



Australian Government

Department of the Environment, Water, Heritage and the Arts

Marine and Tropical Sciences Research Facility Milestone Report, 8 June 2009

Program 5ii: Climate Change: Rainforests and Catchments

Project 2.5ii.2: Climate change: Scaling from trees to ecosystems

Project Leader: Dr Michael Liddell, James Cook University (JCU)

Summary

In Year 3 of this project changes have occurred in the personnel structure of the team but the project itself has run according to schedule:

Team membership – MTSRF Project 2.5ii.2

Staff Member	Organisation	Responsible for
Assoc. Prof. Michael Liddell	JCU	Objective A
Dr Will Edwards	JCU	Objective B
Dr Paul Nelson	JCU	Objective C
Prof. Caroline Gross	UNE	Objective D
Prof. Nigel Stork	Uni Melbourne	Objective E

The interconnections between the different sub-projects are now producing important results as the results re-enforce each other or break down pre-conceived views on lowland rainforest sensitivity to climate, as detailed in the summaries below.

Objective A has had a good year of data collection at the Canopy Crane flux station. An interesting result to come out of the 2008/2009 carbon flux data is that nocturnal respiration at the crane site has reduced dramatically since 2001, apparently as a result of normal rainfall patterns being re-established. To investigate this in detail an analysis of soil CO₂ fluxes has commenced at the site. A large amount of spatial variation has been observed in the soil fluxes. The new Discovery Tower flux station is collecting data in a reliable manner and effectively providing replication for the fluxes from the canopy crane tower.

Objective B has completed three census intervals of data collection. Analysis of the dendrometer band data has demonstrated that there have been no significant differences between years in the increase in DBH across the 175 trees in the sample set. In conjunction with climate data this is not surprising as the last two years have had rainfall within 0.5m of the 3.9m mean for Cape Tribulation. The conversion of change in DBH into change in biomass has indicated differences between certain families, some families such as Apocynaceae slowly increase biomass whereas others such as Myrtaceae are quick to increase biomass. This is another indicator that it will be species level sensitivity to climate change which will be important in understanding the future trajectory of these forests.

Objective C has continued the regular measurements of soil water content, temperature, water potential. In addition this year the analysis of the organic components of the soil profile was commenced. Analysis of the chemical composition of the leaf litter using ¹³C NMR indicates that the litter changes from carbohydrate dominant to aliphatic hydrocarbon dominant as the litter mineralises. Analysis of the change in water content of the soil has shown that the crane site has a well drained soil which rarely achieves saturation even during the wet season. Under the current climatic regime there is negligible change in watertable depth through the year. Thus, the forest appears to rely on soil profile water and shut down use of water extensively by the end of the dry season.

Objective D has completed the first year of research. As this is a pioneering study in the use of digital photography to capture changes in phenological patterns it is not surprising that progress was a little slower than was initially anticipated. This was largely due to development of the new methodology. This has now been achieved and data collection commenced at the start of 2009. Analysis is on-going and Skyrail have made available a ten-year prior record of visual phenological records.

Objective E has stayed on track with the insect sampling / identification of leaf-litter species occurring at monthly intervals throughout the year, the collection is now approaching 7000 beetles. Using the three-year data set and corresponding microclimate data, preliminary analyses suggested the best correlation between beetle density and climatic drivers was with temperature and relative humidity, rather than with rainfall as might have been expected. A litter manipulation experiment indicated that leaf litter volume drives beetle abundance until the response plateaus at high litter input. Climate change will increase the temperature in the Daintree and under drought conditions there will be enhanced levels of litter input. Under this scenario leaf litter beetles may respond through population increases.

Each of the sub-projects dealing with Objectives (a)-(e) have completed significant research activities during year three of the project. In the final milestone the delivery is concerned with providing end of year reports on the third year of activities.

Project Outputs / Milestones

Targeted Activity	Due Date
Report 2 submission: • End of year report on the seasonal variation in fluxes (fluxes of carbon, water) linked to microclimate variables in the Daintree including the first year of data from the Discovery Tower. Early results on soil carbon fluxes will also be reported (Objective A). • End of year report on tree physiology and the risks and threats to lowland rainforest canopy tree productivity under changing rainfall and temperature scenarios (Objective B). • End of year report on the results of water uptake and carbon turnover measurements at the Australian Canopy Crane Research Facility site (Objective C). • End of year report of the results on the annual variations in phenology over the Skyrail transect and correlations will be made with species also present at the canopy crane site (Objective D). • End of year report on ground organic resource fluctuations and variations in insect populations. How insect population changes relate to: variations in the quality and quantity of resources, ecosystem status / productivity and climate variability will be examined (Objective E). • Summary of communication activities undertaken through the course of Year 3 of project, including any examples of application of the results by MTSRF projects, Skyrail, Discovery Centre or ARC.	8 June 2009

Project Outputs / Milestones

Description of the results achieved for this milestone

The project is running on schedule. Detailed descriptions of the year's results for each of the objectives are provided in this section.

Objective A – To improve our understanding of the factors influencing the variability in carbon and water fluxes from the rainforest through a long-term study in parallel with microclimate measurements.

Summary

The Australian Canopy Crane flux site at Cape Tribulation has been in operation throughout the last year and it appears that nocturnal respiration may be stabilising at lower values following three years of normal rainfall. To investigate this in detail the first measurements of the spatial variability in the soil fluxes has begun. The new Discovery Tower at Cow Bay has been in operation since December 2008, the fluxes are comparable to the Canopy Crane fluxes and a quantitative comparison will be made in ARP4 when a full year of data collection has been completed in parallel at both sites.

Activities

Flux measurements commenced again at the canopy crane site in June 2008 following a hiatus of nearly a year. Since then the station has run reliably over the last year with the exception of a few system crashes due to software failures.

The new flux station at the Discovery Centre was installed in December 2008. There have been a few issues with power supply problems, data storage and communications resulting in quite a lot of data loss in the early months. Over the last two months the system appears to be stabilising into a reliable station. The settling in period is quite normal for a new flux site, particularly where a different hardware configuration is used.

Soil fluxes have been measured using a portable LICOR automatic chamber. This has involved placing sixteen collars in spots selected for potential maximum variability in soil fluxes and carrying out point measurements. In addition to the soil fluxes volumetric water content and temperature were also measured.

Results

In Figure A1 the fluxes of carbon in the early years of the canopy crane site are contrasted with the above canopy carbon fluxes from 2008/2009.

The focus at the canopy crane site is on analysing daytime fluxes, as these are intrinsically more reliable in a flux site located in complex topography. When we look closely at Figure A1 in the photosynthetic dominated section of the plot (daytime fluxes) there is some change in shape but the largest change in recent times is clearly in the night-time data where there has been a substantial reduction in respiration.

These carbon flux results are still preliminary as there are many quality control steps yet to be applied to the data and, in addition, we must recall that the night-time data can only be regarded as semi-quantitative due to the topography of the lowland Daintree region (drainage flow from the Tablelands is a natural phenomenon). Given these precautions in analysis we should focus our attention not on the numeric value of the change in respiration rather on the direction of the change. As the experimental set-up of the flux system (location

of sensors) has not changed since 2001 it would seem reasonable to expect that there is/are environmental driver(s) for the observed reduction in respiration.

The Cape Tribulation rainforest was subject to Tropical Cyclone *Rona* in February 1999 and we had assumed that recovery was rapid as in the early years we saw no significant change in respiration. The recent results indicate that either this significant impact on the forest or the subsequent strong drought that commenced in 2001 and ended in 2004 (see Figure A2), may have increased the respiration of the forest for a considerable period. In the last two years we have had normal rainfall ($4.0 \pm 0.4\text{m}$) which may have allowed the system to approach a more steady state situation. Obviously another decade of data collection will help to resolve the situation as regards the carbon balance in the forest.

A major driver of soil respiration (the dominant component of night-time respiration) is temperature. Over the last three years the average temperature on site has been $23.6 \pm 0.4^\circ\text{C}$ with a slight shift towards higher temperatures. We are working to obtain microclimate data collected previously by Prof. Steve Turton (Australian Tropical Forest Institute, 1998-2004) to enable us to make a comparison with the earlier flux data and will be carrying out gap filling to deal with periods where there is missing data at the micrometeorology station.

