Africa from the Treetops

H. Bruce Rinker   Margaret D. Lowman   Mark W. Moffett

Canopy Studies: A Sense of the Vast & Infinite

Alfred R. Wallace in *Tropical Nature* (1878) wrote compellingly about the architecture of an equatorial forest:

> *The observer new to the scene would perhaps be first struck by the varied yet symmetrical trunks, which rise up with perfect straightness to a great height without a branch, and which, being placed at a considerable average distance apart, give an impression similar to that produced by the columns of some enormous building. Overhead, at a height, perhaps, of a hundred feet, is an almost broken canopy of foliage formed by the meeting together of these great trees and their interlacing branches; and this canopy is usually so dense that but an indistinct glimmer of the sky is to be seen, and even the intense tropical sunlight only penetrates to the ground subdued and broken up into scattered fragments. There is a weird gloom and a solemn silence, which combine to produce a sense of the vast—the primeval—almost of the infinite. It is a world in which man seems an intruder . . . .*

Only during the past 15 years has our understanding of canopy ecology expanded substantially beyond this 19th-century, ground-based perspective (Lowman & Moffett 1993).

For tropical ecologists and educators, entering the world's rainforests has been a relatively easy affair; but accessing the treetops has proven difficult at best. It is in the treetops, of course, where most of the world's estimated 30 million species live (Erwin 1982; May 1992). Ropes, walkways and cranes are currently employed for entering and studying a tropical habitat sometimes 40 or 50 meters off the forest floor (Perry 1981; Wilson 1991; Parker et al. 1992). However, none of these methods seems as efficient or as inviting as the three-part invention of Francis Hallé, Professor of Tropical Botany at the University of Montpellier and head of the treetop mission. The equipment developed by Hallé and four other French researchers consists of a colorful dirigible (hot-air filled with a capacity of 7500 cubic meters and a top speed of 30 kph), a 600-square-meter raft weighing 750 kg, and a newly-designed triangular sled with each side 9 m long (Figure 1).

H. Bruce Rinker is Science Department Chairman at Millbrook School, School Rd., Millbrook, NY 12545. **Margaret D. Lowman** is Director of Research at Selby Botanical Gardens, 811 S. Palm Ave., Sarasota, FL 34236. **Mark W. Moffett** is with the Museum of Comparative Zoology, Harvard University, Cambridge, MA 02138.

The mission, christened *Operation Radeau des Cimes*, operated in French Guiana in 1990 and will eventually tour the globe's equatorial rainforests (Hallé 1990). In 1991 it was used in Cameroon in the lowland rainforests of Réserve de Campo on the coastal border between Cameroon and Equatorial Guinea (Figure 2). The de Campo wildlife reserve is part of the dense Guinea-Congo humid forest. Hornbills, bee eaters, Gabon vipers, *Colobus* monkeys, tsetse flies, dynastid beetles, and Congo ants were among the more notable fauna.

Sadly, many of the larger native mammals such as the gorilla, chimpanzee and elephant are now locally extinct because of overhunting and habitat disturbance from the collection of firewood, the major cause of deforestation in the region. This poses an ecological conundrum for members of the plant family, Apocynaceae, whose seeds are dispersed only by elephants after they have passed through the animals' digestive tracts. The local absence of elephants seems to insure the local extinction of the entire plant family (Figures 3–6).

The expedition was funded by ELF, the public-service arm of a large oil corporation based in Paris. Here from October to December 1991, 60 biologists from all over the world gathered to study tropical ecology at two-week intervals. The study site was divided into three distinct areas: the base camp with facilities for meals, meetings, and laboratory work; the landing area for flight and maintenance operations; and the research zone where the treetop raft was positioned (Figure 7). The latter was never more than 4 km from the base camp and was moved weekly to minimize damage to the supporting trees. The entire study site was located approximately 10 km from the Atlantic Ocean.

Our American Team: One Tropical Ecologist, an Ant Expert & a Biology Teacher

We arrived in November 1991 to study insect herbivory in the rainforest canopy. Our project was proposed in response to an invitation in the 25 January 1991 issue of *Science* and was accepted by the mission's scientific committee in July 1991. Methods included fogging a specific volume of vegetation with a biodegradable pesticide and collecting the insects on a square-meter cloth; sweeping through the forest different treetops within one day (Lowman et al. 1992, 1993). Auxiliary projects included the construction of a profile of the forest (Figure 10) immediately under the treetop raft at one of its locations and the creation of a curriculum package on treetop ecology for students in secondary schools.

Our project data are still under analysis. However, we can provide a preliminary report on arthropod diversity on canopy foliage (Lowman et al. in preparation), the first of its kind from Africa (Table 1). The high proportion of Hymenoptera (virtually all of them ants) is comparable to that found in neotropical and most Asian rainforests. The data from the Cameroon site are ambiguous as to whether ants are relatively more abundant in the canopy than in the vegetation at ground level. However, spiders take up a relatively greater proportion of the samples in the canopy whereas Diptera and Lepidoptera appear relatively more abundant at ground level. A highlight of the expedition was our discovery of possibly two species, an arboreal *Oecophylla* or weaver ant and an associated ant-mimicking *Myrmarachne* spider. Confirmation is forthcoming from the Harvard biologists who are examining our collection.

