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ABSTRACTS

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DISTRIBUTION AND DYNAMICS OF CANOPY GAPS IN A TROPICAL FOREST IN MALAYSIA

The authors analyzed distribution and dynamics of forest gaps using aerial pictures of Pasoh Forest Reserve in peninsular Malaysia to study the forest dynamics in a lowland tropical forest. Stereo-pairs of aerial pictures of the core area of the forest (500 × 1,000 m) were taken in May 1995 and February 1997; then the canopy height was measured at every 2.5-m grid. Estimates were then made for area and distribution of gaps by classifying canopy by height. Areas with a canopy height taller than 15 m were considered as "canopy;" areas with lower canopy heights were considered as "gap." Such gap areas accounted for 11.2% of the whole study site in 1995 and 8.7% in 1997. This small change in gap ratio was the result of 4.0% of the total area becoming newly formed gap during this period. At the same time, 6.5% of the area recovered from gap to canopy. Using a transition matrix of canopy height, the authors predict that the gap area will occupy 7.5% of the forest in the future.

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DO ANTS CONTROL GALL MIDGES IN NEOTROPICAL CANOPIES?

The authors studied two canopies of the widely distributed Amazonian tree, *Goupia glabra* Aubl. (Celastraceae), at heights of 38 m and 45 m near Manaus, Brazil. They fogged the trees with 1% natural pyrethrum at intervals of 6 or 24 months from 1991 to 1994. Although a total of 95 ant species occurred on a single tree, Hymenoptera (mostly Formicidae) and Diptera dominated. Most ants were foraging permanently in the canopy, and their recolonization after fogging seemed to follow stochastic pathways. The capture data indicated a biotic interaction primarily between predating ants and gall midges (Cecidomyiidae) and secondarily between gall midges and the parasitic Hymenoptera. Data from tree canopies of a lowland floodplain forest on Borneo obtained by Stork in 1991 suggest that a low number of ant species might result in a reduced predation of Cecidomyiidae galls by ants, which favors an interaction primarily between the parasitic Hymenoptera and the gall midges.

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TRANSPIRATION MEASUREMENTS: THE SURUMONI CRANE PROJECT, VENEZUELA

In addition to energy-exchange studies in the Surumoni tropical rain forest, the author presents the first results of a study on measuring transpiration as a key part of the water budget. In investigations of ten trees, comparisons between the rainy (July) and dry (November) seasons revealed various behaviors of different species at the same site. In general, he distinguished two types of

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behavior regarding daily adaptation of the tree species to water supply and demand. Most species showed reduced water consumption during the dry season. A Vochysiaceae (*Qualea* species) demonstrated a water demand that was balanced throughout the year, in contrast to most of the other tree species studied. The first balance of the total water consumption of the Surumoni crane site amounted to 10–12% of transpiration losses in comparison to the total rainfall. These results correspond well to similar studies conducted in Peru and the Ivory Coast.

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GROWTH AND SIZE-FREQUENCY DISTRIBUTION OF SHOOT POPULATIONS IN CANOPY LAYERS OF *QUERCUS LEUCOTRICHOPHORA* (FAGACEAE)

The author analyzed the growth of first-order lateral shoots in three canopy layers of evergreen Himalayan taxa (*Quercus leucotrichophora* or banj oak) growing under three banj oak forest stands (1,160 to 1,800 m altitude). Determinate patterns of shoot growth differed by 7 to 15 days between the lower and higher altitudes. Different levels of statistical significance were obtained for shoot length and diameter and leaf numbers in extension growth last year and thus far this year. In the canopy, the size of this year's shoots exceeded last year's. The lower canopy differs significantly in shoot length from those of the upper and middle canopies, reflecting differences in resource-capturing ability. Leaf number per shoot was significantly higher in high-altitude mixed-species forest than in oak-dominated stands. The author suggests that such studies of tree growth may be useful both for understanding the ecology of the taxa and for conservation management.

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INSECT FAUNA DIFFERENCES BETWEEN MATURE RAIN FOREST TREES AND THEIR SEEDLINGS: AN EXAMPLE FROM GUYANA

The free-living insect herbivores foraging on 10,000 seedlings were surveyed monthly for more than a year in an unlogged forest plot, 1 km^2 in size, in Guyana. Insects were hand-collected from the seedlings of five species of common rain forest trees. Overall, a total of 9,056 insect specimens represented 345 species. The insects were collected from 250 sampling stations, each representing a parent tree and its seedlings. In October 1997, half of the parent trees of the stations were felled to mimic selective logging and to allow the authors to continue monitoring the insect population in the logged plot for a year. During felling, insects were collected from the foliage of felled trees with a sampling effort similar to that of the insect survey taken on seedlings in September 1997. The authors compare the insect fauna collected on seedlings and parent trees during the two surveys. For a similar sample size, the foliage of parent trees yielded twice as many insect individuals and three times more insect species than did the foliage of seedlings. Additional data obtained from similar insect collections made during an 8-month survey of the understory of the study plot are used to discuss the relationships between the insect fauna of parent trees and seedlings. Although the data contain a number of potential biases, the authors conclude that the insect fauna of parent trees is definitively more abundant and diverse than that of seedlings.

BERNARD, ENRICO, Biological Dynamics of Forest Fragments Project, Brazilian National Institute for Research in the Amazon (INPA), Manaus, Brazil

VERTICAL STRATIFICATION OF BAT COMMUNITIES IN TREE-FALL GAPS IN CENTRAL AMAZONIAN PRIMARY FORESTS

The author investigated the vertical stratification of bat communities that use as habitat small tree-fall gaps in primary forests of Central Amazonia (80 km north of Manaus, Brazil). He used

capture nets in the canopy (at heights of 17 to 30 m) and in the understory (at heights from 0 to 2.5 m). By sampling 17 small natural tree-fall gaps (70 to 240 m^2) during one year (3,398.5 mistnet-hours), he was able to capture 936 individuals, belonging to 6 families, 27 genera, and 51 species. Utilizing Non-Metric Multidimensional Scaling (NMMDS), he verified a well marked vertical stratification among bat communities, which showed a heterogeneous distribution between understory and canopy, with the canopy being an intensely utilized region. Species of the subfamily Stenodermatinae were more abundant near canopy. Carollinae and Phyllostominae used the understory more frequently, as did subfamilies Glossophaginae and Lonchophyllinae. Sturnirinae was equally distributed between canopy and understory. The family Mormoopidae utilized the understory, as did Thyropteridae. Members of the families Emballonuridae and Vespertilionidae were equally abundant in understory and canopy, while Molossidae mostly utilized the region above the canopy, with sporadic incursions into gap interiors.

BOURICIUS, WILLARD, BART BOURICIUS, and PHIL WITTMAN,* Canopy Construction, Inc., Amherst, MA, USA

CALCULATING CONSTRUCTION PARAMETERS FOR CANOPY WALKWAY SYSTEMS

As researchers and owners of eco-tourist facilities discover the efficacy of the physically undemanding canopy access provided by support/suspension bridges built in the treetops, they are designing and building more and more of these forest canopy walkways. Funding restrictions coupled with weight loads, stresses, and safety are prime factors involved in site and materials selection as well as in ultimate usage limitations. The authors describe a BASIC language program (QBASIC on a PC) developed to consider such variables as tilt of span, length of span, weight of span, and safety factors at different loads and to calculate the appropriate catenary curve to build a walkway span. An iterative process is used to solve the engineering algorithms involved. The utility of the program lies in its simple interface–no special knowledge is required. This allows the owner and designer of a canopy walkway to quickly conduct "what if" scenarios involving different sites and material restrictions.

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GENETIC DIVERSITY OF TEMPERATE EPIPHYTES EXAMINED WITH RAPDS: PRELIMINARY RESULTS

Approximately 10% of all vascular plant species are epiphytic, including at least 31% of all monocots. Despite the richness of the epiphytic habit, genetic diversity among epiphytes has received little attention. Major epiphytic groups share reproductive characters that are known to have contrasting effects on genetic diversity, and levels of diversity may vary widely among species. The authors are examining genetic diversity in the epiphyte species *Epidendrum conopseum* (greenfly orchid), *Polypodium polypodioides* (resurrection fern), and *Tillandsia usneoides* (Spanish moss). Populations sampled in North Carolina and South Carolina were subjected to random amplified polymorphic DNA (RAPD) analysis.

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SAMPLING ARBOREAL LICHEN COMMUNITIES AS MICROCLIMATE INDICATORS IN WET-TEMPERATE RAIN FORESTS OF NORTHERN INTERIOR BRITISH COLUMBIA

Wet temperate spruce-fir rain forest ecosystems (*Picea englemannii/Abies lasiocarpa*) on the windward slopes of the Cariboo and northern Rocky Mountains in northern interior British Colum-

bia support abundant canopy lichen communities. Gradients in the physical environment influence the distribution of arboreal lichens in these forests. The authors used single-rope canopy access techniques to sample these lichen communities. Depending on the canopy structure, they combined visual (cover) and biomass sampling techniques. Height above the forest floor proved to be the most significant physical factor influencing the distribution of pendulous fruticose lichens. A gradient in height separates *Alectoria* and *Bryoria* species complexes into distinct canopy strata. Foliose lichens, in contrast, are more sensitive to changes in the size and presumed age of host substrate. These community gradients appear strongly linked to the combined influences of canopy microclimate and architecture.

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EPIPHYTIC FERN DIVERSITY AND STRATIFICATION ON TRUNKS OF *HYERONIMA ALCHORNEIODES* (EUPHORBIACEAE) AT LA SELVA BIOLOGICAL STATION, COSTA RICA

The authors compare occurrence patterns of epiphytic ferns on the trunks of seven trees of *Hyeronima alchorneioides* (Euphorbiaceae) with those of terrestrial pteridophytes at the La Selva Biological Station in Heredia province, Costa Rica, to determine if the epiphytic and terrestrial habits host different fern species. Differences in frond morphology of epiphytic and terrestrial ferns were also examined. A total of 16 species of epiphytic ferns and 17 terrestrial ferns were recorded, with only 1 species (*Olfersia cervina*) occurring on both substrates. Based on fern composition, trees could be divided into three zones: the crotch, the buttress and the bole (extending between buttress and crotch). The crotch was dominated by *Oleandra articulata, Elaphoglossum herminieri,* and *Vittaria stipitata.* The buttress was dominated by *Trichomanes eckmanii, T. godmanii,* and Vittariaceae gametophytes. The bole consistently lacked ferns. In percent cover and number of species, simple-leafed ferns dominated the epiphytic condition (10 of 16 species), whereas ferns with dissected leaves dominated the terrestrial flora (with only 1 of 17 species having simple leaves). These results indicate that a species turnover of ferns occurs from the terrestrial to the epiphytic habit and that epiphytic ferns tend to have simple leaves, while terrestrial ferns tend to have dissected leaves. The authors found a predictable stratification of the dominant epiphytic ferns on *Hyeronima alchorneioides.*

CARLSEN, MONICA, Facultad de Ciencias, Universidad Central de Venezuela, Caracas, Venezuela

STRUCTURE AND DIVERSITY OF THE VASCULAR EPIPHYTE COMMUNITY IN THE OVERSTORY OF A TROPICAL RAIN FOREST IN SURUMONI, AMAZONAS STATE, VENEZUELA

The author, with the aid of a large tower crane, studied the structure of the vascular epiphyte community in the upper canopy (20–28 m) of a riverine tropical rain forest. The forest is located near Caño Surumoni, a small tributary of the Orinoco River, in Amazonas State, Venezuela. The crane was installed by the Austrian Academy of Sciences for canopy research in a 1.5 ha forest area. The overstory or upper canopy in the study plot contains 147 trees, representing 16 families and approximately 22 species. Of these trees, 29% bear at least one epiphyte. In this stratum, 243 epiphytic individuals were found, representing 8 families and 24 species. The family Orchidaceae presented the greatest number of species (12). Only five species, *Codonanthe crassifolia,* (Gesneriaceae), *Microgramma baldwini* (Polypodiaceae), *Cattleya violacea* (Orchidaceae), *Anthurium gracile* (Araceae), and *Aechmea tillandsiodes* (Bromeliaceae), presented the highest number of individuals. Apparently, no relationship exists between any given epiphyte and its phorophyte; however, a correlation might be established between epiphyte number and type of tree bark. The spatial distribution of epiphytes showed patterns associated with height from forest floor and supporting branch diameter, inclination angle, and attachment position. Although these patterns may vary among epiphyte species, the number of species generally increases with support diameter and de-

creases with support inclination angle or attachment position. Species of Es*chweilera* (Lecythidaceae) exhibited the greatest abundance of epiphytes.

CARNEVALI, GERMÁN, Centro Investigación Científica de Yucatan, Mérida, Yucatán, Mexico

SYSTEMATICS, PHYLOGENY, AND TWIG EPIPHYTISM IN *CRYPTOCENTRUM* (ORCHIDACEAE)

The author's monograph of the neotropical epiphytic orchid genus *Cryptocentrum* Benth. is of evolutionary interest because the genus includes both twig epiphytes and larger branch epiphytes, its relationships with the rest of the Maxillariinae are uncertain, and species delimitation within the genus was unclear. The study combined living and herbarium material, laboratory studies, and field work in several countries. Chromosome counts for seven species (2n = 30–38) are newly reported. The morphological and ecological adaptations of the twig epiphytes in the genus are reviewed, and a study of allozyme variation in selected species suggests a wide range of genetic variation in the genus and less genetic variation and heterozygotes in twig-epiphytic members. A cladistic analysis using 25 morphological and anatomical characters indicates that *Cryptocentrum* is monophyletic; that the most likely sister group is *Anthosyphon* Schltr. which shares a sepaline cup and spur; that three clades within the genus are treated as subgenera; and that the twig epiphytic habit evolved at least twice within *Cryptocentrum.* The monograph recognizes 3 subgenera, 17 species (5 new), and 3 subspecies.

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LINKING LEAF LIFE SPAN TO PLANT GROWTH STRATEGIES IN 15 SPECIES OF CO-OCCURRING OAKS (*QUERCUS FAGACEAE*)

The authors are monitoring phenology, leaf longevity, gas exchange, and relative growth rates in eight evergreen and seven deciduous species of oaks (*Quercus*) which co-occur in northern Florida. First-year results showed that the deciduous oaks have higher specific leaf area and higher maximum photosynthetic rates on a mass basis than the evergreen species. The deciduous species produce only one major cohort of leaves each year and drop them before winter. The evergreen species, however, have a range of leaf lifespans, with some species producing multiple cohorts of leaves per year and others producing only one cohort per year. Maximum photosynthetic rates, averaged for each species, appear to be linked to resource availability. Species which prefer fertile, mesic to hydric soils tend to assimilate carbon faster and grow faster than species from xeric soils, regardless of leaf habit.

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ANT GARDENS OF THE RAIN FOREST CANOPY OF SURUMONI, VENEZUELA

When the Austrian Academy of Sciences installed a research crane in Surumoni, near La Esmeralda in the Amazonas State of Venezuela, it advanced such studies as the mutualistic systems formed by ants and epiphytes interacting in rain forest midcanopies. Ants build an aerial nest with a material called carton in the roots of an epiphyte. They continue to add seeds of other epiphytes into the carton until the system becomes a complex structure known as an ant garden (AG). The crane allows researchers direct access to AGs to study their spatial distribution, floristic composition, and internal characteristics with a minimum of disturbance. Using the crane, the authors filmed or photographed external components (plants, ants, carton) for identification purposes and measured AGs when possible. Internal components (fine roots, ant brood, and workers) were sampled with a small metal corer, preserved in ethanol, and viewed under optical and electron microscopes. Plants

more frequently found belong to the families Araceae, Bromeliaceae, and Gesneriaceae. Associated to their fine roots are N_2 fixing cyanobacteria. Ants found in the majority of AGs were *Crematogaster* cf. *limata parabiotica* (Forel), alone or in parabiosis with *Anochetus emarginatus* (superspecies), *Paratrechina* species, and the termite *Nasutitermes* species. The authors provide the following model of the mutualistic interactions involved in the AGs: external roots give the nest structural support and obtain nutrients from the carton; fine roots, strongly suberized, obtain water and nutrients from ant detritus; and their associations with cyanobacteria guarantee a supply of N_2. Cyanobacteria may also recycle carbon from ant detritus. Ants bring allochthonous organic material (plant sap, insects, seeds) to the nest as food for their larvae, build the carton nest, and disperse epiphyte seeds and cyanobacteria. Epiphytes develop more efficiently associated with ants than they do alone. Some epiphyte species cannot live away from this type of mutualism.