The new flux system at the Discovery Tower is mounted on a twelve-metre mast at the top of the 23m tower to place it in the roughness sub-layer above the canopy (Figure A3). Collection of flux data is at 10Hz, which is the same sampling frequency used at the canopy crane site. The amount of flux data that overlaps temporally is limited between the canopy crane site and the Discovery Tower at present but it has indicated that the fluxes (carbon, water, sensible heat) are comparable. The data at this stage is too sparse to analyse the

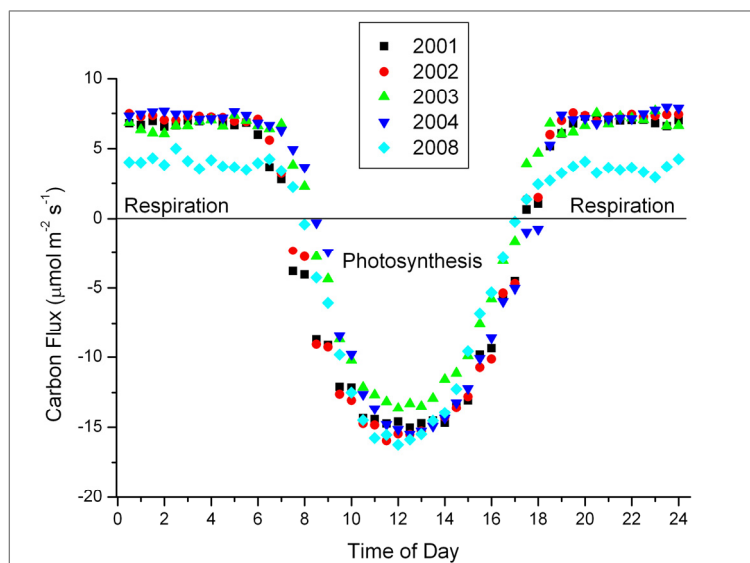


Figure A1: Diurnal variation in carbon fluxes (half-hour averages).

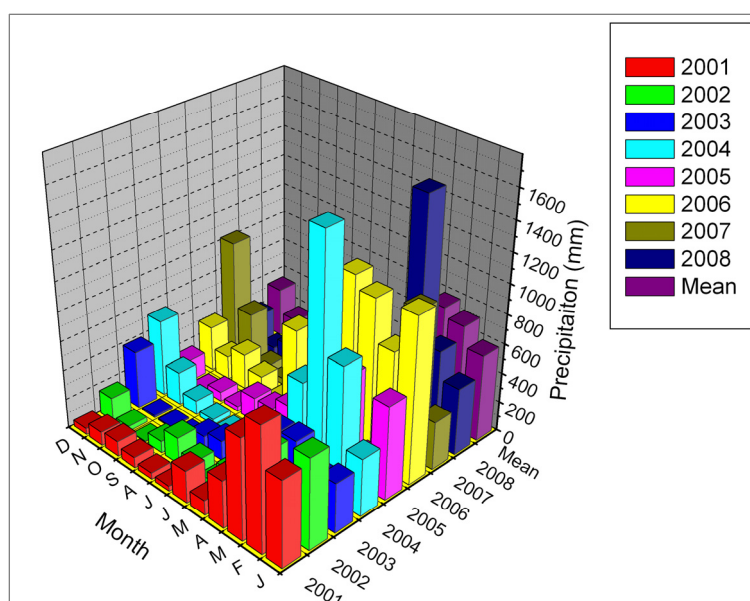


Figure A2: Monthly rainfall (© Bureau of Meteorology).

detail. When we have a complete year of data from both sites we will be in a position to make a valid numeric comparison between the sites.

A new direction commenced in this sub-project in the current year has been to start the measurement of carbon dioxide soil fluxes at the canopy crane site. In collaboration with Prof. Michael Bird, a JCU Honours student, Kalu Davies, has commenced collecting CO₂ fluxes from sixteen well separated soil collars. Early results shown in Figure A4 demonstrate that there are a wide range of fluxes around the site and these fluxes appear to be water limited. Once a larger set of data has been collected a temperature, soil water response function will be developed which will be of use in understanding the carbon balance at the site. It is interesting to note that the daily soil fluxes that we measured in April 2002 at the crane site using an automatic chamber were around 10 $\mu\text{mol m}^{-2} \text{s}^{-1}$. The soil fluxes from 2002 were obtained using a JCU designed chamber but there is no reason to expect they are substantially in error. In 2002 when the forest was under drought conditions the soil was drier (15-33% volumetric soil water content) and the soil flux measurements were also made earlier in the year. We would expect higher air temperatures (>2°C) in April would contribute to the fluxes being higher than those obtained this year when measurements were taken in May and June. The results though may also be used to back up the flux data in that it appears that basic soil respiration in the forest may indeed have been higher in the early years post-cyclone. Data collected next April and the development of the response function should help to resolve this.

The soil fluxes we have obtained in 2009 may be compared to recent results reported from the rainforests of Borneo (Ohashi *et al.* 2008) where at similar soil water content their median values 4-6 $\mu\text{mol m}^{-2} \text{s}^{-1}$ are found to be quite comparable to those found at Cape Tribulation in 2009.



Figure A3: The Discovery Tower eddy covariance system.

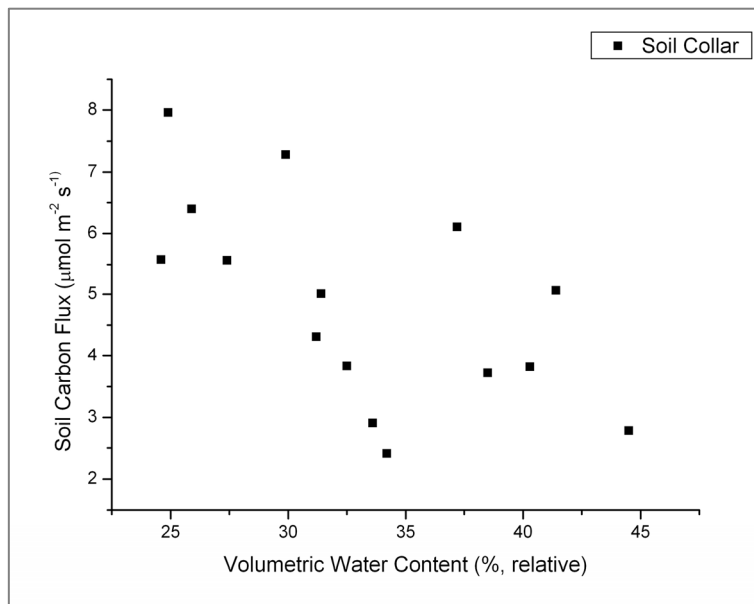


Figure A4: Flux measurements at the canopy crane site.

References

Bureau of Meteorology rainfall data from Station 031012 Cape Tribulation Store. Provided by the Cairns office of the Observation section of BOM.

Ohashi, M., Kumagai, T., Kume, T., Gyokusen, K., Saitoh, T. M. and Suzuki, M. (2008) Characteristics of soil CO₂ efflux variability in an aseasonal tropical rainforest in Borneo Island. *Biogeochemistry* 90: 275-289.

Objective B – Report on tree physiology and the risks and threats to lowland rainforest canopy tree productivity under changing rainfall and temperature scenarios.

Activities

The data collection continues for leaf litter, dendrometer and conductance. In April this year the LAI measurements were initiated, these measurements are now on-going at quarterly intervals.

Results

In 2007, Franks and colleagues began measurements of tree growth increments and forest production and turnover. Tree growth was estimated from dendrometer bands placed on almost all (n=170) individual trees greater than 10cm DBH at the time of commencement. Forest productivity/turnover was assessed monthly as dry mass of plant components (wood, leaf, fruits-and-flowers) in 25 x 1m² litter traps placed at random positions within a 1ha area of forest directly underneath the Canopy Crane.

The following is the preliminary analyses conducted since receiving the data generated under this objective:

1. Dendrometer measurements of stem incremental growth.

In total, 170 trees with initial stem diameters at breast height greater than 10cm were selected. As expected, representation of individuals within species and families are not equal (Appendix 3, Figure B1). These trees come from 18 plant families and are typical components of this forest type.

