LIFE IN THE TREETOPS – A CONCISE SUMMARY OF FOREST CANOPY ECOLOGY

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Summary

Forest canopies contain a major portion of the diversity of organisms on Earth and constitute the bulk of photosynthetically-active biomass in forest ecosystems. For these reasons, canopy research has become integral to the management of forest ecosystems, and to our better understanding of global change. Ecological research in forest canopies is relatively recent and has been primarily descriptive in scope. The development of new methods of canopy access has enabled scientists to conduct more quantified research in tree crowns. Studies of sessile organisms, mobile organisms, and canopy interactions and processes have emerged as sub-disciplines of canopy biology, each requiring different methods for collecting data. Canopy biology is beginning to shift from a descriptive autecology of individuals to a more complex ecosystem approach, although some types of field work are still limited by access.

Questions currently addressed in canopy research are extremely diverse, but emphasize comparisons with respect to spatial and temporal variation. Spatial scales range from leaves (e.g. quantifying the number of mites on individual phylloplanes) to trees (e.g. measuring photosynthesis between sun and shade leaves), to forest stands (e.g. measuring turbulence above the canopy, or calculating the carbon storage of entire stands) and entire landscapes (e.g. comparing mammal populations between different forest types). Temporal variation is of particular significance in tropical forest canopies, where populations of organisms and their resources have diurnal, seasonal, or even annual periodicity. As the methods for canopy access improve, more rigorous hypotheses-driven field studies remain a future priority of this newly-coalesced discipline. Because forests are integral for understanding global change, canopy ecology research has been prioritized, especially in many tropical and arctic forest ecosystems.

1. History of Canopy Biology

"There awaits a rich harvest for the naturalist who overcomes the obstacles - gravitation, ants, thorns, rotten trunks - and mounts to the summits of jungle trees..."
(Beebe et al 1917)

1.1. Introduction

E.O. Wilson called it "*the last frontier*" of biological research on the planet. Andrew Mitchell referred to its invisible inhabitants as "*a world I could only dream of*". Tom Lovejoy confessed that "*the canopy rendered me the biologist's equivalent of Tantalus from the very outside*". Steve Sutton compared it to "*Alice grows up*" in his description of canopy science moving from a sense of wonder to a reality of hypotheses. Nalini Nadkarni exclaimed about "*tree climbing for grown-ups*", and Meg Lowman simply noted, "*My career is not conventional. I climb trees*". In 1985, these six individuals quoted above represented almost half of the canopy biology community worldwide. Today, only two decades later, several hundred explorers work relentlessly to describe and understand Wilson's "last frontier".

The forest canopy is defined as "the top layer of a forest or wooded ecosystem consisting of overlapping leaves and branches of trees, shrubs, or both". Studies of plant canopies typically include four organizational levels of approach: individual organs (leaves, stems, or branches), the whole plant, the entire stand, or the plant community. Canopy biology is a relatively new discipline of forest science that incorporates the study of mobile and sessile forest organisms and the processes that link them as an ecological system. With the more recent urgency surrounding climate change research, the forest canopy represents an interface between earth and atmosphere; and dynamics such as insect outbreaks serve as early warning signals to hotter, drier climatic conditions.

Forest canopies have long eluded scientists because of the logistical difficulties of reaching tree crowns and the subsequent challenges of sampling once one gets up there. Only in the last decade have field biologists begun extensive exploration of this unknown world of plants, insects, birds, mammals, and their interactions. These logistic strides are attributed to the development of several innovative and creative techniques that facilitate ascent into tree crowns.

Biologists in the 19th and 20th centuries traditionally based their ideas about forests on observations made at ground level. These ground-based perceptions are summarized in a comment by Alfred R. Wallace in 1878:

Overhead, at a height, perhaps, of a hundred feet, is an almost unbroken 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…it is a world in which man seems an intruder, and where he feels overwhelmed.

Ideas about forest canopies had changed very little for a hundred years until the 1970s, when biologists first adapted technical mountain-climbing hardware for ascending tall trees. Termed SRT (single rope techniques), this versatile method enables scientists to reach the mid-canopy with ease, and hang suspended on a rope to make observations of pollinators, epiphytes, herbivores, birds, monkeys, and other biological phenomena (Figure 1).

Figure 1. SRT (single rope techniques) was one of the first canopy access methods developed, and continues to offer safe, affordable (albeit solo) methodology for treetop research.

