Margaret Lowman · Soubadra Devy
T. Ganesh *Editors*

# Treetops at Risk

## Challenges of Global Canopy Ecology and Conservation

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# Foreword

E.O. Wilson has said that we are letting "nature slip through our fingers." Depleting Earth's fabric of life means we could slip through hers. In a few decades, I have personally witnessed the loss or serious decline of about half of the coral reefs, kelp forests, seagrass meadows and mangroves, elimination of 90 % of many kinds of fish and other ocean wildlife, creation of hundreds of coastal dead zones, a sharp reduction in oxygen-generating carbon dioxide-absorbing phytoplankton, acidification of the ocean, acceleration of global warming, a swift reduction of polar ice, and introduction of tons of toxins and plastic into the blue heart of the planet.

The good news is that we have arrived at the "sweet spot" in our history. Never before could we so clearly grasp our dependence on – and loss of – intact, living systems that underpin everything we care about. Never again will there be a chance as good as the present time to restore and protect the natural systems that keep us alive. Now we know what no one knew when I was a child. Making peace with nature is the best hope for having an enduring future for humankind.

In this volume, international forest scientists describe the challenges, methods, and their hope for conservation of these terrestrial systems. Like the oceans, forests are critical hot spots for biodiversity, and their future health is intertwined with that of humans.

Raleigh, NC, USA — Sylvia Earle (aka "Her Deepness")

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# Part I
# Emerging Issues

## Introduction

The notion of "treetops at risk" is an understatement. According to Laurance (this section), over half of the world's original forests have been destroyed. Although tree-planting remedies often occur, many countries restore nonnative forests or plantations, both of which have significantly different impacts on planetary health. In this first section, called "Emerging Issues," authors comment on challenges facing our global forests—from logging to climate change to insidious shrinkage of forest boundaries, the human race is intent upon reducing the world's forest resources. Canopies are part of this critical package—forest canopies provide unique ecosystem services to all life on Earth, and so the notion of "treetops at risk" indicates our current plight. The authors in this section represent synthesizers, leaders, and consensus builders in the world of canopy biology. They all spoke at the 5th International Canopy Conference in Bangalore, India, during 2010. From that collaborative conference, this book had its inspiration. In this introductory section, authors provide commentary about solutions, threats, and the future of global forests and their canopies.

# Chapter 1
# The Role of Scientific Conferences to Foster Conservation Solutions for Global Forests

**Margaret Lowman, Soubadra Devy, and T. Ganesh**

**Keywords** Canopy conference • Science education • India • Forest conservation

The professional group of biologists who prioritize studies of the forest canopy hosted their first international conference in Sarasota, Florida, in 1994, and the field's first textbook was published the same year. Subsequently, canopy scientists have convened a dedicated conference every 4 years, with a mission of advancing the scientific field through collaborative exchange of ideas. For its first time ever, the fifth International Canopy Conference (ICC) convened in an emerging country, hosted by Ashoka Trust for Research in Ecology and the Environment (ATREE) in Bangalore, India. Also, for the first time ever, education outreach was added as a new session to the conference agenda, including a highly popular canopy education workshop that drew Indian students, teachers, scientists, and stakeholders from all regions of the country. This session was advertised as an open forum where laypersons and teachers could interface with canopy scientists, who enthusiastically shared their experiences, thereby taking science outside the conventional walls of academia. In a country like India, this was groundbreaking. In subsequent feedback, we were inspired by the reports of burgeoning education outreach activities in India spawned by this conference session.

Like many developing countries, India needs success in advancing its forest conservation. The Western Ghats forest region in southern India is one of India's

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**Fig. 1.1** Teaching Indian students about canopy access

four designated biodiversity hotspots, and the other three also contain critical forest habitat. India is losing 2 % of its forests annually (see Seidler et al.'s chapter), and charismatic megafauna such as tigers, leopards, and Indian elephants remain poster children for India's forest conservation, as well as the potential economy of ecotourism for future generations. The promotion of education outreach at the ICC fostered new enthusiasm in forest canopy conservation using canopies as a "hook" to inspire rapid action. New outreach programs promoted by canopy scientists throughout India after this conference included (1) tree planting programs in schoolyards, (2) citizen surveys of butterflies, (3) Fulbright funding for canopy education outreach, (4) participation by canopy scientists in Earthwatch field courses for HSBC Bank employees, (5) graduate training programs in canopy access (Fig. 1.1), (6) publication of a canopy science book for the public, and (7) a certificate course in conservation for young professionals. All these activities illustrate the genesis of a new

**Fig. 1.2** Future women scientists of Assam, India

culture among Indian canopy scientists to engage in education outreach. One year later, hundreds of Indian students and thousands of citizens benefited directly from this one session at the canopy conference.