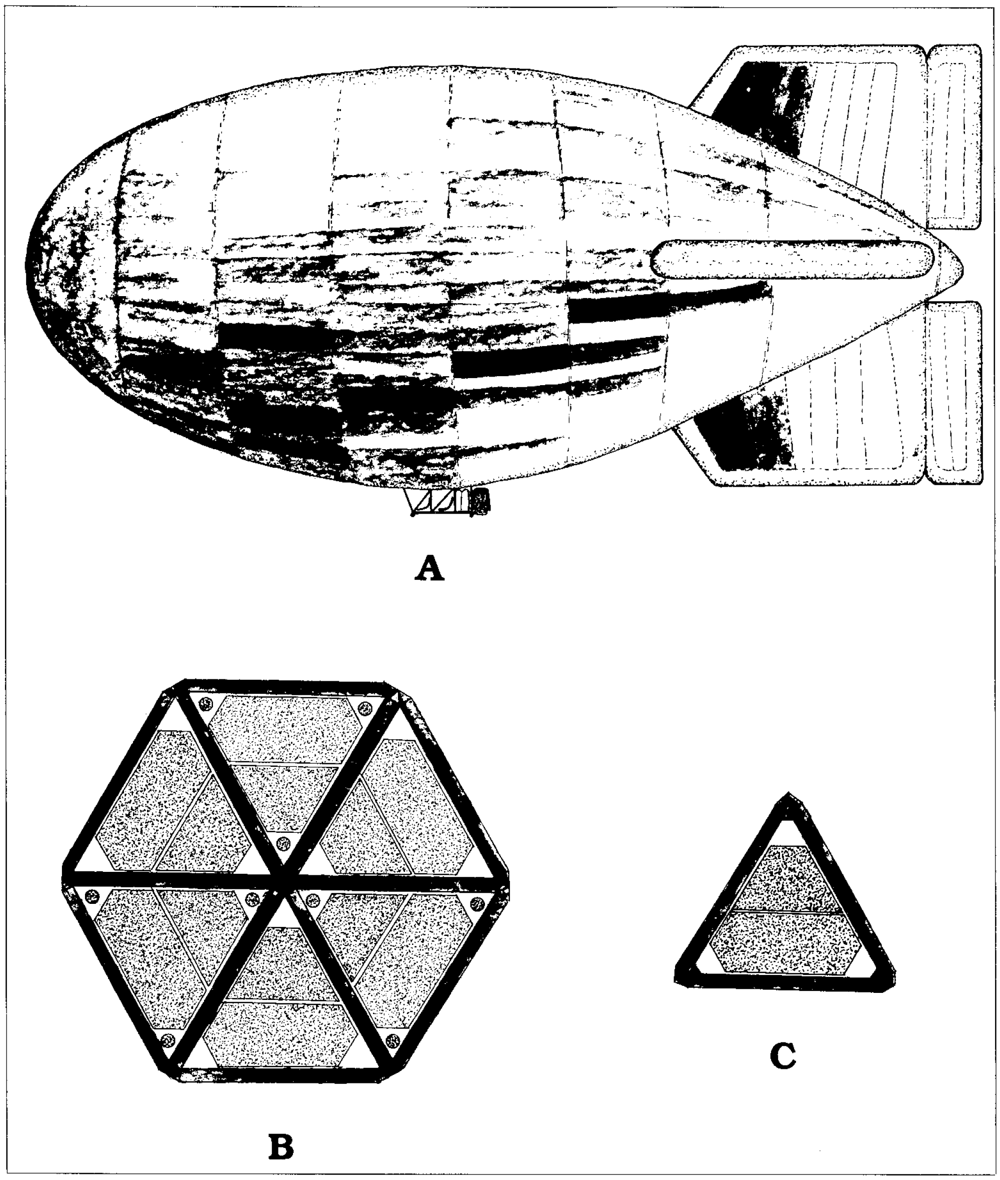

Figure 1. The equipment for the treetop mission: (A) side-view of the 7500 m^3 dirigible or airship; (B) top-view of the raft, the size of two tennis courts; and (C) top-view of the sled. The canopy raft is transported by the dirigible to the treetops, lowered onto the branches, and then detached and allowed to settle. It is then accessed by ropes by researchers from the ground. Hanging from the bottom of the airship, the sled always remains attached during flight and gently enters gaps in the forest to access the outer tree branches. (Drawings by H. Bruce Rinker)

with nets for insects and other invertebrates; and measuring various aspects of foliage including leaf toughness, surface area damaged by insects, and total mass of leaves before and after drying. These methods were employed on the forest floor, on the treetop raft, and from the sled (Figures 8 and 9). The latter, holding three people at a time, was tethered to the bottom of the airship and easily moved along a transect to access many treetops in each sampling exercise. Sled-sweeping, a new technique that we developed for sampling insects in the uppermost foliage, offers ecologists a replicable and statistically valid sampling method that can be used in many