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SITE CONDITIONS OF AN URBAN WOODED AREA OF MEXICO CITY THAT HOSTS *CLADOCOLEA LONICEROIDES* VAN TIEGHEM (LORANTHACEAE)

The authors studied an urban wooded area of southern Mexico City (Mexico) that hosts the hemiparasite, *Cladocolea loniceroides* (also known as injerto or muerdago), to correlate its presence with environmental conditions and types of perturbation. Their methodology consisted of a survey of the distribution, environmental conditions, and types of perturbation associated with 960 trees, including those with the hemiparasite. The authors report the following results: 1) of the 56 tree species (36 families) identified, 15 species were hosts; 2) approximately 23% of the wooded zone was infested; and 3) the main perturbation factors associated with parasitized trees were soil compaction, low soil fertility, and other site limitations. These and other factors favor the spread of the hemiparasite.

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BIODIVERSITY AND ARCHITECTURE IN THE CROWNS OF CHILE'S ANCIENT ALERCE TREES (*FITZROYA CUPRESSOIDES*)

Fitzroya cupressoides, or alerce, a conifer that occurs in southern Chile and southwestern Argentina, grows to tremendous size and is known for exceptional longevity. A 3,622-year crossdated chronology established the alerce as the second longest living tree after California's *Pinus longaeva.* Despite the ecological importance and endangered status of the alerce, remarkably little is known about plant and insect communities that thrive in the crown. To generate a preliminary assessment of alerce crown architecture and plant and arthropod diversity, the authors climbed seven alerce individuals and collected samples. They measured the trunk and crown architecture of each tree and sampled lianas, epiphytes, and arthropods in a series of height-stratified plots. Filmy ferns were the dominant vascular epiphytes while bryophytes, lichens, and three species of lianas were also abundant in well-developed communities. Several trees and shrubs were discovered growing epiphytically in these crowns. Arthopod diversity and abundance was very low, even compared with conifers from climatically similar habitats in the Pacific Northwest of the USA. Herbivory was negligible, with less than 1% in all foliage samples.

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RECOLONIZATION OF BIGLEAF MAPLE BRANCHES BY EPIPHYTIC BRYOPHYTES FOLLOWING EXPERIMENTAL DISTURBANCE: EVIDENCE FOR AUTOGENIC FACTORS IN EARLY SUCCESSION

The authors describe the response of arboreal bryophyte communities on bigleaf maple trees (*Acer macrophyllum*) in Olympia, WA, following their experimental removal from the trees. Approximately 6% of the cleared area was recolonized by bryophytes one year following stripping. Encroachment accounted for 96% of this recolonization; growth from residual particles, dispersed fragments, and/or micropropagules accounted for the remaining 4%. Consequently, disturbance size may affect the time necessary for recolonization. The authors propose a model for epiphyte colonization in this system: aerially dispersed bryophytes have a very small probability of retention and establishment on bare bark. For most species, this probability is increased by the presence of encroaching bryophytes that precede them, which may facilitate the establishment and retention of airborne fragments and propagules by increasing the substrate's roughness and its capacity to retain water and nutrients. Disturbance does not appear to play a significant role in maintaining bryophyte diversity at this successional stage, as local species richness was not significantly changed following experimental disturbance.

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MORPHOLOGICAL VERSUS PHYSIOLOGICAL ADJUSTMENT OF O'HIA ACROSS NUTRIENT AND SUBSTRATE AGE GRADIENTS IN HAWAII

Leaf-level studies of o'hia (*Metrosideros polymorpha*) across substrate age gradients in the Hawaiian islands show differential patterns of adjustment to both nutrient limitation and removal of this limitation by long-term, ongoing forest fertilization. The study sites differ in age of the underlying volcanic substrate and in being demonstratively limited by nitrogen in the young site (Volcano, Hawaii) and phosphorus in the old site (Kokee, Kauai). Increased nutrient availability at the young site led to larger leaf size and weights, resulting in a larger leaf surface area for CO_2 capture. Accordingly, the overall effect of larger leaves is an increase in total biomass. Increased nutrient availability at the old site led to an increase in the photosynthetic rate per unit surface area with no concomitant change in leaf size, again resulting in an overall increase in total biomass. These responses imply differential strategies associated with nutrient limitation. An N-limited system may have a high level of plasticity in morphological traits and fixed physiological characteristics. In a P-limited and older site, the effects of weathering and soil compaction may introduce new limitations, thus fixing morphological characteristics and forcing plasticity in physiological characteristics.

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SILVICULTURAL SYSTEMS DESIGN AND FOREST CANOPY PROCESSES

Much of the public debate about biodiversity and the future of forested landscapes in western North America has been presented as a choice between designating forested lands for intensive forest management, including clearcut harvesting, or placing forested lands in parks or protected areas. The authors increasingly have recognized the need for a third choice, silvicultural systems that allow for partial removal of forest products while providing for the retention of forest cover and maintenance of natural ecological processes. Their evidence from partial cutting of silvicultural systems trials in coniferous forest ecosystems in British Columbia suggests that canopy epiphyte communities can be quite sensitive to the progressive loss of forest cover, with displacement of epiphytes from one canopy stratum to another followed by threshold effect and with changes in

canopy microclimate and windscouring that can result in the rapid loss of entire ecological guilds. They evaluate how the implementation of these silvicultural systems can be expected to influence functional processes in forest canopies.

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ANT-PLANT RELATIONSHIPS: COMPARING CANOPIES OF TWO TROPICAL ATLANTIC FORESTS

The authors studied the distribution of dominant arboreal ants in two equatorial Atlantic forests, one in Cameroon (Campo Forest Reserve) and the other in French Guiana (Forêt de Paracou), using the "treetop raft" and the "canopy sled." Dominant arboreal ants are characterized by extremely populous societies, nest-building abilities, and highly developed intraspecific as well as interspecific territoriality that results in a distribution of their territories in a mosaic pattern in the forest canopy. The 167 trees sampled in Cameroon, belonging to 29 families and 63 species, were occupied by only three dominant ant species: *Oecophylla longinoda* and two *Crematogaster* species. *Crematogaster depressa* was by far the most frequent (88.6% of the trees). Nondominant ants were relatively rare. The 171 trees sampled in French Guiana, belonging to 35 families and 90 species, with five dominant species: *Azteca instabilis* (32 trees), *Cephalotes atratus* (18 trees), *Azteca* species gp. chartifex (17 trees), *Dolichoderus quadridenticulatus* (16 trees), and *Crematogaster limata* (15 trees). *Azteca instabilis* and *D. quadridenticulatus* were mostly alone in the trees they inhabited, while *C. limata, C. atratus,* and, in a lesser way, *A. chartifex* were usually associated with non-dominant ant species. Results of the study are discussed in terms of biodiversity with an emphasis on the role of the dominant ant species.

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BREEDING SYSTEMS IN BEE-POLLINATED CANOPY FORESTS OF SOUTHWESTERN GHATS, INDIA

A study of canopy tree species pollinated by bees at Kakachi, a mid-elevation site in the South-western Ghats of India, revealed only two species of social bees on site. The bees were, nevertheless, the major pollinators of canopy trees accounting for 20% (18 species) of the total of 90 tree species recorded at the study site. Solitary bees were distinctly absent at tree level. Examination of the breeding systems of bee-pollinated tree species showed that a greater proportion of hermaphrodite species were self-compatible (9 not self-compatible to 11 self-compatible), and only two out-crossed. Out-crossing was more a consequence of dioecy. Most of the self-compatible species were at low density and flowered suprannually. Out-crossed species were at high density and flowered annually. The incidence of self-compatibility in montane sites in the neotropics has been attributed to low pollinator activity resulting from prevalent poor climatic conditions. In Kakachi, climatic conditions were not as severe as in other montane sites, nor was bee activity deterred by abiotic factors. Self compatibility in the canopy trees at Kakachi could be a response to such factors as low density, suprannual flowering, and the dependence of pollination on just two species of bees.

DIAZ SANTOS, FABRICIO, Fundación Cocibolca, Managua, Nicaragua

PREFERENCE OF ORCHIDS FOR TREE GENUS GROUPS IN A NICARAGUAN TROPICAL RAIN FOREST

The author observed the frequencies of epiphytic orchids collected in a Nicaraguan tropical rain forest. Clustering analyses revealed three tree genus groups closely related to three orchid species: *Scaphyglottis behrii* Helms., *Maxillaria neglecta* (Schltr.) L.O. Williams, and *Dichaea panamensis* Lindl., which are the largest orchids in the forest. In the first tree genus group, which contained

the largest trees in the forest, he found *S. behrii* and *M. neglecta* to be the most frequent species. In the second tree genus group, comprised of smaller trees, he found *D. panamensis* most frequently. Where he did not find these orchids present in the trees, a third tree genus group contained several orchids but at relatively low frequencies.

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THE VEGETATION CANOPY LIDAR MISSION: CANOPY STRUCTURE FROM LA SELVA, COSTA RICA

Scheduled for launch in early 2000, the Vegetation Canopy Lidar (VCL) is a satellite sensor that will provide global inventories of the three-dimensional structure of forest canopies. VCL will use multiple lasers producing 25 m footprints spaced contiguously along track and 2 km apart across track It is designed to record: (1) canopy top heights, (2) vertical distribution of intercepted canopy surfaces, and (3) ground surface elevations. These data will be gridded into 2 km and 1° products to parameterize land surface biophysical models and to improve estimates of aboveground biomass, with a particular emphasis in the tropics. The authors analyzed examples of vertical profile data and spatial patterns of canopy attributes (e.g., tree height and gaps) acquired with an airborne VCL simulator over the La Selva Biological Station with respect to stand types based on edaphic and topographic associations and disturbance history (i.e., old-growth versus secondary rain forests).

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CHARACTERISTICS OF SOUTHERN PINE BEETLE GAPS IN CENTRAL GEORGIA, USA

In 1997, the authors compared 20 gaps created by southern pine beetle infestation to 20 adjacent, non-infested areas in central Georgia, USA. To evaluate how the infestation impacted the successional development of the gaps, they determined the species composition of three strata: upperstory (trees equal to or greater than 20 cm, dbh [diameter at breast height]); mid-story (trees smaller than 20 cm dbh, but greater than 10 cm dbh); and understory (trees smaller than 10 cm dbh). Plot values of basal area, stem density, and quadratic mean diameter by canopy strata and species were analyzed to determine the significance of differences in tree abundance and size between gap and control plots. Size and abundance of several hardwood species were significantly lower in the presence versus absence of pine beetle infestation, suggesting that mixed pine and hardwood stands may have a reduced predisposition to attack.

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DIVERSITY OF LIANAS AND VASCULAR EPIPHYTES IN TROPICAL FORESTS OF THE ALBERTINE RIFT, WESTERN UGANDA

The authors documented the diversity of lianas and epiphytes in forests of the Albertine rift near the central African Pleistocene refugium between Uganda and Congo–forests considered to be centers of species richness. Belt transects and tree climbing were used for the assessments. The epiphytes consisted mainly of Orchidaceae, Aspleniaceae, and Polypodiaceae. Mature moist forests had a higher diversity of epiphytic flora both in terms of species and abundance as compared to forests dominated by *Cynometra* (Leguminosae). The most abundant liana families were Celastraceae, Apocynaceae, Asclepiadaceae, Menispermaceae, and Icacinaceae. The diversity and abundance of lianas was lower in climax *Cynometra* forest as compared to relatively young mixed forest.

Despite the generally low species diversity in *Cynometra* forests, the authors recorded the rare orchid *Distylodon comptum,* a Budongo endemic previously known only from the type specimen. The liana, *Efulensia montana* (Passifloraceae), was recorded in Bwindi forest which is nearest to the Congo Pleistocene refugium where the species also occurs. A tendency for higher epiphyte diversity was observed along river valleys compared to hill tops in contrast to observations on the lianas.

ERWIN,* TERRY, and DAWN SOUTHARD, Megadiversity Group, Neotropical Forest Canopy Laboratory, Department of Entomology, Smithsonian Institution, Washington, DC, USA

AMAZONIAN BETA-DIVERSITY AND ITS IMPLICATIONS FOR THE CONSERVATION OF CANOPY ARTHROPODS

The world's highest terrestrial biodiversity occurs in the western Amazon Basin, partly because of the contemporary richness of tree species and their dispersion and partly because so many of the tree species have rich insect faunas. Other multidimensional historical factors spread across some 40 million years of continental separateness. In addition, the mosaic of forest communities, habitats, and microhabitats provide a fine-grain landscape in which speciation has been, and still is, apparently rampant. Complementarity data suggest that substantial faunal turnover of canopy arthropods occurs within 200 kilometers and is virtually complete within 500 kilometers. The authors thus contend that, as patches of forest go down to burning, the axe, or the bulldozer, far more species are likely becoming extinct than previously estimated, even by the supposed wildest of those estimates. They conclude that conservation measures, to be effective for the greater part of biodiversity (i.e., terrestrial arthropods), must take into account the uniqueness of small patches of evolution and species accumulation within the broader landscape's carpet of apparent homogeneous green.

FAGAN,* LAURA, and NEVILLE WINCHESTER, Department of Biology, University of Victoria, Victoria, British Columbia, Canada

ARBOREAL ORIBATID MITES: DIVERSITY AND RATES OF CANOPY COLONIZATION IN A CANADIAN MONTANE FOREST

To investigate principles of island biogeography, the authors are examining arthropod species inhabiting the montane forest canopy at three elevational sites (800 m, 1,000 m, and 1,200 m) at Mt. Cain on Vancouver Island, British Columbia, Canada. They placed sterile litter bags in the canopy and on the ground beside nine trees of *Abies amabilis* to determine which arthropod species colonize needle microhabitats, the order in which they colonize, and the colonization rate of oribatid mites (*Acari oribatida*). During three sample periods, they extracted arthropods from each litter bag using a modified Lussenhop method, counted them, and identified them to order. Nested analysis of variance was performed on principal components to test for variation in abundance of arthropods colonizing litter bags from different elevations, trees, and branches. Evidence suggests a difference in the number and kinds of arthropod orders colonizing litter bags among sites; but no general positive relationship was found between arthropod abundance and particular trees or branches. The authors conclude that their colonization study of experimental substrates enables further assessment of microarthropod diversity in the montane canopy and advances understanding of the biology of key soil organisms inhabiting the lichen-rich canopy of montane *Abies amabilis.*

FIGUEROA-RANGEL, BLANCA LORENA, and MIGUEL OLVERA VARGAS,* Universidad de Guadalajara, Jalisco, Mexico

CANOPY SPECIES COMPOSITION AND SITE CONDITIONS IN MIXED-OAK FORESTS OF SIERRA DE MANANTLAN, MEXICO

The authors conducted a study of species composition and site conditions in mixed-oak forests of western Mexico, collecting data from 60 permanent plots (0.05 ha each). They evaluated the

forest canopy for species composition and structure, considering the number of individuals by species and family, height and diameter of individual trees, crown position, and canopy openness. Site conditions, such as altitude, aspect, slope, topography, and litter depth, also were considered. Following establishment of the study plots in 1994, the first remeasurement was made in 1997. Classification and ordination of plots resulted in seven communities dominated by six oak species: *Quercus candicans, Q. castanea, Q. crassipes, Q. laurina, Q. obtusata* and *Q. rugosa.* The main variables were physiographical factors related to differences in species composition. *Quercus* species were dominant and codominant elements in the canopy, although other species presented the highest abundance values. Remeasurement data indicated that canopy dynamics are affected more by changes in stand structure, specifically density, than by changes in species composition.

