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THE TROPICAL RAIN FOREST CANOPY: RESEARCHING A NEW FRONTIER

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Canopy biology has attained a maturity as a discipline over the last fifteen years or so with the development and dissemination of tree access technologies, mostly among tropical researchers (Mitchell 1986 and Moffett 1993). Actually, many of the most popular methods, such as platforms and walkways, had been tried out decades earlier. (For example, Ivan T. Sanderson used a bow and arrow in the 1930's to shoot a fishing line over a tree limb in order to then pull lianas into place for climbing. Any modern rope climber will recognize his procedure (Sanderson & Loth 1965: 220)—though *sans* jumars!) While the strategies of today's arboreal biologists may seldom be new, the innovation of high-tensile, light-weight, low-cost, and reliable construction materials have made canopy study more practicable and safe, and therefore more widely palatable as an option for scientific research.

With the perfection of effective technological climbing methods, such as the 'Radeau des Cimes' (the canopy raft: Hallé 1990) and the canopy crane (Parker *et al.* 1992), and of ground-based methods such as fogging (Erwin 1990), canopy biology can finally be said to have reached the start of a new era. Researchers now spend less time fretting over how to prudently work in the treetops, and more time pondering the difficulties in recording meaningful canopy data, analyzing it, and interpreting the results.

Studies of the canopy community to date have focused on the treetops at a gross level—as when, for example, entomologists inventory the arthropod community in whole tree crowns by fogging or botanists produce profile diagrams of forest transects. While such approaches will continue to be necessary in surveying and comparing forests around the world, it is becoming obvious that we also need to examine canopy processes at finer scales.

Because of the structural complexity of the canopy, following fine-scale changes in this ecosystem will be daunting. Consider the manpower, time and computer space required to obtain (at several year intervals) the two-dimensional maps of rainforest plots that have become crucial to many scientists working on Barro Colorado Island, Panama or Pasoh, Malaysia. Canopy research will necessitate a similarly detailed data base, but in three canopy dimensions. Moreover, the substrate of the canopy ecosystem changes at short intervals and unpredictably, as branches expand, lengthen, subdivide, or die, and as trees themselves come and go. Despite the age of canopy communities (they are presumably as old as the trees) tracking their dynamics will require updating canopy maps at more frequent intervals than is done for tree plots—possibly several times a year.

Procedures are now under development to map canopy ecosystems and follow them through time (Parker *et al.* 1992, Nychka & Nadkarni 1993). Although most projects would benefit by applying techniques like these, the effort required to map sufficiently large sample areas will dissuade most researchers from using them. It is for this reason, then, that joint projects to coordinate these labor-intensive steps will become increasingly significant.

The simplicity and cost-effectiveness of rope climbing assures that research by lone scientists and students will remain important for studies of individual species and some aspects of community ecology. However, the ease with which recent innovations, like the canopy crane and canopy raft, permit multiple teams of scientists to work within the same volume of canopy will make these approaches increasingly pivotal in achieving an integrated understanding of forest community dynamics.

This shift in approach has already begun. For example, while projects on the canopy raft started out as largely independent, plans for the upcoming expedition feature a coordinated effort of the sort I describe by a few teams working on complementary projects: leaf nutrients, leaf herbivory, leaf allozyme activity, insect diversity, and mosaics of ant territories—all in relation to a common data base of tree and canopy architecture.

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CANOPY WALKWAYS—TECHNIQUES FOR THEIR DESIGN AND CONSTRUCTION

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Walkways offer a permanent and relatively expensive method of access to forest canopies for long term and collaborative biological studies. A new concept in walkway construction was designed for a temperate maple-beech forest in Massachusetts. The design utilizes two modules (a bridge and a platform) that can be reiterated in a number of patterns to suit different sites and budgets. The details of walkway construction and hardware have been quantified (Lowman and Bouricius, unpublished), and a prototype walkway is available for inspection in Williamstown, Massachusetts. At this site, we have been involved with students in studies of arboreal mammals, seasonal variation in forest insect populations, and defoliation of oak trees by gypsy moths.

Other walkways in various stages of progress by us exist at Millbrook School (NY), Hampshire College (MA), and Blue Creek (Belize, Central America).