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WHAT'S UP? PERSPECTIVES FROM THE FIRST INTERNATIONAL FOREST CANOPY CONFERENCE AT SARASOTA, FLORIDA, 1994

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Jumars, caribineers, pole pruners, tree bicycles, Bosun's chairs, booms, peconhas . . . these terms are not listed in most biological dictionaries. Nor are construction cranes or large treehouses or hot-air dirigibles listed as priority equipment for any scientific laboratories. But these are the essential tools required to provide some of the exciting results reported at the recent First International Forest Canopy Conference during November 1994 at The Marie Selby Botanical Gardens in Sarasota, Florida.

Entitled **Forest Canopies: Biodiversity, Ecology and Conservation**, the Symposium attracted more than 200 scientists from 26 countries (TABLE 1). Over the span of four days, 52 papers were given in six plenary sessions (see Selbyana 15(2)), and over 40 posters were displayed. Workshops covered such subjects as herbivory measurements; canopy access "nuts and bolts"; the canopy raft of Operation Canopée; and the initiation of the International Canopy Network. A field trip to local subtropical habitats was also offered.

In addition to the scientific program, there were evening presentations for the public, including Mark Moffett of the National Geographic, presenting a panorama of canopy projects worldwide; Andrew Mitchell of Earthwatch Europe presenting a visionary image of "Biotopia," a canopy research-teaching-living station for the future; and a visual comparison of Australian and neotropical flora by Anthony Irvine of Commonwealth Scientific and Industrial Research Organization, Australia.

The atmosphere of the meeting was enthusiastic, supportive and interactive. For many, this was a first chance to meet and speak with others who are excited about canopy studies. The interaction of disciplines that are normally separated into different departments and institutions was effective; the mixture of physical scientists, biologists and chemists was productive. The inclusion of educators, conservation experts and arborists was a welcome addition to a format that usually hosts only scientists.

The Conference had been in the planning stages

TABLE 1. Summary of countries of origin of the participants at the First International Canopy Conference in Sarasota, Florida, 1994.

No.	Country
2	Australia
4	Austria
3	Belize
7	Brazil
1	Brunei
1	Cameroon
8	Canada
3	Colombia
2	Costa Rica
1	Ecuador
6	England
5	France
3	Germany
1	Indonesia
3	Japan
8	Mexico
6	Panama
1	Province of China
1	Scotland
1	South Africa
1	Sri Lanka
2	Sweden
3	Netherlands
149	USA
1	Wales
1	Zaire
Total	223 participants
	60 women
	163 men

since 1991, when the two Co-Chairs (Lowman, Hallé) first met while studying equatorial African rain forests in a hot air balloon over Cameroon, Africa. Professor Francis Hallé is a specialist in canopy architecture who developed the famous dirigible for canopy studies; and Dr. Margaret Lowman has studied herbivory in many forest types throughout the world and pioneered the use of canopy walkways and platforms. Both scientists recognized that most of the important pioneers in this relatively new biological frontier had never met one another since most canopy biologists work in very remote locations. Funds to facilitate the attendance of scientists from developing countries were obtained from the National Science Foundation and the Biodiversity Support Program in Washington, DC.

Many scientists traveled from their remote field sites to attend and report on their new and innovative research. Sessions were organized to cover a broad spectrum of topics: Canopy Architecture, Populations Dynamics of Canopy Organisms, Conservation of Forest Canopies, Canopy Environments and Environmental Interactions, The Ecology of the Subcanopy and Canopy Processes (see Selbyana 15(2) 1994 for a complete program). The Program Committee met at the end of the Symposium and synthesized the major issues discussed at the conference, as listed below.

1) Often raised questions were, "*What is canopy science, and should it be defined as a new discipline*?" These questions have many answers and stimulated much discussion without any cohesive answer. In addition, a large diversity of methods are being used to study the forest canopy at many different spatial and temporal scales. Canopy study may (or may not be) an entity unto itself, but it also links to other parts of the forest. The canopy is a region with a complex set of features, interactions and organisms. "Canopy science" is, at best, a term that links biological research within this environmental region of the planet. The canopy is a critical region for photosynthesis and nutrient transfer for the entire forest ecosystems. Anything that affects the forest also affects the canopy, and vice versa. Important issues such as global change, biodiversity and conservation need to be incorporated into canopy research.

2) The non-uniform sampling techniques used by canopy researchers appear to be creative and flexible, but these attributes have some negative consequences. It is time to develop consistent methods to facilitate comparisons of results both within and between different forest communities. Coming together to become aware of the research activities of others at this meeting was an important first step in the process of developing methodologies that will enable results to be directly comparable.

