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The Canopy of a Temperate Floodplain Forest

Results from five years of research at the Leipzig Canopy Crane

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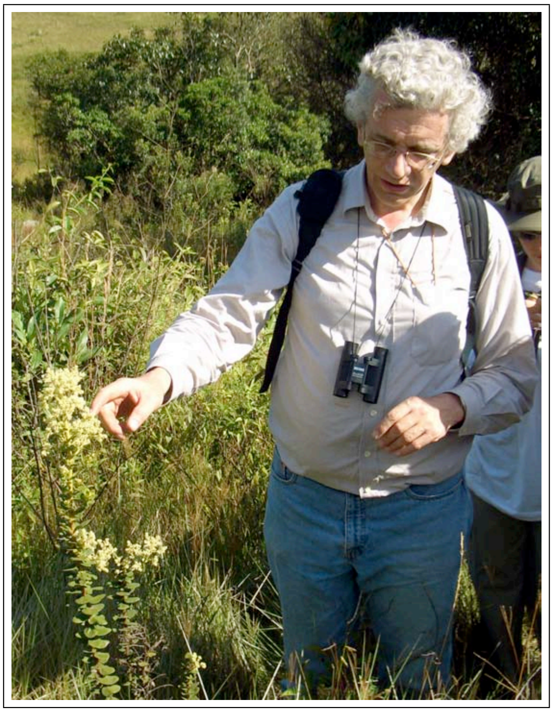

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We dedicate this book to the late Prof. Dr. Wilfried Morawetz, who died too young and unfortunately did not live to see its publication. Without his visionary enthusiasm, leading to the setup of two canopy crane research facilities (Surumoni and LAK), the world of canopy research would definitely be the poorer. His passing away leaves a big void in canopy science.

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Foreword

Welcome of the Head of Environment, Public Order and Sports.

Why the city of Leipzig supports the Leipzig Canopy Crane Project? Leipzig's floodplain forest is in many aspects a worldwide uniqueness.

While most of the cities are happy if they are surrounded by many forests, most of Leipzig's floodplain forest stretches across the densely populated urban area. Therefore it is an intensively used recreation area for our citizens, which has to match a lot or requests, like hiking, cycling, jogging, riding, or making campfire.

But Leipzig's floodplain forest is also an area with a huge biodiversity. More than 40 tree species, 100 breeding birds, many rare butterflies and beetles are registered in large numbers that are unique in Central Europe. Nevertheless the natural scenery is also characterised by intensive, but sustainable forestry operations producing valuable timber an other products, e.g. seeds, for hundreds of years.

The city of Leipzig, one of the biggest non-state owners in the floodplain forest, takes care for the guarantee of its recreation function, for the conservation of its biodiversity, and for the sustainable utilisation of its products. But without comprehensive knowledge of the forest ecosystem it is not possible ot match and balance the functions mentioned before. Therefore the Leipzig Canopy Crane Project is not only an interesting research project, which is supported by the city of Leipzig, but also a tool to gain new fundamental insights into the functioning of our woods. This is of crucial importance in order to make well-founded decisions which can effect the Leipzig floodplain forest in many ways.

This is the reason, why the city of Leipzig will furthermore support the Leipzig Canopy Crane Project within the scope of its possibilities.

Inge Kunath
Head of Environment, Public Order and Sports

Preface

The Leipzig Canopy Crane (LAK) project started in March 2001. Since then it is one of few scientific ventures in temperate regions that focuses on biological diversity in tree crowns and it is the first that investigates the ecosystem riparian forest both on the forest floor and in the forest canopy. As every project designed for long-term ecological studies, the LAK project saw its first years in the meticulous survey and monitoring of the investigation site, which is an indispensable necessity for subsequent studies of functional aspects, interdependencies of organisms and structural components.

This volume presents a comprehensive overview of the main scientific activities from studies of soil reliefs over tree genetics and tree phenology to arthropods, bats, and fungi that populate the forest canopy.

This book is designed to meet the attention of scientists involved with canopy research. As it also aims inspiring every ecologist, a brief summary of past and present scientific activities in forest canopies follows this chapter. We hope that it will help the unprovided reader getting familiar with foggers, climbing gear, and canopy cranes.

