Selbyana 14: 75–79

A NEW TECHNIQUE FOR TAXONOMIC AND ECOLOGICAL SAMPLING IN RAIN FOREST CANOPIES

MARGARET LOWMAN

Selby Botanical Gardens, 811 S. Palm Avenue, Sarasota, Florida 34236

MARK MOFFETT

Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts 02138

H. BRUCE RINKER

Science Department, Millbrook School, Millbrook, New York 12545

ABSTRACT. A new technique for sampling in tree canopies is described. "Sled sweeping" provides replicated estimates of relative insect, foliage or flower abundance in tree canopies in a homogeneous fashion, and can be replicated over many trees in rapid succession. We illustrate its use for estimates of diversity and the relative distribution of insects in tropical forests, as well as a measure of variability of insect abundance among tree canopies. We also discuss applications of the sled for floristic, pollination and taxonomic studies of epiphytes and other canopy phenomena.

Access to tropical forest canopies has been greatly enhanced by the development of technical climbing hardware (e.g., Lowman 1984, Nadkarni 1984), but most methods do not allow access to the uppermost branches. These canopy branches, with their active phenological constituents of leaves and flowers (Lowman 1992) may contain the majority of insects, epiphytes and organisms dependent upon photosynthesis. Access to this uppermost region will enhance studies of pollination, herbivory and other interactions.

The greatest diversity of organisms in the world, predominantly invertebrates, is hypothesized to live in the canopies of tropical trees. This topic is currently the subject of intense debate and interest (reviewed by Wilson 1989). The numbers of species on earth, conservatively estimated at 3 million (Southwood 1978a, Strong *et al.* 1984) and 10 million (Wilson 1989) during the last decade, have skyrocketed to 30 million with Erwin's fogging studies in neotropical rain forests (Erwin 1982, 1991) and more recently to 32.5 million as Erwin analyzes his data (Erwin 1992). But these high estimates have been criticized, since they are extrapolations from several tree canopies over a relatively short time period (Gaston 1991). The limitations of sampling techniques in tree canopies make it difficult—nearly impossible—to accurately quantify the distribution and diversity of invertebrates in rain forests (rev. in Southwood 1978b, Lowman 1982, 1985, Erwin 1989).

One of the major problems for canopy research is the obvious logistic difficulty associated with access (rev. in Mitchell 1982, Wilson 1991). During the last decade, several new and innovative techniques have been employed:

1. Canopy fogging for invertebrates, whereby a nonpersistent insecticide mist is sprayed throughout a column of forest from an apparatus hoisted up into the canopy and insects fall onto sheets of specific area or other collecting devices on the forest floor (Erwin 1983, Stork 1991, Kitching *et al.* 1993).
2. Technical climbing hardware and ropes that enable vertical access to different levels of foliage, epiphytes, or other organisms (e.g., Perry 1978, Lowman 1984, Nadkarni 1984).
3. Canopy walkways, offering permanent access to sections of understory canopy (e.g., Wint 1983, Lowman 1985).
4. Canopy rafts, or *Radeau des Cimes,* powered by a dirigible, that can be placed temporarily atop the canopy for access to foliage around the edges of the structure (Hallé & Blanc 1990, Hallé & Pascal 1992).
5. Construction cranes (Parker et al. 1992).

All of these methods have obvious limitations for ecological sampling, (see TABLE 1).

METHODS

During the 1991 expedition of Opération Canopée in the Biafran-Congo Basin equatorial rain forests of Cameroon, a new sampling technique was designed to overcome some of the limitations of reaching uppermost canopy branches. A canopy sled (a portable triangular raft, 5 m × 5 m × 5 m) was constructed to "sail" atop the rain forest canopy, maneuvered by the dirigible. The sled was used by us for ecological sampling of patchiness of insect distribution in many canopy trees within close proximity, and by other canopy biologists for collections of canopy leaves, flowers, fungi, vines, and pollinators. The uppermost

TABLE 1. Current major techniques of access into rainforest canopies and their respective features for fieldwork.

