level, the epiphyte composition among localities was roughly homogeneous and dominated by epiphytic flowering groups: such as Orchidaceae, Asclepiadaceae, Moraceae. While in ferns and fern allies, Polypodiaceae, Hymenophyllaceae and Aspleniaceae were dominant families. At the generic level, epiphytic flora was dominant by Asplenium, Bulbophyllum, Dendrobium and Ficus. The proportion of genera with tropical distributions decreased along the increasing latitude. In the phytogeography aspect, genera with Tropical Asia to Tropical Australia distributions made up 38.27 % , 30.85%, 26.37%, 22.39% of Singapore, Hainan, Taiwan and Xishuangbanna respectively, while genera with Tropical Asia distributions contributed almost 33.58 % Of Xishuangbanna.

The results of this study highlight the importance of epiphytes in Xishuangbanna relative to other Asian biodiversity hotspot.

Keywords: vascular epiphytes, phytogeography, biodiversity, epiphyte quotient, canopy

Epiphytes: ecological processes and patterns of distribution

Edicson A Parra Sanchez, Imperial College, London

The impact of regional and local factors on biodiversity is a crucial research question in rapidly changing human-modified landscapes. For epiphytes, an important and particularly sensitive group in tropical forest, these habitat alterations impose physical and physiological barriers to acquiring resources. The scope of this study includes patterns of habitat loss and the effects of forest cover, connectivity, patch size, and a gradient of matrix-edge-interior on species richness, abundance and community composition of vascular epiphytes.

The study was carried out in five fragments embedded in a human-modified landscape, and one protected area in the Brazilian Atlantic forest. Vascular epiphytes were sampled in the canopy and understory strata, in three habitats, matrix, edge, and forest interior.

In total, 6192 stands were surveyed, representing 42 species of vascular epiphytes recorded in 2719 trees in the understory, 75 canopy trees, and 25 trees in the matrix. Epiphyte abundance and community composition were the most informative diversity metrics. Results show a combined effect of landscape and local-scale characteristics influencing epiphyte communities in a human-modified landscape. At the landscape scale, species abundance was positively related to forest cover, whereas community composition dissimilarity was higher when fragments were further apart. Trees in the matrix supported more species than forest edge and interior, when forest cover and distance increased. I found a reduction in species richness and abundance in the understory and canopy from the matrix to the edge. Likewise, community composition did differ along the matrix-edge-interior gradient, and this pattern was mainly driven by species turnover, particularly higher in the understory. Furthermore, the absence of shade-preferring and well-dispersed taxa in the edge and matrix suggests that drought conditions are an important factor structuring epiphyte

communities. In addition, the dominance of adult individuals suggests that the conditions to promote the establishment of seedlings and juveniles stages might have been lost.

Potential for evolutionary responses to the decrease in the rainfall regime in vascular epiphytes' functional traits in the temperate forest

Alfredo Saldaña, Depto. de Botánica, Universidad de Concepción, Chile

Vascular epiphytes are considered vulnerable to anthropogenic climate change because they are de-coupled from the soil and are more directly affected by atmospheric conditions. To predict the impacts that climate change will have on epiphytes, information on the relative vulnerabilities and the role of functional responses to these changes is necessary. The optimum phenotype can change with the environmental change (environmental sensitivity of selection). Populations with reaction norms showing plasticity with the similar trend of environmental sensitivity of selection should persist under higher rates of environmental change. In the last decade, a declining trend in rainfall in south-central Chile (ca. 30%) has been identified. Most vascular epiphyte species can be found in this zone. To assess vascular epiphytes' potential evolutionary response to environmental change, it was measured the phenotypic selection on the populations' functional traits (WUE-water use efficiency, succulence, and LMA) of epiphyte species that are present along a latitudinal/rainfall gradient. In the north site, it was evaluated the environmental sensitivity of selection on these functional traits in two water availability treatments, to identify the potential change in the optimum phenotype to cope with extreme droughts. Selection of traits that reduce water loss and optimize nutrient use efficiency was stronger in epiphyte populations in the northern site (lower rainfall) than in those in southern. The ability to cope with extreme droughts can be related to changes in the optimum phenotype of these functional traits. When undergoing drought treatments epiphyte species' functional traits in the site with the lowest rainfall showed reaction norms similar to the environmental sensitivity's selection of these traits. These results demonstrate that vascular epiphyte species in the temperate forests of south-central Chile show the potential for evolutionary responses to a decrease in the rainfall regime in functional traits related to water and nutrient use efficiency. Acknowledgements FONDECYT-1140455.

