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life in the Treetops - a planetary biodiversity hotspot

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Life in the Treetops – A Planetary Biodiversity Hotspot ~2000 words

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SUMMARY

Forest canopies are home to an estimated 50% of terrestrial biodiversity but remain relatively unexplored until just four decades ago (reviewed in Lowman and Rinker 2004). As one of the first global arbornauts to research this eighth continent, I share an abbreviated history of canopy science, and how treetop access has inspired forest conservation. The arboreal toolkit of ropes and harnesses, canopy walkways, dirigible and inflatable rafts, construction cranes, drones, and LIDAR has revealed that forests provide many important ecosystem services, essential for life on earth. Yet despite millions of research dollars, extensive time, and extraordinary intellectual capital, the degradation of tropical rain forests is accelerating and does not correlate with the extent of scientific investments (Racelis and Barsimantov 2013). A few case studies illustrate how canopy access methods can inspire innovative approaches to conservation: 1. Use treetop walkways for education and ecotourism, not just research, so that indigenous communities can earn sustainable income without logging; 2. Incorporate citizen scientists into forest field research through BioBlitzes or virtual technologies that are now relatively inexpensive and far-reaching; 3. Inspire girls, especially in developing countries, to become stewards of their local forests; and 4. Seek diverse stakeholders in forest conservation actions, including religious and corporate leaders. Can treetop exploration inspire a renaissance in botany, engaging the public about the importance of trees, forests, and their biodiversity?

SOCIETAL IMPACT STATEMENT

Forests are currently under global threat from human activities, despite the fact that recent findings confirm trees are critical for the health of humans as well as for the entire planet. Advances in *whole forest* research, which includes the upper reaches and not just the forest floor, are providing critical information about carbon storage, biodiversity, water cycles, and other essential ecosystem services provided by trees. The toolkit to study forest canopies is relatively new and vastly underfunded, despite our growing recognition of the global importance of trees. The forest canopy toolkit is proving instrumental to jumpstart innovative actions to conserve forest ecosystems.

KEYWORDS - forest canopy, treetops, conservation, walkways, arbornauts, tropical rain forests

Short History of the Canopy Research Toolkit

SCUBA gear was invented in the 1950s which expanded the scope of coral reef research, and humans went to the Moon in the 1960s, launching a new era of space exploration. A few early biologists, including Peter Ashton and Kamal Bawa, created rudimentary methods to study pollinators and flowering in Asian tropical canopies, but their techniques were not easy to replicate in multiple sites (reviewed in Lowman, Schowalter and Franklin 2012). The toolkit to explore the treetops in an affordable and replicatable fashion was not well developed until the 1980s, making canopy biology a very infant science (Lowman and Rinker 2004). Whereas astronauts study outer space, arbornauts explore the canopy. It seems extraordinary that the tops of trees, which exist commonly in backyards and streetscapes around the world, were not part of forestry research until the last few decades. The development of SRT (single rope techniques) and canopy walkways allowed forest scientists to engage in whole-forest research, instead of a narrow focus on the forest floor. Over the past several decades, new canopy access tools have facilitated whole-tree research. Concurrent with this chronology, a few seminal studies catapulted the world of canopy research, in particular the ground-based work of Terry Erwin, Smithsonian entomologist, who fogged tropical trees in Panama, causing insects to fall to the forest floor, and generated his astounding estimate of over 30 million species in the world (Erwin 1982).

For over one hundred years, most American foresters walked through the forest and essentially based all their findings on a narrow view at ground level. Occasionally, a tree was cut down that offered a chance for observations of its upper reaches, but more likely the entire trunk was harvested for profit. Several rudimentary canopy explorations were made during the mid-twentieth Century, including walkways built for Operation Drake from Oxford, England or a few medical towers used to study insect vectors in Asian tropical forests (Mitchell, Secoy, and Jackson 2002).