The first chapter "Soil attributes, stand structure, and aspects of forest regeneration" imparts detailed knowledge of basic components of the investigation site. Starting with high scale soil reliefs, soil topography, and changes in soil compositions (Krüger *et al.*) the reader will also learn about the high diversity of woody plant species in the investigated area (Seele), of vertical light transmittance patterns (Horchler), and of the canopy surface structure of the forest stand (Rohrschneider *et al.*) as a fundamental basis for the following papers of species diversity, distribution of organisms, and organismic interaction. Knowledge of forest regeneration dynamics is of outstanding value in the context of the LAK project that functions only in conjunction with the city's forestry (see foreword by Inge Kunath). Homscheid & Horchler examined patterns of leaf fall, whereas the paper by Schöne & Jentsch provides detailed information about the history, the current situation, and succession tendencies of Leipzig's riparian forests and highlights the influence of brown coal mining activities, river straightenings and air pollution over the ecosystem.

By getting to the second chapter "Tree phenology, genetic variation, and herbivory", the reader likewise reaches the forest canopy. Tal & Morawetz supply evidence that investigating processes in the canopy – in that case flowering and fruiting phenology – is needed to understand patterns that are observable on the forest floor (e.g. seedling establishment). Tal & Morawetz elaborate complex gender distributions among tree species and individual trees. The study of Parolin *et al.* present a starting point for further investigation of somatic mutation within trees. Slowly but surely, we come up to the huge world of canopy arthropods. Mitcherling & Horchler assessed the extent of herbivory as a key process in forest ecosystems, ecosystem compartments and trophic levels across space and time by inspecting damage of living foliage in the canopy. Another study of herbivory focused on the leaf quality of a single tree species with respect to palatability of leaves and larvae development in time and space (Ruhnke *et al.*).

The third chapter is almost completely dedicated to studies of arthropod diversity and distribution within the canopy. On the basis of standardised sampling protocols (Arndt & Unterseher), the papers easily can be compared with each other and stress once more the importance of a forest rich in tree species and structural components for the sustainment of biodiversity. Using a combination of different trap types a comprehensive analysis of the diversity of spiders from the trunk layer and the canopy was realised by Stenchly et al. The study of bugs (Heteroptera) was conducted in the canopy layer and assessed the tree association of the insects (Arndt *et al.*). The Investigation of Gruppe also focused on one taxon, the Neuropterida, which can be generally regarded as poorly studied. His results revealed an inter alia separation of the neuropterid communities on different tree species. Because of a large amount of dead branches in the canopy, it was assumed that the diversity of arthropods, which depend on this substrate is also high. Schmidt *et al.* confirm this hypothesis. He and his colleagues could identify 175 species of xylobiontic beetles (Coleoptera). Within the ecological guild of mycetophageous beetles they found significant differences in numbers of species on different tree species building bridges to the mycological studies of Unterseher & Tal at the end of the chapter. Arndt & Hielscher studied a second group of Coleoptera, the ground beetles (Carabidae). The species set of the canopy could be divided into several ecological groups, such as strictly arboricolous species as well as species with ground-canopy interactions.

Fröhlich *et al.* assessed the diversity of nocturnal macro-Lepidoptera. With around 1000 individuals analysed they make first statements of spatio-temporal activity patterns of these organisms. Floren & Sprick finally knocked down more than 95 000 arthropods by means of fogging canopy trees close to the crane site in spring 2003. They present an exhaustive overview of arthropod diversity in this central European forest canopy and point to the great importance of the organisms for many processes in the ecosystem.

Studies of vertebrates are almost completely missing in this volume, though there is considerable activity of squirrels, tree frogs, and of course, of birds in the canopy of the crane site. In 2003 the work of a diploma student revealed an extraordinary species richness and abundance of bats. Within only one vegetation period she could detect 15 species (about 75% of all species recorded in Saxony) and distinct niche separation at the crane site (Fichtner 2004, unpublished diploma thesis). Rieger & Nagel take up this study and present own data gathered during an intensive monitoring period of two weeks. As a result, they obtained an impression of the daily "when" and the three-dimensional "where" of bats in a temperate deciduous forest. First results from an ornithological study in spring 2005 indicate a high number and density of bird species with distinguishable activity patterns in different forest patches and tree species.

