

Phylogenetic diversity, functional traits, and tropical forest succession

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ABSTRACT

This dissertation investigated changes in phylogenetic and functional diversity during ecological succession following anthropogenic disturbance in the lowland forests of New Guinea. Plant evolutionary history, functional traits, and interactions with insect herbivores were examined to address questions related to patterns of plant diversity, species coexistence, and possible mechanisms maintaining diversity in tropical forests. Chapter 1 investigated the recovery of forest structure, species diversity, and functional diversity during succession by examining a chronosequence of survey plots located in younger secondary, older secondary, and primary forest. Secondary forests had less biomass and lower species richness compared to primary forests. They also had higher specific leaf area (SLA) and foliar nitrogen and their leaves were more likely to contain latex. By contrast, trees in primary forest had high wood density and foliar carbon, larger seeds, and taller trees with larger crowns. These changes reflect the contrasting life histories of trees in young and old forests and possibly reflect a tradeoff between growth rates and life span that suggests deterministic processes such as environmental filtering or competition may drive species coexistence during succession. Chapter 2 compared plant community phylogenetic structure along a successional gradient in lowland New Guinea based on a chloroplast DNA phylogeny. The sensitivity of results to different methods of phylogenetic branch length estimation was assessed by comparison of equal branch

lengths, genetic distance, time-calibration, and a relaxed molecular clock Bayesian estimate. Mean phylogenetic distance among co-occurring trees increased with total basal area per plot, a proxy for forest age. Significant phylogenetic clustering was detected in secondary forest whereas primary forest was significantly over-dispersed relative to null expectations. The sensitivity of these patterns to various methods of branch length estimation and phylogenetic uncertainty was also examined. Power to detect community phylogenetic patterns when equal branch lengths were assumed was weak in comparison to direct molecular and time-calibrated measures of divergence. Inferred change during forest succession was also robust to phylogenetic uncertainty so long as temporal information was incorporated in estimates of divergence. The observed patterns are consistent with processes of environmental filtering during tropical forest succession giving way to other processes in primary forests including density-dependent mortality.

Chapter 3 examined the degree to which the abundance of herbivores in a rain forest community is explained by the functional traits of host plants. Per-tree caterpillar and leaf miner abundance was measured together with total leaf biomass (kg), percentage of immature foliage, specific leaf area ($\text{cm}^2 \text{g}^{-1}$), leaf nitrogen content (% dry mass), and presence of exudates. Apart from leaf nitrogen content, neither plant resources nor herbivore abundance showed evidence of phylogenetic conservatism in our community sample. The plant traits explained only 30% and 16% of variation among individual trees in caterpillar and leaf miner abundance. Leaf biomass was a stronger predictor of herbivore abundance than either resource quality (leaf nitrogen content) or palatability (percent immature foliage, specific leaf area). The primary importance of resource quantity was also observed at the plant species level in analyses of species means and

phylogenetic generalized least squares regression. Plant exudates significantly depressed herbivore abundance but apparent convergence among community members evidently weakens the power of plant phylogeny alone to predict herbivore community patterns. Leaf nitrogen content, explaining to some extent caterpillar abundance, provides an alternative example of how a conserved trait at one trophic level can influence community-wide patterns at another.

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CHAPTER 1

Species richness, forest structure, and functional diversity during succession in the New Guinea lowlands

“Overhead the jungle soon met in an archway, and by the time they passed the first bend in the stream it had become a tunnel whose walls were composed of foliage and whose roadbed was covered in slime. The sunlight filtered through a vast intricate web of leaves and fronds and vines and trees, until it absorbed the color of the jungle and became at last a green shimmering wash of velvet. The light eddied and shifted as though refracting through the intricate vaults of a cathedral; all about they were surrounded by the jungle, dark and murmurous. They were engulfed in sounds and smells, absorbed in the fatty compacted marrows of the jungle. The moist ferny odors, the rot and ordure, the wet pungent smell of growing things, filled their senses.”

The Naked and the Dead, Norman Mailer, 1948

Introduction

Over half of all temperate and tropical forested areas have been classified as regenerating, younger secondary forests (Dupuy and Chazdon 2006, FAO 2010). These areas are important reservoirs of biodiversity in increasingly fragmented landscapes (Chazdon 2003) and also significant sources of timber and non-timber products (Chazdon and Coe 1999, Ticktin 2004). The trajectory of ecological succession in these secondary forests is not clear because factors such as fire, characteristics of remnant vegetation, past land use intensity, and soil properties all influence how forests succession proceeds (Moran et al. 2000, Guariguata and Ostertag 2001, Hooper et al. 2004). Despite this variation, the general patterns of structure and functional diversity during succession in tropical forests have been well described (Oliver and Larson 1990). Herbaceous species, vines, lianas, and shrubs dominate the “stand initiation” phase of succession. Following

this, “pioneer” trees become common, creating a closed canopy in 5-10 years before the beginning of a “stem exclusion phase.” At this point, early colonizing trees become larger and light levels dramatically decrease favoring the establishment of shade-tolerant seedlings. Finally, during the “understory reinitiation stage” a slow turnover of shade-tolerant species begins in the canopy and subcanopy and large gaps formed by tree falls create high light environment areas for new recruits. In this final stage, vertical and horizontal structure becomes well developed, large trees are present, and there is high species diversity in all vegetative layers (Oliver and Larson 1990).

These structural changes, and their affect on environmental conditions during succession, have been documented in many other tropical forests around the world (Saldarriaga et al. 1988, Corlett 1995, Denslow and Guzman 2000, Guariguata and Ostertag 2001, Bischoff et al. 2005, Ruiz et al. 2005, Chazdon 2008, Lebrija-Trejos et al. 2008, Norden et al. 2009, Lebrija-Trejos et al. 2010). Light levels, soil temperature, and air temperature under the canopy all decrease as basal area increases during succession (Lebrija-Trejos et al. 2010). Classical niche theory (Hutchinson 1957, Grubb 1977) predicts that differences among species in environmental conditions required for germination and establishment might be an important factor in determining species coexistence during succession and a trade-off is maintained between rates of growth versus mortality in the heterogeneous light environment of closed canopy forests (Wright et al. 2010). Under the theory, trees with traits that confer rapid dispersal ability and fast growth at the expense of lifespan will be favored in the high light environment of early succession whereas the low resource environment of primary forests will favor trees that

grow slowly but can establish and survive in low light and possess structural defense against pests to ensure long lifespan (Wright et al. 2004, Lebrija-Trejos et al. 2010).

Different components of tropical forest succession have been documented in many parts of the world (Saldarriaga et al. 1988, Guariguata and Ostertag 2001, Chazdon 2003, Chazdon et al. 2007) yet few studies have characterized forest structure, diversity, and functional traits during succession in a single forest community. The objective of this study was to document changes in these forest attributes during recovery from disturbance in the New Guinea lowlands. The study examined changes in forest structure and tree architecture (basal area, stem density, tree height, crown dimensions), plant richness (species density, species frequency, Fisher's alpha, Shannon Index, and Simpson Index), and functional traits that impact establishment, performance, and competitive ability during succession. Traits included specific leaf area ($\text{cm}^2 \text{g}^{-1}$), wood density (g/ml), % foliar nitrogen, % foliar carbon, seed mass (g), tree height (m), tree crown width and height (m), and crown volume (m^3). The study site was ideal for an investigation of forest succession where shifting agriculture presented a mosaic of different forest ages. The island of New Guinea has high levels of plant endemism (Paijmans 1976) and is recognized as one of the world's largest remaining tropical wilderness areas based on the extent of relatively undisturbed forest (Mittermeier et al. 1998). Studies of montane or small volcanic islands have described aspects of succession on New Guinea (Corlett 1987, Vanvalkenburg and Ketner 1994, Harrison et al. 2001) but lowland rainforest succession is poorly documented. The island of New Guinea is experiencing high rates of deforestation, particularly in the more accessible lowland areas. Shearman and Bryan (2011) estimated that between 1972 and 2002 Papua New

Guinea, which comprises the eastern half of the island, suffered a 30% net loss of the lowland forest through clearing or degradation and that 67% of the lowland rainforest area is threatened by future degradation. Despite the biological importance of New Guinea's forest, little is known about how they might respond to large-scale conversion.

This study tested several predictions about forest structure, tree architecture, species diversity, and functional traits:

- (1) As observed in previous studies of tropical forest succession (Guariguata et al. 1997, Chazdon et al. 2007), stem density is predicted to be greatest in older secondary forests
- (2) Basal area is predicted to be highest in primary forest (Oliver and Larson 1990)
- (3) Crown width, crown volume, and tree height is predicted to be highest in primary forests (Horn 1971, Oliver and Larson 1990)
- (4) Species richness is predicted to increase during succession (Oliver and Larson 1990).
- (5) As observed in previous studies of resource allocation theory (Wright et al. 2004, Wright et al. 2010), trees in younger secondary forest are predicted to have high specific leaf area and foliar nitrogen associated with rapid growth whereas primary trees are predicted to have large seeds, high wood density, and high foliar carbon better suited to survival and longevity in low light environments.

Methods

Field plots – We surveyed a total forest area of 4.75 hectares near Wanang (145° 5' 32" E, 5° 14' 26"S) in Madang Province, Papua New Guinea (Fig. 1.1A). The field site is part of an extensive mixed evergreen forest, 100 - 200 m above sea level, on latosols in the Ramu River Basin (Paijmans 1976, Wood 1982). The region has a humid climate, a

mean annual rainfall of 3,500 mm with a mild dry season from July to September, and a mean monthly temperature of 26°C (McAlpine et al. 1983). We sampled a total of nineteen 0.25 hectare (50 m by 50 m) plots. Five plots were in younger secondary forest (3-9 years since disturbance), seven plots were in older secondary forest (10-30 years since disturbance), and seven plots were in primary forest (> 50 years since disturbance) (Fig. 1.1B). Primary forest is used here as a relative term to indicate forests that are older than older succession but which may include elements of late secondary and mature forest. Approximate ages were obtained through interviews with landowners. A minimum age for primary forest in the area was estimated from Royal Australian Survey Corps aerial photographs, where the presence of multi-layered canopy in 1973 suggests no anthropogenic disturbance since at least the late 1950s. Four of the older secondary plots and four of the primary plots were contiguous (i.e., 1 hectare plots) that were part of another study that destructively sampled all trees. The plots were surrounded by contiguous lowland rainforest. The younger and older secondary plots and four of the primary plots were embedded in an area of secondary forest whereas the remaining primary plots were in an area of relatively undisturbed primary forest. Local landowners practice subsistence agriculture in 0.25-1.0 hectare gardens planted after felling and burning of primary forest. Succession ensues when garden plots are abandoned after 2-3 years of low intensity cultivation.

The dominant human land use in the area was subsistence agriculture practiced in 0.25-1 hectare gardens that are planted after felling and burning older secondary or primary forests. Succession ensued when plots are abandoned after 2-3 years of low intensity cultivation. These gardens were not grazed or mechanically cultivated. For this

study, younger and older secondary survey plots were located in forest recently disturbed by this subsistence agriculture. Approximate age since disturbance was obtained from interviews with landowners.

In each plot, all trees with dbh ≥ 5 cm were measured, tagged, and identified to estimate species diversity, number of stems, and basal area for each plot. The chronosequence approach we used has limitations because it assumes constant environmental conditions, site history, and seed availability across all sites (Chazdon 2008) but the substitution of time for space can reasonably reflect successional changes in diversity and structure (Capers et al. 2005, Lebrija-Trejos et al. 2008, Walker et al. 2010). At this site, all survey plots were embedded in a contiguous area of forest with no barriers to seed dispersal and land use history was similar in all plots.

Soil sampling – Soil samples were taken from 11 of the 19 survey plots (5 younger secondary, 3 older secondary, and 3 primary). We sampled mineral soil at 0-10 cm and 10 - 20 cm depths from three random locations in each quarter of each plot. All samples were air dried in the field, then crushed and passed through a 2 mm sieve for analysis at the Research Analytical Laboratory of the University of Minnesota. Results were averaged for each successional stage. Total soil nitrogen was measured using the Dumas method on a LECO FP-528 nitrogen analyzer (AOAC International 1995). Total soil organic carbon was measured by dry combustion at 2500°F and subsequent measurement of CO₂ evolution by infrared spectrum absorption using a Skalar Primacs carbon furnace. Textural analysis was carried out using the hydrometer method (Gee and Bauder 1986) to determine the proportion of sand (2000-50 μ m), silt (50-2.0 μ m), and clay (<2.0 μ m) particles. Soil phosphorus was measured using the Bray-1 extractable method

(Bray and Kurtz 1945). Soil pH in water was determined on a 1:1 soil/water mixture using a Beckman pH meter. Organic matter was determined using the loss of ignition method (Blume et al. 1990). Exchangeable K was measured by mixing dried soil and ammonium acetate and subsequent quantification with inductively coupled plasma atomic emission spectroscopy.

Species identification – Following field identification, vouchers were collected and their identity confirmed at the Papua New Guinea Forest Research Institute herbarium (LAE). Complete sets of vouchers were deposited at LAE and the University of Minnesota Herbarium, J. F. Bell Museum of Natural History (MIN) with additional material distributed to herbaria including Harvard University (A), the Smithsonian Institution (US), Royal Botanic Gardens, Kew (K), Nationaal Herbarium Nederland, Leiden (L), Australian National Herbarium (CANB), Singapore Botanic Garden (SING), Field Museum of Natural History (F), New York Botanical Gardens (NY), and Missouri Botanical Garden (MO).

Measurements of diversity – Species density was quantified by tallying the number of species per survey plot. To account for differences in sample size and stem density, three indices of diversity were used to assess species richness in the surveyed plots. Fisher's alpha is the parameter of a fitted logarithmic series distribution (Fisher et al. 1943, Hayek and Buzas 1997, Leigh 1999) and is less affected by sample size than simply counting the number of species.

$$S = a * \ln(1 + n/a)$$

Where:

S = number of taxa

n = number of individuals

a = Fisher's alpha

The Shannon index estimates the uncertainty of picking a given species at random from a sample and increases as the number of species and species evenness increase (Hayek and Buzas 1997).

$$D = 1 - \frac{\sum_{i=1}^s n_i(n_i-1)}{N(N-1)}$$

Where:

D = Simpons's index

S = number of species

N = total number of individuals

n_i = number of individuals of species i

The Simpson index (Simpson 1943) measures the probability that two individuals chosen at random from a community are the same species (Magurran 1988) and is highest when the abundance of each species is completely even.

$$H' = -\sum_{i=1}^s p_i \ln p_i$$

Where:

H' = Shannon index

S = number of species

p_i = relative number of individuals of each species

n_i = number of individuals of each species

N = total number of individuals

To compare the accumulation of species within a site as a function of the number of individuals sampled, rarefaction curves were constructed for each successional stage with the Mao Tau function. All measures of diversity were calculated using EstimateS (Colwell 2009).

Importance values – Calculation of importance values followed the procedure used by McIntosh (1957) and is the sum of relative dominance (species basal area divided by total basal area) and relative density (number of stems of one species divided by total number of stems).

$$IV_i = (BA_i / BA_{total}) + (\# \text{ stems}_i / \# \text{ stems}_{total})$$

Where:

IV_i = importance value of species i

BA_i = basal area of species i

BA_{total} = total basal area for all species

$\# \text{ stems}_i$ = number of stems of species i

$\# \text{ stems}_{total}$ = total number of stems

Functional traits – Specific leaf area (SLA) is defined as fresh leaf area divided by dry leaf mass and was calculated from approximately ten discs per species with a diameter of 2.3 cm punched from fresh leaves. Disc samples were drawn from all woody stems ≥ 5 cm dbh in two hectares of forests and where species were represented by more than one individual, SLA was averaged across all individuals in the two hectare sample.

Wood density is the dry mass of a section of a tree's main stem divided by the volume of the same section when fresh (g/ml). For each species occurring in two hectares of destructively sampled vegetation, wood samples were collected for up to six individuals ≥ 5 cm dbh in order to obtain species averages for wood density. A section of trunk was cut in the field, fresh volume was measured by submerging the section in a flask of water and the sections were then oven dried to a constant weight. Wood density values for each species were obtained by averaging multiple samples (1-22) per species.

For the measurement of foliar nitrogen and carbon, leaves were sampled from up to four individuals per tree species. Three randomly chosen leaf discs per tree were

bulked and ground by hand in liquid nitrogen or in a TissueLyzer (Qiagen). Analysis was carried out at the University of Nebraska using dry combustion gas chromatography on a COSTECH analytical elemental combustion system ESC 4010. This method generates the mass of each element that is subsequently converted to percentage of the total mass of the sample.

Seed mass was obtained from the Seed Information Database (Royal Botanic Gardens Kew 2008). For most species (295 out of 351) congeneric or confamilial means were used because seed mass was not available for the particular species in question. Using average values may render the results for seed mass overly optimistic since duplicating values in this way does not truly recover the degrees of freedom lost because values are missing (Ter Braak and Šmilauer 2002).

Crown depth, crown width, and total tree height were measured after trees were felled in the destructively sampled one hectare plots. Crown depth represents the distance from the first main branch to the top of the crown. The maximum value per species for each tree dimension was used in all analyses. The presence or absence of latex in leaves and wood was also noted.

Relationship between traits and basal area – Regression analyses, performed in JMP ver. 8.0.1 (SAS Institute, Inc., Cary, NC, USA), assessed the relationship between per plot community weighted means of each trait and total basal area per plot. Total basal area per plot served as a proxy for forest age because accurate records of forest age were not available.

Multivariate analysis – To investigate whether suites of plant functional traits were associated with different forest successional stages a redundancy analysis (RDA)

was performed in Canoco for Windows, v. 4.5 (Biometris, Wageningen). RDA is a constrained (direct gradient) analysis that searches for the best explanatory variables while the ordination axes are constrained by the environmental variables. The constrained axes correspond to the directions of the greatest dataset variability that can be explained by the environmental variables (Ter Braak and Šmilauer 2002). For this study, the values of 9 traits for 341 plant species were the explanatory variables and the environmental variable was the relative abundances of plant species in younger secondary, older secondary, and primary forest. Since the traits were measured in different units and the analysis was constrained by species abundance, RDA was the appropriate ordination model (Ter Braak and Šmilauer 2002).

A detrended correspondence analysis (DCA) was run to evaluate the association of species with particular successional stages. DCA is an unconstrained ordination approach that was used to assess whether survey plots segregated with respect to successional stage based on plant species composition.

Results

Chemical properties of the soils in the survey plots were not significantly different across the successional gradient with the exception of potassium which was significantly lower in primary plots compared to younger secondary (Table 1.1). Soil texture, however, did vary across the gradient. Primary forest plots contained, on average, significantly more sand and less silt than younger and older secondary plots while younger secondary plots contained more clay than older secondary and primary plots. These differences in

soil potassium and soil texture were driven by one primary plot close to the Wanang II River. In other respects, this plot was similar to the rest of the primary forest.

Primary forest contained on average more stems with dbh >10 cm per hectare than younger secondary plots (Table 1.2). Primary forest also had higher basal area of stems with dbh > 10 cm and all stems combined. All size classes of trees in primary forest included more species than younger or older secondary forest. Fisher's alpha was positively correlated with basal area (Fig. 1.2). Simpson and Shannon indices were also positively correlated with basal area ($R^2 = 0.55$, $p < 0.001$ and $R^2 = 0.54$, $p < 0.001$) and species accumulation curves showed that richness was higher in primary forests for small and large stems (Fig. 1.3).

The frequency distribution of species was relatively consistent across all three successional stages (Appendix 1) and most species were represented by 10 or fewer individual stems (84%, 79%, and 84% in younger secondary, older secondary, and primary forest respectively). Thirteen plant families in primary forest accounted for over three quarters (77%) of the total basal area (Appendix 2). Just five families accounted for a similar fraction of basal area in younger and older secondary forest (74% and 79% respectively, Appendix 2). A turnover of the most important species occurs between older secondary and primary succession (Table 1.3). In the younger and older secondary forests, the species with the highest importance values were *Trichospermum pleiostigma*, *Maracanga tanarius*, *Ficus pungens*, and *F. variegata*. By contrast, *Pometia pinnata*, *Horsfieldia basifissa*, and *Teijsmanniodendron bogoriense* had the highest importance values in primary forest.

Primary forests had higher wood density, seed weight, foliar carbon, crown volume, and tree height (Fig. 1.4 and 1.5). By contrast, younger secondary forests had higher specific leaf area and foliar nitrogen and more species that contained latex in their leaves. The redundancy analysis of trait distribution (Fig. 1.5) indicated a small but significant amount of variation in all plant traits combined was explained by the relative abundance of species in each successional stage (Eigenvalue = 0.048, $p = 0.002$) and the direction of increasing trait values was the same as observed in the regression analyses. Plots from younger and older secondary forest were more similar to each other in terms of species composition than to primary plots (Figure 1.6) according to the detrended correspondence analysis.

Standardized by dbh class (5-10 cm, 10-25 cm, 25+ cm), tree height and canopy dimensions changed significantly in older secondary and primary forests. Trees in the medium and large dbh classes were taller in the primary forest with significantly greater trunk heights (distance from ground to first branch) and crown heights (Fig. 1.7). Trees in the smallest dbh class had wider crowns in primary forest. Overall crown volume was significantly higher in the small and medium dbh size classes in primary forest.

Discussion

Throughout the tropics, secondary forests are becoming a more common feature of the landscape as a result of large-scale timber harvest. The successional trajectory of these communities is unclear and can be strongly influenced by the intensity of past land use. Previous studies have documented changes in forest structure, tree architecture, species richness, and functional traits. Some studies have examined different

combinations of these variables but few have documented changes in these aspects of succession in a single forest community. For this study, we took a chronosequence approach to study these changes across a successional gradient in lowland New Guinea and tested predictions related to the recovery of forest structure, species diversity, and functional traits.

Soils – Soil nutrients were generally constant across the study area with only a slight increase in potassium in younger secondary versus primary forest. This observation is consistent with the common geomorphic processes, parent material, soil age, and climate of the study site. Previous studies suggest that soil nutrients can affect the spatial distribution of trees (Moran et al. 2000, Paoli et al. 2006, John et al. 2007, Schreeg et al. 2010) by impacting the growth-mortality trade-off that shapes forest succession (Russo et al. 2008). That the soils across all survey plots in this study were relatively constant suggests that the spatial distribution of trees and successional trajectory of disturbed areas was not confounded by the effects of soil nutrients. The effects of soil biota were not accounted for in the present study but this often overlooked factor can potentially strongly impact patterns of forest recovery and species diversity (Booth and Hoeksema 2010, Mangan et al. 2010, Miki et al. 2010).

In general, soils at the study site had higher pH and higher levels of potassium and phosphorous compared to other lowland rainforests in Colombia, Panama, and Ecuador (John et al. 2007). By contrast, soil carbon and nitrogen were lower in New Guinea than Borneo (Paoli et al. 2006).

Soils in primary forest had, on average, a higher sand component and lower silt and clay components compared to younger secondary and older secondary forest.

However, this apparent difference appears to be driven by one plot near the Wanang II River (Figure 1.1B) that in other respects has similar soil characteristics and species composition to the other primary survey plots. Differences in soil texture can affect soil moisture but the potential effect on successional trajectory is hard to quantify without more detailed association of edaphic conditions and forest diversity across a larger area.

Forest structure – Older secondary forests did not have significantly higher density of stems contradicting the prediction based on observations made in other tropical forests in Costa Rica (Letcher and Chazdon 2009) and Colombia (Saldarriaga et al. 1988, Ruiz et al. 2005). Typically, high stem density occurs before the onset of stem exclusion when shading from the canopy of pioneer species and other density dependent forces leads to stand thinning and reduced stem density. The observed stem density in New Guinea may appear different from other tropical forests because this study focused on broadly defined age classes. Lacking reliable estimates of time since disturbance forced me to take this approach. Finer age class divisions may have captured the more typical pattern of high stem density in intermediate aged forests. Another possible reason for the differences in stem density between New Guinea and other tropical forests is the lower intensity of land use in New Guinea. Land use and its impact on soils prior to the onset of succession can be an important factor in successional trajectories (Moran et al. 2000, Chazdon 2003). At the New Guinea site, landowners practice traditional subsistence agricultural that involves clearing small areas that are lightly cultivated and abandoned after two or three years. These gardens are not grazed and none of the survey plots had a long history of cultivation. Also, these small areas of regenerating forest are embedded in

a larger area of contiguous forest unlike the secondary forests under investigation in Costa Rica that are part of a predominantly agricultural landscape.

That basal area increased during succession was in line with predictions based on succession theory. The rapid increase in basal area between older secondary and primary forests likely reflected the broad age classes used in this study. Compared to other lowland tropical forests, New Guinea had a higher density of large stems but lower basal area than observed in Singapore (Lum et al. 2004) and in Cameroon (Chuyong et al. 2004). By contrast, lowland forest in Colombia contained more stems per hectare but lower basal area (Chuyong et al. 2004). New Guinea's forest structure appears to lie within the range previously observed in other forests in the new and old world tropics.

Species diversity - That the observed diversity indices increased during succession (Fig. 1.2 and 1.3) is consistent with predictions based on previous studies across successional gradients in Colombia, (Ruiz et al. 2005), Venezuela (Saldarriaga et al. 1988), and Costa Rica (Ruiz et al. 2005). In the New Guinea lowlands, small trees were more diverse than large trees in both older secondary and primary forests indicating a possible filtering mechanism that attenuates canopy tree diversity. Some species present in the understory may lack the traits necessary to successfully compete for a position in the canopy. A previous study in Costa Rica (Letcher 2010) found that phylogenetic diversity decreased within intermediate aged forests such that small trees (dbh 5-9.9 cm) were more diverse than larger trees with $\text{dbh} \geq 10$ cm.

Trees with $\text{dbh} > 10$ cm in New Guinea's primary forest had values for Fisher's alpha that were within the range observed in other tropical forests. They had higher alpha values than forests in Panama and Colombia, comparable values to forests in Cameroon

and Singapore, but lower values than observed in Malaysia and Ecuador (Condit et al. 1996, Leigh 1999, Chuyong et al. 2004, Lum et al. 2004, Valencia et al. 2004, Vallejo et al. 2004).

Frequency distribution – A typical species frequency distribution for tropical forests (Morley 2000) was observed in the New Guinea lowlands (Appendix 1). In all successional stages, most species were represented by only a few stems. Furthermore, in all three stages of succession, close to 75% of the total basal area was accounted for by a small number of highly speciose families (Appendix 2). A similar profile was observed in a previous study in New Guinea at 550 m (Weiblen 1998). Dominant species are generally not a feature of lowland tropical forests and in the most diverse forest, every second tree can be a different species (Morley 2000).

Functional traits – Plant species growing at different points on a successional gradient in closed canopy forests differ in their environmental requirements as light levels, temperature, and relative humidity change (Lebrija-Trejos et al. 2010). Biotic and abiotic variables can act on plant functional traits to constrain species to a particular set of environmental conditions, their regeneration niche (Grubb 1977). If these predictions are true, species with certain combinations of traits should be associated with different successional stages. On the other hand, stochastic processes, such as dispersal, might also be important in determining where species grow (Hubbell 2001) or a combination of these two mechanisms may affect patterns of species coexistence (Adler et al. 2007) with younger secondary being more affected by the random processes of dispersal and colonization and later stages being driven by deterministic processes (Chazdon 2008).

This study demonstrates that certain plant species tended to be more abundant at particular points on the successional gradient and there were suites of plant species closely associated with young or mature forests. For example, *Ficus pungens*, *Ficus nodosa*, and *Trema orientalis* are examples of species that are abundant in younger secondary and older secondary forest whereas *Horsfieldia basifissa*, *Gnetum gnemon*, and *Syzygium longipes* were more strongly associated with primary forest (Figure 1.6). Other species, such as *Canarium acutifolium*, *Myristica fatua*, and *Chisocheton cumingianus*, were common in young and mature forests. A second axis of variation appears to correspond to the composition of species within individual plots and may reflect competitive interactions between species such that certain species often co-occur (e.g. *Vitex cofassus* and *Macaranga aleuritoides*) whereas others rarely appear together (e.g., *Vitex cofassus* and *Trema orientalis*). In addition, survey plots located in younger and older secondary forest were more similar to each other in terms of species composition than they were to plots located in primary forest suggesting that patterns of species abundance repeated across the landscape. Trees in each successional stage also tended to share functional traits allowing them to be more successful at different points on the successional gradient. Trees growing in younger and older secondary forests in the New Guinea lowlands had leaves with high SLA and foliar nitrogen (Fig. 1.4 and 1.5) as observed in previous studies of other rainforest communities (Popma et al. 1992, Poorter et al. 2004). Trees with high SLA, a measure of leaf biomass allocated to light harvesting, have less dense leaf tissue so less investment in structural defenses, shorter leaf life span, relatively high rates of photosynthesis per unit of mass, and high growth rates (Schadler et al. 2003, Poorter et al. 2004, Agrawal and Fishbein 2006). Foliar nitrogen is an

important component of proteins involved in photosynthesis (Wright et al. 2004, Lambers et al. 2006) and is positively correlated with photosynthetic rates (Reich et al. 1994). When light resources are not limiting, high SLA and foliar nitrogen allow pioneer species to mature quickly in the highly competitive younger secondary environment. However, these leaves are prone to attack by insect herbivores since they are highly nutritious and not well defended (Coley and Barone 1996). Previous work at this site (Chapter 3) indicated that, compared to primary forest, many more younger secondary trees contained latex in their leaves (65% versus 37%). Furthermore, caterpillar abundance was 71% higher and leaf-miner abundance was 70% higher on trees where latex was absent in secondary and primary forests. The higher number of younger secondary trees with latex and the lower abundance of leaf herbivores on these trees suggests that this trait is an important defense against herbivores in leaves that are otherwise poorly defended (Farrell et al. 1991, Agrawal 2004b, Agrawal and Fishbein 2006).

As predicted, trees in late succession had higher wood density and foliar carbon, their seeds had greater mass, they had a larger crown volume, and they were taller than in younger secondary forest. High wood density gives trees the durability, longevity, and structural strength to withstand prolonged exposure to stresses such as wind, lianas, pests, and pathogens (Augspurger 1984, Pearce 1996). Previous studies have found similar increases in wood density during succession (Falster and Westoby 2005, Poorter et al. 2010). High wood density increases survival potential of trees in primary forest but it leads to slow growth rates (Falster and Westoby 2005). Foliar carbon is required for respiration and it is the primary component of leaf biomass (Lambers et al. 2006). High

foliar carbon is positively correlated with leaf life span and negatively correlated with herbivory (Agrawal 2004a, Poorter et al. 2004).

Seed mass was highest in the late succession forest of the New Guinea lowlands. Previous studies suggest that the higher seed mass of shade tolerant species is correlated with a decrease in seed number and an increase in seedling size making these seedlings better equipped for success in the low light environment of primary forests (Coomes and Grubb 2003, Muller-Landau 2010). By contrast, younger secondary species generally produce many small seeds that are wind dispersed making them more likely to colonize newly disturbed habitat (Grubb and Metcalfe 1996). Seed dispersal determines the distribution and abundance of potential recruits and is an important aspect of plant population dynamics and community structure (Levin et al. 2003, Levine and Murrell 2003, Westcott et al. 2008).

Crown volume and tree height also increased during succession (Fig. 4 and 5). Trees of primary forests were taller in medium and large dbh classes whereas crown volume was greater in small and medium trees (Fig 6). Tree architecture impacts a plants overall vigor by affecting how it intercepts light (Horn 1971, Thomas and Bazzaz 1999) and previous studies have demonstrated that repeated architectural patterns can be observed in trees growing in different regions (Hallé 1974, Tomlinson 1983). Theoretical predictions (Horn 1971) suggest younger secondary trees are likely to be tall and thin to maximize their chances of reaching light. That primary trees in the medium and large size classes were taller than younger secondary trees in the New Guinea lowland appears to contradict these predictions. However, at this site trees in these larger size classes were in or above the canopy of the primary forest where they must maintain their position to

maximize light harvesting but where there is no need for rapid vertical growth that is associated with the smaller trees in younger secondary forest.

Crown volume was larger in primary forest in the small and medium dbh size classes as predicted by tree architecture theory (Horn 1971). Light levels below the canopy are lower in primary forests so trees in the understory require a higher overall crown volume to harvest enough light for survival. The wider canopies of small trees in the primary forest is also in line with theoretical predictions that suggest wide, shallow crowns intercept more light and limit self-shading (Horn 1971).

The patterns observed in this study are based on forests recovering from low intensity anthropogenic disturbance. Whether they would be consistent with observations from forests recovering from small-scale natural disturbances such as wind throw or landslides is unclear. Previous studies suggest human activities can alter the successional trajectories of forests depending on the intensity of land use and degree of disturbance (Burslem et al. 2000, Chazdon 2003). The anthropogenic disturbances in this forest were not caused by mechanized tree felling or intense cultivation and the disturbed areas were part of a contiguous matrix of young and old forest with no barriers to dispersal. As a result, the successional trajectory of these small-scale disturbances is likely to be similar to those resulting from natural tree falls or landslides.

Including finer scale estimates of forest age, particularly in older secondary forests, would provide a better opportunity to evaluate how quickly species and functional diversity recovers relative to old growth forests. Detailed land use records were not available and tropical trees generally lack obvious growth rings (Whitmore

1998) so it was not possible to go beyond coarse estimates to assess age since disturbance.

Conclusions – This study demonstrated that species density, forest structure, and functional diversity in the lowlands of New Guinea varied during succession in ways that allow predictions to be made about forest recovery. As predicted, stem density, basal area, and species diversity increased as forests recovered from disturbance. Furthermore, as predicted, younger and older secondary forests were dominated by species with high specific leaf area and foliar nitrogen, traits that associated with fast growth but which reflect a low investment in protection from herbivores. However, younger secondary trees are more likely to contain latex, a defensive syndrome that is an important herbivore deterrent. By contrast, primary species had large seeds, high wood density, and high foliar carbon. These traits are associated with slow growth rates but reflect a higher investment in structural defenses from herbivores that is likely to yield long-term benefits and allow these trees to have a longer life span. These opposing syndromes have been interpreted as strategies that fall on opposite ends of a successional spectrum (Reich et al. 2003, Wright et al. 2004). A growth-mortality trade-off (Wright et al. 2010) may explain the observation that some species are more abundant in younger secondary forest whereas others are more abundant in primary forest and indicate the importance of deterministic processes in driving community assembly during ecological succession.

The patterns of forest structure, species diversity, and functional traits observed in New Guinea's lowlands are inline with theoretical predictions (Horn 1971, Oliver and Larson 1990) and observations from New World tropical forests (Ruiz et al. 2005, Chazdon et al. 2007). This significant finding suggests general hypotheses of ecological

succession, based mostly on studies of New World tropical forests, are broadly applicable to forests across the tropics.

Table 1.1. Soil chemical and physical properties from the New Guinea lowlands. Values are averages (and standard deviation) for all plots in each successional stage. Within each row, successional stages that do not share a letter are significantly different (ANOVA, $\alpha = 0.05$). n = number of samples per successional stage.

Table 1.1

Soil property	Successional Stage		
	Younger secondary (n=14)	Older secondary (n=12)	Primary (n=12)
pH	6.25 (0.19) a	6.28 (0.16) a	6.21 (0.29) a
P (mg kg ⁻¹)	9.14 (3.67) a	10.00 (3.27) a	9.36 (4.84) a
K (mg kg ⁻¹)	360.643 (63.45) a	334.08 (90.8) ab	293.5 (66.85) b
C (%)	2.96 (0.98) a	2.59 (1.13) a	2.35 (1.2) a
N (%)	0.23 (0.08) a	0.23 (0.09) a	0.19 (0.1) a
Organic matter (%)	8.05 (1.69) a	6.93 (2.43) a	6.25 (2.3) a
Sand (%)	18.95 (2.57) b	21.39 (4.2) b	37.21 (11.55) a
Silt (%)	38.42 (1.85) a	43.62 (4.71) a	31.77 (7.88) b
Clay (%)	42.7 (2.59) a	35.05 (7.3) b	31.05 (4.4) b

Table 1.2. Mean (\pm standard deviation) species richness, tree density, and basal area per hectare by successional stage in the lowlands of New Guinea. Significant differences between successional stages for each size class are indicated by different letters (ANOVA, $\alpha = 0.05$). Younger secondary (3-9 years since disturbance), older secondary (10-30 years since disturbance), primary (>50 years since disturbance).

Table 1.2

DBH (cm):	Number of stems per hectare			Basal area (m ² ha ⁻¹)			Species per hectare		
	5-10	>10	All*	5-10	>10	All*	5-10	>10	All*
Successional stage									
Young secondary	740±178.6 a	338±190.8 b	1079±171.6 a	2.8±0.75 a	9.5±5.34 b	12.3±4.90 b	106±35.7 b	49±19.6 b	120±37.2 b
Older secondary	812±229.2 a	515±104.3 ab	1326±326.6 a	3.2±0.82 a	12.78±3.75 b	15.9±4.21 b	93±34.41 b	50±23.00 b	105±38.85 b
Primary	752±69.1 a	535±44.9 a	1287±102.5 a	3.0±0.28 a	27.4±4.95 a	30.4±4.90 a	154±9.24 a	118±11.80 a	187±11.22 a

*All stems with dbh ≥ 5 cm

Table 1.3. Stem density, basal area, relative dominance (Rel. dom.), relative density (Rel. den.), and importance values (I.V.) in the lowland rainforest of New Guinea. Younger secondary (3-9 years since disturbance), older secondary (10-30 years since disturbance), primary (>50 years since disturbance).

Table 1.3

Younger secondary (1.25 ha)						
Family	Species	Basal area (m ²)	No. stems	Rel. dom.	Rel. den.	I. V.
Malvaceae	<i>Trichospermum pleiostigma</i>	3.929	125	25.42	9.27	34.70
Moraceae	<i>Ficus pungens</i>	1.269	213	8.21	15.80	24.01
Euphorbiaceae	<i>Macaranga tanarius</i>	1.755	112	11.35	8.31	19.66
Ulmaceae	<i>Trema orientalis</i>	1.348	38	8.73	2.82	11.54
Moraceae	<i>Ficus nodosa</i>	0.412	92	2.66	6.82	9.49
Lamiaceae	<i>Vitex cofassus</i>	0.576	71	3.73	5.27	9.00
Urticaceae	<i>Pipturus argenteus</i>	0.233	74	1.51	5.49	7.00
Euphorbiaceae	<i>Macaranga aleuritoides</i>	0.312	43	2.02	3.19	5.21
Moraceae	<i>Ficus variegata</i>	0.273	39	1.77	2.89	4.66
Malvaceae	<i>Commersonia bartramia</i>	0.329	23	2.13	1.71	3.83
	All stems	15.455	1348	100	100	200

Older secondary (1.75 ha)						
Family	Species	Basal area (m ²)	# stems	Rel. dom.	Rel. den.	I. V.
Malvaceae	<i>Trichospermum pleiostigma</i>	5.415	249	18.39	10.14	28.53
Euphorbiaceae	<i>Macaranga tanarius</i>	3.711	361	12.60	14.70	27.30
Moraceae	<i>Ficus variegata</i>	1.657	270	5.63	10.99	16.62
Euphorbiaceae	<i>Macaranga aleuritoides</i>	1.282	199	4.35	8.10	12.46
Ulmaceae	<i>Trema orientalis</i>	2.395	68	8.13	2.77	10.90
Moraceae	<i>Ficus pungens</i>	1.193	134	4.05	5.46	9.51
	<i>Melanolepis</i>					
Euphorbiaceae	<i>multiglandulosa</i>	1.194	117	4.05	4.76	8.82
Malvaceae	<i>Commersonia bartramia</i>	0.666	47	2.26	1.91	4.17
Lamiaceae	<i>Vitex cofassus</i>	0.495	56	1.68	2.28	3.96
Malvaceae	<i>Sterculia schumanniana</i>	1.000	10	3.40	0.41	3.80
	All stems	29.445	2456	100	100	200

Primary (1.75 ha)						
Family	Species	Basal area (m ²)	# stems	Rel. dom.	Rel. den.	I. V.
Sapindaceae	<i>Pometia pinnata</i>	4.994	79	8.84	3.37	12.21
Myristicaceae	<i>Horsfieldia basifissa</i>	1.530	153	2.71	6.53	9.24
	<i>Teijsmanniodendron</i>					
Lamiaceae	<i>bogoriense</i>	3.438	72	6.09	3.07	9.16
	<i>Gymnacranthera</i>					
Myristicaceae	<i>paniculata</i>	1.287	129	2.28	5.51	7.79
	<i>Mastixiodendron</i>					
Rubiaceae	<i>pachyclados</i>	2.484	74	4.40	3.16	7.56
	<i>Pimelodendron</i>					
Euphorbiaceae	<i>amboinicum</i>	2.080	78	3.68	3.33	7.01
Cannabaceae	<i>Celtis latifolia</i>	1.544	47	2.73	2.01	4.74
Meliaceae	<i>Chisocheton trichocladus</i>	0.993	47	1.76	2.01	3.76
Rubiaceae	<i>Neonauclea obversifolia</i>	1.692	17	3.00	0.73	3.72
Gnetaceae	<i>Gnetum gnemon</i>	0.869	49	1.54	2.09	3.63
	All stems	56.480	2342	100	100	200

Figure 1.1. (A) Location of study site near Wanang, Madang Province, Papua New Guinea. (B) Location of survey plots (0.25 ha) near Wanang village. Diamonds = younger secondary, triangles = older secondary, squares = primary. The older secondary and primary points closest to Wanang village each represent four contiguous 0.25 ha plots (i.e., 1 hectare plots).

Figure 1.1A

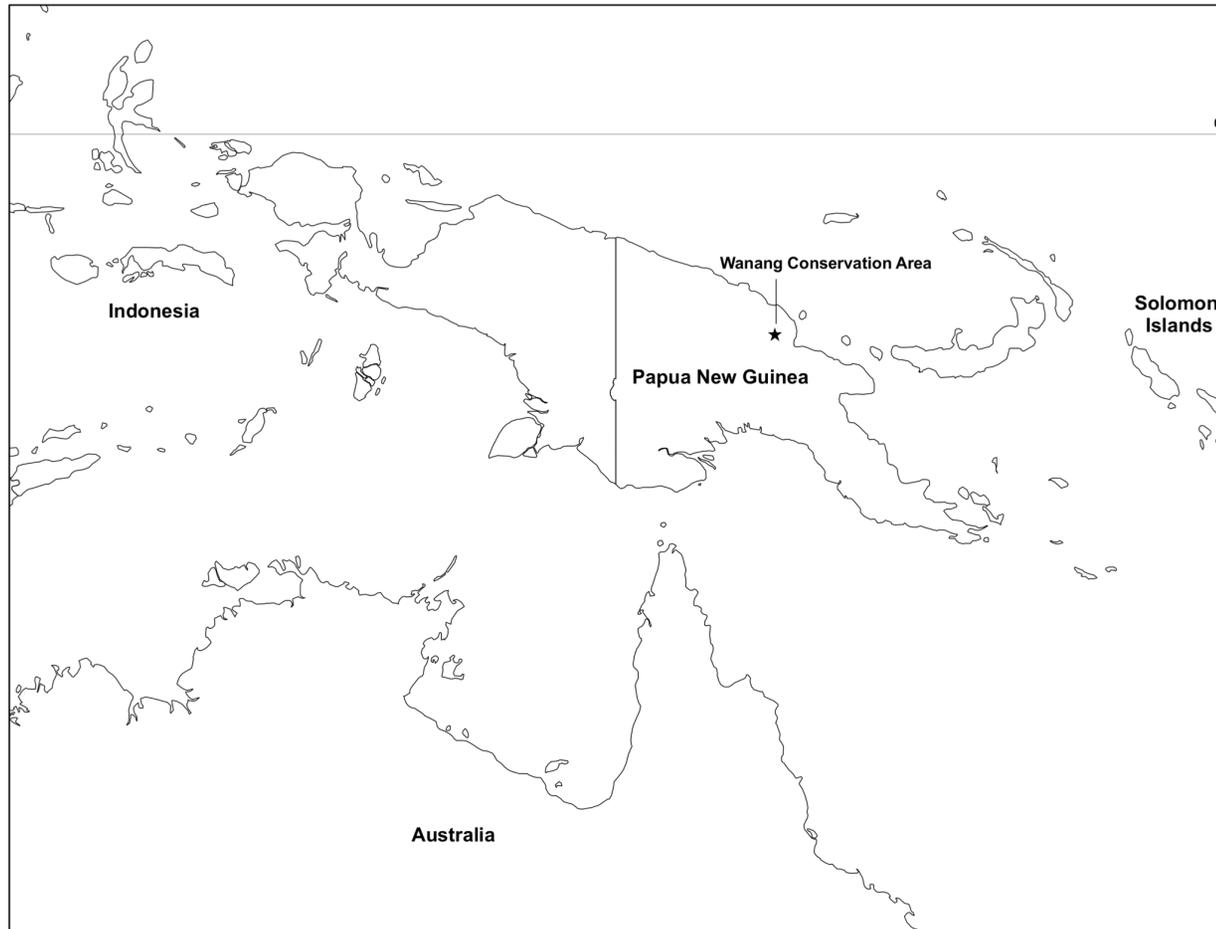


Figure 1.1B

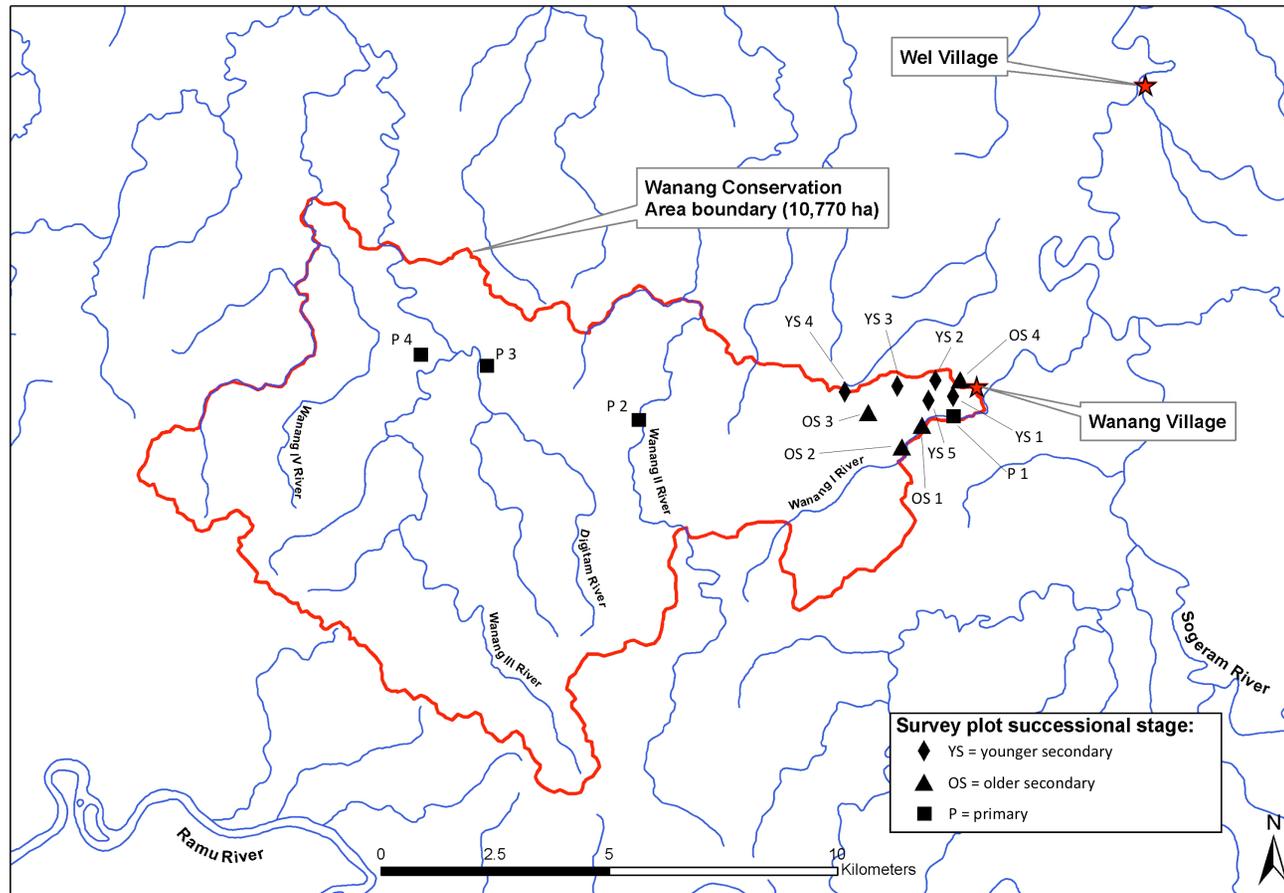


Figure 1.2. Fisher's alpha versus basal area for nineteen plots in the New Guinea lowlands. Values represent diversity in 0.25 hectare plots in three successional stages (younger secondary forest = diamonds, older secondary forest = triangles, primary forest = squares).