FLOREN, A., and K.E. LINSENMAIR,* Zoology III, University of Wurzburg, Wurzburg, Germany

CHANGES IN ARTHROPOD COMMUNITY STRUCTURE ON A DISTURBANCE GRADIENT IN THE TROPICS

The authors compared structure and species composition of arboreal arthropod communities on conspecific trees in mature and secondary forests disturbed 5, 15, and 45 years ago. With increasing time of regeneration, community structure at a high taxonomic level showed distinct differences; for instance, the ant fauna increased significantly in species number and abundance. Ant community structure, highly predictable in the youngest forest, became progressively unpredictable as the forest structure became more complex. Several species of different orders, found in large abundancies in the disturbed forests, remained rare in the mature forest. Changes in community structure and distribution patterns of species indicate a change of the structuring mechanisms from predominant deterministic processes in disturbed forests to stochastic processes in mature lowland rain forest.

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EPIPHYTIC BIOMASS IN COCOA PLANTATIONS OF NORTHEASTERN BRAZIL

Northeastern Brazil has large portions of cleared area used for cocoa plantations (*Theobroma cacao* L.). In this plantation system, called "cabruca," the understory is logged, which provides open space for *T. cacao* trees that grow under the shade of taller remnant trees from the Atlantic Rainforest. The author has observed that approximately 90 to 100% of these remnant trees are phorophytes of epiphytic bromeliads. She describes how epiphytes are structured in *Lecythis pisonis* crowns and estimates the biomass supported by this tree species. Nine epiphytic bromeliad species averaged 240 kg per tree, with a total of 605 rosettes of bromeliads in canopies of *Lecythis pisonis.* Four species occupied tree crowns in a normal pattern of distribution; and five showed some preference for other light or humidity conditions. The large amounts of bromeliads and species per tree demonstrate the value of the cabruca plantation system in buffering epiphytic extinction in the region. The epiphytic biomass suggests that canopies can be richer in nutrients than the forest soil.

FREIBERG, MARTIN, University of Ulm, Ulm, Germany

THE INFLUENCE OF CANOPY EPIPHYTES ON TEMPERATURE IN A TROPICAL RAIN FOREST OF FRENCH GUIANA

Epiphytic vegetation, microclimate, and humus accumulations of tropical trees are closely interrelated. The aim of the study was to measure the effect of epiphytic vegetation on the temperature around epiphyte-laden branches in the canopy. The investigation was carried out close to the Aratai field station in the Reserve Naturelle des Nouragues of French Guiana. Measuring equipment powered by solar panels was installed in a 52 m high *Virola michelii* tree 37 m above the forest floor. Three branches were equipped with four sets of sensors for temperature, humidity, wind speed, and photon flux density. The sensors were placed above, below, and to each side of the branches. Each

set consisted of six sensors with distances of 1, 15, 25, 50, 75, and 100 cm from the branch surface, for an overall total of 72 sensors. The author presents data on temperature. Two weeks after logging of data started, the epiphytic vegetation was removed completely on a length of 1 m before and 1 m after the sensor installation site on one of the three branches. Since June 1997, data have been logged at 5 minute intervals. The most profound temperature gradients evolved at sunrise (warming phase) and in the late afternoon (cooling phase). The temperature gradient between aerosphere and ramosphere may exceed 6°C. When external winds were low, a heat bubble formed above and a cold bubble below epiphyte-laden branches. No bubbles developed on the naked branch, although a small temperature gradient close to the branch surface caused by shade was present as well. Generally, the aerosphere above the epiphyte-laden branch warmed much more and the aerosphere below stayed cooler than did corresponding areas of the naked branch.

FUBUSA, YARED, The Jane Goodall Institute, Silver Spring, MD, USA

THE JANE GOODALL INSTITUTE: THE LAST TREE

The Jane Goodall Institute, a tax-exempt, nonprofit organization, was founded in 1977, after Goodall's mother had a dream. In it, an equatorial rain forest in Africa began to vanish, until only one tree and one chimpanzee mother remained under the last tree. With more and more forests vanishing in Africa, remaining animal habitats are in danger. The institute is committed to wildlife research and conservation, particularly of chimpanzees; the welfare of nonhuman animals; and environmental and humanitarian education. The institute reports that chimpanzees are disappearing in Africa. Formerly found in 25 countries, they are gone from 4 of those and very nearly vanished from 5 others. Only in the central part of their range are they found today in large numbers, where the last of the African rain forests still stand in Cameroon, Gabon, Zaire, and the Congo. The world's largest preserves of global biological diversity, including the last tropical rain forests, among them the Amazon basin, are now in danger. The institute calls on people around the world to serve in rain forest conservation.

GANESAN,* V., Department of Botany , ANJA College, Sivakasi, TN, India; and K. PALIWAL, Department of Plant Sciences, M..K. University, Madurai, TN, India

ASSESSING THE SUCCESSIONAL STATUS OF *TERMINALIA BELLIRICA* (COMBRETACEAE)

The tree, *Terminalia bellirica* (Gaetrn.) Roxb. is found commonly in the tropical rain forest regions of Western Ghats of South India. The authors assessed the successional status of the species by relating its growth and adaptive characteristics to open and shade conditions. They made and compared observations on shoot dynamics, leaf dynamics, and allocation strategies of biomass, nitrogen, and phosphorus in open- and shade-grown individuals. Their data reveal that *T. bellirica* is an early successional tree with an exploitative strategy evident from such results as faster extension growth, rapid leaf production, short life span, rapid turnover of leaves, unaffected allocation of dry matter to the stem and root components because of shading, and greater allocation of nitrogen and phosphorus to leaves. Although *T. bellirica* is an early successional tree, it showed some adaptations for survival and growth under shade.

GANESH, T., Ashoka Trust for Research in Ecology and Environment, Bangalore, India; and M. SOUBADRA DEVY,* Department of Biology, Madras Christian College, Pondicherry, India

FLOWER USE BY ARBOREAL MAMMALS AND POLLINATION OF A RAIN FOREST TREE SPECIES IN SOUTHWESTERN GHATS, INDIA

Cullenia exarillata (Bombacaceae), a dominant canopy tree in the mid-elevation wet evergreen forest of southwestern Ghats, India, exhibits cauliflory and produces flowers with a fleshy calyx

modified into a tubular structure. The calyx, which is imbedded with nectaries and can be removed without damaging the ovary and style in mature flowers, forms the basic reward for flower visitors. Observations of flower manipulation by visitors were made by the authors from tree platforms erected in the canopy; they also obtained data from fallen eaten flowers. Using flower traps set on the ground, they estimated flower production. Flowering occurs in the forest during the early dry season when fruits are scarce. Six species of nonvolant mammals, one species of bat, and many birds eat the flowers. Among these, only mammals were observed removing the calyx imbedded with nectar; however, these mammals also damage the flowers. Giant squirrels, flying squirrels, and striped squirrels predate on the flowers. Palm civets and monkeys also damage the flowers, but some escape total predation. Bird-visited flowers, even if not completely damaged, abort later on. Predation by bats is less than that by other mammals. Preliminary experiments reveal that *Cullenia* is outcrossed, and mammals are responsible for fruitset, thereby providing evidence for a predator-pollinator system in a syndrome of mammal-pollinated species.

GERING, JON C., and THOMAS O. CRIST, Department of Zoology, Miami University, Oxford, OH, USA

PATTERNS OF BEETLE (COLEOPTERA) DIVERSITY AMONG CANOPIES OF REPRESENTATIVE TREE SPECIES IN AN OLD-GROWTH TEMPERATE DECIDUOUS FOREST

The authors investigated patterns of beetle (Coleoptera) richness and abundance among four tree species–sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), red oak (*Quercus rubra*), and white oak (*Quercus alba*)–in an old-growth deciduous forest in southwestern Ohio, USA. They obtained samples of beetle communities from six individual trees of each of the four tree species (N=24) between June and July of 1998, using an insecticide fogging technique. At dawn on windless mornings, the canopy of each tree was inundated for 3 minutes with 0.5 liters of a 0.5% pyrethrin-based insecticide (Pyrenone 50, AgrEvo Products) emitted from a radio-controlled Curtis Dyna-Fogger. The fogger was suspended from the canopy and rotated through a circular arc, as the insecticide was applied. Insects were collected in an array of eight 0.5 m^2 collecting trays mounted on 1 m steel poles and positioned under the canopy so that insects from neighboring tree canopies were unlikely to be collected. Preliminary results suggest that beetle abundance is significantly higher in oaks than in other trees and that abundance of some beetle families, especially snout beetles (Curculionidae) may be responsible for this difference. Species richness was lowest in beech trees, whereas oaks contained the most beetle species. The authors analyze the results using multivariate techniques and discuss the patterns of beetle diversity in relation to the structural attributes, leaf chemistry, and spatial relationship of the sampled trees.

GLEISSNER, PETER, Botanical Garden, RWTH, Aachen, Germany

HOW THE PROBLEM OF SEXES IS DEALT WITH IN TREE BRANCHING

In adult woody plants, one group of meristems, buds, or shoot sections guarantees vegetative continuation, while a reproductive group functions only for a short period during pollination or diaspore production. These reproductive elements originate from the purely vegetative shoot sections by different methods of segregation. The author uses the unit of extension (UE) as the reference matrix to describe different types of allocation: (1) terminal flowering in competition with the vegetative apex (e.g., *Acer pseudoplatanus*), (2) lateral inflorescence shoots occupying a vacant UE section (e.g., *Fraxinus excelsior*); (3) mixed structure of terminal flowering and lateral inflorescence shoots (e.g., *Carpinus betulus*), (4) partial or full displacement of lateral vegetative meristems (e.g., *Quercus* species), (5) accessory buds developing into both vegetative and reproductive organs (e.g., *Robinia* species), (6) long-term reproductive capacity by accessory or prophyll shoots (widespread in tropical families), (7) alternation between a reproductive and a non-reproductive UE form (e.g., *Fagus sylvatica*), and (8) insertion of an additional short shoot-like reproductive element (e.g., *Tilia platyphyllos*). A change of arrangement also is possible because the UE program undergoes a regressive metamorphosis at subordinate branches or during tree aging. At the branch level, the structural relationship of vegetative and reproductive meristems is described by the 'shoot

chain' in terms of monopodial, anathic-sympodial, or anthetic-sympodial. Although the author based his research on the structural comparison of temperate deciduous species, the results can be extrapolated to some coniferous species.

GRUNER, DANIEL S., University of Hawaii, Dept. of Zoology, Honolulu, HI, USA

HERBIVORY AND ARTHROPOD DIVERSITY ACROSS A LONG AGE GRADIENT IN THE HAWAIIAN ISLANDS

The Hawaiian Islands are a natural laboratory for ecological studies. The islands form a replicated time series where many ecosystem and community factors are constant along a gradient of underlying volcanic substrate age (300 to 4.1 millions years old). Arthropod lineages are conserved among study sites, and the canopy is dominated by a single tree species, *Metrosideros polymorpha* (Myrtaceae). In 1997 and 1998, the author sampled free-living arthropods and herbivory on *M. polymorpha* at four sites on three islands. Sampling mature sun leaves from each cardinal direction of 41 trees in a multi-scale stratified design, he measured damage caused by the dominant herbivorous guild, a species complex of gall-forming psyllids. Significantly less herbivory at the Molokai site (1.4 million years old) was unrelated to foliar nitrogen concentrations, foliar morphology, tree size, canopy cover, or cardinal aspect. Ongoing analysis of free-living arthropod communities, as sampled by pyrethrum canopy fogging, will address an alternate working hypothesis, that recent anthropogenic impacts have resulted in low densities of insectivorous birds at the Molokai site, which could trigger an increase in invertebrate predators and a top-down trophic cascade.

HADLEY, JULIAN, Harvard Forest, Harvard University, Petersham, MA, USA

A PRELIMINARY MODEL OF CARBON EXCHANGE BY AN OLD-GROWTH EASTERN HEMLOCK STAND

During the fall and summer of 1997, the author estimated the carbon budget of an eastern hemlock (*Tsuga canadensis* L.) stand approximately 200 years old, using measurements of net photosynthesis (Pn), foliar respiration (Rf), woody tissue respiration (Rw), and soil respiration (Rs). Net carbon exchange was estimated for the upper, middle, and lower portions of the hemlock canopy as well as for the boles and understory. Estimated net carbon exchange for the stand was negative in July and August and near zero in September and October, when declines in Rs and Rw more than compensated for declines in Pn because of shorter day length and the onset of subfreezing night temperatures. Over the four months of July through October, hemlock trees took up about 2 Mg C/ha (ignoring root respiration), but Rs of about 4.6 Mg C/ha led to a net carbon loss from the system. During the summer, carbon uptake was primarily limited by high atmospheric vapor pressure deficits which reduced Pn and by high Rw associated with growth. In October, subfreezing nights began to limit Pn, which was drastically reduced during November. A general climate warming would probably further limit Pn during the summer but increase Pn in autumn and spring. The highest rates of net carbon uptake by the system may occur in April and May, when night temperatures are above freezing but low soil temperatures still limit Rs.

HAINES,* B. L., and D.A. CROSSLEY, JR., University of Georgia, Athens, GA, USA

DEFOLIATION OF A SOUTHERN APPALACHIAN HARDWOOD FOREST BY CANKERWORM (*ALSOPHILA POMETARIA*): IMPACT ON THROUGHFALL, LITTER, SOIL, AND STREAM SOLUTION CHEMISTRY

The authors associated an increased rate of NO_3 loss via stream water with increased defoliation by the fall cankerworm on Watershed 27 at the Coweeta Hydrologic Laboratory, Otto, North Carolina. The percent defoliation of *Quercus primus* L. along three transects that displayed differing degrees of defoliation provided an index of defoliation on the watershed. This oak was about 33%

defoliated during 1974 and about 16% defoliated during 1975. The authors determined concentrations of H, NH_4, Na, K, Ca, Mg, NO_3, Cl, PO_4, and SO_4 in rainfall, throughfall, litter solution, soil solution, and stream water. Solutions sampled at 30 cm in the soil usually showed concentrations of NH_4, Na, K, Ca, NO_3, PO_4, and SO_4 in excess of the control and increasing defoliation between sample transects. Stream water from defoliated Watershed 27 was enriched in NH_4, NO_3 and SO_4, in comparison to the control Watershed 7.

HEATWOLE,* HAROLD, North Carolina State University, Raleigh, NC, USA; MARGARET LOWMAN, Marie Selby Botanical Gardens, Sarasota, FL, USA; and KIRSTI ABBOTT, CSIRO Cotton Research Unit, Narrabri, Australia

HOW VARIABLE IS THE INTENSITY OF INSECT GRAZING IN EUCALYPT CANOPIES OF AUSTRALIA AND ELSEWHERE?

The authors sampled old leaves from a variety of eucalypt species in an array of habitats in eastern Australia, ranging from tropical Queensland to cool temperate ACT (Australian Capital Territory), and assessed the proportion of surface area lost to insect grazing using planimetry. Although variability was high among individual trees, it was higher overall than expected on the basis of worldwide herbivory rates. Similar studies were conducted in other regions of the world where eucalypts have been introduced and, in many cases, established as plantations. The extent of herbivory on *Eucalyptus* canopies in Australia was many fold higher than on eucalypts introduced into other parts of the world.

HIETZ,* PETER, and JULISKA AUSSERER, Institute of Botany, University of Agricultural Science, Vienna, Austria

POPULATION DYNAMICS AND GROWTH OF EPIPHYTES IN A HUMID MONTANE FOREST IN MEXICO

Although rain forest canopies and forest dynamics are being studied intensively, little is known about the population dynamics of epiphytes. To study epiphyte mortality and survival, the authors used computer-assisted image analysis on photographs repeated over a 5-year period of branch sections carrying several thousand individuals of more than 40 species of vascular epiphytes. Bromeliad sizes measured on photographs were used to calculate growth rates. Epiphytes falling with their supporting branch were presumed to have died on the ground. Overall, branchfall accounted for almost half of recorded deaths and for more than half of deaths involving plants growing on small branches. Calculated growth rates, especially of juvenile bromeliads, were low; most plants take ten years or more to become fertile, depending on species, position within the canopy, and growth model applied. The authors conclude that the study should help them understand the structure of the canopy vegetation observed, how diversity is maintained in this habitat, and how species survival is affected by natural as well as human disturbance.