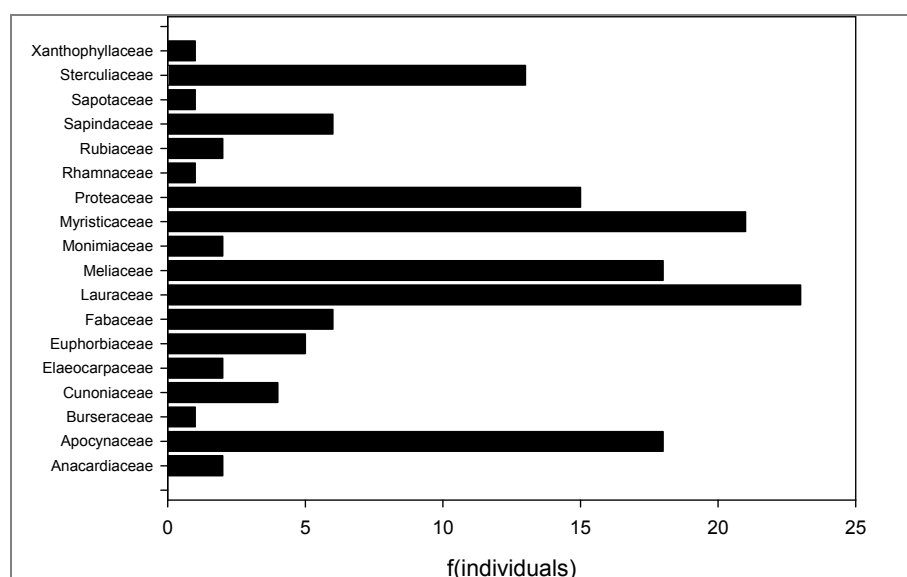


Figure B1:
Breakdown of individuals within eighteen plant families included in the dendrometer (growth increment) study.

As expected, there is unequal representation of individuals at both the species and family levels (Figure B2).

Tree incremental growth has been assessed on four occasions; March 2007, March 2008, September 2008, and May 2009. Thus there are three between-census intervals over which to make comparisons. I began by examining absolute size increase across all trees between intervals (termed time 1, time 2 and time 3 hereafter), and testing for differences between intervals. The distributions of changes in DBH within intervals were not normal, and included both zero and negative values. In this case, attempts at normalisation via techniques such as *ln* transformation are impossible and therefore non-parametric Kruskal-Wallis comparisons were used. When significant differences were detected I then performed all possible pairwise comparisons between groups via Wilcoxon rank-sum tests with Bonferroni corrected *P*. I performed this analysis twice: first, without consideration of the differences in time between census intervals, and second after transforming growth estimates in each species to account for the differences in duration between sample periods.

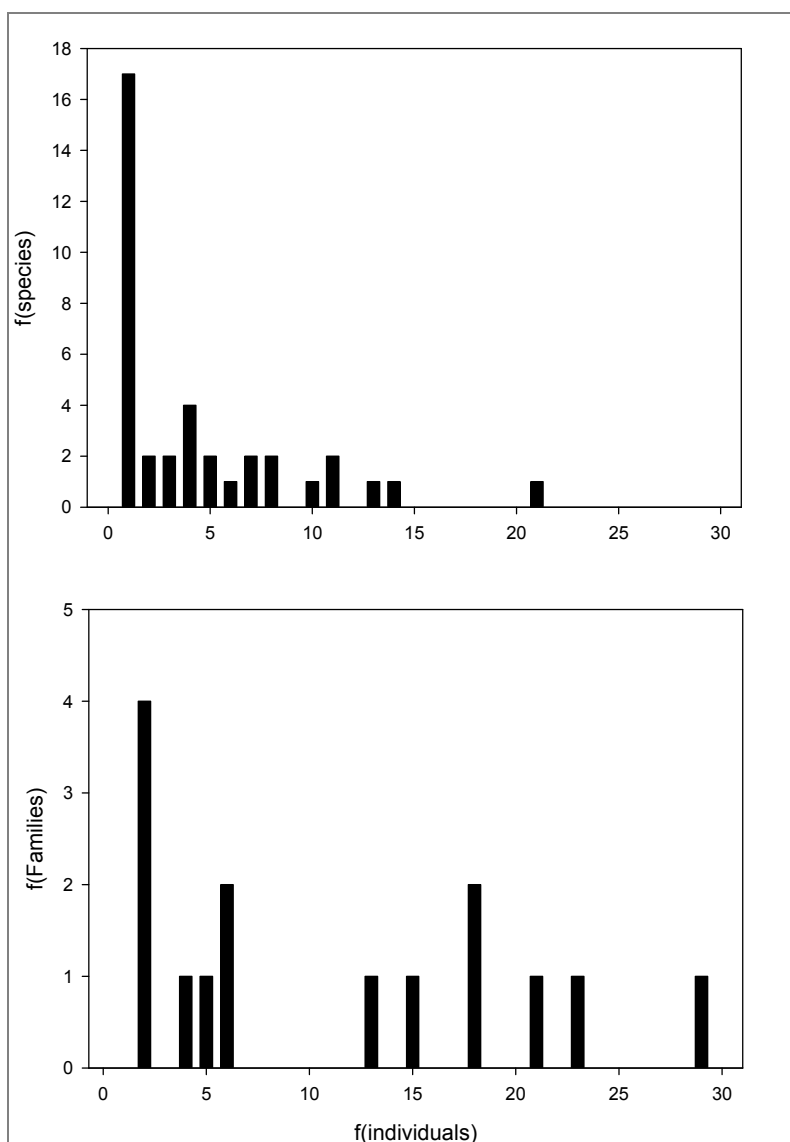


Figure B2: The frequency of distribution of individuals within Species (*top*) and Families (*bottom*) of a sample of 170 trees measured for incremental growth at Australian Canopy Crane Research Facility in North Queensland.

There were significant differences in the distributions of incremental increase in DBH between periods (Kruskal-Wallis chi-square = 25.2925, $df = 2$, $P < 0.001$) (Figure 3a). Wilcoxon rank-sum tests indicated differences between 1 vs 2 (rank-sum normal statistic with correction $Z = 4.8581$, $P < 0.001$), 1 vs 3 (rank-sum normal statistic with correction $Z = 3.6875$, $P = 0.0002$) but no difference between 2 and 3 ($Z = -0.7526$, $P = 0.4517$). However, when standardised for time (months between sampling) there was no evidence for any significant differences between samples (Kruskal-Wallis chi-square = 1.7001, $df = 2$, $P = 0.4274$) (Figure B3). These results provide little evidence for between-year or between season differences in growth in DBH.

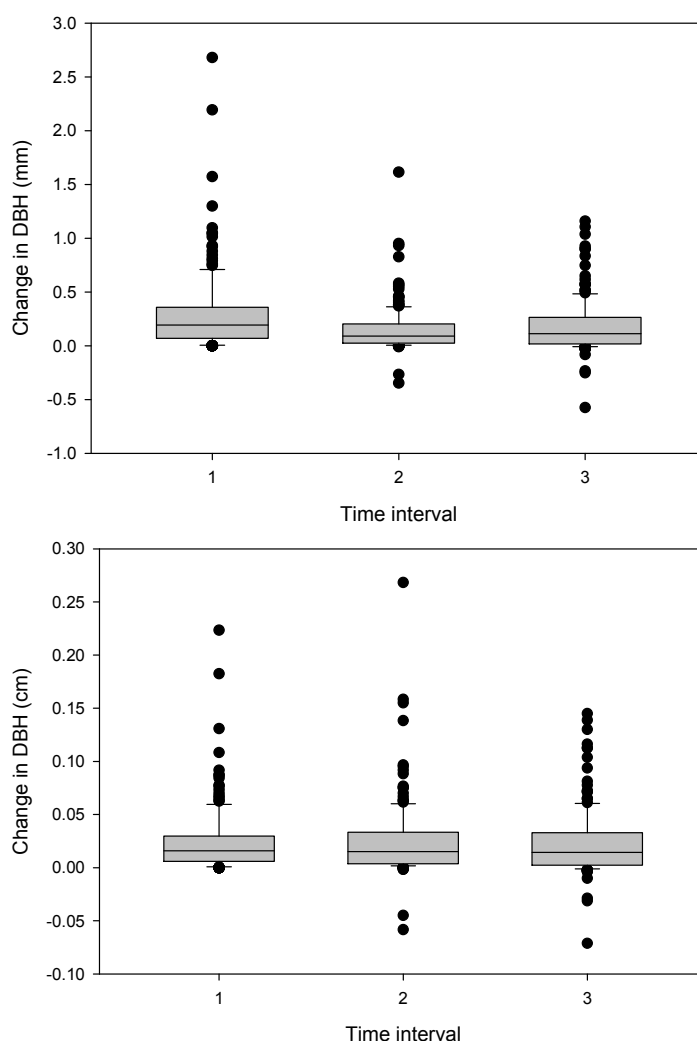


Figure B3: Distribution of change in DBH between census periods. (x-axis legends 1 = Mar07 – Mar 08, 2 = Mar 08 – Sept 08, 3 = Sept 08 – May 09). The top graph shows distribution of absolute change; the lower graph shows change standardised for between-sample time differences.