Method	Advantages	Disadvantages
Single rope techniques	Access to different canopy heights Shifts easily between trees and sites Easy to operate alone or in pairs Easy to replicate between canopies Relatively inexpensive	No access to uppermost canopy Requires time and effort Only one researcher per rope Requires skill to operate safely Limited to sampling in close proximity to rope
Walkways	Permanent structure Permanent access to specific trees Moderately inexpensive Can work at night and in bad weather Can be expanded as time and funds allow Allows collaborative work	Cannot be moved to new sites Cannot reach more than 5–8 trees (in most cases) No access to uppermost canopy Expansion limited to available strong trees Can result in overuse of adjacent trees
Canopy cranes	Permanent access to different trees Easy to replicate between trees Allows collaborative work	Cannot reach far beyond length of the boom Access to lower canopy may be impeded (by density of upper crown) Limited number of workers at one time (3) Expensive to own and maintain
Raft/sled inflatables	Allows replicative, quantifiable sampling Access to uppermost canopy Allows collaborative work Minimal damage to sites Can sample many crowns over a short duration	Not functional in bad weather Expensive to own and maintain Good access to lower canopy levels with ropes Only 3–6 researchers in the canopy at one time Site selection important (to minimize damage to inflatables) Short durations of "flights" by sled; raft restricted to semi-permanent "moorings"

crown has not been reliably sampled by any other method.

In a fashion similar to fishing-boats trawling with nets in shallow waters, we conducted sweep netting in replicated individual canopies over 5-min durations from the sled along a transect, at a height of 35–45 m on top of the canopy (FIGURE 1). Each sample, collectively comprising 10 full sweeps taken from each tree canopy, was collected with nets of 38 cm diameter and dense sailcloth mesh. The net was sprayed lightly with a knockdown nonpersistent insecticide (Prentex, active ingredient 3% Resmethrin) to allow easy transfer of insects out of the nets into a plastic bag. (An improved net, with multiple clip-off nets to allow faster sampling, is being designed for future sled sweeping.)

RESULTS AND DISCUSSION

Insects collected by the replicated technique of 10 sweeps per tree canopy were compared for abundance and diversity. Over 2 days, we collected samples from 25 canopies. The total number of insects ranged from 2–32 individuals per canopy sample. Mean number of individuals was 12.1 (SE 4.1) and number of species was 8.7 (SE 4.4). Over 40% of the insects in the upper canopy comprised ants (and >75% of those were *Crematogaster* species).

Although the identification of insects to the level of species has not yet been completed, the proportions of each order collected from sled sweeping in the uppermost crown were as follows (expressed as proportions of total catch): Hymenoptera 40.9, Diptera 6.9, Coleoptera 13.9, Homoptera 9.2, Collembola 0.3, Hemiptera 4.6, Orthoptera 3.0, Lepidoptera 3.3, Blattodea 0.7, spiders 13.2, and miscellaneous 4.0. All taxa that were represented by <3% were lumped together as "miscellaneous." Further analyses of insect species, host trees and herbivory levels are underway (Lowman, Moffett and Rinker unpubl.).

The new technique of "sled sweeping" offers taxonomists an ability to collect flowers, fruits and leaves from the uppermost canopy; and ecologists an opportunity to conduct statistically valid, repeated samples of foliage insects or other organisms from the uppermost canopy, a region not previously accessible for replicated ecologi-