Figure 1.2

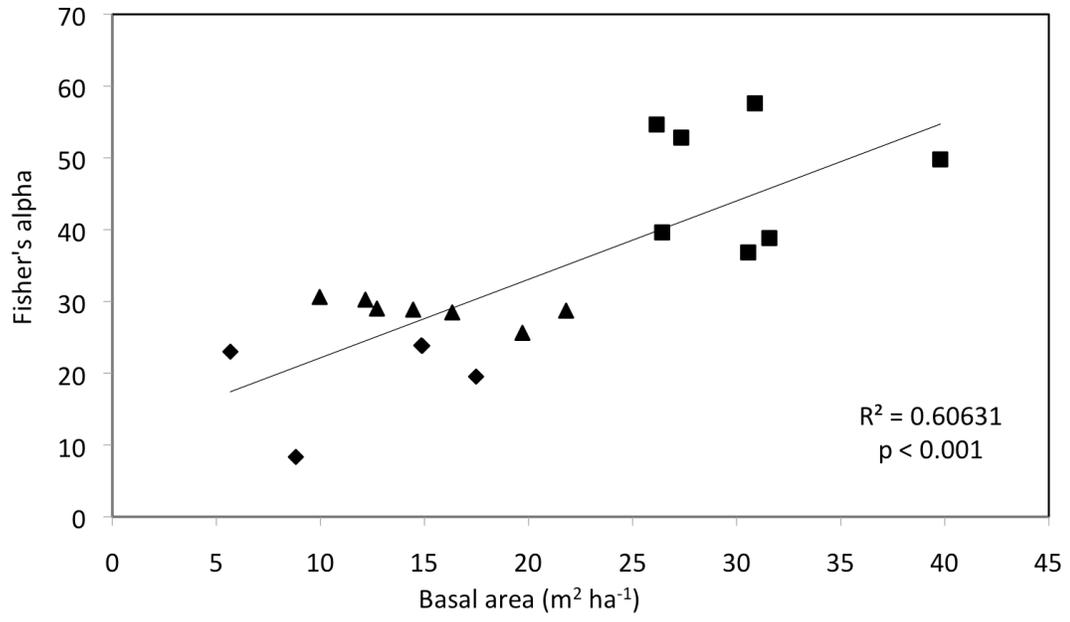


Figure 1.3. Species accumulations curves based on seven 0.25 ha plots per successional stage for small stems (dbh 5-10 cm) and large stems (dbh > 10 cm) for older secondary and primary forest in the same plots. Curves for younger secondary forest similar to older secondary and were omitted for clarity.

Figure 1.3

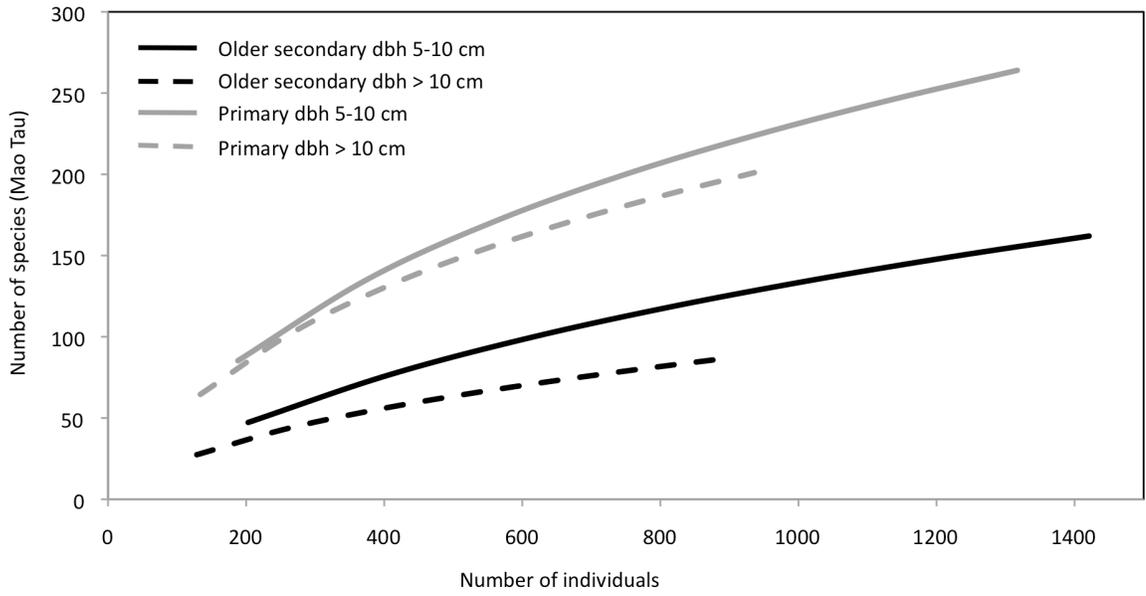


Figure 1.4. Community weighted mean trait values per plot versus total basal area per plot for traits in nineteen 0.25 hectare plots in three successional stages in the New Guinea lowlands (younger secondary = diamonds, older secondary = triangles, primary = squares). (A) wood density (g ml^{-1}), (B) specific leaf area ($\text{cm}^2 \text{g}^{-1}$), (C) seed mass per 1,000 seeds (g), (D) % foliar carbon, (E) % foliar nitrogen, (F) crown volume (m^3), and (G) tree height (m).

Figure 1.4

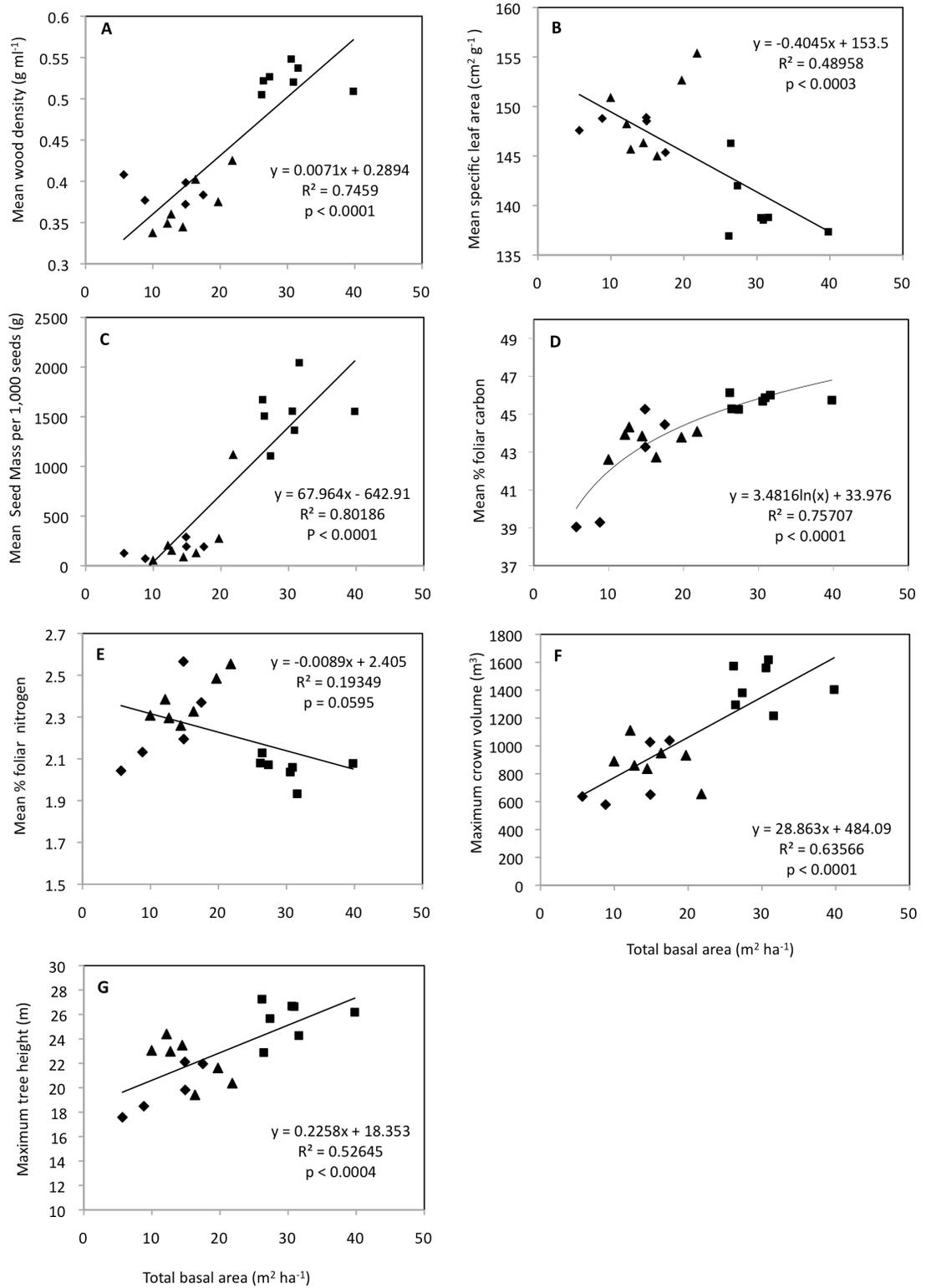


Figure 1.5. Redundancy analysis of traits and their relationships with successional stage based on the relative abundance of 341 tree species with dbh \geq 5 cm from New Guinea's lowland forest. Younger secondary plots are represented by diamonds (YS), older secondary plots by triangles (OS), and primary plots by squares (P). SeedMass = mean 1,000 seed mass (g), Carbon = mean % foliar carbon, WoodDen = mean wood density (g ml^{-1}), Height = maximum tree height (m), CrownVol = maximum crown volume (m^3), DBH = maximum diameter at breast height (cm), LatAbs = latex absent in leaves, LatPres = latex present in leaves, SLA = mean specific leaf area ($\text{cm}^{-2} \text{g}^{-1}$), Nitrogen = mean % foliar nitrogen. All data were centered and standardized. First canonical axis significance test based on Monte Carlo test (499 permutations under reduced model). Eigenvalue = 0.048, $p = 0.002$.

Figure 1.5

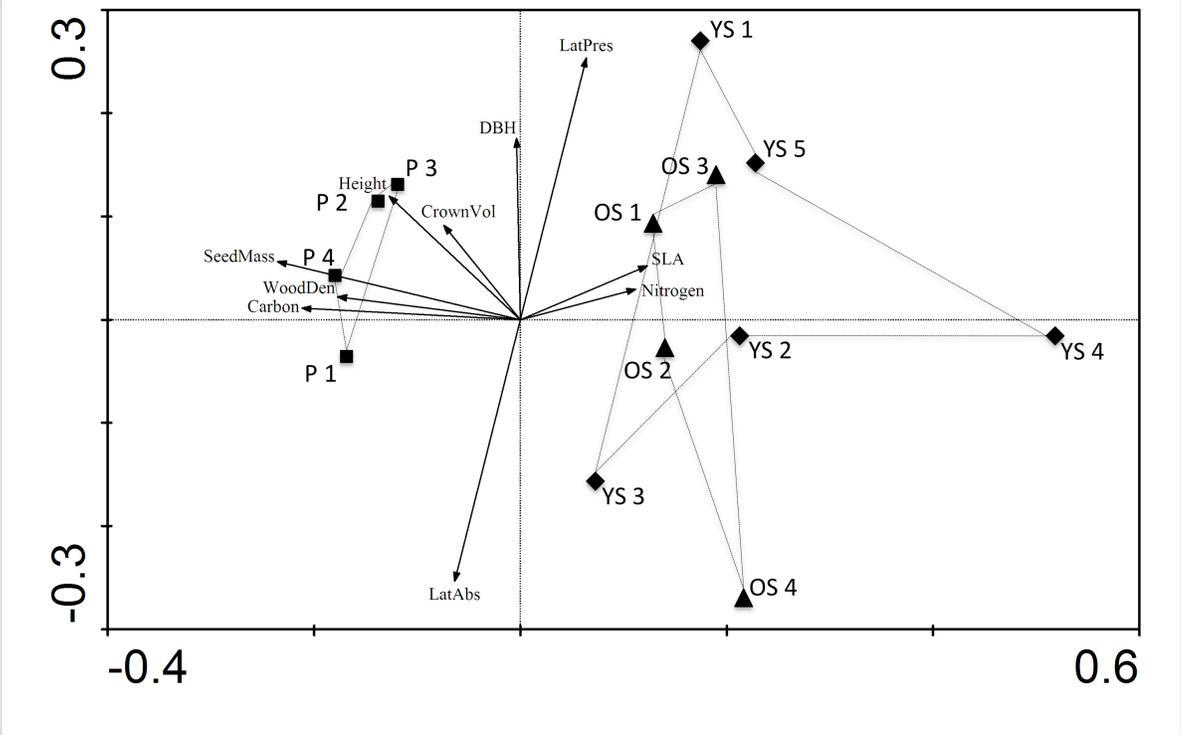


Figure 1.6. (A) Detrended correspondence analysis (DCA) of species association with successional stage in lowland New Guinea rainforest. Younger secondary plots are represented by diamonds (YS), older secondary plots by triangles (OS), and primary plots by squares (P). For clarity, only the 64 species best characterized by the ordination were included on the figure. First canonical axis significance test based on Monte Carlo test (499 permutations under reduced model), Eigenvalue = 0.776, $p = 0.002$. (B) Table of species abbreviations from DCA figure with full names.

Figure 1.6A

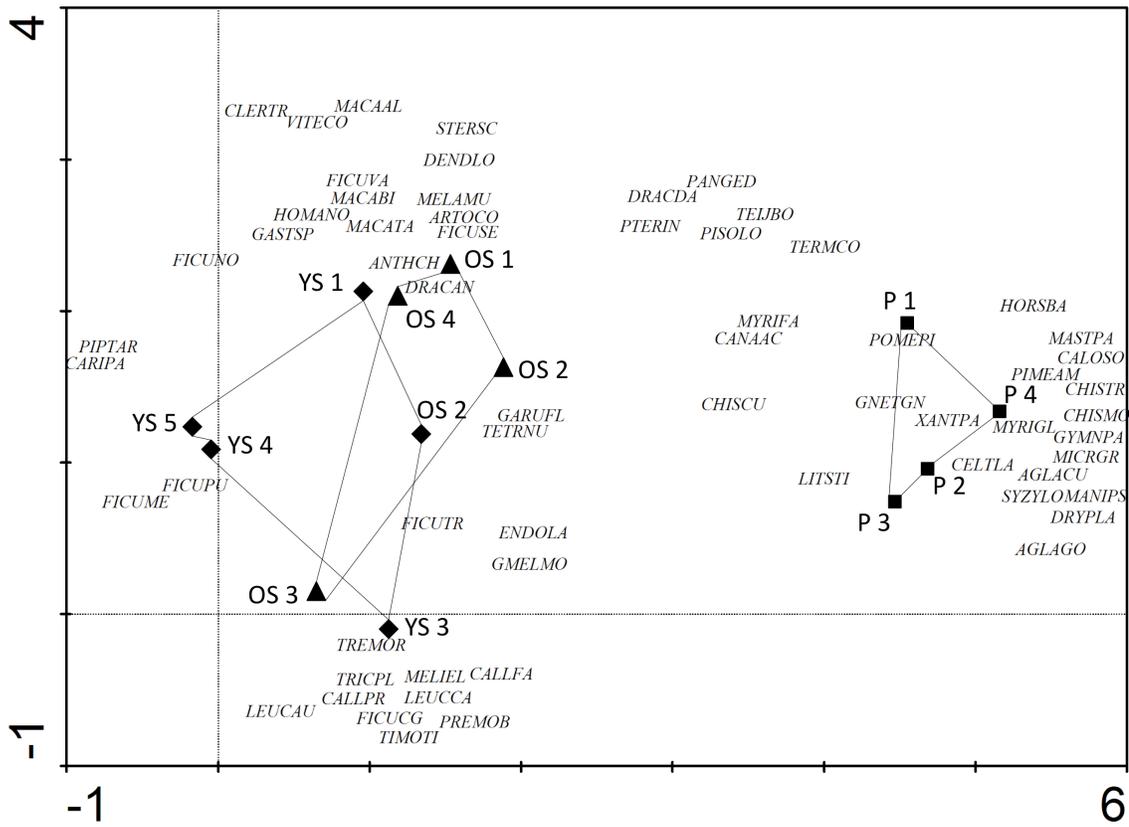
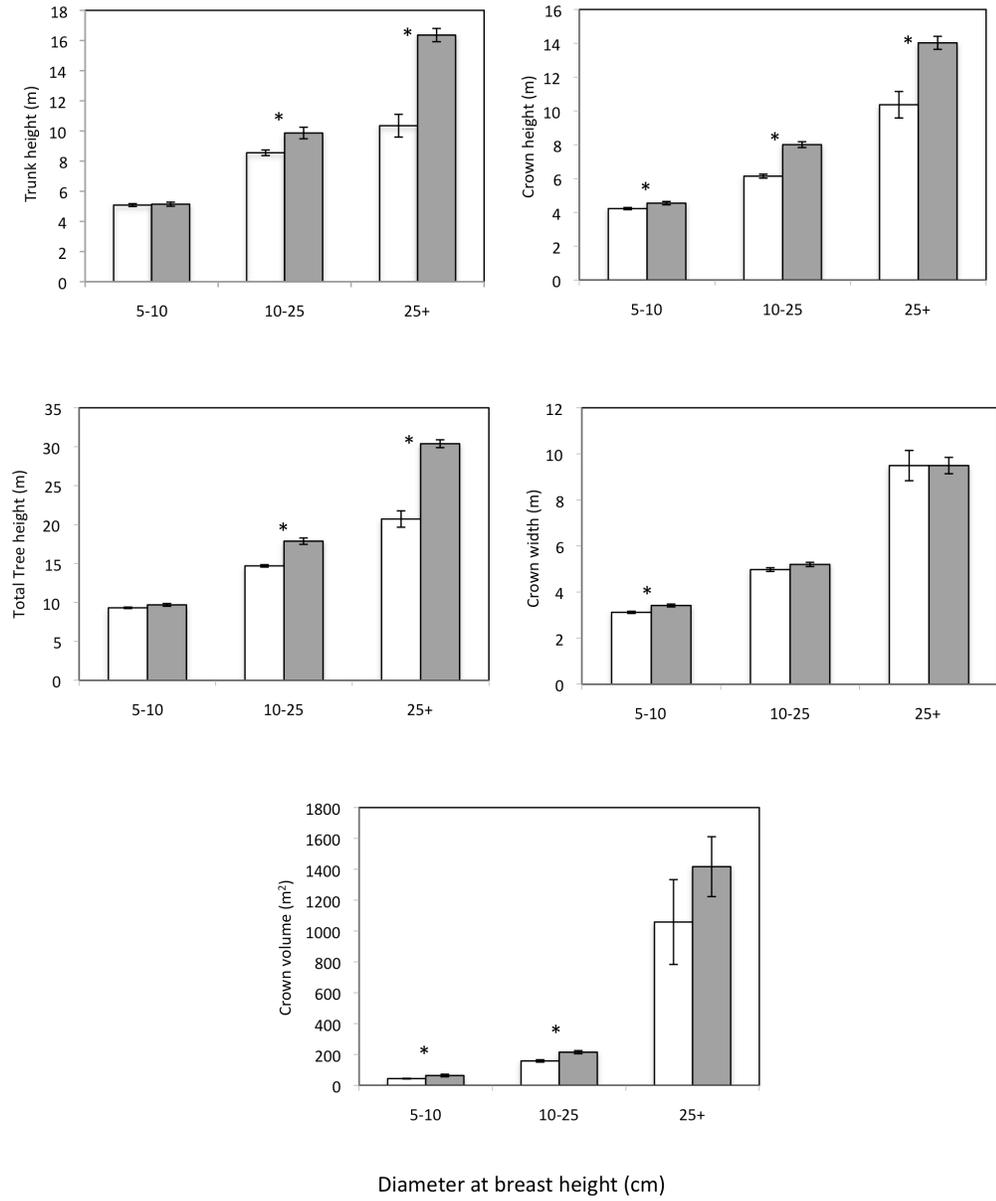


Figure 1.6B

AGLACU= <i>Aglaia cucullata</i>	HORSBA= <i>Horsfieldia basifissa</i>
AGLAGO= <i>Aglaia goebeliana</i>	HORSSY= <i>Horsfieldia sylvestris</i>
AILAIN= <i>Ailanthus integrifolia</i>	KLEIHO= <i>Kleinhovia hospita</i>
ALSOSC= <i>Alstonia scholaris</i>	LEEAIN= <i>Leea indica</i>
ANTIAN= <i>Antidesma angulatum</i>	LEPICO= <i>Lepidopetalum comesperma</i>
ARTOCO= <i>Artocarpus communis</i>	LEUCAU= <i>Leucosyke australis</i>
ARTOLA= <i>Artocarpus lacucha</i>	LEUCCA= <i>Leucosyke capitellata</i>
CALLFA= <i>Callicarpa farinosa</i>	LITSTI= <i>Litsea timoriana</i>
CALLPR= <i>Callicarpa pentandra</i>	MACAAL= <i>Macaranga aleuritoides</i>
CALOSO= <i>Calophyllum soulattri</i>	MACABI= <i>Macaranga bifoveata</i>
CANAAC= <i>Canarium acutifolium</i>	MACAPU= <i>Macaranga punctata</i>
CARIPA= <i>Carica papaya</i>	MACAQU= <i>Macaranga quadriglandulosa</i>
CELTLA= <i>Celtis latifolia</i>	MACATA= <i>Macaranga tanarius</i>
CHISCU= <i>Chisocheton cumingianus</i>	MANAME= <i>Maniltoa megalcephala</i>
CHISMO= <i>Chisocheton montana</i>	MANAPS= <i>Maniltoa psilogyne</i>
CHISTR= <i>Chisocheton trichocladus</i>	MASTPA= <i>Mastixiodendron pachyclados</i>
CLERTR= <i>Clerodendrum trachyanum</i>	MELIEL= <i>Melicope elleryana</i>
DENDLO= <i>Dendrocnide longifolia</i>	MELEMU= <i>Melanolepis multiglandulosa</i>
DRACAN= <i>Dracaena angustifolius</i>	MICRGR= <i>Microcos grandiflora</i>
DRACDA= <i>Dracontomelon dao</i>	MILLPI= <i>Millettia pinnata</i>
DRYPLA= <i>Drypetes lasiogynoides</i>	MYRIFA= <i>Myristica fatua</i>
DYSOAN= <i>Dysoxylum annae</i>	MYRIGL= <i>Myristica globosa</i>
DYSOGA= <i>Dysoxylum gaudichaudianum</i>	PALAMO= <i>Palaquium morobense</i>
DYSOMI= <i>Dysoxylum micranthum</i>	PANGED= <i>Pangium edule</i>
DYSPE= <i>Dysoxylum pettigrewianum</i>	PHYLCL= <i>Phyllanthus clamboides</i>
ELAEAM= <i>Elaeocarpus amplifolius</i>	PICRJA= <i>Picrasma javanica</i>
ENDOLA= <i>Endospermum labios</i>	PIPTAR= <i>Pipturus argenteus</i>
ERYTCA= <i>Erythrospermum candidum</i>	PISOLO= <i>Pisonia longilostris</i>
FICUCG= <i>Ficus congesta</i>	PLAN= <i>Planchonella</i>
FICUCP= <i>Ficus copiosa</i>	POLYGL= <i>Polyalthia glauca</i>
FICUGU= <i>Ficus gul</i>	POMEPI= <i>Pometia pinnata</i>
FICUME= <i>Ficus melinocarpa</i>	PREMOB= <i>Premna obtusifolia</i>
FICUNO= <i>Ficus nodosa</i>	PTERIN= <i>Pterocarpus indicus</i>
FICUPU= <i>Ficus pungens</i>	SEMESC= <i>Semecarpus schlechteri</i>
FICUSE= <i>Ficus semivestita</i>	STERAM= <i>Sterculia ampla</i>
FICUTR= <i>Ficus trachypison</i>	STEGHI= <i>Stegathera hirsuta</i>
FICUVA= <i>Ficus variegata</i>	STERSC= <i>Sterculia schumanniana</i>
FICUWA= <i>Ficus wassa</i>	STERSHI= <i>Sterculia shillinglawii</i>
GARUGL= <i>Garuga floribunda</i>	SYSYLO= <i>Syzygium longipes</i>
GASTSP= <i>Gastonia spectabilis</i>	TEIJBO= <i>Teijsmanniodendron bogoriense</i>
GLIRSE= <i>Gliricidia sepium</i>	TERMCO= <i>Terminalia complanata</i>
GMELMO= <i>Gmelina moluccana</i>	TETRNU= <i>Tetrameles nudiflora</i>
GNETGN= <i>Gnetum gnemon</i>	TIMOTI= <i>Timonius timon</i>
GNETGS= <i>Gnetum gnemonoides</i>	TREMOR= <i>Trema orientalis</i>
GYMNP A= <i>Gymnacranthera paniculata</i>	TRICPL= <i>Trichospermum pleiostigma</i>
HAPLFL= <i>Haplolobus floribunda</i>	UNCAUN= <i>Uncaria appendiculata</i>
HARPLO= <i>Harpullia longipetala</i>	VITECO= <i>Vitex cofassus</i>
HOMANO= <i>Homalanthus novoguineensis</i>	

Figure 1.7. Mean tree dimensions, standardized by dbh, in one hectare of older secondary forest (white bars) and one hectare of primary forest (gray bars) in the New Guinea lowlands. Dimensions in each category in the same dbh class marked with * are significantly different (ANOVA, $\alpha = 0.05$). Error bars are \pm SE.

Figure 1.7



CHAPTER 2

Change in community phylogenetic structure during tropical forest succession: evidence from New Guinea

“What a wondrous problem it is, what a play of forces, determining the kind and proportion of each plant in a square yard of turf!”

Charles Darwin, letter to J. D. Hooker, 3 June 1857

Introduction

Tropical rain forests are the most productive and biologically diverse terrestrial ecosystems (Leigh 1999). They cover less than 10% of the Earth’s land surface yet contain close to half of all species. A fundamental question for ecologists concerns mechanisms of species coexistence, particularly at small spatial scales in diverse forests (Wright 2002). For example, one-hectare plots in lowland rain forest can contain several hundred tree species (Proctor et al. 1983, Leigh 1999) whereas in most temperate regions a similar sized plot would include less than 20 species (Burnham et al. 1992, Leigh 1999). The concept of limiting similarity makes the high diversity in tropical areas hard to explain. This idea was based on experiments demonstrating that laboratory communities could not coexist over the long term when resources were limited (Gause 1934). Gause’s experiments verified the theoretical prediction that became known as the competitive exclusion principle (Hardin 1960). This tenet also led to the idea that a species could not become part of a community without the counteracting loss of another and that ‘rules’ govern the assembly of communities (Diamond 1975).

Approaches to understanding the assembly and maintenance of diverse communities combine a regional historical perspective (Ricklefs 1987) with an emphasis on the ecological niche (Diamond 1975). In this framework, local community diversity is a reflection of regional availability (Ricklefs 1987, McPeck and Brown 2000), environmental

filters that restrict membership of a community to species possessing the necessary phenotypes, and local interactions affecting survival (Diamond 1975, Bazzaz 1991, Weiher and Keddy 1995, Webb 2000, HilleRisLambers et al. 2002, Wright 2002, Cavender-Bares et al. 2004a, Cavender-Bares et al. 2004b, Svenning et al. 2008). Alternatively, neutral theory (Hubbell 2001) assumes that species are competitive equivalents with the same prospects for survival and reproduction. In this situation, functional differences between species are unimportant and communities are the result of processes such as dispersal, speciation, and extinction with ecological processes such as competition playing a limited role (Hubbell 2001).

A phylogenetic perspective that recognizes the dual role of evolutionary history in generating species diversity and in shaping phenotypes may provide insight into the relative importance of different processes affecting species coexistence and community assembly (Webb et al. 2002). Phylogenetic community ecology attempts to connect the evolutionary history of coexisting organisms with ecological mechanisms driving patterns of distribution and abundance (Kraft et al. 2007, Cavender-Bares et al. 2009).

Estimates of community phylogeny have been used to test assembly hypotheses related to ecological processes such as environmental filtering and competition (Webb et al. 2002). Environmental filters can restrict long-term community membership to those individuals that possess phenotypes necessary for survival and successful reproduction (Weiher and Keddy 1995, Webb 2000, Webb et al. 2002) resulting in a community of species that share a closer evolutionary history than would be expected by chance (phylogenetic clustering). By contrast, competition theory (Svenning et al. 2008) predicts that closely related species with similar phenotypes are more likely to compete directly

with each other and less likely to coexist. A community comprised of species more distantly related than expected by chance (phylogenetic over-dispersion) may signal competitive exclusion if we assume niche conservatism (Ackerly 2004). However, traits influencing community membership can also be convergent (Cavender-Bares et al. 2006) such that the assumption of niche conservatism is not always appropriate (Swenson and Enquist 2009). Other community ecological processes further complicate the interpretation of community phylogenetic patterns. Trophic interactions are predicted to have negative density-dependent effects impacting the distribution of diversity such that recruitment of species in proximity to close relatives can be limited by specialized pests and pathogens (Gilbert and Webb 2007) which tend to yield patterns of over-dispersion (Wills et al. 2006, Comita et al. 2010). Mutualism and facilitation might produce patterns of clustering by promoting benefits to close relatives through mechanisms such as shared pollinators (Sargent and Ackerly 2008) or over-dispersion where positive interactions occur between distant relatives. The latter has been noted where ‘nurse plants’ facilitate protected microhabitats for the germination and establishment of distant relatives (Valiente-Banuet and Verdu 2007).

Each of the aforementioned processes has been invoked to account for patterns of diversity in the tropics that also happen to be the ancestral home of many flowering plant lineages. The challenge of explaining elevated tropical plant diversity has made the region a particular target for community phylogenetic analysis (Webb 2000, Kembel and Hubbell 2006, Kress et al. 2009, Gonzalez et al. 2010, Letcher 2010). The island of New Guinea, although recognized for high biological diversity, endemism, and the world’s third largest undisturbed tropical forest after the Amazon and Congo basins has, however,

not been the subject of a community phylogenetic study. We investigated New Guinea lowland rain forest succession and expanded upon similar investigations (Letcher 2010) by applying DNA sequences to estimate phylogenetic branch lengths directly. Studies using DNA sequences for direct community phylogeny estimation have not investigated forest succession (Kress et al. 2009) even as secondary forest has become a predominant feature of tropical landscapes.

Empirical studies and forest succession theory predict changes in abiotic conditions during succession (Oliver and Larson 1990, Lebrija-Trejos et al. 2010). Phylogenetic niche-conservatism assumes that ecologically similar species are likely to be closely related such that the homogenous conditions of young secondary forests are expected to support a phylogenetically clustered community whereas the heterogeneous abiotic conditions of primary forest, along with perhaps other processes such as competitive exclusion and density-dependent mortality, favors primary forest over-dispersion. We tested the prediction that the overall community phylogenetic pattern shifts from that of clustering to over-dispersion during ecological succession using basal area as a proxy for forest age.

Methods

Survey plots – A total forest area of 4.75 hectares were surveyed near Wanang (145° 5' 32" E, 5° 14' 26" S), Madang Province, Papua New Guinea. The field site is in a mosaic of primary and secondary rainforest vegetation at 100 – 200 m above sea level. It is part of an extensive mixed evergreen forest on latosols in the Ramu River basin. The region is characterized by a humid climate with mean annual rainfall of 3,500 mm, a mild dry

season from July to September, and mean monthly temperature of 26 °C (McAlpine et al. 1983). Sampling included nineteen 0.25 hectare plots (50 m by 50 m). Five plots were located in younger secondary forest (<10 years since disturbance), seven plots in older secondary forest (10-20 years since disturbance), and seven plots in primary forest (>50 years since disturbance). Plots were not randomly located but were rather based on the distribution of abandoned subsistence agricultural plots in the study area. Approximate ages were obtained through interviews with landowners. A minimum age for primary forest in the area was estimated from Royal Australian Survey Corps aerial photographs, where the presence of multi-layered canopy in 1973 suggests no anthropogenic disturbance since at least the late 1950s. Local landowners practice subsistence agriculture in 0.25-1.0 hectare gardens planted after felling and burning of primary forest. Succession ensues when garden plots are abandoned after 2-3 years of low intensity cultivation.

Species identification – Trees with diameter at breast height (dbh) \geq 5 cm were measured, tagged, and identified to estimate species abundance (based on the number of individual stems per species) and diversity for each plot. Following preliminary field identification by foresters, vouchers were collected and verified at the Papua New Guinea Forest Research Institute, Lae herbarium (LAE). Complete sets of vouchers were deposited at LAE and the Herbarium of the J. F. Bell Museum of Natural History at the University of Minnesota (MIN) with additional material distributed to herbaria including A, US, K, L, CANB, SING, F, NY, and MO.

DNA sequencing – Leaf discs were taken from multiple individuals for all species in the nineteen survey plots. Discs with a diameter of 2.3 cm were punched from fresh

leaves in the field and temporarily stored in paper envelopes over silica gel. Leaf discs were stored in a -80°C frozen tissue collection at the University of Minnesota and DNA was isolated from up to four discs per species at the Smithsonian Institution. We sequenced according to published protocols (Kress et al. 2009) the gene for the large subunit of ribulose-1,5-bisphosphate carboxylase-oxygenase (*rbcL*), a conserved coding locus that is easily amplified and known to accurately place most land plant taxa in orders and families. Chromatograms were imported into Sequencher version 4.6 (Gene Codes Corporation, Ann Arbor, Michigan), trimmed, and assembled into contigs. New sequences were deposited in GenBank (accession numbers JF738369-JF739166) and aligned with previously published sequences from the survey plots (Hollingsworth et al. 2009, Novotny et al. 2010).

Phylogenetic analysis – We estimated phylogenetic relationships among all species of woody plants including trees, shrubs, and vines ≥ 5 cm dbh that occurred in the sample plots. A neighbor-joining tree of 860 *rbcL* sequences representing 349 species and up to four samples per species was obtained using PAUP* ver. 4 (Swofford 2001) and resolved the monophyly of most orders and families. Sequences that appeared out of position relative to expected placement within orders and families prompted re-examination and re-sequencing of voucher specimens that, in five cases, corrected field misidentifications. Taxon sampling and sequence variation in *rbcL* was insufficient to evaluate species monophyly with confidence. The dataset was pruned to include a single sequence per species for the purpose of Bayesian phylogenetic analysis (see also *Sensitivity Analysis*). A general time-reversible model of molecular evolution with

parameters for invariant sites and rate heterogeneity among sites (GTR+ Γ +I) was selected for the pruned 349-taxon dataset using the Akaike Information Criterion.

Bayesian analysis was conducted using BEAST (Drummond and Rambaut 2007) under GTR+ Γ +I so that phylogenetic relationships and divergence times could be estimated simultaneously. We assumed a relaxed molecular clock considering that *rbcL* strongly rejected a strict clock according to the likelihood-ratio test ($\chi^2= 688$, $df = 347$, $p<0.001$). Topological constraints were enforced to incorporate prior knowledge of well-supported relationships while allowing unresolved relationships to be estimated from sequence variation in the community sample (Kress et al. 2010). Constraints included the monophyly of Angiosperm Phylogeny Group (Wikström et al. 2001, APG 2009) orders and families as well as ordinal and familial relationships based on consensus among three broad-scale analyses: a three-gene analysis (18S rDNA, *rbcL*, and *atpB*) of 567 taxa (Soltis et al. 2000), an 83 (plastid) gene analysis of 86 species (Moore et al. 2010), and a 12 gene (10 plastid, two nuclear) analysis of >100 species (Wang et al. 2009). Only nodes supported by >95% posterior probability or 80% bootstrap in these studies were constrained with two exceptions (i.e., the relationship between Salicaceae and Passifloraceae, with 50-80% support, and the relationship between Polygalaceae and the rest of the Fabales, with 50-75% support). Familial relationships within orders were constrained according to the following treatments: Rosales (Wang et al. 2009), Fabales (Banks et al. 2008), Malpighiales (Davis et al. 2005), Sapindales (Gadek et al. 1996, Muellner et al. 2007), Malvales (Fay et al. 1998, Bayer et al. 1999), Myrtales (Conti et al. 1997, Bremer et al. 1999, Sytsma et al. 2004, Wilson et al. 2005), Gentianales (Bremer et al. 1999, Rova et al. 2002), Lamiales (Oxelman et al. 1999, Soltis et al. 2001), Ericales

(Anderberg et al. 2002), Laurales (Doyle and Endress 2000, Soltis et al. 2000), and Magnoliales (Doyle and Endress 2000, Soltis et al. 2000). The monophyly of genera was also enforced except for *Dracontomelon*, *Chisocheton*, and *Aglaia*, which are considered paraphyletic (Muellner et al. 2003). Support for these phylogenetic hypotheses is far more extensive than what can be expected from community barcodes and it is desirable to incorporate this prior information while resolving the remaining relationships with DNA sequences from community members. We further assessed the sensitivity of results to uncertainty associated with this approach (see *Sensitivity Analysis*).

Information on the minimum ages of major angiosperm lineages was incorporated in the Bayesian analysis by setting node age priors in BEAST. Thirty-one nodes were identified using Phylomatic (<http://www.phylodiversity.net/phyloomatic/phyloomatic.html>). We applied these as node age priors in Bayesian analysis along with *rbcL* sequences, model parameters, and topological constraints as described above. A Markov-chain Monte Carlo simulation of 10 million generations was sampled every 1,000 generations and the first 1,000 trees were discarded as burn-in. Among the posterior distribution of 9,000 trees, the topology with the highest likelihood was used to quantify community phylogenetic patterns.

Community phylogeny metrics – Mean pair-wise phylogenetic distance (MPD) and mean nearest taxon phylogenetic distance (MNTD) among individuals occurring in each survey plot was calculated using the Picante package (Kembel et al. 2010). These metrics describe different components of phylogenetic diversity. By taking into account all pair-wise distances in a sample of taxa, MPD provides an overall measure of phylogenetic diversity whereas MNTD, in quantifying distances between nearest neighbors, describes

the degree to which community members are terminally clustered (Webb 2000). Null models were used to compare these community phylogenetic distance metrics to expectations of neutral theory (Hubbell 2001). The independent swap algorithm (Gotelli and Entsminger 2003) was used to randomize patterns of species co-occurrence while maintaining per-plot species richness and the frequency of species occurrence among plots. These assumptions are known to minimize Type I error (Kembel and Hubbell 2006). The procedure further assumes that species may freely disperse among plots in a few generations and that the probability of colonization is proportional to the frequency of species occurrence among plots. These assumptions are reasonable given the proximity of our plots in a contiguous forest area.

The independent swap algorithm generates matrices composed of plots by species abundance and searches for “checkerboard” patterns (Diamond 1975). Such patterns consist of $(0,n)$ and $(n,0)$ or $(n,0)$ and $(0,n)$ where n and 0 represent the abundance and the absence of a particular species in two plots, respectively. When such patterns are encountered, the species abundance n and its absence are swapped between the plots. Abundance-weighted swapping is comparable to the 3x null model of Hardy (2008) and is interpreted in terms of phylogenetic structure among individuals rather than among species (Kembel et al. 2010).

Ten thousand swaps per run of the model produced thoroughly randomized matrices for the calculation of MPD and MNTD under null expectations (Gotelli 1996). Phylogenetic distance metrics were calculated for each of 999 randomized matrices per plot and standardized effect sizes (SES) were calculated by comparing observed per-plot means relative to the distribution of per-plot mean distance under the null distribution

(Gotelli and Rohde 2002). The standardized effect size is defined as $(X - X_{null})/sd_{null}$ where X = observed mean phylogenetic distance per plot, X_{null} = mean phylogenetic distance of the null distribution, and sd_{null} = standard deviation of phylogenetic distance under the null. Standardized effect sizes for MPD and MNTD are equivalent to the net relatedness index (NRI) and the nearest taxon index (NTI) multiplied by -1, respectively (Webb et al. 2002). Significantly positive values of SES for a particular community sample indicate phylogenetic over-dispersion whereas significantly negative values indicate clustering (Webb et al. 2008, Kembel et al. 2010). These measures were averaged among plots within each successional stage so that the significance of overall patterns could be assessed by two-tailed t -tests.

Sensitivity analysis – We investigated the sensitivity of pattern detection to sources of error in phylogeny estimation including phylogenetic uncertainty and phylogenetic branch length assumptions. In the absence of information about evolutionary rates or divergence times, phylogenetic distance is sometimes approximated by the number of nodes separating any two taxa in a phylogeny. A popular improvement on this assumption is to incorporate minimum age estimates available for higher taxa and to evenly space the ages of intervening nodes such that branch length variance between dated nodes is minimal (Webb et al. 2008). Other approaches directly estimate genetic divergence of DNA sequences obtained from community members (Kress et al. 2009, Pei et al. 2011) or integrate such data with minimum age estimates using relaxed molecular clock assumptions as we did (Drummond and Rambaut 2007). Kress et al. (2009) advocated the use of DNA sequences over approximations of divergence times (Kembel and Hubbell 2006, Letcher 2010) or equal branch lengths (Webb 2000). We compared

these assumptions using the same topology to examine their influence on the inference of community phylogenetic patterns.

Branch lengths were estimated by four different methods on the Bayesian topology described in *Phylogenetic Analysis*. First, we applied an equal branch length assumption (EBL) using the “compute.brln” command in Picante (Kembel et al. 2010). Second, branch lengths proportion to genetic distance (ML) were obtained by estimating in PAUP* ver. 4 (Swofford 2001) the likelihood of observing the *rbcL* sequence data under GTR+ Γ +I. Third, branch lengths were adjusted according to 31 minimum age estimates for major clades as implemented in Phylocom (Webb et al. 2008). The branch length adjustment algorithm (BLADJ) assigned branch lengths in millions of years to 31 dated nodes and evenly spaced the remaining nodes. Fourth, a relaxed molecular clock Bayesian estimate integrating *rbcL* divergence and the aforementioned minimum age estimates for major clades as described in *Phylogenetic Analysis*.