Keywords: Evolutionary response, Epiphytes, Climate change

Functional patterns of epiphyte assemblages across an environmental gradient in the Colombian Andes

Claudia Milena Agudelo (ab), Ana Maria Benavides (b), Alvaro Duque (c). a. Corporación para Investigaciones Biológicas – CIB, Medellín, Colombia. b. Posgrado en Bosques y Conservación Ambiental, Universidad Nacional de Colombia Sede Medellín, Medellín,

Colombia. c. Departamento de Ciencias Forestales, Universidad Nacional de Colombia Sede Medellín, Medellín, Colombia

In tropical forests, vascular epiphytes can represent up to 50% of the total vascular species. However, little is known about the functional diversity and how it can determine the response of epiphyte assemblages to environmental variation at regional scale. In this study, we aim to characterize the functional diversity of vascular epiphytes along a wide environmental gradient covered by 10 forests with changes in elevation from 50 to 3000 m in the Colombian Andes. The research questions to answer are: 1) Can epiphyte assemblages be differentiated by functional types? 2) At which extent can the demographic performance (mortality) of functional assemblages of epiphyte species be determined by the environmental variation? To answer these questions, we measured seven functional leaf traits of the 163 most abundant epiphyte species found in the 10 sites: leaf area, specific leaf area, leaf dry-matter content, leaf thickness; force to punch, stomata density, and potential conductance index. The species were hierarchically grouped into seven functional groups. Non-metric dimensional scaling ordinations and linear regressions showed that functional composition of epiphyte species was primarily driven by annual temperature and precipitation. Mortality rates of functional groups were mainly determined by changes in temperature. The distributional pattern of the functional types of epiphyte species was largely determined by the environmental variation. Species associated to functional types with high capacity to acquire resources dominated forests at low elevation, while functional types with higher capacity to invest resources dominated in highlands. Mortality rates were higher in lowlands than in highlands. Overall, our results suggest that the leaf economic spectrum of epiphyte species is quite specialized and adapted to the local environmental conditions, which in case of modification by disturbance or global warming would need a high migration rate or capability of adaptation for species survival.

Keywords: functional strategies environmental variation traits

Functional traits in epiphyte ecology

Katrin Wagner (University of Oldenburg), Gunnar Petter (University of Göttingen), Wolfgang Wanek (University of Vienna), Eduardo Sánchez (University of Panama), Gerhard Zotz (University of Oldenburg), Juliano Sarmento Cabral (University of Würzburg) and Holger Kreft (University of Göttingen)

Vascular epiphyte species are not randomly distributed in the canopy but rather partition their habitat along environmental gradients. Particularly clear distributional patterns can be discerned along the vertical axis from the stem base of host trees to the outer canopy. However, studying *distributional* patterns at the species level tells us little about the mechanisms underlying such distributional patterns. A promising field of research that can improve our understanding in this regard is the systematic study of functional traits. We investigated leaf traits in a vascular epiphyte

assemblage (10 different traits, 83 sampled species, and > 1000 sampled individuals) in a Panamanian lowland rainforest. Many of the traits (especially specific leaf area and chlorophyll content) were significantly correlated with height above the forest floor. Such correlations were not only observed at the community but also at the intraspecific level. Differences in trait values between major taxonomic groups indicated that some leaf traits are taxonomically conserved. In addition to presenting the results of this study, ideas will be discussed on how the study of functional traits can generally help to elucidate different aspects of epiphyte ecology such as host tree specificity.