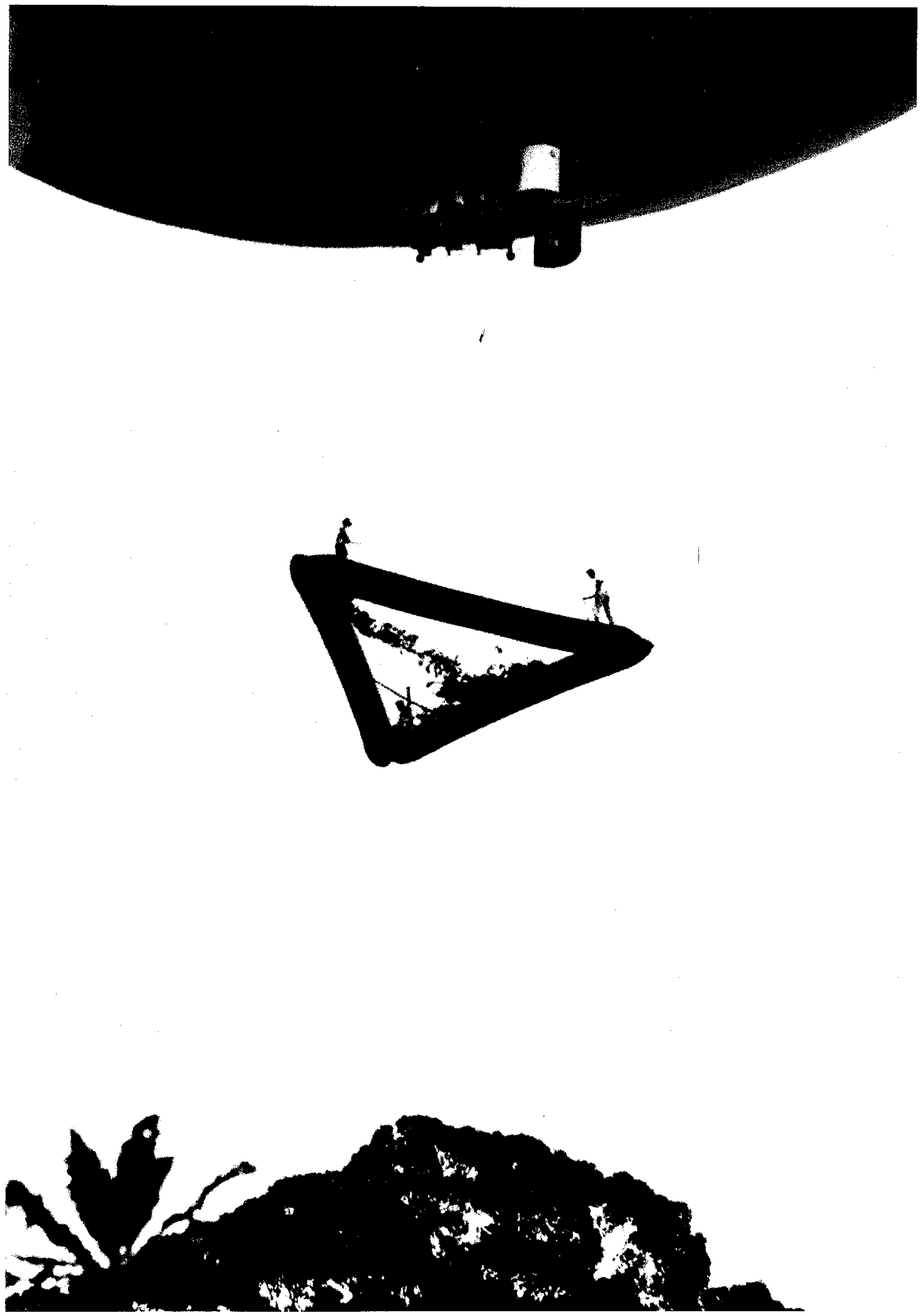

FIGURE 1. The portable sled (5 m × 5 m × 5 m) suspended from a balloon or dirigible as researchers ascend from the ground into the upper canopy for foliage sweep sampling (Cameroon, Africa, November 1991).

cal sampling. Insect data from tropical tree canopies is historically limited to a few tree canopies at a few sites, because most techniques are so labor-intensive (Erwin 1982, Kitching *et al.* 1993). The sled enabled participants on Opération Canopée to undertake comparative studies of insects, flowers, or foliage between many different canopies within a single day. The construc-

FIGURE 2. A depiction of sweep netting in the uppermost canopy from the portable sled that is maneuvered by a dirigible overhead.

tion of portable sleds is also less expensive then the larger, more permanently-situated raft structure.

Although the resulting data on abundance of insects may appear low upon first glance, the uppermost region of canopy is analogous to a desert, with extreme windy and sunny conditions. The high variability (ranging from 2 to 32 individuals per sample) suggests that insect distribution in tropical forests may be much more patchy than originally predicted. Some trees had relatively high densities, while others were relatively depauperate in insects. Abundance appeared to coincide with phenological events (e.g., flowers, leaf flushes). If this is the case, then current extrapolations of biodiversity may be altered by the heterogeneity of insect distribution in tree canopies (e.g., Erwin 1991), since all trees may not harbor high insect diversity at any one time period. Instead, guilds of foliage feeders and pollinators (as well as their predators and parasitoids) may shift between tree crowns, in synchrony with the phenological events that impart resources, namely flowering and leafing.

Further sampling is underway to examine the hypothesis that insect distribution in tropical forest tree canopies is patchy, and related to the heterogeneity of plant resources.

