The Australian Canopy Crane

1999-2005

Supporting World Class Canopy Research

Discovering An Unknown Frontier:
The Rainforest Canopy

The forest canopy is where the atmosphere meets the biosphere. It is where photosynthetic processes take place and, not surprisingly, where most biotic interactions occur. Perhaps as much as half of all biodiversity on Earth is to be found in tropical rainforests, and a large proportion of this biodiversity is to be found within the canopy, referred to by some as 'the last biological frontier'.

This report provides a summary of the achievements in canopy research, training, education, and policy development resulting from the establishment of the Australian Canopy Crane Research Facility in 1998. First trialed by the Smithsonian Tropical Research Institute in Panama, the use of industrial cranes in tropical forests has opened up the canopy to exploration by scientists in the same way that the deep-sea submersible has provided access to the ocean floor. With the installation of the Australian Canopy Crane in the Daintree rainforest of far north Queensland, Australia now has a unique national research facility capable of providing vital information on a poorly known part of our rainforests – the forest canopy.

The purchase and installation of the crane and associated research station was funded by the Australian Research Council's Competitive Infrastructure Scheme and three initial partners, James Cook University, Griffith University and The University of Queensland. The Rainforest CRC and partner universities funded much of the research that was conducted during the crane's six years of operation. We hope that the new Commonwealth funded Marine and Tropical Sciences Research Facility, to commence business in 2006, will continue this support. We are grateful to a number of sponsors for their financial and in-kind support including Australian Geographic, Fuchs Oils, Coconut Beach Resort and an anonymous donor.

The Australian Canopy Crane forms part of the international Global Canopy Programme, a network that links studies of forest canopies worldwide. The facility has been used in over thirty research projects involving more than eighty scientists from Australia and overseas. Several core projects are providing long-term data on the rainforest canopy. The research team using the facility has an impressive publication and training record and is internationally recognised. Australian canopy researchers co-organised the Third International Canopy Conference in Cairns in June 2002, and co-authored a seminal paper on canopy science in the prestigious journal *Science* in 2003. Several researchers are key players in the Global Canopy Programme.

The Australian Canopy Crane represents an important national research asset. Over the past six years this significant investment has assisted Australia in developing a greater understanding of the unique rainforest canopy environment.

Professor Norman Palmer
Pro Vice Chancellor Research and International,
James Cook University

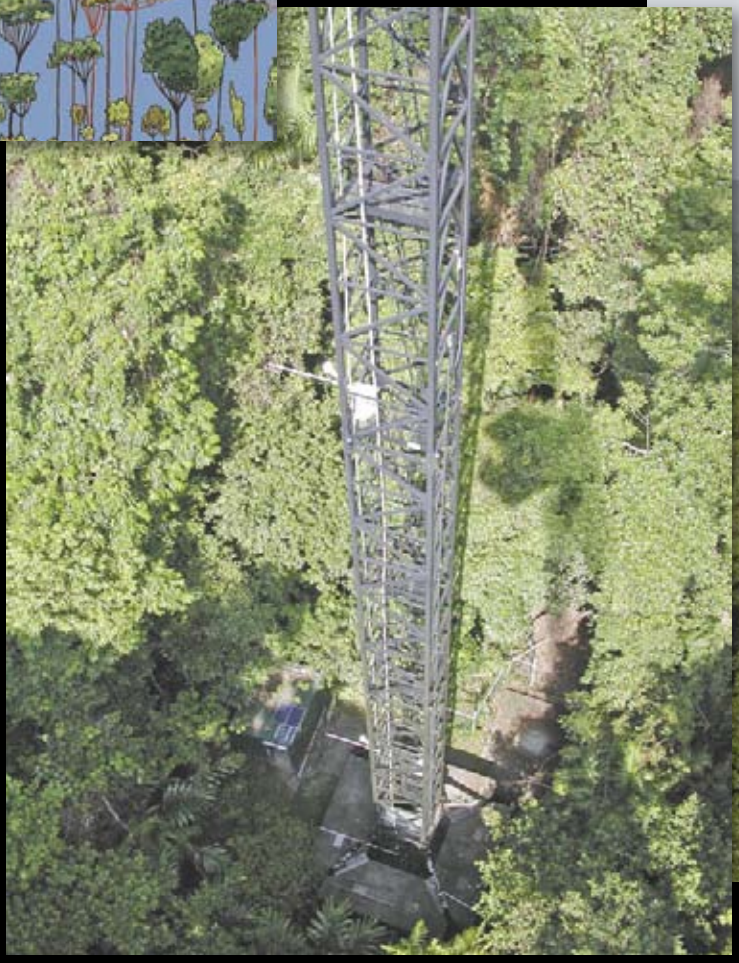
Professor Nigel Stork
Director, Australian Canopy Crane Research Facility
Chief Executive Officer, Rainforest CRC

Managed by the Rainforest CRC, the Australian Canopy Crane is a joint venture between James Cook University, Griffith University and The University of Queensland

features

The Crane Emerges

A conceptual diagram, showing the set up of the crane in relation to the forest canopy.



In November 1998, a two-day precision operation saw over 100 tonnes of steel and concrete lowered in 42 separate loads by helicopter into the rainforest as the Australian Canopy Crane, the first of its kind in the southern hemisphere, was constructed upwards from the ground. The Liebherr 91 EC, freestanding construction tower crane is located in forest abutting the Daintree National Park, less than two kilometres south of Cape Tribulation in far north Queensland. This area is home to many of the rare and endangered species of plants for which the region is famous. The crane is 48.5 metres tall and has a jib length of 55 metres, providing access to about one hectare of rainforest.

Researchers access the canopy from a 'gondola' suspended from the crane jib, which can be moved from ground level to well above the canopy and maneuvered anywhere within the arc of the crane jib. The gondola can carry up to three persons with computer and scientific equipment and cameras. The crane is operated by the Rainforest CRC's full-time crane driver, or by one of the onsite researchers who are fully trained and licensed to operate the crane, and is usually operated from within the gondola via a hand-held remote control. Researchers may communicate with ground staff based at the research laboratory through two-way radio.

The Wet Tropics of Queensland World Heritage Area (Image: Paul Reddell).

The Location

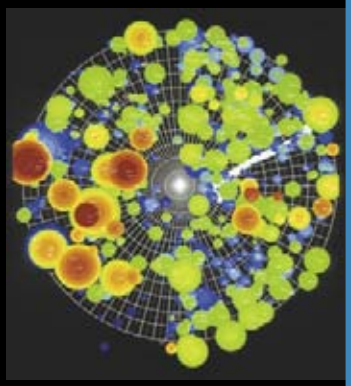
The average rainfall for the site is 3,500 millimetres a year, however averages have varied from 6,000 millimetres in 1999 to 2,500 millimetres in 2002. The site experiences a strong wet season with most rain occurring between December and April, although rain occurs in most months. Northern Australia is subject to tropical cyclones in the wet season and their occurrence is unpredictable. An automatic weather station is located in a clearing 500 metres from the base of the crane. Measurements since January 1999 are available for wind velocity and direction, rainfall, air temperature, relative humidity and solar radiation. The crane is also fitted with additional micro-meteorological instrumentation at 45 metres.

The Wet Tropics of Queensland World Heritage Area

Although rainforest currently covers less than 0.2% of Australia's landmass, some thirty million years ago about one third of the continent was covered in rainforest. As the continent moved northward and became drier the rainforests shrank. Today, about half of Australia's rainforests are found in the Wet Tropics Bioregion, a narrow tropical belt 400 kilometres long, occurring where the mountainous Great Dividing Range meets the sea.

These forests support about eight hundred species of vertebrates, many of which are endemic, and about five thousand species of plants, at least 1,300 species of which are endemic. These forests are also of evolutionary significance, as twelve of the world's nineteen families of primitive flowering plants are found there, two of which are endemic. This compares with the Amazon basin where just nine families of primitive flowering plants occur, and of these none are endemic to that area.

In 1988 the rainforests among which the Australian Canopy Crane is situated were declared the Wet Tropics of Queensland World Heritage Area. This is one of the few areas in the world where the reef meets the rainforest and the only place where two World Heritage areas sit side by side.