HUNTER,* MARK D., and D.A. CROSSLEY, JR., Institute of Ecology, University of Georgia, Athens, GA, USA

CANOPY-FOREST FLOOR INTERACTIONS IN THEORY AND PRACTICE

From both physiological and ecological perspectives, processes in the canopy of forests cannot be studied in isolation from processes on the forest floor. Soil provides the structural matrix, nutrients, and water for the growth and reproduction of canopy trees. Canopies, in turn, are major sources of nutrients that return to the forest floor. Tree canopies, as major determinants of light and temperature conditions at ground level, influence the availability of soil resources for other members of the community both above and below ground. The cycling of materials and the concomitant modification of the environment provide a "feedback loop" from forest floor to canopy and back

to forest floor. Understanding this feedback loop will require collaborative efforts among plant physiologists, soil ecologists, and canopy biologists. The authors describe components of the feedback loop that have been documented to date and indicate gaps in current knowledge that must be filled to "close the loop."

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DIVERSITY OF ARTHROPODS ASSOCIATED WITH SAPOTACEAE AND LECYTHIDACEAE TREE CANOPIES AT THE ADOLPHO DUCKE FOREST RESERVE, MANAUS, AMAZONAS, BRAZIL

The Amazon rain forest is the largest in the world, but despite its richness in fauna and flora, few studies have been conducted on the fauna associated with the thousands of tree species in forest canopies. The authors designed an experiment to evaluate the arthropod fauna of the tree canopies of Lecythidaceae and Sapotaceae families, during dry and rainy seasons. They collected arthropods using a canopy fogging method on the following tree species: *Eschweilera atropetiolata, E. pseudodecolorans, E. rodriguesiana, E. romeucardosoi, E. wachenheimii,* and *Corythophora alta* (Lecythidaceae); and *Ecclinusa guianensis, Pouteria glomerata,* and *Micropholis guyanensis* (Sapotaceae). A minimum of 20 sample units was taken from each tree, but at present, only 10 are being studied. Initial results show that ants are dominant in almost all tree species, during both seasons. During the rainy season, individual abundance and species richness are greater. Arthropod fauna is more diverse in Lecythidaceae than in Sapotaceae canopies. Faunistic similarity among and within tree species, genera, and families, in both seasons, is very high, possibly indicating, a low arthropod/plant specificity.

HUSK,* GEORGE J., JASON GODIN, and JOHN F. WEISHAMPEL, University of Central Florida, Orlando, FL, USA

BIOGEOCHEMISTRY OF SPANISH MOSS IN ORANGE COUNTY, FLORIDA: A 25-YEAR REVISIT

Spanish moss, *Tillandsia usneoides* L. (Bromeliaceae), is an epiphyte that occurs on the southeastern coastal plain of the United States. In the early 1970s, as part of his Ph.D. research, William H. Schlesinger collected Spanish moss from such host species as pine (*Pinus* species), cypress (*Taxodium* species), and oak (*Quercus* species), from 24 forested sites in western Orange County, Florida. He measured the concentration of nine nutrients in the moss: Ca, Cu, Fe, K, Mg, Mn, N, P, and Zn. Since then, the Orange County landscape has changed considerably because of tourism and rapid population growth, with residential and commercial developments replacing many forested and agricultural areas. This has led to changes in patterns of anthropogenic inputs into the biogeochemical cycles, such as those of nitrogen and phosphorus. To quantify the dynamics in nutrient concentrations in Spanish moss, the authors replicated the Schlesinger study and assessed inter- and intra-site changes using ordination techniques.

KAHEMBWE, FRANCES, Forestry Research Institute, Kampala, Uganda

TROPICAL HIGH FOREST CANOPY MANAGEMENT PRACTICES IN UGANDA: A CASE STUDY OF THE BUDONGO FOREST

The author reviewed tropical high forest (THF) canopy management practices carried out in Uganda during the period from 1940 to the late 1950s under various silvicultural operations. The main objective of THF management was to increase productivity, in terms of volume, of commercially desirable timber species at that time. A number of experiments were established to study and

monitor, on a long-term basis, the effects of various treatments that mainly involved forest canopy manipulation to create gaps for forest regeneration. The author describes the Budongo Forest, one of Uganda's main sources of mahogany woods, and presents the results and impacts of silvicultural operations on forest structure and biodiversity.

KALKO, ELISABETH K.V., Animal Physiology, University of Tuebingen, Tuebingen, Germany/ Smithsonian Tropical Research Institute, Balboa, Panama/National Museum of Natural History, Washington, DC, USA; and C.O. HANDLEY, National Museum of Natural History, Washington, DC, USA

VERTICAL STRATIFICATION IN NEOTROPICAL BAT COMMUNITIES

Bats (*Chiroptera*) influence critical processes in tropical forest communities because of their role in dispersing seeds, pollinating flowers, and reducing insect populations. Recent advances in recording and analyzing bat ultrasound calls, useful in species identification, combined with mistnetting and improved technologies for observations at night increasingly permit comprehensive studies of this important group. Specifically, results from application of improved inventory techniques in Panama and Brazil show a much higher diversity of bats than previously thought. Further, it is now becoming clear that different groups of bat species exhibit a vertical stratification and effectively partition the understory, subcanopy, and canopy as well as gaps and open spaces above the canopy as foraging sites. The degree of species-specific specialization among these habitat types is reflected in the structure of echo-location signals and wing morphology. The authors conclude that, nonetheless, basic natural histories of high-flying species associated with the forest canopy and open-air environments remain relatively poorly known and their study represents a research priority with potentially valuable conservation implications.

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LEAF LONGEVITY OF FOREST TREES

Even though a forest canopy retains leaf cover throughout a growth season or year, it replaces leaves frequently. Thus leaf life span is one of the main issues of forest canopy dynamics. Leaf longevity (t*), maximizing carbon gain, is expressed as $t^* = (2bC/a)^{1/2}$ where a is the maximum photosynthetic rate, b is potential leaf longevity, and C is construction cost of a leaf. The author tested the validity of this theoretical model by examining the above parameters and by comparing expected and obtained leaf longevities. Using data sets obtained by Kitajima et al. (1977), by Ackerly and Bazzaz (1996), and by personal observation, the author found a match between observed and expected leaf longevity. By considering the differences between actual values of observed and expected leaf longevities, the author developed a concept of the "mean labor time" of a leaf.

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ECOPHYSIOLOGY OF CANOPY LEAVES: CONSTRAINTS ON RESOURCE ALLOCATIONS IN TIME AND SPACE

Although canopy trees are the dominant components of forest communities, they still face limitations in resource supply rates. In a seasonal tropical forest, rainy season is a time of limited solar radiation, while dry season is a time of limited water supply. Mineral nutrient availability in soil tends to decline gradually through the rainy season. Phenology of leaf production and loss may be understood through seasonal changes in resource supply rates. The authors note that observed seasonal changes of leaf nitrogen concentration, leaf mass per area, and leaf photosynthetic capacity

are supportive of this perspective. Although life history and tree growth rate are a strong determinant, longevity of individual leaves rather than being a fixed parameter for a species is variable and constrained by branch architecture, phenology of crown development, and within-crown microenvironment. How rapidly leaf photosynthetic capacity declines with leaf age, an integrated result of optimization strategies, is the most direct physiological predictor of the longevity of a leaf.

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NEGOTIATING THE CANOPY WITH THE LARGEST CANOPY ANIMAL–THE ORANGUTAN

As the largest of canopy animals, orangutans provide an excellent test of the limits of body weight on the arboreal lifestyle. On average, wild adult male orangutans weigh 86.3 kg and females weigh 38.5 kg. Such large animals move through the canopy by quadrumanual clambering (using all four hands and feet to grasp and pull themselves along) and occasional brachiation (particularly by smaller individuals). They also effectively use their body weight to bend and sway small trees, using the stored momentum in the tree as a spring to propel themselves across a gap until they can grasp an adjacent branch. Orangutans spend less than 4% of their time on the ground. To elucidate the relationship between body size and canopy usage, the author studied the sex differences between male and female orangutans. Data are presented on the time spent arboreal, the type of locomotion used, the substrates used, body position in the canopy, and travel height. Significant differences were found between males and females in all categories. Male body size, which was found to constrain some forms of travel, permitted males to use the structure of the canopy to propel themselves in ways more difficult for females.

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BIODIVERSITY AND ECOLOGY OF LICHENS IN AN AMAZONIAN TROPICAL LOWLAND RAIN FOREST

The authors investigated the biodiversity of lichens within a tropical lowland rain forest in southern Venezuela, within the scope of the Canopy Research Project Surumoni. Their primary aim was to illuminate lichen diversity and ecology, emphasizing vertical and horizontal distribution patterns. Using a mobile tower crane and mountaineering techniques, they collected lichens of seven phorophytes belonging to two species. Of the total of 202 species in 23 families detected, more than half were only tentatively named. Compared with results of Montfoort and Ek's research in French Guiana, the average species number per tree is clearly higher at Surumoni, leading to a significantly raised function of cumulative species numbers. The authors predict a considerably higher total number of lichen species at the study site. Among recorded families, the Thelotremataceae, Graphidaceae, and Trypetheliaceae are dominant and represent about 70% of total species richness. They show, just as species do, a more or less pronounced height zone preference, with Thelotremataceae dominating the lower and Graphidaceae and Trypetheliaceae, the upper forest strata. In addition to largely climate-dependent vertical distribution patterns, lichens demonstrate substrate specificity, which was calculated by comparing the degree of species similarity. Results revealed a markedly higher intraspecific than interspecific conformity.

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DISTRIBUTION AND ECOLOGY OF BROMELIACEAE ALONG TWO ALTITUDINAL TRANSECTS IN THE BOLIVIAN ANDES

During a 5-month period in 1996 as part of a project on the biodiversity of Andean montane forests, the author studied the distribution and ecology of Bromeliaceae along two altitudinal tran-

sects in different ecoregions of the Bolivian Eastern Cordillera. He located the Masicuri Transect at 450 to 2,400 m elevation in the semi-humid Tucumán-Bolivian Forest. The most species-diverse genus in this transect was *Tillandsia,* particularly the gray, epiphytic species that peaked in diversity at 450 to 1,000 m elevation. These plants adapt well to the relatively dry climate by means of their dense cover of scales and their Crassulean Acid Metabolism (CAM). The Carrasco Transect, from 300 to 4,000 m elevation, located in the perhumid montane Yungas Forest, was characterized by the presence of tank-bromeliads of the subfamily Tillandsioideae, especially the genus *Guzmania.* These C-3 epiphytes were dominant at the temperate mid-elevations between 1,000 and 2,000 m, with annual rainfall of about 6,000 mm.

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NECTAR-SUGAR COMPOSITION OF BROMELIACEAE IN RELATION TO POLLINATOR TYPES

Nectar is the major flower reward for pollinators of Bromeliaceae, and its composition does not appear to be constrained solely by phylogeny. Main components of the nectar are the sugar sucrose and the hexoses, glucose and fructose, which can be found in almost all nectar at varying concentrations. A large number of Bromeliads, especially in Billbergia (subfamily Bromelioideae), Puya and Pitcairnia (both subfamily Pitcairnioideae) have showy, colorful flowers and/or bracts and are pollinated by hummingbirds. These normally day-blooming flowers typically have sucrose-rich nectar. Some night-blooming Bromeliads with inflorescences in tones of yellow and green give off a garlic-like odor and have hexose-rich nectars. These are usually bat-pollinated and are found mostly in Werauhia and Vriesea (both subfamily Tillandsioideae). Of interest is the nectar-composition of the unspecialized white flowers of some Guzmania which open just after dark and stay open during the following day. Analysis of these flowers showed rather hexose-rich nectar which would indicate chiropterophily, but to date no observations on the real pollinators are known.

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A NEW CANOPY WALKWAY AT THE TIPUTINI BIODIVERSITY STATION IN ECUADOR

A new canopy walkway was installed recently by Canopy Construction Associates, Inc., at the Tiputini Biodiversity Station (TBS), a field station located on the Tiputini River in Amazonian Ecuador. TBS, established in 1995 as a private venture between Boston University and the Universidad San Francisco de Quito, offers undergraduate and graduate courses in rain forest ecology, opportunities for researchers, and accommodations and programs for ecotourists. Private sources funded construction of the walkway, which is approximately 90 m long comprised of individual spans that range from 10 to 35 m in length. The main spans range from 30 to 35 m above the ground, and two of the support trees have crows nests that extend up to 8 m above the platforms. The walkway was designed and constructed using stainless steel cables for span support, galvanized drop-forged hardware, polywood (plastic) treads and platforms, aluminum ladders, and Dacron rope and netting. To the authors' knowledge, this is the first time that polywood has been used in the construction of a canopy walk. Polywood, a product used by the U.S. National Park Service and Disney World for the construction of bridges and other outdoor structures, is expected to outlast traditional wood treads and platforms by several years.

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GLIDING VERTEBRATES IN RAIN FOREST CANOPIES: A NEW HYPOTHESIS TO EXPLAIN THEIR UNEQUAL GEOGRAPHICAL DISTRIBUTION

One of the remaining mysteries of the rain forest canopy is the unequal distribution of gliding vertebrates in rain forests on different continents. In Borneo, for example, no less than 33 different

species of vertebrates use gliding or parachuting locomotion, including the colugo or "flying lemur," flying squirrels, agamid and gekkonid lizards, snakes, and frogs. In the Amazon, no gliding or parachuting species are present. The author contends that independent evolution of gliding in so many disparate vertebrate groups in Southeast Asia seems to preclude an argument from historical accident and to suggest looking to features of the environment for an explanation. Previous authors suggested that unique aspects of forest structure and size in Southeast Asia led to the evolution of these traits. The author reexamined these hypotheses and proposed another. Evidence suggests that patterns of resource distribution in Southeast Asian forests are more patchy in both space and time compared with other regions. The evolution of larger body size, brachiation, and more nomadism in Southeast Asian forest vertebrates have been suggested as adaptations to this greater patchiness of resources. The author proposes that gliding, as a very efficient form of locomotion, may be another evolutionary solution to the problem of dealing with more dispersed resources in the environment.

LARKIN, DOUG, Children's Environmental Trust Foundation, International, Zeeland, MI, USA

YOUTH IN THE CANOPY: ONE ORGANIZATION'S SUCCESS IN THE PERUVIAN AMAZON

In early summer 1992, three teachers from Zeeland, MI, USA, organized and conducted what may be the first student rainforest workshop in the Upper Amazon of Peru. The success of this workshop, involving 39 middle-school students, and the publicity received from it stimulated the formation of Children's Environmental Trust Foundation, International (CET). The foundation develops, promotes, and conducts curriculum-driven, experiential workshops in the rain forests of the Peruvian Amazon. A fundamental element of the workshop experiences is the study of canopy life. Studies during a year of academic preparation include the rain forest canopy. Following the preparatory year, students are immersed in the rain forest and attend workshops led by rain forest authorities and/or local guides. Each session includes hands-on study of the rain forest canopy. Depending on location, students access the canopy in one of three ways: a suspended walkway system; a 110-foot tower with a second 90-foot platform reached by means of zip line; or ropes and ascenders. CET, which to date has hosted more than 2,000 students from middle-school to college age, is striving to have a significant positive influence on rain forest preservation and conservation.

LERDAU, MANUEL, State University of New York, Stony Brook, NY, USA

BIOLOGICAL DIVERSITY AND TRACE GAS EXCHANGE BETWEEN FOREST CANOPIES AND THE ATMOSPHERE

Forest canopies are the single most important terrestrial habitat involved with the exchange of trace gases between the Earth's surface and the atmosphere. In addition to water and carbon dioxide fluxes, forest canopies are the primary source for reduced photochemically reactive compounds such as hydrocarbons. Canopies are also major sinks for atmospheric oxidants such as ozone and dinitrogen oxide. The author presents results from field and literature review studies that demonstrate the role of biological diversity in determining the magnitudes of these exchanges and the impacts of land use changes on the fluxes of chemically reactive compounds. He suggests that alterations in species composition have the potential to dramatically effect atmospheric chemistry and air quality.

LI XIAOMING,* ZENG FANJIANG, and ZHANG XIMING, Xinjiang Institute of Biology, Pedology and Desert Research, Chinese Academy of Sciences, Urumqi, P.R. China; and KAKUBARI YOSHITAKA, Institute of Silviculture, Faculty of Agriculture, Shizuoka University, Shizuoka, Japan

GAS EXCHANGE CHARACTERISTICS OF FOUR *POPULUS* SPECIES IN A FOREST CANOPY AT THE SOUTHERN MARGIN OF TAKLIMAKAN DESERT, CHINA

In a natural forest environment, the authors measured gas exchange characteristics of the canopy layer of four *Populus* species: *P. euphratica, P. pruinosa, P. alba* variety, and *P. nigra* variety.