Finally, I examined the relationship between DBH at first census and DBH at final census (Figure B4). There was no significant, simple linear relationship between these two values as might be expected. Recently, Cade and Guo (2000) showed that a quantile regression fit (Cade and Noon 2003) of a modified Ricker function $y = \beta_0 X^{\beta_1} e^{\beta_2 X} \epsilon$ was the best-fit relationship between mature plant density and initial germination density and the data distribution looked similar to that in Figure B4. I intend to examine this pattern using this

technique in future. I have recently learned the quant.reg procedure in 'R' required to perform this analysis.

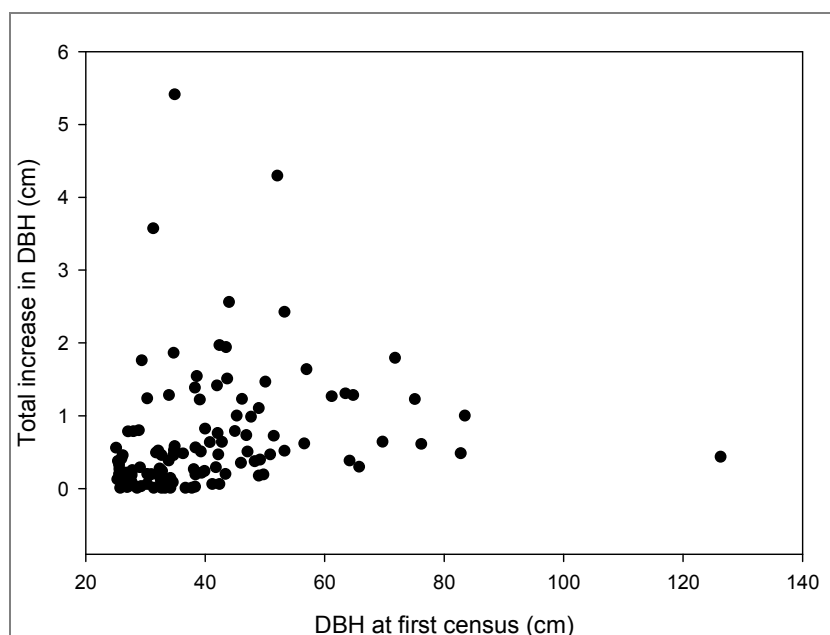


Figure B4: The relationship between total increase in DBH and initial size (DBH).

2. Change in biomass

Change in girth is not necessarily reflective of change in biomass. This is because species differ in wood density, and because a small increment in DBH in an initially large stem will produce a much greater increase in biomass than an equal increment in an originally small stem. To examine increase in biomass I began by attempting to determine records for wood density for all trees. Two individual trees had died and were removed. Density measurements were not undertaken previously on representative individuals from each species, which, in my opinion, was an oversight and will be performed in ARP4.

I have added wood density estimates for as many species as possible from The Australian Greenhouse Office (AGO) and CSIRO Forestry and Forest Products (FFP) [Updated Australian Species Wood Density Database](http://www.climatechange.gov.au/ncas/reports/tr18final.html) – July 2003 Woody Density Phase 1 – State of Knowledge National Carbon Accounting System – Technical Report No. 18 (available download database from <http://www.climatechange.gov.au/ncas/reports/tr18final.html>).

In total, I found records of wood density for 115 individuals. For all 115 I calculated net change in above-ground biomass (AGB) using the allometric models of Chave et al (2005). I calculated AGB based on the allometric model for wet forest stands and without knowledge of individual plant height (H) distributions:

$$AGB_{est} = \rho * \exp(-1.239 + 1.980\ln(D) + 0.207(\ln(D^2)) - 0.0281(\ln(D^3)))$$

where ρ is density (estimated as $g.cm^{-3}$) and D is stem diameter.

Because wood density estimates were not available for all individuals, I considered attempts to generate meaningful estimates for increments in total AGB could not be performed. There were, however, six families that were represented by greater than ten individuals where wood density was available. Thus I tested the null hypothesis that there was no difference in

the accumulated AGB between families. Again, because of non-normality, I used Kruskal-Wallis rank sum test followed by pairwise Wilcoxon rank-sum tests. Given six families, this resulted in 15 post-hoc comparisons and alpha was corrected to $P = 0.0033$.

There were significant differences in increase AGB between families (Kruskal-Wallis chi-square = 28.842, $df = 5$, $P < 0.001$) (Figure B5).

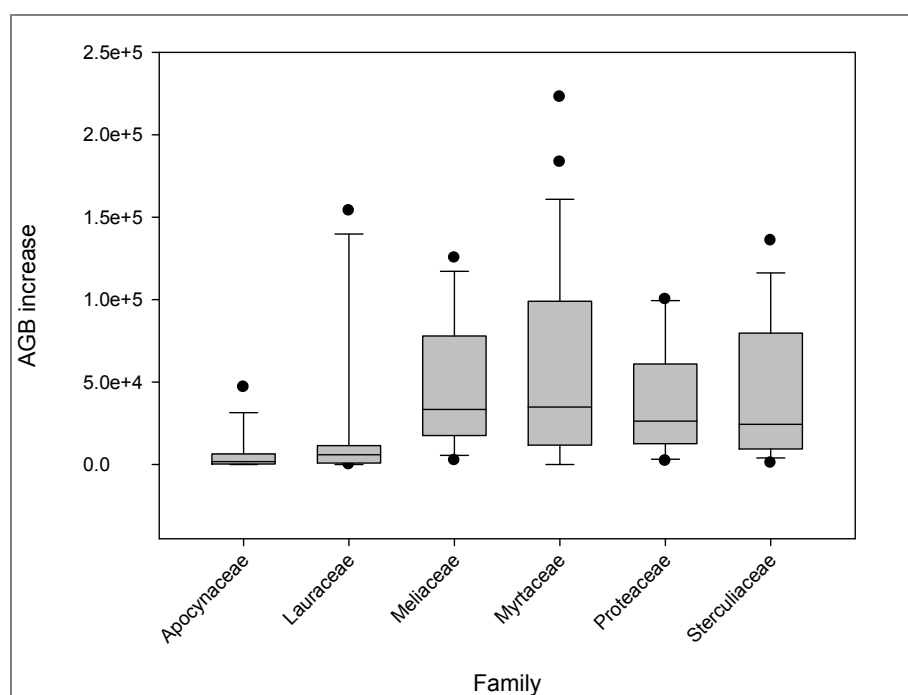


Figure B5: Comparison of median growth within families (Families represented by > 10 individuals) (Families – alphabetical order Apocynaceae (n=17), Lauraceae (n=10), Meliaceae (n=12), Myrtaceae (n=28), Proteaceae (n=15), Sterculiaceae (n=13)).

Overall differences were due to significant pairwise differences between Apocynaceae and: Meliaceae ($Z = -3.7907$, $P = 0.0002$), Myrtaceae ($Z = -3.8112$, $P = 0.0001$), Proteaceae ($Z = -3.7797$, $P = 0.0002$), and Sterculiaceae ($Z = -3.4776$, $P = 0.0005$). There were no other significant differences among any pair-wise comparisons.

3. Litter trap measurements to monitor and compare carbon storage and turnover across species.

I have performed an initial (preliminary) analysis of the litter trap data (Figure B6). The data are circular by nature and must be analysed as such. Since becoming involved in this project a large proportion of my time devoted to this component has been reformatting data in order to conform to the circular statistical procedure.

Ideally, this data will be analysed using techniques such as tests for homogeneity of concentration parameters as well as circular analysis of variance. These techniques are all easily accessible, but require purchase of specialist software packages. I have been unable to ascertain what the previous principle investigator was intending. Full analysis pending arrival of Oriana circular statistics package (Copyright 2009 Kovach Computing Services,

Anglesey, Wales. All Rights Reserved. Portions copyright Addinsoft, Provalis Research, and Data Description Inc).