A GIS site map (right), prepared by Dr Martin Freiberg and others, shows the location, identification, height and *dbh* (diameter breast height) of the 657 trees in 32 families and 79 species on the plot with trunk diameter larger than 10 centimetres. For at least half of the tree species at the crane site there are three or more individuals, for example, there are 55 individuals of the locally endemic black palm (*Normanbya normanbyi*). A similar map has been prepared for all epiphytes. Both maps were produced in 2000-2001 and are being resurveyed in 2005. No comprehensive survey has yet been undertaken of the vertebrates at the site, although a species list has been developed which includes restricted and endangered species such as the Southern Cassowary (*Casuarius casuarius*), Bennetts Tree Kangaroo (*Dendrolagus bennettianus*) and the Australian Lacelid (*Nyctimystes dayi*).

Tropical Cyclones at the Crane Site

On 11 February 1999, just two months after the crane was installed, Category 3 tropical cyclone Rona, with a maximum wind gust of 158 kilometres per hour, hit the coast about five kilometres south of the crane site. The site was severely damaged with perhaps as much as ten percent of the trees brought down and fifty percent of the remaining trees suffering major canopy damage. Prior to the cyclone, canopy cover was almost complete and there were few places to bring the gondola to ground level. Cyclone Rona opened many gaps in the canopy.

The crane site has been home to a number of 'resident' cassowaries since its initial set up (Image: Sarah Boulter).

Even though two large trees were felled next to the crane, destroying the equipment shed, the crane was untouched. Prior to the cyclone about thirty to fifty percent of the canopy was covered with vines which were brought down during the storm, making access to the crane very difficult. The cyclone hit a large area of north Queensland however the impact was patchy with some areas of rainforest receiving little damage, even as close as 100 metres from the crane.

Damage caused by Category 3 tropical cyclone Rona.

Cyclone Rona has provided a unique opportunity to study the remarkably rapid natural recovery of the rainforest. Only a few months after the cyclone hit, seedlings had developed in the larger sunlit gaps created by tree falls. Those trees that had been stripped of leaves began to recover immediately. Today, six years later, it would be very difficult for most people to know that there had been a cyclone through this part of the forest.

Research Program

Over thirty projects involving more than eighty researchers from Australia and overseas have been conducted at the Australian Canopy Crane site. Crane research is coordinated under four theme areas:

Theme 1: Canopy-Atmosphere Interactions

Leader: Dr Michael Liddell, James Cook University

Theme 2: Biodiversity

Leader: Professor Nigel Stork, James Cook University

Theme 3: Ecological Processes

Leader: Professor Roger Kitching, Griffith University

Theme 4: Physiological processes

Leader: Dr Peter Franks, James Cook University

The facility has provided a wonderful opportunity for postgraduate students to access the forest canopy for their research. Examples of postgraduate and other research projects conducted at the facility follow.

Canopy-Atmosphere Interactions

Tropical rainforests contain 52% of the world's forest carbon, and carry out 26% of the net primary productivity of the world's forests. A small disturbance to tropical forests can therefore have a major impact on the global carbon cycle and hence the global climate.

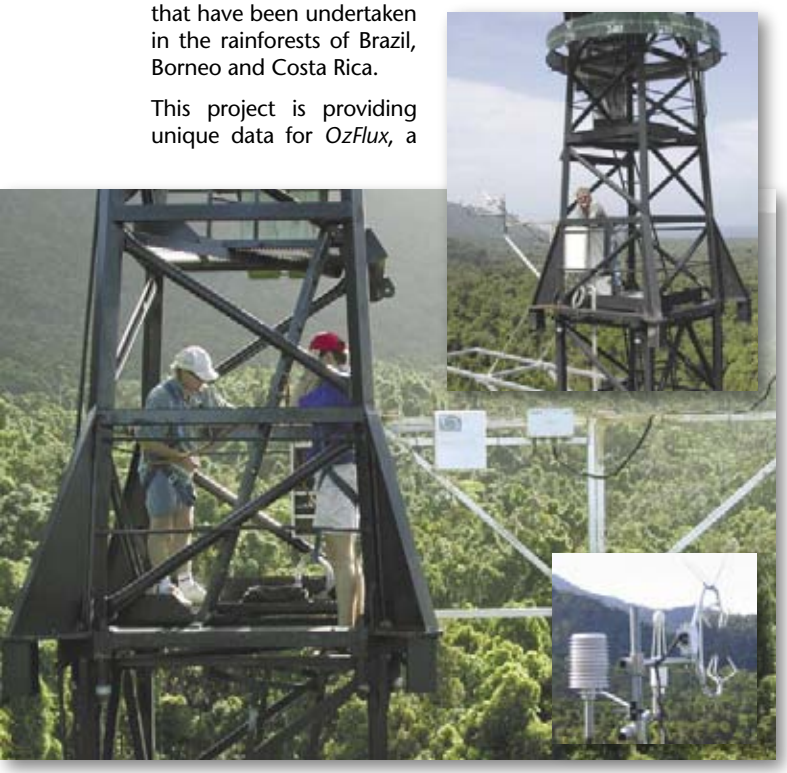
Measuring Carbon and Water Fluxes in Tropical Rainforest – The Influence of Climate

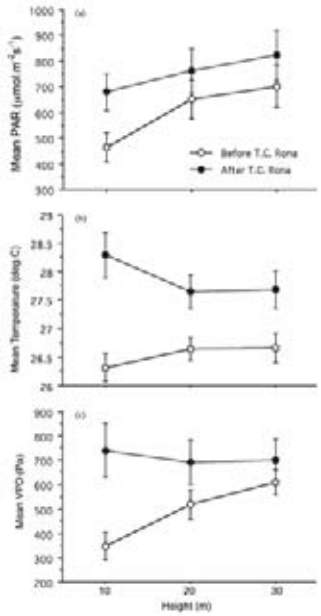
Michael Liddell and Steve Turton
James Cook University

Tropical rainforests cover twelve percent of the Earth's surface and store forty percent of the carbon residing in terrestrial vegetation. Even a slight perturbation to these sensitive ecosystems could lead to a major shift in the atmospheric concentration of carbon dioxide. This long-term flux study is specifically looking at the influence of climatic stress events on the carbon and water balance of the rainforest.

The Australian Canopy Crane is fitted with Eddy Covariance carbon/water flux and micrometeorological instrumentation, which measures the movement of carbon and water from an area of approximately twenty hectares centered at the crane tower. Two hundred gigabytes of data have been collected since March 2001. Initial processing of this large data set has indicated that the rainforest responds quite dramatically to disturbances in the climate. In 2002-2003, a once-in-fifty-year drought occurred. Between 2001 and 2003, the rainforest surrounding the crane site changed from being a 'sink' for carbon to a source of carbon. Detailed analysis of the first three-year data set is currently in progress. When complete, the analysis will allow comparison with the few flux studies that have been undertaken in the rainforests of Brazil, Borneo and Costa Rica.

This project is providing unique data for *OzFlux*, a network of micrometeorological flux stations located at various sites within Australia and New Zealand. *OzFlux* is also part of the two hundred global FLUXNET sites using eddy covariance methods to measure the exchanges of carbon dioxide, water vapour and energy between terrestrial ecosystems and the atmosphere.





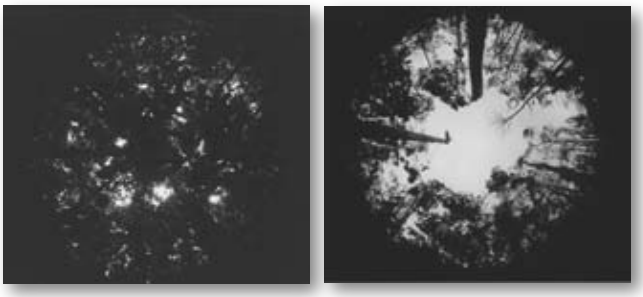
(a) Mean hourly photosynthetically active radiation (PAR); (b) air temperature; and (c) vapour pressure deficit (VPD) at three heights on the Australian Canopy Crane tower measured six days before Cyclone Rona (5-10 February 1999), and six days after (12-17 February 1999). Values shown are means (± 1 SE) for daylight hours only. Data for the actual day the cyclone passed through the crane site region (11 February 1999) are not included.

Impacts of a Severe Tropical Cyclone on the Microclimate of a Rainforest Canopy in Northeast Australia

Steve Turton, Danny Siegenthaler and Simon Grove
James Cook University

Tropical cyclones that occur along the northeastern Australian coast can cause severe damage to rainforests, resulting in high levels of light penetration to the normally heavily shaded forest floor following destruction of rainforest canopy. In the first study of its kind, this project examined the immediate impacts of Cyclone Rona on the microclimate of the rainforest canopy at the Australian Canopy Crane site, which experienced the direct impact of the storm's core.