There are a number of exciting reasons for the escalating priority in canopy research during the past two decades. First, as rainforests continue to decline due to human activities, the urgency of surveying the enormous biodiversity of their tree crowns challenges some researchers. There are reputedly many orchids, as well as other plants and countless invertebrates, which inhabit the treetops, and perhaps have escaped detection due to their aerial location. Many of these organisms are important not just as keystone species to the health of the rain forest ecosystem, but also as sources of medicines, foods, and materials. Second, canopy processes are essential to life on our planet—canopy organisms are integral to the maintenance of rain forest ecosystems, and the canopy is a major site of productivity in terms of photosynthesis, nutrient cycling, and exchange of carbon dioxide. As the economics of our planet become better understood, the rain forest has emerged as a critical region where ecosystem services abound. Tropical rain forests contribute to our global economy by providing productivity (as a center for photosynthesis), medicines, materials and foods; housing a genetic library; through nutrient cycling, carbon storage and other important sinks; as a climate stabilizer; conservation of water runoff; and as a cultural heritage. And third, many researchers confess to a simple curiosity to explore this previously inaccessible region of our planet. There are relatively few unknown frontiers left in the 21st century field biology, but the treetops (like the ocean floor and the soil ecosystem) remain as yet little understood.

1.2. Chronology of the Development of Canopy Access Tools

Binoculars and telescopes were probably the first tools for canopy exploration. Charles Darwin, in the 19th century, looked into the tropical rainforest foliage, exclaiming:

Delight itself…is a weak term to express the feelings of a naturalist who, for the first time, has wandered by himself in a Brazilian forest. The elegance of the grasses, the novelty of the parasitical plants, the beauty of the flowers, the glossy green of the foliage, but above all the general luxuriance of the vegetation, filled me with admiration. A most paradoxical mixture of sound and silence pervades the shady parts of the wood. The noise from the insects is so loud, that it may be heard even in a vessel anchored several hundred yards from the shore; yet within the recesses of the forests a universal silence appears to reign. To a person fond of natural history, such a day as this brings with it a deeper pleasure than he can ever hope to experience again." (Darwin 1883).

In 1926, a biologist named Allee made the first published, quantified measurements of the canopy environment in Panama. Only three years later, scientists erected an observation platform in British Guiana where they baited traps for canopy organisms. Sadly, no data were published; but the chronology of canopy access begins with these activities of the 1920s.

Thirty years later in the 1950s, a steel tower was constructed in Mpanga Forest Reserve in Uganda to study gradients from the forest floor to the canopy. Towers provided access to monitor insect vectors of human diseases, which remain the first (and landmark) applied biological studies conducted in the forest canopy. The 1970s represented the era of SRT (single rope techniques). This portable, relatively inexpensive technique for canopy access allowed graduate students and others with a modest budget to survey life at the top. Don Perry first used SRT at LaSelva in Costa Rica, examining the ecology of a Kapok tree. Perry went on to develop the canopy web, the aerial tram, and other methods that were creative extensions of a rope system. Ropes were not effective, however, to reach the leafy perimeters of tree crowns, since the ropes had to be looped over sturdy branches usually close to the tree trunk. To access the leafy outer foliage of canopy trees, botanist Peter Ashton invented the canopy boom, a horizontal bar with a bosun's chair at one end, which could be swung around into the leafy canopy away from the woody trunks. In Pasoh, Malaysia, booms solved the mystery of the pollination of dipterocarp flowers. In recent years, Ashton's "magic missile" can be used in conjunction with conventional SRT to expand access throughout the canopy (Figure 2).

Figure 2. The canopy boom was developed in Malaysia for studies of Dipterocarp pollination.

In the 1980s, engineers pioneered the notion of canopy walkway construction, including Ilar Muul who built the first canopy walkway in Malaysia anchored in tree crowns, and also Meg Lowman who independently conceived the notion of a walkway in Lamington National Park, Australia. Complementary ladders were also used for studies of canopy vertebrates, phenology, and insect outbreaks. Canopy walkways were resurrected and burgeoned later in the 1990s with the modular construction of Canopy Construction Associates (www.canopyconstruction.org), founded by Meg Lowman and Bart Bouricius in Massachusetts. Since then, canopy walkways and ladders used in conjunction with climbing ropes and other tools have become popular as permanent canopy field sites (Figure 3). Subsequently, conservation projects that link economics to ecology for tropical forests have been formulated around canopy walkways (www.treefoundation.org).

Throughout the 1980s, biologists utilized combinations of canopy access tools including SRT, walkways, canopy booms, ladders, cherry pickers, or other creative means. In 1982, Terry Erwin revolutionized our estimates of biodiversity by introducing fogging apparatus into canopy research. By misting the treetop of a *Luehea seemanii* in Panama, he collected the rain of insects and counted the diversity of species, especially beetles. Erwin's extrapolations raised our estimates of global biodiversity from almost 10 million to over 30 million. Fogging continues to be utilized extensively by rainforest biologists who need to estimate the diversity of life in the treetops. Canopy science moved from a "sense of wonder" and exploration to a more rigorous science where hypotheses were tested and vast databases were collected.

Figure 3. Canopy walkways were developed in Indonesia and Australia simultaneously, and today over 20 walkways are in use for research and education as well as providing conservation of local forests through ecotourism.