The daily schedule was a routine of intensive field and laboratory work mixed with opportunities for dialogue with other biologists. Concurrent with our work were numerous projects dealing with nutrient- and water-transport in canopy and understory trees, plant architecture, relations between rainforest vegetation and immediate atmospheric conditions, roles and variety of epiphytes, pollination and energetics, and several surveys of the taxonomic diversity of endemic invertebrates. For the two-month 1991

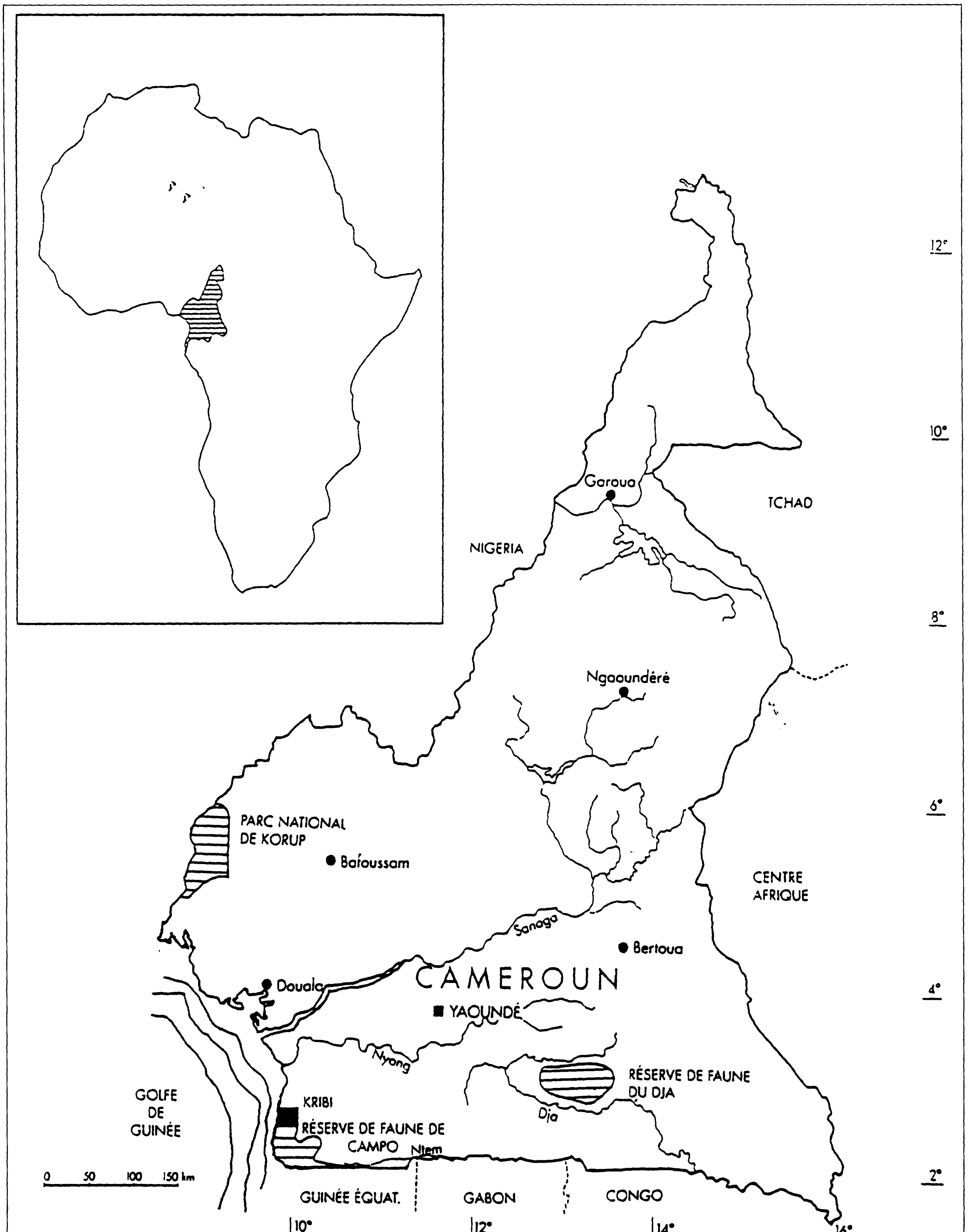

Figure 2. Réserve de Faune de Campo, the location of the 1991 raft expedition [from Francis Hallé and Olivier Pascal (Eds.), *Biologie d'une Canopée de Forêt Équatoriale II* (p. 9)].

mission there were 25 to 30 research projects grouped into nine broad categories including bioclimatology, forest ecology, genetics and evolution, parasitology and medicine, and zoology.