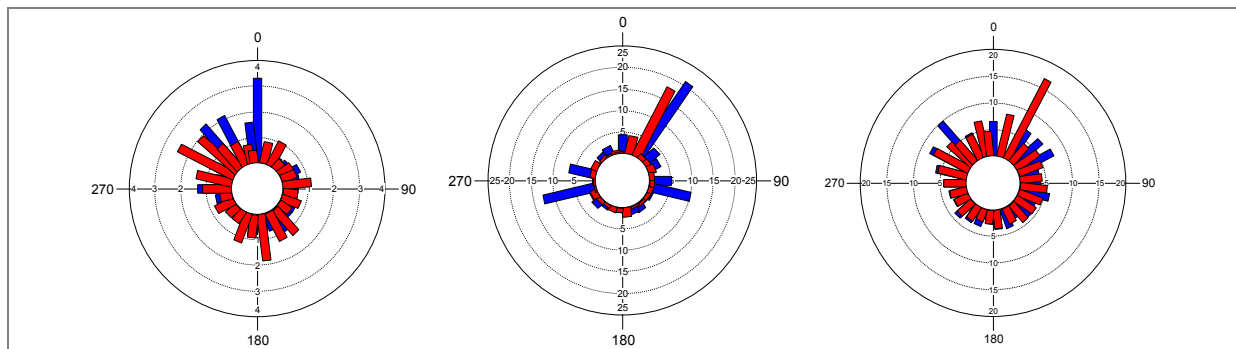


Figure B6: Preliminary analysis (circular histograms) of litter trap data. Results are the mean weight (mg) from 25 litter traps samples (approx.) two weekly intervals. Figures are (from left) Flowers and fruit, wood, leaf. Histograms are blue (2007) and red (2008).

References

Cade, B. S. and Guo, Q. (2000) Estimating effects of constraints on plant performance with regression quantiles. *Oikos* 91: 245-54.

Cade, B. S. and Noon, B. R. (2003) A gentle introduction to quantile regression for ecologists. *Frontiers in Ecology and Environment* 1: 412-20.

Chave, J., Andalo, C., Brown, S., Cairns, M. A., Chambers, J. Q., Eamus, D., Folster, H., Fromand, F., Higuchi, N., Kira, T., Lescure J.-P., Nelson, B. W., Ogawa, H., Puig, H., Riera, B. and Yamakura, T. (2005) Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia* 145: 87-99.

Ilic, J., Boland, D., McDonald, M., Downes, G. and Blakemore, P. (2003) [Updated Australian Species Wood Density Database](http://www.climatechange.gov.au/ncas/reports/tr18final.html) – July 2003 Woody Density Phase 1 – State of Knowledge National Carbon Accounting System – Technical Report No. 18 (available download database from <http://www.climatechange.gov.au/ncas/reports/tr18final.html>).

Kovach Computing Services (2009) Oriana statistical package for analysis of circular data. Anglesey, Wales.

Objective C – Report on the results of water uptake and carbon turnover measurements at the canopy crane site.

Summary

Patterns of water uptake from throughout the soil profile, over seasons and rainfall events are now known. Over the course of the dry season subsoil moisture was steadily depleted, with occasional rainfall not being adequate to recharge the profile. During the wet season the soil rarely, if ever, reached saturation, showing a well-drained profile and therefore presumably no limitation to water uptake by lack of oxygen. When the soil was wet, there was much greater uptake from surface soil than subsoil. When the soil was dry, total uptake was much less, and the difference between depths was less. The depth to watertable was very stable, at 10-13 m depth, suggesting negligible uptake of water from the watertable.

The nature of carbon compounds showed a gradient from carbohydrate-dominated in litter to aliphatic-dominated deep in the soil profile. The effects of litterfall on mineralisation of carbon and emission of greenhouse gases are currently being examined.

Activities

Soil water content and potential (to 1.5m depth) and watertable depth were monitored throughout the year using methods described previously. Watertable depth sensors and loggers (Odyssey) were installed in July 2008.

Soil water samples were taken at different depths in the profile throughout the year, using suction applied to porous ceramic cups. Composite samples are being prepared to provide sufficient sample isotopic and molecular analyses to enable downward fluxes to be estimated.

The nature of carbon compounds in litter and soil was examined using ^{13}C nuclear magnetic resonance (NMR) spectroscopy, carried out at the University of Adelaide/CSIRO facility in Adelaide.

A litter exclusion/addition experiment was carried out during the wet season to determine the effects of litter addition on emission of the greenhouse gases CO_2 , CH_4 and N_2O . This will enable the seasonal effects of litterfall to be separated from seasonal effects on soil water content, temperature and other factors. Details of the experimental design are given under objective e. The gas emissions were sampled by PhD candidate Sarah Connor using a static chamber method with three chambers per plot, and samples taken over the course of an hour. Soil temperature and water content were measured and soil samples were taken for analysis of C and N. Gas samples will be analysed shortly using the greenhouse gas GC recently installed at JCU Cairns.

Results

Now that over a full year of soil water content data have been collected, the full seasonal picture has emerged (Figure C1). Over the course of the dry season subsoil moisture was steadily depleted, with occasional rainfall not being adequate to recharge the profile. Fluctuations in soil water content decreased with depth. By mid December soil water content and potential were extremely low throughout the profile, apart from moderate and brief wetting of the topsoil. Water uptake (transpiration) during December was generally low, but responded rapidly to the rainfall that did occur. The dry subsoil conditions at this time meant the plants were forced to rely on the topsoil for water supply. Soil water potential was drier than -300 kPa at all depths during most of December. During the wet season the soil rarely, if

ever, reached saturation, showing a well-drained profile and therefore presumably no limitation to water uptake by lack of oxygen.

Water uptake from different depths is shown in Figure C2. Points show change in water content during a day, with more negative being faster drying. When the soil was wet, there was much greater uptake from surface soil than subsoil (more negative values for surface layer). When the soil was dry, total uptake was much less, and the difference between depths was less. During dry periods there was often less uptake from surface layers than from subsoil layers.

Over the period July 2008 to April 2009 the depth to watertable was very stable, at 10-13m depth. There was negligible diurnal fluctuation, suggesting negligible uptake of water from the watertable. However, we still plan to measure isotopic composition of water from soil profile, aquifer and xylem, to determine if xylem water originates from the soil profile or aquifer.

Carbon in litter inputs is mineralised back to carbon dioxide at different rates depending on the nature of the carbon compounds. The nature of the carbon compounds can be determined using ^{13}C NMR spectroscopy. We obtained ^{13}C NMR spectra of litter and soil organic matter from various depths. The litter is dominated by carbohydrate, but carbohydrate is preferentially mineralised, so the amount of carbohydrate relative to other compounds decreases with depth (Figure C3).

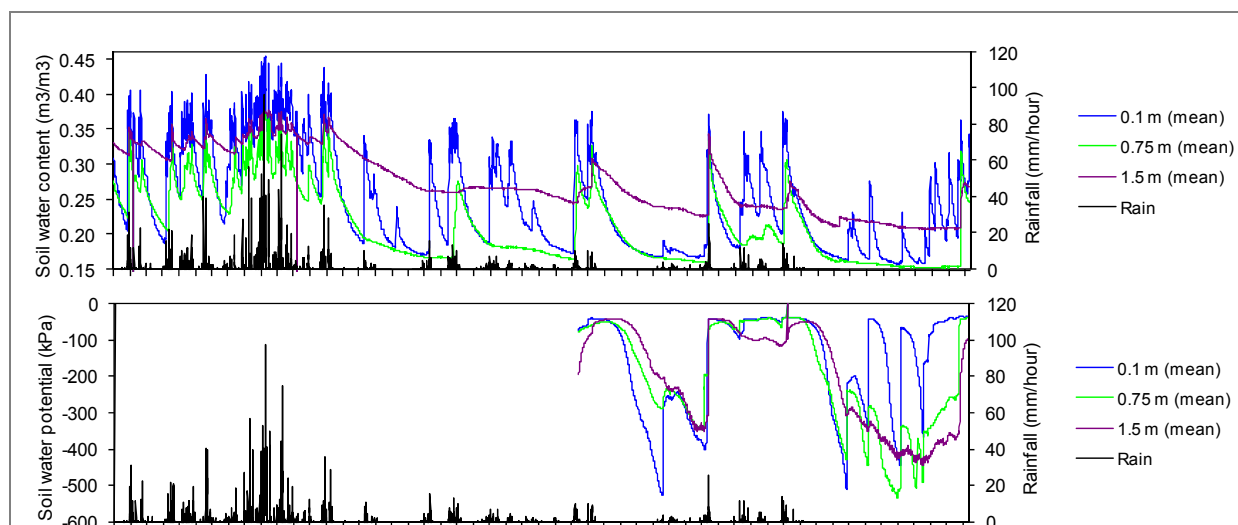


Figure C1: Soil water content (top) and soil water potential (bottom) over the course of 2008. Some rainfall data are missing for Apr-May and Nov-Dec.