The first efficient, affordable, and easy-to-replicate methods to study whole forests came into practice in 1979. At that time, I started asking questions about leaf longevity in the rain forests of Australia, but a half a world away in Costa Rica another student from San Jose State University, California named Don Perry was also studying tropical forest ecology. We both independently determined that accurate tropical forest research required access into the whole tree, not just the forest floor. Don purchased some climbing equipment from American recreational outlets, while I sewed and constructed my own harness because Australia did not have access to those types of gear. In Australia, I also welded a slingshot in the university shop, which ultimately required a permit to maintain and operate. Because there was no internet at that time, neither Don nor I learned about one another until we both published our findings some three years later (Lowman, 1984; Perry, 1986). He went on to teach SRT to a handful of neotropical forest students, and I trained a bevy of researchers in the Austral-Asian forest ecosystems. The use of SRT spread quickly around the planet, and became a widely used, inexpensive tool to access the tops of almost any trees in any forests. This led to amazing discoveries about the critical importance of forests that were not accurately measured from ground level (Lowman and Moffett 1993).

The first canopy walkway for permanent education and research access was opened in Queensland, Australia during 1985. The owner of an ecotourist lodge and I designed this walkway both to educate visitors and to facilitate my teams of Earthwatch volunteers, so they could safely work in the canopy as a team (not solo) and during the night or inclement weather, otherwise impossible with single rope techniques. This first walkway was constructed in Lamington National Park, but within several months another was completed in Lambir National Park, Malaysia by Maryland engineer, Ilar Muul. These two walkways, ours with pole construction and Muul's using cabled necklaces strung around tall trees, set the stage for future construction of walkways throughout the world. Both designs are useful in different situations, depending on topography, tree height, visitors, and diversity of uses. Increasingly, walkways provide sustainable income from ecotourism to indigenous people who serve as naturalists, boat operators and lodge operators, instead of earning short-term income from logging (Lowman, 2009). The proliferation of walkways has advanced treetop research in three ways: 1. Allowing teams of scientists to work together in the treetops; 2. Facilitating safe observations in the dark or during inclement weather, and 3. Inspiring long-term observations using devices such as camera traps, permanently marked leaves or epiphytes, and executing repeat-transects.

In the early 1990s, Alan Smith of the Smithsonian Institution, placed a construction crane amidst tall trees in Panama's tropical forests. This new technique was expensive (approximately a million dollars to establish, plus additional costs for a unionized crane driver), but offered detailed access to every leaf, insect, or reptile found within reach of a crane arm (Parker, Smith, and Hogan 1992). Cranes now exist in approximately ten locations around the world but require a significant budget to operate that is beyond the scope of most students and researchers. Three cranes are forthcoming in China's tropical forests, Panama still houses two, and Europe has several in temperate forests; while Venezuela, Queensland, and Oregon have dismantled their cranes.

A fourth, and perhaps the most innovative canopy access tool, involves inflatables. The French pioneered *Radeau des Cimes* (raft on the roof of the world) under the direction of Frances Halle of the Institut de Botanique in Montpelier France (Hallé and Pascal 1991). This includes a canopy raft, hot-air balloon and a sled to facilitate canopy sampling. The inflatables also require approximately a million dollars of funding to launch an expedition, but they historically have provided approximately 50 scientists to collaborate as a team throughout one expedition. Over time, the inflatables have surveyed the rain forests of Cameroon, Panama, Brazil, Gabon, and Australia (reviewed in Lowman, Schowalter, and Franklin 2012).

Some of the newest canopy access technologies include drones and LIDAR. While drones are still in pilot stages, and illegal in some regions, they offer relatively inexpensive overviews of forests, including the documentation of flowering phenologies, mapping of tree species, or detection of illegal logging. LIDAR (**LI**ght **D**etection **A**nd **R**anging) is a sophisticated aerial reconnaissance apparatus that requires a dedicated camera and airplane beyond the budget of most researchers, but offers extraordinary information on canopy health, growth history, and physiology (Asner, Martin, Anderson, and Knapp 2016). Arizona State University currently houses a major center for LIDAR under the leadership of Greg Asner and Roberta Martin, where they have combined LIDAR with HiFIS (high-fidelity imagine spectroscopy), to quantify the California drought through overflights that accurately calculated tree mortality (Asner, Brodrick, Anderson, Vaughn, Knapp, and Martin 2015). Applications of LIDAR and related aerial imagery almost supersede the need for ground-truthing (aka climbing), but not quite! Recent research on redwood transpiration was most successful using a combination of LIDAR and climbing (Ambrose, Baxter, Martin, Francis, Asner, Nydick & Dawson 2018), where they calculated these tall trees transpire up to 500-800 liters of water daily.