Our day usually began at 0500 with the inflation of the airship (Figure 11). This task always took one hour and required the assistance of many researchers. By 0600 the dirigible was launched and began its

Figure 3. Three surprises about the Cameroon rainforest: very dense undergrowth, few epiphytes, and thick organic soil (photo by H. Bruce Rinker).

scheduled work. Each team knew in advance when its members could employ the balloon for data collecting. By 0800 or 0900 the dirigible returned to

Figure 4. An early-morning view over the treetops (photo by H. Bruce Rinker).

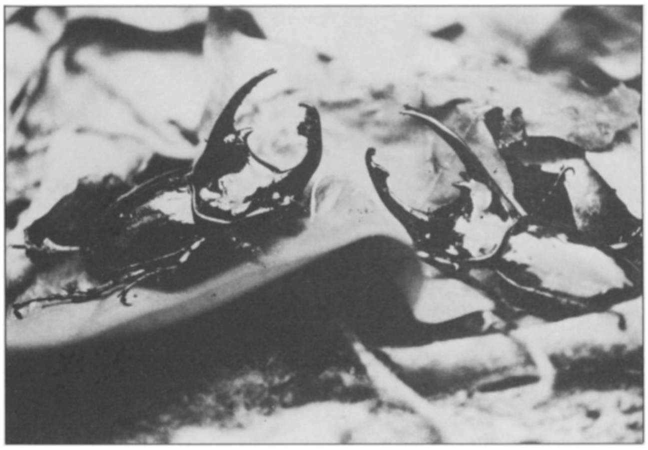

Figure 5. Two male dynastid beetles confronting each other on the forest floor (photo by H. Bruce Rinker).

the launch pad and was deflated, not working later because of increasing winds from the ocean (Figure 12). A puncture in the airship's synthetic surface as it cruised just above the tree line could have delayed the entire expedition and caused serious injury.

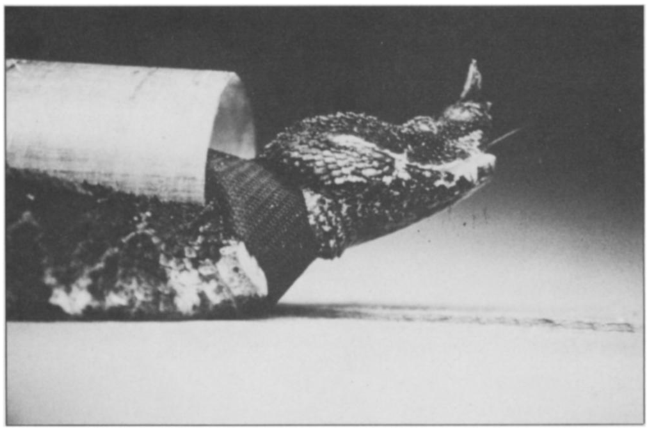

Figure 6. Gabon viper (*Bitis gabonica*), a common animal near the base camp, held in a slip-noose (photo by H. Bruce Rinker).

After breakfast we worked either in the field or in the laboratory (complete with a climate-controlled room, drying oven, refrigeration, and several SUN computer workstations with scanner and optical disc powered by a distant generator). A midday meal was followed by more research until 1900, when all researchers gathered under the thatched roof of the *boucarou* to hear a progress report from one of the teams. During our two-week stay at the camp, every lecture except for one was given in English though there were two German teams, one Japanese group, and several French parties overlapping with our American team. Dinner commenced promptly at 2000, and more work followed until 2300 or so.

Figure 7. View of the base camp from the airship (photo by H. Bruce Rinker).

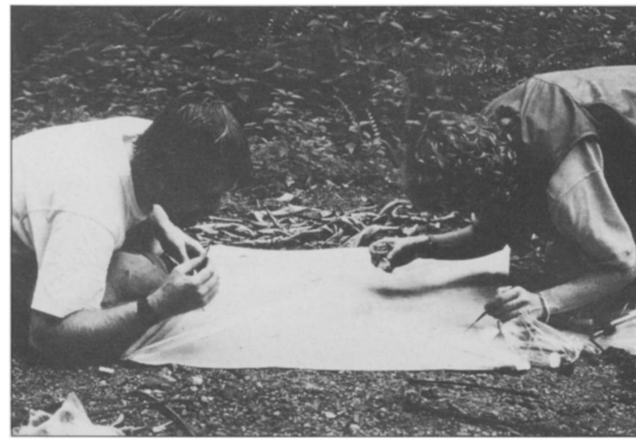

Figure 8. Tropical ecologist Lowman (left) and myrmecologist Moffett collecting invertebrates from a fogging exercise (photo by H. Bruce Rinker).