Keywords: functional traits vascular epiphytes specific

Effects of aging and fragmentation on performance of clonal epiphytes

Huazheng Lu[1,4], Liang Song[1], Wenyao Liu[1*], Feihai Yu[2*], Baogui Li[1], Liqing Sha[1], Xiaobao Deng[1], Jiaolin Zhang[1], Shugang Lu[3]

[1] Key Laboratory of Tropical Forest Ecology, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Menglun, China, [2] School of Nature Conservation, Beijing Forestry University, Beijing, China, [3] Institute of Ecology and Geobotany, Yunnan University, Kunming, China, [4] University of Chinese Academy of Sciences, Beijing, China

Disturbance and microhabitat fragmentation are ubiquitous in forest canopies which vary in environmental conditions, structure and resources. Clonal epiphytes can experience stressful and heterogeneous canopy habitat with physiological integration. But how ageing and fragmentation influence the performance of epiphytes is poorly understood. To test the degree of dependence on resource sharing with ageing and the effect of fragmentation (fragment size) on performance of a clone, a field experiment was carried out on the effects of relative age (infant, juvenile, maturity of offspring) and fragment size (more than three, three, two and one ramet, i.e. different fragmentation degrees) on performance of three epiphytic ferns in Southwest China. The results showed that the relative age and fragment size had significant effects on survival probability and growth of epiphytes and that there was significant interaction-effect as well, although there were few influences on morphological and physiological traits. Noteworthy is that the biomass of the mature ramet (donor) was less than that of immature surviving ones (receiver), whereas the mass per ramet in large fragments was more than small fragments. The study verified the decreasing degree of dependence on clonal integration during ageing and increasing negative effect on performance of epiphytes with fragmentation; it showed the cost of a donor but benefit of a clone of epiphytes in forest canopy as well.

Key words: disturbance, forest canopy, epiphyte, clonal integration, resource sharing, ageing, fragmentation, cost and benefit

Diversity distribution pattern of vascular epiphytes and climbing plants along the latitudinal gradient in Continental

María Moreno-Chacón & Alfredo Saldaña. Departamento de Botánica, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, Chile

Poster

Although vascular epiphytes and climbing plants are distinctive component in Chilean temperate forests, these plants have received little attention in ecological studies. This work aims to describe the latitudinal distribution range and the spatial patterning of α-diversity and β-diversity of this group of plants along a latitudinal gradient in continental Chile (17°29' S - 56°32' S).

We have occurrence data for 141 species of vascular epiphytes and climbing plants obtained from the databases maintained in the Herbarium of Universidad de Concepción (CONC). Additionally, we also used data from the "Catalog of vascular plants of the South Cone" by the Instituto de Botánica Darwinion and carried out an exhaustive bibliographic review to check the species occurrence along the latitudinal gradient. All this information was used to build a species matrix of presence-absence of the species along of the whole latitudinal range that comprises continental Chile. We obtained the richness and composition of the species for each latitudinal degree, and calculated the species β-diversity Wilson-Shmida Index between pares of adjacent latitudinal stripes.

Our results show that i) for the latitudinal distribution range, the epiphytes species in general have a wide latitudinal range located mainly in the mediterranean and temperate zones, while the climbing species are found along all climatic zones in Chile and have narrower distribution ranges. ii) for the α-diversity, epiphytes have the highest species richness concentrated between 40º-45º S degrees, while climbing plants have their peak of diversity around 35º S. Finally, iii) β-diversity index indicates that epiphytes show more changes in composition at the northern part of their distribution, while the composition of climbing plants shows no trend circumscribed to any specific zone, and the composition changes occur along the whole latitudinal gradient.

Keynotes: α-diversity, β-diversity, latitudinal distribution

Organic nitrogen contributing to N economy of epiphytic bryophytes

Liang Song[1], Hua-Zheng Lu[1, 2], Xing-Liang Xu[3], Su Li[1], Xian-Meng Shi[1, 2], Xi Chen[1, 2], Yi-Wu[1, 2], Jun-Biao Huang[1, 2], Quan Chen[1, 2], Shuai Liu[1, 2], Chuan-Sheng Wu[1, 2, 4], Wen-Yao Liu[1]

[1] Key Laboratory of Tropical Forest Ecology, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, P. R. China