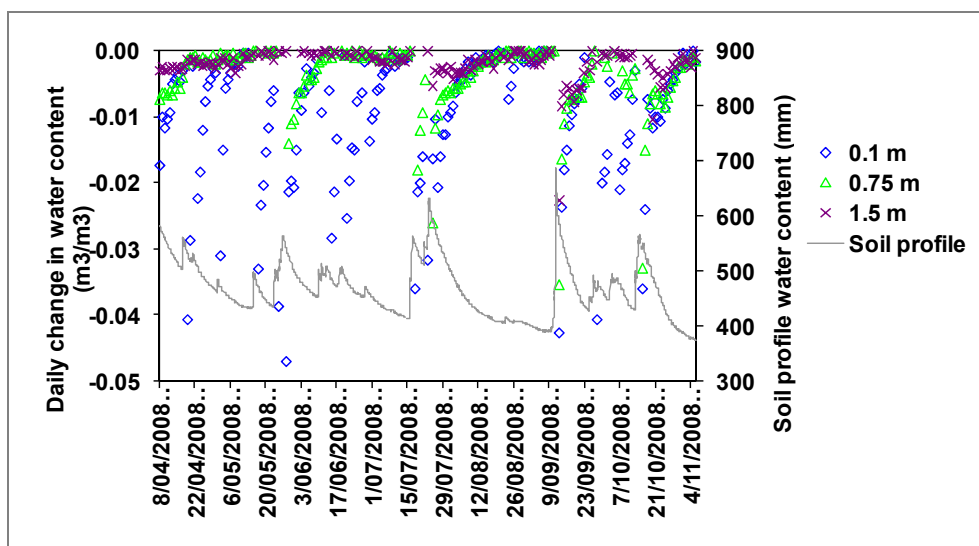


Figure C2: Uptake of water from different depths. Grey line shows soil water content. Points show change in water content over 24 hours. The more negative the value the greater the water uptake.

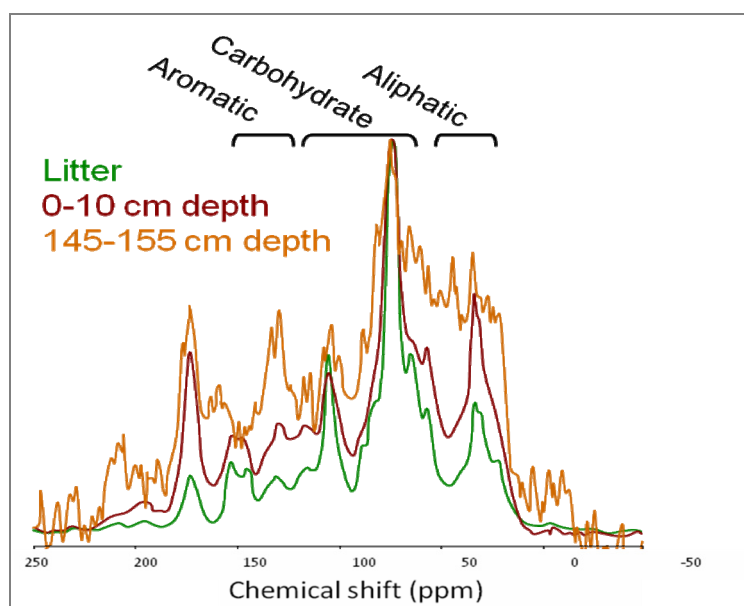


Figure C3: ^{13}C NMR spectra of litter, topsoil and subsoil, normalized to the height of the largest (carbohydrate) peak.

Objective D – Report on the results of annual variations in phenology along the Skyrail transect and correlations with species also present at the canopy crane site.

Activities and Results

During 2008, the technique for gathering digital phenological data from tree canopies using the unique access presented by the gondola of the Skyrail was developed and refined. This involved the trialling of several video and camera capturing techniques. Professional photographers were consulted on ways to maximize contrast and to minimise bright sunlight when shooting down on to a canopy. A Sony DSLR α -700 was eventually chosen as the tool to capture the data. Data are stored as 12MB images that, over the long cableway run of Skyrail, need 'stitching' together to form a transect of readable images, see Figure D1. The process of 'stitching' has not been straight forward although Nichols has successfully devised a technique using a high-end Stitching program (Canon Photostitch 3.1). With the technical matters resolved, qualitative data on flowering and fruiting episodes (tree and species level) has been gathered from digital images for 2009 at Skyrail (Jan – May). Nichols captures images monthly at the Skyrail site and visually at the Crane site. At the Canopy Crane site visual monitoring was chosen as it proved impractical to carry out digital stitching using the radial patterns made possible using the gondola of the crane. Again data collection at the Canopy Crane site commenced at the start of 2009.

The species lists are provisional for both locations as vouchering of specimens is currently underway. There is a moderate level of overlap in species composition between the two sites which will allow for latitudinal comparisons (82 species at Crane, 107 species at Skyrail, 19 species in common). Climatic information for the same phenological periods is being captured. At the Crane site there has been an All Weather Station (AWS) in operation since September 1998. At Skyrail the site operators have had low accuracy rain, temperature and relative humidity measurements on-going for a considerable period at two of the stations (Red Peak, Barron Falls). We are currently arranging for the installation of two AWS at these sites so that this data set can be augmented with more accurate data.

These climatic data will be used in time to look at the significance of phenological patterns against any changes on climate. To this end the team has been very fortunate to receive in-kind observational data from Skyrail covering periods from at least 1996 to the present. Two workers at Skyrail collected phenological data in the 1990s using visual identification and we have been offered access to the phenology data collected by Mr Tore Lien Linde (see below). This will enable a 10 year phenological spectrum to be built that will greatly assist with establishing baseline conditions.

In June 2009 a Phenology Team meeting was held at JCU with Gross (UNE), Liddell (JCU), Nichols (JCU) and Skyrail Evan Tandy, Tore Lien Linde and Cairns City Council staff Bob Jago and Richard Bellerio in attendance. At this productive meeting data were shared (e.g. see above) or sourced (e.g. Skyrail volumetric data, CCC) and additional access to Skyrail for data calibration were organised. A protocol for the distribution and back-up of data was determined that involves two digital files per census period to be lodged at JCU and one copy to be sent to Gross at UNE. Discussions on methods for validation of species identity at Skyrail was also discussed and it was resolved that the researchers would assist Skyrail with vouchering and collection methodology for plant specimens. To this end, Prof Gross met with Prof Crayn (Director, Australian Tropical Herbarium) to discuss collection permits and the vouchering of Skyrail and the Crane study sites. Prof Crayn was very keen to assist with the collection of botanical vouchers from these locations.



Figure D1: Two stitched images from Skyrail (April, March 2009). These images are composites of six images taken sequentially between towers 7 and 8 and stitched together with Canon Photostitch 3.1 software.

SkyRail have agreed to provide one day per month of Tore's time to assist in the Phenology project. This is necessary as the data analysis can only commence when the trees are identified correctly. We had initially assumed that the trees would be labelled into a spreadsheet and then Bob would identify them. Once the number of images became apparent per transect this method was ruled out. The approach developed has been to record the individual identified trees on a 'stitched transect' and store the identified trees in an Excel database file. The correct identification often relies on the presence of flowers or fruits and so the development of the transect database will be a work in progress for many years. The Cairns Council have indicated that they are prepared to provide Bob Jagos expertise for identification of trees where it is necessary.

In each census the specimens which are in flower/fruit which have been identified are then recorded in a separate section of the database. The selection of core trees then will be possible only after a substantial collection interval has passed and a big enough set of identified trees has been stored in the database. It was a bit presumptive when we drafted ARP3 to assume that we would have fully identified the trees in the SkyRail transect and have collected a whole years data. The technological challenges were more complex than we had imagined (we even had a Sony expert on site) but we are now all confident that the project is going according to plan. The first round of data analyses will begin with the impending arrival of the SkyRail data collection from Tore Linde with Prof Gross.

Objective E – Report on ground organic resource fluctuations and variations in insect populations. How insect population changes relate to: variations in the quality and quantity of resources, ecosystem status / productivity and climate variability will be examined.