Because *P. euphratica* and *P. alba* varieties have two types of leaves, they compared photosynthesis and transpiration of the two leaf types using a gas exchange system. Results suggest that the differences in photosynthetic and transpiration rates of the leaf types result from differences in chlorophyll content and water potential in the leaves. In addition, the authors measured diurnal changes and light curves of gas exchanges for these four *Populus* species.

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CANOPY HERBIVORY AND SOIL NUTRIENT AVAILABILITY

The idea that canopy herbivory increases nutrient (especially nitrogen) availability to plants by liberating nutrients "locked" in biomass has persisted despite scant evidence. Several recent studies indicate that excretory products from canopy invertebrate herbivores contain highly labile carbon and that the input of available carbon to the soil stimulates the growth of microbes, which can consume the available nitrogen. Therefore, in the short term, the net effect of herbivory is to reduce available nitrogen for plants. In the longer term, the ability of microbes to retain nitrogen depends on the persistence of the carbon supply. In the very long term, herbivory may reduce nutrient availability by preferentially damaging or killing higher nitrogen individuals or species, thus conferring competitive or evolutionary advantages on lower nitrogen plants that tend to retard rates of nitrogen cycling.

MADIGOSKY,* STEPHEN R., and STEPHANIE SKELLY, Widener University, Dept. of Environmental Science, Chester, PA, USA

MICROMETEOROLOGIC CHARACTERISTICS OF A PRIMARY TROPICAL AMAZON RAIN FOREST AT ACEER IN IQUITOS, PERU

To interpret micrometeorologic conditions of a primary rain forest environment, the authors used a series of dataloggers that measure air temperature, relative humidity, and light intensity. The series was vertically employed within the canopy walkway system at the Amazon Center for Environmental Education and Research (ACEER) near Iquitos, Peru. Measurements were collected daily and intermittently since 1966 at select locations from the forest floor to the upper reaches of the canopy. Distinct profiles were encountered for these parameters throughout the canopy and over extended periods. Daily cycles were apparent and somewhat predictable, especially for temperature and relative humidity at nearly all levels within the canopy. Daily levels of rainfall, monitored from January 1995 to the present, revealed distinct seasonal patterns with consistent increases of precipitation observed over the past 4 years, especially during the months of March, April, and May. Employment of dataloggers in a rain forest environment has provided a useful means of gathering baseline data to more fully understand the dynamics of the forest.

MANTOVANI, ANDRE, Federal University of Rio do Janeiro, Rio de Janeiro, Brazil

CONSIDERING EPIPHYTISM IN THE FAMILY ARACEAE

Among all epiphytic species, nearly 80% belong to only four families: Bromeliaceae, Orchidaceae, Polypodiaceae, and Araceae. Adaptations to life in the forest canopy of these families, except the Araceae, are well known. Book reviews do not consider Aroids basically because of a lack of information. To contribute to the knowledge of the vegetative basis for epiphytism in Araceae, the author studied water, nutritional, and structural relationships. He studied four species representing a hypothetical transition from ground to canopy: *Rhodospatha oblongata* (secondary hemiepiphyte), *Anthurium longifolium* (shade epiphyte), *Philodendron alternans* (primary hemiepiphyte), and *Philodendron crassinervium* (sun epiphyte). His investigations were performed at Reserva Botânica das águas Claras in Silva Jardim county, Rio de Janeiro state, southeastern Brazil (22°30'S; 42°30'W). Abiotic conditions along a vertical profile inside the forest indicated increasing drought and expo-

sure toward the canopy. Young individual plants were studied to detect adaptations to their establishment in the epiphytic habit, and all species were analysed for structural variations. Results showed that higher positions in the forest were attained by morphological, physiological, and structural modifications. Morphological mechanisms were hyponastic and rolling leaf movements. Physiological mechanisms were increasing succulence, sclerophylly, epidermal resistance, efficient stomatal responses, and relative foliar reflexivity. Structural mechanisms were increase of leaf, cuticle, and mesophyll thickness; higher values of internal cellular area and air spaces; lower stomatal densities of epiphytes; and the relationship between higher positions and anatomical plasticities. These data and results of the author's studies of soil and foliar nutrition and productivity suggest that epiphytism in the Araceae family is based on conservative strategies.

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POPULATION DYNAMICS OF TILLANDSIA BRACHYCAULOS IN A TROPICAL DECIDUOUS FOREST

Tillandsia brachycaulos (Bromeliaceae) is an epiphytic monocarpic herb that reproduces by seeds and basal offshoots. The authors present the results of a one-year study of the population dynamics in this bromeliad. Demographic parameters, such as mortality, fecundity, and growth, were estimated in 872 individuals occurring on nine phorophytes in a low deciduous forest in the Yucatan Peninsula, Mexico. The mortality rate was 27.65%, and preliminary observations suggest possible causes of mortality as the fall of individuals from phorophytes and the decay of apical meristem in the center of the rosette. Average fecundity was 1.99 capsules per individual rosette, and the growth rate (measured as leaf production) was 22.8 leaves per plant per year. Using Lefkovitch matrix models, they estimated the population growth rate and, with elasticity analysis, determined the key stages to attain an intrinsic population growth rate. The authors discuss management programs, conservation aspects, and the contribution of asexual and sexual reproduction in the maintenance of wild populations.

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DISTRIBUTION OF *POMATOCALPA SPICATA* (ORCHIDACEAE) WITHIN AND AMONG HOST TREES IN MANUSELA NATIONAL PARK, MALUKU ARCHIPELAGO, INDONESIA

The authors conducted host preference observations of *Pomatocalpa spicata* in Manusela National Park. Their results showed that this species has a strong host preference for Myristicaceae and Myrtaceae, especially *Myristica succadanea* and *Syzygium* species. Data indicated that *P. spicata* is primarily a plant of the main host trunk rather than a canopy epiphyte. The results suggest that this orchid is non-randomly distributed both among potential host species and within individual host plants.

MUSTALICH, ROGER, West Chester University, PA, USA/Amazon Center for Environmental Education and Research Foundation (ACEER)/Environmental Health Program; and STEPHEN L. TIMME,* Sperry Herbarium, Pittsburg State University, Pittsburg, KS, USA/ACEER

HOW STRATEGIC PARTNERSHIPS AMONG SCIENTISTS AND POLICY MAKERS FOSTER NATURAL RESOURCES DECISION MAKING IN THE PERUVIAN AMAZON

Tropical rain forest conservation requires a delicate balance between what often appear to be conflicting interests: preservation of biodiversity and indigenous knowledge and concurrent pressures for rapid economic development to mitigate property and improve overall quality of life. Little

disagreement exists regarding the need to integrate and empower local peoples in the decision-making process, but the authors note that in many areas of Amazonia, full integration of local peoples in natural resource decision making is still not a reality. To begin the difficult process of local empowerment, the Amazon Center for Environmental Education and Research Foundation (ACEER) has forged a series of strategic partnerships in the arenas of rain forest education and research. ACEER has created strategic partnerships with U.S. and Peruvian universities, natural resources agencies, research institutions, regional governments, local and international nonprofit organizations, and private corporations to advance partnerships that focus efforts on addressing local needs. As a result of such partnerships, local decision making is improving–from the grassroots level of villagers to the professional ranks of Amazonian universities, research institutions, and local governments. The growth of local decision making suggests an emerging model for sustainable development that does not force a false choice between conserving biodiversity and promoting economic development.

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INTERNATIONAL CANOPY NETWORK: A PATHWAY OF GLOBAL COMMUNICATION TO FOSTER FOREST CANOPY RESEARCH, EDUCATION, POLICY, AND CONSERVATION

The International Canopy Network (ICAN) was created in 1994 to facilitate communication among individuals and institutions concerned with research, education, and conservation of organisms in tree crowns and forest canopies. Prior to establishment of ICAN, the field of canopy studies suffered from a lack of communication among diverse disciplines, institutions, and individual researchers. Core activities of ICAN include maintaining an electronic mail bulletin board, circulating a quarterly newsletter and member directory, organizing canopy symposia, maintaining a bibliographic database, and creating instructional materials about forest canopies for children. Study of the forest canopy has reached a critical stage in its development from a young, "frontier" area of study to a vibrant and coalescing field of investigation and communication. Many current environmental and social issues at global scales–such as environmental change, acid deposition, loss of biodiversity–are related directly to knowledge of forest canopies. Enabling canopy researchers to communicate with each other and with those outside the field is an essential element in addressing these issues. Another activity to facilitate communication of canopy research at a global scale involves active collaboration among computer scientists and canopy ecologists to create informatics tools that can provide efficient transfer of canopy-related datasets among researchers. Pilot sets of canopy data at the Wind River Canopy Crane Research Facility in Washington state, USA, are serving to create, test, and evaluate database tools, metadata databases, and visualization programs to link datasets that relate to tree crowns and forest canopy. The process will enable scientists working at different sites on related questions to create comparable datasets. It also will allow data to be "translated" more easily from one spatial scale to another.

NADKARNI, NALINI, The Evergreen State College, Olympia, WA, USA

SEEING THE CANOPY WORLD IN THREE DIMENSIONS: THE CANOPY MOBILE

The rapid development and strong interest in canopy studies in society have generated an array of activities, outlets, and expressions for those involved with canopy work. The author has created a dynamic three-dimensional mobile that represents the multiple aspects of canopy studies to identify the many facets of life to which canopy studies relate. The existing and potential canopy efforts represented by components of the mobile are grouped into the general categories of research, education, conservation, recreation, and aesthetics. The dynamic nature of the mobile may help viewers to "see" new connections among these activities and to envision future possibilities for not-yet-existing actions that will promote the generation and dissemination of current understanding of the canopy. Three-dimensional kinetic art, by creatively integrating the information and structural relationships of the canopy world's components, places individual activities in a larger context and may lead to new ideas and directions in canopy studies.

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APPLYING CANOPY ARCHITECTURAL DYNAMICS TO TREE POPULATION DYNAMICS

The authors studied the canopy architecture of Ogawa Forest Reserve, a temperate deciduous forest in central Japan, by means of ground observation and digital elevation analyses of data obtained from aerial photographs. Using these analyses, they estimated the creation and closure over 15 years of the canopy gap as defined by different height. The three-dimensional architecture of gaps was inversely conical but not cylindrical. They then combined their findings with shrub and subcanopy tree demography that has been studied to make matrix models with gap and non-gap sub-populations in the same forest.

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PATTERNS OF EPIPHYTE DIVERSITY IN NEOTROPICAL RAIN FORESTS

Epiphytic plants are a major element of biodiversity; approximately 10% of all vascular plants (= 20,000 species) are epiphytes. Studies at two 400 ha mountain rain forest sites in western Ecuador show that, on a local scale, epiphytes represent roughly 30% of all species of vascular plants. The number of epiphyte species is extremely high on small sections of host surface (85 species on 40 m^2). Within the same small subplot, alpha-diversity of epiphytes is higher than that of terrestrial plants, whereas their beta-diversity is lower when several plots are compared. On the other hand, the two Ecuadorian study sites (25 km apart and roughly on the same altitudinal level around 2,000 m) have only 35% of all epiphyte species in common. In comparison, the epiphytic vegetation at the Surumoni crane project site in a lowland rain forest in Venezuela is much less diverse and abundant (771 individuals out of 52 species in the 1.5 ha plot), with many species very rare (less than 2 individuals in the plot). The overall analysis shows that the spatial pattern of epiphyte diversity is surprisingly complex and extremely scale-dependent.

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EPIPHYTES IN CAMEROON: A SURVEY OF HOST TREES AND HUMAN ACTIVITY

The authors surveyed the epiphyte flora in the humid zone of Cameroon. Their objectives were to examine the diversity and relative abundance of epiphytes in undisturbed forests and in plantations or open areas, to compare epiphyte richness in the two types of habitats, to identify epiphyte populations on host tree species, and to examine the impact of human activity on epiphytes. Preliminary results show that epiphyte flora is more diverse, more abundant, and richer in plantations or open areas. The epiphyte population on each host tree species differs with habitat and site. Human activity reduces epiphyte populations, particularly with current agricultural practices; but human activity can serve as a catalyst for the dynamism of epiphyte populations. To disseminate conservation ideas to the villagers, the authors organized meetings in three villages near the study sites.

NÚÑEZ VARGAS, M. PERCY, Andean Ecological Association, ANDE, Cusco, Peru

FOREST CANOPY FLORA OF THE HISTORICAL SANCTUARY OF MACHU PICCHU, URUBAMBA CUSCO, PERU

Among common species well represented in the mountains of Machu Picchu, some reaching altitudes of 2,600 m, are *Clarisis biflora, Cedrela odorata, Celtis iguanaea, Psychotria carthage-*

nensis, Adenaria floribunda, Ficus trigona, Trema micrantha, and *Tessaria integrifolia.* In mountain humid forests, the author reports Symplocaceae (12 species), Sabiaceae (4 species), Lauraceae (20 species), Styracaceae (5 species), Brunelliaceae (2 species), Monimiaceae (10 species), Chloranthaceae (6 species), Theaceae (4 species), Melastomataceae (40 species), and Podocarpaceae (3 species). A 2 × 200 m transect with trees larger than 2.5 cm dbh revealed a diversity of 92 species. The flora of the sanctuary is estimated at 3,000 species in a 32,000 ha area that encompasses inter-Andean valleys, Puna, high Andean *Polylepis* woodlands, jungles, and cloud forests. Species rare in their distribution are *Zanthoxylum mantaro* (a second record for Peru) and *Ficus crassiuscula.* The only endemic species may be *Senna vargasii* and *Pentacalia nunezii.* To better understand these species, the author compared regional floristics at equivalent altitudes in southern Peru and found, for instance, that the *Cecropia tacuna* described in central Peru is widespread in *la ceja* of Cusco. He observes that conservation biology in Peru is becoming a utopic dream, as the chaotic state of the land-tenure system, rampant cattle ranching, and frequent large-scale fires, with the burning of entire landscapes (e.g., August 1997), become more commonplace and threaten the ecosystem.

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CARBON AND ENERGY EXCHANGE FROM A LOWLAND FOREST IN COSTA RICA

Eddy covariance measurements of H_2O, energy, and CO_2 currently are being conducted in tropical lowland wet forest at the La Selva Biological Station in Costa Rica. The authors are using a system based on a closed path infrared gas analyzer with the sample inlets and sonic anemometer mounted on a 42 m tower. Prevailing winds are easterly with a relatively clean air from the Caribbean. The tower footprint is predominantly primary upland forest, whose average height is 21 m with emergents exceeding 35 m. Concurrent measurements include standard micrometeorological sensors for energy balance and six levels of continuous canopy profile sampling for CO_2, H_2O, and air temperatures. A suite of complementary plot-level primary productivity measurements also are being made in the region surrounding the footprint. Canopy roughness at the site is very high. Nevertheless, because of stable air, coupling between the atmosphere and canopy is frequently insufficient for the assumptions of the eddy covariance. Preliminary data analysis to date indicate that energy losses are dominated by latent heat fluxes. Net daily carbon exchange of the forest appears to be negative, that is, the forest is sequestering carbon. The forest does not appear to light saturate under natural light regimes.

OZANNE, CLAIRE M.P., School of Life Sciences, Roehampton Institute, London, UK

CANOPY ARTHROPODS OF TEMPERATE CONIFEROUS AND BROAD-LEAVED TREES: A COMPARATIVE STUDY

The author compared canopy fauna of four coniferous tree species with fauna of four deciduous broad-leaved trees. Sampling was carried out using pyrethrin knockdown. Mean densities of arthropods were significantly higher for conifers ($P<0.001$), and biomass was greater. The species richness of epiphyte feeders and predators was comparable for conifers and broad-leaved trees; however, species richness of herbivores was significantly greater on broadleaves. Woodland specialist species were found in both habitat types. Comparisons also were made with data from other studies in temperate and tropical regions. For instance, old-growth Sitka spruce in Canadian and UK plantation trees were dominated by the same invertebrate groups, although individual species were less likely to be canopy specialists. The author concluded that plantation conifers can provide functional forest habitat. In the UK, they could be used to increase the area of conifers, a diminished and fragmented resource, on sites that are not themselves of significant conservation value globally.