[2] University of Chinese Academy of Sciences, Beijing, P. R. China

biodiversity hot spots call for more attention to the biodiversity value of non-pristine environments. As structurally dependent life form epiphytes may be particularly threatened by forest loss. We studied epiphyte assemblages in human-modified landscape in the lowlands of western Panama. A surprisingly rich flora was found in a first census of epiphyte assemblages growing on pasture trees. The re-census eight years later shows now that these assemblages were actually expanding in this human-modified landscape. Similar to unrestricted growth of epiphyte assemblages in undisturbed habitat documented in Panama and Venezuela, we found a substantial increase of abundance on the trees still present, more than compensating for the epiphytes lost with their hosts between the two censuses. In addition to the epiphyte census on pasture trees we established a baseline data set of epiphyte diversity in human settlements within the same region. The species pool here was considerably smaller than in pastures but diversity per tree was comparable to that of the less disturbed habitat. In general, epiphytes in the lowlands are able to support a certain degree of drought, but, as expected, sites with higher annual rainfall supported a higher diversity of epiphytes. However, community growth rates and precipitation were uncorrelated, suggesting that the species present were adapted to the current environmental conditions. The overall promising state of these epiphyte assemblages may foster the colonisation of potentially developing secondary forest as has been suggested by some authors.

Keywords: vascular-epiphytes, land-use change, tropical lowland

Effects of land-use change on vascular epiphyte diversity in Sumatra (Indonesia)

Tim Böhnert a,b,* , Arne Wenzel a, Christian Altenhövel a, Lukas Beeretz a, Sri Sudarmiyati Tjitrosoedirdjo c, Ana Meijide d, Katja Rembold a, Holger Kreft a,* a Biodiversity, Macroecology & Conservation Biogeography, University of Göttingen, Germany b Current affiliation: Nees Institute for Biodiversity of Plants, University of Bonn, Germany c SEAMEO BIOTROP, Jalan Raya Tajur Km. 6, 16144 Bogor, Indonesia d Bioclimatology, University of Göttingen, Germany

Land-use change is the main driver of biodiversity loss in the tropics worldwide. Lowland rainforest regions in Southeast Asia are experiencing particularly high rates of large-scale conversion of forests and agroforests into monocultural tree plantations including oil palm and rubber with devastating effects on forest-depending species. Canopy-dwelling organisms such as epiphytes might be particularly susceptible to changes in land-use, vegetation structure, and microclimate but the consequences of these effects in Southeast Asia are poorly known for this plant group. We investigated the diversity of vascular epiphytes in four major land-use systems in Jambi Province (Sumatra, Indonesia). Epiphyte communities were sampled in 120 20 x 20 m plots in Bukit Duabelas National Park (lowland rainforest) and in surrounding jungle rubber agroforests as well as in rubber and oil palm plantations owned by smallholders. At plot level, forest, jungle rubber, and oil palm were statistically indistinguishable in terms of richness, diversity, and evenness but had significantly higher values than rubber. Oil palm plantations had the highest epiphyte abundance, but lowest

total species number of all systems. Furthermore, oil palm had distinct, fern-dominated epiphyte communities that differed significantly from the other systems. In conclusion, the conservation value of monocultural tree plantations for epiphytes appears to be very low. Jungle rubber, an extensively managed but vanishing system, represents a significant refuge for epiphytes and could play a vital role in conserving epiphyte biodiversity, especially concerning ferns and orchids. Non-orchid angiosperms, however, mainly occurred in forest and are thus most threatened by forest conversion.

Keywords: epiphytes, oil palm, agroforests

Assessing Urbanization Impacts on Canopy Epiphyte Biodiversity and Function in Pacific Northwest (USA) Forests

Hannah M. Prather & Todd N. Rosenstiel, Portland State University, Department of Biology

While relatively small in size, the epiphytic lichens and mosses of forest canopies in the Pacific Northwest have a big impact on many essential ecosystem services, including the facilitation of biodiversity and the cycling of nutrients in these forested ecosystems. Although ecologically important, epiphytic lichens and mosses are especially sensitive to the heavy metal and nitrogen deposition resulting from urban pollution. Our preliminary studies indicate that exposure to urban pollutants may lead to dramatic shifts in the epiphytic communities in forest canopies of the Pacific Northwest (PNW), including the total loss of very sensitive, yet ecologically important, nitrogen-fixing lichens. Although the sensitivity of epiphytic nitrogen-fixing lichens makes these species particularly vulnerable to atmospheric pollution, to date there has been no comprehensive study to assess the impacts of urbanization on PNW forest canopy epiphytic communities and canopy nutrient cycling, despite continued growth in transportation and transportation-sourced pollutants throughout the PNW.