Even as systematic knowledge improves, evolutionary relationships among at least some members of most communities are likely to remain uncertain and community phylogenetic distance metrics could potentially be affected. Recent simulations (Swenson 2009) indicated that detection of community phylogenetic structure need not be strongly influenced by terminal phylogenetic resolution (e.g., relationships among congeners). We investigated the impact of phylogenetic uncertainty on power to detect clustering and over-dispersion by comparing the significance of patterns inferred from the Bayes topology to those drawn from 100 randomly resolved constraint trees. This approach permuted relationships that were inferred from the *rbcL* sequences of community members while maintaining relationships strongly supported by independent evidence (as

described in *Phylogenetic Analysis*). We also investigated whether clustering and over-dispersion were sensitive to the choice of topology from the Bayesian posterior distribution.

Results

Taxonomic richness among 19 survey plots was highest in primary forest (Fig. 2.1A). Basal area was also significantly higher in primary forest than secondary forest (Fig. 2.1B), but stems per unit area was not (Fig. 2.1C). A global Moran's I test for regression residuals ($p = 0.79$) and a simultaneous auto-regression model (Dormann et al. 2007) failed to identify spatial auto-correlation among plots ($\lambda = -0.0135$, LR = 2.2, $p = 0.13$).

Bayesian analysis of *rbcL* sequences from the 349 woody plant species recorded in 19 survey plots yielded $\geq 95\%$ posterior probability for most community phylogenetic relationships (Appendix 4). Appendix 5 lists all GenBank accession numbers. Besides 141 nodes that were constrained according to prior systematic knowledge, incorporating the primary plant DNA barcode resolved an additional 62 out of 208 nodes with $\geq 95\%$ posterior probability. This approach represents a substantial improvement over the 40% resolution provided by Phylomatic.

Except when branch lengths were assumed to be equal, MPD was strongly and positively correlated with basal area (Fig. 2.2). However, MNTD was significantly correlated with basal area only under a relaxed molecular clock. When community phylogenetic structure was detected, secondary forests tended to be clustered whereas primary forests were over-dispersed (Table 2.1). Time-calibrated branch length assumptions (BLADJ and Bayes) exhibited greater power to detect phylogenetic structure

(significant MPD in 13 and 12 out of 19 plots, respectively) compared to six plots under the equal branch length assumption and five under non-ultrametric *rbcL* sequence divergence. Per-plot MNTD under various branch length assumptions was correlated with MNTD under Bayes ($r^2 = 0.43-0.69$). This was only true for MPD in the case of time-calibrated branch length assumptions ($r^2 = 0.28$).

Two-tailed *t*-tests of standardized effects sizes for MPD indicated overall phylogenetic clustering in secondary forest compared to over-dispersion in primary forest (Fig. 2.3). This pattern was robust to branch length assumptions except in the case of equal branches where no overall pattern was detected in secondary forest and primary forest was found to be significantly clustered instead of over-dispersed (see Discussion). The directionality of MNTD standardized effect sizes was similar to that of MPD, but differences in significance occurred in all three successional stages.

The sensitivity of these patterns to topological inaccuracy was investigated by examining the significance of MPD and MNTD metrics for each of the most highly clustered and over-dispersed plots given 100 randomly resolved constraint trees. When time-calibrated branch lengths were assumed, pattern detection was not affected by uncertainty associated with phylogenetic relationships inferred directly from the *rbcL* sequences of community members. However, patterns were sensitive in the case of the equal branch length assumption, where significant clustering and over-dispersion was not detected among all randomly resolved constraint trees. When branch lengths were proportional to maximum likelihood estimates of *rbcL* divergence, clustering and over-dispersion were also sensitive to the choice of tree topology.

Discussion

Interpreting community phylogenetic patterns – The accumulation of basal area and taxonomic diversity during forest succession in New Guinea (Fig. 2.1) is consistent with previous studies of other lowland tropical forests. In Costa Rica, basal area and taxonomic diversity increased with forest age (Montgomery and Chazdon 2001, Norden et al. 2009, Letcher 2010) and similar patterns were identified in Borneo (Bischoff et al. 2005). The overall phylogenetic distribution of community members in New Guinea lowland rain forest also increased with age (Fig. 2.2) at deep and shallow phylogenetic scales (MPD and MNTD, respectively). Given that changes in phylogenetic pattern and species richness are confounded, we also compared standardized effect sizes to chance expectations and we identified an overall shift from phylogenetic clustering in secondary forest to primary forest over-dispersion (Fig. 2.3). The pattern may be interpreted in terms of ecological processes affecting community assembly. We regard the overall lack of phylogenetic pattern in younger secondary forest plots as a reflection of the more or less random dynamics of colonization by pioneer species. Phylogenetic clustering in older secondary plots is consistent with a relatively homogeneous environment favoring suites of related species that happen to share conserved traits associated with rapid growth in this environment (Oliver and Larson 1990, Kraft and Ackerly 2010).

By contrast, primary forest over-dispersion could be explained in a number of ways. Closely related trees with similar traits might be locally excluded by competition or distantly related species with convergent traits may be filtered into the same environment (Cavender-Bares et al. 2009, Cornwell and Ackerly 2009). Alternatively, density-dependent trophic interactions (Gilbert and Webb 2007, Comita et al. 2010) or mutualism

and facilitation (Valiente-Banuet and Verdu 2007, Sargent and Ackerly 2008) could influence the pattern.

Non-random patterns of tree species co-occurrence in tropical forests are well-documented (Webb 2000, Kembel and Hubbell 2006, Kress et al. 2009, Kraft and Ackerly 2010, Letcher 2010). In Borneo, an overall pattern of phylogenetic clustering was detected using a community phylogeny with equal branch lengths (Webb 2000). That habitat associations were stronger for adult trees than seedlings was interpreted as evidence of environmental filtering (Webb and Peart 2000). A recent application of the branch length adjustment algorithm found, to the contrary, that coexisting tree species in Costa Rican secondary forests were more distantly related than expected by chance (Letcher 2010). Overall differences between the New Guinean and Costa Rican patterns may be attributed to several factors. First, the strength and direction of the Costa Rican pattern differed among diameter size-classes in each successional stage such that the smallest trees (0.5-5.0 cm) of the youngest forest (10-15 years old) were over-dispersed whereas trees ≥ 10 cm dbh were phylogenetically clustered. We did not measure trees < 5 cm dbh such that the New Guinea pattern is in fact consistent with Costa Rican findings for secondary forest trees of comparable size. Another consideration is that, in Costa Rica, forests had colonized abandoned pasture compared to lightly cultivated subsistence agricultural plots in New Guinea. The higher intensity of disturbance in Costa Rica might also have altered the successional trajectory of this site (Chazdon 2003).

In French Guiana, phylogenetic diversity differed between the seedling layer and the canopy layer (Gonzalez et al. 2010). That the canopy harbored more species and greater phylogenetic diversity than the understory was interpreted as evidence of

recruitment into the canopy of multiple seedling cohorts during succession. Our comparison of different successional stages also supports this interpretation where species richness and mean phylogenetic distance increased with forest age. The hypothesis that recruitment during the later phases of succession favors more phylogenetically distant taxa than during early succession possibly due to density-dependent mortality (Comita, et al. 2010) deserves further investigation.

Phylogenetic assumptions – The interpretation of community phylogenetic patterns depends on assumptions about the relatedness of community members (tree topology) and the extent of temporal divergence or trait divergence among co-occurring species (branch lengths). For example, Kembel and Hubbell (2006) inferred phylogenetic clustering in Panamanian plateau forest and over-dispersion in swamp and slope habitats under Phylomatic assumptions (Webb, et al. 2008) whereas Kress et al. (2009) detected the opposite pattern using DNA sequences. It is necessary to consider differences among various assumptions if meaningful inferences about ecological process are to be gained.

Equating branch lengths assumes that anagenesis (evolutionary change along branches) is highly correlated with cladogenesis (speciation). However, the evolution of traits affecting community membership may be decoupled from speciation in which case additional information on evolutionary rates is desirable. Assuming equal branch lengths will also tend to overestimate phylogenetic distance between close relatives and underestimate the divergence of distantly related species in ecological community samples that are highly heterogeneous from a phylogenetic standpoint. The pattern of primary forest clustering detected under the equal branch assumption appears to be an artifact of underestimating the divergence of distantly related community members. Our

results further suggest that the equal branch length assumption generally has lower statistical power to detect deviations from null models than time-calibrated assumptions.

DNA sequences or barcodes such as *rbcL* provide estimates of anagenesis (numbers of substitutions per site) that find ecological interpretation if rates of molecular evolution are assumed to be correlated with morphological trait evolution. Although this assumption is generally supported for particular clades (Omland 1997) local and regional communities are taxonomically heterogeneous and there is potential for biased estimates of trait evolution in communities given the possibility for erroneous inferences to be drawn from incomplete taxon samples (Zwickl and Hillis 2002). More work is needed to assess whether time-calibrated and relaxed molecular clock methods of branch length estimation might improve accuracy in this respect. In either case, divergence times are assumed to correlate with the phenotypic dissimilarity of lineages arising from their independent evolution under models of Brownian motion. Our results suggest that phylogenetic patterns in New Guinea lowland rain forest tree communities are robust to branch length assumptions so long as divergence is calibrated with respect to time, either by branch length adjustment (BLADJ) or a relaxed molecular clock (Fig. 2.3).

Findings from New Guinea are consistent with Kress et al. (2009) in demonstrating that DNA barcodes improve the resolution of community phylogeny beyond Phylomatic. Whether the detection of phylogenetic pattern is enhanced by such improvement is a separate question that we investigated by comparing our results to randomly resolved constraint trees. Only when branch lengths were assumed to be equal or directly proportional to DNA sequence divergence was the detection of clustering and over-dispersion sensitive to uncertainty about phylogenetic relationships among

community members. Calibrating divergence with respect to time, either by branch length adjustment (BLADJ) or a relaxed molecular clock, may also reduce the chance of Type II error in analyses of community phylogenetic structure.

We favor the inference of community phylogeny from a combination of current systematic knowledge with DNA sequences from community members. This approach minimizes inaccuracy associated with phylogenetic inference from incomplete taxon samples (Zwickl and Hillis 2002) while maximizing topological resolution (Uriarte, et al. 2010) and adding power to detect community phylogenetic patterns with relaxed molecular clock branch length assumptions. Although patterns inferred under these conditions are among the most likely to be robust, it is necessary to bear in mind that they also depend to some extent on the spatial scale under investigation (Cavender-Bares et al. 2006, Swenson and Enquist 2007) and the relative size of samples to the regional species pool (Kraft, et al. 2007). In any event, empirical results from New Guinea are consistent with recent simulations (Swenson 2009) suggesting that topological uncertainty may not strongly affect the detection of community phylogenetic patterns.

Conclusions

Community phylogenetic patterns in New Guinea lowland rain forest shift from clustering to over-dispersion during the course of ecological succession. Comparisons to null models indicate that the change is not simply explained by the overall accumulation of phylogenetic diversity as forests grow older but ecological mechanisms favoring the co-existence of distantly related taxa. Findings from 0.25 ha plots are consistent with the hypothesis that relatively homogenous conditions in younger secondary forests favor the

coexistence of related species, which happen to share functional traits associated with success in this environment. The pattern of over-dispersion apparent in primary forests is consistent with explanations such as environmental filtering of convergent lineages or the competitive exclusion of relatives characterized by trait conservatism. If close relatives with conserved traits share specialized enemies such as pests and pathogens (Wills et al. 2006), then perhaps trophic interactions could mediate local competition (Gilbert and Webb 2007, Comita et al. 2010). On the other hand, convergent lineages might engage in mutualisms, and such facilitation could produce the same pattern (Valiente-Banuet and Verdu 2007, Sargent and Ackerly 2008).

The overall increase in phylogenetic diversity of primary forest compared to secondary forest may reflect increased time for colonization following disturbance or, alternatively, greater environmental heterogeneity that could facilitate species coexistence. Examining the phylogenetic distribution of plant functional traits related to survival, reproduction, and dispersal (Kembel 2009) in the context of forest succession could further refine mechanistic hypotheses on species coexistence (Kraft and Ackerly 2010, Uriarte et al. 2010) and growth-mortality trade-offs accounting for life history differences among primary and secondary forest tree species (Wright et al. 2010). We hope that such investigations may inform the design of experiments to directly investigate ecological processes affecting community phylogenetic patterns (Cavender-Bares et al. 2009).

Table 2.1. Phylogenetic distance in community samples of lowland New Guinea woody plants ($\text{dbh} \geq 5$ cm) from nineteen 0.25 ha plots representing forests in three age classes. Per plot mean phylogenetic distance (MPD) and observed mean nearest taxon distance (MNTD) are compared among four different branch length assumptions. Phylogenetic distance was estimated under an identical topology and assumptions of (1) equal branch lengths (EBL), (2) a maximum likelihood estimate of *rbcL* divergence (ML), (3) branch lengths adjusted with respect to the minimum age estimates for major clades (BLADJ), and (4) an *rbcL* relaxed molecular clock Bayesian estimate calibrated by minimum age estimates for major clades (Bayes). N = number of species per plot. Significant departures from null expectations are indicated in bold type with ‡ indicating phylogenetic clustering and † indicating over-dispersion.

Table 2.1

Forest age	N	MPD				MNTD			
		EBL	ML	BLADJ	Bayes	EBL	ML	BLADJ	Bayes
Younger secondary	32	13.82 ‡	0.11 ‡	140.08 ‡	119.89 ‡	5.11	0.03	75.0	43.58
	62	19.26	0.18	224.07	215.54	5.17	0.03	95.96	57.43
	64	17.38 ‡	0.18	204.44	214.19	5.75	0.06 †	102.81	92.23 †
	34	14.09 ‡	0.10 ‡	127.21 ‡	106.94 ‡	3.70 ‡	0.02 ‡	48.94 ‡	26.38 ‡
	54	21.58 †	0.17	205.71	208.64	4.27	0.02	63.52 ‡	40.50
Older secondary	61	17.13 ‡	0.14 ‡	185.41 ‡	168.93 ‡	3.55 ‡	0.03	76.81	47.80
	85	20.02	0.19	238.83	235.27	4.49	0.04	95.23	56.10
	55	18.81	0.17	203.13	195.65	4.51	0.03	76.47	44.50
	46	18.49	0.14 ‡	173.37 ‡	168.86 ‡	4.20 ‡	0.02	66.49 ‡	40.74
	35	20.52	0.15	182.20	182.72	5.63	0.02 ‡	70.35 ‡	40.07 ‡
	47	19.08	0.15	185.31 ‡	182.74	5.40	0.02	79.23	46.28
35	17.43	0.14	167.20 ‡	163.35 ‡	5.48	0.03	77.48	44.13	
Primary	101	18.20 ‡	0.20	285.96 †	261.23 †	4.14	0.03	96.61	49.00
	85	18.35	0.19	285.32 †	259.07 †	4.45	0.03	116.13 †	60.14
	104	19.33	0.21 †	318.94 †	278.07 †	4.48	0.05 †	131.84 †	68.34 †
	120	19.51	0.19	300.45 †	281.02 †	3.81	0.02	95.15	44.97
	106	19.74	0.21 †	306.10 †	273.23 †	3.97	0.03	101.19	49.79
	102	18.85	0.20	321.92 †	280.21 †	4.29	0.03	116.33 †	47.12
	109	19.77	0.19	287.69 †	272.42 †	4.31	0.02	101.63 †	48.09

Figure 2.1. New Guinea lowland rain forest composition and structure in nineteen 0.25 ha plots representing younger secondary (N = 5), older secondary forest (N = 7), and primary forest (N = 7). (A) Taxonomic composition, (B) mean basal area per 0.25 ha, and (C) mean stems with dbh \geq 5 cm. Error bars represent one standard deviation. Bars with different letters were significantly different based on ANOVA ($p < 0.05$).

Figure 2.1

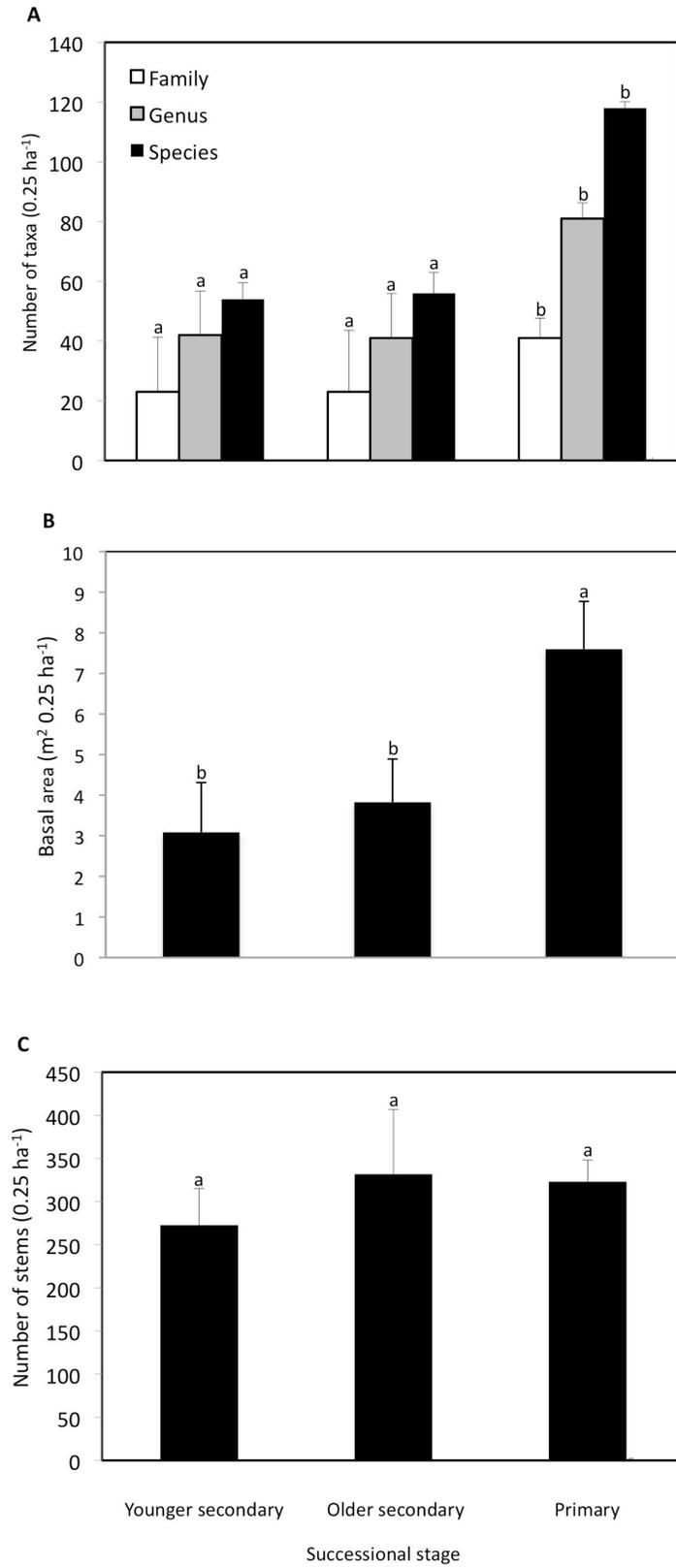


Figure 2.2. Mean phylogenetic distance of New Guinea woody plants ($\text{dbh} \geq 5 \text{ cm}$) from nineteen 0.25 ha plots with respect to basal area (m^2 per 0.25 ha), a proxy for forest age. Per-plot mean pair-wise distance (MPD) and mean nearest taxon distance (MNTD) are depicted under four methods of branch length estimation and an identical topology. Assumptions included (1) equal branch lengths (EBL), (2) a maximum likelihood estimate of *rbcL* divergence (ML), (3) branch lengths adjusted with respect to minimum age estimates for major clades (BLADJ), and (4) an *rbcL* relaxed molecular clock Bayesian estimate calibrated by minimum age estimates for major clades (Bayes). Correlation coefficients (r^2) and p -values are indicated to the right of each linear regression.

Figure 2.2

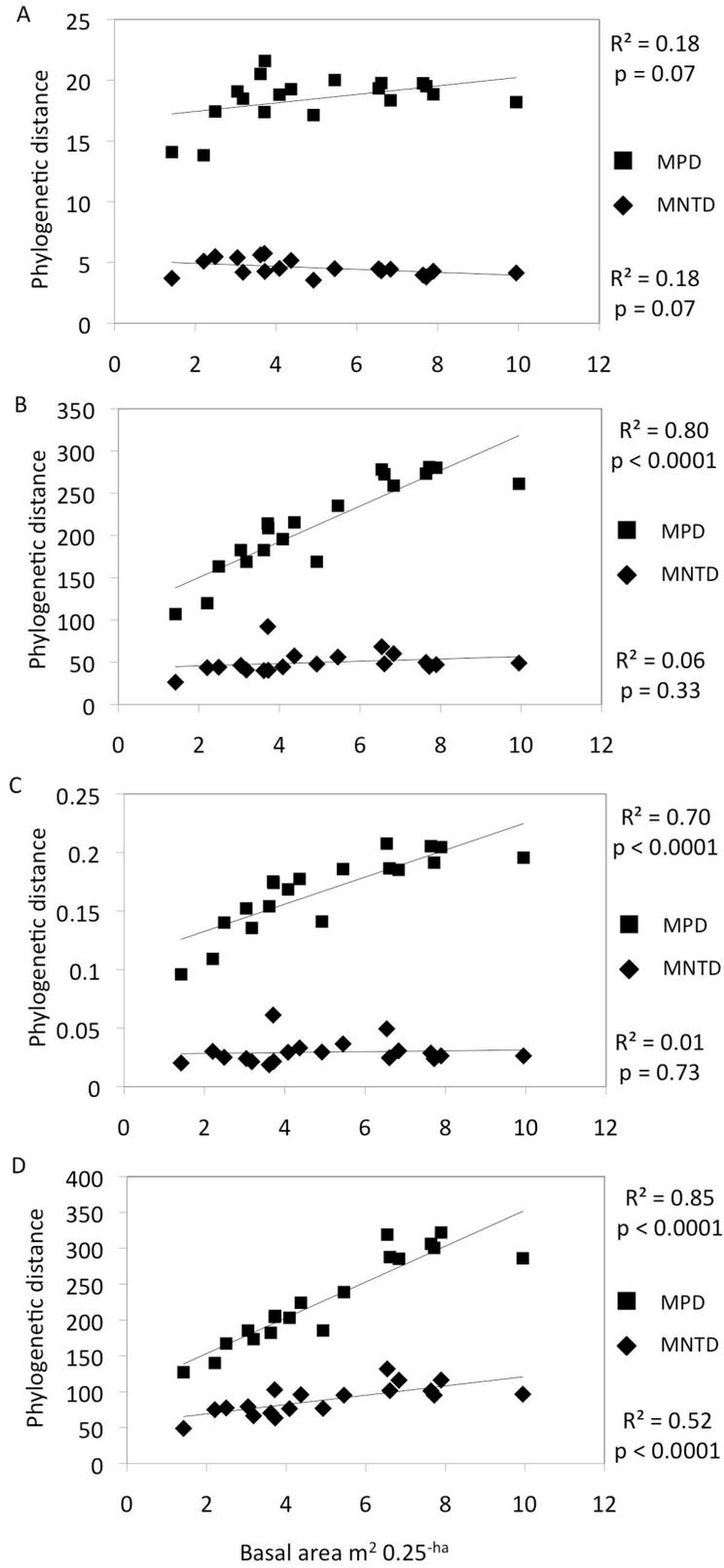
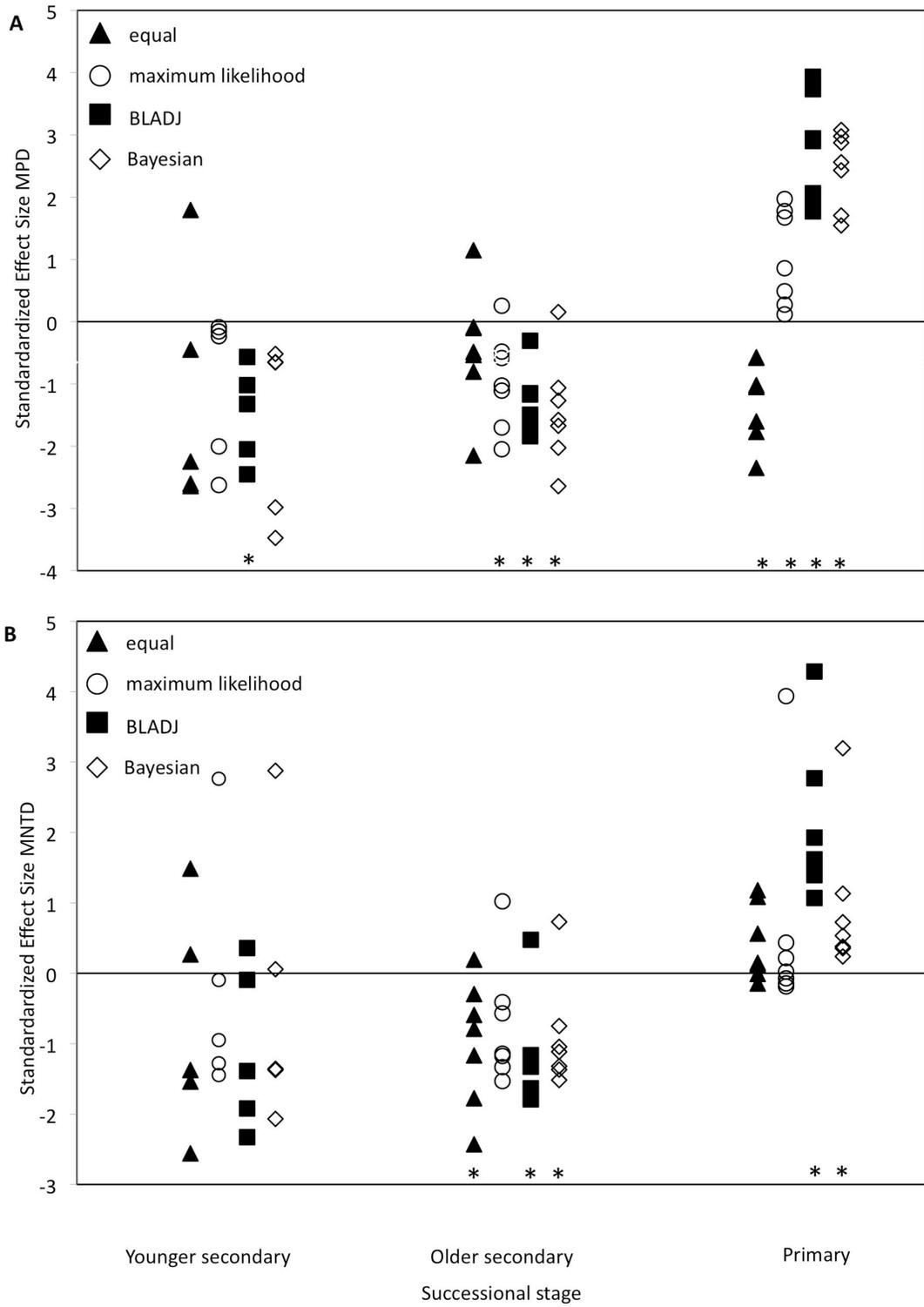


Figure 2.3. Standardized effect size (SES) for mean pair-wise phylogenetic distance (MPD) of younger secondary, older secondary, and primary New Guinea lowland forest. Points represent SES for 0.25 ha plots under four different methods of phylogenetic branch length estimation as described in Figure 2. Positive values indicate overdispersion whereas negative values indicate clustering. Asterisks indicate overall significance according to two-tailed t -tests ($p < 0.05$).

Figure 2.3



CHAPTER 3

Predicting tropical insect herbivore abundance from host plant traits and phylogeny

Introduction

A general aim of phylogenetic community ecology is to interpret patterns of species distribution and abundance in terms of evolutionary processes and ecological mechanisms (Kraft et al. 2007, Cavender-Bares et al. 2009). Diverse tropical forests have been particularly fertile ground for testing theories on mechanisms of species coexistence in communities (Wright 2002) where trophic interactions may affect patterns of plant community phylogenetic diversity (Lamarre et al. this volume). The idea that density-dependent processes involving specialized pests and pathogens could limit the recruitment of related plants in close proximity is not new (Janzen 1970, Connell 1971). Recent evidence suggests that trophic interactions indeed play a role in structuring the distribution of tropical tree community phylogenetic diversity (Wills et al. 2006, Comita et al. 2010, Metz et al. 2010) but it is less clear how the abundance of natural enemies is distributed with respect to the vegetation.

Insect herbivores feeding on tropical foliage are an obvious target for investigating this problem because tropical vegetation is extraordinarily diverse (Leigh 1999) and foliage can be particularly vulnerable to herbivory (Coley and Barone 1996). A broad array of plant morphological, physiological, and chemical defenses are present (Agrawal and Fishbein 2006). For example, rapid leaf expansion (Coley and Aide 1991) and delayed greening (Kursar and Coley 1992) have been regarded as plant adaptations that limit herbivory and nutrient loss. Evidence that evolved defenses play a role in mediating plant-herbivore interactions (Agrawal 2005) has supported the view that a phylogenetic context is needed to test predictions about trophic relationships (Lamarre et al. this volume). The distribution of herbivore dietary preferences with respect to plant

community phylogeny has further suggested that many tropical insect species are clade specialists (Tavakilian et al. 1997, Berkov and Tavakilian 1999, Novotny et al. 2002, Novotny et al. 2004, Novotny and Basset 2005, Odegaard et al. 2005, Weiblen et al. 2006, Dyer et al. 2007, Hulcr et al. 2007, Novotny et al. 2010). However, it is unclear what effect the phylogenetic distribution of plant traits might have on overall patterns of herbivore abundance at the community level.

Whether host plant phylogeny can predict the abundance of herbivores depends on the conservatism or lability of traits associated with herbivory (Fine et al. 2006). Phylogenetic ecology has identified ample evidence of particular plant defensive adaptations or herbivore specialization according to this approach (Weiblen et al. 2006, Agrawal et al. 2009a) but whether phylogenetic considerations improve predictive models relating plant traits to overall herbivore abundance in communities is unknown. We examined this possibility through analyses of a unique plant-herbivore community data set from New Guinea.

Ecological theory predicts that the abundance of consumers such as insect herbivores should be related to plant resources in a predictable manner. However, the abundance of herbivorous insects in forest communities is challenging to measure due to the dynamics of species populations in space and time (Lawton and Gaston 1989). Factors including disease, predators (Mooney et al. 2010), parasitoids, and a dynamic abiotic environment (e.g. seasonality) pose further complications for such a simple theory. Nonetheless, a few general predictions can be stated. First, the plants having greater biomass are expected to host greater numbers of leaf herbivores (Basset 1996, Marques et al. 2000). Second, plants of higher nutritional quality are expected to support

more herbivores than plants of lower quality (Basset 1991, Poorter et al. 2004, Cornelissen and Stiling 2006). Third, the theory of plant life-history trade-offs (Wright et al. 2010) predicts that plants investing relatively more resources in defense than in rapid growth should harbor fewer herbivores than plants at the other end of the resource allocation spectrum (Herms and Mattson 1992). Fourth, statistical power to detect such relationships will be higher in a phylogenetic context for conserved traits whereas no effect is expected for traits that lack community phylogenetic signal (Fine et al. 2006, Gilbert and Webb 2007).

Destructive sampling of vegetation offers a rare opportunity to simultaneously investigate predicted relationships between leaf traits and leaf-chewing insect abundance at the community level. We harvested each tree in two hectares of New Guinea lowland rain forest to measure leaf availability, nutrient quality, and palatability while collecting all leaf-chewing caterpillars and leaf miners. Almost all caterpillars were Lepidoptera and most leaf miners too (mostly Gracillariidae), although some Diptera and Coleoptera leaf miners were included (Novotny et al. 2010). For simplicity, all are assumed to be Lepidoptera in this discussion and this group was the focus of analysis because its members were the least likely to be separated from their host plants during felling due to their apterous condition and intimate associations (i.e. feeding internally between the epidermal layers of leaves in the case of miners; Sinclair and Hughes 2010). Gradual felling of all trees in primary and secondary forest plots over a two-year period provided instantaneous measures of these variables on a per-tree basis. We compared the relative strength of correlations among resource availability (as measured by total leaf biomass per plant), resource quality (as measured by leaf nitrogen content on a mass basis),

palatability (as measured by specific leaf area and the presence or absence of exudates), and herbivore abundance at the community level. Fresh leaf area divided by dry leaf mass (SLA) is a measure of plant investment in photosynthetic capacity relative to structural elements (Cornelissen et al. 2003) and, following Poorter, et al. (2004), we used SLA as a proxy for palatability given the tendency for leaves with low SLA to have higher lignin content and C:N ratios. Plant exudates are often a conveyance for mechanical and chemical plant defense including toxic secondary metabolites reducing palatability (Farrell et al. 1991, Coley and Barone 1996, Agrawal 2004b, Agrawal and Fishbein 2006).

A community phylogeny estimate for tree species in the data set was obtained by Bayesian analysis of chloroplast DNA sequences in conjunction with minimum age estimates and well-supported relationships for major seed plant clades as described in Whitfeld et al. (accepted). Trait relationships at the level of individual trees were examined using multiple and stepwise regression whereas phylogenetic generalized least squares regression examined these relationships among tree species means. Each trait was tested for evidence of phylogenetic conservatism in our community sample (Blomberg and Garland 2002, Losos 2008). This approach evaluated the conditions under which community phylogenetic information is expected to improve predictions of overall herbivore abundance from plant traits.

Methods

Field plots – Two 100 m x 100 m plots near Wanang (145° 10' 55" E, 5° 13' 51" S), Madang Province, Papua New Guinea were destructively sampled. The two plots were

800 m apart in a mosaic of primary and secondary rainforest vegetation at 100 – 200 m above sea level in an extensive mixed evergreen forest on latosols in the Ramu River basin (Paijmans 1976, Wood 1982). The climate is generally humid and relatively aseasonal. Historical readings from Madang (70 km east, 1956-1970) (McAlpine et al. 1983) indicated mean annual rainfall of 3,500 mm and mean monthly temperature between 26.2 and 26.7°C. Mean monthly rainfall exceeded 100 mm throughout the year except during August to September based on readings taken between January 1994 and December 1996 from a site 70 km east of the study area (Novotny and Basset 1998). A minimum age for the primary forest plot was estimated from Royal Australian Survey Corps aerial photographs, where the presence of multi-layered canopy in 1973 suggests no anthropogenic disturbance since at least the late 1950s. Local landowners practice subsistence agriculture in 0.25-1.0 hectare gardens planted after felling and burning of primary forest. Succession ensues when garden plots are abandoned after 2-3 years of low intensity cultivation. The secondary forest plot was located in garden plot that had been abandoned a decade earlier according to interviews with landowners. All woody plants with diameter at breast height (DBH) \geq 5cm were measured and identified to species prior to sampling.

Destructive sampling – We coordinated our sampling with local landowners who were planning to clear the sites for subsistence gardens. Each 100 m by 100 m plot was subdivided into 20 m by 20 m subplots. For each subplot, the understory (i.e., all vegetation less than 1.4 m in height) was cleared followed by removal of all trees < 5 cm diameter with machetes while taking care to minimize disturbance to the remaining vegetation. Orderly felling of trees \geq 5 cm in diameter with a chain saw proceeded one

tree at a time from the midstory to the canopy by severing lianas and dropping trees into artificial gaps created during the course of subplot removal. This procedure minimized the disturbance of remaining vegetation as much as could be expected during logging. Immediately upon felling, trees were inspected for the presence of caterpillars and leaf-miners by a team of eight field. Live caterpillars were hand-collected and placed in plastic vials for processing whereas leaves containing miners were collected and stored in plastic bags. Caterpillar and leaf-miner abundance per tree was obtained by summing total numbers of live insects. Following inspection of the foliage for herbivores, field assistants manually stripped all leaves from each felled tree and weighed the total leaf biomass in kg.

Specific leaf area (SLA), defined as fresh leaf area divided by dry leaf mass, was estimated from leaf discs punched from multiple individuals for all species in the survey plots with the dual purpose of DNA collection. Discs were collected from fully expanded, mature leaves without obvious signs of pathogen or herbivore damage. The discs had a diameter of 2.3 cm and were punched from fresh leaves in the field, temporarily stored in paper envelopes over silica gel, and subsequently stored in a -80°C frozen tissue collection at the University of Minnesota. Mean SLA per species was obtained by averaging multiple samples per species. The presence or absence of exudates including latex and resin was also noted.

Leaves were sampled from up to four individuals per tree species for the measurement of foliar nitrogen. Three randomly chosen leaf samples per tree were bulked and ground by hand in liquid nitrogen or in a TissueLyzer (Qiagen). Analysis was carried out at the University of Nebraska using dry combustion gas chromatography on a

COSTECH analytical elemental combustion system ESC 4010. This method yields the mass of an element that is subsequently converted to a percentage of the total mass of the sample.

Community phylogeny – Estimation of community phylogeny followed the procedure outlined in Whitfeld et al. (accepted) based on the gene for the large subunit of ribulose-1,5-bisphosphate carboxylase-oxygenase (*rbcL*), a conserved coding locus that is easily amplified and known to accurately place most land plant taxa in orders and families. We sequenced according to published protocols (Kress et al. 2005, Kress and Erickson 2007, Kress et al. 2009) and all sequences were deposited in GenBank (accession numbers JF738369-JF739166).

We estimated phylogenetic relationships among all species of woody plants including trees, shrubs, and vines ≥ 5 cm DBH that occurred in the two 100 m by 100 m plots and a series of 0.25 ha satellite plots that were part of an effort to examine change in phylogenetic structure during succession (Whitfeld et al. accepted). Sequences were analyzed using Bayesian methods under a general time-reversible model of molecular evolution with parameters for invariant sites and rate heterogeneity among sites (GTR+ Γ +I) selected using the Akaike Information Criterion as implemented in ModelTest version 3.7 (Posada and Crandall 1998). Bayesian analysis was conducted using BEAST (Drummond and Rambaut 2007) under GTR+ Γ +I so that phylogenetic relationships and divergence times could be estimated simultaneously. Topological constraints, based on major angiosperm clades (APG 2009) and assumptions of monophyly below the ordinal rank were enforced to incorporate prior knowledge of well-supported relationships (Beaulieu et al. this volume) while allowing unresolved

relationships to be estimated from sequence variation in the community sample (Kress et al. 2010). Information on the minimum ages of major angiosperm lineages was incorporated in the Bayesian analysis by setting node age priors in BEAST. Thirty-one nodes with ages based on Wikström et al. (2001) were identified using Phylomatic (<http://www.phylodiversity.net/phylomatic/phylomatic.html>). We applied these as node age priors in Bayesian analysis along with *rbcL* sequences, model parameters, and topological constraints as described above to estimate branch lengths. A Markov-chain Monte Carlo simulation of 10 million generations was sampled every 1,000 generations and the first 1,000 trees were discarded as burn-in. Among the posterior distribution of 9,000 trees, the topology with the highest likelihood was used to quantify community phylogenetic patterns. For the present study, the resulting estimate of community phylogeny was pruned to include only those species occurring in the two 100 m by 100 m plots.

Phylogenetic trait conservatism – Phylogenetic trait conservatism was assessed using the *K*-statistic (Blomberg et al. 2003) that compares the observed trait distribution in community samples to expectations under Brownian motion model of trait evolution. Calculations of *K*-values for the traits included in this study were performed in Picante (Kembel et al. 2010) based on 2,150 individuals representing 183 species for which comparable data were available. We also analyzed a subset of 84 species with ≥ 5 individuals out of concern that rarely sampled species yield inaccurate estimates of mean herbivore abundance and total leaf biomass given the extremes of intra-specific variability in these traits. Common species represented >90% of individuals in our plots.

Values of the K -statistic approaching zero approximate a random distribution of trait values with respect to the plant community phylogeny whereas values approaching one imply trait values match expectations under a Brownian motion model of evolution (Ackerly 2009). P-values were derived from the comparison of observed K to a null distribution obtained by 999 randomizations of trait values across the tips of the community phylogeny. We chose this approach over Mantel tests because the latter lacks power and is known to involve high type-I error with phylogenetic information whereas Blomberg's K does not (Harmon and Glor 2010).

Regression analysis – Comparable functional trait and insect abundance data from the 2,150 individual trees were analyzed under a general model incorporating resource quantity (leaf biomass, dbh), quality (foliar nitrogen), palatability (specific leaf area, percentage of immature foliage, and the presence of exudate), and the month in which trees were felled. The best fit model was chosen based on the minimum AIC score. The sample size for regression analyses was not identical to the numbers of stems surveyed in the plots due to missing data for a small number of individual tree (i.e. leaf biomass was recorded but SLA was unavailable, etc.). Individual plants with zero values for leaf biomass (e.g. leafless trees at the time of felling) or zero herbivore abundance (e.g. foliage entirely lacking caterpillars or leaf miners) were included in analyses performed using JMP ver. 8.0.1 (SAS Institute, Inc., Cary, NC, USA). Individual-level and species-level regression analyses assumed the independence of trait values however phylogenetic trait conservatism violates this assumption. We used a phylogenetic generalized least squares (PGLS) approach (Martins and Hansen 1997) to regress trait differences among sister groups. The method incorporates tree topology and branch lengths to minimize

variance of the regression slope and intercept using the generalized least squares equation (a Gauss–Markov estimator) (Grafen 1989, Martins and Hansen 1997, Garland and Ives 2000). Analysis of trait differences among sister groups was performed using COMPARE 4.6b (Martins 2004) available online (<http://compare.bio.indiana.edu/>).

Results

Stand characteristics of primary and secondary plots are provided in Table 3.1. The density of stems was comparable whereas tree species richness, basal area, and leaf biomass per hectare was substantially higher in the primary forest. Overall caterpillar abundance in secondary forest was nearly twice that of primary forest whereas leaf miner abundance was comparable. These trends at the stand level were consistent with significantly higher mean caterpillar abundance per tree and per kg foliage in secondary vegetation than in primary forest whereas miner abundance did not differ among plots. Specific leaf area and nitrogen content were also higher on average in secondary forest trees. Evidence that total leaf biomass per tree was significantly lower in secondary forest, where trees were also smaller on average, is consistent with tree allometry ($r^2 = 0.56$, $p < 0.0001$) relating leaf biomass as a log function of plant size ($r^2 = 0.56$, $p < 0.0001$) (Fig. 3.1A). Appendix 6 includes complete trait data for this study. Herbivore abundance at the time of felling ranged from 475 caterpillars in one tree to no caterpillars in 29% of trees. Leaf miners were considerably less abundant, ranging from a maximum of 109 in one tree to none in 67% of trees at the time of felling. Herbivores per kg foliage was not strongly related to plant size although small trees hosted much higher densities on occasion than did large trees (Fig. 3.1B & C).

Results of analyses of variance among plant traits and herbivore abundance on individual trees yielded highly similar results when primary and secondary forest trees were treated separately or pooled and here we report results based on the combined data set for the sake of brevity. Plant traits including biomass (foliage and dbh), nutritional quality (foliar nitrogen), and palatability (specific leaf area, percent immature foliage, and exudate) were considered along with the timing of sampling in the full regression model. The best fit model, based on minimum AIC scores, explained 30% of variation in caterpillar abundance per tree and 13% for caterpillars per kg foliage (Table 3.2A). Leaf miner abundance was explained to a lesser extent (Table 3.2B). Total leaf biomass, the percentage of immature foliage, and the month in which trees were sampled were consistently significant predictors of herbivore abundance and leaf nitrogen was generally significant. The presence of exudate had a stronger negative effect on per-tree caterpillar abundance than on leaf miners (Fig. 3.2).

Species mean values for plant traits and herbivore abundance were more or less randomly distributed with respect to host plant community phylogeny according to generally low values of Blomberg's K (Table 3.3). Only leaf nitrogen content showed evidence of phylogenetic conservatism in the community sample. This was the case according to analyses of either the entire data set of 183 tree species or a subset of 84 common species represented by ≥ 5 individuals. In the case of exudate, we calculated the D statistic for phylogenetic signal as a binary trait (Fritz and Purvis 2010). The statistic is based on the sum of sister clade differences. Conserved traits have the same state in related species at the tips of the phylogeny such that the sum of sister clade differences is low compared to the case of convergent traits where the sum of sister clade differences is

high. The observed D value of 1.15 compared to a null expectation of 0.93 was not significant and the phylogenetic distribution of the trait illustrates that it is rather highly convergent (Fig. 3.3).

Regression analysis based on species trait means identified the strongest predictor of caterpillar abundance per tree to be total leaf biomass (Table 3.4A). This was true whether all species or only common species were considered and whether or not phylogenetic relationships between trees species were taken into account. Overall, the best fitting model, explaining 34% of caterpillar abundance variation, included only common tree species and accounted for their phylogenetic relationships. Foliar nitrogen and SLA were also included in the best fitting model although the latter was not significant. Comparable results were obtained for caterpillars per kg foliage although less variation was explained ($r^2 = 0.04-0.08$; model not shown). Plant traits also explained more variation in leaf miner abundance per tree when only common species and their phylogenetic relationships were considered (Table 3.4B). No plant trait explained significant variation in leaf miners per kg foliage (model not shown).

Discussion

Recent ecological studies of plant-herbivore interactions have argued for the importance of phylogenetic context to identify the mechanisms responsible for patterns in trophic relationships (Lamarre et al. this volume). Although this may be the case for particular plant defenses (Fine et al. 2006, Agrawal et al. 2009a) and the dietary specialization of particular herbivore species (Weiblen et al. 2006), the overall abundance of leaf-chewing herbivores and most of the leaf traits we examined showed little evidence of phylogenetic

signal (Table 3.3). Whether phylogenetic considerations improved the fit of trait-based models predicting herbivore abundance depended on the size of the plant species pool (Table 3.4). Models incorporating phylogeny were less predictive when all plant species were analyzed but proved more predictive when only common species were analyzed. We would expect power to detect phylogenetic effects to decline with the size of the species pool but, to the contrary, we found stronger effects with the subset of common species which we attribute to improved accuracy in estimating species means. Leaf biomass and herbivore abundance per plant are extremely variable among individuals in species populations such that sampling only a few individuals could introduce considerable error to comparisons at the species level.