The last chapter in the development of tools for canopy research involves the ability to expand into the realm of integrated, collaborative research projects. In general, SRT, booms, cherry pickers, scaffolding, ladders, and to some extent canopy walkways are more limited in scope, favoring solo work or small studies rather than large comprehensive studies (although some of the most recently constructed walkways are of sizeable dimension and less limited in carrying capacity). Two scientists (Francis Hallé and Alan Smith) expanded the scope of canopy research with their creative genius on two separate continents. Hallé designed a colorful hot-air balloon, called *Radeau des*

Cimes (or raft on the rooftop of the world). His inflatable raft is 27 m in diameter and forms a platform on top of the forest canopy that is utilized as a base camp for researchers in the uppermost canopy. A dirigible, or hot air balloon, is used in conjunction with the raft, serving to move the raft to new positions throughout the forests and also to move researchers within the above-canopy atmosphere for studies of the canopy-air interface. In 1991, the Radeau des Cimes expedition team pioneered a new canopy technique called the *sled*, or skimmer. This small (5 m) equilateral, triangular mini-raft was towed across the canopy by the dirigible, similar to a boat with a trawling apparatus in the water column of the ocean. It facilitated the rapid collection of canopy leaves, flowers, vines, and epiphytes as well as their pollinators and herbivores. In Madagascar in 2001, Hallé's team launched a new device that was essentially an individual cell within the crown of one tree whereby researchers could be dropped off by the balloon for temporary residence inside the metal frame of the canopy camp (Figures 4, 5).

Figure 4. The dirigible, or hot-air balloon provides collaborative research opportunities, and also allows access to the uppermost canopy

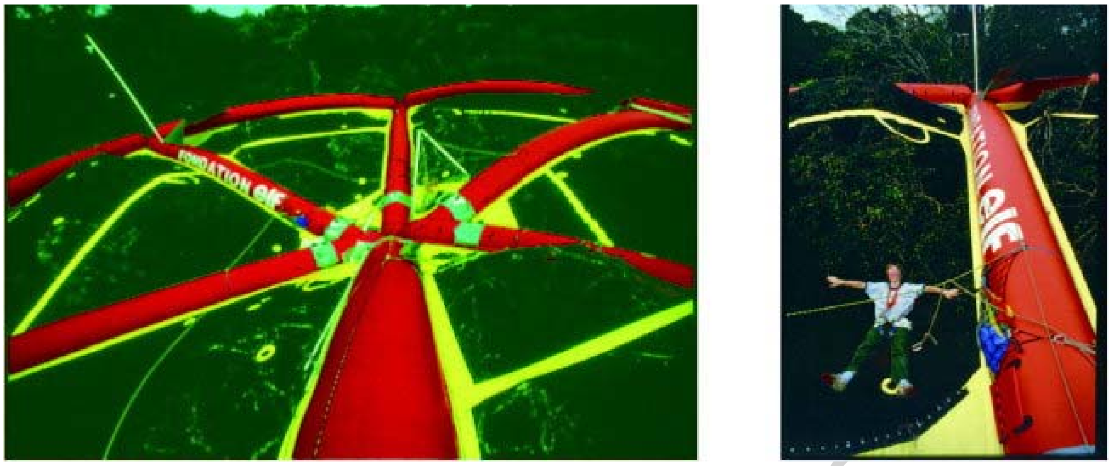

Figure 5. The canopy raft serves as a base camp for researchers in the canopy.

Alan Smith, during his research career with Smithsonian Tropical Research Institute in Panama, first considered the notion of using a construction crane for treetop exploration in 1990. A 40-m long crane was erected in a Panamanian dry forest, and since then, seven other crane operations have commenced. Cranes are quite expensive to install and operate (usually ranging from $1 to $5 million), but they offer unparalleled access to the uppermost canopy as well as to any section of the understory that is within reach of the crane arm (Figure 6).

Figure 6. Construction cranes provide comprehensive access to a relatively small section of forest, and approximately ten cranes are currently in use worldwide.

Andrew Mitchell, director of the Global Canopy Programme in England, aspires to create the most ambitious canopy tool ever, Biotopia. This concept integrates several field methods together, including cranes, walkways, canopy rafts, towers, and ropes, and it will essentially comprise a field station dedicated to canopy research.

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Biographical Sketch

Dr. Margaret ("Canopymeg") Lowman is Professor of Biology and Environmental Studies and Director of Environmental Initiatives at New College of Florida, the liberal arts, honors college for the state of Florida. As one of the first pioneers of canopy research, she also directs the Center for Canopy Ecology, serves as Vice President for the Ecological Society of America, and serves as the Vice President for Research and Education of The Explorers Club. Meg has used a wide variety of canopy access techniques to address a diverse array of research questions in the treetops and written over 95 peer-review publications as well as four books about forest canopy ecology.