PADILLA, LUIS, New York State College of Veterinary Medicine, Cornell University, Ithaca, NY, USA; and DEEDRA MCCLEARN,* Organización para Estudios Tropicales, San Pedro, Costa Rica

MONITORING CANOPY MAMMAL ACTIVITY WITH INFRA-RED ACTIVATED AUTOMATIC CAMERAS (TRAILMASTER™)

Using commercial (TrailMaster™) infra-red activated automatic cameras, the authors studied arboreal mammals at three sites 15 to 19 m above the forest floor in the Barro Colorado Nature Monument, Republic of Panama. They conducted the study during the rainy season (June-August) of 1995, with all recorded events occurring between 1800 and 0500 hours. Of the 237 photographic events recorded, 218 were identified as containing the Central American woolly opossum (*Caluromys derbianus*); 15 contained kinkajous (*Potos flavus*); three had common opossums (*Didelphis marsupialis*); and one had a mouse opossum (*Marmosa robinsoni*). In 3% of the *C. derbianus* photographs, pairs of animals were recorded simultaneously. Most *P. flavus* photographic events occurred between 0100 and 0400 hours, whereas most *C. derbianus* events occurred earlier (with a peak at 1900 hours). Results suggest infra-red triggered automatic cameras as a powerful tool for documenting the mammalian biodiversity of a region, as well as for studying patterns of activity of arboreal mammals.

PARKER, GEOFFREY G., Smithsonian Environmental Research Center, Edgewater, MD, USA

A SURVEY OF VERTICAL LIGHT TRANSMITTANCE IN FOREST CANOPIES: AVERAGE PATTERNS, VARIATION, AND IMPLICATIONS

The pattern of light attenuation in a canopy indicates distribution of absorbing surfaces, sites of photosynthesis, and attendant ecological processes. Recent advances in canopy access methods make it possible to account for spatial variability in canopy light environments. The author summarizes results of spatially intensive observations of canopy light, taken in a variety of canopies with sensors deployed from tower cranes, telescoping poles, or in-canopy balloons. Diverse vertical light patterns are found within and between forests. The shape of individual profiles varies distinctly between needle- and broad-leaved forests. Average profiles depend on the forest type and developmental stage, especially on stand productivity and vertical pattern of leaf area density. Transmittance at the forest floor and vertical gradients of understory light depend not only on total leaf surface area but also on vertical distribution of foliage. In general, spatial variation is highest at canopy levels where the transmittance gradient is greatest, which makes the light environment most difficult to quantify where absorption is maximal. In most canopies, this transition zone is narrow and within the upper canopy. In some canopies, however, it extends over the majority of levels. The distribution of transmittance is neither constant nor symmetrical, and a marked vertical decrease occurs in transmittance skewness with height above ground. These results have implications for measuring, modeling, and managing canopy light environments.

PARRADO-ROSSELLI,* ANGELA, and JAIME CAVELIER, University of Los Andes, Department of Biological Sciences, Bogotá, Colombia

FRUIT SIZE AND PRIMARY SEED DISPERSAL OF FIVE CANOPY PLANT SPECIES OF THE COLOMBIAN AMAZON

The authors recorded primary seed dispersal at the canopy level in five tree species of a "Tierra Firme" forest along the Caquetá River, in the Colombian Amazon. The trees were *Trattinnickia* species (Burseraceae), *Ocotea* species (Lauraceae), *Hebepetalum humirifolium* and *Roucheria punctata* (Linaceae), and *Micropholis venulosa* (Sapotaceae). With these five single-seeded species, they tested the hypothesis that the larger the fruit size, the lower the seed dispersal. They also evaluated the effect of fruit size on the feeding behavior of diurnal frugivores, such as feeding rates, fruit removal, and fruit damage. Primary seed dispersal was calculated as the difference between initial crop size minus seeds removed by mechanisms other than diurnal frugivory (i.e., wind, rainfall, and nocturnal frugivores) or by being dropped, regurgitated, defecated, and damaged at the tree by

birds or mammals. They also estimated primary seed dispersal by counting the number and frequency of frugivore species at a tree and the percentage of fruits removed by animals. Results showed that primary seed dispersal was lower for larger fruits only when data were calculated knowing the original crop size. This relationship did not hold when primary dispersal was estimated by counting the number and frequency of visitors (species) and the percentage of fruits removed by frugivores. Fruit size was a better estimator of seed dispersal than seed size, fruit weight, or pulp content. In addition, larger fruit size correlated negatively with feeding rates (number of seeds removed away from the tree crown); it was positively correlated with fruit handling time and percentage of fruits dropped below the tree crown. Among the 33 bird species observed during the study, the authors considered only *Trogon melanurus, T. violaceus, T. viridis,* and *Ramphastos tucanus* to be good seed dispersers for the five tree species studied.

PITKÄNEN, SARI, Forestry Faculty, University of Joensuu, Joensuu, Finland

CLASSIFYING VEGETATION DIVERSITY TO MANAGE BOREAL FORESTS FOR BIODIVERSITY

To assess the diversity of ground vegetation in managed boreal forests, the author developed a classification based on the variation and abundance of ground vegetation species and forest stand structure. Diversity indices calculated for forest classes described the diversity of ground vegetation within forest classes. Results showed the major factors affecting species diversity to be fertility; canopy structure (number of tree species, basal area, and crown cover); successional stage of the stand; development stage and age of the stand; soil type; and variables in managing the stand. The most distinguishable diversity indices were similar to those developed by Pielous J. Simpson. Species richness and the highest alpha diversity appeared in young stands on mesic forest sites with low crown cover. Beta diversity was high, with the highest in the data found along the fertility gradient. Results suggest the possibility of assessing vegetation diversity by means of the stand variables and forest classes developed in this study and of using such assessments in planning forest management with respect to biodiversity.

PRELEUTHNER,* MONIKA, PIA GRUBBAUER, and HANS WINKLER, Konrad Lorenz-Institute for Comparative Ethology, Austrian Academy of Sciences, Vienna, Austria

ARE CANOPY BIRDS ETHOLOGICALLY AND ECOLOGICALLY DISTINCT?

Some scientists divide lowland tropical rain forests (LTR) into two distinct habitats, the canopy and the forest interior, with differences related to microclimatic stability and patterns of avian ecology. The authors, by comparing foraging behavior, locomotion, and micro- and macrohabitat use by bird species in the canopy versus those in the forest interior of an LTR on the Suromoni River (Amazonas, Venezuela), found clear indications that canopy birds form an ecologically distinct subset of the avifauna. In addition to 5,000 behavioral observations, the authors captured 900 birds in the understory and canopy to obtain data on body mass, molt, and external morphology. Morphological measurements were augmented with measurements on museum specimens. Canopy data were collected with the aid of a mobile tower crane that served as an observatory and facilitated the placing of mist nets. The canopy was used by 69% of the 182 bird species analyzed, with 42% exclusively using this habitat. The proportion of obligate frugivores in the total avifauna was 15%, but 74% of the canopy species were frugivores or omnivores; in the forest interior, only 4% of the species were frugivorous. Canopy birds exhibited a more diverse foraging behavior, with foraging modes accounting for the most significant differences between birds of the canopy and those of the interior. Locomotion styles and selection of foraging substrate also accounted for differences. Morphological differences between species of the canopy and the interior are less distinct; but species using both the canopy and upper subcanopy possess well-developed distal wing sections, short legs, and wide gapes–traits predicted to be correlated with the higher mobility and frugivory of canopy birds.

PRÓSPERI,* J., and G. CABALLÉ, Laboratoire de Botanique, Montpellier, France; and Y. CARAGLIO, Programme de Modélisation des Plantes, Montpellier, France

LIANAS AND HEMI-EPIPHYTES: "EPI-PHENOMENA" OR REAL PLAYERS IN FOREST DYNAMICS?

When observing rain forest canopies, it is evident that mixed in with tree crowns are crownlets of aerial leafy shoots of either lianas or hemi-epiphytes. These specialized life forms share a number of similarities, including spatial conditions and the requirement of a host plant. To better understand their biology, the authors compared aspects of the approaches taken by these groups to seedling and establishment phases, architectural development, vegetative propagation, response to environmental conditions, forest colonization, and taxonomic repartition. Although poorly known and often neglected life forms, lianas and hemi-epiphytes are frequently found in the tropical canopy–an expression of their wide architectural adaptability and close co-evolution with tropical canopy trees. The prevalence of lianas and hemi-epiphytes in tropical canopies leads the authors to speculate about their role in forest dynamics.

RAO,* K.S., R.K. MAIKHURI, R.L. SEMWAL, and K.G. SAXENA, G.B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, Almora, India

CANOPY DEVELOPMENT STUDIES IN AN ECOREGENERATION SITE IN GARHWAL, HIMALAYA

The authors took measurements in the early development of a mixed stand (*Albizzia lebbek, Alnus nepalensis, Boehmaria rugulosa, Celtis australis, Dalbergia sissoo, Ficus glomerata,* and *Grewia optiva*) in Himalaya. The goal was to determine interspecific differences in structural characteristics that lead to good ecological combining ability in local/naturalized species used for eco-regeneration. They established plantations at a density of 1,110 trees/ha on abandoned terraced agricultural land and 8,575 trees/ha on degraded forest land. From 19 multipurpose tree species used for co-regeneration, species were selected for analysis to represent a range of crown structure, leaf morphology, and phenology. Partially stratified canopy formation occurred from the third year onward on abandoned terraced agricultural land and from the fifth year onward on regenerated degraded forest land. Although *Grewia optiva* showed comparatively higher growth at both sites in the early years, *Boehmaria rugulosa, Ficus glomerata,* and *Dalbergia sissoo* showed equally good growth in later years. By the end of the fifth year, cumulative growth is almost similar for these species. Interspecific competition, which was not considered in the present study, might be one of the major reasons for differences in growth pattern within a species.

REYNOLDS,* BARBARA C., and MARK D. HUNTER, Institute of Ecology, University of Georgia, Athens, GA, USA

EFFECTS OF CANOPY HERBIVORY ON SOIL PROCESSES ALONG AN ELEVATION GRADIENT IN THE SOUTHERN APPALACHIANS

The authors found that the timing of herbivore-derived inputs, such as greenfall, frass, and modified throughfall, varies along an elevation gradient in the mountains of western North Carolina. Inputs of frass, greenfall, and throughfall, which could be major nutrient resources for soil communities, occur earlier at low elevations. Significant differences in nutrient concentrations in throughfall occur along the gradient. Depending on site or nutrient, herbivore input explains 25 to 50% of the variance in throughfall chemistry. Their data indicates that canopy herbivores are an important influence on nutrients reaching the forest floor.

RIBEIRO,* SÉRVIO P., CABI Bioscience Environment, Silwood Park, Ascot, UK, and Brazil; MARIA JOSÉ V. DE VASCONCELOS, MAURÍCIO S. ANTUNES, and EDILSON PAIVA, EMBRAPA Maize and Sorghum, Brazil; and VALERIE K. BROWN, CABI Bioscience Environment, Silwood Park, Ascot, UK

CONTRASTING GENETIC DIVERSITY OF *TABEBUIA* (BIGNONIACEAE) IN THE WETLAND PANTANAL AND CERRADO OF BRAZIL

In this study, the authors investigated the insect guild structure, patterns of herbivory on tree crowns, and genetic diversity of *Tabebuia aurea* and *T. ochracea* (Bignoniaceae). They compared a monodominant population of *T. aurea* in the Brazilian wetland, Pantanal Matogrossense, with a less dense population in savanna (= cerrado), where *T. ochracea* occurs in sympatry. Insect samples were taken and herbivory rates assessed from random leaves, flower buds, and fruits throughout the crowns of 60 trees. The sampling effort was proportional to the size of individual branches. Insect herbivore species richness on *T. ochracea* was approximately twice that on *T. aurea*; it was also greater in the cerrado than in the Pantanal for the latter species. Rates of herbivory were higher on *T. aurea* in the cerrado than in the Pantanal; and, within the cerrado, rates were higher on *T. aurea* than on *T. ochracea* (ANOVA, $p < 0.001$). The authors used RAPD to analyse genetic variability in a total of 45 trees. The mean genetic dissimilarity for *T. ochracea* was approximately twice that for *T. aurea.* Most genetic variability of *T. aurea* was the result of between-subpopulation variance in the cerrado, contrasting with a high within-subpopulation variability of *T. ochracea.* The results suggest that *T. aurea* is a pioneer species, occurring in a metapopulation structure.

RINKER, H. BRUCE, Millbrook School, Millbrook, NY, USA

CANOPY ECOLOGY: A HIGH-PRIORITY LINK BETWEEN RESEARCH AND EDUCATION

Students are interested in treetop studies because important contributions can be made more easily than in already established scientific fields and because the process of reaching the canopy is so exciting. In 1995, Millbrook School constructed a forest canopy walkway along an oak-maple wooded slope on the campus (41°51'N, 73°37'W). Millbrook, founded in 1931, is a small, coeducational, independent boarding school in the mid-Hudson Valley of New York State. From its inception, stewardship and service have been vital elements of the school's mission. The walkway represents a natural extension of that philosophy and provides the only treetop laboratory in the world among secondary schools. A founding member of the Northeast Canopy Consortium, the Millbrook facility is an aerial laboratory with education and research as its primary goals. The author provides structural details for the walkway, an emerging canopy curriculum with samples of workshop ideas, a look at some ongoing site-studies, and suggestions for collaborative projects with researchers worldwide.

RINKER, H. BRUCE, Millbrook School, Millbrook, NY, USA

CANOPY MIST-NETTING FROM AN AERIAL LABORATORY

Bird banding from Millbrook School's forest canopy walkway began in the early spring of 1997. The school, which holds a master station permit for banding from the United States Fish and Wildlife Service and the New York State Department of Environmental Conservation, has been running a student-training program for bird banding since 1939. More than 25,000 birds (approximately 100 species) have been banded during those 60 years. The technique for deploying mist-nets in the forest canopy, piloted by Stokes and Schultz at Hampshire College, uses ten 12 m standard nets with 30 mm mesh openings. Three nets extend from two canopy platforms; three are placed on the ground as replicates; and the other four are stationed elsewhere for comparative ecological sampling. Results from four consecutive seasons of operation (2 spring and 2 fall migrations) are promising. The author reports that the students have accumulated more than 1,300 net-hours and have banded approximately 140 birds (36 species). The presentation provides capture rates for four ecological sites (canopy, forest floor, forest edge, and hedgerow). Comparisons are

made between Millbrook School and Hampshire College for number of birds, number of birds per 100 net-hours, number of species, and total number of net-hours.

RISLEY, LANCE, William Paterson University, Wayne, NJ, USA

HERBIVORY IN THE CANOPY AND DECOMPOSITION ON THE FOREST FLOOR: INSECTS FORGE A LINK

Herbivorous insects are responsible for a light, but steady rain of high quality materials from the canopy to the forest floor that influences rates of nutrient cycling. The author reports on a series of studies in deciduous forests of the eastern USA. Results showed that herbivore-caused green leaf fall (greenfall) contributed significantly to annual foliar litterfall, occurring from spring leaf flush until autumn leaf senescence. Novel caterpillar feeding behavior (e.g., petiole clipping) was responsible for most greenfall biomass; simulated damage to leaf blades did not result in greenfall. Relatively light greenfall biomass was magnified by concentrations of nitrogen that were significantly higher than those in senesced, autumn leaves. In unconfined and confined litter decomposition experiments, greenfall lost weight faster than senesced leaves of the same species. This series of studies, which describes one of many links between the canopy and the forest floor, reinforces the concept of herbivorous insects as regulators of ecosystem processes.

ROLLENBECK, R., Geographical Institute, University of Mannheim, Mannheim, Germany

STUDIES OF THE HYDROLOGICAL CYCLE AT THE RIO SURUMONI CRANE PROJECT, VENEZUELA

Since 1996, the University of Mannheim's Geographical Institute has measured microclimatological parameters to determine the energy balance at the site of the Surumoni research crane maintained by the Austrian Academy of Sciences. The study site, located in the upper Orinoco region of southern Venezuela, includes a small-scale catchment area; and thus in 1997, several additional sensors were placed to measure parameters of the water balance. The installation enables modeling of the various hydrological processes in high temporal and spatial resolution. All values are recorded in 10-minute intervals and stored in dataloggers. In addition to microclimate measurements at several elevations, the instrumentation allows such measurements as tree transpiration, precipitation, throughfall, soil-water content and movement, and overland flow. First estimates of the basic terms of the water-balance equation for the site suggest agreement with values from other locations in the tropics. For instance, total throughfall in the recent dry season amounted to 48% of precipitation.