3) How did this meeting reflect (or not) the field of canopy study? Who was missing? The meeting was dominated by North Americans, a continent where canopy study is a well-recognized discipline. Europeans were under-represented in proportion to their relative abundance in this area of research. Africans, Latin Americans and Asians were least well represented, but that also reflected the fact that canopy studies have not been priorities in those regions. Of the African, Asian and Latin American scientists who contributed, many were assisted by grants from the National Science Foundation and Biodiversity Support Program. We need to develop mechanisms to increase the pursuit of canopy studies in these tropical regions and to continue to fund scientists from tropical countries to attend international meetings.

4) Safety for researchers remains a primary concern. We need to identify and emphasize safe standards for techniques and equipment. The formation of a committee to establish a ropes/access course with a printed manual was suggested.

5) Study of the physical environment has not been well recognized as an integral facet of canopy biology, but greater collaboration with physical scientists may help. Use of powerful technical tools such as GIS and remote sensing by biologists should be encouraged.

6) An unresolved issue in canopy research is ethics. Discussions were initiated on the extent of "damage" to trees and canopy organisms that is done inadvertently by researchers who climb. Methods to reduce or mitigate this damage should be investigated and communicated.

7) Symposium participants strongly felt that stronger networking among canopy researchers is needed. The dissemination of canopy research efforts has not been well coordinated. A computer e-mail bulletin board has been initiated, and suggestions were made to hold regular meetings, publish in a few specialized journals (e.g. *Selbyana*, *Biotropica* are some obvious examples), and collaborate more effectively on methodologies.

8) What topics were missing? Participants present suggested fifty topics for a future meeting (TABLE 2). Common suggestions included boreal forest canopy biology, birds, primates, microbes, long-term studies, bacteria, gas fluxes, epiphylly, inter-continental comparisons and plant pathogens.

9) Forest conservation is a critical issue for the future of forest canopy studies. We need to identify mechanisms to effectively conserve natural forest habitats (and their canopies). Canopy researchers need to communicate the conservation implications of their work. Education and collaboration with scientists in developing countries, ecotourism and ethnobotanical work were suggested as some activities that contribute to conservation.

10) Conference participants were surveyed for suggestions on the location and content of a future international canopy meeting. A strong majority suggested the next meeting be held again at Selby Gardens in Florida. This location is accessible to Latin Americans, Americans and Europeans. The Gardens has a large support staff to assist with a conference, which most academic institutions do not. To ensure a balance of geographic locations, however, it was suggested that smaller workshops on specific topics occur in Europe and perhaps in South America. There are tentative plans to hold workshops in Panama, in France and in Brazil in 1996, each with a different focus. The Second International Canopy Conference will be held in Sarasota, Florida, from 4–9 November 1998, at which time an expanded group of sessions, and an access workshop before the conference will be featured. We look forward to sharing results with all of you in three years!

TABLE 2. List of potential sessions and presentations for the Second International Canopy Conference (scheduled in 1998), as suggested by the participants at the 1994 meeting.

• Buds and phenology	• More on management issues
• More on organisms	• More physiology specific to canopy ecology
• Physicists and chemists to be included with biologists	• Statistical analysis techniques
• More temperate biology	• Pollination studies of Orchidaceae
• Mechanistic processes in maintaining high tropical diversities	• More plant–animal interactions
• Methods	• Dynamics of gaps
• Systematics of canopy species	• Ornithology
• More microclimatology, emphasis on canopy structure	• Gas exchange, more systems approaches
• More on vertebrate usage of canopies	• Emphasis on conservation
• Mammals and primate ecology	• Public education opportunities (e.g., ecotourism impacts)
• More remote sensing	• Visible near-infrared, thermal radiation interaction with the canopy
• More canopy research, more science, less access talk	• Research results as well as techniques of canopy research
• More computing, spatial data analysis	• Microbial ecology
• Frugivory	• Ant–plant relationships
• Animal communities	• More on vines
• Palm crowns	• Nematodes
• Photosynthetic bacteria (blue-greens)	• Orchid germination & establishment
• Non-mycorrhizal fungi	• Micro-aquatics (animal & plants)
• Lightning & static electricity, powerlines	• Hydrocarbon agrosols (effects on insect breeding & flight, epiphyte growth, tree, vine, epiphyte flowering)
• Volcanoes & ash, sulphur, etc.	• Prehominid canopy evolution of primates
• Camouflage & other pigments	• Efficiencies of flying, gliding, leaping, brachiating, running, etc.
• Effects of deciduousness in tropics	• Taxonomic distribution of canopy species
• Talking trees?	• Pollinators & phenology cycles year round (relays to maintain species)
• Total fractal & scaling patterns, micro to global	• Artificial canopy materials & construction (for exhibits, zoos, greenhouses, labs, conservation)
• Robotic devices for canopy exploration	• Bioengineering & nanotechnology threats to canopy biosphere

SUMMARY OF CONFERENCE SESSIONS

Summary of Session I: Population Dynamics of Organisms in the Canopy

Chairperson: Margaret Lowman, Marie Selby Botanical Gardens

Session I emphasized the challenges of research on plant and animal populations living in the forest canopy. This subject has been more extensively studied in invertebrates than any other organismal group, and the speakers reflected this. No ornithologist was able to commit to a presentation, so the session had this unfortunate omission in its consideration of canopy organisms. Speakers included two mammalogists, four botanists, two acarologists (specifically mites) and three entomologists who studied arthropod diversity at a broader level; additional presentations were included as posters.