Microclimate measurements commenced at the site in December 1998, consisting of two types of monitoring: (1) standard meteorological measurements using an automatic weather station in a clearing near the crane; and (2) profile measurements of air temperature, relative humidity and photosynthetically-



Hemispherical photographs ('hemiphots') taken of a research site within the Australian Canopy Crane plot before (left) and after (right) Cyclone Rona hit the Cape Tribulation area in 1999.

active radiation (PAR) at three separate heights on the crane tower. Vapour pressure deficit (VPD) was calculated from the temperature and humidity data. PAR, air temperature and VPD measurements taken from the crane tower six days immediately before and six days after the cyclone demonstrate the enormous changes caused by defoliation and structural damage to the canopy.

The most profound microclimatic changes were to the sub-canopy of the forest. Increases in PAR, air temperature and VPD in the lower canopy following the cyclone undoubtedly impacted on plant taxa normally tolerant of dim, cool and relatively humid conditions. While there were short- and medium-term ecological responses to this natural event, one would expect the forest biomass to eventually recover in the absence of any more direct impacts from tropical cyclones. Current studies at the site are documenting the longer-term recovery of the forest within the one-hectare plot covered by the crane.

The Importance of *Asplenium nidus* as Climate Buffer in the Canopy of a Lowland Tropical Rainforest

Martin Freiberg, Universität Ulm
(now at The University of Leipzig), Germany

Steve Turton, James Cook University

The bird's nest fern, *Asplenium nidus*, contributes significantly to the epiphytic biomass in the canopies of southeast Asia and northern Australia. This study examined microclimatic changes

in the dry season. One of two neighboring epiphytes of the same size and age was artificially irrigated before, during and after the dry period of 2000, and the microclimate within and around the ferns was monitored over eight months using a series of sensors designed and built by Martin Freiberg.

During the dry season the non-irrigated fern was constantly desiccated and the accumulated substrate finally reached ambient humidity, while the irrigated fern maintained a difference of about twenty percent. In the following rainy season, the accumulated substrate was close to saturation reflecting the difference in humidity of the surrounding canopy air.

The accumulated humus of the non-irrigated bird's nest fern dried out following six weeks with no rain. Even longer periods of dryness kill the roots that cling to the bark, and eventually epiphytes on vertical stems fall to the ground where some of them survive for some time. Periods of drought longer than eight weeks can kill plants that reside in branch forks. The analysis of the whole epiphyte population within the one-hectare Australian Canopy Crane plot and morphological age determination of all plants enabled an evaluation of the historical development of the population. The oldest plant originated in 1985, just one year after the longest drought recorded for the site. It was suspect that the 1984 drought killed every *Asplenium* of the plot. Other years with low recruitment coincided well with long drought periods.

Small-scale Structure of the Forest Canopy at the Australian Canopy Crane Site from Ground-based Lidar Measurements

Geoffrey Parker, Smithsonian Environmental Research Center, United States

Jess, as he is known, has created a unique data set of the structure of the forest canopy as part of a comparative study of canopy structure among forests in many parts of the world, having visited nearly all canopy crane sites.

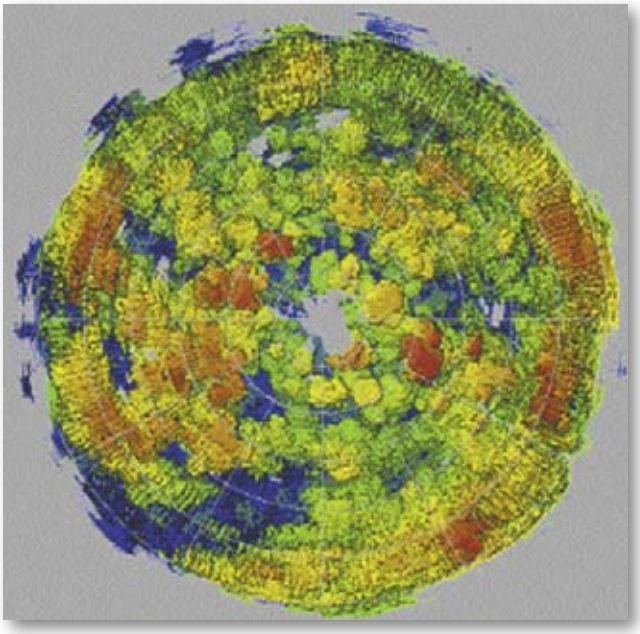
Jess used a portable laser range-finding system to make dense measurements of the location of canopy elements during a visit to the Australian Canopy Crane in June 2002. He then assembled the measurements to create high-resolution three-dimensional views of the canopy structure. Canopy structure is important for a variety of critical forest functions, including mass and energy exchanges between the forest and the atmosphere. Obtaining the measurements of canopy structure necessary to understanding these forest functions has been difficult. Most available techniques provide poor spatial resolution and are at scales not linked to the footprints of canopy functions. Consequently, progress in understanding canopy structure-function relationships has been slow.

Fine-scale Measurement of Three-dimensional Forest Canopy Structure Using the Canopy Crane and Laser Plane Range-finding Method

Takafumi Tanaka, Nagoya University, Japan

Steve Turton, James Cook University

Forest canopy structure affects both the radiation regime and turbulent transfer characteristics of gas exchange in the canopy. Obtaining accurate information on forest canopy structure is problematic. To date there are no high-resolution methods to measure the three-dimensional structure of a forest canopy. In this project, the structure of forest canopy around the one-hectare Australian Canopy Crane plot was measured at a fine spatial resolution and captured as digital data using the laser plane range-finding method. Spatial fluctuations of top position of the canopy were found to have reasonable correspondence to validation measurements. The results have been compiled as a digital elevation map of the canopy. Frequency, patterns and size of canopy surface were also examined considering their difference between heights.



The calibrated height distribution of the rainforest canopy at the Australian Canopy Crane site, with consideration of terrain increment (Image: Takafumi Tanaka).

Biodiversity

Some scientists have argued that the canopy of a tropical forest is the most species-rich environment on Earth. Many crane studies have focused on discovering what lives within the canopy, particularly insects and fungi, and understanding the role of that biodiversity in the canopy stratum.

Many taxonomists from Australia and around the world have used the Australian Canopy Crane to look for particular groups of insects and fungi and to discover new species. Visitors to the site have included specialists researching ants, beetles, wasps, grasshoppers, spiders, flies and fungi.