The dynamism of populations in space and time that results from seasonal variation in the abiotic environment (Lawton and Gaston 1989) or trophic cascades involving natural enemies of herbivores (Mooney et al. 2010) could also weaken relationships between plant traits and instantaneous measures of herbivore abundance. Although the study site is relatively aseasonal, with mean monthly rainfall exceeding 100 mm in all months of the year but two (Novotny and Basset 1998), the month in which a tree was sampled explained a major component of variation in folivore abundance (Table 3.2). Seasonal patterns of insect abundance are best examined in particular tree species that were felled throughout the year rather than in the entire sample because our design did not control for monthly variability in the size or species composition of felled trees. Significant monthly variation in herbivore density per kg foliage was detected in half of the 12 tree species that were sampled during at least ten months of the year. For example, herbivores per kg of foliage in *Trichospermum pleiostigma* (Malvaceae) exhibited

relatively strong seasonal variation (Fig. 3.4) such that abundance peaked following the wettest months and declined with the onset of the driest months.

In spite of seasonality, a significant component of variation among individual trees in leaf-chewing insect abundance could be explained by the leaf traits we measured, and more so for caterpillars than for leaf miners (Table 3.2). Among the relationships between leaf traits and herbivore abundance, we predicted that resource availability would have the greatest influence. As expected, total leaf biomass in terms of kg foliage per tree was generally more important than either resource quality (approximated by N content) or palatability (percentage of immature foliage and SLA). Leaf biomass as a major determinant of leaf-chewing insect abundance is consistent with the prediction of the resource availability hypothesis (Herms and Mattson 1992) and evidence from other systems (Basset 1996, Marques et al. 2000). Our finding that overall insect abundance is related more strongly to resource availability than to other plant traits has been observed in other systems (Crist et al. 2006, Pringle et al. 2010).

Even though plant resource availability appears to be a first-order predictor of natural enemy abundance variation among individual trees and tree species, we expected plants with higher nutritional quality to support more herbivores. Foliar nitrogen provided evidence for plant resource quality affecting community structure at the next trophic level. Nitrogen is known to influence the growth and abundance of insect populations (Basset 1991, Cornelissen and Stiling 2006) and a small but significant component of abundance variation among trees in our community sample can be attributed to this factor. Further investigation is needed to determine whether the observation that nitrogen content is generally more important for caterpillars than leaf miners (Table 3.2 and 3.4)

results from life history differences among these guilds (Novotny et al. 2010) or is due to a lack of statistical power arising from the relative rarity of leaf miners in our data set (Table 3.1).

The prediction that trees with low SLA, and therefore relatively greater investment in leaf structural components, would host fewer numbers of herbivores (Poorter et al. 2004) did not draw support from comparisons among individual trees except in the case of leaf miners per kg foliage (Table 3.2). It was also only rather weakly supported at the tree species level (Table 3.4). Although SLA is thought to be correlated with a general life history trade-off between rapid plant growth and avoidance of mortality by investment in anti-herbivore defense (Fine et al. 2006, Wright et al. 2010), it is far from a direct measure of palatability and it clearly did not account for the overall abundance of leaf-chewing insect communities as well as leaf biomass which is a function of plant size (Fig. 3.1). These findings would seem to favor the importance of resource availability over plant defense for community-wide patterns of herbivory but direct investigation of palatability by way of plant secondary chemistry (Agrawal et al. 2009b, Kursar et al. 2009) at the community level is needed.

Exudates, including the latex and resins that convey the defensive plant secondary metabolites of foliage to herbivores, provide a somewhat more direct measure of palatability than SLA. The presence of exudate is often implicated in plant defense (Farrell et al. 1991, Coley and Barone 1996, Agrawal 2004b, Agrawal and Fishbein 2006) and herbivory is known to increase when exudate production is disrupted experimentally (Dussourd and Eisner 1987). This trait appears to have a substantial impact on herbivore community abundance (Fig. 3.4) that is consistent with predictions

from plant defense theory (Herms and Mattson 1992, Agrawal and Fishbein 2006). It is striking that exudates were recorded in more than half of all trees measured in our New Guinea forest plots and it is arguable that the ecological importance of such evolved defenses could influence the community distribution of plant-herbivore interactions (Agrawal 2005). Exudate showed no evidence of phylogenetic trait conservatism and instead appears rather highly convergent in our community sample (Fig. 3.3). Repeated and independent evolution of adaptive defensive traits such as exudates among diverse plant lineages (Farrell et al. 1991) in fact minimizes the likelihood of detecting phylogenetic signal in communities where trophic interactions could facilitate the co-occurrence of species with convergent traits (i.e. competitive advantage of exudate bearing trees relative to non-exudate bearing trees in the presence of abundant herbivores). When trait parallelism and convergence are widespread, ecologists should take care not to use phylogeny as a proxy for ecological similarity in explaining community-wide patterns. We argue that phylogeny need not contribute to the solution of every problem in ecology. In the case of trophic interactions at the community level, we think it is important for ecologists to recognize the limitations of a phylogenetic approach especially as it has gained popularity in recent literature on plant-insect interactions.

On the other hand, nitrogen content, illustrates how a plant trait displaying phylogenetic signal may weakly influence herbivore community abundance patterns. Phylogenetic signal in nutrient availability has been observed in another tropical forest (Kraft and Ackerly 2010, Kraft et al. 2010) and in our study PGLS demonstrated that consideration of host plant relatedness did increase the power of leaf nitrogen to predict caterpillar abundance on a per tree and per unit of foliage basis. This provides evidence

that the community phylogenetic distribution of a trait at one trophic level can to some extent affect overall community structure at another trophic level.

A logical next step in these investigations is to assess herbivore species distributions with respect to plant phylogeny and traits where we expect the strength of relationship between the community distribution of plant defensive traits and specialized herbivores to be stronger (Weiblen et al. 2006). DNA barcoding of herbivores may aid in identifying not only species but also patterns of dietary specialization (Craft et al. 2010) in relation to the phylogenetic distribution of particular plant defenses (Agrawal et al. 2009b).

Although our un-replicated plot design weakens the comparison of secondary and primary forest attributes, differences in plant functional traits observed in our New Guinea plots are consistent with other tropical forests (Popma et al. 1992, Poorter et al. 2004) and predictions from resource allocation theory. That the trees of secondary forest had higher SLA and foliar nitrogen than primary forest trees is typical for this high-light environment where low investment in structural defense, high growth rates, and relatively high rates of photosynthesis per unit of mass are commonly observed (Schadler et al. 2003, Poorter et al. 2004, Agrawal and Fishbein 2006).

Observed patterns of SLA and foliar nitrogen associated with secondary and primary forests may reflect a trade-off between plant growth syndromes associated with survival in two rather different environments. Trees of high resource secondary forests maximize photosynthesis and growth (high SLA and foliar nitrogen) while investing less in structural defenses and relying on abundant exudate to deter herbivores. This puts secondary forests at one end of a spectrum that is interpreted as tradeoff between the rate

of investment in biomass and the speed of return on that investment (Reich et al. 2003, Wright et al. 2004). The greater leaf biomass of older forests (Guariguata et al. 1997, Chazdon 2003) is consistent with this view.

While previous studies have demonstrated the potential importance of herbivorous insects on habitat specialization of plants (Fine et al. 2004, Fine et al. 2006), few other studies have attempted to compare the abundance of insect herbivores between different successional stages. Higher rates of herbivory in early succession (Herms and Mattson 1992, Poorter et al. 2004) and in communities dominated by shade-intolerant trees (Basset 1996) have been reported in some previous studies, whereas others (Leps et al. 2001) found little evidence of differences in herbivore species abundance among successional stages. The higher overall total abundance of caterpillars per hectare, per tree, and per kg of foliage in younger secondary forest is consistent with expectations based on foliage quality and palatability. However, we found the strongest predictor of insect abundance was leaf biomass, making the higher abundance of insects in secondary forest seem paradoxical in light of the larger trees and greater biomass of primary forests. Nevertheless, Figs. 3.1B and 3.1C indicate that the density of herbivores per unit foliage declines with tree size. That smaller trees appear to be disproportionately attacked by herbivores appears to explain the lesser overall abundance of caterpillars in primary forest. Whether the apparent lower density of herbivores on larger trees has a biological explanation or is an artifact of our destructive sampling will require further investigation. Although we focused on non-volant herbivores (i.e. leaf miners, leaf-tying and leaf-rolling caterpillars), we would expect caterpillars as well as leaves containing miners to be more likely become detached from large trees than small trees during felling. Whether

this is true of our method could be determined in future by analysis of herbivory rates based on an extensive archive of digitally photographed leaves from each tree in our data set. If this pattern proves not to be an artifact, it potentially provides a mechanism for density-dependent mortality (Wills et al. 2006, Comita et al. 2010, Metz et al. 2010).

We conclude with a discussion of the implications of these findings for tropical forest management in light of the current overall trend toward conversion of primary forest to secondary forest. Disturbance leads to well documented changes in the structural and functional diversity of plant communities (Guariguata et al. 1997, Chazdon 2003, Poorter et al. 2004, Santos et al. 2010) and we observed generally similar trends in New Guinea. The impacts of forest conversion on herbivorous insects are less well understood. Based on our comparison of secondary and primary forests, younger vegetation appears to support greater numbers of insect herbivores per hectare, per tree, and per kg of biomass. Given the unprecedented rate and extent of tropical forest conversion worldwide, the predicted increase in abundance of leaf-chewing caterpillars poses a challenge for forest management, especially where outbreaks may threaten forest regeneration after logging and small areas of remaining intact forests.

In light of observed decreases in host plant phylogenetic diversity in secondary versus primary forest in New Guinea (Whitfeld et al. accepted) and Costa Rica (Letcher 2010), an assessment of insect herbivore richness in early and late succession is needed to understand the full impact of forest conversion on overall biodiversity. Also, investigation of plant secondary chemistry could examine the extent to which chemical defenses are deployed and their cost relative to structural defenses in protecting host plants from insect herbivores. Analysis of the degree to which these chemicals are

phylogenetically conserved or convergent in host plants would enable further predictions to be made about the degree to which host plants have adapted to their herbivore enemies. A better understanding of diversity in secondary forests is particularly important as these communities become a dominant feature of tropical landscapes and their role in species conservation (Chazdon et al. 2009) becomes more important.

Table 3.1. Plant traits and insect herbivore abundance in one-hectare plots of secondary and primary New Guinea lowland rain forest vegetation. Values in (A) are based on all woody stems with DBH \geq 5 cm in each 100 m by 100 m plot and (B) per-plot means (with standard deviations in parentheses) for a subset of species with comparable data for all traits and insect abundances (n = 1,056 and 1,094 for secondary and primary, respectively). P values represent significance for ANOVA in traits, insect abundance per tree, and per kg foliage.

Table 3.1

A. Total per ha	Secondary	Primary	<i>P</i>
Stems \geq 5cm	1,206	1,336	-
Basal area (m ² ha ⁻¹)	13.6	29.9	-
Species richness	90	213	-
Leaf biomass (kg)	6,036	10,500	-
Caterpillars	14,053	7,256	-
Leaf miners	1,548	1,852	-
B. Mean (SD)			
Leaf biomass per tree (kg)	5.72 (9.83)	9.60 (9.83)	<0.0001
Foliar nitrogen (%)	2.32 (0.48)	2.08 (0.52)	<0.0001
Specific leaf area (cm ² /g)	147.01 (35.23)	140.03 (39.95)	<0.0001
Caterpillars per tree	13.31 (36.60)	6.63 (16.19)	<0.0001
Caterpillars per kg foliage	3.03 (0.32)	1.82 (0.31)	<0.01
Leaf miners per tree	1.37 (5.69)	1.69 (5.37)	n.s.
Leaf miners per kg foliage	0.56 (2.53)	0.39 (2.04)	n.s.

Table 3.2. Results of best fit multiple regression for (A) caterpillar abundance per tree and per kg foliage and (B) leaf miner abundance per tree and per kg foliage. Data drawn from 2,150 individual trees on two hectares of New Guinea lowland rain forest. The full model combined traits reflecting resource quantity (leaf biomass, dbh), quality (leaf nitrogen), and palatability (specific leaf area, percent immature foliage, exudate) with seasonality. Best fitting model was chosen based on minimum AIC score.

Table 3.2

A. Caterpillars

per tree: $r^2 = 0.30$			
Parameter	SS	F-ratio	p
Total leaf biomass	138.97	648.502	<0.0001
Foliar nitrogen	22.66	105.73	<0.0001
Month sampled	31.20	13.24	<0.0001
% immature foliage	10.72	50.02	<0.0001
Exudate	1.63	7.61	0.006
per kg foliage: $r^2 = 0.13$			
Parameter	SS	F-ratio	p
Month sampled	13.72	11.81	<0.0001
% immature foliage	8.04	76.17	<0.0001
Foliar nitrogen	7.60	72.00	<0.0001
Total leaf biomass	2.16	20.43	<0.0001
Exudate	0.83	7.89	0.005

Table 3.2 (continued)

B. Leaf miners

per tree: $r^2 = 0.16$			
Parameter	SS	F-ratio	p
Month sampled	11.86	11.34	<0.0001
Total leaf biomass	3.98	41.89	<0.0001
dbh	2.86	30.06	<0.0001
Foliar nitrogen	1.28	13.41	0.0002
% immature foliage	0.58	6.07	0.01
per kg foliage $r^2 = 0.06$			
Parameter	SS	F-ratio	p
Month sampled	2.59	6.78	<0.0001
Total leaf biomass	1.38	39.80	<0.0001
dbh	0.42	12.30	0.00035
% immature foliage	0.26	7.41	0.007
Specific leaf area	0.23	6.63	0.01

Table 3.3. Tests for plant trait phylogenetic conservatism based on Blomberg's K statistic for a community sample of all 183 woody plant species with DBH ≥ 5 cm (K_{all}) and 84 species with and ≥ 5 stems (K_{common}) in two hectares of New Guinea lowland rainforest. Values approaching zero approximate a random distribution of trait values with respect to the plant community phylogeny whereas values approaching one imply trait values matching expectations under the Brownian motion model of evolution. P values are derived from the comparison of observed K to a null distribution obtained by 999 randomizations of trait values across the tips of the community phylogeny. Significance was comparable for the full dataset and the reduced dataset.

Table 3.3

Trait	K_{all}	K_{common}	P
Stem density per hectare	0.06	0.06	n.s.
Diameter at breast height (cm)	0.09	0.19	n.s.
Leaf biomass per tree (kg)	0.06	0.17	n.s.
Leaf nitrogen content (% dry mass)	0.16	0.24	<0.005
Specific leaf area (cm ² /g)	0.10	0.18	n.s.
Caterpillar abundance per tree	0.12	0.16	n.s.
Caterpillar abundance per kg foliage	0.18	0.13	n.s.
Leaf miner abundance per tree	0.06	0.15	n.s.
Leaf miner abundance per kg foliage	0.09	0.11	n.s.

Table 3.4. Results of best fit multiple regression for (A) caterpillar abundance per-tree and (B) leaf miner abundance against plant traits drawn from two hectares of New Guinea lowland rain forest. Species means were analyzed for all 183 woody plant species with dbh \geq 5 cm (all species) and a community sample of 84 species with dbh \geq 5 stems (common species) and based on ahistorical correlations (AH) and phylogenetic generalized least squares regression (PGLS). The full model combined traits reflecting resource quantity (leaf biomass, dbh), quality (leaf nitrogen), and palatability (specific leaf area, exudate). Best fitting model was chosen based on minimum AIC score.

Table 3.4
A. Caterpillars per tree

All species			
AH: $r^2 = 0.25$			
Parameter	SS	F-ratio	p
Total leaf biomass	7.04	53.05	<0.0001
Specific leaf area	2.12	15.98	<0.0001

PGLS: $r^2 = 0.20$			
Parameter	SS	F-ratio	p
Total leaf biomass	146.32	37.61	<0.0001
Specific leaf area	11.05	2.84	0.09
Foliar nitrogen	9.11	2.34	0.13

Common species			
AH $r^2 = 0.28$			
Parameter	SS	F-ratio	p
Total leaf biomass	2.18	26.96	<0.0001
Foliar nitrogen	0.28	3.51	0.06

PGLS: $r^2 = 0.34$			
Parameter	SS	F-ratio	p
Total leaf biomass	0.07	25.59	<0.0001
Foliar nitrogen	0.03	11.84	0.0009
Specific leaf area	0.01	2.65	0.11

Table 3.4 (continued)
 B. Leaf miners per tree

All species			
AH: $r^2 = 0.09$			
Parameter	SS	F-ratio	p
Total leaf biomass	0.94	19.19	<0.0001
Specific leaf area	0.11	2.29	0.13

PGLS: $r^2 = 0.06$			
Parameter	SS	F-ratio	p
Total leaf biomass	16.13	10.82	0.001
Specific leaf area	4.26	2.86	0.09

Common species			
AH: $r^2 = 0.21$			
Parameter	SS	F-ratio	p
dbh	0.42	21.49	<0.0001

PGLS: $r^2 = 0.35$			
Parameter	SS	F-ratio	p
Exudate	0.01	13.18	0.0005
dbh	0.01	9.66	0.003
Total leaf biomass	0.001	1.72	0.19

Figure 3.1. Total leaf biomass and herbivore abundance per tree as functions of diameter at breast height based on 2,150 stems in two hectares of New Guinea lowland rain forest for (A) leaf biomass, (B) caterpillar density per kg foliage, and (C) leaf miner density per kg foliage.

Figure 3.1

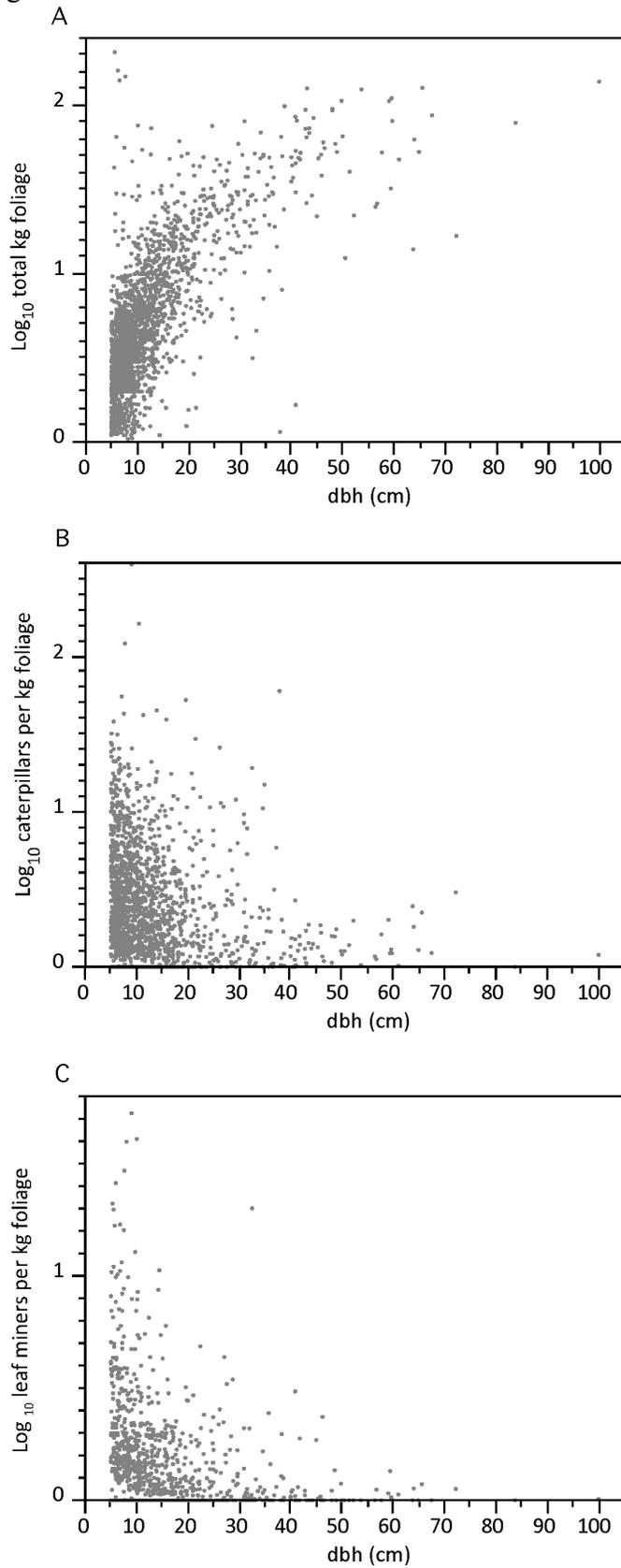


Figure 3.2. (A) Mean abundance of caterpillars and leaf miners per tree in the presence or absence of exudates including latex and resin. Samples included 1,040 exudate bearing trees and 1,110 non-exudate bearing trees in two hectares of New Guinea lowland rain forest. Bars indicate standard errors. Both guilds were significantly less abundant in the presence of exudate (ANOVA; $F = 16.19$, $p < 0.0001$ for caterpillars; $F = 15.28$, $p < 0.0001$ for leaf miners).

Figure 3.2

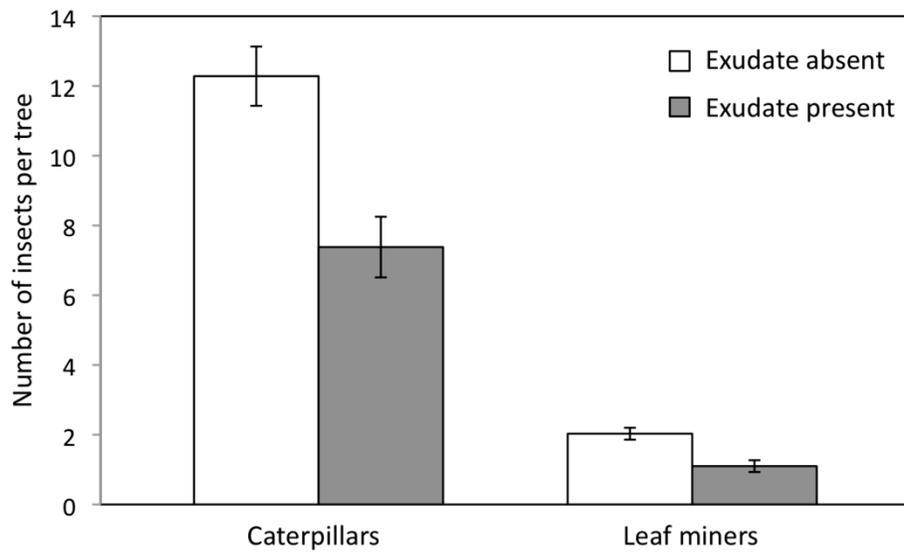


Figure 3.3. A community phylogeny of 183 woody plant species with ≥ 5 cm dbh encountered in two hectares of New Guinea lowland rain forest. The maximum-likelihood tree among a Bayesian posterior distribution of 9,000 phylogenetic trees is displayed with branch lengths proportional to time in millions of years. The presence or absence of exudate (including latex and resins) is indicated by open and closed circles at the tips of the trees. Only families with at least one species containing exudate are named to illustrate the convergence in this trait.

Figure 3.3

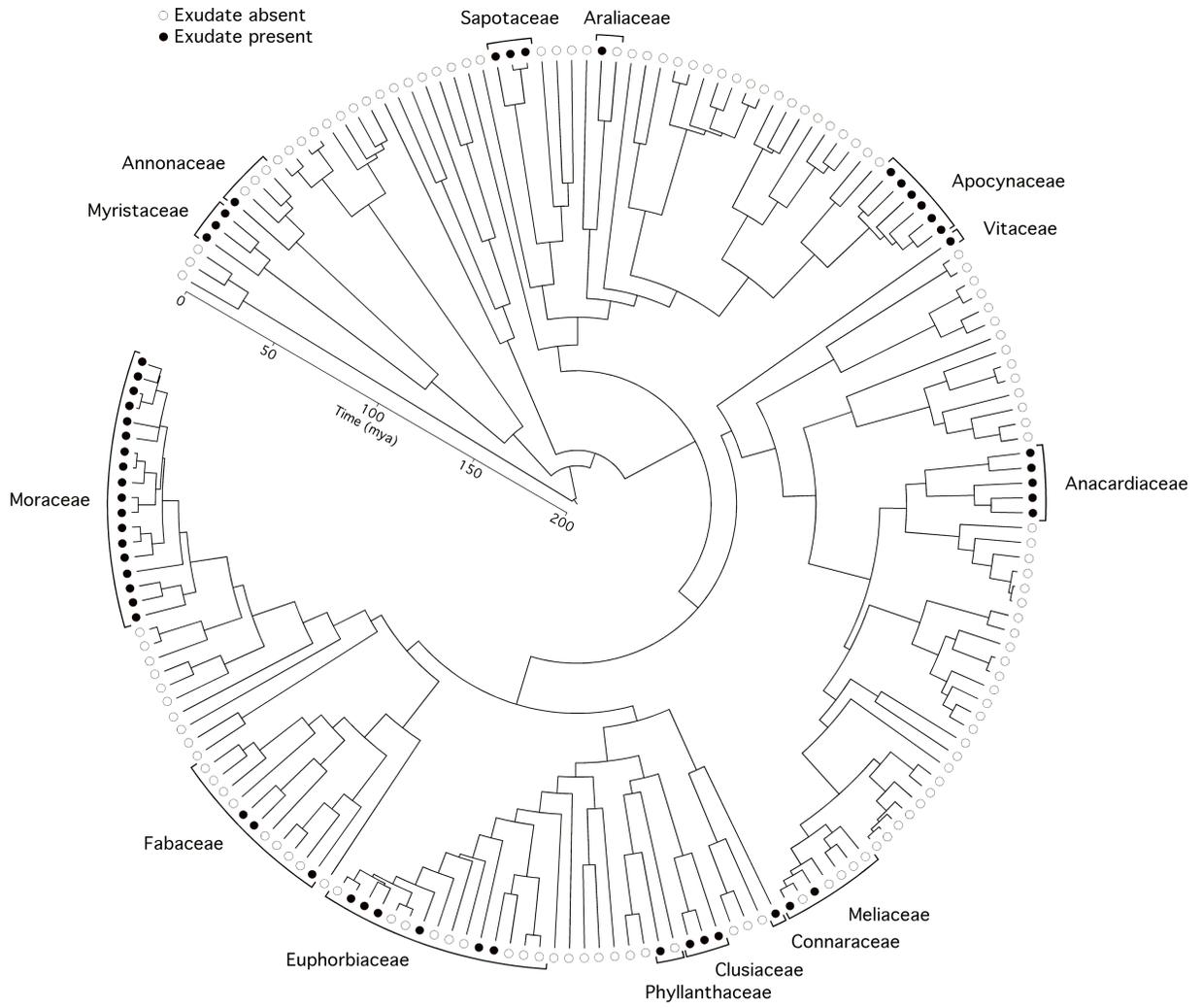
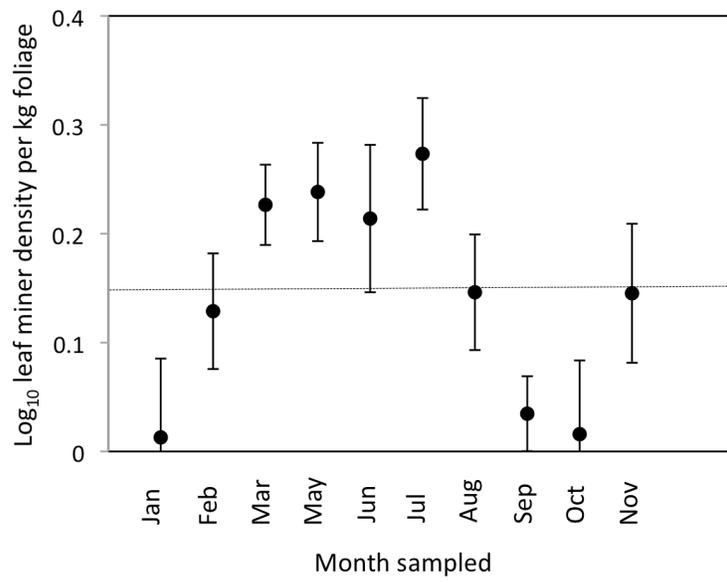
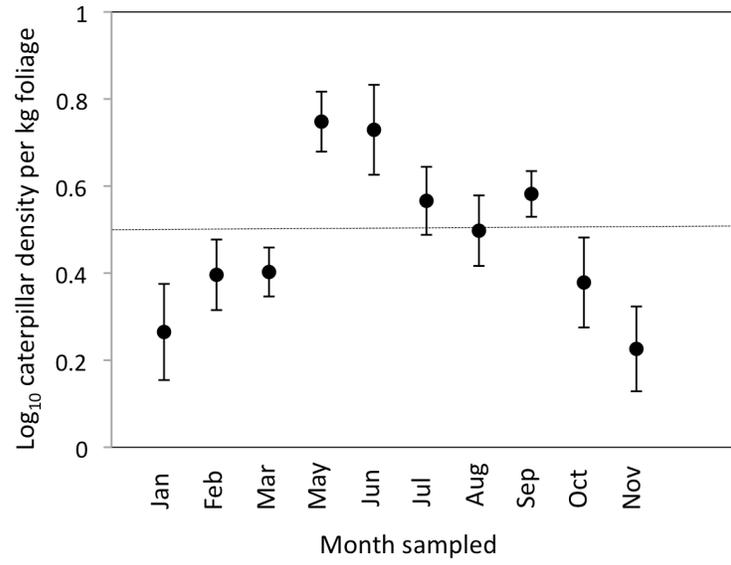


Figure 3.4. Seasonality of caterpillar and leaf miner abundance on *Trichospermum pleiostigma* (Malvaceae) based on insects per kg foliage on 151 individual trees in two hectares of New Guinea lowland rainforest. Dotted line shows the overall mean number of insects per kg foliage.

Figure 3.4



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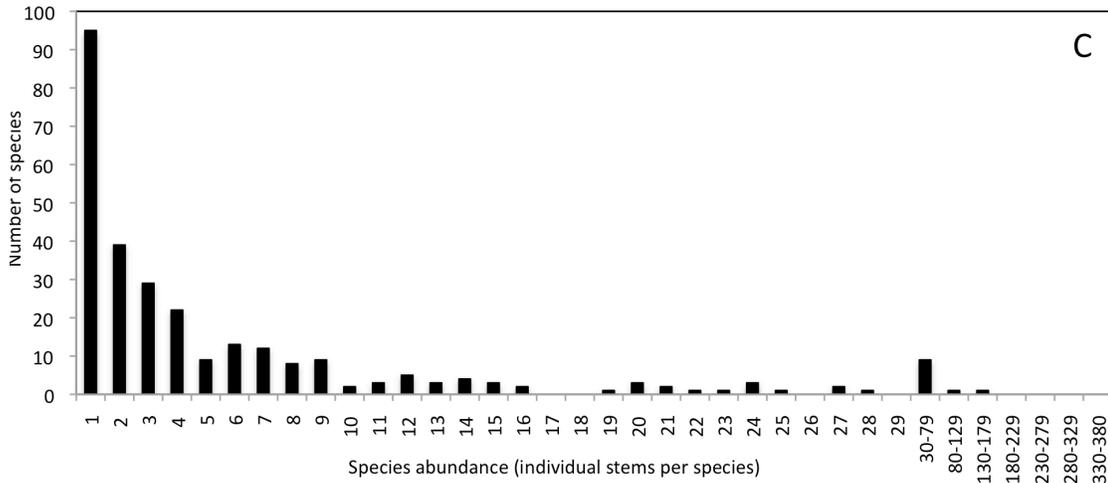
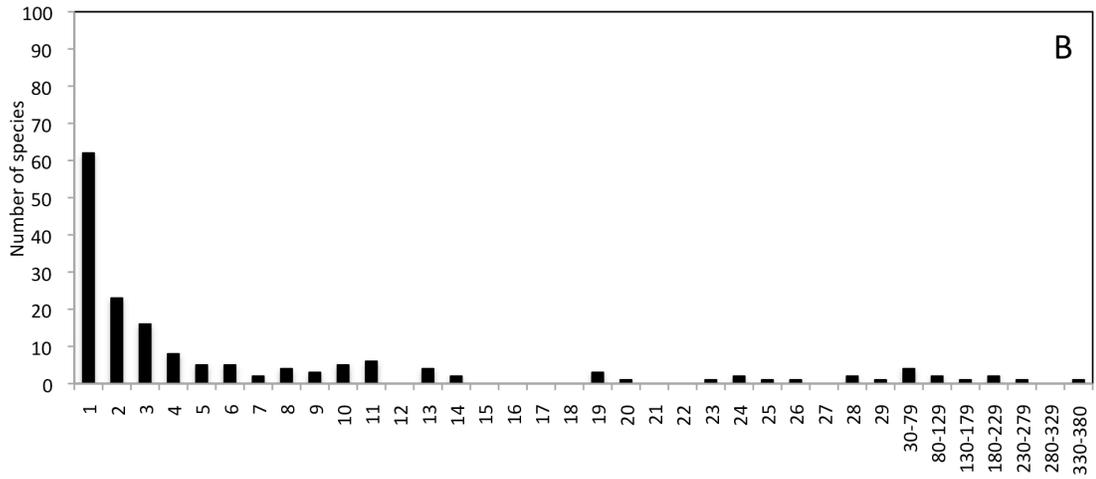
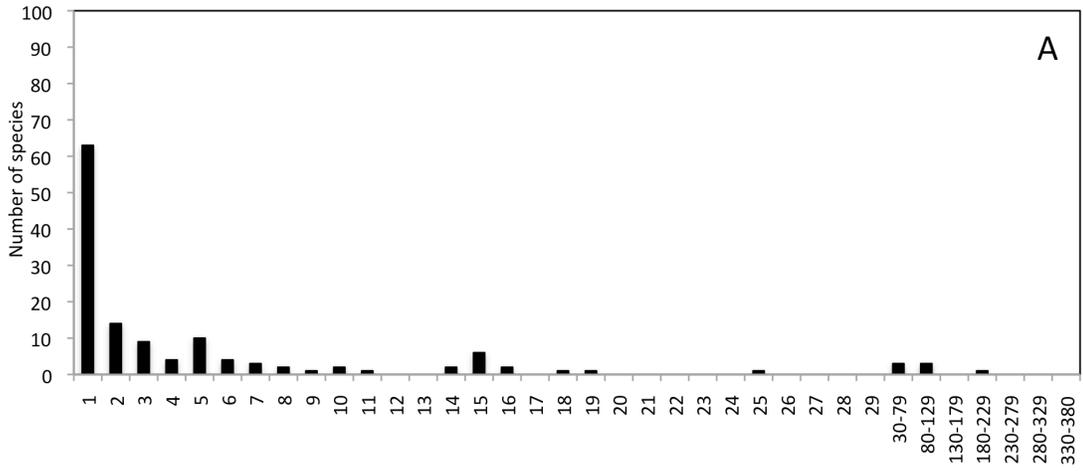
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APPENDICES

Appendix 1. Species frequency distribution for nineteen survey plots in the lowlands of New Guinea. (A) younger secondary forest (1.25 hectares), (B) older secondary forest (1.75 hectares), (C) primary forest (1.75 hectares).

Appendix 1



Appendix 2. The 25 most abundant plant families (in terms of basal area) in the New Guinea lowlands (dbh \geq 5 cm). Total area surveyed for young secondary forest = 1.25 ha, for older secondary forest = 1.75 ha, and for primary forest = 1.75 ha.

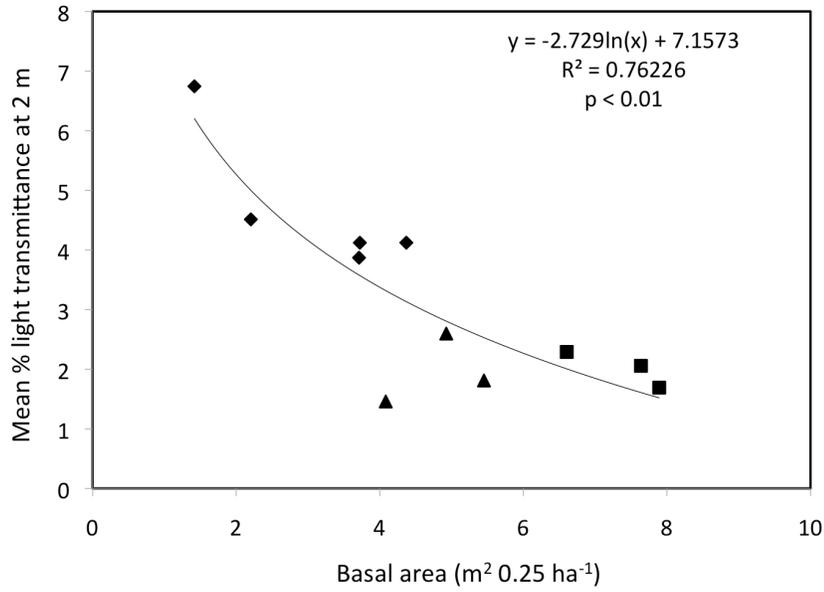
Appendix 2.

Younger secondary			Older secondary			Primary		
Family	Basal		Family	Basal		Family	Basal	
	area (m ²)	No. of Species		area (m ²)	No. of Species		area (m ²)	No. of Species
Malvaceae	4.347	8	Malvaceae	6.870	14	Sapindaceae	5.179	15
Euphorbiaceae	2.443	10	Euphorbiaceae	6.845	12	Meliaceae	5.013	30
Moraceae	2.386	19	Moraceae	4.212	24	Rubiaceae	4.456	18
Ulmaceae	1.348	1	Ulmaceae	2.395	1	Myristicaceae	3.620	12
Lamiaceae	0.964	10	Lamiaceae	1.860	10	Moraceae	3.422	29
Rubiaceae	0.742	5	Fabaceae	1.488	11	Lamiaceae	3.236	6
Lauraceae	0.376	4	Rubiaceae	0.646	10	Fabaceae	3.130	16
Burseraceae	0.336	4	Meliaceae	0.625	10	Combretaceae	3.071	5
Urticaceae	0.332	5	Burseraceae	0.391	5	Euphorbiaceae	2.971	17
Sapindaceae	0.325	9	Urticaceae	0.341	6	Malvaceae	2.227	9
Araliaceae	0.319	2	Anacardiaceae	0.255	6	Cannabaceae	1.962	2
Rutaceae	0.258	3	Myristicaceae	0.254	9	Burseraceae	1.479	10
Salicaceae	0.137	2	Salicaceae	0.212	3	Sapotaceae	1.316	9
Annonaceae	0.133	1	Rutaceae	0.203	1	Gnetaceae	1.042	3
Caricaceae	0.124	1	Araliaceae	0.196	2	Apocynaceae	1.036	5
Phyllanthaceae	0.108	5	Gnetaceae	0.159	1	Lauraceae	0.994	14
Cannabaceae	0.097	1	Lauraceae	0.143	7	Anacardiaceae	0.970	7
Apocynaceae	0.088	4	Tetramelaceae	0.139	2	Elaeocarpaceae	0.923	5
Arecaceae	0.088	4	Sapindaceae	0.121	7	Annonaceae	0.825	8
Fabaceae	0.082	5	Nyctaginaceae	0.109	1	Achariaceae	0.729	1
Tetramelaceae	0.078	2	Arecaceae	0.078	4	Myrtaceae	0.621	15
Myristicaceae	0.054	6	Phyllanthaceae	0.073	5	Phyllanthaceae	0.494	7
Asparagaceae	0.040	1	Apocynaceae	0.047	5	Polygalaceae	0.433	1
Meliaceae	0.038	5	Combretaceae	0.046	3	Loganiaceae	0.397	2
Unknown	0.037	1	Lecythidaceae	0.043	2	Salicaceae	0.385	4

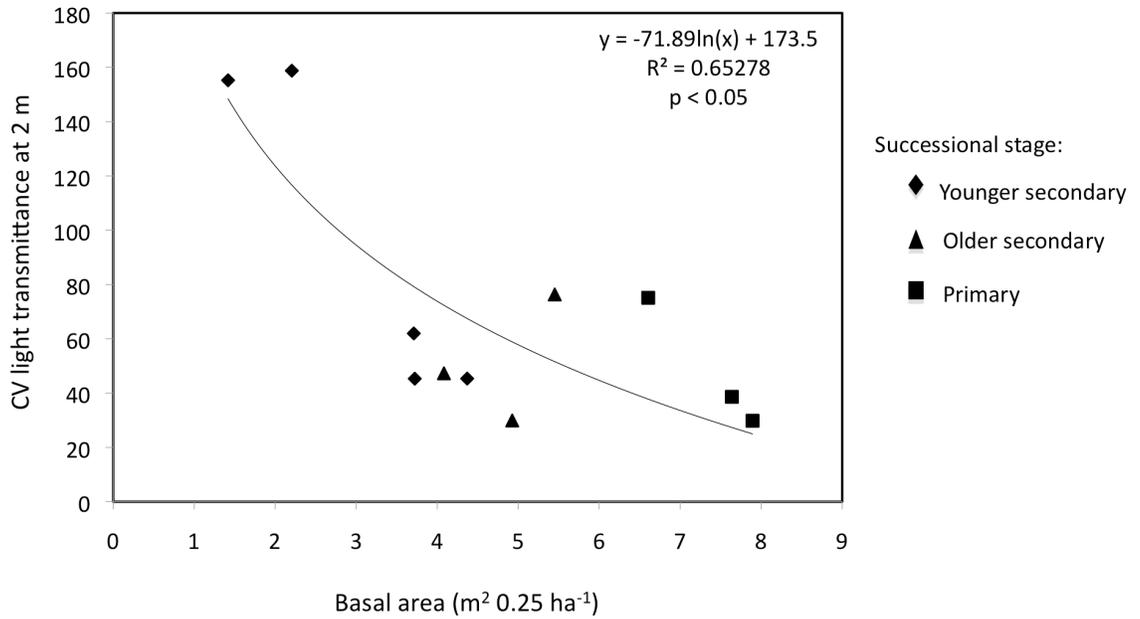
Appendix 3. (A) Mean light levels per plot at 2 m above ground versus total basal area of woody plants ≥ 5 cm dbh per plot and (B) coefficient of variation (CV) versus total basal area. Points represent the mean measurement at different positions in eleven 0.25 ha (50 m by 50 m) plots located in the lowland rainforest of New Guinea.

Appendix 3.