Terry Erwin (Smithsonian), a recognized authority on the populations of insects living in tropical forest canopies, presented the introductory talk. Erwin highlighted the events and studies of different biodiversity groups throughout the world, and then presented results of his latest study that examines the impact of logging roads in South America on the populations of insects in the canopy. This project is still in progress, but the results to date indicate that dust and other physical impacts of roads through neotropical forests significantly reduce the insects living in close proximity to the disturbance. Erwin uses chemical fogging as his major access technique.

Jay Malcolm (Queens University, Canada) and Julio Voltolini (University of Sao Paulo, Brazil) spoke about their research on small mammal populations in the canopy, featuring the unusual technique of the peconha as an access method. Their work was conducted both in Africa and South America, and they documented very different populations of mammals between the canopy and the understory levels of forests.

Dave Walter (University of Queensland, Australia) and Dennis O'Dowd (Monash University, Australia) reported on their studies of mites on leaf surfaces in the forest canopy. An accurate count of this group of organisms would likely increase the current estimates of biodiversity considerably, since they appear diverse and abundant and are little studied. Mites live in leaf domatia, in epiphylly and have often been overlooked in many studies of canopy invertebrates. Walter and O'Dowd work from canopy platforms and towers, utilizing pole pruners to reach foliage.

Nigel Stork, (British Museum, England) another renowned authority on arthropods in forest canopies, reported on his work in the paleotropical forests of Indonesia (which are quite different from Erwin's neotropical sites). Like Erwin, Stork uses insecticidal fogging techniques to collect his samples. Stork contrasted the high diversity estimates obtained from canopy fogging in Indonesia with similar studies in the temperate canopies of Britain.

Robin Foster and Margaret Lowman (Marie Selby Botanical Gardens, Florida and Smithsonian Tropical Research Institute) presented the general results from their new studies on canopy trees at Barro Colorado Island, Panama. Using the 50 ha plots and "accessing" the canopy with binoculars, they are examining the crown status of canopy trees in hopes of accurately estimating the future reproductive status of different species. The traditional measure of DBH as a way of ranking species importance may not be very accurate if trees are covered with vines or have dead crowns which rendered them reproductively inactive. They have found that almost one quarter of the canopy trees are physically unable to bear flowers and fruits.

Jack Schultz (Penn State University, Pennsylvania) reviewed temperate canopy insect studies; in particular, oak forests dominated by gypsy moths. He cited some difficulties in obtaining accurate systematic results even in "our own backyards"; for example, even the well known red oak family is not taxonomically well worked out (so, obviously tropical trees may be even worse!). He pleaded with canopy biologists to address hypotheses and conduct sound experimental field work whenever possible, rather than merely using the descriptive approach of Darwin and other earlier naturalists. He has worked mainly with small trees accessible by foot or with ladders.

Doug Reagan (Woodward Clyde, Colorado) talked about his studies of lizards in the rain forest canopies of Puerto Rico, including the impacts of Hurricane Hugo on lizard populations. Like small mammals, lizard species are partitioned throughout different levels of the canopy. Reagan used towers for access, as well as SRT (single rope techniques).

Guadelupe Williams-Linera (Instituto de Ecologia, Mexico) and Bob Lawton (University of Alabama) reviewed their work on hemi-epiphyte populations in forest canopies, including different examples of figs and *Clusia* from their respective study areas of Mexico and Costa Rica. They have used SRT and towers to conduct research.

In general, biologists studying populations in forest canopies confronted major difficulties with

sampling (how to count mobile organisms, how to reach and count sessile organisms, how to see and recognize small organisms such as mites, how to sample effectively with replication for all groups). In addition, most agreed that studies needed to be long term and that funding and the infancy of canopy biology have thus far precluded any opportunities to examine patterns over long time periods.

In a discussion session at the end, the Chair addressed the question, "How many species are there?". Erwin replied that he had made errors in some of his earlier work based on inadequate sampling, but that he felt convinced that there were approximately 30 million (!). Stork rebutted this with an estimate of 10 million based on his field work from the old world and on museum collections. Walter recognized that, if mites are as diverse as they appear, these figures may all change. Others recognized that the groups of fungi and bacteria, as well as the entire soil environment, are "black boxes" in science that make this question hard to answer with any conviction. Jack Schultz reiterated his pleas for replicated sampling so that any results can be considered with confidence.