Diversity and Composition of Beetle Communities

Nigel Stork, James Cook University

Peter Grimbacher, Griffith University

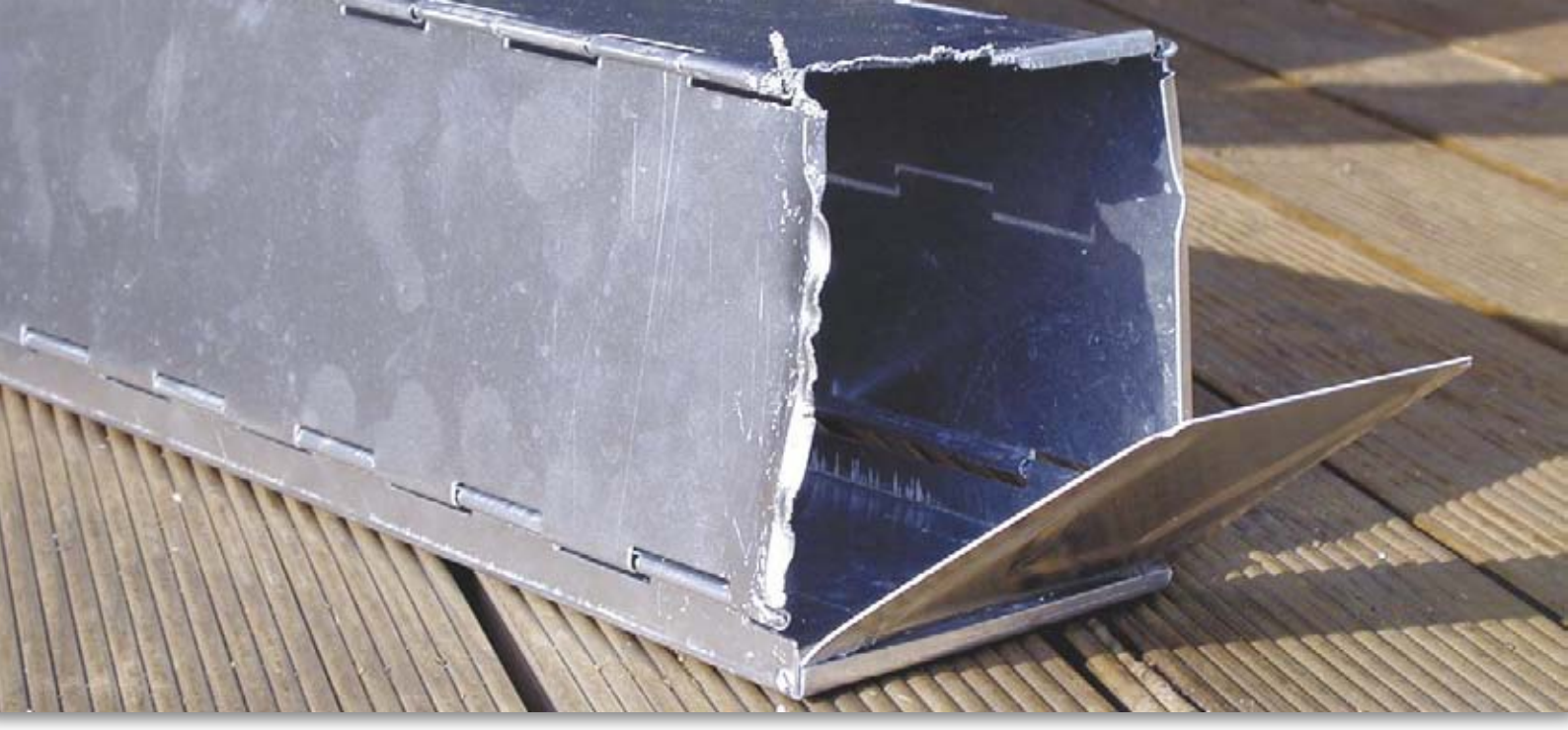
A critical factor in estimating regional and global diversity is the determination of what proportion of forest species are found only in its canopy. Dogma has it that the canopy has a 'separate' faunal component, however this assertion has been seldom tested.

Canopy and ground samples were collected using five pairs of combination Malaise/Flight Intercept traps (one suspended in the canopy and one placed on the ground) for two weeks every month for four years from February 2000. After a mammoth sorting and preparation effort involving volunteers from Green Corps, a total of 29,986 beetles were sorted to reveal 1,473 species and 77 families, making this one of the largest such datasets ever compiled.

Initial statistical analyses suggest that perhaps as much as twenty to thirty percent of the species can be clearly identified as canopy 'specialists'. Surprisingly, the long-term beetle data also show that the one-in-fifty-year drought during 2002 and 2003 appeared to have little effect on the diversity and abundance of beetles at the Australian Canopy Crane site.

Top: A malaise trap, suspended in the rainforest canopy at the Australian Canopy Crane site, targets free flying insects.

Bottom: Nigel Stork looks over one of his many beetle specimen trays, kept at James Cook University. Nigel has completed the sorting and documenting of almost 30,000 beetle individuals collected from the rainforest canopy at the Australian Canopy Crane site.



A simple but effective rodent trap used by Romina Rader for her studies into rainforest seed predation.

Vertical Distribution of Small Mammals and Their Impact Upon *Acmena graveolens* Seed Survivorship

Romina Rader, James Cook University

Although seed dispersal and predation are important ecological processes that structure and maintain diversity in tropical forest communities, the role of rodents as seed predators and dispersers in Australian rainforests is largely unknown. Romina's observations suggest that the role of rodents may be more complex than simply seed predation or dispersal. Removal of the seeds from *Acmena graveolens* fruit by rodents may protect those seeds from seed predators such as insects.

Trapping results suggest five species present at the Australian Canopy Crane site have a preference for different layers of the canopy. The giant white-tailed rat (*Uromys caudimaculatus*), the Antechinus (*Antechinus flavipes rubeculous*) and the fawn-footed Melomys (*Melomys cervinipes*), were most often captured in the understorey layer but frequented all other layers to varying degrees. The Cape York rat (*Rattus leucopus*) was most commonly caught on the ground but ventured up into the understorey. The prehensile-tailed rat (*Pogonomys sp.*), an extremely rare and poorly known species, was captured exclusively in the top two canopy layers.

Spatial Distribution of Epiphytes, Hemiepiphytes and Root-climbers in an Australian Lowland Rainforest

Martin Freiberg, Universität Ulm
(now at The University of Leipzig), Germany
Steve Turton, James Cook University

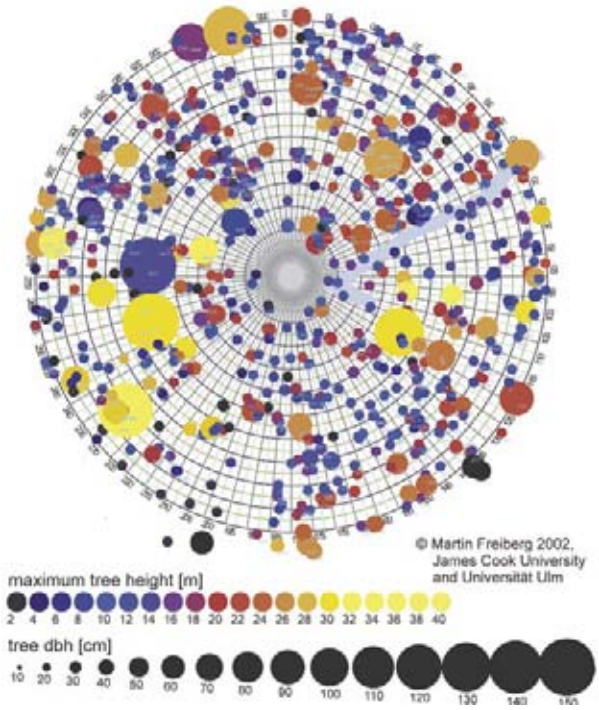
Cyclone Rona had a significant impact on the tree structure of the Australian Canopy Crane's rainforest site at Cape Tribulation. In order to evaluate the post-cyclone recovery of the vegetation that depends on rainforest trees such as epiphytes, hemiepiphytes and root-climbers, the locations of these plants on trunks and within tree crowns were mapped using a tree map of the research site. The map (shown right) includes the position of the trees, their height, the largest diameter of the crown, the height of the first ramification, form of the crown and species name. First results show that a heavy growth acceleration of root-climbers appeared close to the opened canopy. Epiphytes fell to the ground during the cyclone, however neither an accelerated resettlement nor a significant dying of the epiphytes was detected. The site will be resurveyed in 2005 to determine the change in epiphyte, hemiepiphyte and vine load six years following the impact of Cyclone Rona.

Comparison of the Mite Fauna (Acari: Mesostigmata) of Suspended Litter, Forest Floor Litter and Decaying Wood

Frédéric Beaulieu, The University of Queensland

What kinds of mites live in the forest canopy and from where do they originate? To answer these questions, Frédéric sampled Mesostigmata mites in soil and litter from the ground and suspended soil and litter from the crowns of crow's nest ferns (*Asplenium nidus L.*). Mites were extracted from samples using Tullgren-modified Berlese funnels.

In total, 37 morphospecies of Mesostigmata were identified from 427 individuals collected. This study is part of a larger research project that aims at understanding the habitat distribution of a large group of predatory mites (Mesostigmata, excluding Uropodina) in the wet forests of south-east Queensland and northern Queensland.



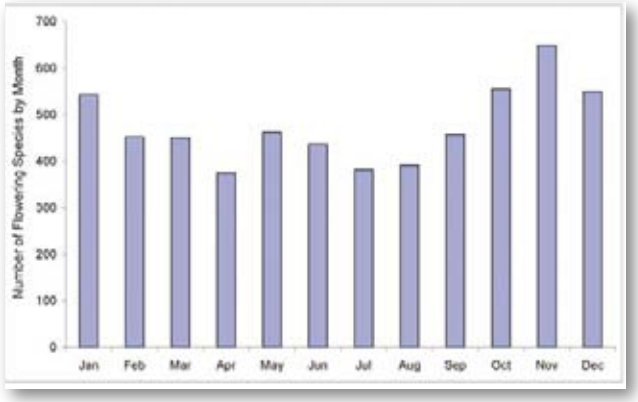
Ecological Processes

Following the Biodiversity theme, this stream of research considers the significance of a highly diverse canopy fauna, and the underlying processes that both drive the diversity and the interactions between the canopy and other strata of the forest and landscape.