Secondary Education Absent as a Primary Mission Goal

Our team was one of only two for the entire 1991 mission to have a secondary-school educator as a research participant. Education was not among the nine broad categories of study for *Operation Radeau des Cimes* in Cameroon (although it is certainly an underlying aim of all scientists). Considering the alarming rate of development in the world's rainforests, this link between research and education of young people needs to be given a higher priority in the scientific community. In addition to scientific research and documentation, education can play a significant role in our understanding the rich complexities of this biome before it becomes adulterated habitat. The commitment of educators depends on their access to the tropics—not just through textbooks, erudite journals, and colorful posters, but through their active involvement with rainforest research. Easier access to the treetops for biologists also prescribes easier access for educators and students. Collaboration is indispensable in light of the scope of our ecological troubles.

During one of our evening discussions with other researchers in the African forest, we concluded with a plea for members of the scientific community to employ educators and students in their basic research. We noted the short period of time remaining to solve global ecological troubles such as overpopulation and declining biodiversity and the accelerating rate of scientific illiteracy in the United States and elsewhere (Hively 1988; Wilson 1988; Committee on High-School Biology Education 1990; Uno 1990). Students, prepared by educators and scientists, can learn not only the techniques and skills involved with data collection, but can also acquire an aptitude and a sense of community early in their careers important for success in the scientific world. And, importantly, the scientists can have good data collected free by young people desperate to make a difference. For more than a decade, Rinker has trained high school students to work collaboratively with scientists in

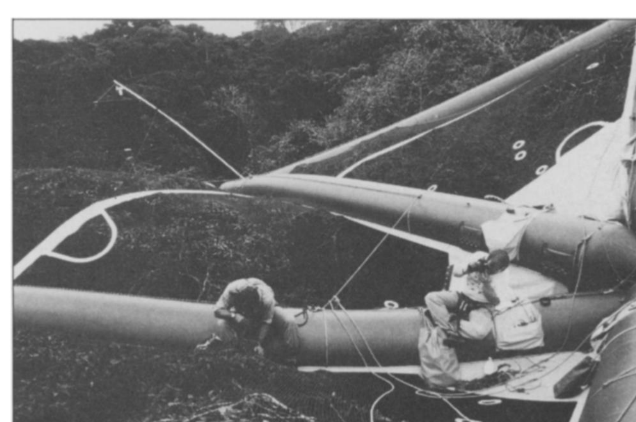

Figure 9. Biology teacher Rinker using an aspirator to collect small insects as Moffett photographed him (photo by Margaret D. Lowman).