In a discussion about the future of canopy taxonomy, American scientists offered a pessimistic view of the future of systematics, since so little funding for training of new systematists exists. Guadelupe Williams-Linera from Mexico offered a more positive note, saying that her Institution had good numbers of students currently in training. Everyone realizes that the backlog of new species requiring cataloging by systematists is a significant bottleneck to the future of any biodiversity studies.

Session II: Canopy Processes

Chairperson: Joseph Wright, Smithsonian Tropical Research Institute

The canopy processes session covered a range of topics including nutrient cycling, plant water and nutrient relations, photosynthesis, leaf herbivory, mycology and plant and insect seasonality. Randy Currah and Katherine Richardson (University of Alberta, Canada) enumerated the fungi associated with epiphytic plants in Costa Rica, while Takakazu Yumoto (Kobe University, Japan) and Tamiji Inoue (Kyoto University, Japan) considered the seasonality of plant reproduction and insect activity for a dipterocarp forest in Borneo. Both these pioneering studies address areas where the absence of knowledge is nearly complete.

Nalini Nadkarni (The Evergreen State College, Washington) and Darwyn Coxson (University of Northern British Columbia, Canada) reviewed nutrient cycling in tropical forest canopies. They emphasized the decomposition of fine litter trapped in the forest canopy, the development of soil mats along cloud forest branches and root production by the host tree on soil-encrusted branches high above the forest floor. Nadkarni and Coxson concluded with a call for standardized methodologies and long-term experimental studies that could apply equally to all canopy studies.

Martin Barker and Peter Becker (University of Brunei, Brunei) compared nutrient uptake by conspecific trees in tall, species rich dipterocarp forests and also in nearby heath forests. The short stature and low tree species richness of heath forests is widely believed to be a consequence of their infertile podzolic soils. In fact, Barker and Becker found that nutrient uptake was consistently greater in heath forests than in nearby species rich forests. This surprising result overturns current dogma about the causes of heath forest and has important implications for theories relating plant species richness and soil fertility in tropical forests.

Margaret Lowman (Marie Selby Botanical Gardens) and Joseph Wright (Smithsonian Tropical Research Institute, Panama) compared herbivory rates in the canopies of forests from Panama and Australia. Leaf life times were subannual in Panama and ranged up to 12 years in Australia. Surprisingly, the proportion of leaf tissue removed by herbivores was several fold higher in Australia. This first intercontinental comparison of canopy herbivory rates suggests strong continental differences. Further studies will be needed to confirm this preliminary result.

Stephen Mulkey (University of Missouri, Missouri) and five collaborators evaluated leaf allocation in the canopy of a tropical dry forest. They reported strong seasonal differences in photosynthetic capacity, nitrogen concentrations and leaf specific mass within single branches. These differences corresponded with seasonal differences in rainfall, cloud cover and light levels. As a consequence, tree crowns present a mix of leaves that changes seasonally with the potential to maximize photosynthesis at the sunniest times of year.

Finally, Timothy Schowalter (Oregon State University, Oregon) documented insects associated with disturbed and intact forests in three distinct biomes. In all three forests, numbers of sap sucking insects were greatest in regenerating forests while numbers of leaf chewers, predators and detritivores were greatest in intact stands.

These differences have important implications for forest succession and conservation.

Session III: Conservation of Forest Canopies

Chairperson: Dr. Kathryn Saterson, Biodiversity Support Program, Washington DC
(a consortium of World Wildlife Fund, The Nature Conservancy and World Resources Institute)

Session III, on Conservation of Forest Canopies, had a broader focus than other sessions due to the obvious fact that the forest canopy cannot be conserved without conserving the whole forest. The session included presentations by ecologists, sociologists, educators, entomologists and ethnobotanists. Talks ranged from broad perspectives on overall forest management to focused solutions for conserving specific canopy families.

Kathryn Saterson's opening remarks on "Forest Conservation in a Changing World" focused on recent lessons about successful conservation approaches, the role of canopy research in influencing forest conservation policy and practice and mechanisms for scientists to individually and collectively apply their research to conservation. The keynote address by Gary Hartshorn (World Wildlife Fund) outlined a number of innovative approaches to sustainably managing tropical forests. Hartshorn noted that most of the remaining forest in forest-rich tropical nations will never be included in formal protected areas. Those unprotected forests need to be sustainably managed for timber production in order to prevent their complete destruction and conversion to other land uses. Hartshorn provided examples from Peru, Papua, New Guinea and Costa Rica of projects that demonstrate potential for sustainable timber production.

Jill Belsky (University of Montana) presented the results of her exploration of the potential for sustainably harvesting rattan from forests within Kerenci Sablat National Park in Sumatra, Indonesia, in order to contribute to forest conservation. She found that one species of rattan, *Calamus exilis*, may be suited to sustained yield harvest which could contribute to the livelihood of poor households and create incentives for communities to maintain forests (instead of converting forest to much needed farmland). However, in order for sustainable rattan harvesting to be allowed in the park there will first need to be significant changes in government policies, the resource rights of local communities and local management institutions.