Reproductive Ecology in the Canopy

Roger Kitching, Sarah Boulter, Bradley Howlett and Kylie Goodall, Griffith University

The flowering biology of the rainforest canopy and the role of flower visitors are poorly known. This study has been conducted in a comprehensive 'top-down' approach. An initial massive data-mining exercise, largely from herbarium sheets, resulted in over 120,000 collection records from which flowering patterns of the Wet Tropics flora can be analysed. A clear seasonal peak in flowering at the end of the dry/start of the wet season was apparent from the analysis, although more aseasonal patterns are common at lower latitudes.



Number of plant species flowering by month for the entire Wet Tropics bioregion.

A flower wasp visits the flowers of Syzygium gustavioides, a large canopy tree that produces small fragile flowers held in large inflorescences, conspicuous from above the canopy (Image: Sarah Boulter).

Based at the Australian Canopy Crane site, studies focused on the fauna visiting the flowers of canopy plants. Using a combination of trapping techniques, visitor profiles have been built for a total of twelve plant species including palms, shrubs, vines and trees. Where flowering coincides among species, visitor fauna can be compared to determine the fidelity of flower visitors. While it was found that a high diversity of insects visit many plant species (up to eighty beetle species visit a single plant species) there are specific associations with particular plant species and trends of host specificity among beetle species. A few plants have been the subject of highly detailed pollination studies including two species of *Syzygium* (see Sarah Boulter's project *The Reproductive Biology of Two Species of Syzygium*) and the locally endemic, monoecious palm *Normanbya normanbyi*.

To avoid pollination male and female flowers of N. normanbyi are never open together on the same plant and potential pollinators must not only move between plants, but also visit both male and female flowers. While *N. normanbyi* attracted huge numbers of a previously undescribed 'Derelomini' beetle, a known group of palm pollinators from other international studies, it was found that these beetles restricted their visits to male flowers and were unlikely to be pollinators. Current work is focusing on the interaction between pollinators and their hosts across the landscape, using genetic techniques to determine the distance pollen is being moved between individual plants to help predict the long-term viability of smaller groups of isolated individuals.

The Reproductive Biology of Two Species of *Syzygium*

Sarah Boulter, Griffith University (University Medal Winner)

This project focused on the very different reproductive ecology of two congeneric canopy trees. *Syzygium sayeri* is a xenogamous species with poor self-compatibility and moderate levels of natural out-crossing. Robust flowers are produced in inflorescences held under the canopy producing copious amounts of weak to moderate nectar day and night. Day visits were dominated by honeyeater species, and a variety of insects.

The bridled honeyeater is a regular visitor to Syzygium sayeri, a rainforest giant with a canopy that stretches up to thirty metres in diameter, with hundreds of medium-sized, robust flowers produced and held in inflorescences under the tree's canopy from about June to October (Image: Sarah Boulter).

Swarming Sphingid moths moved in for short but frenzied feeding sessions at dusk. Night-time saw the arrival of blossom bats. Exclusion studies showed that all visitors played a role in pollination – half by larger insects and vertebrates and half by smaller insects.

By contrast, *S. gustavioides* was never visited by a vertebrate species. Flowers are smaller and more delicate and held in showy displays on the outside of the canopy. Insect visitors were both abundant and diverse. Pollination of *S. gustavioides* was performed by most insect visitors, and this rainforest giant demonstrated a truly generalist pollination system.

The World Herbivory Project

Angela Moles, Macquarie University
Will Edwards, James Cook University

The idea that interactions between organisms are more intense in the tropics underpins much thinking about tropical ecology, global patterns in plant and animal traits, and latitudinal gradients in biodiversity.

Using the Australian Canopy Crane, Angela and Will measured herbivory within the canopy as part of a large international collaborative team aiming to provide the first direct and global test of this idea by quantifying the intensity of herbivory, seed predation and density-dependent seedling mortality at approximately one hundred sites around the world. The main questions they hope to answer are whether the proportion of leaf production consumed by herbivores is greater near the equator, and whether seed predators near the equator kill a greater proportion of seeds.

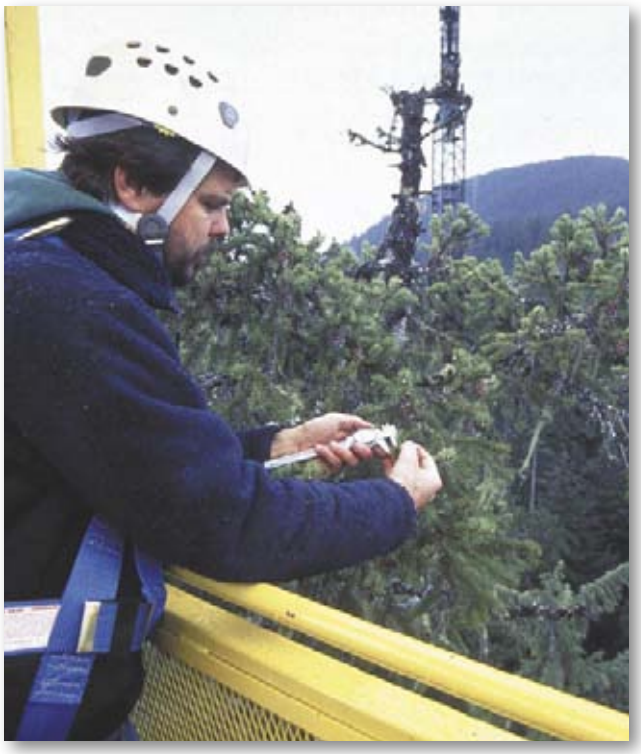
The team will also investigate the causes of any latitudinal gradients by determining which environmental variables are most closely associated with the strength of biotic interactions, and by quantifying the relationships among latitude, herbivore abundance, resource availability, plant defences and herbivore damage.

How Availability and Quality of Nectar and Honeydew Shape an Australian Rainforest Ant Community

Nico Blüthgen, Universität Bayreuth, Germany

Nico studied the role of nectar and honeydew sources for the ant community at the Australian Canopy Crane site and surrounding rainforest. Honeydew and nectar sources were very common in vegetation and frequently used by ants. Nico demonstrated the importance of amino acids in nectar for the distribution of ants on plants.

Competitive dominant ants were shown to actively monopolize nectar and honeydew sources that were particularly rich in amino acids (HPLC analysis), suppressing the choices of the rest of the ant community. Only in the absence of competitors, most ant species preferentially selected nectars that contained amino acid mixtures. Stable isotope analysis indicated that nectar and honeydew provide highly important sources of nitrogen for arboreal ant species. Different sugars such as melezitose, a dominant honeydew compound, were found to be much less important for ant resource preferences than previously suggested by other studies.



Top: David Shaw tests his herbivory measurement technique at the Wind River Canopy Crane in the United States.

Right: Crane operator, Richard Cooper, based at the Australian Canopy Crane Research Facility with visiting researcher, David Shaw, from the United States.

Development of a Novel Method for Assessing Stand Level Herbivory in Forests: Using the International Canopy Crane Network

David Shaw, Wind River Canopy Crane Research Facility, United States

Kristina Ernest, Central Washington University, United States

Bruce Rinker, Marie Selby Botanical Gardens, Florida, United States

Meg Lowman, New College of Florida, United States

Stand level rates of herbivory in forests have been difficult to estimate. Accurate methods that scale up to the stand level from leaves or branches require numerous measurements at various sampling scales (e.g. leaves, branches, crown sections, heights, individual trees, species). David Shaw and co-researchers have designed a technique to measure herbivory and tested this at the Australian Canopy Crane and at the Wind River Canopy Crane Research Facility in the United States. At randomly selected locations the percentage of leaf area missing due to herbivory is measured, with ten leaves per sample unit randomly sampled using a 50cm x 50cm sample frame. They found that the average level of herbivory was 8.9% at the Australian site compared to only 1.6% at the Wind River facility.