We are indebted to many colleagues and institutions who contributed with great efforts to the successful start of the Leipzig Canopy Crane (LAK) Project and the realisation of the present volume: all contributors to this book; the Helmholtz Centre for Environmental Research – UFZ for funding the first six years through the projects UFZ-16/200 and UFZ-04/2004; the Faculty of Biology, Pharmacy and Psychology and the Department of Planning and Technology (Dezernat Planung und Technik, Abt. Betriebstechnik und Betriebsfhrung) of the University of Leipzig for further financial support; the Environmental Protection Office (Amt für Umweltschutz, Leipzig), the Office for Green Spaces, Department of Urban Forests (Grünflächenamt, Abt. Stadtforsten, Leipzig), and the Botanical Garden (Förderverein des Botanischen Gartens, Leipzig) for financial, technical and personnel support over the last seven or more years; the regional council (Regierungspräsidium, Leipzig) for providing the required permissions for our investigations in the protected forest area; Peter J. Horchler, the first coordinator of the project. We thank Kronen – Verlag, Hamburg for providing the beautiful, introductory illustrations for each of the three parts.

Finally, we are especially grateful to Mr. Andreas Sickert, Head of the Department of Urban Forests Leipzig. His great personal effort, his professional and profound suggestions and recommendations throughout the years contributed largely to the scientific concepts of the LAK Project.

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A short introduction to canopy science

Martin Unterseher

Figure 1 – Panorama view of the riparian forest canopy at the crane site in Leipzig.

BEGINNINGS

It is nearly impossible to define an exact starting point for canopy research because the hidden life in the treetops attracted naturalists such as Alexander von Humboldt for a long time. One of the first successful attempts to explore the rainforest roof was made in 1929 during an Oxford University expedition to Moraballi Creek in British Guiana. With an enormous assortment of military equipment such as rocket-firing machines, line-throwing guns or rope ladders, and the help of many natives, the explorers managed to reach several crowns without felling the trees and to install simple, temporary platforms (Mitchell 1989, pp. 23–25).

Apart from this rare example, serious investigations of forest canopies started in the second half of the 20^{th} century not until new methods of reaching the treetops were successfully established. With permanent platforms or towers it was then possible to conduct longer or even permanent studies in tree crowns. The most famous canopy project at that time were certainly the studies on the steel tower in Mpanga Forest in Uganda. Built by the East African Virus Research Institute, it followed the trends of studying mosquitoes and other tropical biting insects since the secret of yellow fever cycle was disclosed in the mid 20^{th} century by Jorge Boshell and others (e.g. Bugher *et al.* 1944; Galindo & Trapido 1955). The studies of Corbet, Haddow and others (Corbet; Haddow & Corbet; Dirmhirn, all 1961) revolutionised the perception of ecological processes and abiotic parameters high above the forest.

CLIMBING FOREST TREES

Almost two decades later canopy scientists used further technologies adapted to biological research in tropical forests and launched the next generation of canopy science. One certainly could cite the initial works of Perry (1978), Erwin & Scott (1980) and Erwin (1982) as milestones in canopy research. For the first time, Donald Perry used climbing gear that was slightly modified from alpine techniques to meet the demands of tropical forest canopies. He and his colleagues built cobweb-like nettings high above the ground on which they managed to move inside the canopy up and down, and from treetop to treetop. Thus they could assess and demonstrate the separation of organisms (e.g. moths and bees) and dynamics (e.g. flowering and pollination) systematically from the forest floor to the upper canopy (e.g. Bawa *et al.* 1985). With their work Perry and his colleagues are exceedingly responisble that the vertical stratification of tropical forests is generally accepted in tropical biology nowadays (e.g. De Vries *et al.* 1997; Schulze *et al.* 2001)

FOGGING TREE CROWNS

Unlike Donald Perry, Terry Erwin and Joachim Adis (Erwin & Scott 1980; Erwin 1982; Adis *et al.* 1984) studied the canopy fauna from the forest floor. They used motor-driven 'foggers' to blast insecticides up into the tree crowns and collected the downfalling arthropods for identification. With their results and estimations of arthropod communities and species diversity in forest canopies (Erwin 1988), they expanded tropical biology and the discussions of global biodiversity to a great extent (e.g. Hawksworth *et al.* 1995; Ødegaard 2000; Ødegaard *et al.* 2000) and even encouraged the 'skeptical environmentalist', Bjørn Lomborg, to critically debate on "how many species are there" (Lomborg 2001, pp. 249–257). The method of fogging trees is widely used with several modifications in canopy research these days (e.g. Henry & de Paula 2004; Schonberg *et al.* 2004; Floren & Linsenmair 2005; Novotny & Basset 2005; Battirola *et al.* 2005) and is an effective tool to consistently bringing to light new arthropod species, genera and even families and orders. This is not surprising as many organisms are predicted to be canopy specialists that, if ever, are rarely seen at ground level (Ozanne *et al.* 2003).