A

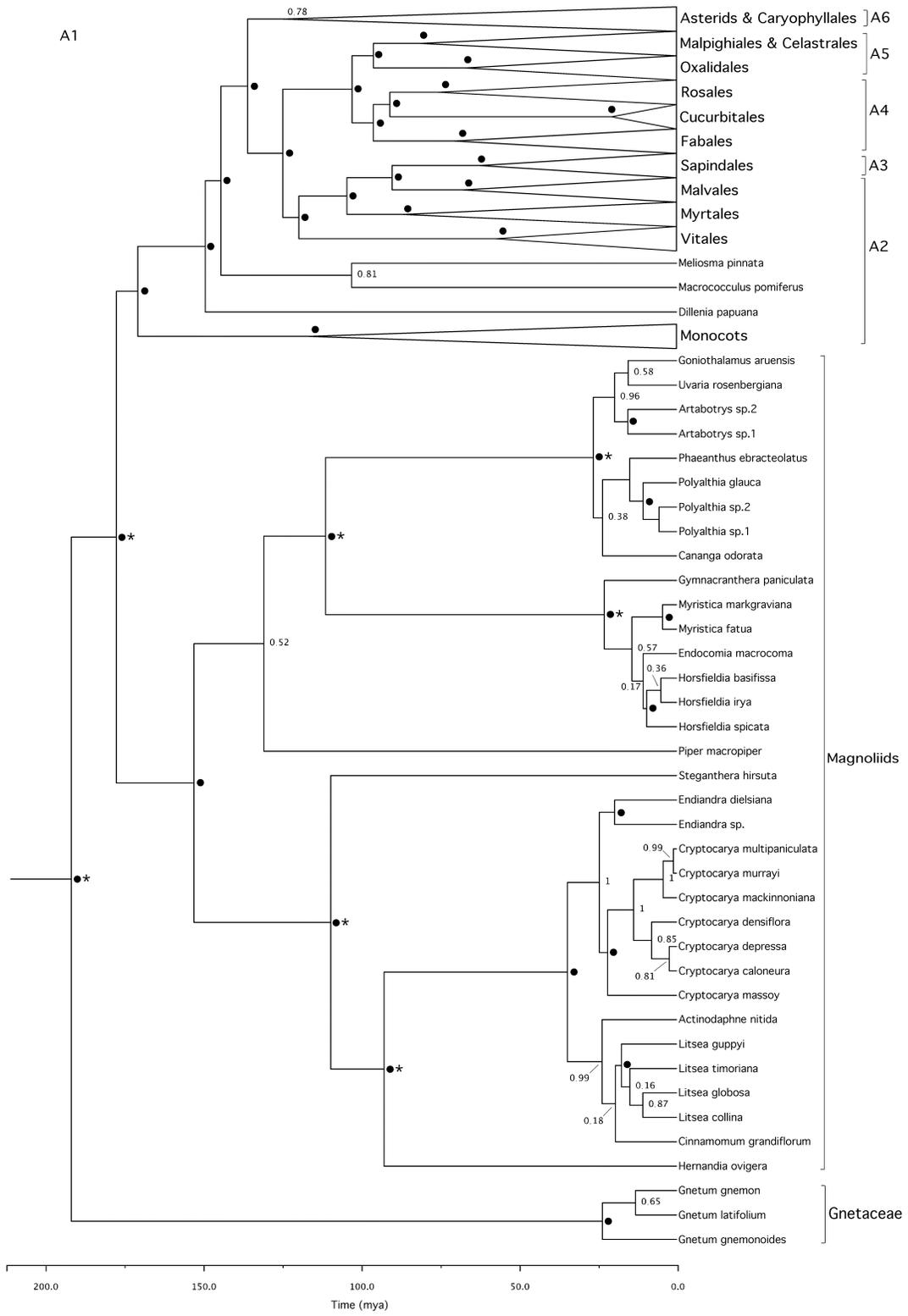


B

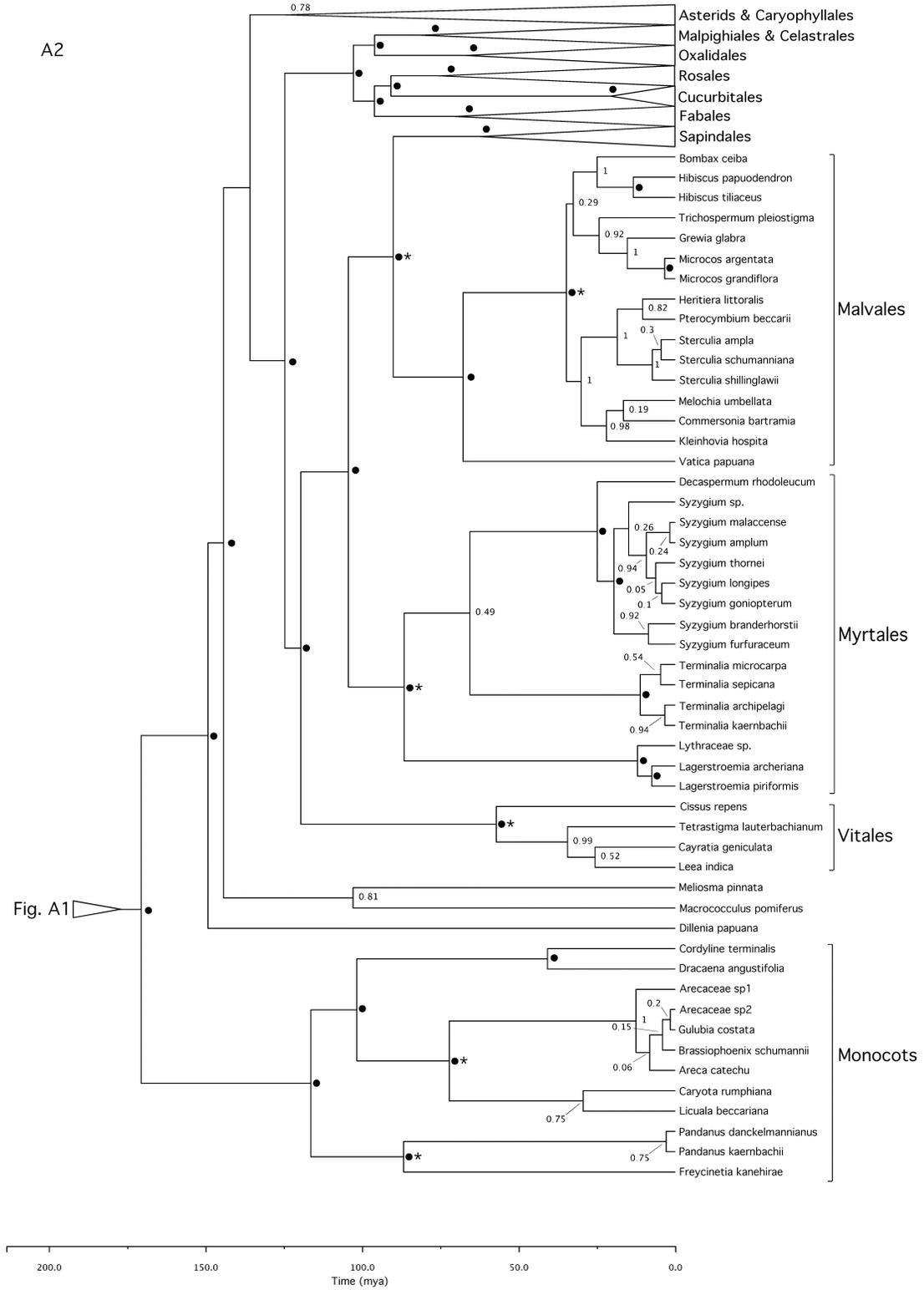


Appendix 4. A community phylogeny of 349 woody plant species ≥ 5 cm dbh encountered in nineteen 0.25 ha New Guinea lowland rain forest sample plots. Clades represented by triangles A are expanded in B-F. The maximum-likelihood tree among a Bayesian posterior distribution of 9,000 phylogenetic trees is displayed with branch lengths proportional to time in millions of years. Nodes are labeled with either Bayesian posterior probabilities or circles where topological constraints were enforced. Asterisks indicate 31 nodes where prior information on the minimum ages of major angiosperm clades served to calibrate *rbcL* divergence under the assumptions of GTR+ Γ +I and a relaxed molecular clock. (A) Gnetales and Magnoliids. (B) Monocots, Vitales, Myrtales, and Malvales. (C) Sapindales. (D) Fabales, Cucurbitales, and Rosales. (E) Oxalidales, Malpighiales, and Celastrales. (F) Caryophyllales and Asterids.

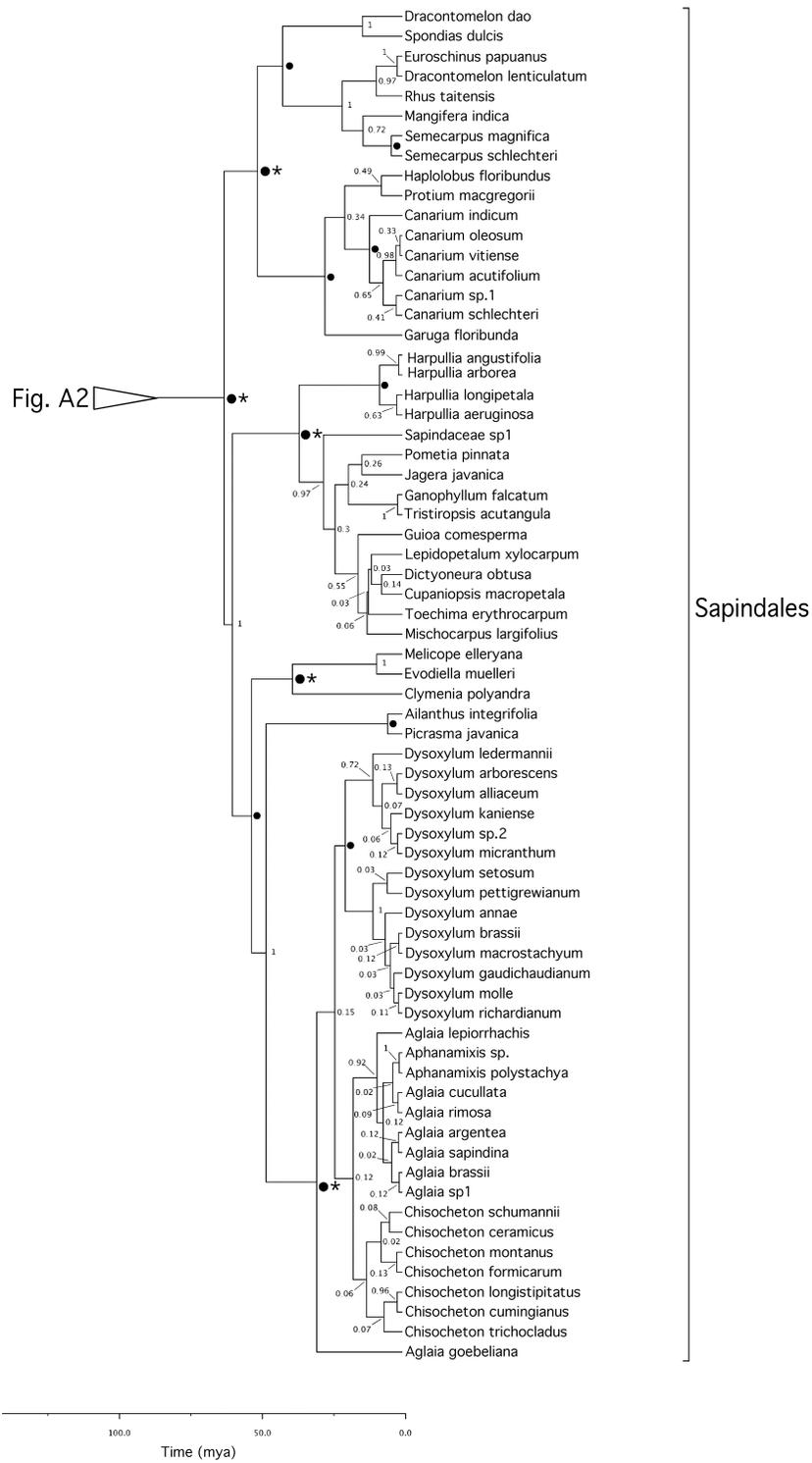
Appendix 4A



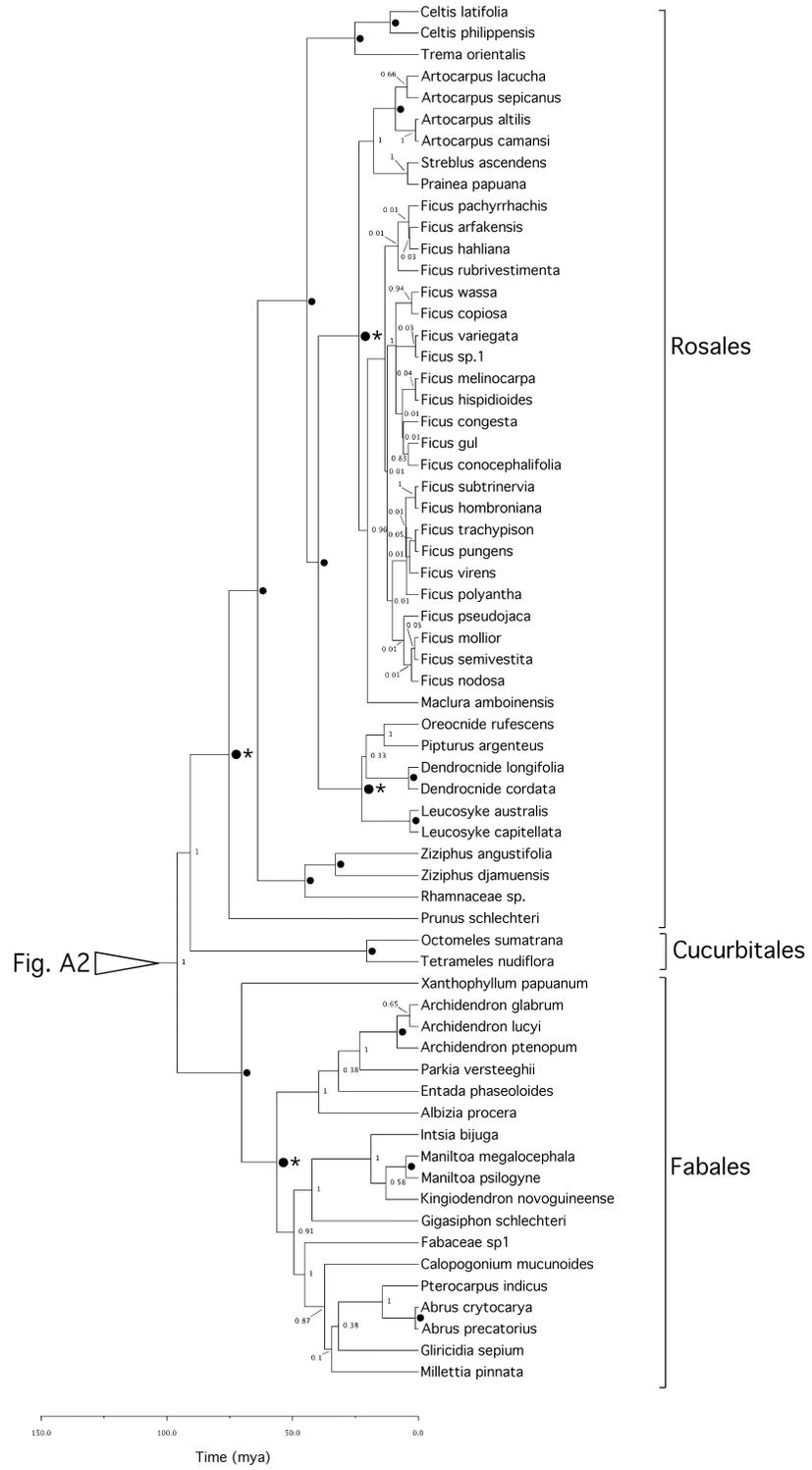
Appendix 4B



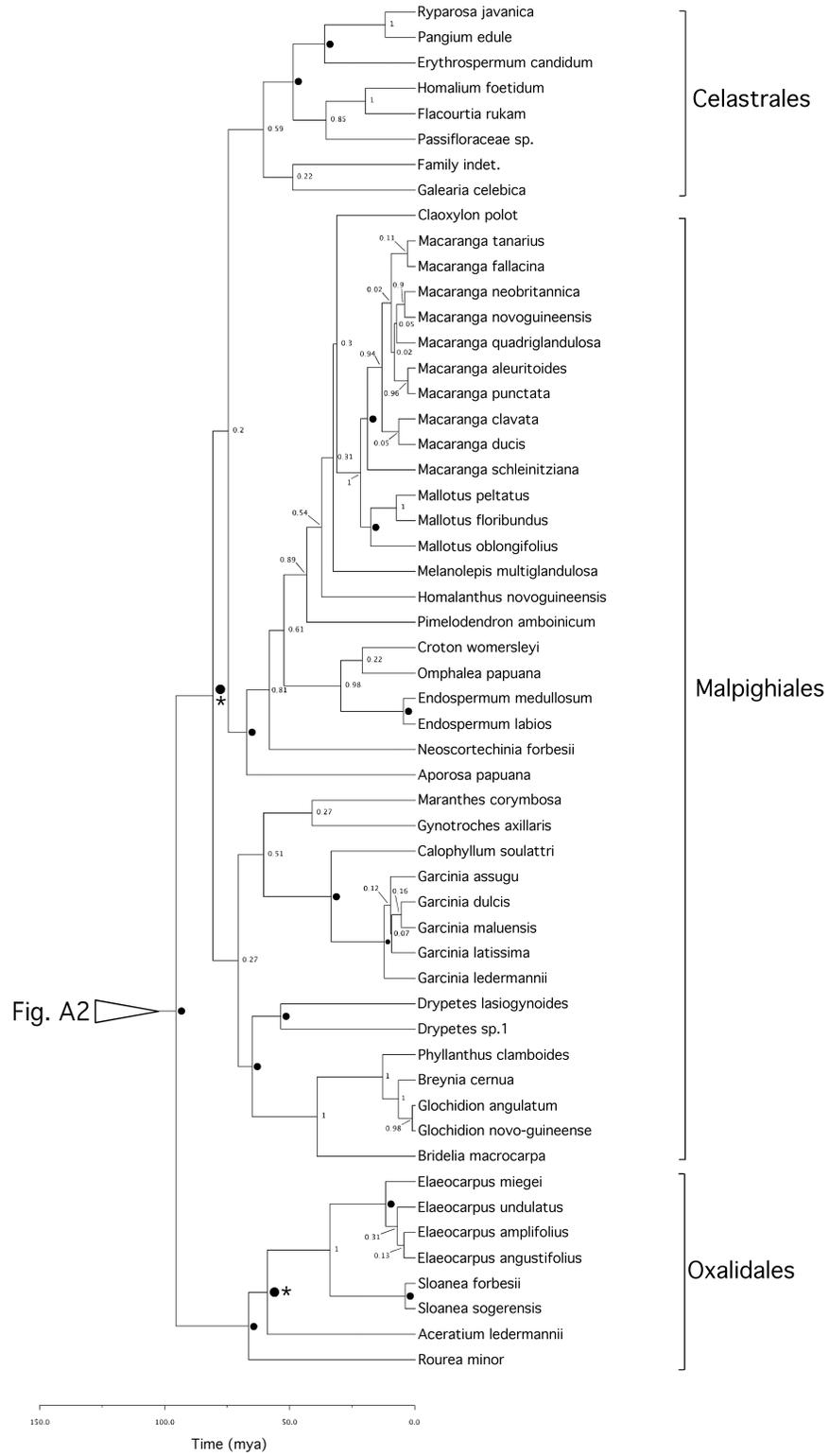
Appendix 4C



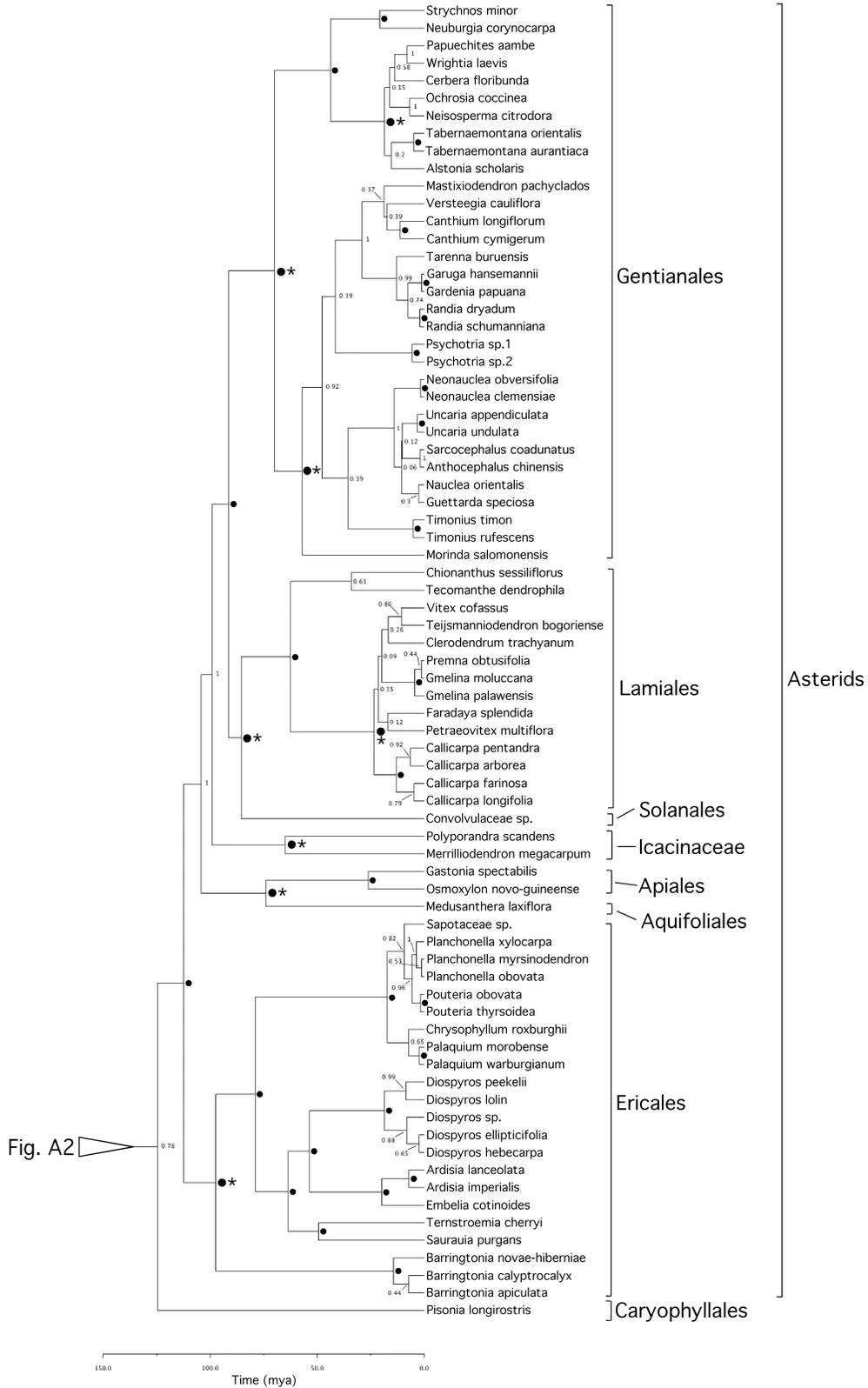
Appendix 4D



Appendix 4E



Appendix 4F



Appendix 5. GenBank accession numbers for all *rbcL* sequences included in the final maximum likelihood analysis plus additional sequences that were included in the preliminary neighbor joining tree.

Appendix 5.

Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Achariaceae	<i>Pangium edule</i>	G. D. Weiblen	WP1A0025	10-Mar-06	Papua New Guinea	JF738617
Achariaceae	<i>Pangium edule</i>	G. D. Weiblen	WP1B0079	20-Mar-06	Papua New Guinea	JF738644
Achariaceae	<i>Pangium edule</i>	G. D. Weiblen	WP2A0448	5-Apr-06	Papua New Guinea	JF738714
Achariaceae	<i>Pangium edule</i>	G. D. Weiblen	WP3E0782	26-Sep-06	Papua New Guinea	JF738860
Achariaceae	<i>Pangium edule</i>	G. D. Weiblen	WP5D1226	10-May-07	Papua New Guinea	JF738995
Achariaceae	<i>Pangium edule</i>	G. D. Weiblen	WP5E1265	26-Apr-07	Papua New Guinea	JF739015
Actinidiaceae	<i>Saurauia purgans</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB4D0201	26-Jul-08	Papua New Guinea	JF738387
Anacardiaceae	<i>Buchanania arborescens</i>	G. D. Weiblen	WP2E0320	9-Sep-06	Papua New Guinea	JF738787
Anacardiaceae	<i>Dracontomelon dao</i>	G. D. Weiblen	WS5B0402	7-Nov-06	Papua New Guinea	JF739152
Anacardiaceae	<i>Dracontomelon lenticulatum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB3A0162	18-Jul-08	Papua New Guinea	JF738580
Anacardiaceae	<i>Dracontomelon lenticulatum</i>	G. D. Weiblen	WP3D0730	14-Feb-07	Papua New Guinea	JF738844
Anacardiaceae	<i>Euroschinus papuanus</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC3A0079	31-Jul-08	Papua New Guinea	JF738401
Anacardiaceae	<i>Euroschinus papuanus</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC1A0009	3-Sep-08	Papua New Guinea	JF738511
Anacardiaceae	<i>Mangifera indica</i>	G. D. Weiblen	WS3B1217	13-Oct-06	Papua New Guinea	JF739081
Anacardiaceae	<i>Mangifera indica</i>	G. D. Weiblen	WS3C1222	4-Dec-06	Papua New Guinea	JF739088
Anacardiaceae	<i>Rhus taitensis</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB2D0089	26-Jul-08	Papua New Guinea	JF738382
Anacardiaceae	<i>Rhus taitensis</i>	G. D. Weiblen	WS3A0154	10-Apr-06	Papua New Guinea	JF739070
Anacardiaceae	<i>Semecarpus magnifica</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE4C0215	7-Aug-08	Papua New Guinea	JF738428
Anacardiaceae	<i>Semecarpus magnifica</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC3B0134	3-Sep-08	Papua New Guinea	JF738529
Anacardiaceae	<i>Semecarpus schlechteri</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB4B0287	19-Jul-08	Papua New Guinea	JF738585
Anacardiaceae	<i>Semecarpus schlechteri</i>	G. D. Weiblen	WP1D0189	5-Jul-06	Papua New Guinea	JF738682
Anacardiaceae	<i>Semecarpus schlechteri</i>	G. D. Weiblen	WP2B0416	26-Apr-06	Papua New Guinea	JF738726
Anacardiaceae	<i>Semecarpus schlechteri</i>	G. D. Weiblen	WP4E0832	30-Oct-06	Papua New Guinea	JF738945
Anacardiaceae	<i>Spondias dulcis</i>	G. D. Weiblen	WS4A0227	16-May-06	Papua New Guinea	JF739098
Anacardiaceae	<i>Spondias dulcis</i>	G. D. Weiblen	WS5B0380	6-Nov-06	Papua New Guinea	JF739148
Annonaceae	<i>Artabotrys</i> sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB3C0185	29-Aug-09	Papua New Guinea	JF738488
Annonaceae	<i>Artabotrys</i> sp.	G. D. Weiblen	WP5B1081	11-Oct-07	Papua New Guinea	JF738959
Annonaceae	<i>Cananga odorata</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC1B0008	31-Jul-08	Papua New Guinea	JF738393
Annonaceae	<i>Cananga odorata</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE3A0114	7-Aug-08	Papua New Guinea	JF738422
Annonaceae	<i>Cananga odorata</i>	G. D. Weiblen	WS4A0270	16-May-06	Papua New Guinea	JF739102
Annonaceae	<i>Goniothalamus aruensis</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA2C0092	13-Aug-08	Papua New Guinea	JF738446
Annonaceae	<i>Phaeanthus macropodus</i>	G. D. Weiblen	WP5D1244	17-May-07	Papua New Guinea	JF738999

Appendix 5. Cont'd

Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Annonaceae	<i>Polyalthia glauca</i>	G. D. Weiblen	WP2A0425	5-May-06	Papua New Guinea	JF738705
Annonaceae	<i>Polyalthia glauca</i>	G. D. Weiblen	WP2B0534	12-Jun-06	Papua New Guinea	JF738738
Annonaceae	<i>Polyalthia glauca</i>	G. D. Weiblen	WP5B1093	8-Oct-07	Papua New Guinea	JF738962
Annonaceae	<i>Polyalthia glauca</i>	G. D. Weiblen	WP5B1121	10-Oct-07	Papua New Guinea	JF738966
Annonaceae	<i>Polyalthia oblongifolia</i>	G. D. Weiblen	WP4C0918	19-Apr-07	Papua New Guinea	JF738915
Annonaceae	<i>Polyalthia</i> sp.	G. D. Weiblen	WP1B0096	21-Mar-06	Papua New Guinea	JF738652
Annonaceae	<i>Polyalthia</i> sp.	G. D. Weiblen	WP2A0446	17-Jul-07	Papua New Guinea	JF738713
Annonaceae	<i>Polyalthia</i> sp.	G. D. Weiblen	WP3A0576	10-Jul-07	Papua New Guinea	JF738798
Apocynaceae	<i>Alstonia scholaris</i>	G. D. Weiblen	WP1B0083	20-Mar-06	Papua New Guinea	JF738647
Apocynaceae	<i>Alstonia scholaris</i>	G. D. Weiblen	WP5A1104	29-Sep-07	Papua New Guinea	JF738956
Apocynaceae	<i>Alstonia scholaris</i>	G. D. Weiblen	WS3D0905	24-May-07	Papua New Guinea	JF739092
Apocynaceae	<i>Alstonia scholaris</i>	G. D. Weiblen	WS4C0694	28-Nov-06	Papua New Guinea	JF739118
Apocynaceae	<i>Cerbera floribunda</i>	G. D. Weiblen	WP3D0704	15-Feb-07	Papua New Guinea	JF738836
Apocynaceae	<i>Cerbera floribunda</i>	G. D. Weiblen	WP5B1131	8-Oct-07	Papua New Guinea	JF738972
Apocynaceae	<i>Cerbera floribunda</i>	G. D. Weiblen	WS3C0648	8-Dec-06	Papua New Guinea	JF739082
Apocynaceae	<i>Cerbera floribunda</i>	G. D. Weiblen	WS4E1136	20-Sep-07	Papua New Guinea	JF739129
Apocynaceae	<i>Neisosperma citrodora</i>	G. D. Weiblen	WP1D0139	6-Jul-06	Papua New Guinea	JF738672
Apocynaceae	<i>Neisosperma citrodora</i>	G. D. Weiblen	WP2B0495	22-Apr-06	Papua New Guinea	JF738735
Apocynaceae	<i>Neisosperma citrodora</i>	G. D. Weiblen	WP3B0610	27-Jun-07	Papua New Guinea	JF738814
Apocynaceae	<i>Neisosperma citrodora</i>	G. D. Weiblen	WP3E0775	20-Sep-06	Papua New Guinea	JF738858
Apocynaceae	<i>Papuechites aambe</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC4D0182	3-Sep-08	Papua New Guinea	JF738536
Apocynaceae	<i>Papuechites aambe</i>	G. D. Weiblen	WP1A0046	14-Mar-06	Papua New Guinea	JF738629
Apocynaceae	<i>Tabernaemontana aurantiaca</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE1E0048	7-Aug-08	Papua New Guinea	JF738421
Apocynaceae	<i>Tabernaemontana aurantiaca</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA3D0211	15-Jul-08	Papua New Guinea	JF738554
Apocynaceae	<i>Voacanga grandifolia</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC2E0045	31-Jul-08	Papua New Guinea	JF738399
Apocynaceae	<i>Wrightia laevis</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE1A0010	7-Aug-08	Papua New Guinea	JF738418
Apocynaceae	<i>Wrightia laevis</i>	G. D. Weiblen	WS2D0941	30-May-07	Papua New Guinea	JF739066
Araliaceae	<i>Gastonia spectabilis</i>	G. D. Weiblen	WS2E0994	31-Jul-07	Papua New Guinea	JF739067
Araliaceae	<i>Osmoxylon novo-guineense</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA2E0160	15-Jul-08	Papua New Guinea	JF738553
Araliaceae	<i>Osmoxylon novo-guineense</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB1D0061	18-Jul-08	Papua New Guinea	JF738571
Araliaceae	<i>Osmoxylon novo-guineense</i>	G. D. Weiblen	WP2D0382	19-Aug-06	Papua New Guinea	JF738774
Araliaceae	<i>Polyscias ledermannii</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB1E0053	25-Jul-08	Papua New Guinea	JF738377

Appendix 5. Cont'd

Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Arecaceae	<i>Areca catechu</i>	G. D. Weiblen	WS3B1213	13-Oct-06	Papua New Guinea	JF739079
Arecaceae	<i>Areca catechu</i>	G. D. Weiblen	WS3B1214	13-Oct-06	Papua New Guinea	JF739080
Arecaceae	<i>Areca catechu</i>	G. D. Weiblen	WS3C1220	5-Dec-06	Papua New Guinea	JF739087
Arecaceae	<i>Areca catechu</i>	G. D. Weiblen	WS3C1223	5-Dec-06	Papua New Guinea	JF739089
Arecaceae	<i>Caryota rumphiana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB5C0311	29-Aug-08	Papua New Guinea	JF738501
Arecaceae	<i>Caryota rumphiana</i>	G. D. Weiblen	WP3A0578	18-Jul-07	Papua New Guinea	JF738799
Arecaceae	<i>Caryota rumphiana</i>	G. D. Weiblen	WP4D0878	27-Mar-07	Papua New Guinea	JF738928
Arecaceae	<i>Gulubia costata</i>	G. D. Weiblen	WP1B0056	13-Mar-06	Papua New Guinea	JF738635
Arecaceae	<i>Gulubia costata</i>	G. D. Weiblen	WP2C0384	15-Jun-06	Papua New Guinea	JF738745
Arecaceae	<i>Gulubia costata</i>	G. D. Weiblen	WP4A0996	28-Aug-07	Papua New Guinea	JF738879
Arecaceae	<i>Gulubia costata</i>	G. D. Weiblen	WP4E0825	1-Nov-06	Papua New Guinea	JF738940
Arecaceae	<i>Hydriastele costata</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC1C0019	28-Jul-08	Papua New Guinea	JF738396
Arecaceae	<i>Hydriastele costata</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB2A0147	18-Jul-08	Papua New Guinea	JF738572
Arecaceae	<i>Licuala beccariana</i>	G. D. Weiblen	WP1D0198	6-Jul-06	Papua New Guinea	JF738686
Arecaceae	<i>Licuala beccariana</i>	G. D. Weiblen	WP1E0234	4-Aug-06	Papua New Guinea	JF738690
Arecaceae	<i>Licuala beccariana</i>	G. D. Weiblen	WP5B1083	9-Oct-07	Papua New Guinea	JF738960
Asparagaceae	<i>Cordyline terminalis</i>	G. D. Weiblen	WS3B0487	10-Oct-06	Papua New Guinea	JF739075
Asparagaceae	<i>Dracaena angustifolia</i>	G. D. Weiblen	WP1B0065	20-Mar-06	Papua New Guinea	JF738638
Asparagaceae	<i>Dracaena angustifolia</i>	G. D. Weiblen	WP2A1304	6-Apr-06	Papua New Guinea	JF738718
Asparagaceae	<i>Dracaena angustifolia</i>	G. D. Weiblen	WP5C1146	18-Jun-07	Papua New Guinea	JF738979
Asparagaceae	<i>Dracaena angustifolia</i>	G. D. Weiblen	WS2B0519	1-Sep-06	Papua New Guinea	JF739058
Bignoniaceae	<i>Tecomnanthe dendrophila</i>	G. D. Weiblen	WP1D0193	8-Aug-06	Papua New Guinea	JF738685
Boraginaceae	<i>Boraginaceae</i> sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA5B0264	14-Aug-08	Papua New Guinea	JF738471
Burseraceae	<i>Canarium acutifolium</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB1B0029	18-Jul-08	Papua New Guinea	JF738565
Burseraceae	<i>Canarium acutifolium</i>	G. D. Weiblen	WP3E0787	19-Sep-06	Papua New Guinea	JF738861
Burseraceae	<i>Canarium acutifolium</i>	G. D. Weiblen	WS5B0396	7-Nov-06	Papua New Guinea	JF739151
Burseraceae	<i>Canarium indicum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA4E0304	15-Jul-08	Papua New Guinea	JF738558
Burseraceae	<i>Canarium indicum</i>	G. D. Weiblen	WP1C0166	8-Jul-06	Papua New Guinea	JF738666
Burseraceae	<i>Canarium indicum</i>	G. D. Weiblen	WP5D1217	3-May-07	Papua New Guinea	JF738993
Burseraceae	<i>Canarium oleosum</i>	G. D. Weiblen	WP2B0500	5-May-06	Papua New Guinea	JF738736
Burseraceae	<i>Canarium schlechteri</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE5E0285	7-Aug-08	Papua New Guinea	JF738431
Burseraceae	<i>Canarium schlechteri</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB4A0309	19-Jul-08	Papua New Guinea	JF738584

Appendix 5. Cont'd

Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Burseraceae	Canarium sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC4B0214	3-Sep-08	Papua New Guinea	JF738532
Burseraceae	Canarium vitiense	G. D. Weiblen	WP1B0097	21-Mar-06	Papua New Guinea	JF738653
Burseraceae	Garuga floribunda	G. D. Weiblen	WP1A0042	6-Mar-06	Papua New Guinea	JF738628
Burseraceae	Garuga floribunda	G. D. Weiblen	WS1B0562	22-Jul-06	Papua New Guinea	JF739035
Burseraceae	Garuga floribunda	G. D. Weiblen	WS3B0475	11-Oct-06	Papua New Guinea	JF739074
Burseraceae	Garuga floribunda	G. D. Weiblen	WS3E1028	7-Sep-07	Papua New Guinea	JF739095
Burseraceae	Haplolobus floribunda	G. D. Weiblen	WP2B0405	28-Apr-06	Papua New Guinea	JF738721
Burseraceae	Haplolobus floribunda	G. D. Weiblen	WP4E0839	28-Oct-06	Papua New Guinea	JF738947
Burseraceae	Protium macgregorii	G. D. Weiblen	WP1E0252	1-Aug-06	Papua New Guinea	JF738696
Cannabaceae	Celtis latifolia	G. D. Weiblen	WP1B0055	8-Mar-06	Papua New Guinea	JF738634
Cannabaceae	Celtis latifolia	G. D. Weiblen	WP5E1261	28-Apr-07	Papua New Guinea	JF739012
Cannabaceae	Celtis latifolia	G. D. Weiblen	WS4E1123	18-Sep-07	Papua New Guinea	JF739127
Cannabaceae	Celtis philippensis	G. D. Weiblen	WP1C0134	1-Jul-06	Papua New Guinea	JF738662
Cannabaceae	Celtis philippensis	G. D. Weiblen	WP3A0601	30-Aug-07	Papua New Guinea	JF738801
Cannabaceae	Celtis philippensis	G. D. Weiblen	WP3D0686	27-Mar-07	Papua New Guinea	JF738830
Cannabaceae	Celtis philippensis	G. D. Weiblen	WP3D0709	8-Feb-07	Papua New Guinea	JF738837
Chrysobalanaceae	Maranthes corymbosa	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA2E0063	13-Aug-08	Papua New Guinea	JF738447
Chrysobalanaceae	Maranthes corymbosa	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB5E0341	29-Aug-08	Papua New Guinea	JF738506
Clusiaceae	Calophyllum soulattri	G. D. Weiblen	WP1B0075	16-Mar-06	Papua New Guinea	JF738643
Clusiaceae	Calophyllum soulattri	G. D. Weiblen	WP2D0377	14-Aug-06	Papua New Guinea	JF738770
Clusiaceae	Calophyllum soulattri	G. D. Weiblen	WP4D0793	15-Mar-07	Papua New Guinea	JF738924
Clusiaceae	Calophyllum soulattri	G. D. Weiblen	WP4E0822	26-Oct-06	Papua New Guinea	JF738939
Clusiaceae	Garcinia assugu	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA5B0261	14-Aug-08	Papua New Guinea	JF738470
Clusiaceae	Garcinia dulcis	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA1A0001	13-Aug-08	Papua New Guinea	JF738433
Clusiaceae	Garcinia ledermannii	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC1A0007	3-Sep-08	Papua New Guinea	JF738510
Clusiaceae	Garcinia maluensis	G. D. Weiblen	WP3B0591	23-Jun-07	Papua New Guinea	JF738807
Combretaceae	Terminalia archipelagi	G. D. Weiblen	WP2E0308	13-Sep-06	Papua New Guinea	JF738784
Combretaceae	Terminalia complanata	G. D. Weiblen	WP1A0028	6-Mar-06	Papua New Guinea	JF738620
Combretaceae	Terminalia complanata	G. D. Weiblen	WS5B0361	8-Nov-06	Papua New Guinea	JF739145
Combretaceae	Terminalia kaernbachii	G. D. Weiblen	WP1D0190	5-Jul-06	Papua New Guinea	JF738683
Combretaceae	Terminalia kaernbachii	G. D. Weiblen	WP5D1175	14-May-07	Papua New Guinea	JF738989
Combretaceae	Terminalia kaernbachii	G. D. Weiblen	WP5E1196	2-May-07	Papua New Guinea	JF739003

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Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Combretaceae	<i>Terminalia microcarpa</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC4C0211	4-Sep-08	Papua New Guinea	JF738535
Combretaceae	<i>Terminalia sepicana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA1D0034	13-Aug-08	Papua New Guinea	JF738436
Combretaceae	<i>Terminalia sepicana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA2A0111	13-Aug-08	Papua New Guinea	JF738443
Connaraceae	<i>Rourea minor</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB3C0183	29-Aug-09	Papua New Guinea	JF738487
Connaraceae	<i>Rourea minor</i>	G. D. Weiblen	WP3D1314	13-Feb-07	Papua New Guinea	JF738847
Convolvulaceae	<i>Convolvulaceae sp.</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB2D0090	29-Aug-09	Papua New Guinea	JF738481
Dilleniaceae	<i>Dillenia papuana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA1D0060	14-Jul-08	Papua New Guinea	JF738547
Dipterocarpaceae	<i>Vatica papuana</i>	G. D. Weiblen	WP1A0001	3-Mar-06	Papua New Guinea	JF738601
Dipterocarpaceae	<i>Vatica papuana</i>	G. D. Weiblen	WP1A0013	7-Mar-06	Papua New Guinea	JF738608
Dipterocarpaceae	<i>Vatica papuana</i>	G. D. Weiblen	WP1A0021	9-Mar-06	Papua New Guinea	JF738615
Dipterocarpaceae	<i>Vatica papuana</i>	G. D. Weiblen	WP2A0428	7-Apr-06	Papua New Guinea	JF738706
Ebenaceae	<i>Diospyros elliptica</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA4E0302	14-Aug-08	Papua New Guinea	JF738464
Ebenaceae	<i>Diospyros elliptica</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB3A0154	29-Aug-09	Papua New Guinea	JF738484
Ebenaceae	<i>Diospyros ellipticifolia</i>	G. D. Weiblen	WP1E0240	3-Aug-06	Papua New Guinea	JF738691
Ebenaceae	<i>Diospyros ellipticifolia</i>	G. D. Weiblen	WP5B1128	6-Oct-07	Papua New Guinea	JF738970
Ebenaceae	<i>Diospyros hebecarpa</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB2B0130	18-Jul-08	Papua New Guinea	JF738575
Ebenaceae	<i>Diospyros lolin</i>	G. D. Weiblen	WS1Z3283	24-Apr-08	Papua New Guinea	JF739048
Ebenaceae	<i>Diospyros peekelii</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC1E0051	3-Sep-08	Papua New Guinea	JF738519
Elaeocarpaceae	<i>Aceratium oppositifolium</i>	G. D. Weiblen	WP3E0774	20-Sep-06	Papua New Guinea	JF738857
Elaeocarpaceae	<i>Boraginaceae amplifolius</i>	G. D. Weiblen	WP2C0467	7-Jun-06	Papua New Guinea	JF738756
Elaeocarpaceae	<i>Elaeocarpus amplifolius</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC2C0097	3-Sep-08	Papua New Guinea	JF738525
Elaeocarpaceae	<i>Elaeocarpus amplifolius</i>	G. D. Weiblen	WP1A0031	3-Mar-06	Papua New Guinea	JF738623
Elaeocarpaceae	<i>Elaeocarpus amplifolius</i>	G. D. Weiblen	WP1B0057	17-Mar-06	Papua New Guinea	JF738636
Elaeocarpaceae	<i>Elaeocarpus amplifolius</i>	G. D. Weiblen	WP1B0080	18-Mar-06	Papua New Guinea	JF738645
Elaeocarpaceae	<i>Elaeocarpus amplifolius</i>	G. D. Weiblen	WP3D0722	7-Feb-07	Papua New Guinea	JF738841
Elaeocarpaceae	<i>Elaeocarpus miegei</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB3D0191	29-Aug-09	Papua New Guinea	JF738489
Elaeocarpaceae	<i>Elaeocarpus miegei</i>	G. D. Weiblen	WP3A0509	17-Jul-07	Papua New Guinea	JF738791
Elaeocarpaceae	<i>Sloanea sogerensis</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA3D0146	14-Aug-08	Papua New Guinea	JF738455
Elaeocarpaceae	<i>Sloanea sogerensis</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC4E0178	3-Sep-08	Papua New Guinea	JF738542
Elaeocarpaceae	<i>Sloanea sogerensis</i>	G. D. Weiblen	WP3D0726	7-Feb-07	Papua New Guinea	JF738843
Euphorbiaceae	<i>Claoxylon polot</i>	G. D. Weiblen	WS3D0903	24-May-07	Papua New Guinea	JF739091
Euphorbiaceae	<i>Croton womersleyi</i>	G. D. Weiblen	WP2C0459	6-Jun-06	Papua New Guinea	JF738754

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Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Euphorbiaceae	Endospermum labios	G. D. Weiblen	WP4C1330	9-Apr-07	Papua New Guinea	JF738920
Euphorbiaceae	Endospermum labios	G. D. Weiblen	WS4C0688	28-Nov-06	Papua New Guinea	JF739115
Euphorbiaceae	Endospermum labios	G. D. Weiblen	WS4E1147	24-Sep-07	Papua New Guinea	JF739132
Euphorbiaceae	Endospermum labios	G. D. Weiblen	WS4E1161	18-Sep-07	Papua New Guinea	JF739137
Euphorbiaceae	Endospermum medullosum	G. D. Weiblen	WP1A0034	13-Mar-06	Papua New Guinea	JF738624
Euphorbiaceae	Homalanthus novoguineensis	T. J. S. Whitfeld, G. Sosanika, B. Bau	OA1D0053	23-Jul-08	Papua New Guinea	JF738369
Euphorbiaceae	Homalanthus novoguineensis	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA5D0367	15-Jul-08	Papua New Guinea	JF738560
Euphorbiaceae	Homalanthus novoguineensis	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB2E0080	18-Jul-08	Papua New Guinea	JF738577
Euphorbiaceae	Macaranga aleuritoides	G. D. Weiblen	WP2B0401	6-Mar-06	Papua New Guinea	JF738719
Euphorbiaceae	Macaranga aleuritoides	G. D. Weiblen	WP4A0985	27-Aug-07	Papua New Guinea	JF738876
Euphorbiaceae	Macaranga aleuritoides	G. D. Weiblen	WS1A0017	22-Feb-06	Papua New Guinea	JF739031
Euphorbiaceae	Macaranga aleuritoides	G. D. Weiblen	WS4E1149	22-Sep-07	Papua New Guinea	JF739133
Euphorbiaceae	Macaranga bifoveata	G. D. Weiblen	WP4A1038	25-Aug-07	Papua New Guinea	JF738885
Euphorbiaceae	Macaranga bifoveata	G. D. Weiblen	WS1A0051	24-Feb-06	Papua New Guinea	JF739034
Euphorbiaceae	Macaranga bifoveata	G. D. Weiblen	WS1D0945	5-Jun-07	Papua New Guinea	JF739038
Euphorbiaceae	Macaranga bifoveata	G. D. Weiblen	WS4E1159	17-Sep-07	Papua New Guinea	JF739135
Euphorbiaceae	Macaranga fallacina	G. D. Weiblen	WP1C0165	25-May-06	Papua New Guinea	JF738665
Euphorbiaceae	Macaranga fallacina	G. D. Weiblen	WP3A0512	10-Jul-07	Papua New Guinea	JF738793
Euphorbiaceae	Macaranga fallacina	G. D. Weiblen	WS5B0395	10-Nov-06	Papua New Guinea	JF739150
Euphorbiaceae	Macaranga neobritannica	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC3C0104	31-Jul-08	Papua New Guinea	JF738407
Euphorbiaceae	Macaranga neobritannica	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB3B0162	29-Aug-09	Papua New Guinea	JF738486
Euphorbiaceae	Macaranga neobritannica	G. D. Weiblen	WP4A0980	24-Aug-07	Papua New Guinea	JF738873
Euphorbiaceae	Macaranga neobritannica	G. D. Weiblen	WP4D0893	22-Mar-07	Papua New Guinea	JF738932
Euphorbiaceae	Macaranga neobritannica	G. D. Weiblen	WS4C0686	29-Nov-06	Papua New Guinea	JF739113
Euphorbiaceae	Macaranga neobritannica	G. D. Weiblen	WS5B0357	10-Nov-06	Papua New Guinea	JF739144
Euphorbiaceae	Macaranga punctata	G. D. Weiblen	WP2A0421	4-Apr-06	Papua New Guinea	JF738703
Euphorbiaceae	Macaranga punctata	G. D. Weiblen	WP2B0492	25-Apr-06	Papua New Guinea	JF738734
Euphorbiaceae	Macaranga punctata	G. D. Weiblen	WP3E0778	21-Sep-06	Papua New Guinea	JF738859
Euphorbiaceae	Macaranga punctata	G. D. Weiblen	WP5D1237	14-May-07	Papua New Guinea	JF738997
Euphorbiaceae	Macaranga quadriglandulosa	G. D. Weiblen	WS1A0015	24-Feb-06	Papua New Guinea	JF739029
Euphorbiaceae	Macaranga quadriglandulosa	G. D. Weiblen	WS1E0960	24-Jul-07	Papua New Guinea	JF739042
Euphorbiaceae	Macaranga quadriglandulosa	G. D. Weiblen	WS4B0411	21-Oct-06	Papua New Guinea	JF739103