Summary

1. A manuscript on seasonality of beetles during the period 2000-2004 was published in May 2009.
2. A leaf litter manipulation experiment was completed in February 2009.
3. Sampling of the leaf litter inhabiting beetle time-series commenced in 2006 continues.
4. Preliminary analyses suggest that the seasonality of climate and resources may both be important in explaining seasonality of leaf litter inhabiting beetles.

Activities

A manuscript documenting the seasonality of beetle assemblages (based on four years of sampling at the crane site (2000-2004)) was published (May issue) in the journal *Biotropica*:

Grimbacher, P. S. and N. E. Stork (2009) Seasonality of a Diverse Beetle Assemblage Inhabiting Lowland Tropical Rainforest in Australia. *Biotropica* 41(3): 328-337.

Sampling of insects inhabiting leaf litter was initiated in January 2006 and is ongoing. This involves a monthly collection of five litres of finely sifted leaf-litter, collected from the ground at the crane site. This material is then run through Tullgren funnels for approximately twelve hours to extract insects, from which the beetles are removed, counted and stored in ethanol. Following the microhabitat sampling, beetle specimens are processed (removed from samples) and dry-mounted ahead of species identification. This process is very tedious and time consuming but it is essential for species-level identification.

A leaf litter manipulation experiment was initiated in September 2008 to alter the amount of leaf litter in plots on the ground. Three treatments were tested among six replicate 3x3m plots. Leaf litter was excluded from plots with bird netting (mesh size 2x2 cm) suspended 100-150cm above the ground (exclusion treatment). Each of the leaf litter addition plots (addition treatment) received a monthly addition of sixty litres of sifted (to remove invertebrates) leaf litter collected nearby. Control plots were marked out but otherwise unaltered. The experiment was completed in early February 2009 when the leaf litter from each plot was collected and the insects inhabiting the leaf litter were extracted with Tullgren funnels.

Results

The monthly beetle collecting time series has so far captured 6,700 beetles (Jan 2006-Mar 2009). For this experiment a standard volume of fine leaf litter (five litres) is collected from the ground under the circumference of the canopy crane at Cape Tribulation. Standardising the volume of leaf litter, allows us to examine temporal variation in insect density, independent of seasonal variations in leaf litter fall and volume (see Objective B). This time series (Figure E1) shows both seasonal and yearly variation in beetle density. Climatic variables also show seasonal variation (Figure E2).

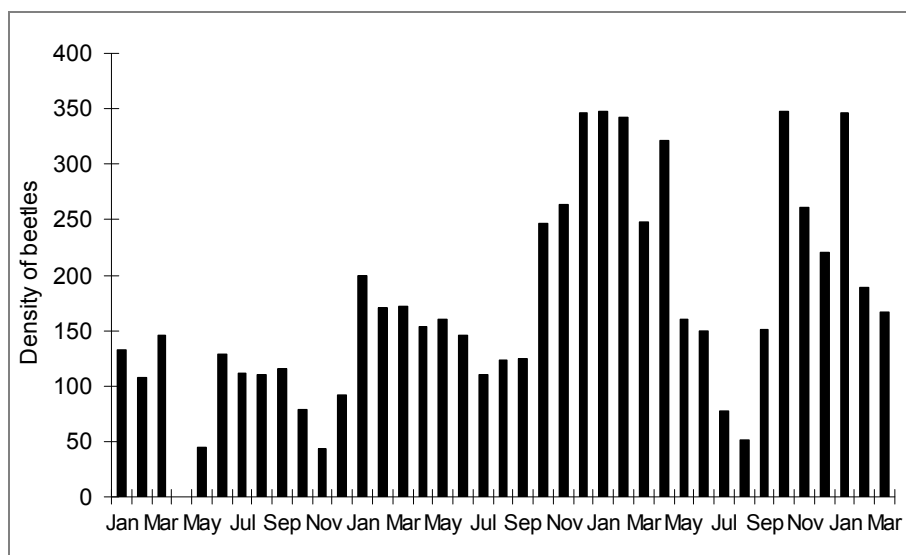


Figure E1: Temporal variation in the density of beetles extracted from monthly collections of leaf litter (five litres) from the ground at the Canopy Crane Research Facility, Cape Tribulation.

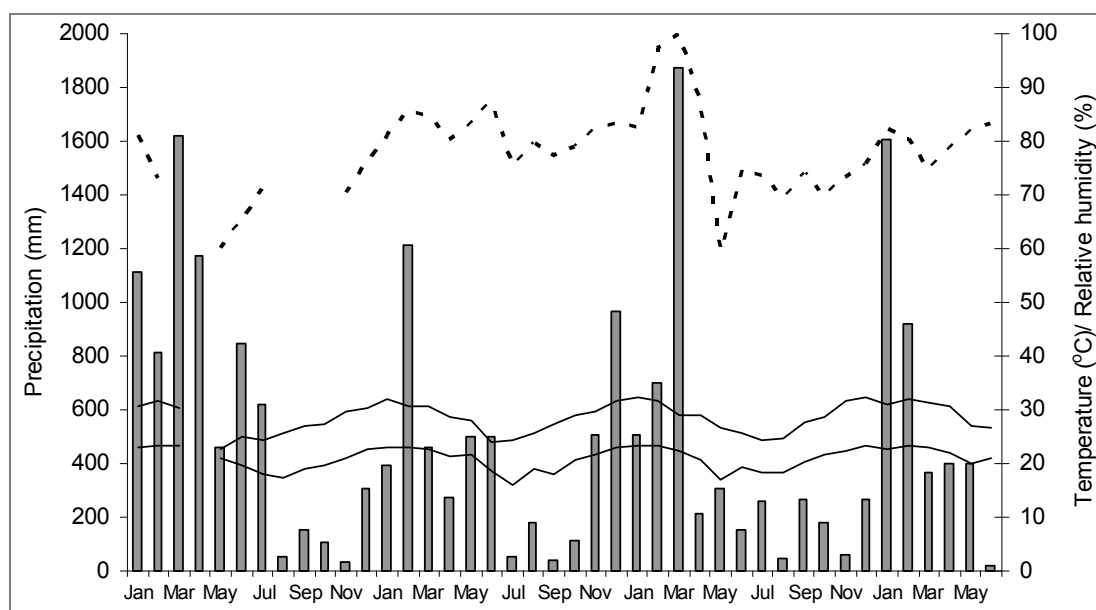


Figure E2: Total monthly precipitation (bars), mean daily minimum and maximum temperature (solid lines) and mean daily relative humidity (dashed line) for the Canopy Crane Research Facility, Cape Tribulation between January 2006 and June 2009.

When the climatic data was tested against monthly beetle density counts, measures of temperature and relative humidity were positively correlated (Table E1). Interestingly, solar radiation, evaporation and total monthly rainfall were not significantly correlated with monthly beetle density counts (Table E1). Taking all climatic variables (including one temperature measure – the mean) into account only marginally improved the strength of the correlation (Table E1).

As temporal autocorrelation and intercorrelation of climatic parameters has not been accounted for in these preliminary analyses, it would be premature to draw too many

conclusions from these results. Nevertheless, they do show that some climatic parameters may be important in explaining temporal variation in beetle density.

Table E1: Linear regression results between monthly beetle density values and climatic variables. *P*-values less than 0.05 are in bold. *n*=38 in all tests except * where *n*=34 due to missing climatic data.

Climatic variable	<i>r</i>	<i>P</i> -value
Daily average:		
Mean temperature	0.55	0.0004
Maximum temperature	0.57	0.0002
Minimum temperature	0.48	0.002
Solar radiation	0.32	0.17
*Relative humidity	0.49	0.002
Evaporation	0.08	0.65
Total monthly rainfall	0.30	0.07
*All (multiple regression)	0.63	0.005

The leaf litter manipulation experiment, run between September 2008 and February 2009, captured a total of 3337 beetles. The plots where leaf litter was excluded had significantly fewer beetles than control plots or plots where leaf litter was added (*P*=0.05, Figure E3). However, there were not significantly more beetles in the leaf litter addition plots than the control plots (Figure E3). These results show that leaf litter fall influences beetle population fluctuations although beetle responses to variations in leaf litter fall appear to show threshold responses. That is beetle abundance increases with leaf litter fall up to a point but above this level, additional leaf litter has little influence on beetles. Further data regarding the specific volume and nutritional values of the leaf litter are being collated and these may allow us to tease apart the factors influencing temporal variation in beetle populations.