ACKNOWLEDGMENTS

We are extremely grateful to Francis Hallé and the staff of Opération Canopée for making this field work possible. The expedition was kindly funded by Elf Foundation/Paris as a grant to ML. We also acknowledge the staff of Williams College Center for Environmental Studies (ML), and Millbrook School (HR) for allowing us to participate in this expedition, and to the Lowmans for child care assistance.

LITERATURE CITED

ERWIN, T. L. 1982. Tropical forests: their richness in Coleoptera and other Arthropod species. Coleopterists' Bulletin 36: 74–75.

———. 1983. Beetles and other Arthropods of the tropical forest canopies at Manaus, Brasil, sampled with insecticidal fogging techniques. Pp. 59–75 *in* S. L. SUTTON, T. C. WHITMORE, AND A. C. CHADWICK, eds., Tropical rain forests: ecology and management. Blackwell Scientific Publications, Oxford, United Kingdom.

———. 1989. Canopy arthropod biodiversity: a chronology of sampling techniques and results. Rev. Per. Ent. 32: 71–77.

———. 1991. How many species are there?: revisited. Conserv. Biol. 5: 330–333.

———. 1992. Stratification and distribution of neotropical forest microhabitats and associated arthropod faunules; a methodology report. AIBS (ATB) Conference Abstracts, Honolulu, Hawaii.

GASTON K. J. 1991. The magnitude of global insect species richness. Conserv. Biol. 5: 283–295.

HALLÉ F. AND P. BLANC, eds. 1990. Biologie d'une canopée de forêt équatoriale. (Rapport de mission "radeau des cimes", Oct–Nov 1989, Guyane Francaise). Institut botanique, Montpellier FR. 231 pp.

——— AND O. PASCAL, eds. 1992. Biologie d'une canopée de forêt équatoriale II (Rapport de mission "Radeau des Cimes", Septembre–Décembre 1991, Campo, Cameroun). Institut botanique, FR. 200 pp.

KITCHING R. L., J. BERGELSON, M. D. LOWMAN, AND S. MCINTYRE. 1993. The biodiversity of arthropods from Australian rain forest canopies: general introduction, methods, sites and ordinal results. Austr. J. Ecol. (in press).

LOWMAN M. D. 1982. Seasonal variations in insect abundance among several Australian rain forests, with particular reference to phytophagous types. Austr. J. Ecol. 7: 353–361.

———. 1984. Herbivory in rain forest canopies—is it as intense as we thought? Biotropica 16: 14–18.

———. 1985. Spatial and temporal variability in herbivory of Australian rain forest canopies. Aust. J. Ecol. 10: 7–14.

———. 1992. Leaf growth dynamics and herbivory in five species of Australian rain-forest canopy trees. J. Ecol. 80: 433–447.

MITCHELL A. 1982. Reaching the rain forest roof. UNEP.

———. 1986. The enchanted canopy—secrets from the rainforest roof. Williams Collins Publishers, London.

NADKARNI N. 1984. Epiphyte biomass and nutrient capital of a neotropical elfin forest. Biotropica 16: 249–256.

PARKER G., SMITH A. P. AND HOGAN K. P. 1992. Access to the upper canopy with a large tower crane. Bioscience 42: 664–671.

PERRY D. 1978. A method of access into the crowns of emergent and canopy trees. Biotropica 10: 155–157.

SOUTHWOOD T. R. E. 1978a. The components of diversity. Symp. R. Entomol. Soc. Lond. 9: 19–40.

———. 1978b. Ecological methods. Chapman & Hall, London.

STORK N. 1991. The composition of the arthropod fauna of Bornean lowland rainforest trees. J. Trop. Ecol. 7: 161–180.

STRONG D. R., J. H. LAWTON, AND T. R. E. SOUTHWOOD. 1984. Insects on plants. Blackwell Scientific Publications, Great Britain.

WILSON E. O., ed. 1989. Biodiversity. Nat. Academy of Sciences, USA.

———. 1991. Rainforest canopy, the high frontier. Nat. Geographic 180(6): 78–107.

WINT W. 1983. Leaf damage in tropical rain forest canopies. Pp. 229–241 *in* S. L. SUTTON, T C. WHITMORE, AND A. C. CHADWICK, eds., Tropical rain forest: ecology and management. Blackwell Scientific Publications, London.