Daniela Inkrot's study focused on the flowering pattern of a population of black palms (Normbanbya Normanbyi).

Fruiting Phenology of a Lowland Rainforest Community: Patterns and Adaptations

Christian Geyer, The University of Leipzig, Germany

Christian examined the fruiting phenology of a complex mesophyll vine forest located within the Daintree rainforest. The two-year study questioned whether fruiting within the rainforest community follows a certain pattern, and if it does, whether this pattern reoccurs in a subsequent year. Furthermore the study sought to find out whether certain patterns of fruiting phenology can be explained by the functional morphology and adaptation of the fruit produced, for example, anemochory occurs most during dry and windy seasons and vice versa. Crane access of all the different layers of the rainforest allowed Christian to include trees, shrubs and even vines in his research.

Flowering Phenology of a Complex Mesophyll Vine Forest Plant Community

Daniela Inkrot, The University of Leipzig, Germany

Daniela focused on two different aspects of the flowering phenology – the flowering phenology pattern of a complex mesophyll vine forest plant community (trees, vines and understorey plants), taking into consideration the course of climatic parameters; and the population genetics of *Normanbya normanbyi* (Arecaceae) in connection with its flowering phenology.

In context of the first aspect Daniela questioned how the phenology and function (species interaction, species conservation) of a tropical rainforest were associated and what flowering phenological patterns the plant community (on a species and individual basis) showed over a period of two years.

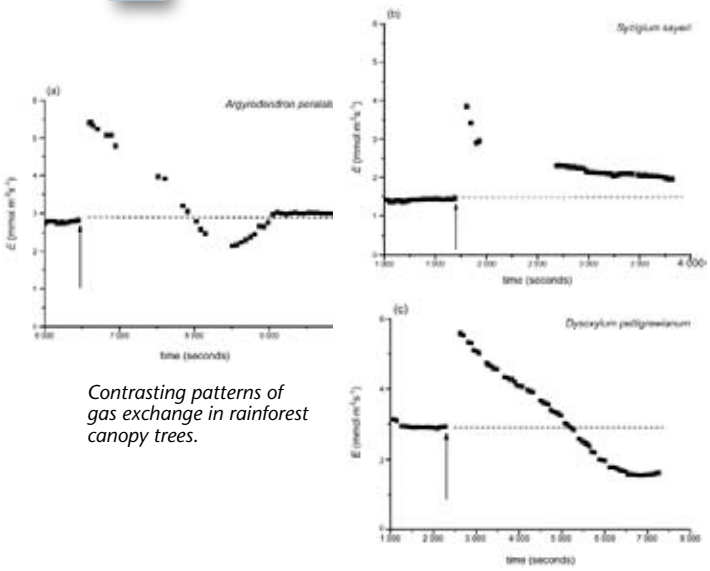
The main hypothesis identified in this study reveals a certain flowering pattern with an increased flowering activity period recurs every year, though the value changes. Consequently the flowering phenological pattern varies in intra- and inter-annual comparison. Equally, the composition of species during times of high flower abundance differs. Despite these differences the percentage of syndromes of flowering remains constant. Climbers and trees that show the same pollination syndromes do have similar phenological patterns. Precipitation and the resulting water availability do have more influence on the expression of the phenological patterns than the Photosynthetically Active Radiance (PAR).

The central issue of the second aspect is to explain the flowering phenology of a plant population (of *Normanbya normanbyi*) by analysing the relatedness structure. Due to the very dense stock structure of *N. normanbyi* along streams, a high genetic structure can be supposed. Additionally, Daniela's work suggests that the degree of relationship within a population determines the generative phenological pattern of the individual plants. Closely related palms flower at different times to avoid a mutual pollination (kin mating).

theme 4

Physiological Processes

Research at the Australian Canopy Crane site involving sophisticated physiological measurements on individual leaves in the canopy is highlighting the inherent physiological diversity of the canopy, and providing essential data for the construction and testing of models that predict the pattern of canopy gas exchange regulation.



Contrasting patterns of gas exchange in rainforest canopy trees.

Daniel Falster used the Australian Canopy Crane to gain access to tall tree species during his research on the potential height of plants and light availability.

Stomatal Control and Hydraulic Conductance with Special Reference to Tall Trees

Peter Franks, James Cook University

Peter's research has helped to establish how the photosynthetic properties of the rainforest canopy vary both spatially and temporally, contributing to our ability to model the changes in productivity and structure of similar forests in response to, for example, global climate change. The Australian Canopy Crane gave Peter the ability to study spatial variation in canopy photosynthesis at the leaf level, enabling him to track these changes while the canopy recovered from tropical cyclone Rona.

Rebecca Miller studied a range of characteristics plants use as defences against herbivores.

The graphs (shown above) show the response of transpiration rate *E* in three co-occurring tropical rainforest canopy trees to a step change in evaporative demand (from 1.0 to 2.0 kPa). Arrows indicate the time at which the step change was applied. Three categories of response are illustrated, as indicated by the position of the new steady state *E* relative to *E* at 1.0 kPa: (a) *E* is held almost constant; (b) *E* increases with the increase in evaporative demand (most typical type of response); and (c) *E* declines to a value below what it was prior to the step change in evaporative demand. These differences in the control of evaporative water loss between species translate into different modes of water use, water status and photosynthetic productivity, indicating that the gas exchange of the canopy as a whole responds heterogeneously to changing climate. Data were collected from sun leaves at the top of the canopy on 35 metre tall trees at the crane site.

Seasonal Variation in Secondary Metabolites (Defence) and Herbivory

Rebecca Miller, The University of Melbourne

Tropical rainforest plants possess a range of characteristics, both physical and chemical, which may confer protection against herbivores. Rebecca investigated the seasonal variation in allocation to defence, examining species of trees with contrasting nitrogen-based defences, and involved the seasonal determination of secondary metabolite concentration and herbivory, as well as stable isotope analyses. These experiments were analysed in the context of defence theories such as the resource availability hypothesis (e.g. the carbon/nutrient balance theory), and the optimal allocation theory that provide a framework for predictions about patterns in defence allocation under varying conditions.

Alternative Height Strategies Among Dicot Rainforest Species in Tropical Australia

Daniel Falster, Macquarie University

'Potential height' spans at least an order of magnitude across species and is considered an important indicator of light capture strategy in plants. Daniel tested the proposition that contrasting correlations between height and other plant attributes would be observed among sets of species selected to span these two gradients. He selected 45 rainforest species in Australia's Wet Tropics to span gradients of light income and successional status, and measured several traits influencing light capture/ regeneration strategy on mature individuals, with the Australian Canopy Crane enabling access to taller species.

Publications

Publications stemming from research based at the Australian Canopy Crane site.

Basset, Y., Horlyck, V., Wright, S. J. and Stork, N. E. (2004) Preamble (in) *Studying Forest Canopies from Above: The International Canopy Crane Network*. Basset, Y., Horlyck, V. and Wright, S. J. (Eds). Smithsonian Tropical Research Institute, Panama. pp. 63-66.

Basset, Y., Wright, S. J. and Stork, N. E. (2004) Conclusions: The Future of the International Canopy Crane Network (in) *Studying Forest Canopies from Above: The International Canopy Crane Network*. Basset, Y., Horlyck, V. and Wright, S. J. (Eds). Smithsonian Tropical Research Institute, Panama. pp. 175-180.

Blüthgen, N. and Fiedler, K. (2002) Interactions Between Weaver Ants (*Oecophylla smaragdina*), Homopterans, Trees and Lianas in an Australian Rainforest Canopy. *Journal of Animal Ecology* 71: 793-801.

Blüthgen, N., Gebauer, G. and Fiedler, K. (2003) Disentangling a Rainforest Food Web Using Stable Isotopes: Dietary Diversity in a Species-rich Ant Community. *Oecologia* 137: 426-435.

Blüthgen, N. and Fiedler, K. (2004) Preferences for Sugars and Amino Acids and Their Conditionality in a Diverse Nectar-feeding Ant Community. *Journal of Animal Ecology* 73: 155-166.

Blüthgen, N. and Fiedler, K. (2004) Competition for Composition: Lessons from Nectar-feeding Ant Communities. *Ecology* 85: 1479-1485.

Blüthgen, N., Gottsberger, G. and Fiedler, K. (2004) Sugar and Amino Acid Composition of Ant-attended Nectar and Honeydew Sources from an Australian Rainforest. *Austral Ecology* 29: 418-429.