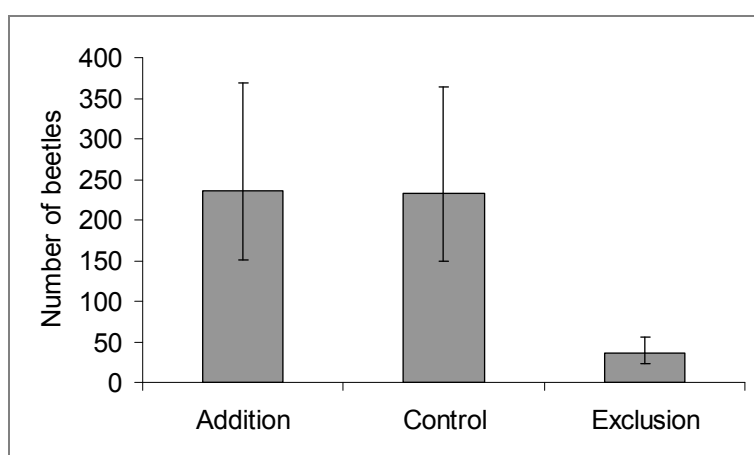


Figure e3. Preliminary results of beetle abundance among leaf litter manipulation treatments near the Canopy Crane Research Facility, Cape Tribulation. In this experiment leaf litter was added, excluded (with bird netting) or unaltered (control) to six replicate 3x3m plots over five months.

Appendix 1 – Summary of Project Meeting Outcomes

Project 2.5ii.2: Climate Change: Scaling from trees to ecosystems

18 May 2009

Attendees: Paul Nelson (PN), Michael Liddell (ML), Will Edwards (WE), Peter Grimbacher (PG), Caroline Gross (CG), Cassandra Nichols (CN).

Venue: Mike Liddell's office, JCU Cairns and Teleconference

Due to busy schedules this meeting was a series of brief meetings or teleconferences with the various sub-project teams.

ML: Confirmed that the project needed the final end of year report in by 8 June and indicated email reminders would be coming out.

Budget update: The project was running on budget. Attention was drawn to the problems that had arisen because of the departure of Peter Franks. Each of the sub-projects was informed of the specific amounts that needed to be expended before the end of the financial year. Commitments were needed by the end of June.

Each of the sub-projects provided an update on their current status.

Objective a – Atmospheric Fluxes

The two flux systems are operational but one month of data was lost on the Discovery Tower system due to data storage problems. Communications problems have been resolved and the ability to remotely log on to the Discovery Tower system is working well.

Objective b – Plant Physiology

The leaf litter work is on-going. The TROBIT team assisted with the re-census of the DBH plot on the week of the 7 May. Data for this will become available in ARP4.

Objective c – Soil structure / hydrology

The soil pit instrumentation is running well. The data loggers have been replaced with finer resolution instruments on the bores and the lower resolution data downloaded.

Objective d – Phenology

A separate sub-project meeting was organised to coincide with Caroline Gross visit to Skyrail and the Crane site in early June. Collaborative ventures have been established with Skyrail and Cairns City Council to assist in the longevity of this sub-project.

Objective e – Insect population variability

The litter insect collection is running on schedule along with pinning in the lab. Carl finished his gondola work. Peter Grimbacher is analysing the data in Melbourne while Cassandra and Andrew carry out the field work on site.

Other Business

None.

The next project meeting is scheduled for July 2009.

Appendix 2 – Publications

Articles published or submitted during in ARP3 that relate to research done at the Australian Canopy Crane site by MTSRF team members.

Asner, G. P., Martin, R. E., Ford, A. J., Metcalfe, D. J. and Liddell, M. J. (2009) Leaf chemical and spectral diversity in Australian tropical forests. *Ecological Applications* 19: 236-253 (MTSRF Project 2.5ii.2 Objectives A and B).

Gauthier, A., Amiotte-Suchet, P., Nelson, P. N., Lévêque, J. and Hénault, C. (Submitted) Dynamics of the water extractable organic carbon pool during mineralisation in soils from coniferous and deciduous forests. *Plant and Soil* (MTSRF Project 2.5ii.2 Objective C).

Grimbacher, P. S. and Stork, N. E. (2009) Seasonality of a diverse beetle assemblage inhabiting lowland tropical rainforest in Australia. *Biotropica* 41: 328-337 (MTSRF Project 2.5ii.2 Objective E).

Appendix 3 – Species list and sample size for trees (>10 cm DBH) included in dendrometer study at the Australian Canopy Crane Research Facility, North Queensland

Family	Genus	Species	n
Anacardiaceae	<i>Semecarpus</i>	<i>Semecarpus australiensis</i>	2
Apocynaceae	<i>Alstonia</i>	<i>Alstonia scholaris</i>	14
Apocynaceae	<i>Wrightia</i>	<i>Wrightia laevis</i> (subsp. <i>millgar</i>)	4
Burseraceae	<i>Canarium</i>	<i>Canarium vitiense</i>	1
Cunoniaceae	<i>Gillbeea</i>	<i>Gillbeea adenopetala</i>	4
Elaeocarpaceae	<i>Elaeocarpus</i>	<i>Elaeocarpus angustifolius</i>	2
Euphorbiaceae	<i>Cleistanthus</i>	<i>Cleistanthus myrianthus</i>	4
Euphorbiaceae	<i>Rockinghamia</i>	<i>Rockinghamia angustifolia</i>	1
Fabaceae	<i>Castanospermum</i>	<i>Castanospermum australe</i>	6
Lauraceae	<i>Endiandra</i>	<i>Endiandra microneura</i>	10
Lauraceae	<i>Cryptocarya</i>	<i>Cryptocarya mackinnoniana</i>	7
Lauraceae	<i>Cryptocarya</i>	<i>Cryptocarya grandis</i>	3
Lauraceae	<i>Cryptocarya</i>	<i>Cryptocarya hypospodia</i>	1
Lauraceae	<i>Cryptocarya</i>	<i>Cryptocarya murrayi</i>	1
Lauraceae	<i>Litsea</i>	<i>Litsea leefeana</i>	1
Meliaceae	<i>Dysoxylum</i>	<i>Dysoxylum pettigrewianum</i>	7
Meliaceae	<i>Dysoxylum</i>	<i>Dysoxylum papuanum</i>	5
Meliaceae	<i>Dysoxylum</i>	<i>Dysoxylum alliaceum</i>	4
Meliaceae	<i>Dysoxylum</i>	<i>Dysoxylum arborescens</i>	1
Meliaceae	<i>Toona</i>	<i>Toona ciliata</i>	1
Monimiaceae	<i>Doryphora</i>	<i>Doryphora aromatica</i>	1

Family	Genus	Species	n
Monimiaceae	<i>Tetrasynandra</i>	<i>Tetrasynandra laxiflora</i>	1
Myristicaceae	<i>Myristica</i>	<i>Myristica insipida</i>	21
Myrtaceae	<i>Acmena</i>	<i>Acmena graveolens</i>	11
Myrtaceae	<i>Syzygium</i>	<i>Syzygium gustavioides</i>	8
Myrtaceae	<i>Syzygium</i>	<i>Syzygium sayeri</i>	8
Myrtaceae	<i>Syzygium</i>	<i>Syzygium cormiflorum</i>	1
Myrtaceae	<i>Syzygium</i>	<i>Syzygium kuranda</i>	1
Proteaceae	<i>Cardwellia</i>	<i>Cardwellia sublimis</i>	11
Proteaceae	<i>Musgravea</i>	<i>Musgravea heterophylla</i>	3
Proteaceae	<i>Austromuelleria</i>	<i>Austromuelleria trinervia</i>	1
Rhamnaceae	<i>Emmanosperma</i>	<i>Emmanosperma cunninghamii</i>	1
Rubiaceae	<i>Antirhea</i>	<i>Antirhea tenuiflora</i>	1
Rubiaceae	<i>Neonauclea</i>	<i>Neonauclea glabra</i>	1
Sapindaceae	<i>Synima</i>	<i>Synima cordierorum</i>	5
Sapindaceae	<i>Ganophyllum</i>	<i>Ganophyllum falcatum</i>	1
Sapotaceae	<i>Palaquium</i>	<i>Palaquium galactoxylon</i>	1
Sterculiaceae	<i>Argyrodendron</i>	<i>Argyrodendron peralatum</i>	13
Xanthophyllaceae	<i>Xanthophyllum</i>	<i>Xanthophyllum octandrum</i>	1