The potential impact of ecotourism on the Costa Rican rainforest canopy was addressed by Donald Perry (Rainforest Aerial Tram, Costa Rica). Perry described how a rainforest aerial tram carries 20 cars with up to six people each through the canopy in a private nature reserve in Costa Rica. He will use the site to educate visitors about rainforest conservation and to conduct some research with visitor participation.

Bruce Rinker (Millbrook School, New York) outlined a curriculum for high school students that he is developing based on the rainforest canopy as a frontier for exploration. Recent expansion of direct and indirect canopy access techniques will make it possible for students to access the canopy, learn of its wonders and better understand the urgent need for forest conservation.

Sergio Guevara (Instituto de Ecologia, Veracruz, Mexico) studied the ecology of fragmented canopy remnants of tropical rain forest within pastures in Los Tuxtlas, Mexico. The isolated trees that remain when the forest is cleared for pasture were found to be associated with a diversity of rain forest species under their canopy. Guevara found 105 rainforest species growing under the canopies of 50 isolated trees in pasture.

The effects of forest degradation on fruit-feeding nymphalid butterflies in an Ecuadorian rainforest was described by Phil DeVries (Harvard University, Massachusetts). DeVries compared the species richness, abundance and seasonality of fruit feeding nymphalids within and between old secondary forest and intact forest. His preliminary results suggest that species richness and abundance was highest in the understory and that species richness was lowest in intact forest.

Helenice Mercier (University of Sao Paulo, Brazil) reported on her work developing a tissue culture technique to conserve two native bromeliads from the Atlantic Forest in Brazil that are endangered due to deforestation and their harvest as ornamentals. She has had success in the propagation of the two *Vriesea* species through *in vitro* seed germination production of multiple seedlings, and *in vitro* leaf culture production of multiple shoots that can be rooted. She did not observe mutants with these techniques. These propagation techniques can contribute to conservation of endangered bromeliads through reintroduction into the forest, or by commercially selling the propagated plants to decrease the harvest from natural forest.

Bradley Bennett (Florida International University, Florida) presented the results of his review of the ethnobotanical and economic botany literature of the neotropics for epiphytes, lianas and parasitic plants. These plants are all dependent on a canopy tree as host and are important to humans as sources of food, fiber, medicine

and other materials. Bennett found reference to 776 useful species of these host-dependent vascular plants (representing 363 genera and 70 families) including vanilla and passion fruit. The economic and subsistence importance of these plants to humans reinforces the importance of conserving rainforests.

Ingrid Olmsted (Centro De Investigacion Cientifica, Yucatan, Mexico) reported on her work on the conservation of epiphytes in the Yucatan peninsula. The Yucatan is home to about 100 epiphyte species found in six different forest habitat types. The low, inundated forests are the least disturbed forest type and are home to 45% of the epiphyte species. Loss of habitat and over collection of some species increases the need for conservation measures. More than 50% of the Yucatan's original forest is already destroyed. There are efforts to conserve epiphytes and their habitats in the eight natural areas of the peninsula. Olmsted discussed conservation measures involving government agencies, research institutions and local people.

Session IV: The Ecology and Dynamics of the Subcanopy

Chairperson: Phyllis Coley, University of Utah

Research on plant ecology is clearly incomplete without considering the canopy. This is the segment of a forest with both the greatest diversity as well as the largest biomass of trees, lianas and epiphytes. In addition, important processes affecting forest-wide budgets such as photosynthesis and gas exchange, occur at the interface between leaves and the atmosphere. And finally, as the abiotic environment in the canopy is certainly different and perhaps harsher than the subcanopy, there may be unique adaptations of plants capable of surviving in the canopy. However, the canopy is not isolated from processes and interactions occurring in the roots, understory and subcanopy. Canopy trees, lianas and hemi-epiphytes all maintain physical connections with the subcanopy for portions of their life history, and all are linked by shared interactions with herbivores, dispersers and pathogens.

Access to the canopy has opened a wealth of comparative studies with the understory. It is clear that many species of epiphytic plants (Harry Luther, Marie Selby Botanical Gardens), herbivores (John Barone, Smithsonian Tropical Research Institute) and pathogens (Greg Gilbert, STRI) show specialization for different strata in the forest. Although some species sweep from forest floor to upper canopy, the majority appear to be vertically stratified. Comparative studies evaluating the consequences of these differences in species distribution are still largely lacking.