Here we present results from a study investigating how urbanization in the PNW dramatically alters and impacts epiphytic community structure and nutrient cycling within mature canopies of *Pseudotsuga menziesii*. We discuss the results of paired ground and arboreal epiphyte surveys and matched measures of epiphyte N-fixation across an urban to rural study gradient in Portland, Oregon (USA). Our results suggest that on-going urbanization within the Pacific Northwest may have significant, and surprisingly far-reaching, effects on ecosystem properties of regional exurban forested ecosystems. The impacts of an altered ground and arboreal epiphytic community on PNW forest processes, and the associated impacts to biogeochemical cycles, ecosystem services, and forest resilience to global change will be discussed.

Keywords: Urbanization Forests Epiphytes Air Quality

Climb Up - The Past, Present, and Future of Canopy Science

Meg Lowman, California Academy of Sciences, USA

After ~ 40 years of development, canopy science is still an emerging frontier of exploration promising not only adventure and scientific discovery but also solutions to global challenges. The toolkit of canopy scientists has advanced from simple ropes and harnesses to collaborative cranes and hot-air balloons, with aerial field stations soon to emerge. The history of canopy science is relatively short, but also parallels our emerging knowledge about forests as elixirs of global health. Important environmental issues such as climate change, biodiversity conservation, and whole forest interactions have inspired data collection within canopies as well as above and below canopies, and catalyzing large-scale ecological monitoring. But perhaps most important, canopy ecology may herald a new set of metrics in scientific achievement for the next generation of ecologists. As canopy science matures, the treetops have become scientific, economic, and social drivers for outreach in education and conservation. Rather than relying on technical scientific publications and data sets as the only measures for promotion and tenure, the next generation of ecologists increasingly prioritizes education outreach and applied conservation as additional metrics for success as a scientific professional. The integration of research, education outreach and conservation as the new tool kit for young ecologists may lead to better stewardship of forest

Recent development of canopy science and crane network in China

Akihiro NAKAMURA, Key Laboratory of Tropical Forest Ecology, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences

The canopy community is vitally important for the essential roles in ecosystem functioning and services that it plays. Over the last several decades there have been significant advances in canopy science, and we have gained extensive amount of information about the importance of forests and their canopies in promoting human well-being. There, however, remain many challenges in understanding canopy systems in order to make predictions about the consequences of global-scale human disturbances and their impact on forest biodiversity and ecosystem functioning. Further research is needed to understand forests and their canopy ecosystems.

What makes canopy science very unique from other disciplines is the difficulties in accessing canopy and collecting spatially and temporary extensive data. Although there are myriads of techniques available (e.g. single rope technique, canopy walkways, and canopy raft and hot air balloon) one of the most versatile methodologies is the use of cranes with which the researchers on-board a

gondola can access almost anywhere in the canopy strata within the reach of a canopy crane. Recent boosts in science funding in China has enabled establishment of a network of canopy cranes. There are seven canopy cranes built or under construction, and additional cranes are planned to be erected in the near future. The lack of spatial (and temporal) replication was one of the issues that has significantly reduced scientific rigour of canopy studies. This, however, is expected to become a thing of the past. Here we call for international collaboration between Chinese and other international canopy scientists to enhance local, regional and global scale canopy studies using the network of global canopy cranes.

Key words: canopy, crane, China, global

Prediction of response of insect-plant interactions to global warming on the correct time scale by using integrating altitudinal gradient study with warming experiment

Masahiro Nakamura, Moeko Minoshima, Hideaki Shibata, Kentaro Takagi, Tsutom Hiura,
Hokkaido University