Appendix 5. Cont'd

Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Euphorbiaceae	<i>Macaranga quadriglandulosa</i>	G. D. Weiblen	WS4C0709	27-Nov-06	Papua New Guinea	JF739120
Euphorbiaceae	<i>Macaranga schleinitziana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC4D0193	3-Sep-08	Papua New Guinea	JF738538
Euphorbiaceae	<i>Macaranga tanarius</i>	G. D. Weiblen	WP2C0468	16-Jun-06	Papua New Guinea	JF738757
Euphorbiaceae	<i>Macaranga tanarius</i>	G. D. Weiblen	WS1A0003	27-Feb-06	Papua New Guinea	JF739027
Euphorbiaceae	<i>Macaranga tanarius</i>	G. D. Weiblen	WS4A0261	18-May-06	Papua New Guinea	JF739100
Euphorbiaceae	<i>Macaranga tanarius</i>	G. D. Weiblen	WS5A0347	28-Jun-06	Papua New Guinea	JF739143
Euphorbiaceae	<i>Macaranga tanarius</i>	G. D. Weiblen	WS5D0837	28-Feb-07	Papua New Guinea	JF739166
Euphorbiaceae	<i>Mallotus chromocarpus</i>	G. D. Weiblen	WP5E1279	26-Apr-07	Papua New Guinea	JF739020
Euphorbiaceae	<i>Mallotus floribundus</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB2B0127	18-Jul-08	Papua New Guinea	JF738574
Euphorbiaceae	<i>Mallotus oblongifolius</i>	G. D. Weiblen	WP5B1094	8-Oct-07	Papua New Guinea	JF738963
Euphorbiaceae	<i>Mallotus peltatus</i>	G. D. Weiblen	WP4A0962	21-Aug-07	Papua New Guinea	JF738867
Euphorbiaceae	<i>Mallotus peltatus</i>	G. D. Weiblen	WP4A0971	27-Aug-07	Papua New Guinea	JF738870
Euphorbiaceae	<i>Melanolepis multiglandulosa</i>	G. D. Weiblen	WS1A0016	27-Feb-06	Papua New Guinea	JF739030
Euphorbiaceae	<i>Melanolepis multiglandulosa</i>	G. D. Weiblen	WS4E1150	24-Sep-07	Papua New Guinea	JF739134
Euphorbiaceae	<i>Melanolepis multiglandulosa</i>	G. D. Weiblen	WS5D0800	27-Feb-07	Papua New Guinea	JF739159
Euphorbiaceae	<i>Neoscortechinia forbesii</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB1B0025	29-Aug-08	Papua New Guinea	JF738476
Euphorbiaceae	<i>Neoscortechinia forbesii</i>	G. D. Weiblen	WP1B0091	21-Mar-06	Papua New Guinea	JF738649
Euphorbiaceae	<i>Omphalea papuana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA5E0294	14-Aug-08	Papua New Guinea	JF738474
Euphorbiaceae	<i>Omphalea papuana</i>	G. D. Weiblen	WP1A0017	14-Mar-06	Papua New Guinea	JF738611
Euphorbiaceae	<i>Omphalea papuana</i>	G. D. Weiblen	WP2E0265	14-Sep-06	Papua New Guinea	JF738777
Euphorbiaceae	<i>Omphalea papuana</i>	G. D. Weiblen	WP3D0687	24-Mar-07	Papua New Guinea	JF738831
Euphorbiaceae	<i>Pimelodendron amboinicum</i>	G. D. Weiblen	WP1A0011	4-Mar-06	Papua New Guinea	JF738607
Euphorbiaceae	<i>Pimelodendron amboinicum</i>	G. D. Weiblen	WP2B0479	1-May-06	Papua New Guinea	JF738729
Fabaceae	<i>Abrus precatorius</i>	G. D. Weiblen	WP1B1285	16-Mar-06	Papua New Guinea	JF738654
Fabaceae	<i>Abrus</i> sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA4A0222	14-Aug-08	Papua New Guinea	JF738461
Fabaceae	<i>Albizia procera</i>	G. D. Weiblen	WS1Z3308	22-Apr-08	Papua New Guinea	JF739049
Fabaceae	<i>Archidendron glabrum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA1E0070	14-Jul-08	Papua New Guinea	JF738549
Fabaceae	<i>Archidendron glabrum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB4C0279	18-Jul-08	Papua New Guinea	JF738586
Fabaceae	<i>Archidendron lucyi</i>	G. D. Weiblen	WP4E0827	27-Oct-06	Papua New Guinea	JF738941
Fabaceae	<i>Archidendron ptenopum</i>	G. D. Weiblen	WP3C0622	16-Apr-07	Papua New Guinea	JF738819
Fabaceae	<i>Archidendron ptenopum</i>	G. D. Weiblen	WP4A1046	22-Aug-07	Papua New Guinea	JF738889
Fabaceae	<i>Archidendron ptenopum</i>	G. D. Weiblen	WP5D1182	11-May-07	Papua New Guinea	JF738990

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Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Fabaceae	<i>Calopogonium mucunoides</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB2B0131	18-Jul-08	Papua New Guinea	JF738576
Fabaceae	<i>Entada phaseoloides</i>	G. D. Weiblen	WP4B1016	31-Aug-07	Papua New Guinea	JF738904
Fabaceae	Fabaceae sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA1A0005	14-Jul-08	Papua New Guinea	JF738544
Fabaceae	<i>Gigasiphon schlechteri</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB1B0030	18-Jul-08	Papua New Guinea	JF738566
Fabaceae	<i>Gigasiphon schlechteri</i>	G. D. Weiblen	WP2D0379	21-Mar-07	Papua New Guinea	JF738772
Fabaceae	<i>Gliricidia sepium</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB4C0224	26-Jul-08	Papua New Guinea	JF738386
Fabaceae	<i>Gliricidia sepium</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OD3C0113	5-Aug-08	Papua New Guinea	JF738413
Fabaceae	<i>Intsia bijuga</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC4C0209	3-Sep-08	Papua New Guinea	JF738534
Fabaceae	<i>Intsia bijuga</i>	G. D. Weiblen	WP2D0356	18-Aug-06	Papua New Guinea	JF738765
Fabaceae	<i>Kingiodendron novoguineense</i>	G. D. Weiblen	WP1A0010	4-Mar-06	Papua New Guinea	JF738606
Fabaceae	<i>Kingiodendron novoguineense</i>	G. D. Weiblen	WP1A0036	4-Mar-06	Papua New Guinea	JF738626
Fabaceae	<i>Kingiodendron novoguineense</i>	G. D. Weiblen	WP3A1306	11-Jul-07	Papua New Guinea	JF738803
Fabaceae	<i>Kingiodendron novoguineense</i>	G. D. Weiblen	WS4E1137	18-Sep-07	Papua New Guinea	JF739130
Fabaceae	<i>Maniltoa lenticellata</i>	G. D. Weiblen	WP5C1354	18-Jun-07	Papua New Guinea	JF738986
Fabaceae	<i>Maniltoa megalcephala</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE4A0252	7-Aug-08	Papua New Guinea	JF738427
Fabaceae	<i>Maniltoa megalcephala</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA5D0288	14-Aug-08	Papua New Guinea	JF738473
Fabaceae	<i>Maniltoa megalcephala</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB5D0331	29-Aug-08	Papua New Guinea	JF738504
Fabaceae	<i>Maniltoa megalcephala</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SC3A0176	20-Aug-08	Papua New Guinea	JF738596
Fabaceae	<i>Maniltoa psilogyne</i>	G. D. Weiblen	WP3A0515	17-Jul-07	Papua New Guinea	JF738794
Fabaceae	<i>Maniltoa psilogyne</i>	G. D. Weiblen	WP4B1020	1-Sep-07	Papua New Guinea	JF738905
Fabaceae	<i>Millettia pinnata</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB5A0246	26-Jul-08	Papua New Guinea	JF738390
Fabaceae	<i>Millettia pinnata</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SC1E0073	20-Aug-08	Papua New Guinea	JF738594
Fabaceae	<i>Millettia pinnata</i>	G. D. Weiblen	WP4C0859	20-Apr-07	Papua New Guinea	JF738907
Fabaceae	<i>Parkia versteeghii</i>	G. D. Weiblen	WP2A0437	14-Jun-06	Papua New Guinea	JF738709
Fabaceae	<i>Pterocarpus indicus</i>	G. D. Weiblen	WP2D0381	10-Apr-07	Papua New Guinea	JF738773
Fabaceae	<i>Pterocarpus indicus</i>	G. D. Weiblen	WP3B0593	2-Jul-07	Papua New Guinea	JF738809
Fabaceae	<i>Pterocarpus indicus</i>	G. D. Weiblen	WS2B0531	24-Aug-06	Papua New Guinea	JF739060
Fabaceae	<i>Pterocarpus indicus</i>	G. D. Weiblen	WS5D0795	22-Feb-07	Papua New Guinea	JF739158
Gnetaceae	<i>Gnetum gnemon</i>	G. D. Weiblen	WP1A0035	3-Mar-06	Papua New Guinea	JF738625
Gnetaceae	<i>Gnetum gnemon</i>	G. D. Weiblen	WP3D0694	13-Feb-07	Papua New Guinea	JF738833
Gnetaceae	<i>Gnetum gnemon</i>	G. D. Weiblen	WP4A0983	24-Aug-07	Papua New Guinea	JF738874
Gnetaceae	<i>Gnetum gnemon</i>	G. D. Weiblen	WS4E1160	17-Sep-07	Papua New Guinea	JF739136

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Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Gnetaceae	<i>Gnetum gnemonoides</i>	G. D. Weiblen	WP1C0173	2-Jun-06	Papua New Guinea	JF738669
Gnetaceae	<i>Gnetum gnemonoides</i>	G. D. Weiblen	WP2E0282	7-Sep-06	Papua New Guinea	JF738779
Gnetaceae	<i>Gnetum gnemonoides</i>	G. D. Weiblen	WP5E1263	5-May-07	Papua New Guinea	JF739013
Gnetaceae	<i>Gnetum latifolium</i>	G. D. Weiblen	WP1C0114	26-May-06	Papua New Guinea	JF738659
Gnetaceae	<i>Gnetum latifolium</i>	G. D. Weiblen	WP2E0264	14-Sep-06	Papua New Guinea	JF738776
Gnetaceae	<i>Gnetum latifolium</i>	G. D. Weiblen	WP3B0599	28-Jun-07	Papua New Guinea	JF738813
Gnetaceae	<i>Gnetum latifolium</i>	G. D. Weiblen	WP5B1350	10-Oct-07	Papua New Guinea	JF738973
Hernandiaceae	<i>Hernandia ovigera</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC4E0172	3-Sep-08	Papua New Guinea	JF738539
Icacinaceae	<i>Merrilliodendron megacarpum</i>	G. D. Weiblen	WP1A0008	3-Mar-06	Papua New Guinea	JF738605
Icacinaceae	<i>Merrilliodendron megacarpum</i>	G. D. Weiblen	WP2E0285	6-Sep-06	Papua New Guinea	JF738780
Icacinaceae	<i>Polyporandra scandens</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA1D0044	13-Aug-08	Papua New Guinea	JF738439
Lamiaceae	<i>Callicarpa arborea</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB3C0164	26-Jul-08	Papua New Guinea	JF738383
Lamiaceae	<i>Callicarpa arborea</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC1B0011	31-Jul-08	Papua New Guinea	JF738395
Lamiaceae	<i>Callicarpa farinosa</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE1C0025	7-Aug-08	Papua New Guinea	JF738419
Lamiaceae	<i>Callicarpa farinosa</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB1A0004	15-Jul-08	Papua New Guinea	JF738562
Lamiaceae	<i>Callicarpa farinosa</i>	G. D. Weiblen	WS4B0436	18-Oct-06	Papua New Guinea	JF739109
Lamiaceae	<i>Callicarpa longifolia</i>	G. D. Weiblen	WS2B0516	28-Aug-06	Papua New Guinea	JF739056
Lamiaceae	<i>Callicarpa longifolia</i>	G. D. Weiblen	WS3C0652	8-Dec-06	Papua New Guinea	JF739083
Lamiaceae	<i>Callicarpa pentandra</i>	G. D. Weiblen	WS1Z3257	22-Apr-08	Papua New Guinea	JF739047
Lamiaceae	<i>Faradaya sp.lendida</i>	G. D. Weiblen	WP3C0640	14-Apr-07	Papua New Guinea	JF738822
Lamiaceae	<i>Gmelina moluccana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB5A0244	26-Jul-08	Papua New Guinea	JF738389
Lamiaceae	<i>Gmelina moluccana</i>	G. D. Weiblen	WS1B0613	27-Jul-06	Papua New Guinea	JF739037
Lamiaceae	<i>Gmelina moluccana</i>	G. D. Weiblen	ws4b0431	20-Oct-06	Papua New Guinea	JF739108
Lamiaceae	<i>Gmelina moluccana</i>	G. D. Weiblen	WS5A0329	29-Jun-06	Papua New Guinea	JF739140
Lamiaceae	<i>Gmelina palawensis</i>	G. D. Weiblen	WP3E1315	28-Mar-07	Papua New Guinea	JF738866
Lamiaceae	<i>Petraeovitex multiflora</i>	G. D. Weiblen	WP1Z3127	12-Apr-08	Papua New Guinea	JF738701
Lamiaceae	<i>Petraeovitex multiflora</i>	G. D. Weiblen	WP3B0586	30-Aug-07	Papua New Guinea	JF738805
Lamiaceae	<i>Premna obtusifolia</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA1C0047	14-Jul-08	Papua New Guinea	JF738546
Lamiaceae	<i>Premna obtusifolia</i>	G. D. Weiblen	WS2D0929	1-Jun-07	Papua New Guinea	JF739064
Lamiaceae	<i>Premna obtusifolia</i>	G. D. Weiblen	WS2D0933	1-Jun-07	Papua New Guinea	JF739065
Lamiaceae	<i>Teijsmanniodendron bogoriense</i>	G. D. Weiblen	WP1A0019	14-Mar-06	Papua New Guinea	JF738613
Lamiaceae	<i>Teijsmanniodendron bogoriense</i>	G. D. Weiblen	WP1D0145	4-Jul-06	Papua New Guinea	JF738674

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Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Lamiaceae	<i>Teijsmanniodendron bogoriense</i>	G. D. Weiblen	WP5E1278	26-Apr-07	Papua New Guinea	JF739019
Lamiaceae	<i>Vitex cofassus</i>	G. D. Weiblen	WS2A0074	23-Mar-06	Papua New Guinea	JF739053
Lamiaceae	<i>Vitex cofassus</i>	G. D. Weiblen	WS2A0128	27-Mar-06	Papua New Guinea	JF739054
Lamiaceae	<i>Vitex cofassus</i>	G. D. Weiblen	WS3E1057	5-Sep-07	Papua New Guinea	JF739096
Lamiaceae	<i>Vitex cofassus</i>	G. D. Weiblen	WS4B0453	17-Oct-06	Papua New Guinea	JF739110
Lamiaceae	<i>Vitex cofassus</i>	G. D. Weiblen	WS5A0276	22-Jun-06	Papua New Guinea	JF739138
Lauraceae	<i>Actinodaphne nitida</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC4D0134	31-Jul-08	Papua New Guinea	JF738408
Lauraceae	<i>Cinnamomum grandiflorum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC1B0025	3-Sep-08	Papua New Guinea	JF738514
Lauraceae	<i>Cinnamomum grandiflorum</i>	G. D. Weiblen	WP1E0253	1-Aug-06	Papua New Guinea	JF738697
Lauraceae	<i>Cinnamomum grandiflorum</i>	G. D. Weiblen	WP4A1032	23-Aug-07	Papua New Guinea	JF738882
Lauraceae	<i>Cinnamomum grandiflorum</i>	G. D. Weiblen	WP5E1273	28-Apr-07	Papua New Guinea	JF739016
Lauraceae	<i>Cryptocarya caloneura</i>	G. D. Weiblen	WP2B0404	1-May-06	Papua New Guinea	JF738720
Lauraceae	<i>Cryptocarya caloneura</i>	G. D. Weiblen	WP2B0417	4-May-06	Papua New Guinea	JF738727
Lauraceae	<i>Cryptocarya densiflora</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA2A0082	14-Jul-08	Papua New Guinea	JF738550
Lauraceae	<i>Cryptocarya depressa</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB1D0060	18-Jul-08	Papua New Guinea	JF738570
Lauraceae	<i>Cryptocarya depressa</i>	G. D. Weiblen	WP3B0653	23-Jun-07	Papua New Guinea	JF738817
Lauraceae	<i>Cryptocarya mackinnoniana</i>	G. D. Weiblen	WP1C0170	29-May-06	Papua New Guinea	JF738668
Lauraceae	<i>Cryptocarya mackinnoniana</i>	G. D. Weiblen	WP2B0550	22-Apr-06	Papua New Guinea	JF738740
Lauraceae	<i>Cryptocarya mackinnoniana</i>	G. D. Weiblen	WP4A1023	21-Aug-07	Papua New Guinea	JF738880
Lauraceae	<i>Cryptocarya mackinnoniana</i>	G. D. Weiblen	WP4B0951	13-Aug-07	Papua New Guinea	JF738897
Lauraceae	<i>Cryptocarya mackinnoniana</i>	G. D. Weiblen	WP4C0862	11-Apr-07	Papua New Guinea	JF738908
Lauraceae	<i>Cryptocarya sp.</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB1B0021	29-Aug-08	Papua New Guinea	JF738475
Lauraceae	<i>Cryptocarya sp.</i>	G. D. Weiblen	WP2B1302	25-Apr-06	Papua New Guinea	JF738741
Lauraceae	<i>Cryptocarya sp.</i>	G. D. Weiblen	WP4C0865	17-Apr-07	Papua New Guinea	JF738909
Lauraceae	<i>Endiandra squarrosa</i>	G. D. Weiblen	WP1B0051	9-Mar-06	Papua New Guinea	JF738632
Lauraceae	<i>Endiandra squarrosa</i>	G. D. Weiblen	WP3D0712	9-Feb-07	Papua New Guinea	JF738838
Lauraceae	<i>Endiandra squarrosa</i>	G. D. Weiblen	WP4B1013	1-Sep-07	Papua New Guinea	JF738902
Lauraceae	<i>Endiandra squarrosa</i>	G. D. Weiblen	WP5D1166	14-May-07	Papua New Guinea	JF738987
Lauraceae	<i>Litsea collina</i>	G. D. Weiblen	WP3A0573	10-Jul-07	Papua New Guinea	JF738797
Lauraceae	<i>Litsea globosa</i>	G. D. Weiblen	WS1Z3315	21-Apr-08	Papua New Guinea	JF739050
Lauraceae	<i>Litsea timoriana</i>	G. D. Weiblen	WP1A0018	10-Mar-06	Papua New Guinea	JF738612
Lauraceae	<i>Litsea timoriana</i>	G. D. Weiblen	WP3D0691	12-Feb-07	Papua New Guinea	JF738832

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Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Lauraceae	<i>Litsea timoriana</i>	G. D. Weiblen	WP5C1161	18-Jun-07	Papua New Guinea	JF738982
Lauraceae	<i>Litsea timoriana</i>	G. D. Weiblen	WP5E1276	26-Apr-07	Papua New Guinea	JF739017
Lecythidaceae	<i>Barringtonia apiculata</i>	G. D. Weiblen	WP2E0318	5-Sep-06	Papua New Guinea	JF738786
Lecythidaceae	<i>Barringtonia apiculata</i>	G. D. Weiblen	WP4B1002	15-Aug-07	Papua New Guinea	JF738898
Lecythidaceae	<i>Barringtonia apiculata</i>	G. D. Weiblen	WS1A0001	27-Feb-06	Papua New Guinea	JF739025
Lecythidaceae	<i>Barringtonia calyptrocalyx</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB4C0252	29-Aug-08	Papua New Guinea	JF738495
Lecythidaceae	<i>Barringtonia novae-hiberniae</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA1C0022	13-Aug-08	Papua New Guinea	JF738435
Loganiaceae	<i>Neuburgia corynocarpa</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB5E0294	26-Jul-08	Papua New Guinea	JF738392
Loganiaceae	<i>Neuburgia corynocarpa</i>	G. D. Weiblen	WP2C0396	1-Jun-06	Papua New Guinea	JF738749
Loganiaceae	<i>Neuburgia corynocarpa</i>	G. D. Weiblen	WP4D0876	24-Mar-07	Papua New Guinea	JF738927
Loganiaceae	<i>Strychnos minor</i>	G. D. Weiblen	WP2A0527	14-Mar-06	Papua New Guinea	JF738715
Loganiaceae	<i>Strychnos minor</i>	G. D. Weiblen	WP4B0854	16-Aug-07	Papua New Guinea	JF738892
Loganiaceae	<i>Strychnos minor</i>	G. D. Weiblen	WP4D0900	3-May-07	Papua New Guinea	JF738934
Lythraceae	<i>Lagerstroemia archeriana</i>	G. D. Weiblen	WP5D1233	15-May-07	Papua New Guinea	JF738996
Lythraceae	<i>Lagerstroemia piriformis</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA4A0220	14-Aug-08	Papua New Guinea	JF738459
Lythraceae	<i>Lythraceae</i> sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC5D0215	31-Jul-08	Papua New Guinea	JF738410
Malvaceae	<i>Bombax ceiba</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB1D0059	18-Jul-08	Papua New Guinea	JF738569
Malvaceae	<i>Commersonia bartramia</i>	G. D. Weiblen	WS1A0002	27-Feb-06	Papua New Guinea	JF739026
Malvaceae	<i>Commersonia bartramia</i>	G. D. Weiblen	WS1B0591	22-Jul-06	Papua New Guinea	JF739036
Malvaceae	<i>Commersonia bartramia</i>	G. D. Weiblen	WS3C0659	6-Dec-06	Papua New Guinea	JF739084
Malvaceae	<i>Commersonia bartramia</i>	G. D. Weiblen	WS4B0430	18-Oct-06	Papua New Guinea	JF739107
Malvaceae	<i>Commersonia bartramia</i>	G. D. Weiblen	WS5A0335	1-Jul-06	Papua New Guinea	JF739142
Malvaceae	<i>Commersonia bartramia</i>	G. D. Weiblen	WS5C0738	17-Nov-06	Papua New Guinea	JF739153
Malvaceae	<i>Grewia glabra</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OA1E0066	23-Jul-08	Papua New Guinea	JF738370
Malvaceae	<i>Heritiera littoralis</i>	G. D. Weiblen	WP3E0770	21-Sep-06	Papua New Guinea	JF738856
Malvaceae	<i>Hibiscus papuodendron</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE4E0182	7-Aug-08	Papua New Guinea	JF738429
Malvaceae	<i>Hibiscus papuodendron</i>	G. D. Weiblen	WP2D0373	15-Aug-06	Papua New Guinea	JF738769
Malvaceae	<i>Hibiscus tiliaceus</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA2D0135	14-Jul-08	Papua New Guinea	JF738552
Malvaceae	<i>Kleinhovia hospita</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA1E0069	14-Jul-08	Papua New Guinea	JF738548
Malvaceae	<i>Kleinhovia hospita</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB2E0095	18-Jul-08	Papua New Guinea	JF738579
Malvaceae	<i>Melochia umbellata</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB3E0201	19-Jul-08	Papua New Guinea	JF738583
Malvaceae	<i>Microcos argentata</i>	G. D. Weiblen	WP1D0181	12-Jul-06	Papua New Guinea	JF738679

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Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Malvaceae	<i>Microcos argentata</i>	G. D. Weiblen	WP3A0507	11-Jul-07	Papua New Guinea	JF738790
Malvaceae	<i>Microcos argentata</i>	G. D. Weiblen	WP5D1243	14-May-07	Papua New Guinea	JF738998
Malvaceae	<i>Microcos grandiflora</i>	G. D. Weiblen	WP4A1034	20-Aug-07	Papua New Guinea	JF738883
Malvaceae	<i>Microcos grandiflora</i>	G. D. Weiblen	WP5C1245	19-May-07	Papua New Guinea	JF738985
Malvaceae	<i>Passifloraceae argentata</i>	G. D. Weiblen	WP2C0470	7-Jun-06	Papua New Guinea	JF738758
Malvaceae	<i>Pterocymbium beccarii</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB1B0011	18-Jul-08	Papua New Guinea	JF738563
Malvaceae	<i>Pterocymbium beccarii</i>	G. D. Weiblen	WP2B0502	10-Jul-07	Papua New Guinea	JF738737
Malvaceae	<i>Sterculia ampla</i>	G. D. Weiblen	WP4A1047	22-Aug-07	Papua New Guinea	JF738890
Malvaceae	<i>Sterculia ampla</i>	G. D. Weiblen	WS5B0364	8-Nov-06	Papua New Guinea	JF739146
Malvaceae	<i>Sterculia schumanniana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA2C0117	14-Jul-08	Papua New Guinea	JF738551
Malvaceae	<i>Sterculia schumanniana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB1D0052	18-Jul-08	Papua New Guinea	JF738568
Malvaceae	<i>Sterculia schumanniana</i>	G. D. Weiblen	WP4A0984	24-Aug-07	Papua New Guinea	JF738875
Malvaceae	<i>Sterculia schumanniana</i>	G. D. Weiblen	WP5A1000	28-Sep-07	Papua New Guinea	JF738950
Malvaceae	<i>Sterculia schumanniana</i>	G. D. Weiblen	WP5B1352	6-Oct-07	Papua New Guinea	JF738974
Malvaceae	<i>Trichospermum pleiostigma</i>	G. D. Weiblen	WS1A0004	27-Feb-06	Papua New Guinea	JF739028
Malvaceae	<i>Trichospermum pleiostigma</i>	G. D. Weiblen	WS3D0924	23-May-07	Papua New Guinea	JF739094
Malvaceae	<i>Trichospermum pleiostigma</i>	G. D. Weiblen	WS5C0769	21-Nov-06	Papua New Guinea	JF739154
Malvaceae	<i>Trichospermum pleiostigma</i>	G. D. Weiblen	WS5D0836	12-Mar-07	Papua New Guinea	JF739165
Meliaceae	<i>Aglaia argentea</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA4B0203	14-Aug-08	Papua New Guinea	JF738463
Meliaceae	<i>Aglaia argentea</i>	G. D. Weiblen	WP1A0029	6-Mar-06	Papua New Guinea	JF738621
Meliaceae	<i>Aglaia argentea</i>	G. D. Weiblen	WP4A0967	21-Aug-07	Papua New Guinea	JF738868
Meliaceae	<i>Aglaia brassii</i>	G. D. Weiblen	WP1B0095	18-Mar-06	Papua New Guinea	JF738651
Meliaceae	<i>Aglaia brassii</i>	G. D. Weiblen	WP2C0388	6-Jun-06	Papua New Guinea	JF738746
Meliaceae	<i>Aglaia cucullata</i>	G. D. Weiblen	WP2D0370	16-Aug-06	Papua New Guinea	JF738768
Meliaceae	<i>Aglaia goebeliana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC1E0049	3-Sep-08	Papua New Guinea	JF738518
Meliaceae	<i>Aglaia leporrhachis</i>	G. D. Weiblen	WP2B0486	24-Apr-06	Papua New Guinea	JF738731
Meliaceae	<i>Aglaia leporrhachis</i>	G. D. Weiblen	WP3B0596	28-Jun-07	Papua New Guinea	JF738812
Meliaceae	<i>Aglaia leporrhachis</i>	G. D. Weiblen	WP4C0875	7-Apr-07	Papua New Guinea	JF738911
Meliaceae	<i>Aglaia leporrhachis</i>	G. D. Weiblen	WP5A1050	29-Sep-07	Papua New Guinea	JF738951
Meliaceae	<i>Aglaia rimosa</i>	G. D. Weiblen	WP1D0180	4-Jul-06	Papua New Guinea	JF738678
Meliaceae	<i>Aglaia rimosa</i>	G. D. Weiblen	WP4B1334	9-Aug-07	Papua New Guinea	JF738906
Meliaceae	<i>Aglaia sapindina</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB1E0064	25-Jul-08	Papua New Guinea	JF738380

Appendix 5. Cont'd

Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Meliaceae	<i>Aglaia</i> sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA3E0160	14-Aug-08	Papua New Guinea	JF738456
Meliaceae	<i>Aglaia</i> sp.	G. D. Weiblen	WP5C1165	15-Jun-07	Papua New Guinea	JF738984
Meliaceae	<i>Aphanamixis polystachya</i>	G. D. Weiblen	WP1A0048	16-Mar-06	Papua New Guinea	JF738631
Meliaceae	<i>Aphanamixis polystachya</i>	G. D. Weiblen	WP1Z3069	3-Apr-08	Papua New Guinea	JF738699
Meliaceae	<i>Aphanamixis polystachya</i>	G. D. Weiblen	WP3A0511	14-Jul-07	Papua New Guinea	JF738792
Meliaceae	<i>Aphanamixis polystachya</i>	G. D. Weiblen	WP3E0805	27-Sep-06	Papua New Guinea	JF738863
Meliaceae	<i>Aphanamixis polystachya</i>	G. D. Weiblen	WP4A0995	22-Aug-07	Papua New Guinea	JF738878
Meliaceae	<i>Aphanamixis polystachya</i>	G. D. Weiblen	WP4D0879	19-Mar-07	Papua New Guinea	JF738929
Meliaceae	<i>Aphanamixis</i> sp.	G. D. Weiblen	WP4D0905	17-Mar-07	Papua New Guinea	JF738937
Meliaceae	<i>Chisocheton ceramicus</i>	G. D. Weiblen	WP1E0250	1-Aug-06	Papua New Guinea	JF738695
Meliaceae	<i>Chisocheton ceramicus</i>	G. D. Weiblen	WP2A0528	1-Apr-06	Papua New Guinea	JF738716
Meliaceae	<i>Chisocheton ceramicus</i>	G. D. Weiblen	WP2D0378	14-Aug-06	Papua New Guinea	JF738771
Meliaceae	<i>Chisocheton ceramicus</i>	G. D. Weiblen	WP3D0684	17-Mar-07	Papua New Guinea	JF738829
Meliaceae	<i>Chisocheton ceramicus</i>	G. D. Weiblen	WP3D0716	9-Feb-07	Papua New Guinea	JF738840
Meliaceae	<i>Chisocheton ceramicus</i>	G. D. Weiblen	WP3D0725	7-Feb-07	Papua New Guinea	JF738842
Meliaceae	<i>Chisocheton ceramicus</i>	G. D. Weiblen	WP3E0811	23-Sep-06	Papua New Guinea	JF738865
Meliaceae	<i>Chisocheton ceramicus</i>	G. D. Weiblen	WP4A1024	23-Aug-07	Papua New Guinea	JF738881
Meliaceae	<i>Chisocheton ceramicus</i>	G. D. Weiblen	WP5A1077	1-Oct-07	Papua New Guinea	JF738953
Meliaceae	<i>Chisocheton ceramicus</i>	G. D. Weiblen	WS5D0822	24-Feb-07	Papua New Guinea	JF739164
Meliaceae	<i>Chisocheton cumingianus</i>	G. D. Weiblen	WP1D0207	13-Jul-06	Papua New Guinea	JF738688
Meliaceae	<i>Chisocheton cumingianus</i>	G. D. Weiblen	WP2D0327	16-Aug-06	Papua New Guinea	JF738762
Meliaceae	<i>Chisocheton cumingianus</i>	G. D. Weiblen	WP4E0830	28-Oct-06	Papua New Guinea	JF738943
Meliaceae	<i>Chisocheton formicarum</i>	G. D. Weiblen	WP1C0119	25-May-06	Papua New Guinea	JF738660
Meliaceae	<i>Chisocheton formicarum</i>	G. D. Weiblen	WP2D0338	17-Aug-06	Papua New Guinea	JF738764
Meliaceae	<i>Chisocheton montanus</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB3B0159	29-Aug-09	Papua New Guinea	JF738485
Meliaceae	<i>Chisocheton montanus</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC1C0032	3-Sep-08	Papua New Guinea	JF738515
Meliaceae	<i>Chisocheton schumannii</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB1D0036	3-Sep-08	Papua New Guinea	JF738478
Meliaceae	<i>Chisocheton trichocladus</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA1D0040	13-Aug-08	Papua New Guinea	JF738438
Meliaceae	<i>Chisocheton trichocladus</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB5E0334	29-Aug-08	Papua New Guinea	JF738505
Meliaceae	<i>Chisocheton trichocladus</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC1A0015	3-Sep-08	Papua New Guinea	JF738512
Meliaceae	<i>Chisocheton trichocladus</i>	G. D. Weiblen	WP3D0680	14-Feb-07	Papua New Guinea	JF738827
Meliaceae	<i>Chisocheton trichocladus</i>	G. D. Weiblen	WP3E0759	20-Sep-06	Papua New Guinea	JF738853

Appendix 5. Cont'd

Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Meliaceae	<i>Chisocheton trichocladus</i>	G. D. Weiblen	WP4D0768	15-Mar-07	Papua New Guinea	JF738923
Meliaceae	<i>Dysoxylum alliaceum</i>	G. D. Weiblen	WP3A0602	25-Jun-07	Papua New Guinea	JF738802
Meliaceae	<i>Dysoxylum alliaceum</i>	G. D. Weiblen	WP5B1124	8-Oct-07	Papua New Guinea	JF738968
Meliaceae	<i>Dysoxylum annae</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA1D0038	13-Aug-08	Papua New Guinea	JF738437
Meliaceae	<i>Dysoxylum arborescens</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB3E0215	29-Aug-09	Papua New Guinea	JF738491
Meliaceae	<i>Dysoxylum arborescens</i>	G. D. Weiblen	WP1D0136	10-Jul-06	Papua New Guinea	JF738671
Meliaceae	<i>Dysoxylum arborescens</i>	G. D. Weiblen	WP2A0436	6-Apr-06	Papua New Guinea	JF738708
Meliaceae	<i>Dysoxylum arborescens</i>	G. D. Weiblen	WS2B0518	1-Sep-06	Papua New Guinea	JF739057
Meliaceae	<i>Dysoxylum brassii</i>	G. D. Weiblen	WP2A0441	5-Apr-06	Papua New Guinea	JF738712
Meliaceae	<i>Dysoxylum brassii</i>	G. D. Weiblen	WP4C0925	21-Apr-07	Papua New Guinea	JF738916
Meliaceae	<i>Dysoxylum gaudichaudianum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB1C0029	29-Aug-08	Papua New Guinea	JF738477
Meliaceae	<i>Dysoxylum gaudichaudianum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC1E0059	3-Sep-08	Papua New Guinea	JF738520
Meliaceae	<i>Dysoxylum gaudichaudianum</i>	G. D. Weiblen	WS4C0687	29-Nov-06	Papua New Guinea	JF739114
Meliaceae	<i>Dysoxylum kaniense</i>	G. D. Weiblen	WP1A0022	7-Mar-06	Papua New Guinea	JF738616
Meliaceae	<i>Dysoxylum macrostachyum</i>	G. D. Weiblen	WP3A0565	7-Jul-07	Papua New Guinea	JF738796
Meliaceae	<i>Dysoxylum micranthum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OD5E0263	5-Aug-08	Papua New Guinea	JF738417
Meliaceae	<i>Dysoxylum micranthum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB5D0321	29-Aug-08	Papua New Guinea	JF738502
Meliaceae	<i>Dysoxylum micranthum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC1B0019	3-Sep-08	Papua New Guinea	JF738513
Meliaceae	<i>Dysoxylum micranthum</i>	G. D. Weiblen	WP3D0696	8-Feb-07	Papua New Guinea	JF738834
Meliaceae	<i>Dysoxylum molle</i>	G. D. Weiblen	WP2A0439	6-Apr-06	Papua New Guinea	JF738710
Meliaceae	<i>Dysoxylum molle</i>	G. D. Weiblen	WP2A0536	12-Jul-06	Papua New Guinea	JF738717
Meliaceae	<i>Dysoxylum pettigrewianum</i>	G. D. Weiblen	WP4C1329	7-Mar-07	Papua New Guinea	JF738919
Meliaceae	<i>Dysoxylum richardianum</i>	G. D. Weiblen	WP1E0241	9-Aug-06	Papua New Guinea	JF738692
Meliaceae	<i>Dysoxylum richardianum</i>	G. D. Weiblen	WP3B0655	23-Jun-07	Papua New Guinea	JF738818
Meliaceae	<i>Dysoxylum richardianum</i>	G. D. Weiblen	WP3D0713	9-Feb-07	Papua New Guinea	JF738839
Meliaceae	<i>Dysoxylum richardianum</i>	G. D. Weiblen	WP4D0897	22-Mar-07	Papua New Guinea	JF738933
Meliaceae	<i>Dysoxylum richardianum</i>	G. D. Weiblen	WP5C1135	14-Jun-07	Papua New Guinea	JF738977
Meliaceae	<i>Dysoxylum richardianum</i>	G. D. Weiblen	WP5E1365	24-Apr-07	Papua New Guinea	JF739022
Meliaceae	<i>Dysoxylum</i> sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA3D0143	14-Aug-08	Papua New Guinea	JF738454
Meliaceae	<i>Dysoxylum</i> sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA4A0223	14-Aug-08	Papua New Guinea	JF738462
Meliaceae	<i>Dysoxylum</i> sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA5B0250	14-Aug-08	Papua New Guinea	JF738469
Meliaceae	<i>Fabaceae cumingianus</i>	G. D. Weiblen	WP2C0392	7-Jun-06	Papua New Guinea	JF738748

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Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Menispermaceae	Macrococculus pomiferus	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB3C0184	19-Jul-08	Papua New Guinea	JF738582
Monimiaceae	Stegánthera hirsuta	T. J. S. Whitfeld, G. Sosanika, B. Bau	OA2A0231	23-Jul-08	Papua New Guinea	JF738371
Monimiaceae	Stegánthera hirsuta	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA3C0141	14-Aug-08	Papua New Guinea	JF738453
Monimiaceae	Stegánthera hirsuta	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB4D0240	29-Aug-08	Papua New Guinea	JF738497
Monimiaceae	Stegánthera hirsuta	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC1A0004	3-Sep-08	Papua New Guinea	JF738508
Monimiaceae	Stegánthera hirsuta	G. D. Weiblen	WS1Z3331	22-Apr-08	Papua New Guinea	JF739051
Moraceae	Artocarpus altilis	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB1C0029	25-Jul-08	Papua New Guinea	JF738376
Moraceae	Artocarpus camansi	G. D. Weiblen	WS4B0467	21-Oct-06	Papua New Guinea	JF739111
Moraceae	Artocarpus camansi	G. D. Weiblen	WS4B0470	19-Oct-06	Papua New Guinea	JF739112
Moraceae	Artocarpus camansi	G. D. Weiblen	WS4D0844	12-Mar-07	Papua New Guinea	JF739122
Moraceae	Artocarpus lacucha	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB4E0188	26-Jul-08	Papua New Guinea	JF738388
Moraceae	Artocarpus lacucha	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC3A0080	31-Jul-08	Papua New Guinea	JF738402
Moraceae	Artocarpus lacucha	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA3E0226	15-Jul-08	Papua New Guinea	JF738555
Moraceae	Artocarpus lacucha	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB3A0166	19-Jul-08	Papua New Guinea	JF738581
Moraceae	Artocarpus lacucha	T. J. S. Whitfeld, G. Sosanika, B. Bau	SC1C0037	20-Aug-08	Papua New Guinea	JF738590
Moraceae	Artocarpus sepicanus	G. D. Weiblen	WP1A0014	14-Mar-06	Papua New Guinea	JF738609
Moraceae	Artocarpus sepicanus	G. D. Weiblen	WP3B0611	26-Jun-07	Papua New Guinea	JF738815
Moraceae	Artocarpus sepicanus	G. D. Weiblen	WS3A0162	18-Apr-06	Papua New Guinea	JF739071
Moraceae	Artocarpus sp.	G. D. Weiblen	WS1E0979	25-Jul-07	Papua New Guinea	JF739045
Moraceae	Artocarpus sp.	G. D. Weiblen	WS4B0423	20-Oct-06	Papua New Guinea	JF739105
Moraceae	Ficus ampelos	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA4A0219	14-Aug-08	Papua New Guinea	JF738458
Moraceae	Ficus ampelos	G. D. Weiblen	WS3C0660	6-Dec-06	Papua New Guinea	JF739085
Moraceae	Ficus arfakensis	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB2C0107	26-Jul-08	Papua New Guinea	JF738381
Moraceae	Ficus arfakensis	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC4B0216	3-Sep-08	Papua New Guinea	JF738533
Moraceae	Ficus arfakensis	G. D. Weiblen	WP4A0976	25-Aug-07	Papua New Guinea	JF738872
Moraceae	Ficus bernaysii	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB2A0150	18-Jul-08	Papua New Guinea	JF738573
Moraceae	Ficus bernaysii	G. D. Weiblen	WP1B0094	17-Mar-06	Papua New Guinea	JF738650
Moraceae	Ficus bernaysii	G. D. Weiblen	WP2A0440	3-Apr-06	Papua New Guinea	JF738711
Moraceae	Ficus bernaysii	G. D. Weiblen	WP4D0902	15-Mar-07	Papua New Guinea	JF738935
Moraceae	Ficus congesta	G. D. Weiblen	WS3B0495	10-Oct-06	Papua New Guinea	JF739076
Moraceae	Ficus congesta	G. D. Weiblen	WS4B0416	21-Oct-06	Papua New Guinea	JF739104
Moraceae	Ficus conocephalifolia	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC2C0087	3-Sep-08	Papua New Guinea	JF738522

Appendix 5. Cont'd

Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Moraceae	<i>Ficus conocephalifolia</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB5C0349	19-Jul-08	Papua New Guinea	JF738589
Moraceae	<i>Ficus copiosa</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB1B0025	18-Jul-08	Papua New Guinea	JF738564
Moraceae	<i>Ficus gul</i>	G. D. Weiblen	WS2B0544	25-Aug-06	Papua New Guinea	JF739062
Moraceae	<i>Ficus gul</i>	G. D. Weiblen	WS3D0906	25-May-07	Papua New Guinea	JF739093
Moraceae	<i>Ficus hispidioides</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OD4A0203	5-Aug-08	Papua New Guinea	JF738416
Moraceae	<i>Ficus hispidioides</i>	G. D. Weiblen	WS3A0135	14-Apr-06	Papua New Guinea	JF739068
Moraceae	<i>Ficus hombroniana</i>	G. D. Weiblen	WP1D0202	3-Jul-06	Papua New Guinea	JF738687
Moraceae	<i>Ficus hombroniana</i>	G. D. Weiblen	WP2B0419	27-Apr-06	Papua New Guinea	JF738728
Moraceae	<i>Ficus hombroniana</i>	G. D. Weiblen	WP5C1100	16-Jun-07	Papua New Guinea	JF738976
Moraceae	<i>Ficus hombroniana</i>	G. D. Weiblen	WP5E1213	2-May-07	Papua New Guinea	JF739010
Moraceae	<i>Ficus melinocarpa</i>	G. D. Weiblen	WP3A1307	7-Jul-07	Papua New Guinea	JF738804
Moraceae	<i>Ficus melinocarpa</i>	G. D. Weiblen	WS1D0951	9-Jun-07	Papua New Guinea	JF739039
Moraceae	<i>Ficus melinocarpa</i>	G. D. Weiblen	WS1D0954	9-Jun-07	Papua New Guinea	JF739040
Moraceae	<i>Ficus melinocarpa</i>	G. D. Weiblen	WS4A0208	15-May-06	Papua New Guinea	JF739097
Moraceae	<i>Ficus mollior</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB4B0265	29-Aug-08	Papua New Guinea	JF738492
Moraceae	<i>Ficus nodosa</i>	G. D. Weiblen	WP2C0455	9-Jun-06	Papua New Guinea	JF738752
Moraceae	<i>Ficus nodosa</i>	G. D. Weiblen	WS3A0148	13-Apr-06	Papua New Guinea	JF739069
Moraceae	<i>Ficus nodosa</i>	G. D. Weiblen	WS4B0424	20-Oct-06	Papua New Guinea	JF739106
Moraceae	<i>Ficus nodosa</i>	G. D. Weiblen	WS4E1132	18-Sep-07	Papua New Guinea	JF739128
Moraceae	<i>Ficus pachyrrhachis</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC2E0046	31-Jul-08	Papua New Guinea	JF738400
Moraceae	<i>Ficus polyantha</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC2D0080	3-Sep-08	Papua New Guinea	JF738527
Moraceae	<i>Ficus polyantha</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SC3C0213	20-Aug-08	Papua New Guinea	JF738598
Moraceae	<i>Ficus pseudojaca</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA5A0232	14-Aug-08	Papua New Guinea	JF738466
Moraceae	<i>Ficus pseudojaca</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC2E0070	3-Sep-08	Papua New Guinea	JF738528
Moraceae	<i>Ficus pungens</i>	G. D. Weiblen	WP4A0974	28-Aug-07	Papua New Guinea	JF738871
Moraceae	<i>Ficus pungens</i>	G. D. Weiblen	WS1E0980	26-Jul-07	Papua New Guinea	JF739046
Moraceae	<i>Ficus pungens</i>	G. D. Weiblen	WS4E1119	24-Sep-07	Papua New Guinea	JF739126
Moraceae	<i>Ficus pungens</i>	G. D. Weiblen	WS5A0331	1-Jul-06	Papua New Guinea	JF739141
Moraceae	<i>Ficus rubrivestimenta</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA3C0135	14-Aug-08	Papua New Guinea	JF738452
Moraceae	<i>Ficus rubrivestimenta</i>	G. D. Weiblen	WP1B0058	21-Mar-06	Papua New Guinea	JF738637
Moraceae	<i>Ficus rubrivestimenta</i>	G. D. Weiblen	WP1C0106	23-May-06	Papua New Guinea	JF738657
Moraceae	<i>Ficus rubrivestimenta</i>	G. D. Weiblen	WP4E0820	26-Oct-06	Papua New Guinea	JF738938