The upper canopy is not, however, a uniform environment, and significant horizontal variation in microhabitats exists. For example, gap edges may be "hot spots" for not only canopy growth and reproduction, but also for the associated herbivores, seed dispersers and predators (Truman Young, Fordham University, New York). Establishment of hemiepiphytic fig species is tightly coupled with successful dispersal to rare knot-holes in canopy tree crowns (Tim Laman, Harvard University, Massachusetts). Studies of the ecophysiology of canopy epiphytes, largely unstudied, were discussed by Gerhard Zotz (Smithsonian Tropical Research Institute and University of Wurzberg, Germany).

Despite the horizontal variation and the vertical specialization seen for many forest species, there are biologically critical links between the upper canopy and the understory. Studies tend to be carried out in either canopy or understory environments, but the interplay between the two is clearly critical to our understanding of forest dynamics. Physical effects link the levels, particularly through gap formation by falling trees (Young). Young has demonstrated that canopy trees at gap edges are more likely to fall into the gaps, prolonging the existence of gap microsites.

There are also important ecological links between different forest strata. The Janzen/Connell hypothesis for the maintenance of tree species diversity suggests that herbivores and pathogens centered on canopy trees will cause increased mortality of saplings near adult trees. Some of the best evidence in support of this is from a fungal pathogen causing cankers of sapling and adult stems (Gilbert). Since all canopy trees start as saplings in the understory, competitive interactions in the understory may be critical in determining canopy composition. John and Therese Hart (Wildlife Conservation Society, Zaire) have shown that large mammal grazing in the African understory is selective and extensive, and that fast-growing gap specialist plants are preferred.

And finally, there may be evolutionary links between the canopy and understory. Saplings may exist in the shaded understory for decades before making it to the canopy. The abiotic environment in the understory and perhaps the biotic one as well, presents special challenges for survival. In terms of photosynthetic physiology and water relations, we see convergence among unrelated species suggesting that certain physiological syndromes may be adaptive in the understory but not be appropriate in the canopy (Thomas Kursar and Phyllis Coley, Utah State University, Utah). How do characters change through ontogeny in ways related to the different envi-

ronments through which an individual tree must grow?

Research linking canopy and understory processes is rapidly expanding and quantitative and experimental approaches are becoming more common (Zotz, Laman). These new approaches are extremely promising for understanding widespread interactions among plants and animals as well as population dynamics and evolutionary ecology.

Summary V: Canopy Environments and Environmental Interactions

Chairperson: Geoffrey G. Parker, Smithsonian Environmental Research Center, Maryland

This session attempted to introduce important physical-chemical aspects of forest environments to an audience largely concerned with biological aspects of canopies. Because many such effects and/or interactions are influenced by forest structure, all the presentations considered ways in which canopy structure modified the physical environment and its consequences for canopy organisms.

Gary Lovett and Kathleen Weathers (Institute of Ecosystem Studies, New York) defined three classes of processes by which material is deposited onto forest canopies: wet deposition (during precipitation events), dry deposition (between events) and cloud-water deposition (in forest often immersed in fog or cloudwater). Each of these processes is strongly influenced by the form of canopies and the geometry and arrangement of their components. For example, deposition can be very high at forest edges. John Weishampel and Jon Ranson (Goddard Space Flight Center, Maryland) reviewed methods for inferring the composition, stature and function of canopies from remotely sensed data using both active and passive sensors. For example, information from Landsat and Thematic Mapper images can provide some information on stand Leaf Area Index, foliar chemistry, and potentially, rates of chemical transformations. Radar, capable of penetrating cloud cover, can yield structural information about the outer canopy. The laser profiler can provide information about canopy height and internal structure over a footprint measuring only meters. The influence of turbulence as a major mechanism of the canopy-atmosphere exchange of energy and material was described by Dave Fitzjarrald and Kathleen Moore (Atmospheric Sciences Research Center, State University of New York-Albany, New York). He showed the importance of rapid but intermittent gust events and the methods by which turbulent exchange was measured.

Geoffrey Parker (Smithsonian Environmental Research Center, Maryland) defined canopies and noted some common structural and microclimatic trends in forests. He showed that comparisons between canopies were often difficult because canopy structure is not uniformly measured. He noted that forest microclimate observations were often not relevant to the lives of canopy organisms because measurements are usually made in only a few locations, often with long averaging times; examples of dramatic small-scale spatial variation in light environment were given.

David Benzing (Oberlin College, Ohio) examined the ways in which plants, especially epiphytes, responded to resource gradients and microclimatic differentiation within canopies. Processes contributing to the dramatic and rapid change in the chemistry of natural solutions in forests (e.g. precipitation, cloud water, throughfall, stemflow) were discussed by Douglas Schaefer (University of Puerto Rico, Puerto Rico). Stanley Herwitz (Clark University, Massachusetts), with Robert Slye (National Aeronautic and Scientific Administration, Moffett Field, California) and Stephen Turton (James Cook University, Queensland, Australia), discussed the effect of shading by neighboring trees on the interception of direct-beam radiation, using a means for representing crown structure from aerial photographs.