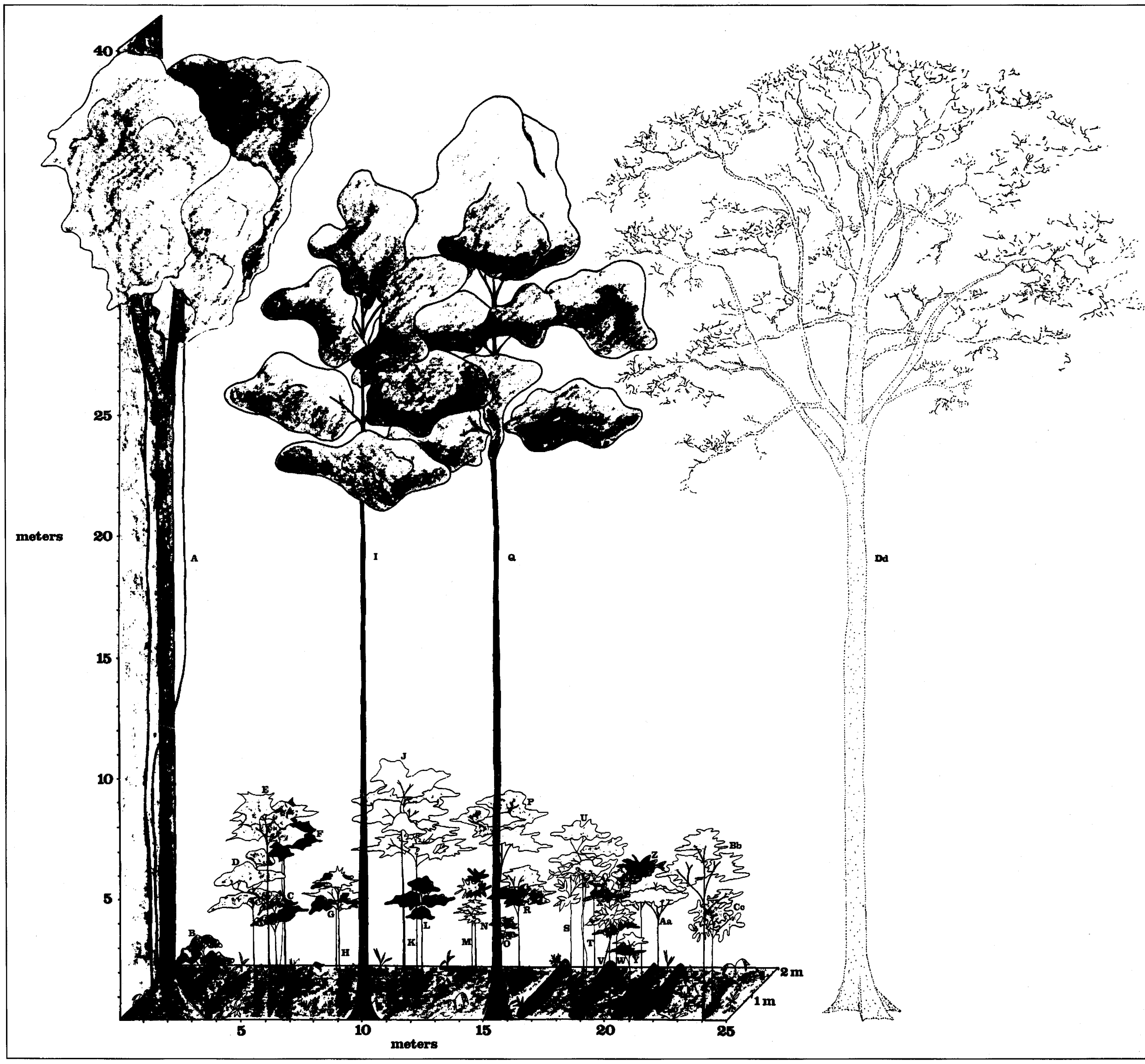

Figure 10. A 2 m × 25 m forest profile; the letters refer to a species key constructed for the site (drawing by H. Bruce Rinker).

the Galápagos Islands, Ecuador's Upper Amazon, public lands in the United States and Canada, and Brazilian Amazonia. Their energetic contributions should not be undervalued because of their age. Hallé nodded in agreement with our suggestion; and, by waving a hand in the direction of the launch pad, commented: "This whole operation was made for young students! Ropes, a colorful balloon, a raft that sits on the treetops. Clearly, all this is for young people." His mission offers inspiration for both scientists and educators.

A Treetops Curriculum

Until recently, the canopy has been inaccessible to all but the most determined and courageous biologists. Now there are methods for entering the treetops of tropical rainforests that make such studies easier not only for scientists but also for educators who recognize the need for experience in this species-rich ecosystem.

We have been involved individually and collectively with rainforest research and education in Cameroon, Costa Rica, Australia, Ecuador, Brazil, Peru, and other tropical locations. From our experiences, we see the growing need for a canopy curriculum for young people, especially for secondary-school students who have both the pluck and ingenuous enthusiasm for this type of work. Rainforested regions like this harbor the majority of the planet's biodiversity and much of its productive

Table 1. Percentages of arthropod individuals belonging to various taxa collected. Taxa are given in order of general importance in samples overall. All taxa represented by less than 3% of the individuals in any sample were lumped into "Misc."

	GROUND		CANOPY		
			From Raft		From Sled
TAXON	Sweep	Spray	Sweep	Spray	Sweep
Hymenoptera	29.2	17.2	29.5	49.2	40.9
Diptera	28.0	23.3	18.4	5.6	6.9
Coleoptera	8.6	10.4	6.8	10.5	13.9
Homoptera	8.3	7.2	3.4	4.0	9.2
Collembola	7.4	13.3	6.2	6.5	0.3
Hemiptera	2.0	2.2	3.4	1.6	4.6
Orthoptera	1.7	4.3	1.4	2.4	3.0
Lepidoptera	1.7	3.2	0.7	0.8	3.3
Blattodea	1.2	2.2	4.8	0.0	0.7
Spiders	8.1	7.5	16.4	16.1	13.2
Misc.	3.9	9.3	8.9	3.2	4.0
NUMBER OF SAMPLES	13.0	9.0	9.0	4.0	25.0
MEAN NUMBER OF INDIVIDUALS PER SAMPLE	46.2	32.9	16.2	31.0	12.1

tissue and, consequently, warrant coverage in science curricula.

A detailed curriculum is underway that emphasizes the rainforest canopy as a frontier of exploration (Rinker et al. in preparation). Rinker suggested a number of broad categories as important points of study (Figure 13) at the first international symposium on canopy ecology in November 1994 at the Selby Botanical Gardens in Sarasota, Florida, for audience comment and review (see Rinker 1994 and Yoon 1994). We are collecting responses from colleagues around the world and incorporating them into the treetops curriculum. Texts for a course in canopy ecology ought to include a generous sampling of such authors as Charles Darwin (*Journal of Researches*, 1845); Alfred R. Wallace (*Malay Archipelago*, 1869; *Tropical Nature*, 1878); William Beebe (*Edge of the Jungle*, 1925; *High Jungle*, 1870); Daniel Janzen (*Costa Rican Natural History*, 1984); Catherine Caufield (*In the Rainforest*, 1985); Andrew Mitchell (*The Enchanted Canopy*, 1986); Donald Perry (*Life Above the Jungle Floor*, 1986); E.O. Wilson (*Biodiversity*, 1988; *The Diversity of Life*, 1992); Mark Moffett (*The High Frontier*, 1993); and M.D. Lowman and N.M. Nadkarni (*Forest Canopies*, 1995). Though these texts do not all deal specifically with tropical canopies (since it is such a novel area for scientific research), much pertinent general information can be gleaned from them. Additionally, even a cursory search of current periodicals such as *Biotropica* and *Selbyana* will reveal a plethora of information about canopy work that has barely entered science textbooks.