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Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Moraceae	<i>Ficus rubrivestimenta</i>	G. D. Weiblen	WP5A1069	1-Oct-07	Papua New Guinea	JF738952
Moraceae	<i>Ficus semivestita</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA3A0118	13-Aug-08	Papua New Guinea	JF738449
Moraceae	<i>Ficus semivestita</i>	G. D. Weiblen	WS3A0171	13-Apr-06	Papua New Guinea	JF739072
Moraceae	<i>Ficus semivestita</i>	G. D. Weiblen	WS4A0252	11-May-06	Papua New Guinea	JF739099
Moraceae	<i>Ficus</i> sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	OD3D0132	5-Aug-08	Papua New Guinea	JF738415
Moraceae	<i>Ficus subcuneata</i>	G. D. Weiblen	WP4E0829	26-Oct-06	Papua New Guinea	JF738942
Moraceae	<i>Ficus subtrinervia</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA4A0213	14-Aug-08	Papua New Guinea	JF738457
Moraceae	<i>Ficus subtrinervia</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC2D0075	3-Sep-08	Papua New Guinea	JF738526
Moraceae	<i>Ficus trachypison</i>	G. D. Weiblen	WP1B0081	20-Mar-06	Papua New Guinea	JF738646
Moraceae	<i>Ficus trachypison</i>	G. D. Weiblen	WP2D0332	12-Aug-06	Papua New Guinea	JF738763
Moraceae	<i>Ficus trachypison</i>	G. D. Weiblen	WS2C0638	26-Jan-07	Papua New Guinea	JF739063
Moraceae	<i>Ficus trachypison</i>	G. D. Weiblen	WS5C0776	17-Nov-06	Papua New Guinea	JF739156
Moraceae	<i>Ficus variegata</i>	G. D. Weiblen	WS1A0018	23-Feb-06	Papua New Guinea	JF739032
Moraceae	<i>Ficus variegata</i>	G. D. Weiblen	WS4C0715	28-Nov-06	Papua New Guinea	JF739121
Moraceae	<i>Ficus variegata</i>	G. D. Weiblen	WS5D0820	27-Feb-07	Papua New Guinea	JF739163
Moraceae	<i>Ficus virens</i>	G. D. Weiblen	WP5B1086	15-Oct-07	Papua New Guinea	JF738961
Moraceae	<i>Ficus wassa</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE4E0186	7-Aug-08	Papua New Guinea	JF738430
Moraceae	<i>Ficus wassa</i>	G. D. Weiblen	WP5E1195	26-Apr-07	Papua New Guinea	JF739002
Moraceae	<i>Ficus wassa</i>	G. D. Weiblen	WS4C0705	28-Nov-06	Papua New Guinea	JF739119
Moraceae	<i>Ficus wassa</i>	G. D. Weiblen	WS5D0808	24-Feb-07	Papua New Guinea	JF739160
Moraceae	<i>Maclura amboinensis</i>	G. D. Weiblen	WP1D0177	10-Jul-06	Papua New Guinea	JF738677
Moraceae	<i>Maclura amboinensis</i>	G. D. Weiblen	WP2E1294	12-Sep-06	Papua New Guinea	JF738788
Moraceae	<i>Maclura amboinensis</i>	G. D. Weiblen	WP3B0592	2-Jul-07	Papua New Guinea	JF738808
Moraceae	<i>Maclura amboinensis</i>	G. D. Weiblen	WP5D1186	18-May-07	Papua New Guinea	JF738991
Moraceae	<i>Prainea papuana</i>	G. D. Weiblen	WP1A0004	3-Mar-06	Papua New Guinea	JF738603
Moraceae	<i>Prainea papuana</i>	G. D. Weiblen	WP2C0476	9-Jun-06	Papua New Guinea	JF738760
Moraceae	<i>Prainea papuana</i>	G. D. Weiblen	WP5A1346	28-Sep-07	Papua New Guinea	JF738958
Moraceae	<i>Prainea papuana</i>	G. D. Weiblen	WP5C1158	16-Jun-07	Papua New Guinea	JF738981
Moraceae	<i>Streblus ascendens</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC2D0051	31-Jul-08	Papua New Guinea	JF738398
Moraceae	<i>Streblus ascendens</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SC4C0280	20-Aug-08	Papua New Guinea	JF738599
Myristicaceae	<i>Endocomia macrocoma</i>	G. D. Weiblen	WP1C0156	25-May-06	Papua New Guinea	JF738664
Myristicaceae	<i>Endocomia macrocoma</i>	G. D. Weiblen	WP4A1035	24-Aug-07	Papua New Guinea	JF738884

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Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Myristicaceae	<i>Gymnacranthera paniculata</i>	G. D. Weiblen	WP1A0005	7-Mar-06	Papua New Guinea	JF738604
Myristicaceae	<i>Gymnacranthera paniculata</i>	G. D. Weiblen	WP5A1102	1-Oct-07	Papua New Guinea	JF738955
Myristicaceae	<i>Gymnacranthera paniculata</i>	G. D. Weiblen	WP5E1363	24-Apr-07	Papua New Guinea	JF739021
Myristicaceae	<i>Horsfieldia basifissa</i>	G. D. Weiblen	WP4B1010	14-Aug-07	Papua New Guinea	JF738900
Myristicaceae	<i>Horsfieldia hellwigii</i>	G. D. Weiblen	WP1C0125	29-May-06	Papua New Guinea	JF738661
Myristicaceae	<i>Horsfieldia irya</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC1A0006	3-Sep-08	Papua New Guinea	JF738509
Myristicaceae	<i>Horsfieldia sp.icata</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC2C0095	3-Sep-08	Papua New Guinea	JF738524
Myristicaceae	<i>Horsfieldia sylvestris</i>	G. D. Weiblen	WP3B0652	23-Jun-07	Papua New Guinea	JF738816
Myristicaceae	<i>Horsfieldia sylvestris</i>	G. D. Weiblen	WP3E0762	20-Sep-06	Papua New Guinea	JF738855
Myristicaceae	<i>Myristica fatua</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB4D0238	29-Aug-08	Papua New Guinea	JF738496
Myristicaceae	<i>Myristica fatua</i>	G. D. Weiblen	WP1A0015	14-Mar-06	Papua New Guinea	JF738610
Myristicaceae	<i>Myristica fatua</i>	G. D. Weiblen	WP1D0188	12-Jul-06	Papua New Guinea	JF738681
Myristicaceae	<i>Myristica fatua</i>	G. D. Weiblen	WP3D0733	2-Feb-07	Papua New Guinea	JF738846
Myristicaceae	<i>Myristica globosa</i>	G. D. Weiblen	WP5E1211	2-May-07	Papua New Guinea	JF739009
Myristicaceae	<i>Myristica hollrungii</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA5A0315	15-Jul-08	Papua New Guinea	JF738559
Myristicaceae	<i>Myristica hollrungii</i>	G. D. Weiblen	WP2B0412	26-Apr-06	Papua New Guinea	JF738724
Myristicaceae	<i>Myristica markgraviana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB5B0303	29-Aug-08	Papua New Guinea	JF738499
Myristicaceae	<i>Myristica markgraviana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB5E0345	29-Aug-08	Papua New Guinea	JF738507
Myrsinaceae	<i>Ardisia imperialis</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA4A0221	14-Aug-08	Papua New Guinea	JF738460
Myrsinaceae	<i>Ardisia lanceolata</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB2E0071	29-Aug-09	Papua New Guinea	JF738482
Myrsinaceae	<i>Ardisia lanceolata</i>	G. D. Weiblen	WS5C0786	22-Nov-06	Papua New Guinea	JF739157
Myrsinaceae	<i>Embelia cotinoides</i>	G. D. Weiblen	WP1D0148	10-Jul-06	Papua New Guinea	JF738675
Myrtaceae	<i>Decaspermum sp.</i>	G. D. Weiblen	WP2C0391	10-Jun-06	Papua New Guinea	JF738747
Myrtaceae	<i>Planchonella myrsinodendron</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB4E0230	29-Aug-08	Papua New Guinea	JF738498
Myrtaceae	<i>Syzygium amplum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB4C0246	29-Aug-08	Papua New Guinea	JF738494
Myrtaceae	<i>Syzygium branderhorstii</i>	G. D. Weiblen	WP3E0750	22-Sep-06	Papua New Guinea	JF738851
Myrtaceae	<i>Syzygium branderhorstii</i>	G. D. Weiblen	WP4A1044	22-Aug-07	Papua New Guinea	JF738888
Myrtaceae	<i>Syzygium branderhorstii</i>	G. D. Weiblen	WP4D0763	20-Mar-07	Papua New Guinea	JF738921
Myrtaceae	<i>Syzygium fastigiatum</i>	G. D. Weiblen	WP3A0559	17-Jul-07	Papua New Guinea	JF738795
Myrtaceae	<i>Syzygium furfuraceum</i>	G. D. Weiblen	WP1C1287	30-May-06	Papua New Guinea	JF738670
Myrtaceae	<i>Syzygium furfuraceum</i>	G. D. Weiblen	WP5B1119	6-Oct-07	Papua New Guinea	JF738965
Myrtaceae	<i>Syzygium gonatanthum</i>	G. D. Weiblen	WP3C0647	31-Mar-07	Papua New Guinea	JF738825

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Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Myrtaceae	<i>Syzygium gonatanthum</i>	G. D. Weiblen	WP3E0757	21-Sep-06	Papua New Guinea	JF738852
Myrtaceae	<i>Syzygium gonatanthum</i>	G. D. Weiblen	WP5C1137	14-Jun-07	Papua New Guinea	JF738978
Myrtaceae	<i>Syzygium goniopterum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB5C0305	29-Aug-08	Papua New Guinea	JF738500
Myrtaceae	<i>Syzygium longipes</i>	G. D. Weiblen	WP2C0346	9-Jun-06	Papua New Guinea	JF738742
Myrtaceae	<i>Syzygium longipes</i>	G. D. Weiblen	WP2D0361	12-Aug-06	Papua New Guinea	JF738767
Myrtaceae	<i>Syzygium longipes</i>	G. D. Weiblen	WP3C0643	30-Mar-07	Papua New Guinea	JF738823
Myrtaceae	<i>Syzygium malaccense</i>	G. D. Weiblen	WP4A1043	22-Aug-07	Papua New Guinea	JF738887
Myrtaceae	<i>Syzygium malaccense</i>	G. D. Weiblen	WP5A1101	29-Sep-07	Papua New Guinea	JF738954
Myrtaceae	<i>Syzygium</i> sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB2C0105	29-Aug-09	Papua New Guinea	JF738479
Myrtaceae	<i>Syzygium thornei</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA5D0286	14-Aug-08	Papua New Guinea	JF738472
Nyctaginaceae	<i>Pisonia longirostris</i>	G. D. Weiblen	WP1A0027	3-Mar-06	Papua New Guinea	JF738619
Nyctaginaceae	<i>Pisonia longirostris</i>	G. D. Weiblen	WP5A1110	2-Oct-07	Papua New Guinea	JF738957
Nyctaginaceae	<i>Pisonia longirostris</i>	G. D. Weiblen	WP5E1204	3-May-07	Papua New Guinea	JF739006
Nyctaginaceae	<i>Pisonia longirostris</i>	G. D. Weiblen	WS4E1142	18-Sep-07	Papua New Guinea	JF739131
Oleaceae	<i>Chionanthus brassii</i>	G. D. Weiblen	WP2E0287	7-Sep-06	Papua New Guinea	JF738781
Oleaceae	<i>Chionanthus brassii</i>	G. D. Weiblen	WP2E0302	8-Sep-06	Papua New Guinea	JF738783
Oleaceae	<i>Chionanthus brassii</i>	G. D. Weiblen	WP4E1322	28-Oct-06	Papua New Guinea	JF738949
Oleaceae	<i>Chionanthus brassii</i>	G. D. Weiblen	WP5B1113	9-Oct-07	Papua New Guinea	JF738964
Oleaceae	<i>Chionanthus sessiliflorus</i>	G. D. Weiblen	WP1C0060	23-May-06	Papua New Guinea	JF738655
Oleaceae	<i>Chionanthus sessiliflorus</i>	G. D. Weiblen	WP3C0646	31-Mar-07	Papua New Guinea	JF738824
Pandaceae	<i>Galearia celebica</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC4E0174	3-Sep-08	Papua New Guinea	JF738541
Pandaceae	<i>Galearia celebica</i>	G. D. Weiblen	WP4B0938	13-Aug-07	Papua New Guinea	JF738894
Pandanaceae	<i>Convolvulaceae kaernbachii</i>	G. D. Weiblen	WP2C0400	8-Jun-06	Papua New Guinea	JF738751
Pandanaceae	<i>Freycinetia kanehirae</i>	G. D. Weiblen	WP5E1203	24-Apr-07	Papua New Guinea	JF739005
Pandanaceae	<i>Pandanus danckelmannianus</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA2C0085	13-Aug-08	Papua New Guinea	JF738445
Pandanaceae	<i>Pandanus danckelmannianus</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC5A0239	4-Sep-08	Papua New Guinea	JF738543
Pandanaceae	<i>Pandanus danckelmannianus</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB5B0338	19-Jul-08	Papua New Guinea	JF738588
Pandanaceae	<i>Pandanus kaernbachii</i>	G. D. Weiblen	WP1A0047	9-Mar-06	Papua New Guinea	JF738630
Pandanaceae	<i>Pandanus kaernbachii</i>	G. D. Weiblen	WP2B0408	8-May-06	Papua New Guinea	JF738723
Pandanaceae	<i>Pandanus kaernbachii</i>	G. D. Weiblen	WP4D0765	22-Mar-07	Papua New Guinea	JF738922
Passifloraceae	<i>Passifloraceae</i> sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC3C0154	3-Sep-08	Papua New Guinea	JF738531
Pentaphylacaceae	<i>Ternstroemia cherryi</i>	G. D. Weiblen	WP1B0090	18-Mar-06	Papua New Guinea	JF738648

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Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Pentaphylacaceae	<i>Ternstroemia cherryi</i>	G. D. Weiblen	WP4B0936	11-Aug-07	Papua New Guinea	JF738893
Pentaphylacaceae	<i>Ternstroemia cherryi</i>	G. D. Weiblen	WP4C0914	7-Apr-07	Papua New Guinea	JF738914
Pentaphylacaceae	<i>Ternstroemia cherryi</i>	G. D. Weiblen	WP4C0928	11-Apr-07	Papua New Guinea	JF738918
Phyllanthaceae	<i>Aporosa papuana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB5D0330	29-Aug-08	Papua New Guinea	JF738503
Phyllanthaceae	<i>Breynia cernua</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC5C0192	31-Jul-08	Papua New Guinea	JF738409
Phyllanthaceae	<i>Breynia cernua</i>	G. D. Weiblen	WS2B0513	22-Aug-06	Papua New Guinea	JF739055
Phyllanthaceae	<i>Bridelia macrocarpa</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE3B0127	7-Aug-08	Papua New Guinea	JF738423
Phyllanthaceae	<i>Bridelia macrocarpa</i>	G. D. Weiblen	WP4B0947	13-Aug-07	Papua New Guinea	JF738896
Phyllanthaceae	<i>Bridelia macrocarpa</i>	G. D. Weiblen	WS1E0956	21-Jul-07	Papua New Guinea	JF739041
Phyllanthaceae	<i>Glochidion angulatum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB3E0177	26-Jul-08	Papua New Guinea	JF738385
Phyllanthaceae	<i>Glochidion angulatum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC1B0009	31-Jul-08	Papua New Guinea	JF738394
Phyllanthaceae	<i>Glochidion novo-guineense</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OD2C0063	5-Aug-08	Papua New Guinea	JF738412
Phyllanthaceae	<i>Phyllanthus clamboides</i>	G. D. Weiblen	WP1A0002	3-Mar-06	Papua New Guinea	JF738602
Phyllanthaceae	<i>Phyllanthus clamboides</i>	G. D. Weiblen	WP5B1123	6-Oct-07	Papua New Guinea	JF738967
Phyllanthaceae	<i>Phyllanthus clamboides</i>	G. D. Weiblen	WP5B1353	9-Oct-07	Papua New Guinea	JF738975
Phyllanthaceae	<i>Phyllanthus clamboides</i>	G. D. Weiblen	WS5B0382	6-Nov-06	Papua New Guinea	JF739149
Polygalaceae	<i>Eriandra fragrans</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE1E0046	7-Aug-08	Papua New Guinea	JF738420
Polygalaceae	<i>Xanthophyllum papuanum</i>	G. D. Weiblen	WP1Z3089	14-Apr-08	Papua New Guinea	JF738700
Polygalaceae	<i>Xanthophyllum papuanum</i>	G. D. Weiblen	WP2C0456	6-Jun-06	Papua New Guinea	JF738753
Polygalaceae	<i>Xanthophyllum papuanum</i>	G. D. Weiblen	WP2C0478	9-Jun-06	Papua New Guinea	JF738761
Polygalaceae	<i>Xanthophyllum papuanum</i>	G. D. Weiblen	WP3E0810	22-Sep-06	Papua New Guinea	JF738864
Polygalaceae	<i>Xanthophyllum papuanum</i>	G. D. Weiblen	WP4A1040	24-Aug-07	Papua New Guinea	JF738886
Polygalaceae	<i>Xanthophyllum papuanum</i>	G. D. Weiblen	WP4C0927	11-Apr-07	Papua New Guinea	JF738917
Polygalaceae	<i>Xanthophyllum papuanum</i>	G. D. Weiblen	WP5B1130	10-Oct-07	Papua New Guinea	JF738971
Polygalaceae	<i>Xanthophyllum papuanum</i>	G. D. Weiblen	WP5D1220	10-May-07	Papua New Guinea	JF738994
Putranjivaceae	<i>Drypetes lasiogynoides</i>	G. D. Weiblen	WP1D0185	4-Jul-06	Papua New Guinea	JF738680
Putranjivaceae	<i>Drypetes lasiogynoides</i>	G. D. Weiblen	WP1E0243	3-Aug-06	Papua New Guinea	JF738693
Putranjivaceae	<i>Drypetes lasiogynoides</i>	G. D. Weiblen	WP3A0580	13-Jul-07	Papua New Guinea	JF738800
Putranjivaceae	<i>Drypetes</i> sp.	G. D. Weiblen	WP4B1005	13-Aug-07	Papua New Guinea	JF738899
Rhamnaceae	<i>Ziziphus angustifolia</i>	G. D. Weiblen	WP1B0067	4-May-06	Papua New Guinea	JF738640
Rhamnaceae	<i>Ziziphus angustifolia</i>	G. D. Weiblen	WP3E0747	22-Sep-06	Papua New Guinea	JF738849
Rhamnaceae	<i>Ziziphus angustifolia</i>	G. D. Weiblen	WP4C0866	18-Apr-07	Papua New Guinea	JF738910

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Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Rhamnaceae	<i>Ziziphus angustifolia</i>	G. D. Weiblen	WP5E1277	24-Apr-07	Papua New Guinea	JF739018
Rhamnaceae	<i>Ziziphus djamuensis</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC2C0083	3-Sep-08	Papua New Guinea	JF738521
Rhizophoraceae	<i>Gynotroches axillaris</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB5A0325	19-Jul-08	Papua New Guinea	JF738587
Rosaceae	<i>Prunus gazelle-peninsulae</i>	G. D. Weiblen	WP4A0989	27-Aug-07	Papua New Guinea	JF738877
Rosaceae	<i>Prunus schlechteri</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA5A0231	14-Aug-08	Papua New Guinea	JF738465
Rosaceae	<i>Prunus schlechteri</i>	G. D. Weiblen	WP2C0348	10-Jun-06	Papua New Guinea	JF738743
Rosaceae	<i>Prunus schlechteri</i>	G. D. Weiblen	WP3D0698	12-Feb-07	Papua New Guinea	JF738835
Rubiaceae	<i>Anthocephalus chinensis</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA4B0249	15-Jul-08	Papua New Guinea	JF738556
Rubiaceae	<i>Anthocephalus chinensis</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB1D0046	18-Jul-08	Papua New Guinea	JF738567
Rubiaceae	<i>Canthium cymigerum</i>	G. D. Weiblen	WP3E0736	24-Oct-06	Papua New Guinea	JF738848
Rubiaceae	<i>Canthium longiflorum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB4B0271	29-Aug-08	Papua New Guinea	JF738493
Rubiaceae	<i>Coelospermum salomonense</i>	G. D. Weiblen	WP2E0267	14-Sep-06	Papua New Guinea	JF738778
Rubiaceae	<i>Gardenia papuana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA2A0108	13-Aug-08	Papua New Guinea	JF738442
Rubiaceae	<i>Gardenia papuana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SC1D0049	20-Aug-08	Papua New Guinea	JF738591
Rubiaceae	<i>Guettarda sp. eciosa</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SC5E0378	20-Aug-08	Papua New Guinea	JF738600
Rubiaceae	<i>Mastixiodendron pachyclados</i>	G. D. Weiblen	WP1C0102	23-May-06	Papua New Guinea	JF738656
Rubiaceae	<i>Mastixiodendron pachyclados</i>	G. D. Weiblen	WP4D0903	17-Mar-07	Papua New Guinea	JF738936
Rubiaceae	<i>Mastixiodendron pachyclados</i>	G. D. Weiblen	WP5E1208	3-May-07	Papua New Guinea	JF739008
Rubiaceae	<i>Morinda citrifolia</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA1A0002	13-Aug-08	Papua New Guinea	JF738434
Rubiaceae	<i>Morinda salomonensis</i>	G. D. Weiblen	WP2E1295	7-Sep-06	Papua New Guinea	JF738789
Rubiaceae	<i>Nauclea orientalis</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC2C0093	3-Sep-08	Papua New Guinea	JF738523
Rubiaceae	<i>Nauclea orientalis</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC3C0146	3-Sep-08	Papua New Guinea	JF738530
Rubiaceae	<i>Neonauclea obversifolia</i>	G. D. Weiblen	WP3D0732	13-Feb-07	Papua New Guinea	JF738845
Rubiaceae	<i>Psychotria sp.</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC3C0098	31-Jul-08	Papua New Guinea	JF738406
Rubiaceae	<i>Psychotria sp.</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE5E0330	7-Aug-08	Papua New Guinea	JF738432
Rubiaceae	<i>Randia schumanniana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC4E0173	3-Sep-08	Papua New Guinea	JF738540
Rubiaceae	<i>Sarcocephalus coadunatus</i>	G. D. Weiblen	WS1A0026	28-Feb-06	Papua New Guinea	JF739033
Rubiaceae	<i>Sarcocephalus coadunatus</i>	G. D. Weiblen	WS3B0501	9-Oct-06	Papua New Guinea	JF739078
Rubiaceae	<i>Sarcocephalus coadunatus</i>	G. D. Weiblen	WS5A0322	22-Jun-06	Papua New Guinea	JF739139
Rubiaceae	<i>Timonius pulposus</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OA2E0079	23-Jul-08	Papua New Guinea	JF738373
Rubiaceae	<i>Timonius timon</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SC3B0204	20-Aug-08	Papua New Guinea	JF738597
Rubiaceae	<i>Timonius timon</i>	G. D. Weiblen	WS2B0541	24-Aug-06	Papua New Guinea	JF739061

Appendix 5. Cont'd

Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Rubiaceae	<i>Timonius timon</i>	G. D. Weiblen	WS3A0176	14-Apr-06	Papua New Guinea	JF739073
Rubiaceae	<i>Uncaria appendiculata</i>	G. D. Weiblen	WP1D0176	2-Jun-06	Papua New Guinea	JF738676
Rubiaceae	<i>Uncaria appendiculata</i>	G. D. Weiblen	WP2E0309	3-Oct-06	Papua New Guinea	JF738785
Rubiaceae	<i>Uncaria appendiculata</i>	G. D. Weiblen	WP5E1207	3-May-07	Papua New Guinea	JF739007
Rubiaceae	<i>Uncaria</i> sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA5E0399	15-Jul-08	Papua New Guinea	JF738561
Rubiaceae	<i>Versteegia cauliflora</i>	G. D. Weiblen	WP1D0191	5-Jul-06	Papua New Guinea	JF738684
Rubiaceae	<i>Versteegia cauliflora</i>	G. D. Weiblen	WP2A0418	6-Apr-06	Papua New Guinea	JF738702
Rubiaceae	<i>Versteegia cauliflora</i>	G. D. Weiblen	WP4A0969	28-Aug-07	Papua New Guinea	JF738869
Rubiaceae	<i>Versteegia cauliflora</i>	G. D. Weiblen	WP4B1015	15-Aug-07	Papua New Guinea	JF738903
Rutaceae	<i>Clymenia polyandra</i>	G. D. Weiblen	WP3C0632	3-Apr-07	Papua New Guinea	JF738820
Rutaceae	<i>Evodiella muelleri</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB5C0270	26-Jul-08	Papua New Guinea	JF738391
Rutaceae	<i>Melicope elleryana</i>	G. D. Weiblen	WS1E0976	25-Jul-07	Papua New Guinea	JF739044
Rutaceae	<i>Melicope elleryana</i>	G. D. Weiblen	WS1Z3334	28-Apr-08	Papua New Guinea	JF739052
Rutaceae	<i>Melicope elleryana</i>	G. D. Weiblen	WS2B0522	1-Sep-06	Papua New Guinea	JF739059
Rutaceae	<i>Melicope elleryana</i>	G. D. Weiblen	WS4C0691	29-Nov-06	Papua New Guinea	JF739116
Rutaceae	<i>Melicope elleryana</i>	G. D. Weiblen	WS4C0692	29-Nov-06	Papua New Guinea	JF739117
Rutaceae	<i>Melicope elleryana</i>	G. D. Weiblen	WS5C0774	16-Nov-06	Papua New Guinea	JF739155
Sabiaceae	<i>Meliosma pinnata</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB3A0143	29-Aug-09	Papua New Guinea	JF738483
Salicaceae	<i>Erythrospermum candidum</i>	G. D. Weiblen	WP1C0112	30-May-06	Papua New Guinea	JF738658
Salicaceae	<i>Erythrospermum candidum</i>	G. D. Weiblen	WP2B0415	1-May-06	Papua New Guinea	JF738725
Salicaceae	<i>Erythrospermum candidum</i>	G. D. Weiblen	WP3B0595	25-Jun-07	Papua New Guinea	JF738811
Salicaceae	<i>Erythrospermum candidum</i>	G. D. Weiblen	WP4E0831	30-Oct-06	Papua New Guinea	JF738944
Salicaceae	<i>Erythrospermum candidum</i>	G. D. Weiblen	WP5B1126	6-Oct-07	Papua New Guinea	JF738969
Salicaceae	<i>Erythrospermum candidum</i>	G. D. Weiblen	WP5D1170	9-May-07	Papua New Guinea	JF738988
Salicaceae	<i>Flacourtia rukam</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SC1E0069	20-Aug-08	Papua New Guinea	JF738593
Salicaceae	<i>Homalium foetidum</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC1D0042	3-Sep-08	Papua New Guinea	JF738517
Salicaceae	<i>Ryparosa javanica</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA1D0046	13-Aug-08	Papua New Guinea	JF738440
Sapindaceae	<i>Allophylus cobbe</i>	G. D. Weiblen	WP3E0748	22-Sep-06	Papua New Guinea	JF738850
Sapindaceae	<i>Cupaniopsis macropetala</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA1E0058	13-Aug-08	Papua New Guinea	JF738441
Sapindaceae	<i>Cupaniopsis macropetala</i>	G. D. Weiblen	WP3B0589	25-Jun-07	Papua New Guinea	JF738806
Sapindaceae	<i>Cupaniopsis macropetala</i>	G. D. Weiblen	WP4B0943	10-Aug-07	Papua New Guinea	JF738895
Sapindaceae	<i>Cupaniopsis</i> sp.	G. D. Weiblen	WP4D0889	23-Mar-07	Papua New Guinea	JF738931

Appendix 5. Cont'd

Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Sapindaceae	Cupaniopsis sp.	G. D. Weiblen	WS4D0845	8-Mar-07	Papua New Guinea	JF739123
Sapindaceae	Dictyoneura obtusa	G. D. Weiblen	WP5E1264	1-May-07	Papua New Guinea	JF739014
Sapindaceae	Ganophyllum falcatum	T. J. S. Whitfeld, G. Sosanika, B. Bau	SC1D0066	20-Aug-08	Papua New Guinea	JF738592
Sapindaceae	Ganophyllum falcatum	G. D. Weiblen	WP2B0483	25-Apr-06	Papua New Guinea	JF738730
Sapindaceae	Guioa comesperma	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE4A0250	7-Aug-08	Papua New Guinea	JF738426
Sapindaceae	Guioa comesperma	G. D. Weiblen	WP2A0423	5-May-06	Papua New Guinea	JF738704
Sapindaceae	Guioa comesperma	G. D. Weiblen	WP2D0358	12-Aug-06	Papua New Guinea	JF738766
Sapindaceae	Guioa comesperma	G. D. Weiblen	WP4A1343	20-Aug-07	Papua New Guinea	JF738891
Sapindaceae	Guioa comesperma	G. D. Weiblen	WP4E0837	27-Oct-06	Papua New Guinea	JF738946
Sapindaceae	Guioa comesperma	G. D. Weiblen	WP5D1215	10-May-07	Papua New Guinea	JF738992
Sapindaceae	Harpullia aeruginosa	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA5A0245	14-Aug-08	Papua New Guinea	JF738468
Sapindaceae	Harpullia angustifolia	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA3B0133	14-Aug-08	Papua New Guinea	JF738451
Sapindaceae	Harpullia arborea	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE3C0139	7-Aug-08	Papua New Guinea	JF738424
Sapindaceae	Harpullia arborea	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA3B0131	13-Aug-08	Papua New Guinea	JF738450
Sapindaceae	Harpullia arborea	G. D. Weiblen	WP2B0407	10-Jun-06	Papua New Guinea	JF738722
Sapindaceae	Harpullia arborea	G. D. Weiblen	WP4D0797	19-Mar-07	Papua New Guinea	JF738925
Sapindaceae	Harpullia arborea	G. D. Weiblen	WP5D1360	15-May-07	Papua New Guinea	JF739000
Sapindaceae	Harpullia longipetala	T. J. S. Whitfeld, G. Sosanika, B. Bau	OA5B0194	23-Jul-08	Papua New Guinea	JF738375
Sapindaceae	Harpullia longipetala	G. D. Weiblen	WP2B0487	26-Apr-06	Papua New Guinea	JF738732
Sapindaceae	Harpullia longipetala	G. D. Weiblen	WP2C0397	16-Jun-06	Papua New Guinea	JF738750
Sapindaceae	Harpullia longipetala	G. D. Weiblen	WP5E1200	1-May-07	Papua New Guinea	JF739004
Sapindaceae	Harpullia ramiflora	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC4D0189	3-Sep-08	Papua New Guinea	JF738537
Sapindaceae	Jagera javanica	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC3B0090	28-Jul-08	Papua New Guinea	JF738404
Sapindaceae	Lepidopetalum xylocarpum	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC3C0096	28-Jul-08	Papua New Guinea	JF738405
Sapindaceae	Lythraceae longipetala	G. D. Weiblen	WP2C0465	7-Jun-06	Papua New Guinea	JF738755
Sapindaceae	Mischocarpus largifolius	G. D. Weiblen	WP5E1258	1-May-07	Papua New Guinea	JF739011
Sapindaceae	Pometia pinnata	G. D. Weiblen	WP1B0066	4-May-06	Papua New Guinea	JF738639
Sapindaceae	Pometia pinnata	G. D. Weiblen	WP4D0850	27-Apr-07	Papua New Guinea	JF738926
Sapindaceae	Pometia pinnata	G. D. Weiblen	WP5C1164	16-Jun-07	Papua New Guinea	JF738983
Sapindaceae	Pometia pinnata	G. D. Weiblen	WP5E1367	26-Apr-06	Papua New Guinea	JF739023
Sapindaceae	Sapindaceae sp.	G. D. Weiblen	WP2C0350	7-Jun-06	Papua New Guinea	JF738744
Sapindaceae	Toechima erythrocarpum	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC3B0087	31-Jul-08	Papua New Guinea	JF738403

Appendix 5. Cont'd

Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Sapindaceae	<i>Tristiropsis acutangula</i>	G. D. Weiblen	WP3B0594	30-Jun-07	Papua New Guinea	JF738810
Sapindaceae	<i>Tristiropsis acutangula</i>	G. D. Weiblen	WP3E0761	22-Sep-06	Papua New Guinea	JF738854
Sapindaceae	<i>Tristiropsis acutangula</i>	G. D. Weiblen	WP3E0803	22-Sep-06	Papua New Guinea	JF738862
Sapotaceae	<i>Chrysophyllum roxburghii</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB2C0107	29-Aug-09	Papua New Guinea	JF738480
Sapotaceae	<i>Palaquium morobense</i>	G. D. Weiblen	WP1A0020	7-Mar-06	Papua New Guinea	JF738614
Sapotaceae	<i>Palaquium morobense</i>	G. D. Weiblen	WP1A0026	6-Mar-06	Papua New Guinea	JF738618
Sapotaceae	<i>Palaquium morobense</i>	G. D. Weiblen	WP1A0030	3-Mar-06	Papua New Guinea	JF738622
Sapotaceae	<i>Palaquium morobense</i>	G. D. Weiblen	WP1B0054	8-Mar-06	Papua New Guinea	JF738633
Sapotaceae	<i>Palaquium morobense</i>	G. D. Weiblen	WP5C1149	20-Jun-07	Papua New Guinea	JF738980
Sapotaceae	<i>Palaquium warburgianum</i>	G. D. Weiblen	WP1B0069	20-Mar-06	Papua New Guinea	JF738641
Sapotaceae	<i>Palaquium warburgianum</i>	G. D. Weiblen	WP1D0143	16-Jun-06	Papua New Guinea	JF738673
Sapotaceae	<i>Palaquium warburgianum</i>	G. D. Weiblen	WP3C0634	3-Apr-07	Papua New Guinea	JF738821
Sapotaceae	<i>Palaquium warburgianum</i>	G. D. Weiblen	WP3D0683	15-Feb-07	Papua New Guinea	JF738828
Sapotaceae	<i>Planchonella myrsinodendron</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB1E0058	25-Jul-08	Papua New Guinea	JF738378
Sapotaceae	<i>Planchonella</i> sp.	G. D. Weiblen	WP1C0151	23-May-06	Papua New Guinea	JF738663
Sapotaceae	<i>Planchonella</i> sp.	G. D. Weiblen	WP2A0433	7-Apr-06	Papua New Guinea	JF738707
Sapotaceae	<i>Planchonella</i> sp.	G. D. Weiblen	WP2B0489	25-Apr-06	Papua New Guinea	JF738733
Sapotaceae	<i>Planchonella</i> sp.	G. D. Weiblen	WP3C0666	2-Apr-07	Papua New Guinea	JF738826
Sapotaceae	<i>Planchonella xylocarpa</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PB3D0206	29-Aug-09	Papua New Guinea	JF738490
Sapotaceae	<i>Pouteria obovata</i>	G. D. Weiblen	WP1E0221	3-Aug-06	Papua New Guinea	JF738689
Sapotaceae	<i>Pouteria obovata</i>	G. D. Weiblen	WP1E0249	1-Aug-06	Papua New Guinea	JF738694
Sapotaceae	<i>Pouteria obovata</i>	G. D. Weiblen	WP1E1290	1-Aug-06	Papua New Guinea	JF738698
Sapotaceae	<i>Pouteria obovata</i>	G. D. Weiblen	WP2B0547	25-Apr-06	Papua New Guinea	JF738739
Sapotaceae	<i>Pouteria obovata</i>	G. D. Weiblen	WP2C0471	16-Jun-06	Papua New Guinea	JF738759
Sapotaceae	<i>Pouteria obovata</i>	G. D. Weiblen	WP4C0910	9-Apr-07	Papua New Guinea	JF738912
Sapotaceae	<i>Pouteria obovata</i>	G. D. Weiblen	WP4E0848	3-May-07	Papua New Guinea	JF738948
Sapotaceae	<i>Pouteria</i> sp.	T. J. S. Whitfeld, G. Sosanika, B. Bau	OE3C0141	7-Aug-08	Papua New Guinea	JF738425
Sapotaceae	<i>Pouteria thyrsoidea</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA2E0072	13-Aug-08	Papua New Guinea	JF738448
Simaroubaceae	<i>Ailanthus integrifolia</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA2A0113	13-Aug-08	Papua New Guinea	JF738444
Simaroubaceae	<i>Ailanthus integrifolia</i>	G. D. Weiblen	WP1B0073	21-Mar-06	Papua New Guinea	JF738642
Simaroubaceae	<i>Picrasma javanica</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OC1E0040	31-Jul-08	Papua New Guinea	JF738397
Stemonuraceae	<i>Medusanthera laxiflora</i>	G. D. Weiblen	WP1A0040	7-Mar-06	Papua New Guinea	JF738627

Appendix 5. Cont'd

Family	Species	Collector	Collection number	Collection date	Country	GenBank Accession No.
Stemonuraceae	<i>Medusanthera laxiflora</i>	G. D. Weiblen	WP1C0167	26-May-06	Papua New Guinea	JF738667
Stemonuraceae	<i>Medusanthera laxiflora</i>	G. D. Weiblen	WP2D1298	12-Aug-06	Papua New Guinea	JF738775
Stemonuraceae	<i>Medusanthera laxiflora</i>	G. D. Weiblen	WP2E0298	5-Sep-06	Papua New Guinea	JF738782
Stemonuraceae	<i>Medusanthera laxiflora</i>	G. D. Weiblen	WP4B1011	13-Aug-07	Papua New Guinea	JF738901
Stemonuraceae	<i>Medusanthera laxiflora</i>	G. D. Weiblen	WP4C0913	7-Apr-07	Papua New Guinea	JF738913
Stemonuraceae	<i>Medusanthera laxiflora</i>	G. D. Weiblen	WP4D0887	20-Mar-07	Papua New Guinea	JF738930
Stemonuraceae	<i>Medusanthera laxiflora</i>	G. D. Weiblen	WP5D1362	12-May-07	Papua New Guinea	JF739001
Tetramelaceae	<i>Octomeles sumatrana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OD3D0131	5-Aug-08	Papua New Guinea	JF738414
Tetramelaceae	<i>Octomeles sumatrana</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SB2E0093	18-Jul-08	Papua New Guinea	JF738578
Tetramelaceae	<i>Octomeles sumatrana</i>	G. D. Weiblen	WS3B0500	11-Oct-06	Papua New Guinea	JF739077
Tetramelaceae	<i>Tetrameles nudiflora</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OA2B0109	23-Jul-08	Papua New Guinea	JF738372
Tetramelaceae	<i>Tetrameles nudiflora</i>	G. D. Weiblen	WS4D0871	8-Mar-07	Papua New Guinea	JF739125
Ulmaceae	<i>Trema orientalis</i>	G. D. Weiblen	WS4A0268	19-May-06	Papua New Guinea	JF739101
Ulmaceae	<i>Trema orientalis</i>	G. D. Weiblen	WS5D0816	28-Feb-07	Papua New Guinea	JF739162
Urticaceae	<i>Dendrocnide cordata</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA4B0252	15-Jul-08	Papua New Guinea	JF738557
Urticaceae	<i>Dendrocnide cordata</i>	G. D. Weiblen	WS5B0366	10-Nov-06	Papua New Guinea	JF739147
Urticaceae	<i>Dendrocnide longifolia</i>	G. D. Weiblen	WS5D0815	26-Feb-07	Papua New Guinea	JF739161
Urticaceae	<i>Leucosyke australis</i>	G. D. Weiblen	WS3C0666	6-Dec-06	Papua New Guinea	JF739086
Urticaceae	<i>Leucosyke australis</i>	G. D. Weiblen	WS3D0902	24-May-07	Papua New Guinea	JF739090
Urticaceae	<i>Leucosyke australis</i>	G. D. Weiblen	WS4D0869	3-Mar-07	Papua New Guinea	JF739124
Urticaceae	<i>Leucosyke capitellata</i>	G. D. Weiblen	WS1E0961	27-Jul-07	Papua New Guinea	JF739043
Urticaceae	<i>Oreocnide rufescens</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB3D0165	26-Jul-08	Papua New Guinea	JF738384
Urticaceae	<i>Oreocnide rufescens</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PC1C0034	3-Sep-08	Papua New Guinea	JF738516
Urticaceae	<i>Pipturus argenteus</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OD1B0013	5-Aug-08	Papua New Guinea	JF738411
Vitaceae	<i>Cayratia geniculata</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OB1E0062	25-Jul-08	Papua New Guinea	JF738379
Vitaceae	<i>Cissus repens</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	PA5A0237	14-Aug-08	Papua New Guinea	JF738467
Vitaceae	<i>Leea indica</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	OA4A0178	23-Jul-08	Papua New Guinea	JF738374
Vitaceae	<i>Leea indica</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SA1B0019	14-Jul-08	Papua New Guinea	JF738545
Vitaceae	<i>Leea indica</i>	T. J. S. Whitfeld, G. Sosanika, B. Bau	SC3A0170	20-Aug-08	Papua New Guinea	JF738595
Vitaceae	<i>Tetrastigma lauterbachianum</i>	G. D. Weiblen	WP5E1369	3-May-07	Papua New Guinea	JF739024

Appendix 6. Values of traits and insect abundance for 224 species of lowland rainforest trees in New Guinea. Values represent species means for all variables except leaf biomass, which represents maximum values per species.