Session VI: Canopy Architecture

Chairperson: Francis Hallé (Institut de Botanique, Montpelier France)

This is not what is usually meant by "summary" because, on the one hand, architectural data were sometimes explicitly produced (see Session I with Terry Erwin, David Walter and Robin Foster; or Session IV with Timothy Laman and Gerhard Zotz) and, on the other hand, several contributions in this Session VI linked canopy architecture to other phenomena (e.g. reproduction). Consequently, instead of trying to summarize the whole session, I prefer to cite the highlights of each contribution.

First, Francis E. Putz (University of Florida, Florida), discussed how trees get rid of vine tangles. Vines appear to be rather detrimental to tree growth, but at the same time, trees are very good at growing up through the vine tangles. Dr. Putz has produced a list of mechanisms by which trees get rid of vines.

Yves Laumonier (Institut de la Carte Intern.

de la Végétation, France) gave us what is possibly the finest application of the canopy raft technique. He has done a refined cartographical representation of a canopy, and many people were convinced that such a detailed base map is a useful tool for studies undertaken by other canopy scientists.

Darlyne Murawski (Harvard University, Massachusetts) presented her study of mating patterns in canopy trees. She explained that, although outcropping predominates in the canopies of pristine forests, it could be replaced by inbreeding in places where the forest has been logged and where, consequently, trees are in low density.

Andrew N. Gillison (CIFOR, Indonesia) discussed the concept of "plant functional attributes" and illustrated how PFA could be used to describe either a vegetation along an altitudinal gradient, or a tropical rainforest along a vertical profile from ground to canopy. He also presented several case studies from French Guyana, Australia and Central Africa.

Roman Dial (Alaska Pacific University, Alaska) showed how tree architecture affects the distribution of both arthropods and *Anolis* lizard communities. Arthropod body-size, lizard removal, gap location and wind direction are important factors, acting at different spatial scales.

Daniel Barthelemy (Cirad/Gerdat, France) gave us an up-to-date summary of what tree architecture actually is, and how it could be simulated. Applications to forest ecology, agriculture and agroforestry were also presented.

Finally I. A. and C.V.S. Gunatilleke (University of Perideniya, Sri Lanka), with S. Dayanandan (Boston University, Massachusetts), have demonstrated that experimental pollination biology in tall trees such as Sri Lankan Dipterocarps was made possible by using canopy platforms. The way seems now open to a real genetic improvement of Dipterocarps, which would be an extremely important achievement in Asiatic forestry.

As a conclusion, I would say proudly that tree architecture, born in the sixties, is no longer a rapid graphic method to identify tropical trees and to assess their growth dynamics. Now, it has become more predictive for it has grown up as a mature science, addressing questions throughout a large array of research fields, and making use of quite sophisticated technology ranging from electrophoresis to experimental pollination, and from large scale 3D wrapping to computer graphics.

Maybe I should also mentioned my own contribution to canopy architecture, in the form of a chapter in the book, *Forest Canopies*, published by Academic Press (1995). In addition, many researchers present at this conference have produced review chapters for this first important volume on canopy biology.

Summary of Workshop Session: Canopy Access Methods

Chairperson: Bart Bouricius, Canopy Construction, Massachusetts

This session combined the presentation of studies that have successfully utilized an important canopy technique, with a canopy access workshop and discussion by access providers, users and documenters. The discussion focused on issues of concern to providers of access methods. Important questions regarding safety protocol, appropriate methods for attaching structures to trees, and equipment strength and durability data were addressed. It was concluded that a network should be established for sharing information about these and other questions. Names and addresses were taken, and a list of important questions was produced. Robbie Oates (Canopy Construction, North Carolina) is organizing a meeting for canopy access providers, and he should be contacted for the list of names and/or questions that came out of the discussion.

John Longino (The Evergreen State College, Washington) presented the first paper, which dealt with species richness of ants in a Costa Rican forest canopy. Longino used fogging with a short-acting insecticide to test for host specificity relative to the diversity of ants found in two groups of trees composed of only one tree species each, and a third group made up of diverse species. Host specificity was not demonstrated by the results. In fact, one of the single species groups of trees produced the greatest number of ant species.

Based on these results, Longino argued that host specificity was not indicated, and that if host specificity does exist, it is probably not very significant. He noted that accidentals (ants that do not live in the canopy) were found in numbers that could confuse the sampling results, if they were not recognized as accidentals and removed from the sample. He suggested that possibly the accidentals wandered into the collecting funnels from the ground.