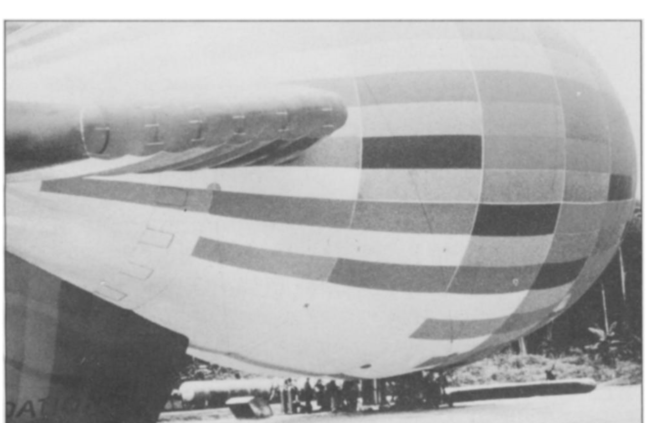

Figure 11. The inflation of the airship, a one-hour process that began daily at 0500 (photograph by H. Bruce Rinker).

A view from the treetops can change even the most stoic, ground-based perspective on forest ecology. Consequently, implementing a canopy curriculum also requires access for the students into the treetops. For older students, this can be done through some of the rainforest programs offered by Earthwatch and perhaps through connections with those research biologists working in Panama, Peru and other countries with treetop access. Lowman has built a platform and walkway 20 meters off the ground in a university-owned tract of oak forest in Massachusetts. Rinker works at a small preparatory boarding school in New York that has prepared a similar perch in a mature oak-maple woods on its campus. Obviously, these are not rainforest pathways; but they certainly give students a three-dimensional view of a habitat that is equally unknown in temperate areas, and it can have application to the tropics. Insect defoliation, acid precipitation, canopy use by birds and mammals, and microclimatic changes need to be

Figure 12. The airship over the camp laboratory (photograph by H. Bruce Rinker).

studied in the treetops of temperate as well as tropical forests.

If direct canopy access is impossible, then remote sensing is a good alternative. Aerial photographs and LANDSAT images may be available through government agencies or archives to provide relevant, breathtaking views of a chosen study site. Remote sensing is an integrative science that draws on biology, physics, geology and mathematics to interpret land use and environmental change. Deforestation rates, wetland monitoring, agricultural practices, and certain wildlife population densities can be determined from the trained use of remote sensing tools (e.g. Laumonier et al. 1992; Monastersky 1993; Skole & Tucker 1993).

Another alternative is the electronic field trip. During February and March 1994, Lowman studied neotropical canopy ecology in the Blue Creek area of Belize via the JASON project as its chief scientist. The project, led by Dr. Robert Ballard of the Woods Hole Oceanographic Institution, was broadcast live from the rainforest in a series of interactive telecasts for science students in North America, the United Kingdom, Bermuda, and Central America. The 1994 Blue Creek expedition used a newly-constructed canopy walkway to survey the biodiversity and plant-insect relationships in a preserve not extensively studied to-date. The expedition curriculum and video series are now available for classroom use from the JASON Foundation for Education and Mind Extension University.

Figure 13. A proposed curriculum for upper-level high school biology students

THE RAINFOREST CANOPY: A FRONTIER OF EXPLORATION FOR HIGH-SCHOOL STUDENTS

I. Description and Location of Tropical Rainforests (including geology and climate)
II. Rainforest Stratification and Tree Architecture (including hydrology, soil profile, and canopy topography)
III. Processes in Forest Canopies
  A. Reproductive Biology (e.g. pollination, flowering, fruiting, and dispersal patterns)
  B. Nutrient Cycling, Storage, and Transfer
  C. Canopy-Atmosphere Interface
  D. Photosynthesis
  E. Large-Scale and Small-Scale Canopy Dynamics (including gap ecology)
IV. Canopy Biodiversity and Interactions
  A. Sessile Organisms (e.g. trees, lianas, parasites, epiphytes, and epiphylls)
  B. Mobile Organisms (e.g. arboreal vertebrates and invertebrates)
V. Development of Canopy Research
  A. Historical Aspects (including a survey of pertinent naturalists and tropical ecologists from the 19th and 20th centuries)
  B. Current Research (including Organization for Tropical Studies, La Selva Biological Station, Selby Botanical Gardens, Brazil's National Institute for Amazon Research, the Smithsonian Tropical Research Institute, and Peru's Amazon Center for Environmental Education and Research)
  C. Tools of Access
VI. Conservation and Ethics
  A. Neotropical Migrants, Deforestation, and Forest Fragmentation
  B. Minimum Critical Size of Ecosystems and Island Biogeography
  C. Extinction and the Integrity of the Global Environment
  D. Products, Climatic Stability, and Cultural Diversity (including agroecology and ethnobotany)
  E. Environmental Action (including a review of relevant conservation organizations) and Ecotourism
  F. Case Studies in New World and Old World Tropics