Natural gradient study and experimental methods detect long (decades to centuries) and short-term (year to decades) ecological responses to global warming respectively. Integration of natural gradient and experiments within a single study would predict how ecological processes are likely to respond to global warming on the correct time scale (decade). To understand how global warming affect plant-insect interactions in the canopy of a mountain birch (*Betula ermanii*), we integrated altitudinal gradient study with warming experiment of tall trees (20 m in height), in which soil and branch were warmed in northern island Japan (Hokkaido). In altitudinal gradient study, herbivory rate increased toward low altitudes. Also, plant growth characteristics (i.e. leaf size and shoot length) increased toward low altitudes, while the concentrations of carbon-based defensive compounds (i.e. condensed tannin and total phenolics) in leaves decreased. In warming experiment, the combination of soil and branch warming increased herbivory rate although soil warming had only marginal effect on it. However, soil warming increased shoot length and decreased the concentrations of condensed tannins and total phenolics. The addition of branch warming to the soil warming further decreased the concentration of only condensed tannin and led to marginal increase in leaf size. The variation of herbivory rate was best explained by the concentration of condensed tannin, which was affected by soil and branch warming. These results from this integration study suggest that short-term responses detected by warming experiment of herbivory, carbon-based defensive chemicals, and plant growth to global warming are consistent with long-term ones detected by altitudinal gradient study, implying that the positive plant-mediated (indirect) effects of global warming on herbivory will work effectively on the correct time scale (decade).

Key words: canopy, defense, growth, herbivory, and plant-meidated

COPAS (Canopy Operating Permanent Access System)

Philippe GAUCHER, Pierre CHARLES-DOMINIQUE & Jérôme CHAVE (CNRS, Centre National de la Recherche Scientifique)

The Nouragues Ecological Research Station (French Guiana) has been a hub for tropical forest research since 1986. Access to the canopy has always been a major concern as canopy research was, and still remains, one of the key challenges in tropical biology and ecosystem science. In 1988, a canopy trail was built up, followed by the « Canopy Bubble » (Bulle des cîmes) six years later. Yet this equipment was limited in space and in time. CNRS (National Center for Scientific Research), in collaboration with European universities, initiated a prototype ensuring permanent access to the canopy of an old-growth tropical forest. Planned in the early 2000s, this project called COPAS (Canopy Operating Permanent Access System) was completed in 2015. It consists in a triangle formed of three 45-m pylons bounding a surface around 2-5 ha. The pylons are equipped with cables on which a suspended seat can move an operator. Movement of the seat is operated by radio control which activates the engines pulling or releasing the cables. The operator can thus move autonomously and in three dimensions within the forest plot.

The presentation will include short subtitled movie explaining the story of the COPAS and its functioning, and an overview of realized scientific projects. We will conclude by describing the other equipment available at the station, which make Nouragues one of the most attractive venues for conducting research in a tropical forest environment.

Keywords: French Guiana Nouragues Ecological Research

Climbing as a key fieldwork skill: Practicalities and considerations when taking research into the canopy

Vicki Tough BSc Zoology, IRATA Level 3 Safety Supervisor, Tree Climbing Instructor

The forest canopy is a major source of biodiversity, playing an important role in ecosystem functioning with development of conservation management plans for species and their habitat requiring information on the whole ecosystems to be effective. Despite this the canopy has remained understudied, primarily due to the inaccessibility and logistical challenges associated with canopy science research.

However, climbing can be an affordable, safe, mobile and low impact access method. Advances in climbing equipment and technical knowledge in the past two decades have seen significant improvements to the efficiency and safety when working at height, yet climbing as a research tool remains widely under represented and under utilised within UK and European Universities.

Globally, 6 canopy science research projects were undertaken over an eight year period. Using only climbing to access the forest canopy, these projects were used to examine the key factors affecting the success of a study carried out at height. The time and financial impact of each project was assessed in terms of minimum training requirements, necessary equipment, assistance from skilled personnel, time in the field, and rescue considerations.

Appropriate climbing and work at height training was crucial to understanding the safety parameters and limitations of accessing and moving around the canopy. This determined -potential sampling methods, which influenced productivity of the data collection. Correct equipment selection, specific training, skills and assistance from trained professionals were necessary considerations at the initial stages of planning and dependent on the conditions and logistics of each project.

The projects that collected the most usable data without exceeding budgets had a team consisting of both climbers and scientists which maximized productivity through combining skills sets and collaborating on project design.

This study highlights the challenges and trends during canopy research projects and provides a resource for others planning similar studies at height.