The notion of including science education and outreach as part of a technical scientific conference agenda was not part of the first ICC, nor of many other scientific meetings several decades ago. Almost 100 years old, the Ecological Society of America (ESA) has witnessed an exponential increase in education sessions at its annual meetings, from less than five in 1990 to over 25 in 2010. The emerging priorities of communicating science and fostering education of diverse stakeholders is an increasingly important platform for scientific conferences, especially given the urgent priorities for STEM (science, technology, engineering, and mathematics) education initiatives in many countries. In India, the priority of education outreach at the canopy conference provided a new model for scientific meetings. This session fostered discussion of a critical question: Will canopy scientists pursue business-as-usual in the face of significant forest degradation, or challenge themselves to do things differently, such as prioritizing education of youth, policy makers, and citizens? Keynote speaker Dr. Thomas Lovejoy (former President, Heinz Center for Economics and Environment, Washington, DC) remarked to the international attendees, "By any measure, tropical forests are in big trouble." But to date, none of the four prior forest canopy conferences celebrated clear links between conventional scientific data collection and forest conservation. The Bangalore, India, conference, for the first time ever, inspired conversation about the role of women in science (especially for developing countries) (Fig. 1.2) and the notion of actions to educate

**Fig. 1.3** Environmental education in rural India – bird spotting

many diverse stakeholders about the importance of their environment. Will innovative approaches for both research and education aimed at engaging citizens and policy makers to achieve better metrics of success for forest canopy conservation?

In India, the notion of "treetops at risk" is a clear threat to human quality of life and also to ecosystem health. Over one hundred teachers of India's southern states representing diverse cultures, ages, gender, and religions eagerly attended the conference and listened to important take-home messages: (1) develop short courses in canopy science for teachers, citizens, and K-12 (Fig. 1.3); (2) create climate change awareness in schools and for regional government; (3) share resources; and (4) plant trees to "green India" as a strategy to offset climate change and sustainable services.

The ICC fostered a dialogue where a combination of economics and environment, via more effective science communication and education outreach, may hold the key to producing a scientifically literate generation of citizens and policy makers. If every practicing scientist were to give 10 % of his or her professional time to education outreach, not exclusively limited to technical publications, then perhaps the notion of a scientifically literate public could be attained. Currently in India and elsewhere, many science professionals still think that education outreach does not fall into their purview. The expanding footprint of education integrated with science at technical conferences provides one metric of hope for improving science literacy among diverse stakeholders, not just scientists.

This volume was inspired by the 5th International Canopy Conference held in Bangalore, India, but the authors and issues have subsequently burgeoned, as has the mission of this book. By sharing the story of Bangalore, we hope to set the stage for this book as a “wake-up call” for scientists in many fields of expertise – we must not only uncover the secrets of how ecosystems operate, but we must also disseminate our findings in a manner that inspires conservation and solutions by the diverse stakeholders that comprise the seven billion people of planet Earth. The stakes for conservation have never been higher. And the ultimate height of the forest canopies represents an epicenter for many global solutions – carbon storage to offset global warming, biodiversity of millions of species, productivity of billions of leaves, shade for humans, freshwater cycling, and essential spiritual sanctuaries.

# Chapter 2
# Greening the Planet?

**Thomas Lovejoy**

**Keywords** Climate change • Carbon sequestration • Ecosystem restoration

In 1896 Swedish scientist Svante Arrhenius addressed a very important question: Why is the Earth a habitable temperature for humans and other forms of life? Why isn't it too cold? The answer (building on the work of the British scientist Tyndall earlier in the century) was the greenhouse effect. He even did a quite accurate projection of what double preindustrial levels of $CO_2$ would do to planetary temperature. What he would not have known was the detailed history of planetary temperature for the previous hundreds of thousands of years – in particular that the last 10,000 years were an unusually stable period of global climate and temperature. During those ten millennia, much of modern civilization (agriculture, human settlements) developed, and all ecosystems adjusted to a stable climate.

That of course is changing because of human activity and rising levels of carbon dioxide in particular. Global temperature is currently approaching 0.9° increase over preindustrial levels. $CO_2$ concentrations are approaching 400 parts per million (ppm) versus 280 ppm in preindustrial time. The lag between reaching a concentration level and the accumulation of heat means that the planet will reach another 1.0° increase even if $CO_2$ concentrations rise no further. Most of the response to climate change to date is relatively minor. Nonetheless, there is substantial reduction in glaciers in the tropics and sea ice in the Arctic Ocean. Sea level is rising in part because of thermal expansion of water but increasingly because of glacial melting. While the sea level end point is fairly clear from understanding past climates, the rate at which it will be reached is not.