Applications of Canopy Access to Forest Conservation

The ability to study whole forests from bottom to top not only expanded our understanding of trees, but canopy access has more recently inspired innovative approaches to conservation. One of the most important efforts is the application of canopy walkways to facilitate forest conservation. One example is the ACTS canopy walkway, located in Amazonian Peru on a tributary of the Napo River, that includes twelve bridges and thirteen platforms over a quarter mile. This structure provides research access to over one hundred species of trees, epiphytes and vines, but perhaps more important, employs over 100 families who make a sustainable living from ecotourism. The existing conservation reserve of 4000 acres has expanded to over one million acres, with indigenous people serving as excellent stewards who prevent poaching because they recognize the importance of keeping the forest intact. Similar links between walkways and local economies exist in other tropical forests, offering an effective bottom-up conservation solution.

Other ways to ensure more effective conservation is to engage a broad array of citizens in field science. The Jason Project, developed by Bob Ballard of Titanic fame, reached millions of middle school youth who virtually visited different marine and terrestrial landscapes (www.jasonlearning.org). I hosted three seasons of virtual canopy exploration with the Jason project, and still hear from young people who ultimately pursued a career in field biology as a result of these school programs (see also Lasky, 1997). Citizen science engagement via BioBlitzes or expedition travel for wannabe scientists also provide effective public conservation education about forests. The engagement of girls, especially in developing countries where they are often the stewards of pollinators, fresh water and firewood, is especially important; and local conservation benefits by empowering women as stakeholders (Lubchenco et al 2016). In Ethiopia, the Coptic or Christian Orthodox priests are the stewards of their last remaining primary forests, that exist in church yards (Lowman, Schowalter, and Franklin 2012). By partnering with the religious leaders, I was able to implement effective conservation of the last remaining church forests by building simple conservation walls with the priests' blessing. These walls exclude cattle and goats from eating the seedlings, reduce firewood collection, and keep the farmers from plowing too close to the forest edges. Such unique collaborations like religion and science can conserve forests more effectively through bottom-up conservation than conventional top-down leadership activities (Lowman and Pallaty 2018).

Future Opportunities

Canopy research is still in its infant stages, but the arbornaut's toolkit is now adequate to explore the whole forest, not just the forest floor. With additional resources, forest canopy access will undoubtedly lead to more discoveries of cryptic biodiversity and quantify the resiliency of tree species with impending climate change. Simple ways to engage locals in bottom-up conservation of global forests include the construction of canopy walkways for ecotourism, the engagement of all ages (and especially girls) in canopy research that in turn educates them about the value of trees, and conservation partnerships between scientists and diverse stakeholders.

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Photo Legends

1. Single rope techniques (SRT) was the first generally used canopy access technique, beginning in the 1980s.
2. Canopy walkways facilitate team research and long-term monitoring, as well as to foster conservation by providing income to indigenous people through ecotourism.
3. Drones offer easy access to flowering/leafing phenology, or mapping the canopy in this image of a new walkway in Quechee, Vermont.

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514x386mm (180 x 180 DPI)

2. Canopy walkways facilitate team research and long-term monitoring, as well as to foster conservation by providing income to indigenous people through ecotourism.

327x219mm (300 x 300 DPI)

3. Drones offer easy access to flowering/leafing phenology, or mapping the canopy in this image of a new walkway in Quechee, Vermont

451x254mm (72 x 72 DPI)