Review of rope-based access methods for the forest canopy: safe and unsafe practices in published information sources and a summary of current methods

Will Koomjian; Emergent Tree Works, Portland, Oregon, USA, David L. Anderson; The Peregrine Fund, Boise, Idaho, USA, Brian French, James Luce; Ascending the Giants, Portland, Oregon USA, Scott Altenhoff; City of Eugene, Parks and Open Space, Eugene, Oregon, USA

Although forest canopies are home to abundant and important ecological processes and contain high levels of biodiversity, access into the canopy has historically been a barrier to research. Rope-based tree climbing offers affordable, portable, and rapid access to the forest canopy and allows repeated sampling required by modern scientific and statistical study design. The primary drawback of rope-based tree climbing is the technical difficulty and inherent danger. A large amount of written material on technical tree climbing is available in the scientific literature and published books dating back over 40 years, but the safety of recommendations in these sources varies widely. We conducted searches for and reviewed 25 published sources that described rope-based methods of canopy access, and evaluated them on pre-selected criteria relating to climber safety. We found a high incidence of unsafe recommendations which, if followed, could lead to climber injury or death. Common errors included recommending methods and equipment suitable for rock climbing which can lead to falls and trauma in tree climbing, outdated information that no longer reflects best practices, and inclusion of photos showing major safety breaches. We also found no correlation between source age and the incidence of safety breaches, and indeed found high numbers of unsafe recommendations in recently published sources. The prevalence of unsafe recommendations and haphazard approach to climber training in the literature is alarming. Of course promotion of safe tree climbing requires more than criticism of published information. With that in mind we provide

basic recommendations to improve safety on a program-level, and to promote sources of quality information and training about tree climbing.

Keywords: tree climbing, canopy access, safety

Arboreal camera trap surveys: research and digital storytelling

Kevin McLean, Yale School of Forestry and Environmental Studies

In tropical forests, as many as three-quarters of vertebrate species use the canopy to some extent, making the treetops a critical sub-habitat within the forest. Despite the diverse community of species and the important ecological roles that they contribute to the ecosystem, population status and trends of many arboreal mammals remain unknown. Recent advances in wildlife survey technology and techniques, however, have made it possible to extend traditional ground-based surveys into the forest canopy using motion-sensitive cameras (camera traps). In the upcoming year, I will use proven arboreal camera trap techniques in tropical forests of Malaysian Borneo and the Ecuadorean Amazon – two biodiversity hotspots that are home to large communities of arboreal species. These surveys will provide baseline data required to initiate long-term ecological research and inform ongoing conservation planning. As part of a Fulbright-National Geographic Digital Storytelling Fellowship, I will communicate the process and results of this work to a public audience through writing, photos, and videos online. I will then curate the media that I collect into an exhibit for museums in both Malaysia and Ecuador.

Keywords: camera trap, mammal, Malaysia, Ecuadorlimb Up - The Past, Present, and Future of Canopy Science

The Leipzig Canopy Crane

Christian Wirth, Martin Freiberg, Ronny Richter

The Leipzig Canopy Crane is situated in Central Germany in a near-natural floodplain forest. It allows access to the canopies of about 900 trees from 16 different species with sufficient replication (> 10 individuals) for 7 dominant tree species of the genera *Acer*, *Tilia*, *Fraxinus*, *Carpinus*, *Ulmus* and *Quercus*. With a jib length of 45 m and moving on 120 m long tracks the 40 m high crane covers an area of undisturbed forest of 1 ha. The platform was established in 2002 and fully renovated in 2014 after a severe flood-related damage. In the last two years the scientific infrastructure was complemented with a climate station and a wireless network of temperature and humidity sensors, phenocams and sap-flux sensors. This set-up provides a representative characterization of canopy microclimate and phenology which is the baseline for any of ecological research. In combination with thermal airborne remote sensing data, tree species signals in air cooling potential are scaled up to the landscape level. Other ongoing projects focus on climate change effects on insect community assembly, the development of tree species detection algorithms from hyperspectral images, and testing the role of species-area relationships in 3D dendritic networks. Future projects will focus on plant-herbivore interactions and the dynamics and structure of decomposer communities (bacteria, fungi, ciliates and micro- and mesofauna). Collaborations are sought particularly in the context of projects employing global networks of canopy access facilities.