Blüthgen N. and Reifenrath, K. (2003) Extrafloral Nectaries in an Australian Rainforest: Structure and Distribution. *Australian Journal of Botany* 51: 515-527.

Blüthgen, N., Stork, N. E., and Fiedler, K. (2004) Bottom-up Control and Co-occurrence in Complex Communities: Honeydew and Nectar Determine a Rainforest Ant Mosaic. *Oikos* 106: 344-358.

Boulter, S. L. (2003) Reproductive Ecology of Two Myrtaceaous Canopy Plant Species: *Syzygium gustavioides* (f. M. Bail.) B. Hyland and S. *sayeri* (F. Muell.) B. Hyland. Honours Thesis, Griffith University, Brisbane, Australia. 96 pp.

Boulter, S. L., Kitching, R. L., Howlett, B. G. and Goodall, K. (In Press) Any Which Way Will Do: The Pollination Biology of a Northern Australian Rainforest Canopy Tree (*Syzygium sayeri*; Myrtaceae). *Biological Journal of the Linnean Society*.

Carver, M., Blüthgen, N., Grimshaw, J. and Bellis, G. (2003) *Aphis clerodendri* Matsumura (Hemiptera: Aphididae), Attendant Ants (Hymenoptera: Formicidae) and Associates on *Clerodendrum* (Verbenaceae) in Australia. *Australian Journal of Entomology* 42: 109-113.

Curtis, I. A. and Turton, S. M. (2002) Solar Radiation Potential and Site Modeling for Photovoltaic Modules in the Daintree Lowlands of Northeastern Australia. *Australian Geographical Studies* 40(3): 278-286.

Franks, P. J. and Brodribb, T. (In Press) Stomatal Control and Water Transport in the Xylem (in) L*ong Distance Transport Processes in Plants*. Holbrook, N. M. and Zwieniecki, M. (Eds). Springer. pp. 69-89.

Franks, P. J. (2005) Hydraulic Conductance in Leaves. Plant, Cell and Environment. Blackwell Publishing (In Review).

Franks, P. J. and Farquhar, G. D. (2005) Dynamic Limitations of Stomatal Response to Environmental Perturbations. Plant Physiology. American Society of Plant Biologists (In Review).

Franks, P. J. (2004) Stomatal control and hydraulic conductance, with special reference to tall trees. *Tree Physiology*, 24, 865-878.

Grove, S. J., Turton, S. M. and Siegenthaler, D. T. (2000) Mosaics of Canopy Openness Induced by Tropical Cyclones in Lowland Rainforests with Contrasting Management Histories in Northeastern Australia. *Journal of Tropical Ecology* 16: 883-894.

Howlett, B. G., Kitching, R. L. and Boulter, S. L. (2005) Interception Traps in Canopy Inflorescences: Targeting a Neglected Fauna. *International Journal of Tropical Insect Science* 25: 1-5.

Lucas, R., Held, A., Phinn, S. and Saatchi, S. (2004) Tropical Forests (in) *Manual of Remote Sensing, Volume 4, Remote Sensing for Natural Resource Assessment*. Ustin, S. (Ed.) Chapter 5. American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland. 768pp.

Nightingale, J. M., Phinn, S. R., and Held, A. J. (2004) Integrating Ecosystem Process Models and Remotely Sensed Data to Map Carbon Fluxes within Tropical Forest Environments. *Progress in Physical Geography* 28(2): 241-281.

Ozanne, C. M. P., Anhuf, D., Boulter, S. L., Keller, M., Kitching, R. L., Körner, C., Meinzer, F. C., Mitchell, A. W., Nakashizuka, T., Silva Dias, P. L., Stork, N. E., Wright, S. J., and Yoshimura, M. (2003) Biodiversity Meets the Atmosphere: A Global View of Forest Canopies. *Science* 301: 183-186.

Siegenthaler, D. T., Turton, S. M. and Rodgers, D. (2000) A Data Collection Module (DCM) for Improved Measurement of Microclimates in Dense Forest Canopies. *Selbyana* 17: 173-176.

Stork, N. E. (2001) The Management Implications of Canopy Research (in) *Tropical Forest Canopies: Ecology and Management*. Linsenmair, K. E., Davis, A. J., Fiala, B., Speight, M. R. (Eds.) Springer. 380pp.

Stork, N. E. amd Cermak, M. (2004) The Australian Canopy Crane (in) *Studying Forest Canopies from Above: The International Canopy Crane Network*. Basset, Y., Horlyck, V. and Wright, S. J. (Eds) Smithsonian Tropical Research Institute, Panama. pp.108-14.

Stork, N. E. (In Press) Forest Science. *Trends in Ecology and Evolution*.

Tanaka, T. and Turton, S. M. (2005) Fine-scale Measurement of Three Dimensional Forest Canopy Structure Using the Canopy Crane and Laser Plane Range-finding Method. *Agricultural and Forest Meteorology* (In Review).

Turton, S. M. and Siegenthaler, D. T. (2004) Immediate Impacts of a Severe Tropical Cyclone on the Microclimate of a Tropical Rainforest Canopy in Northeast Australia. *Journal of Tropical Ecology* 20: 583-586.

Turton, S. M., Tapper, N. J. and Soddell, J. (1999) A Proposal to Measure Diurnal and Seasonal Energetics Above and Within a Lowland Tropical Rainforest Canopy in Northeastern Australia. *Selbyana* 20(2): 345-349.

International Collaboration, Training and Communication

International Crane Users

The Australian Canopy Crane has hosted a number of distinguished research visitors who have used their study leave to work at the crane site.

Dr Martin Freiberg of The University of Leipzig, hosted by Associate Professor Steve Turton, was a Von Humboldt Fellow at James Cook University who played a critical role in the mapping of the trees and epiphytes at the crane site. Dr Freiberg also looked at the microclimate surrounding epiphytes in the canopy during his twelve-month fellowship.

Dr Joe Wright, Deputy Director of the Smithsonian Tropical Research Institute in Panama and Director of their canopy cranes, spent a study year at James Cook University in 2001 and 2002.

Dr Robin Chazdon of the University of Connecticut in the United States used her six-month sabbatical at James Cook University to study light regimes and plants at the crane site.

Dr Takafumi Tanaka of Nagoya University in Japan, hosted by Associate Professor Steve Turton, spent twelve months' study leave at James Cook University to test his laser system to provide high quality mapping of the canopy surface.

Professor Roger Kitching of Griffith University, a 2005 Queensland Smithsonian Fellow, is collaborating in the Panama based IBISCA project with a team of over fifty international scientists and participants to consider biodiversity in the canopy and on the ground.

International Training

Several of the postgraduate students who have long-term projects using the Australian Canopy Crane are from overseas, and we have encouraged students and other researchers to use the crane for comparative studies with other cranes. Three PhD students who are using the Australian Canopy Crane are based in Germany, which has helped to cement a strong partnership with German universities. Several postgraduate students were assisted by undergraduate students from home universities when conducting fieldwork.

For the last few years, the undergraduate subject *Biology of the Rainforest Canopy* has been offered by James Cook University. Many students, including students undertaking Study-Abroad subjects, have taken the course and have spent time at the Australian Canopy Crane gaining first-head experience with rainforest canopy research. Research staff based at the crane site provided a wide range of training lessons and programs for many international student visitors. Regular visitors include students from the School for Field Studies based at Yungaburra on the Atherton Tablelands, The School for International Training, and Iowa State University.

The Australian Canopy Crane served as a core facility for a one-month International Biodiversity training course held at the site in 2000, organised by Professors Roger Kitching and Nigel Stork as part of Australia's commitment to the international program DIWPA (*DIVERSITAS in the Western Pacific and Asia*). The training program hosted nineteen students from eleven countries and was funded by the Government of Japan and the Crawford Fund.

Students from Iowa University visited the Australian Canopy Crane in 2001.

Communication And Policy Development

Third International Canopy Conference, Cairns, June 2002

The Queensland Government and Smithsonian Institution, as part of their collaborative partnership, hosted the Third International Canopy Conference in Cairns. Co-convenors, Professor Nigel Stork and Dr Joe Wright made use of the conference to promote the International Canopy Crane Network and the Australian and Smithsonian canopy cranes in particular.