Conclusion—A Critical Time for Collaboration

In characteristic clear-minded fashion, Wallace wrote that tropical nature produces in the observant a sense of the vast and infinite. Tropical rainforests constitute an ecological type that requires both our intellectual undertakings and emotional vision for its long-term conservation. It is a critical time for collaboration between research and education to halt declining biodiversity and to address accelerating scientific illiteracy, two faces of the same coin of societal ignorance.

Perhaps that is the goal of canopy research—all scientific research for that matter—to produce a sense of the vast and infinite and to promote our sense of wonder, a curiosity that needs to be fed by experience to be long-lived. That seems reason enough to foster a collaborative effort between scientific research and education. It seems reason enough to invite young people to enter the treetops. Ropes, a colorful balloon, a raft that sits on the trees. What better ingredients for learning about a global treasure that needs the energies and enthusiasm of the young to survive?

Acknowledgments

We are grateful to Dr. Francis Hallé and the staff of *Operation Radeau des Cimes* for making our field work possible. We also acknowledge the support of the Williams College Center for Environmental Studies (Williamstown, MA) and Millbrook School (Millbrook, NY) which enabled us to participate on this international expedition. Gratitude is extended to Dr. Vera Krischik (Institute of Ecosystem Studies, Millbrook, NY) for her manuscript review.

References

Committee on High-School Biology Education. (1990). *Fulfilling the promise: Biology education in the nation's schools*. Washington, DC: National Academy Press.

Erwin, T.L. (1982). Tropical forests: Their richness in Coleoptera and other arthropod species. *Coleopterists Bulletin, 36*, 74–75.

Hallé, F. (1990). A raft atop the rain forest. *National Geographic, 178*, 78–107.

Hively, W. (1988). How much science does the public understand? *American Scientist, 76*, 439–444.

Laumonier, Y., Trichon, V., Gastellu-Etchegorry, J.P. & Birnbaum, P. (1992). Heterogeneite geometrique et radiometrique de la canopée: Essa de cartographie. In Francis Hallé and Olivier Pascal (Eds.), *Biologie d'une Canopée de Forêt Équatoriale II* (pp. 271–288). Montpellier, FR: Institut Botanique.

Lowman, M.D. & Moffett, M.W. (1993). The ecology of tropical rain forest canopies. *Trends in Ecology and Evolution, 8*, 104–107.

Lowman, M.D., Moffett, M.W. & Rinker, H.B. (1992). Insect sampling in forest canopies: A new method. In Francis Hallé and Olivier Pascal (Eds.), *Biologie d'une Canopée de Forêt Équatoriale II* (pp. 41–44). Montpellier, FR: Institut Botanique.

Lowman, M.D., Moffett, M.W. & Rinker, H.B. (1993). A technique for taxonomic and ecological sampling in rainforest canopies. *Selbyana, 14*, 75–79.

Lowman, M.D., Moffett, M.W. & Rinker, H.B. (In preparation). Herbivory in African rainforest canopies.

May, R.M. (1992). How many species inhabit the earth? *Scientific American, 267*, 42–48.

Monastersky, R. (1993). The deforestation debate. *Science News, 144*, 26–27.

Parker, G.G., Smith, A.P. & Hogan, K.P. (1992). Access to the upper forest canopy with a large tower crane. *Bioscience, 42*, 664–670.

Perry, D.R. (1981). The tropical rain forest canopy: A method providing total access. *Biotropica, 13*, 283–285.

Rinker, H.B. (1994). The rainforest canopy: A frontier of exploration for high school students. *Selbyana, 15*, A25.

Rinker, H.B., Lowman, M.D. & Moffett, M.W. (In preparation). *The rainforest canopy: A frontier of exploration for high-school students.*

Skole, D. & Tucker, C. (1993). Tropical deforestation and habitat fragmentation in the Amazon: Satellite data from 1978 to 1988. *Science, 260*, 1905–1910.

Uno, G.E. (1990). Inquiry in the classroom. *Bioscience, 40*, 841–843.

Wallace, A.R. (1878). *Tropical nature*. London: Macmillan and Company.

Wilson, E.O. (1988). *Biodiversity*. Washington, DC: National Academy Press.

Wilson, E.O. (1991). Rain forest canopy: The high frontier. *National Geographic, 180*, 78–107.

Yoon, C.K. (1994, 22 November). Biologists master the treetops, the real scene of forest action. *The New York Times*, C1.