SAH, SHAMBHU PRASAD, Central Department of Botany, T.U., Kirtipur, Kathmandu, Nepal

SAL FOREST MANAGEMENT OPTIONS IN THE NEPAL TERAI

The author presents an overview on the status of management options for the sal forest, *Shorea robusta* (Dipterocarpaceae), in Nepal. The country has two types of sal forest: lowland, such as the Terai sal forest, and hill sal forest. In the Terai region, sal is a dominant tree species (45% of total forest by volume). In hill forests, however, sal species constitute only a minor plant species, by volume. The author discusses the socio-economic and environmental impacts on the local community of current trends to exploit sal forest resources. In India, sal consistently has proved difficult to regenerate in a reliable way; however, in Nepal, successful natural regeneration (up to 10,000 seedlings per ha) has been demonstrated with a proper forest management system and protection against forest fire and grazing. The author discusses the current controversy regarding conversion of the Terai sal forest into a productive forest and describes the potential for productive forests in Nepal.

SAKAI,* SHOKO, KUNIYASU MOMOSE, TAKAKAZU YUMOTO, MAKOTO KATO, and TAMIJI INOUE, Center for Ecological Research, Kyoto University, Kyoto, Japan

BEETLE POLLINATION OF *SHOREA PARVIFOLIA* (SECTION MUTICA, DIPTEROCARPACEAE) IN A GENERAL FLOWERING PERIOD IN SARAWAK, MALAYSIA

The authors studied the pollination ecology of an emergent tree species, *Shorea* (section Mutica) *parvifolia* (Dipterocarpaceae), using the canopy observation system in a lowland dipterocarp forest in Sarawak, Malaysia, during a general flowering period in 1996. Although the species was reported to be pollinated by thrips in Peninsular Malaysia, observations of flower visitors and pollination experiments indicated that beetles (Chrysomelidae and Curculionidae, Coleoptera) contributed to pollination of *S. parvifolia* in Sarawak. Beetles accounted for 74% of the flower visitors collected by net-sweeping, and 30% of the beetles carried pollen; thrips accounted for 16% of visitors, and 12% of the thrips carried pollen. The apical parts of the petals and the pollen served as a reward for the beetles. Thrips stayed inside the flower almost continuously after arrival, and movements among flowers were rare. Fruit set was significantly increased by introduction of beetles to bagged flowers, but not by introduction of thrips. Hand-pollination experiments and comparison of fruit set in untreated, bagged, and open flowers suggested that *S. parvifolia* was mainly outbreeding.

SALVADOR-VAN EYSENRODE,* DAVID, JAN BOGAERT, and IVAN IMPENS, Laboratory of Plant Ecology, Department of Biology, University of Antwerp, Wilrijk, Belgium

HORIZONTAL CANOPY GAP OCCLUSION AT THE TIPUTINI BIODIVERSITY STATION, AMAZONIAN ECUADOR

Canopy gaps in tropical rain forests are instrumental in forest regeneration. The rate at which gaps are created in these forests is relatively well documented. Except for gap vertical occlusion, the ways in which gaps close are poorly known. Using digital hemispherical pictures as a tool, the authors have observed the horizontal closure process in 15 gaps from shortly after their formation. Nine months later, gap area, shape, and orientation were found to be highly variable. Although immediate closure is not always the rule, horizontal closure makes an important contribution to the occlusion of the opened forest.

SANTIAGO, LOUIS S., Department of Botany, University of Hawaii, Honolulu, HI, USA/ Department of Botany, University of Florida, Gainesville, FL, USA

A BOTTOM-UP APPROACH TO SCALING CANOPY TRANSPIRATION IN A HAWAIIAN MONTANE FOREST

The author found that montane wet forests in Hawaii represent a unique opportunity for estimating transpiration processes at different scales because of a single canopy species, *Metrosideros polymorpha* Gaud. (Myrtaceae). He measured transpiration as basal sap flow in canopy trees on moderately sloped substrates with closed canopies (90%) and on level substrates with open canopies (50–60%) and a dense understory of the sedge *Carex alligata.* Microclimatic conditions were monitored during transpiration measures to compare actual transpiration with Penman potential evapotranspiration (PET). He documented forest stand parameters including tree density, basal area, sapwood area, canopy height, and leaf area index (LAI) and used the data to scale transpiration from individual trees to the stand level. LAI was measured with a new technique using enlarged photographs of individual tree crowns and allometric relationships. He scaled basal sap flow to the stand level by multiplying basal area-normalized sap flow values by stand basal area. The contribution of sunlit understory to total stand transpiration was modeled using measures of stomatal resistance, microclimatic data, and the Penman-Monteith equation. Stand transpiration estimates ranged from 79% to 89% of PET for closed canopy stands and from 28% to 51% of PET for open canopy stands. He correlated stand transpiration estimates tightly to LAI and maintained this linear relationship when including the contribution of the understory. Results showed that the need to

scale estimates of water use from a sample of individual stems to a homogeneous stand may be met by applying scalars of flux based on tree size.

SCHOWALTER, TIMOTHY, Oregon State University, Corvallis, OR, USA

CANOPY HERBIVORE EFFECTS ON FOREST FLOOR PROCESSES IN CONIFEROUS FOREST OF THE PACIFIC NORTHWESTERN USA

The author studied the multiple effects of canopy herbivores on forest floor processes. Experimental manipulation of the abundance of herbivores (leaf chewers and sap-suckers) on Douglas-fir saplings resulted in significant increases in throughfall volume, litterfall mass, and N, K, and Ca fluxes, as well as a significant change in the temporal pattern of litterfall. In addition, three litter microarthropods were significantly more abundant in litterbags under saplings with augmented leaf chewer abundances. In a separate study, shoot-feeding aphids significantly reduced root tissue density during 1- and 2-year feeding periods. This result suggests major depletion of root carbohydrates to replace carbohydrates lost from the shoot. When feeding was terminated after 1 year, root tissue density remained depressed, because carbohydrate storage in roots likely affects root respiration and plant interactions with mycorrhizae.

SCHROEDER, BIRGIT, Geographical Institute, University of Mannheim, Mannheim, Germany

APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEMS AND DIGITAL ELEVATION MODELS IN BASIC RESEARCH PROJECTS

Very high resolution data of investigated terrain in the upper Orinoco region of southern Venezuela are necessary to derive exact calculations of heat/energy and water budgets. At the Surumoni River camp, the author collected these data with a leveling instrument and later processed them into a digital elevation model with the Geographical Information System SURFER 5.0. This basic map served to simulate the precipitation-runoff processes in a small-scale watershed area. As a first estimate, a simple precipitation-runoff model was established to calculate the processes with little input data and low-cost GIS software.

SCHUBERT,* HOLGER, and ULRICH AMMER, Institute of Land Use Planning and Nature Conservation, Freising, Germany

COMPARISON OF THE ARTHROPOD FAUNA IN CANOPIES OF NATURAL AND MANAGED FORESTS OF SOUTHERN GERMANY

In lower Bavaria (Germany), the authors investigated the canopy arthropod fauna of five different forest types. The forests differed in degree of naturalness, ranging from non-indigenous, intensively managed spruce stands in several commercial forests to stands with increasing naturalness to an old unlogged nature reserve with huge amounts of dead wood. Arthropods were captured with special window traps and newly developed branch-enveloping traps at heights up to 35 m above ground. Although almost all taxa reacted strongly to their host trees, only beetles corresponded to factors reflecting natural attributes of the stand. For example, beetles strongly depended on dead wood structures and their longevity in the forest. Spiders, lacewings, snakeflies and true bugs corresponded weakly to such factors. Instead, they mainly responded to such factors as humidity, light conditions, and structure (e.g., fractal dimensions of tree species). Results of the investigation define the dynamics of nature-related silviculture in middle-European woodlands and contribute to the discussion of whether to protect species diversity or natural processes in modern conservation management.

SHAW,* DAVID, Wind River Canopy Crane Research Facility, Carson, WA, USA; and CATHERINE FLICK, Gifford Pinchot National Forest, Trout Lake, WA, USA

ARE RESIDENT SONGBIRDS STRATIFIED WITHIN THE CANOPY OF A CONIFEROUS OLD-GROWTH FOREST?

Resident songbirds of temperate coniferous forests survive throughout the year, even though resources within the forest change with the seasons. One aspect of their survival may be a generalist strategy that avoids vertical stratification of the canopy. From March 21, 1996, to March 20, 1998, the authors studied five small diurnal songbirds, using the Wind River Canopy Crane. Point counts were used to survey bird occurrence in low, mid, and upper canopy positions. *Loxia curvirosta* (red crossbill) is an upper canopy specialist, while *Troglodytes troglodytes* (winter wren) is a lower canopy specialist. *Regulus satrapa* (golden-crowned kinglet), *Parus rufescens* (chestnut-backed chickadee), and *Certhia americana* (brown creeper) occurred in all zones of the canopy, but their abundance within each zone varied with the seasons. Overall, *R. satrapa* and *C. americana* were most abundant in the midcanopy, while *P. rufescens* was most abundant in the upper canopy. Stratification of resident songbirds is occurring in this canopy.

SHAW,* JUSTINE D., and DANA M. BERGSTROM, Department of Botany and CRC—Tropical Rainforest Ecology and Management, The University of Queensland, Brisbane, QLD, Australia

EPIPHYTE RICHNESS IN SUBTROPICAL RAINFORESTS OF QUEENSLAND, AUSTRALIA

The authors investigated patterns in epiphyte richness across subtropical rainforests in southeast Queensland. The regional flora is comprised of 72 orchid species and 25 pteridophyte species. Large variability in species richness was found across the region, with some sites having more than three times the species richness of others. A study of the relationship between forest type and epiphyte richness revealed that the highest richness (71 species) was found at the site which had the greatest range of forest types (McPherson Ranges). Site richness is influenced strongly by environmental attributes. The authors conclude that epiphytes act as bio-integrators of complex interactions between microclimates and niche availability.

SIEBERT, STEVE, School of Forestry, University of Montana, Missoula, MT, USA

ELEVATIONAL DISTRIBUTION OF RATTAN IN SULAWESI, INDONESIA

The author found that the rattan flora of Central Sulawesi exhibited an abrupt change at approximately 1,200 m elevation corresponding to the transition from lowland to montane forest types on five 10 × 1,000 m transects located on mountains near Lore Lindu N.P. For example, the premier commercial rattan, *Calamus zollingeri* (Arecaceae), was replaced by *Daemonorops sarasinorum* (Arecaceae) over less than 55 m of total vertical distance on all five transects. The montane rattan flora was more diverse than that observed in adjacent lowland areas (at least 14 vs. 8 species in each forest type, respectively, with 6 species observed in both forests). Some montane rattan exhibited restricted and disjunct distributions. These observations have potential significance for biodiversity conservation and rattan management for the following reasons: Sulawesi is currently the primary source of cane for the Indonesian rattan furniture industry; cane harvesting is unregulated; many species of economical value, such as *C. zollingeri* and *D. sarasinorum,* are marketed interchangeably under the same trade names; and the rattan flora remains poorly known taxonomically and ecologically.

SILLETT, STEVE, Department of Biological Sciences, Humboldt State University, Arcata, CA, USA

TREE CROWN STRUCTURE AND VASCULAR EPIPHYTES IN OLD-GROWTH COAST REDWOOD FOREST CANOPIES

The author reports on the complex crowns of large coast redwood trees (*Sequoia sempervirens*) that consist of multiple reiterated trunks. Trunk-to-trunk and trunk-to-branch fusions are common. Trunk diameter above a fusion is often larger than below the fusion, and branches from one trunk that become fused to another trunk maintain their foliage even if they become detached from the original trunk in a storm. Highly reiterated crowns resemble forest stands more than individual trees; each reiterated trunk supports its own branch system. Severe storms induce reiteration-falls as whole sections of complex crowns are lost. Detached reiterations decimate areas of the crown as they fall. Young stands of reiterated trunks arise in damaged areas, and several cohorts of reiterations are often evident in the same tree. Coarse woody debris is frequently retained in complex crowns, providing platforms for further debris accumulation. This debris, as well as scars from torn out trunks, provide entry points for wood decay fungi. Ericaceous shrubs colonize the resulting rotten hollows. Tree foliage initiates humus formation, as it accumulates and decomposes. Once ferns colonize the humus, they contribute substantially to its formation; fern rhizomes and fine roots are the major component of large humus accumulations. Deep, up to 1-m layers of crown humus are exploited by a variety of terrestrial vascular plants as well as by salamanders. Splash zones of sustained stemflow occur beneath deep humus accumulations, supporting aquatic algae and grazing mollusks.

SIMON, ULRICH, Department of Animal Ecology and Tropical Biology, Biocenter of the University of Wurzburg, Wurzburg, Germany

SPIDER SPECIES COMPOSITION: IS IT PREDICTABLE IN PINE TREE CROWNS?

In tropical canopy communities, stochasticity appears to shape species composition. In contrast, the prevailing opinion with regard to temperate systems holds that deterministic factors compose the species assembly, which is thus predictable. To address the remaining question of where in between these two extremes reality lies, the author studied the spider fauna of old pine tree crowns in Central Europe. Over a 3-year period, by trapping spiders with branch eclectors in three different natural pine stands, he found that occurring taxa could be divided into two groups. The first group contained taxa found in high frequencies and abundancies on over 75% of all investigated trees in every year of the study. The second group–not as uniform in pattern of occurrence–was characterized by unpredictability, with species occurring in low numbers of individuals as well as low frequency. Up to 70% of the species found on an individual pine tree, however, were in this unpredictable group. The author concludes that a part of the spider fauna, which because of its high abundance is evidently of ecological importance, can be predicted; but a large portion of the spider community, whose ecological meaning is poorly known because of its rarity, occurs unpredictably and therefore stochastically.

STUNTZ,* SABINE, ULRICH SIMON, and GERHARD ZOTZ, University of Würzburg, Würzburg, Germany

ARTHROPOD DIVERSITY RELATED TO VASCULAR EPIPHYTES AND THE INCREASING STRUCTURAL HETEROGENEITY OF TROPICAL FOREST CANOPIES

The canopy of tropical forests harbors a large proportion of global biodiversity. The major component, arthropods, have a species richness unsurpassed in the world of living beings. Vascular epiphytes may play a major role in the establishment and maintenance of such faunal diversity: The plants may influence the occurrence and abundance of arthropods by (1) substantially increasing the structural heterogeneity of the canopy habitat, (2) providing manifold resources for herbivores, and (3) mitigating microclimatic extremes. Because the degree of this possible influence had not

been studied at a community level, the authors are investigating relationships between epiphyte flora of selected tree crowns and their respective arthropod fauna. Currently, they are carrying out a comprehensive one year survey of arthropods inhabiting tree crowns bearing distinct epiphyte communities in a tropical moist forest in Panama. Various trapping techniques and long-term sampling address the issue of seasonally collected animals. The authors describe and discuss traps and present preliminary results.

SUBBA RAO, M.V., Department of Environmental Sciences, Andhra University, Andhra Pradesh, India

CONSERVING BIODIVERSITY IN THE FORESTS OF EASTERN GHATS, INDIA, WITH SPECIAL REFERENCE TO SPECIES RICHNESS: AN OVERVIEW

The variety of physiographic and climatic conditions of the Eastern Ghats once supported biodiversity with a rich array of flora and fauna and a variety of habitat conditions. Apart from mangrove forests, the Eastern Ghats today has largely dry, arid deciduous forests alternating with scrub jungles. In the region, dense scrub forests are limited now to a few pockets, primarily because of deforestation and swidden or shifting cultivation by tribal people. In fact, survival has become a problem common to all wildlife. For instance, the cheetah is extinct, and the tiger is being pushed to the brink. In this status report on species richness, the author concludes that deforestation has led to a drastic reduction in biodiversity for both plants and animals.