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There is definite increase in the frequency of wildfires from warmer summers, earlier snowmelt, and in certain instances drought associated with climate change. In Costa Rica's Monteverde Cloud Forest, an increasing number of dry days are recorded, since clouds tend to form at higher altitudes more frequently than in the past. This could lead to major change if the trend continues because those forests depend primarily on condensation from clouds as a source of moisture.

Already we are seeing responses in nature. Species are changing their annual cycles: flowering species blooming earlier, birds nesting earlier, and the like. Species are already changing where they occur, e.g., the Edith's Checkerspot Butterfly is clearly moving northward and upward in altitude in western North America. With double preindustrial levels, it has been projected that sugar maple will occur in Canada but not New England. Mostly seen so far in temperate and boreal habitats are decoupling events in which two coincident features of nature begin to disassociate because one uses temperature as a cue and the other day length. These are all relatively minor changes, essentially ripples in nature. Nonetheless, this kind of change is being detected in almost every place that scientists look. So this is now statistically robust.

More serious abrupt change is also beginning to be detected. Tropical coral reefs are particularly sensitive to short periods of elevated water temperature and undergo bleaching events. These are happening with increasing frequency every year with grim implications for the one-twelfth of humanity that depends on the reefs for well-being. Similar abrupt change is occurring in the coniferous forests of western North America. There warmer summers and milder winters have tipped the balance in favor of native bark beetles leading to massive defoliation and subsequent tree mortality (up to 70 % of stands in some instances). Even larger-scale change is being detected in terms of ocean chemistry where elevated $CO_2$ absorbed by the oceans also produces carbonic acid. Ocean pH is already 0.1 pH unit more acidic than in preindustrial times. This carries enormous implications for animal species that build shells or skeletons of calcium carbonate.

In the Amazon the hydrological cycle that produces much of the rainfall and works synergistically with the rain forest (in addition to providing rain further south in agricultural regions) may be approaching a tipping point. A World Bank model of the combined effects of fire, deforestation, and climate change suggests a possible tipping point leading to Amazon dieback in the southern and eastern Amazon at around 20 % deforestation. It is currently at about 19 %. This has significant implications to the health of forest canopies. Looking ahead, we can anticipate that additional climate change would disproportionately affect island species and species at high altitudes. And from past climate change, we know that ecosystems do not move but rather that individual species move individually: almost an ecosystem disassembly with surviving species forming novel ecosystems that are hard to manage in advance.

All of that argues strongly that the 2° of increase that is the target of negotiations is really too much for most ecosystems. Yes, one can make species less vulnerable by restoring natural connections in landscapes. In the end, however, it becomes imperative to seek ways to reduce the amount of climate change that would otherwise take place. Geo-engineering schemes which purport to do so mostly do not because they address temperature (the symptom) rather than the cause (greenhouse gas concentrations). The biology of the living planet can be particularly helpful. A substantial amount of the excess $CO_2$ in the atmosphere actually comes from three centuries of destruction and degradation of ecosystems. Ecosystem restoration at a planetary scale could easily draw down 50 ppm from the atmosphere by converting it into thriving forests, grasslands, and agroecosystems. It is not enough, so we need to find economic ways to do so non-biologically.

It is time to recognize that this planet works as a linked biological and physical system and we should manage it as such. Re-greening the Emerald Planet will make Earth more habitable for ourselves and other forms of life. Efforts to plant trees and restore forest canopy cover represent an important stewardship action.

# Chapter 3
# Comparative Canopy Biology and the Structure of Ecosystems

**Mark W. Moffett**

**Keywords** Architecture • Biofilm • Biodiversity • Biomechanics • Coral reef • Epiphyte • Kelp • Periphyton • Rhizosphere • Stratification

## 1 Summary


- The way ecologists think about canopy biology as a scientific discipline could lead them to overlook different communities of spatially fixed organisms that may have properties usefully compared to or contrasted with forest canopies. This chapter represents a series of discussions and reviews on the possible nature and limits of canopy biology and introduces the prospect of a general comparative science of biological canopies.
- Rather than restricting canopy biology to plants in terrestrial systems, I argue that *canopy* can be defined in terms of the parts of any community of sessile organisms that emerge from a substratum, the structural products derived from them included. This opens the field to diverse communities that could share many properties with forest (or plant) canopies. I overview the canopy literature on kelp forests, algal turfs, periphyton, bacterial films, and coral reefs. The word *canopy* has already been applied to each of these ecosystems. Periphyton and biofilms in particular have great potential as model systems for studying assembly rules for the physical structure and dynamics of canopies.
- Among the similarities and differences between these types of canopy are the distribution of resources, such as light and nutrient gradients; factors affecting these distributions, such as the flow of air or water; and the resulting disposition of


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