CANOPY CRANES

The first installation of a construction tower crane for canopy research in a tropical forest in Panama in 1990 (Parker *et al.* 1992; Smith *et al.* 1993) marked the establishment of the perhaps most effective method to study forest canopies (Körner pers. comm.). Given that the crane is installed and that it is supplied with stable electricity, scientists, operating from a gondola, can virtually reach every location in the three-dimensional catchment area of the crane's jib whenever it is required. The longer such a crane is operating, the cheaper are its maintainance expenses. Furthermore it moves almost soundlessly and apart from cutting a small gap to erect the crane, damage to the investigation site can be reduced to a very minimum. If the crane is mounted on a railroad track (Kirmse *et al.* 2003; Morawetz & Horchler 2004; Unterseher *et al.* 2004; 2005; Unterseher & Tal in press), larger areas and more trees can be studied which increases the amount of useful data (Körner *et al.* 2005). The construction crane as a research tool was so successful that other cranes quickly followed that of the Smithsonian Tropical Research Institute in Panama and are now operating in a variety of both temperate and tropical forests (Mitchell *et al.* 2002; Basset *et al.* 2004).

TOPICS OF CANOPY RESEARCH

As I elaborated on above, the focus on canopy science lay in the tropics from the beginning on, and still does. Considering the number of tower cranes as a research tool, canopy studies in temperate forests are gaining equal priority. This is justified as patterns and processes of temperate forest canopies are far beyond our understanding (Körner *et al.* 2005) and the investigation of organismical diversity seems to be as valuable as in the tropics (e.g. Schmidt *et al.* 2003; Unterseher *et al.* 2005; Arndt 2005; Unterseher & Tal 2006; Schnittler *et al.* in press).

Studying arthropod communities in treetops was very popular *ab initio* in canopy research, since arthropod diversity is huge and promised to be still higher as canopies could be included into the investigations. In the last few years, several books and book chapters about arthropods in forest canopies have been published encompassing dozens of papers and hundreds of references on this massive topic (Stork, Adis & Didham 1997; Basset *et al.* 2003; Erwin 2004; Lowman & Rinker 2004).

Herbivory in forest canopies is closely linked with arthropods since insects play the most important role in leaf-damaging. As its comprehensive study additionally requires analyses of plant-specific processes (e.g. photosynthesis, nutrient contents, and defensive mechanisms of plants), it is mostly treated separately from entomological studies (Lowman 1995; Rinker & Lowman 2004, Shaw 2005).

A third area of canopy science with an increasing mass of publications is the field of remote sensing and the investigation of abiotic patterns in and between tree crowns such as forest structure, light regimes, temperature, or humidity. With modern laser devices (Lefsky *et al.* 1999; 2002), with the combination of canopy cranes and manual perpendicular measuring (Unterseher & Tal 2006), or with data loggers recording small-scale climatic data, canopy models can be computed and provide important information to assess the history and dynamics of an investigation site (Ishii *et al.* 2004; Nadkarni *et al.* 2004), or the dispersion and diversity of organisms in the canopy (McCune *et al.* 2000; Shaw 2004; Unterseher *et al.* 2005; Unterseher & Tal 2006).

The amount of studies and papers dealing with wood decay, leaf-parasitic, endophytic, or epiphyllous fungi, with lichens or other small organisms such as myxomycetes or nematodes still is evanescent but as the implementation of molecular techniques into ecological sciences is enhanced, these organisms probably are the forthcoming protagonists of canopy research.

TO BE CONTINUED

Apart from this brief overview of a fascinating and important science, there exist a number of comprehensive synopses of canopy research (LOWMAN & NADKARNI 1995; STORK, ADIS & DIDHAM 1997; LINSENMAIR *et al.* 2001; MITCHELL, SECOY & JACKSON 2002; and LOWMAN & RINKER 2004), including free online material (BASSET *et al.* 2003). Because research in the treetops additionally is full of emotional sensations (e.g. floating above the forest canopy, Fig. 1) the media regularly approach our scientific activites with impressiv documentaries in television (e.g. ZDF[1] and BBC[2]). On the other hand, scientists too are trying to enhance the public awareness with many books and articles broaching the issue of canopy science in a more popular way (e.g. MITCHELL 1989; LOWMAN 1999; HALLÉ 2001; NADKARNI 2004; and LOWMAN 2005[3]).

Recent studies such as that of gliding ants in tropical forests (YANOVIAK *et al.* 2005) or the influence of elevated CO_2 on mature forest stands (KÖRNER *et al.* 2005) demonstrate that many more unexpected phenomena in the canopy still await the impartial scientist.

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