The second speaker, Neville Winchester (University of Victoria, Canada), discussed the results of sampling the arthropod community in the forest canopy of the Carmanah Valley on Vancouver Island, BC. With colleague Richard Ring, Winchester described the large arthropod community, including many undescribed species, that was dependent on the variety of microhabitats

provided by this old-growth forest. He concluded that removal of this forest would initiate significant species extinctions. Winchester and Ring conducted this research using an access system of bridges and platforms installed in the trees by Stephanie Hughes and Kevin Jordan, (Lester B. Pearson College of the Pacific, Canada).

Scott Mori (The New York Botanical Garden, New York) described his use of French tree spikes to conduct taxonomic surveys of epiphytes in French Guiana, pointing out the advantages of speed and low cost in conducting his diversity surveys. Mori argued that this method produced little mortality to the trees and probably had a negligible impact on plant and animal diversity.

Geoffrey Parker (Smithsonian Environmental Research Center, Maryland), described how construction cranes can be used for prolonged, intensive studies of wide areas of the canopy with little impact, once the cranes are in place. He pointed out that cranes have the advantage of being able to carry heavy loads of people and research equipment to the very top of the canopy layer where research can be carried out in a stable, secure environment. Flexibility and speed of access were also seen as advantages of cranes, which may be mounted on a track to cover a very large area.

Peter Ashton (Harvard University, Massachusetts), was not able to attend the conference. However, his method of the canopy boom, described in his submitted paper, co-authored by Appanah S. and H.T. Chan (Forest Research Institute, Malaysia) was summarized by Mark Moffett, (Harvard University, Massachusetts). Moffett described a telescoping boom which can be mounted in a sling high in the tree in such a way that researchers can be suspended above the top of a tree. Studies in population genetics were carried out in Malaysia using the boom, or "tree prosthesis," to manipulate pollination in emergent Dipterocarp trees.

Tamiji Inoue (Kyoto University, Japan) and Abdul Abang Hamid (Forest Department, Sarawak, Malaysia) described the use of a large 300 m walkway system of towers and bridges in Sarawak to study how three dimensional foraging patterns of pollinators affect genetic structures of plants. These researchers found clear patterns of vertical and phenological distribution among the canopy insects, and concluded that mutualistic relationships in different canopy layers and in different seasons are important in maintaining high biodiversity of both plants and animals.

Finally, Richard A. Ring (University of Victoria, Canada) described research from three canopy access sites on Vancouver Island where his efforts have provided valuable data on diversity and new species. This research was used to bolster successful conservation efforts there. Ring ended his talk with a plea for more emphasis on research in the Pacific Northwest and other forests in non-tropical regions.

After the papers were read, participants prepared for the 4:00 p.m. demonstrations and posters on the south lawn under the Banyan Trees.

Three posters showing walkway systems were exhibited. Paul Donahue and Teresa Wood (Treetop Exploration, Maine) presented a poster describing an extensive walkway system which they constructed in the Peruvian Amazon, using a modified design based on Illar Muul's walkways in Borneo. This walkway system has been used extensively, for educational purposes, by the Amazon Center for Environmental Education and Research, which sponsored the project.

A second poster, by Kevin Jordan and Stephanie Hughes, (Lester B. Pearson College of the Pacific, Canada), described an access system involving platforms and bridges tethered to large coniferous trees. This system was used in several locations by Richard Ring and Neville Winchester for their research in British Columbia.

The last poster exhibited during this part of the session involved a description of a walkway system which Meg Lowman, Bart Bouricius and other Canopy Access Associates developed. This method uses a modification of the arborist's cabling technique to install bridges, platforms, and crows nests at several sites in temperate and tropical forests.

Demonstrations

David Macleod (Delaware), provided an electric winch with which he can hoist people into the canopy. David can use the winch to gain quick access to the canopy in order to secure a pulley on a sling to hoist researchers or eco-tourists up into a tree without damaging the tree.

Paul Donahue and Stephanie Hughes demonstrated an exciting way of climbing trees without the use of arrows, slingshots, spurs, or throwing balls by using nylon web slings around the tree with a sit harness and an etrier to ascend trees up to one and one-half meters in diameter.

Mike Gardner demonstrated his rope step climbing system, which uses a carabiner, consisting of two ascenders and stirrups to climb, inch-worm style.

Robbie Oates (GardenSphere and Canopy Construction, North Carolina), demonstrated slingshot rope placement, climbing poles, throwing bags, and an ascender/taut-line hitch method of rope climbing, as well as his famous "ape climbing" technique.

Bart Bouricius, (Canopy Construction, Mas-

sachusetts), demonstrated a basic bridge consisting of two cables, a rope and a bosn's chair suspended from a pulley which rolled on the upper cable. The researcher, who is also connected to the lower cable with a carabiner and lanyard, walks on the lower cable while sitting in the bosn's chair.

Tom Ness, (New Tribe/Ness Climbgear, Oregon), demonstrated single rope climbing with his modified ascenders and special New Tribe comfortable tree harness.

Participants responded positively to the demonstrations although, for lack of time, some did not get to try out all of the access techniques.