Over eighty of the two hundred conference participants took advantage of the opportunity to visit the Australian Canopy Crane during their visit. In opening the conference, Queensland Premier Peter Beattie committed $50,000AUD in grant funding to the Australian Canopy Crane to ensure its continued collaboration with the Global Canopy Programme – the first funding from any government towards the Global Canopy Programme.

Following the conference a group of eighteen canopy researchers, including Professors Nigel Stork and Roger Kitching, held a Global Canopy Programme retreat at Bloomfield Lodge in far north Queensland to help clarify the Programme's objectives and lead to the development of the Cairns Declaration on Canopy Research (http://www.globalcanopy.org/news/updates/15-08-2002.php)

Canopy Research and Government Policy Development

As part of a Global Canopy Programme project for the Queensland Government, canopy researchers and others from the Rainforest CRC held a workshop at the Environmental Protection Agency

in Brisbane to look at the policy implications of recent canopy and other terrestrial rainforest research. The resulting document, *Environmental Crisis: Climate Change and Terrestrial Biodiversity in Queensland*, which received attention on a national level, identifies actions the Government might introduce to address the impacts of climate change. In his ministerial statement following the official release of the report, Premier Beattie stated 'I commend the efforts of the Rainforest CRC and all who collaborated on the report. I am delighted that their world-class science will continue to inform our environmental protection policies'.

Australian Canopy Crane Open Day

In April 2004, researchers, government representatives and local interest groups met at the Australian Canopy Crane for a series of presentations on the crane facility and its research programs. Researchers, Kylie Goodall and Sarah Boulter, both organisers of the event, said the response to the field day was overwhelming with attendees from the general public, Queensland Parks and Wildlife Service, James Cook University, CSIRO, Daintree Discovery Centre, Cape Tribulation Research Centre, Skyrail and local tourism operators. The Open Day gave many stakeholders their first experience of the rainforest canopy from the vantage point of the crane gondola.

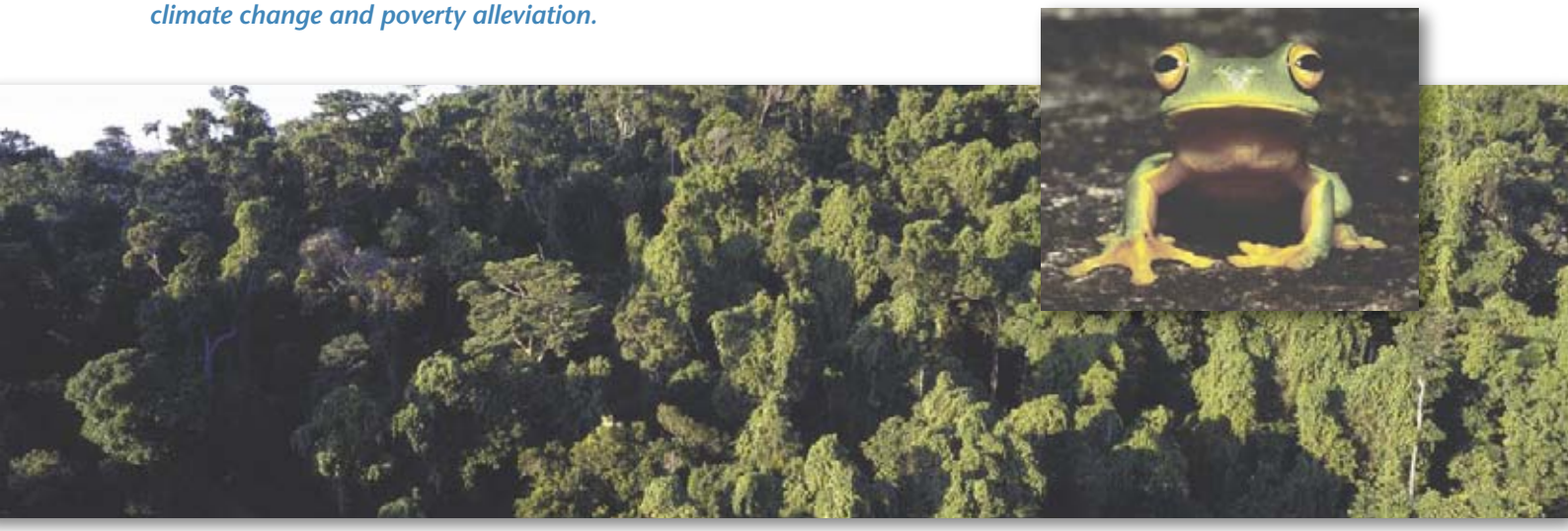
Media

The crane is extremely popular with the media and has featured on numerous television and radio programs in Australia, Japan, Germany and the United Kingdom.

The Australian Canopy Crane featured on the children's program, Totally Wild.

The Global Canopy Programme

A global alliance linking studies of forest canopies worldwide into a collaborative programme of research, education and conservation addressing biodiversity, climate change and poverty alleviation.



The Global Canopy Programme was created in 2000 to link existing and new projects studying the world's forest canopies into one integrated global programme of research, education and conservation. Prime areas for investigation are the function of forest canopies in the maintenance of biodiversity and the influence of forests on climate change, particularly in relation to sequestering carbon from the atmosphere. The Global Canopy Programme links with the International Canopy Crane Network – a consortium of the twelve canopy cranes already in existence for studying forest canopies. Professors Nigel Stork and Roger Kitching have been members of the Global Canopy Programme Steering Committee since its inception and are helping to guide its development. Professor Kitching also co-convenes Canopy Biology Training Programs in Brazil and Malaysia, funded by the UK Foreign and Commonwealth Office Global Opportunities Fund and the UK Darwin Initiative.

The United Nations Environment Programme, with financial support from the Global Environment Facility, has provided funding for proposal development to establish a series of 'whole forest observatories' across the tropics. These will be linked to others already in existence including the Australian Canopy Crane. The network's aim is to investigate how climate change might alter the way forests function and what risks this poses to humans and the huge diversity of life these forests sustain. If the US$17million network is fully funded, the first five observatories will be set up in Brazil, Ghana, Madagascar, India and Malaysia. The Governments of all five countries involved have backed the plan. It is proposed that a canopy crane will be installed at each site to provide mobility within the forest from treetops to soil. Tower instruments will monitor fluxes of water and carbon dioxide between the canopy and the atmosphere. Each observatory will act as a monitoring and early warning system for the signs of climate change and will deliver critical information to a network of stakeholders, including governments and communities.

The Global Canopy Programme's map of existing canopy research sites and planned new Whole Forest Observatories in Brazil, Ghana, Madagascar, India and Malaysia, to be partly funded by UNEP/GEF (Image: Global Canopy Programme).

Funding

The purchase and construction of the Liebherr crane was funded through an Australian Research Council infrastructure grant with matching funds from a consortium involving James Cook University, Griffith University and The University of Queensland. Construction of the on-site laboratory and accommodation facilities was funded by the Cooperative Research Centre for Tropical Rainforest Ecology and Management (Rainforest CRC) with partner universities James Cook University, Griffith University and The University of Queensland.

Studies conducted by researchers and postgraduate students of the three partner universities at the crane site has largely been funded by the Rainforest CRC since 1999.

We wish to thank Coconut Beach Resort, Voyages, Fuchs Oils, Australian Geographic and an anonymous donor for their generous support for the Australian Canopy Crane facility and associated research.

Acknowledgements

For use of images, the Rainforest CRC wishes to acknowledge and thank (in alphabetical order) Sarah Boulter, Michael Cermak, Daniel Falster, Shannon Hogan, Birgit Kuehn, Liz Poon, Paul Reddell and Terry Reis. Thanks are also extended to Sarah Boulter for her guidance and editorial assistance.

We wish to particularly thank a number of people who were instrumental in setting up the Australian Canopy Crane and its research facilities. In particular Fiona Barron, Dennis Rodgers, Michael Cermak and Bill and Craig Jones.

Australian Canopy Crane Pty Ltd

The Australian Canopy Crane Company manages the crane and associated facilities (including the lease or licence of the site) so as to promote and support long-term high quality tropical rainforest research, cooperation in research, and public awareness and education about the canopy crane and associated research.

Correspondence

The Director
Australian Canopy Crane Research Facility
PO Box 6811
Cairns, Queensland 4870, Australia

Telephone: (07) 4042 1246
International: +61 (7) 4042 1246
Email: canopycrane@jcu.edu.au