SZARZYNSKI,* JOERG, and DIETER ANHUF, Geographical Institute, University of Mannheim, Mannheim, Germany

METEOROLOGICAL REGIME AND ENERGY EXCHANGES OF A NEOTROPICAL RAIN FOREST IN SOUTHERN VENEZUELA (SURUMONI-CRANE PROJECT)

Exchanges of energy and water between forest canopies and the atmosphere represent key aspects of global environmental processes, for they largely define ecosystem productivity and modify climates on different scales. At the Surumoni-Crane Plot in Amazonas State, Venezuela, detailed climatological measurements recorded since January 1996 have improved knowledge of these biophysical interactions. The authors investigated meteorological conditions within the forest, especially light environments and photosynthetic photon flux densities but also height-time variability of air temperature, vapor pressure, and wind velocity. Using simultaneous profile data of the same parameters gathered over the canopy, they calculated vertical turbulent fluxes and diffusivities of momentum, heat, and water vapor transfer. Applying various methods based on aerodynamic and energy-balance principles, they estimated the actual evapotranspiration of the forest.

ULLOA, LUIS FELIPE, Bogotá, Colombia

BUILDING SKY WALKS AND PLATFORMS IN TREE CANOPIES OF COLOMBIA: ALTERNATIVES FOR ENVIRONMENTAL EDUCATION, CONSERVATION, AND ECOTOURISM

Colombia is a privileged country located in northern South America with a rich biological diversity, geography, and topography. The author, however, points out deficiencies in scientific accomplishments in biological and ecological research, natural resources management, environmental education, and guidelines for conservation. In addition, canopy biology is an area largely unknown to Colombian scientists, biologists, forest explorers, and forest conservationists. In 1995, the author conducted a canopy access project in a Colombian forest, building platforms and sky walks and using these techniques for canopy conservation. The project also targeted other programs in Colombia, mainly environmental education and ecotourism, that included TV programs, children's summer camps, and work with indigenous people. The author discusses canopy research in Colombia, including its current and future dimensions.

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BIODIVERSITY OF LEAF-MINING AND GALL-MAKING INSECTS IN THE TROPICAL RAIN FOREST CANOPY

The Rio International Convention on Biological Diversity recognized the urgent need to document biodiversity in the face of ongoing worldwide habitat destruction. Arthropods are clearly the most diverse component of terrestrial ecosystems and their potential use for conservation planning is immense. A basic survey is especially needed in tropical forest canopies, where several historical and ecological factors may constrain local insect and plant richness. Insect herbivory in rain forests is usually restricted to young, more palatable leaves, whose production and palatability can be affected drastically by light regime, thus affecting insect foraging patterns. This limitation especially may influence leaf-mining and gall maker insects. Hence, it is expected that both insect abundance and diversity should be different in different forest layers. The authors tested abundance and diversity of leaf-mining and gall-making insects at two sites in Panama: a dry forest on the Caribbean coast and a wet forest on the Pacific coast. Every 15 days for two consecutive years, they sampled 232 host plants at ground and canopy levels in both sites. Preliminary results showed a higher diversity (145 out of 246 species) within the canopy at both sites. No significant differences were found between sites. Only 2 of 137 species of leaf-miners (1.5%) and 1 of 109 gall makers (0.9%) are common to both levels, which confirms the high specificity of insect populations. Of gall makers, 96% belong to *Diptera,* whereas 90% of the leaf-miners belong to *Lepidoptera,* a species that showed a positive correlation among number of species, presence of young leaves, and light intensity. The survey results seem to indicate that young leaves can provide a better food resource for insect populations. If so, light regime would be the true limiting factor for the maintenance of high insect diversity in the tropical canopy.

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SPATIALLY EXPLICIT SAMPLING OF EPIPHYTES AND SUBSTRATES IN SECONDARY MONTANE RAIN FORESTS IN THE COLOMBIAN CENTRAL CORDILLERA

The patchy distribution of epiphytes in forests may be attributed to either non-random propagule supply or non-random distribution of suitable substrates for epiphyte settlement and development (or a combination of both). To assess the effect of these two factors on the settlement of epiphytes, the authors studied the distribution of bromeliad species occurring in a 30-year-old secondary montane forest (3,150 m elevation) in the Central Cordillera of Colombia. In a 5 × 50-m transect, they found four species of Bromeliaceae (*Tillandsia tetrantha, T. compacta, T. orbicularis,* and *T. penlandii*), censused all 250 individuals occurring in the transect, and recorded their coordinates on the ground and their height in the trees. Vascular epiphytes other than bromeliads were rare. They also recorded the life stage of the bromeliad, species of the host tree, height of the host tree, inclination of the substrate, and their position on branches. Host trees were mapped, and differences in ground height on which trees stood were measured. With these data, the authors could test the spatial relationship between older individual bromeliads and their possible offspring. To test the homogeneity of substrate nutrient content and chemical composition within trees, they selected three trees of different species and climbed them, using single-rope climbing techniques. They took 16 samples in duplicate on each tree and determined pH, soluble nutrients, total nutrients, and water holding capacity of bark samples. These data allowed the authors to contrast the relative importance of site factors and mere propagule supply in epiphyte establishment and occurrence. They will quantify not only the extent to which the forest is a patchy environment for epiphytes, as a result of the distribution of suitable hosts, but also the extent to which suitable sites on a single tree may be patchy.

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CANOPY FARMING: AN INNOVATIVE STRATEGY FOR SUSTAINABLE USE OF RAIN FORESTS

In developing new strategies for rain forest conservation through sustainable use, the authors ascribe a major role to forest biodiversity. Faced with the challenge of combining conservation with economic goals, they aimed their efforts at the ecologically sound use of various forest products, both wood and non-wood, thus creating an economic motivation for total protection of the rain forest. They found that the use of select, small products like medicinal species and ornamental plants can offer economic as well as ecological advantages, because their low biomass is paired to high added market value and their extraction from the forest is less disruptive than other products. The innovative canopy farming concept was advanced to introduce the rich potential of this forest level for ecologically sound use, based on the assumption that more valuable forest products are found in habitats with higher biodiversity. In a Costa Rican forest, they conducted a canopy farming feasibility study that focused on ornamental epiphytic orchids as exemplary canopy products. By exploring in situ orchid production techniques and marketing opportunities, the study indicated concrete possibilities for sustainable use of rain forest canopies.

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VERTICAL STRATIFICATION OF MARSUPIALS AND RODENTS IN THE ATLANTIC RAIN FOREST OF SOUTHEASTERN BRAZIL

Although half of the marsupial and rodent species described for the Brazilian Atlantic Forest present scansorial ability, only limited data have been published about these arboreal species. During a 4-year period of monthly trapping, the author studied the species in the southern limit of the Brazilian Atlantic Forest (State of Santa Catarina), capturing 1,243 individuals from three marsupial and 13 rodent species at three forest heights (0 m, 2 m, and 9.5 m). Over half of the species (10 species) were captured above ground. Among these, *Oryzomys ratticeps, Wilfredomys pictipes, Nelomys dasythrix, Gracilinanus microtarsus,* and *Rhipidomys mastacalis* are considered rare or almost unknown. Among terrestrial captures, *Micoureus demerarae* was the eighth most abundant species; and, among all captures from the three strata, it was the second in abundance throughout the community. The author concludes that the richness, relative abundance, and ecological role of these species have been underestimated.

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VERTICAL STRATIFICATION OF EGG PREDATION IN THE ATLANTIC RAIN FOREST OF SOUTHEASTERN BRAZIL

Nest predation rates vary among vegetation layers, with ground nests assumedly suffering greater predation than nests above the ground. This idea has been used to explain the greater cryptic coloration and reduced sexual dichromatism of some ground-nesting birds and the population declines of many neotropical migrant species. In the neotropics, a rich diversity of arboreal mesopredators (i.e., marsupials, rodents, primates) could alter this pattern. To test this assumption, the authors placed 240 artificial nests containing quail eggs filled with wax at three forest heights (0 m, 2 m, and 16 m). The predation rate was highest in the canopy, followed by the understory and the ground level. Comparisons of tooth marks in the eggs and laboratory observations on marsupial and rodent egg predation behavior indicated mammals as possible predators. The authors concluded that assumption of higher egg predation on ground nests needs critical assessment as does the role of arboreal small mammals in neotropical vertebrate community structure and dynamics.

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DISTRIBUTION PATTERNS AND SPECIFICITY OF CHRYSOMELIDS (COLEOPTERA) IN CENTRAL AFRICAN FORESTS

The author collected Chrysomelidae in forests of Kivu and Rwanda but predominately Uganda. Sites ranged from lowland rain forests (670 m elevation) to upper montane forests (2,950 m); and data were collected during both dry and rainy seasons. In Budongo Forest, Uganda, trees were fogged in secondary and adjacent primary forest plots. Results indicated that chrysomelid abundance was strongly influenced by foraging ants in the tree crown. Faunal overlap of leaf beetles was lower on conspecific trees between primary and secondary forest than on different tree species in one of these forest types. The community structure of chrysomelids showed significant differences between seasons in Budongo Forest, and fauna showed much greater similarities between different forests during the dry season. Small Alticinae especially were highly abundant in all forests investigated during the dry season. These beetles possibly were aggregated along a gradient of humidity in the tree crowns. Data indicated low specificity to plant species and high influence of predation and abiotic factors on the composition of arboreal tropical chrysomelid communities.

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LEAF DYNAMICS IN A TROPICAL CLOUD FOREST: HERBIVORY, LIFE-SPAN, AND PHENOLOGY

The author studied leaf dynamics during a 5-year period in a tropical montane cloud forest (1,300 m elevation) in central Veracruz, Mexico. The objective was to determine for both deciduous and broadleaved evergreen tree species patterns of herbivory (3 species), life-spans and survival curves (9 species), and phenology (24 species). Data were recorded using binoculars at the forest floor, ladders to reach middle canopy leaves, and high vantage points to observe the upper part of the canopy. The herbivory rate was higher in the understory than in the canopy; it was higher in young leaves than in mature ones. Mean leaf longevity for deciduous species was 9 months; for evergreen trees, it was 17.6 months. Life-span, however, was not related to leaf habit, since both the shortest (6.4 months) and longest (32.9 months) mean longevities were recorded in evergreens. Survival curves differed between deciduous and evergreens, and specific leaf area was highly correlated with life span. Differences were found in foliar phenology, with leaf fall correlated to minimum temperature only in deciduous species. Leaf flushing was correlated with maximum temperature for all deciduous and several evergreen trees. The author concludes that temperatures may act as proximate cues to leaf phenology, but ultimate causes have to be considered in discussions of leaf dynamics.

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BIODIVERSITY OF ARTHROPODS IN NORTHERN TEMPERATE RAIN FORESTS: FACTUAL FOUNDATIONS OR FICTIONAL MYTHS?

The biodiversity crisis in ancient northern temperate rain forests continues to be accelerated by habitat loss and consequent extinctions of floral and faunal species assemblages that cannot adjust to rapid and often large-scale habitat alterations. Since 1992, in an effort to record arthropod biological diversity in these forests, the author studied canopy arthropods in a number of Vancouver Island rain forest types. Based on his findings, he raised the following questions: (1) Do these ancient forests act as repositories for arthropod biodiversity? (2) How many species of arthropods exist within an ancient forest? (3) Which species assemblages provide clarity for preserving these forests and the biodiversity they contain? The author concludes that answers to these questions are needed to address issues surrounding the maintenance of biological diversity (form and function) in these ancient forests.

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THE ANIMAL COMMUNITY ASSOCIATED WITH CANOPY BROMELIADS OF A LOWLAND RAIN FOREST IN THE PERUVIAN AMAZON

The authors surveyed the community of organisms (>2mm length) found in canopy bromeliads to gain an understanding of species composition, community structure, and the relative biomass of groups using the microhabitat created by the bromeliad tank. Using single rope climbing techniques, they were able to remove selected canopy bromeliads intact from attachment points and immediately place them in a sampling bag. The authors used alcohol to immobilize tank inhabitants, and they dissected each bromeliad leaf by leaf. Collections in this pilot study took place over a period of 2 months, with sampling sites chosen to represent both shaded and sunny locations in the canopy. The data suggested a community dominated by arthropods in various stages of their life cycles. The role of bromeliads as microhabitat was supported by the abundance and diversity of the organisms found.

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MAST FRUITING IN A NEOTROPICAL FOREST IN PANAMA

Mast fruiting is the intermittent production of large seed crops by a population of plants. Interspecifically synchronized mast fruiting occurs in association with El Niño events in the Malaysian tropics, but the authors report interspecifically synchronized mast fruiting for the first site outside Malaysia. On Barro Colorado Island, Panamá, mast fruiting characterizes up to 30% of the tree and liana species. Masting species fruited during the 1991/92 and 1997/98 El Niño events. This interspecific synchrony was reinforced by non-masting species, many of which had their largest fruit crops during the El Niño events. The level of interspecific synchrony observed in Panamá is intermediate between the north temperate zone, where each masting species fruits on its own schedule, and Malaysia, where masting species all disperse seeds within a few weeks of one another. The evolution of mast fruiting may involve resource matching and/or seed predator satiation. Resource matching occurs when seed set responds to favorable climatic variation. Masting coincident with elevated solar inputs during El Niño events may be an example of resource matching. Seed predator satiation selects for enhanced synchrony. The authors are examining the ratio of seedlings recruited per seed produced during mast and non-mast years to evaluate possible seed predator satiation.

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VERTICAL STRATIFICATION OF COMMUNITY STRUCTURE IN WATER-FILLED TREE HOLES IN PANAMA

Results of fogging studies suggest that rain forest canopies support the bulk of global biodiversity. Water-filled tree holes are important aquatic habitats in neotropical forests, yet little is known of their non-mosquito biodiversity. Are canopy tree hole communities more diverse than those of the understory? To answer this question, the author compared macroinvertebrate community structure (species richness and composition) in tree holes at different heights (i.e., canopy, midstory, understory) in the forest of Barro Colorado Island, Panama. Data from 20 repeated censuses of 40 artificial tree holes over three wet seasons revealed a slight but significant decrease in the average number of species present with increasing height above the ground. A similar pattern was observed in data from more than 200 natural tree hole samples. A single top predator species was never found in holes >10 m above ground level, and four mosquito species exhibited stratified vertical distributions. Chemical properties of tree hole water did not differ with height, but data and observations suggest that canopy holes dry out more frequently and are thermally less stable than midstory and understory holes. Harsh thermal conditions and higher disturbance frequency are likely mechanisms for the decline in species richness with height.

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ECOLOGY OF VASCULAR EPIPHYTES IN TWO BIOTOPES OF CAMEROONIAN SEMI-DECIDUOUS FOREST

The authors surveyed epiphyte diversity and abundance in two biotopes of the semi-deciduous forest: dry forest and swamp forest. They collected species at eight sites in each biotope, including 350 individual phorophytes. The dry forest contained 110 epiphyte species, and the swamp forest contained 108. Epiphyte density was highest in the swamp forest, with most branches of large trees at the crown level completely covered by epiphytes. At the family level, the Orchidaceae was the most diversified in both biotopes, and Pteridophytes were abundant in the swamp forest.

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ALTITUDINAL CHANGES IN DIVERSITY AND ABUNDANCE OF NONVASCULAR EPIPHYTES: AN ECOPHYSIOLOGICAL EXPLANATION

Observers have long noted a pronounced increase in the abundance of nonvascular organisms, such as lichens, mosses, and liverworts, with increasing altitude in the tropics. In montane regions, these poikilohydric organisms may account for a considerable biomass in tree crowns, despite being quite inconspicuous in the lowlands. Some 20 years ago, Richards suggested that the apparent unsuitability of lowland tropical forests for lichens and bryophytes was caused by a combination of continuous high temperature, high relative humidity, and low light intensities. Although unequivocal evidence does not yet support this explanation, the results of most studies make it the most probable explanation. The author reports on a number of field and laboratory studies of bryophytes and lichens whose results indicate that, on the one hand, these organisms are likely to dry out during the day, strongly reducing their carbon gain. On the other hand, they are often hydrated at night, leading to considerable respiratory losses at high temperatures. In combination, diurnal drying and nocturnal hydration result in frequent negative 24-hour carbon balances, making growth and survival difficult, if not impossible, in the lowlands.