Appendix 6

Species	Family	Succession stage	Number of stems	Wood			Carbon (%)	Nitrogen (%)	Mature leaves (kg)	Immature leaves (kg)	Total leaves (kg)	Number of caterpillars	Number of leaf miners	Number of wood borers
				SLA (cm ² /g)	Density (g/ml)									
<i>Abrus precatorius</i>	Fabaceae	Late	2	199.78±0.3	0.34±0.07	47.64	2.71	3.2±2.1	0±0	3.2±2.1	5±7.1	2±2.8	331.4	
<i>Aglaia argentea</i>	Meliaceae	Late	3	113.46±20.6	0.60±0.08	44.75	2.23	14.6±7.7	0.538±0.293	15.14±7.7	4.3±7.5	0±0	66.3	
<i>Aglaia brassii</i>	Meliaceae	Late	3	151.53±20.2	0.62±0	46.20	2.92	1.6±0.6	0±0	1.6±0.6	1±1.7	2.7±4.6	-	
<i>Aglaia cucullata</i>	Meliaceae	Late	1	188±0	0.86±0.16	45.12	2.98	1.2±0	0±0	1.2±0	0±0	9±0	32.2	
<i>Aglaia lepiorrhachis</i>	Meliaceae	Late	7	109.96±10.8	0.77±0.07	48.66	2.10	16.2±6.2	0.033±0.013	16.2±6.2	6.6±6.9	1.4±2.9	49.0	
<i>Ailanthus integrifolia</i>	Simaroubaceae	Late	1	129.43±0	0.36±0	40.42	1.90	1.3±0	0.131±0	1.43±0	0±0	0±0	531.5	
<i>Alstonia scholaris</i>	Apocynaceae	Late	4	133.16±34.9	0.33±0.02	47.32	1.95	12.4±5.5	0.501±0.251	12.4±5.5	1.5±3	0±0	33.0	
<i>Alstonia scholaris</i>	Apocynaceae	Early	5	138.77±26.5	0.41±0.01	47.32	1.95	2.5±0.8	0.036±0.016	2.5±0.8	0.2±0.4	0±0	33.0	
<i>Aporosa papuana</i>	Phyllanthaceae	Late	1	105.72±0	0.62±0	42.12	1.59	3.8±0	0±0	3.8±0	5±0	0±0	-	
<i>Archidendron lucyi</i>	Fabaceae	Late	1	197.85±0	0.55±0	46.24	4.24	26.4±0	0±0	26.4±0	7±0	0±0	-	
<i>Archidendron ptenopum</i>	Fabaceae	Late	11	139.29±23.2	0.52±0.13	47.96	2.46	9.2±2.3	1.107±0.332	9.2±2.3	1.1±2	0±0	91.2	
<i>Ardisia lanceolata</i>	Myrsinaceae	Early	1	115.09±0	0.54±0	44.57	1.24	1.2±0	0±0	1.2±0	0±0	0±0	-	
<i>Areca catechu</i>	Arecaceae	Early	9	167.4±25.5	0.13±0	44.44	2.41	2±0.4	0.104±0.035	2±0.4	4±6.1	0±0	177.0	
<i>Artocarpus camansi</i>	Moraceae	Early	4	123.08±16.2	0.34±0.08	41.37	2.26	49±23.5	1.113±0.518	49.03±23.5	4.8±9.5	0±0	781.0	
<i>Artocarpus sepicanus</i>	Moraceae	Late	5	138.52±24.3	0.35±0.03	42.43	1.77	14±4.8	0±0	14±4.8	5±5.5	0±0	281.7	
<i>Artocarpus sepicanus</i>	Moraceae	Early	1	133.59±0	0.45±0	42.43	1.77	5.4±0	0.302±0	5.7±0	0±0	0±0	281.7	
<i>Barringtonia apiculata</i>	Lecythidaceae	Late	3	215.81±18.8	0.50±0.04	45.38	2.19	2.4±1.1	0.253±0.146	2.4±1.1	8±5	1.7±2.9	251.8	
<i>Breynia cernua</i>	Phyllanthaceae	Early	3	192.08±64.9	0.47±0.05	42.47	2.79	3.8±0.6	0.325±0.168	3.89±0.6	185±235.5	0±0	-	
<i>Bridelia macrocarpa</i>	Phyllanthaceae	Late	2	268.63±126.6	0.51±0.04	45.09	2.65	5±2.7	0.333±0.236	5.33±2.7	8.5±12	2±0	-	
<i>Bridelia macrocarpa</i>	Phyllanthaceae	Early	1	292.59±0	0.50±0	45.09	2.65	0.2±0	4.6±0	4.75±0	257±0	0±0	-	
<i>Callicarpa farinosa</i>	Lamiaceae	Early	1	130.24±0	0.59±0	46.61	2.40	1.8±0	0.093±0	1.89±0	4±0	0±0	-	
<i>Callicarpa longifolia</i>	Lamiaceae	Early	8	179.74±42.7	0.52±0.02	48.36	2.29	5±1.8	1.348±0.442	5.29±1.8	8.8±9.2	0.3±0.5	-	
<i>Calophyllum soulattri</i>	Clusiaceae	Late	2	146.3±53.1	0.49±0.11	46.64	1.06	32.2±19.2	0.313±0.221	32.51±19.2	22±29.7	1±1.4	259.0	
<i>Canarium acutifolium</i>	Burseraceae	Late	4	135.2±15.5	0.55±0	41.78	2.41	3.6±1.1	0.075±0.037	3.6±1.1	1.3±1.9	1.3±1.9	-	
<i>Canarium acutifolium</i>	Burseraceae	Early	2	142.45±34.5	0.49±0	41.78	2.41	1.4±0.3	0±0	1.4±0.3	0±0	0±0	-	
<i>Canarium indicum</i>	Burseraceae	Late	2	106.96±2.1	0.56±0.11	45.00	2.00	18.6±1.3	0±0	18.6±1.3	12.5±17.7	13.5±19.1	258.2	
<i>Canarium indicum</i>	Burseraceae	Early	1	103.1±0	0.69±0	45.00	2.00	6.5±0	0.06±0	6.56±0	0±0	0±0	258.2	
<i>Canarium oleosum</i>	Burseraceae	Late	2	137.9±32.7	0.49±0.26	42.59	1.87	7±4.9	0.078±0.055	7.08±4.9	0±0	0±0	-	
<i>Canarium vitiense</i>	Burseraceae	Late	1	128.63±0	0.30±0	42.08	2.30	2±0	0.018±0	2.02±0	2±0	2±0	99.3	
<i>Canthium cymigerum</i>	Rubiaceae	Late	1	138.96±0	0.72±0	46.91	2.07	11±0	0.332±0	11.33±0	2±0	0±0	-	
<i>Caryota rumphiana</i>	Arecaceae	Late	2	93.03±59.8	0.26±0	40.63	2.21	21±2.7	0±0	21±2.7	8±11.3	0±0	149.0	
<i>Celtis latifolia</i>	Cannabaceae	Late	23	113.32±23.2	0.68±0.08	37.77	1.38	80.6±17.9	0.075±0.016	80.6±17.9	5.5±16.6	0.2±0.6	217.0	
<i>Celtis latifolia</i>	Cannabaceae	Early	4	103.32±18.4	0.65±0.08	37.77	1.38	4.8±1.5	0.031±0.015	4.8±1.5	0.5±0.6	0±0	217.0	
<i>Celtis philippensis</i>	Cannabaceae	Late	6	112.37±17.7	0.55±0.1	39.59	2.25	86.3±33.3	0.329±0.134	86.63±33.3	9.3±9.6	0.7±1.6	129.3	
<i>Celtis philippensis</i>	Cannabaceae	Early	1	121.13±0	0.48±0	39.59	2.25	0.4±0	0.026±0	0.43±0	0±0	0±0	129.3	
<i>Cerbera floribunda</i>	Apocynaceae	Late	4	178.2±19.3	0.42±0.03	45.15	1.88	21.5±7	0.403±0.19	21.64±7	0.8±1	0±0	82.0	
<i>Cerbera floribunda</i>	Apocynaceae	Early	2	238.37±54.6	0.55±0.11	45.15	1.88	8±4.3	0.226±0.16	8.23±4.3	2±1.4	0±0	82.0	
<i>Chionanthus sessiliflorus</i>	Oleaceae	Late	3	111.67±13.1	0.65±0.08	46.98	1.42	14±6.4	0±0	14±6.4	18.7±29.8	0±0	-	

Appendix 6. Cont'd

Species	Family	Successio n stage	Number of stems	SLA (cm ² /g)	Wood		Carbon (%)	Nitrogen (%)	Mature leaves (kg)	Immature leaves (kg)	Total leaves (kg)	Number of caterpillars	Number of leaf miners	Number of wood borers
					Density (g/ml)									
Chisocheton ceramicus	Meliaceae	Late	19	149.63±22.5	0.49±0.08	45.43	2.74	32.8±10	1.892±0.55	32.92±10	6.1±9.1	2.3±4.8	385.0	
Chisocheton ceramicus	Meliaceae	Early	1	170.98±0	0.54±0	45.43	2.74	2.5±0	0±0	2.5±0	0±0	0±0	385.0	
Chisocheton formicarum	Meliaceae	Late	2	130.71±11	0.56±0	47.17	3.28	5±1.8	0.368±0.26	5±1.8	2±0	0.5±0.7	-	
Chisocheton trichocladus	Meliaceae	Late	10	138.99±26.7	0.57±0.05	46.14	2.17	11±3.4	0.282±0.098	11±3.4	1.5±1.9	0.2±0.4	-	
Cinnamomum grandiflorum	Lauraceae	Late	3	123.62±26.7	0.38±0.05	46.94	1.82	23.8±11.1	0±0	23.8±11.1	15.7±26.3	8±13.9	40.0	
Claoxylon polot	Euphorbiaceae	Early	1	126.67±0	0.50±0	38.92	1.61	6.4±0	0.322±0	6.72±0	1±0	0±0	-	
Clymenia polyandra	Rutaceae	Late	1	123.29±0	0.83±0	40.75	1.91	8±0	0±0	8±0	0±0	1±0	-	
Commersonia bartramia	Malvaceae	Early	25	174.94±33.7	0.43±0.06	47.27	2.41	17±4.7	0.498±0.151	17.5±4.7	17.9±21.6	3±6.3	28.7	
Cordyline terminalis	Asparagaceae	Early	1	120.78±0	0.49±0	44.47	1.36	2.4±0	0±0	2.4±0	0±0	0±0	-	
Croton womersleyi	Euphorbiaceae	Late	1	216.39±0	0.32±0	40.41	3.36	2.1±0	0±0	2.1±0	0±0	0±0	-	
Cryptocarya caloneura	Lauraceae	Late	3	209.3±83.3	0.46±0.06	46.11	2.33	12.8±5.4	1.6±0.924	12.8±5.4	11.3±14.6	0.7±0.6	335.3	
Cryptocarya depressa	Lauraceae	Late	2	156.84±10.4	0.49±0	46.47	2.25	9.2±3.7	0.041±0.029	9.24±3.7	66±77.8	4.5±6.4	-	
Cryptocarya mackinnoniana	Lauraceae	Late	5	115.44±9.3	0.55±0.25	49.83	2.02	10.2±3.7	0±0	10.2±3.7	2±2.9	0±0	32.0	
Cryptocarya multipaniculata	Lauraceae	Late	2	176.51±41.3	0.44±0.13	48.17	2.05	5.8±0.3	0.119±0.084	5.8±0.3	11±2.8	3±1.4	-	
Cupaniopsis macropetala	Sapindaceae	Late	1	118.37±0	0.73±0.03	46.56	1.92	27.4±0	0±0	27.4±0	6±0	13±0	-	
Dendrocnide longifolia	Urticaceae	Late	3	166.05±70.2	0.27±0.03	39.17	2.00	75±41.5	0.138±0.08	75±41.5	0±0	0±0	161.6	
Dendrocnide longifolia	Urticaceae	Early	11	141.21±32.2	0.26±0.05	39.17	2.00	22±7.3	1.372±0.417	22.13±7.3	1±1.3	0±0	161.6	
Dictyoneura obtusa	Sapindaceae	Late	1	94.43±0	0.81±0	42.13	2.15	13.2±0	0±0	13.2±0	8±0	0±0	19.7	
Diospyros ellipticifolia	Ebenaceae	Late	2	133.84±2.7	0.66±0	45.56	1.86	1.4±0.3	0±0	1.4±0.3	1±1.4	0±0	-	
Dracaena angustifolia	Asparagaceae	Late	4	183.44±41.7	0.41±0.03	45.44	3.10	4.4±1.6	0.087±0.047	4.47±1.6	2.3±3.3	0±0	2206.0	
Dracontomelon dao	Anacardiaceae	Late	7	147.66±39	0.55±0.07	41.43	2.04	80.1±32	0.16±0.06	80.1±32	10.1±11.4	3.1±7	24.0	
Dracontomelon dao	Anacardiaceae	Early	4	153.97±10.4	0.60±0.04	41.43	2.04	4±0.5	0±0	4±0.5	3.8±3	0±0	24.0	
Drypetes lasiogynoides	Putranjivaceae	Late	6	109.74±18.6	0.65±0.04	43.08	1.86	29.2±11.4	0.993±0.405	29.2±11.4	9±10.2	1±2	169.7	
Dysoxylum arborescens	Meliaceae	Late	13	149.58±40.3	0.58±0.04	47.43	1.89	62±17.4	0.034±0.009	62±17.3	8.9±17.4	2.8±7.3	-	
Dysoxylum arborescens	Meliaceae	Early	2	101.58±20.5	0.61±0.13	47.43	1.89	3.5±2.2	0±0	3.5±2.2	2.5±3.5	0±0	-	
Dysoxylum brassii	Meliaceae	Late	2	106.66±15.1	0.70±0.12	50.05	2.60	6.8±2.6	0.199±0.141	7±2.5	1±1.4	6.5±7.8	-	
Dysoxylum gaudichaudianum	Meliaceae	Early	1	167.53±0	0.48±0	44.66	2.59	0.3±0	0±0	0.3±0	0±0	0±0	18.3	
Dysoxylum micranthum	Meliaceae	Late	1	153.88±0	0.72±0	44.54	2.03	3±0	0±0	3±0	2±0	0±0	-	
Dysoxylum molle	Meliaceae	Late	3	118.79±28	0.73±0.07	50.24	2.75	4.8±2.5	0.398±0.221	4.8±2.5	1.7±1.5	2±2.6	-	
Dysoxylum pettigrewianum	Meliaceae	Late	4	170.04±22.5	0.63±0.16	44.87	2.33	11±5.3	0.077±0.039	11.08±5.3	0.3±0.5	2.8±5.5	-	
Dysoxylum richardianum	Meliaceae	Late	7	121.44±20.6	0.66±0.07	49.93	3.00	125.2±48.4	1.6±0.601	126.8±48.4	30.9±57.7	5.7±8.7	-	
Elaeocarpus amplifolius	Elaeocarpaceae	Late	6	148.28±22.7	0.50±0.06	46.06	1.85	6±2.1	0±0	6±2.1	0.8±1	0.3±0.5	-	
Elaeocarpus miegei	Elaeocarpaceae	Late	1	121.84±0	0.61±0	46.58	1.45	4.4±0	0±0	4.4±0	51±0	4±0	-	
Embelia cotinoides	Myrsinaceae	Late	1	128.23±0	0.25±0	-	-	1.8±0	0±0	1.8±0	3±0	0±0	-	
Endospermum labios	Euphorbiaceae	Late	1	314.75±0	0.31±0	42.88	3.68	3.2±0	0.19±0	3.39±0	0±0	0±0	-	
Endospermum labios	Euphorbiaceae	Early	3	167.99±36.2	0.34±0.03	42.88	3.68	2.6±0.5	0.217±0.116	2.64±0.5	3.3±3.5	0±0	-	
Endospermum medullosum	Euphorbiaceae	Late	1	75±0	0.26±0	46.11	2.02	122.2±0	1.826±0	124.03±0	4±0	0±0	314.7	
Entada phaseoloides	Fabaceae	Late	2	203.74±106.2	0.29±0.09	47.05	3.74	1.2±1	0.415±0.294	1.62±1	33±46.7	0.5±0.7	103.0	

Appendix 6. Cont'd

Species	Family	Succession stage	Number of stems	SLA (cm ² /g)	Wood Density (g/ml)	Carbon (%)	Nitrogen (%)	Mature leaves (kg)	Immature leaves (kg)	Total leaves (kg)	Number of caterpillars	Number of leaf miners	Number of wood borers
<i>Erythrospermum candidum</i>	Salicaceae	Late	13	141.45±28.6	0.56±0.07	41.83	2.31	46.6±14	0.335±0.127	46.94±14	3.9±9.2	0.1±0.3	72.0
<i>Faradaya splendida</i>	Lamiaceae	Late	1	153.88±0	0.35±0	47.78	2.41	8.4±0	0.141±0	8.54±0	0±0	0±0	-
<i>Ficus ampelos</i>	Moraceae	Early	1	130.24±0	0.61±0	34.84	1.54	2.4±0	0±0	2.4±0	0±0	0±0	-
<i>Ficus arfakensis</i>	Moraceae	Late	1	127.84±0	0.47±0	36.54	1.63	1.2±0	0±0	1.2±0	0±0	0±0	-
<i>Ficus bernaysii</i>	Moraceae	Late	13	152.25±42.4	0.49±0.03	37.27	1.79	5±1.7	0.137±0.047	5.08±1.6	4.9±11.8	0.4±0.8	232.0
<i>Ficus congesta</i>	Moraceae	Late	2	176.16±6.3	0.39±0	40.81	1.69	2.4±1.2	0.255±0.18	2.65±1.2	4.5±6.4	0±0	-
<i>Ficus congesta</i>	Moraceae	Early	8	135.99±23.8	0.43±0.07	40.81	1.69	11.8±3.1	0.488±0.173	11.8±3.1	6.4±8.3	0±0	-
<i>Ficus gul</i>	Moraceae	Late	1	233.41±0	0.58±0	36.75	1.79	1.4±0	0±0	1.4±0	3±0	1±0	-
<i>Ficus gul</i>	Moraceae	Early	3	141.73±24.1	0.57±0	36.75	1.79	8±3.6	0.097±0.049	8.1±3.6	2.3±4	0±0	-
<i>Ficus hispidooides</i>	Moraceae	Early	1	132.32±0	0.29±0	36.22	2.16	6.3±0	0±0	6.3±0	4±0	1±0	-
<i>Ficus hombroniana</i>	Moraceae	Late	8	126.93±23.1	0.52±0.05	38.63	1.39	28.6±9.6	0.236±0.084	28.6±9.6	33.9±70.4	2.4±4.1	488.5
<i>Ficus melinocarpa</i>	Moraceae	Late	1	229.54±0	0.29±0	36.13	2.12	1.8±0	0±0	1.8±0	0±0	0±0	101.7
<i>Ficus melinocarpa</i>	Moraceae	Early	3	171.06±39.9	0.44±0.09	36.13	2.12	30.8±15.2	0.085±0.049	30.8±15.2	32.3±48.3	0±0	101.7
<i>Ficus nodosa</i>	Moraceae	Late	1	188.85±0	0.21±0	37.60	1.58	1±0	0±0	1±0	2±0	0±0	342.0
<i>Ficus nodosa</i>	Moraceae	Early	10	161.31±39	0.27±0.05	37.60	1.58	7±2.9	2±0.631	9±2.9	2.1±2.6	0.4±1.3	342.0
<i>Ficus pungens</i>	Moraceae	Late	1	153.88±0	0.54±0	37.14	1.88	9.2±0	0.308±0	9.51±0	7±0	0±0	1645.5
<i>Ficus pungens</i>	Moraceae	Early	31	139.6±28.2	0.49±0.11	37.14	1.88	37±9.6	0.924±0.266	37.92±9.6	11±18.1	0.6±0.8	1645.5
<i>Ficus rubrivestimenta</i>	Moraceae	Late	5	157.05±12.5	0.58±0.05	42.76	1.89	9.8±3.2	0.29±0.119	9.91±3.2	28.8±9.9	0.6±0.9	-
<i>Ficus semivestita</i>	Moraceae	Early	3	214.84±42.1	0.21±0.04	40.41	2.24	1.2±0.5	0.072±0.042	1.2±0.5	2.7±1.2	0.3±0.6	-
<i>Ficus trachypison</i>	Moraceae	Late	2	179.91±42.3	0.41±0.02	38.66	1.93	16±10.1	0.083±0.059	16±10.1	4.5±6.4	4±2.8	1065.0
<i>Ficus trachypison</i>	Moraceae	Early	2	181.46±95.2	0.40±0.1	38.66	1.93	3.8±0.2	0±0	3.8±0.2	5±7.1	0±0	1065.0
<i>Ficus variegata</i>	Moraceae	Early	207	153.76±36.8	0.32±0.08	40.44	1.96	41.7±5	9±0.752	41.95±5	2.9±5.9	0.5±1.9	359.1
<i>Ficus wassa</i>	Moraceae	Late	2	127.07±1.6	0.22±0	33.54	1.72	2±1.3	0±0	2±1.3	0.5±0.7	0±0	-
<i>Ficus wassa</i>	Moraceae	Early	4	114.56±25.1	0.63±0.03	33.54	1.72	4±1	0.104±0.052	4.1±1	13.3±25.8	1±2	-
<i>Galearia celebica</i>	Pandaceae	Late	3	138.28±34.5	0.55±0.05	46.04	2.26	51±28.4	0±0	51±28.4	0.7±0.6	0.3±0.6	100.3
<i>Ganophyllum falcatum</i>	Sapindaceae	Late	2	251.47±30.9	0.62±0	47.01	2.30	1.6±0.4	0.009±0.006	1.61±0.4	10±9.9	0±0	-
<i>Garcinia latissima</i>	Clusiaceae	Late	1	107.08±0	0.74±0	42.84	1.53	5±0	0.151±0	5.15±0	0±0	0±0	-
<i>Garcinia maluensis</i>	Clusiaceae	Late	1	143.27±0	0.70±0	42.13	1.62	7.5±0	0±0	7.5±0	14±0	0±0	-
<i>Garuga floribunda</i>	Burseraceae	Late	1	239.36±0	0.39±0	43.76	2.32	1±0	0±0	1±0	0±0	0±0	209.5
<i>Garuga floribunda</i>	Burseraceae	Early	9	149.52±38.6	0.35±0.06	43.76	2.32	55.3±17.8	0.456±0.193	55.3±17.8	2.6±3.2	2.6±4.3	209.5
<i>Gastonia spectabilis</i>	Araliaceae	Early	8	103.14±30.1	0.41±0.12	47.00	1.77	9.6±3.3	0.291±0.12	9.6±3.3	1.4±1.2	0±0	188.5
<i>Gigasiphon schlechteri</i>	Fabaceae	Late	1	261.31±0	0.64±0	46.55	3.56	25.5±0	0.979±0	26.48±0	85±0	0±0	81.0
<i>Gmelina palawensis</i>	Lamiaceae	Late	1	92.74±0	0.46±0	46.06	1.73	3.5±0	0±0	3.5±0	0±0	0±0	-
<i>Gnetum gnemon</i>	Gnetaceae	Late	21	161.25±28.1	0.66±0.05	46.92	3.23	30.4±6.4	0.289±0.075	30.51±6.4	5.8±5.9	2.3±3.3	307.0
<i>Gnetum gnemon</i>	Gnetaceae	Early	1	179.08±0	0.61±0	46.92	3.23	0.5±0	0±0	0.52±0	0±0	0±0	307.0
<i>Gnetum gnemonoides</i>	Gnetaceae	Late	16	106.7±12.5	0.39±0.04	48.02	2.38	72.6±20.4	0.533±0.145	72.6±20.4	23.9±24.6	0.1±0.3	110.6
<i>Gnetum latifolium</i>	Gnetaceae	Late	5	95.43±17.5	0.45±0.02	50.92	3.07	14.4±5.7	0.069±0.031	14.4±5.7	23±25	0.8±1.3	220.6
<i>Guioa comesperma</i>	Sapindaceae	Late	8	139.12±11.1	0.6±0.05	46.71	1.78	15.5±5.1	0.781±0.335	15.5±5.1	12.8±9.8	3.3±3.5	-

Appendix 6. Cont'd

Species	Family	Successio n stage	Number of stems	SLA (cm ² /g)	Wood			Mature leaves (kg)	Immature leaves (kg)	Total leaves (kg)	Number of caterpillars	Number of leaf miners	Number of wood borers
					Density (g/ml)	Carbon (%)	Nitrogen (%)						
<i>Gymnacranthera paniculata</i>	Myristicaceae	Late	57	134.21±21.9	0.48±0.01	47.73	1.77	36.9±5.4	2.8±0.397	39.7±5.4	4±4.5	2.7±5.8	589.7
<i>Gymnacranthera paniculata</i>	Myristicaceae	Early	1	138.03±0	0.48±0.01	47.73	1.77	0.2±0	0±0	0.2±0	0±0	0±0	589.7
<i>Harpullia arborea</i>	Sapindaceae	Late	3	169.24±84.8	0.66±0.09	44.10	2.13	5±2	0.52±0.3	5±2	9.7±12.5	0±0	131.8
<i>Harpullia longipetala</i>	Sapindaceae	Late	3	123.14±6.3	0.59±0.04	45.34	1.61	1.2±0.2	0±0	1.2±0.2	1.3±1.2	0±0	-
<i>Heritiera littoralis</i>	Malvaceae	Late	1	154.45±0	0.68±0	-	-	3.4±0	0±0	3.4±0	2±0	0±0	-
<i>Horsfieldia basifissa</i>	Myristicaceae	Late	118	131.57±18.2	0.44±0.09	47.92	2.03	21.6±4.5	0.802±0.159	21.88±4.5	2±2.9	1.4±2.5	270.7
<i>Horsfieldia basifissa</i>	Myristicaceae	Early	2	150.31±31.2	0.39±0.02	47.92	2.03	5.4±1.2	0.463±0.189	5.86±1.2	19±25.5	0.5±0.7	270.7
<i>Intsia bijuga</i>	Fabaceae	Late	1	174.57±0	0.65±0	43.83	2.86	4.2±0	0.636±0	4.84±0	6±0	0±0	248.0
<i>Intsia bijuga</i>	Fabaceae	Early	2	115.87±33.3	0.65±0	43.83	2.86	137.6±49.7	0.617±0.091	138.09±49.7	28±1.4	1±1.4	248.0
<i>Kingiodendron novoguineense</i>	Fabaceae	Late	4	153.53±45.3	0.73±0.01	45.27	2.27	18.2±6.6	0±0	18.2±6.6	13.3±26.5	0±0	128.0
<i>Kingiodendron novoguineense</i>	Fabaceae	Early	1	123.65±0	0.73±0.01	45.27	2.27	2±0	0±0	2±0	5±0	0±0	128.0
<i>Leucosyke australis</i>	Urticaceae	Early	4	121.56±15.2	0.53±0.1	34.82	1.68	8.5±3.1	0.153±0.067	8.65±3.1	1±0.8	3.3±3.9	-
<i>Leucosyke capitellata</i>	Urticaceae	Early	1	156.78±0	0.45±0	36.81	1.49	22.8±0	0.259±0	23.06±0	7±0	3±0	-
<i>Licuala beccariana</i>	Arecaceae	Late	3	123.05±19.7	0.31±0.14	45.79	1.52	6.4±2.5	0.167±0.096	6.57±2.5	2.7±2.3	0±0	-
<i>Licuala beccariana</i>	Arecaceae	Early	1	102.84±0	0.20±0	45.79	1.52	3±0	0±0	3±0	0±0	0±0	-
<i>Litsea collina</i>	Lauraceae	Late	3	99.18±20.7	0.40±0.02	46.08	1.63	207.1±116.	0.108±0.062	207.21±116	4.7±8.1	0±0	284.2
<i>Litsea guppyi</i>	Lauraceae	Early	1	96.4±0	0.54±0	-	-	1.5±0	0±0	1.5±0	8±0	0±0	-
<i>Litsea timoriana</i>	Lauraceae	Late	36	134.6±20.8	0.40±0.07	46.49	2.01	13±2.5	0.987±0.169	13±2.5	2.7±7.1	1.1±3	163.3
<i>Macaranga aleuritoides</i>	Euphorbiaceae	Late	3	126.99±7.5	0.31±0.02	44.97	2.33	13.4±6.2	0.147±0.03	13.55±6.2	24.7±36	2±2	143.7
<i>Macaranga aleuritoides</i>	Euphorbiaceae	Early	73	134.74±22.6	0.31±0.01	44.97	2.33	60±8.2	0.958±0.186	60.66±8.2	23±25.4	0.9±1.9	143.7
<i>Macaranga bifoveata</i>	Euphorbiaceae	Late	2	175.9±8.9	0.25±0.02	45.37	2.01	2.4±0.2	0.144±0.017	2.54±0.2	8±2.8	0±0	33.7
<i>Macaranga bifoveata</i>	Euphorbiaceae	Early	22	185.39±28.8	0.35±0.05	45.37	2.01	12.4±3.6	0.55±0.145	12.86±3.6	6.3±8.1	0.9±1.2	33.7
<i>Macaranga fallacina</i>	Euphorbiaceae	Late	7	152.81±19.6	0.40±0.07	42.29	1.63	8.4±2.3	0.2±0.063	8.45±2.3	11.1±14	1.9±4.1	-
<i>Macaranga fallacina</i>	Euphorbiaceae	Early	1	138.49±0	0.40±0.07	42.29	1.63	6.2±0	0.294±0	6.49±0	2±0	2±0	-
<i>Macaranga neobritannica</i>	Euphorbiaceae	Late	2	126.06±9.4	0.35±0.04	40.36	1.54	20±12	0.25±0.121	20.25±12	2.5±3.5	2.5±0.7	126.7
<i>Macaranga neobritannica</i>	Euphorbiaceae	Early	3	128.98±6.5	0.36±0	40.36	1.54	8.3±4.3	0.464±0.119	8.71±4.3	3.7±4	0.3±0.6	126.7
<i>Macaranga punctata</i>	Euphorbiaceae	Late	7	196.16±44.2	0.43±0.09	43.32	1.96	4±0.9	0.677±0.205	4.68±0.9	6.9±5.4	5.4±8.4	37.7
<i>Macaranga quadriglandulosa</i>	Euphorbiaceae	Early	11	156.95±25.4	0.42±0.13	45.92	1.85	2.5±0.8	0.089±0.029	2.5±0.8	1.5±1.9	1.1±1.4	-
<i>Macaranga tanarius</i>	Euphorbiaceae	Late	1	131.48±0	0.40±0	45.35	2.21	6±0	0.141±0	6.14±0	8±0	4±0	141.5
<i>Macaranga tanarius</i>	Euphorbiaceae	Early	235	137.67±19.5	0.33±0.04	45.35	2.21	148.1±10.6	1.926±0.278	148.1±10.6	9.4±18.5	1±1.8	141.5
<i>Maclura amboinensis</i>	Moraceae	Late	5	111.69±13.3	0.72±0.03	42.46	2.22	4±1.4	0±0	4±1.3	2.4±2.5	0±0	-
<i>Mallotus peltatus</i>	Euphorbiaceae	Late	10	189.1±23.7	0.82±0.09	42.84	2.29	2±0.5	0.067±0.021	2±0.5	0.4±0.7	0.1±0.3	-
<i>Mangifera indica</i>	Anacardiaceae	Early	3	96.52±13.7	0.55±0.02	42.10	1.32	4.5±1.7	0.188±0.068	4.69±1.7	20.7±34.1	12±20.8	-
<i>Maniltoa psilogyne</i>	Fabaceae	Late	6	108.32±14.2	0.64±0.09	45.85	1.62	97.6±45.7	0±0	97.6±45.7	5.2±4.8	1.7±4.1	558.7
<i>Mastixiodendron pachyclados</i>	Rubiaceae	Late	46	113.7±27.2	0.68±0.03	47.76	1.65	78±15.4	0.874±0.223	78±15.4	3.3±6.6	2±4.3	23.3
<i>Medusanthera laxiflora</i>	Stemonuraceae	Late	10	190.84±33	0.43±0.06	43.86	2.56	3.4±1	0.098±0.033	3.45±1	0.2±0.4	0±0	-
<i>Melanolepis multiglandulosa</i>	Euphorbiaceae	Early	17	174.54±35.1	0.42±0.05	43.74	3.54	10.2±3.5	0.374±0.131	10.56±3.5	0.9±2.4	0±0	17.3
<i>Melicope elleryana</i>	Rutaceae	Early	8	106.8±23	0.48±0.12	44.09	2.19	29.2±8.5	0.738±0.312	29.22±8.5	24.9±28	4.4±5	43.0

Appendix 6. Cont'd

Species	Family	Successio n stage	Number of stems	Wood			Carbon (%)	Nitrogen (%)	Mature leaves (kg)	Immature leaves (kg)	Total leaves (kg)	Number of caterpillars	Number of leaf miners	Number of wood borers
				SLA (cm ² /g)	Density (g/ml)									
Merrilliodendron megacarpum	Icacinaceae	Late	4	145.71±25.5	0.57±0.04	46.51	2.55	4±1.6	0±0	4±1.6	0.8±1.5	0±0	3.3	
Microcos argentata	Malvaceae	Late	9	129.02±22.9	0.38±0.05	42.98	1.69	29.6±10.4	0.188±0.072	29.6±10.4	5.6±6.9	0.3±0.5	106.7	
Microcos grandiflora	Malvaceae	Late	14	134.21±23.2	0.47±0.02	44.22	2.08	48.5±13.7	0.561±0.171	48.5±13.7	19.4±41.7	0.9±1.6	25.0	
Millettia pinnata	Fabaceae	Late	1	195.98±0	0.73±0	46.97	3.48	20±0	0±0	20±0	30±0	12±0	139.7	
Mischocarpus largifolius	Sapindaceae	Late	1	116.71±0	0.83±0	46.66	2.15	3.3±0	0±0	3.3±0	0±0	0±0	52.7	
Myristica fatua	Myristicaceae	Late	14	103.84±16.6	0.41±0.03	47.33	1.72	51.2±14.1	0.389±0.156	51.55±14.1	4±5.4	5.4±12.3	457.0	
Neisosperma citrodora	Apocynaceae	Late	4	183.58±41.3	0.59±0.04	47.37	3.27	5.6±2.3	0.273±0.13	5.6±2.3	4.8±5.2	0.3±0.5	24.0	
Neonauclea obversifolia	Rubiaceae	Late	15	112.99±21.9	0.63±0.05	46.27	1.63	105.3±38	0.795±0.247	105.53±38	26.2±28	6.7±8.8	62.8	
Neoscortechinia forbesii	Euphorbiaceae	Late	2	124.02±0.5	0.55±0	46.24	1.94	16±5.7	0.372±0.263	16±5.7	4±4.2	0±0	92.4	
Neuburgia corynocarpa	Loganiaceae	Late	2	228.96±4.5	0.38±0.09	42.37	2.01	8±5.4	0±0	8±5.4	0±0	0±0	-	
Octomeles sumatrana	Tetramelaceae	Early	1	155.61±0	0.25±0	48.26	3.25	2.2±0	0.292±0	2.49±0	22±0	0±0	-	
Omphalea papuana	Euphorbiaceae	Late	3	109.18±27	0.37±0.05	44.32	1.98	10.3±5.6	0.26±0.137	10.56±5.6	7.3±11.8	0±0	268.5	
Osmoxylon novo-guineense	Araliaceae	Late	2	127.61±22.1	0.37±0.01	48.59	2.32	2±0.7	0.188±0.133	2±0.7	0±0	0±0	-	
Palaquium morobense	Sapotaceae	Late	22	82.58±13.9	0.36±0.06	48.28	1.37	72±17	0.369±0.098	72±17	1.4±2.5	0.7±1.4	308.0	
Palaquium warburgianum	Sapotaceae	Late	4	112.56±2.4	0.48±0	48.67	1.50	2.5±1.1	0.06±0.03	2.56±1	0.3±0.5	0.5±1	-	
Pandanus kaernbachii	Pandanaceae	Late	4	59.37±11.5	0.24±0.02	45.59	1.18	26.5±5.8	0±0	26.5±5.8	0±0	0±0	-	
Pangium edule	Achariaceae	Late	20	198.53±44.8	0.62±0.04	44.60	3.63	125.7±29.2	0.539±0.151	125.7±29.2	7±13.5	2.8±9.1	111.0	
Papuechites aambe	Apocynaceae	Late	1	125.7±0	0.37±0	42.29	1.84	3.6±0	0.289±0	3.89±0	0±0	0±0	397.0	
Parkia versteeghii	Fabaceae	Late	1	198.79±0	0.44±0	44.96	1.63	51.8±0	0±0	51.8±0	32±0	0±0	264.3	
Phaeanthus macropodus	Annonaceae	Late	1	131.9±0	0.64±0	48.77	2.63	29.4±0	0.105±0	29.51±0	1±0	0±0	24.7	
Phyllanthus clamboides	Phyllanthaceae	Late	26	148.1±24.8	0.54±0.04	43.52	1.51	2.6±0.8	0.525±0.137	2.93±0.8	3.6±8.5	0±0	364.0	
Phyllanthus clamboides	Phyllanthaceae	Early	3	143.85±36.2	0.50±0.1	43.52	1.51	2±0.5	0.086±0.044	2.09±0.5	15.3±25.7	0±0	364.0	
Pimelodendron amboinicum	Euphorbiaceae	Late	43	155.04±34.4	0.51±0.04	46.91	2.51	64.2±12.5	6.2±0.997	64.2±12.5	5.2±6.7	0±0.3	3470.3	
Pisonia longirostris	Nyctaginaceae	Late	13	209.34±46.3	0.28±0.04	44.07	3.70	3.6±1.1	0.223±0.074	3.6±1.1	0.6±0.8	0±0	-	
Pisonia longirostris	Nyctaginaceae	Early	1	131.9±0	0.24±0.02	44.07	3.70	1.8±0	0±0	1.8±0	0±0	0±0	46.0	
Polyalthia glauca	Annonaceae	Late	5	118.75±21.6	0.40±0.04	48.34	1.64	34.4±13.6	2.007±0.848	34.48±13.5	2.6±2.8	1.6±2.5	21.3	
Polyalthia oblongifolia	Annonaceae	Late	1	190.59±0	0.46±0	45.00	2.05	5.8±0	0±0	5.8±0	14±0	3±0	324.3	
Pometia pinnata	Sapindaceae	Late	50	128.85±27.2	0.71±0.09	48.36	1.83	140.1±30.7	3±0.518	140.1±30.7	10.6±10.4	4.2±12.6	81.9	
Pometia pinnata	Sapindaceae	Early	1	122.56±0	0.74±0	48.36	1.83	24±0	0.036±0	24.04±0	0±0	2±0	81.9	
Pouteria obovata	Sapotaceae	Late	9	128.4±24.8	0.46±0.15	48.19	2.05	160.7±52.6	0±0	160.7±52.6	1.9±3.3	2.4±5.9	-	
Prainea papuana	Moraceae	Late	6	256.69±83.4	0.49±0.02	44.46	2.75	8.4±2.7	1.2±0.474	8.4±2.7	3.3±3.8	0±0	421.3	
Premna obtusifolia	Lamiaceae	Early	3	146.82±40	0.54±0.01	43.60	2.05	5±1.3	0.379±0.198	5±1.3	20±17.8	2.3±2.1	-	
Protium macgregorii	Burseraceae	Late	1	149.99±0	0.56±0	45.90	1.89	2±0	0±0	2±0	2±0	0±0	-	
Prunus schlechteri	Rosaceae	Late	2	113.77±35.6	0.57±0.07	45.27	1.39	5.2±1.8	0±0	5.2±1.8	5±7.1	0±0	125.7	
Pterocarpus indicus	Fabaceae	Late	2	191.79±87	0.61±0.19	46.89	3.21	15.6±11.1	0.233±0.165	15.83±11.1	20.5±16.3	1±1.4	180.3	
Pterocarpus indicus	Fabaceae	Early	9	234.01±82.9	0.57±0.11	46.89	3.21	50.8±16.4	0.796±0.264	50.8±16.4	21.8±27.9	11±30	180.3	
Pterocymbium beccarii	Malvaceae	Late	3	227.13±64	0.26±0.03	42.95	3.05	2.6±1	0±0	2.6±1	0.3±0.6	0±0	103.7	
Rhus taitensis	Anacardiaceae	Early	1	122.95±0	0.43±0	47.86	2.01	1.5±0	0.115±0	1.62±0	21±0	0±0	-	

Appendix 6. Cont'd

Species	Family	Succession stage	Number of stems	SLA (cm ² /g)	Wood			Mature leaves (kg)	Immature leaves (kg)	Total leaves (kg)	Number of caterpillars	Number of leaf miners	Number of wood borers
					Density (g/ml)	Carbon (%)	Nitrogen (%)						
<i>Rourea minor</i>	Connaraceae	Late	1	95.29±0	0.49±0	42.60	1.57	6±0	0±0	6±0	1±0	0±0	-
<i>Sarcocephalus coadunatus</i>	Rubiaceae	Early	28	119.13±30.8	0.31±0.05	50.25	2.35	29.4±7.8	5.475±1.019	29.4±7.8	28.9±71.6	1.6±3.6	111.0
<i>Semecarpus schlechteri</i>	Anacardiaceae	Late	6	121.95±22.4	0.40±0.03	44.35	2.22	4.4±1.5	0.056±0.023	4.4±1.5	1±1.1	0±0	58.5
<i>Sloanea sogerensis</i>	Elaeocarpaceae	Late	1	125.52±0	0.53±0	45.53	1.54	2±0	0±0	2±0	0±0	0±0	-
<i>Spondias dulcis</i>	Anacardiaceae	Early	3	208.69±60	0.40±0.07	39.33	3.12	9±4.5	0.473±0.273	9.47±4.4	4±4.4	4±4	42.0
<i>Sterculia ampla</i>	Malvaceae	Late	5	189.79±22.1	0.31±0.05	47.27	2.21	49±21.3	0±0	49±21.3	3.6±7	0.2±0.4	30.0
<i>Sterculia ampla</i>	Malvaceae	Early	2	139.2±1.6	0.25±0.01	47.27	2.21	2.8±0.5	0.241±0.17	2.8±0.5	10±8.5	0.5±0.7	30.0
<i>Sterculia schumanniana</i>	Malvaceae	Late	6	151.23±15.7	0.35±0.02	42.49	2.35	64.3±26.9	0.993±0.507	64.3±26.9	2.8±4.3	3.3±7.7	62.7
<i>Strychnos minor</i>	Loganiaceae	Late	10	124.57±17	0.39±0.05	46.44	1.80	31.2±10.2	1.2±0.374	32.4±10.2	12.2±16.4	0.2±0.6	273.2
<i>Syzygium branderhorstii</i>	Myrtaceae	Late	2	95.63±11.3	0.57±0	48.67	1.23	2.8±0.7	0±0	2.8±0.7	3±4.2	0.5±0.7	-
<i>Syzygium furfuraceum</i>	Myrtaceae	Late	4	113.08±48.6	0.40±0.23	48.49	1.93	2.8±1.6	1.404±0.702	4.2±1.5	3.3±5.3	0.3±0.5	145.3
<i>Syzygium gonatanthum</i>	Myrtaceae	Late	5	136.77±18.4	0.66±0.05	46.42	2.01	6.6±1.7	0.461±0.194	6.6±1.7	17.4±14.6	2.6±5.8	23.5
<i>Syzygium longipes</i>	Myrtaceae	Late	8	171.48±28.8	0.68±0.04	48.53	1.38	13±4	0.127±0.045	13.02±4	4.5±2.5	0.3±0.7	62.0
<i>Tabernaemontana orientalis</i>	Apocynaceae	Late	1	268.05±0	0.59±0	43.88	2.78	1.3±0	0.041±0	1.34±0	0±0	2±0	-
<i>Tabernaemontana orientalis</i>	Apocynaceae	Early	1	225.8±0	0.59±0	43.88	2.78	2±0	0±0	2±0	5±0	0±0	-
<i>Tecomanthe dendrophila</i>	Bignoniaceae	Late	1	188.85±0	0.42±0	48.83	2.77	1.8±0	0±0	1.8±0	0±0	0±0	14.0
<i>Teijsmanniodendron bogoriense</i>	Lamiaceae	Late	63	148.58±32.2	0.47±0.05	43.66	1.93	72.4±17	1±0.138	72.4±17	5.8±11.3	3.9±10.2	160.7
<i>Terminalia archipelagi</i>	Combretaceae	Late	1	170.74±0	0.43±0	44.42	2.14	104.8±0	0.919±0	105.72±0	28±0	20±0	113.3
<i>Terminalia kaernbachii</i>	Combretaceae	Late	5	105.64±11.5	0.57±0.05	42.01	2.28	17.5±6.9	0.252±0.124	17.5±6.9	1.2±2.2	0±0	-
<i>Ternstroemia cherryi</i>	Pentaphylacaceae	Late	6	103.5±5.4	0.63±0.06	41.59	1.13	34±16	9±3.593	43±16	12.2±29.8	0.8±2	122.3
<i>Tetrameles nudiflora</i>	Tetramelaceae	Early	4	140.18±45.7	0.20±0.02	45.50	2.46	13±6.2	0.135±0.064	13.14±6.2	10.5±14.6	0.3±0.5	22.0
<i>Tetrastigma lauterbachianum</i>	Vitaceae	Late	1	73.8±0	0.34±0	47.56	1.12	1.8±0	0±0	1.8±0	0±0	0±0	23.5
<i>Timonius timon</i>	Rubiaceae	Early	2	129.69±32.6	0.40±0.07	46.63	1.93	6.6±2.7	0.085±0.012	6.67±2.7	7±7.1	0±0	-
<i>Trema orientalis</i>	Ulmaceae	Early	30	119.74±18.2	0.27±0.04	43.38	2.89	57.5±16	2±0.498	58.48±16	106.6±123.3	5.9±7.7	93.9
<i>Trichospermum pleiostigma</i>	Malvaceae	Early	151	155.57±30	0.23±0.03	47.46	3.18	67.5±8.8	2±0.36	68.39±8.8	15.8±20.2	3.6±10.8	214.7
<i>Tristiropsis acutangula</i>	Sapindaceae	Late	3	135.11±23.3	0.78±0.04	48.08	2.25	6.8±3	0±0	6.8±3	19.7±17	0±0	23.0
<i>Uncaria appendiculata</i>	Rubiaceae	Late	5	86.03±3.6	0.42±0.06	49.33	1.52	16.8±4.6	0.55±0.156	17±4.6	6.8±6.7	2.8±3.9	75.3
<i>Uvaria rosenbergiana</i>	Annonaceae	Late	1	96.4±0	0.38±0	40.66	2.55	2.8±0	0.075±0	2.87±0	0±0	1±0	76.7
<i>Vatica papuana</i>	Dipterocarpaceae	Late	4	123.27±18.2	0.53±0.04	49.34	1.78	92.6±45.9	0.966±0.471	93.57±45.9	8.3±13.9	3±4.7	486.7
<i>Versteegia cauliflora</i>	Rubiaceae	Late	7	130.14±11.4	0.77±0.05	47.18	1.85	4.2±1.3	0.087±0.033	4.2±1.2	3±3.5	0.3±0.8	-
<i>Vitex cofassus</i>	Lamiaceae	Early	46	138.87±29.5	0.55±0.11	45.12	2.03	29±5.2	0.482±0.12	29.34±5.2	2.3±2.9	0.3±0.7	194.3
<i>Wrightia laevis</i>	Apocynaceae	Early	1	234.73±0	0.43±0	43.12	2.81	0.2±0	0±0	0.23±0	0±0	0±0	-
<i>Xanthophyllum papuanum</i>	Polygalaceae	Late	7	157.44±21.8	0.66±0.03	47.85	2.57	13.4±4.9	0.357±0.13	13.48±4.9	34.9±83.9	2.9±5.4	183.0
<i>Ziziphus angustifolia</i>	Rhamnaceae	Late	9	164.21±18.5	0.71±0.02	46.94	2.62	7±2.3	0.562±0.187	7±2.3	5.1±3.3	0.2±0.4	146.3