Effect of isolation on the composition of soil seed banks on the Atherton Tableland, northeast Queensland, Australia

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Abstract

Tropical rainforest rehabilitation is one method to recreate, establish, and accelerate natural successional processes. Tropical rehabilitation has occurred on the Atherton Tableland for 15 years. Currently, rehabilitated sites on the Atherton Tableland are monitored by tree planting agencies for two to three years to reduce exotic species. The 10-12 years following the last monitoring period provides the opportunity to investigate successional processes of these rehabilitated sites.

One method to investigate rehabilitation management is through the soil seed bank. The composition and recruitment pattern of seeds in the soil seed bank may offer information on species that have the potential to germinate in rehabilitated sites following a disturbance. This knowledge is useful to predict future successional patterns within rehabilitated sites.

This study investigated the soil seed bank composition of rehabilitated sites adjacent to – and isolated from – remnant rainforest. In addition, it was determined whether distance from seed source influenced exotic species composition and native species recruitment that occurred to rehabilitated sites. Seventeen rainforest study sites were chosen for investigation: six remnant rainforest sites, six rehabilitated sites adjacent to remnant rainforest, and five rehabilitated sites isolated from remnant rainforest. Twenty soil samples were collected (60 x 60 x 50 mm deep) for each site, and overstorey plant species were recorded. Germination of soil-stored seeds occurred for three months, and seedling identification occurred on a weekly to fortnightly basis. Following species identification, life history traits were collected including: origin (native or exotic), life form, dispersal mechanism, seed size, successional stage, and whether species were recruited to the rehabilitated sites.

Non-parametric tests, Kruskal-Wallis ANOVA and Mann-Whitney *U*-tests were used to determine whether differences occurred between sites in number of seeds, number of species, or life history traits. Spearman's Rank Correlation Coefficient identified positive and negative associations among life history traits.

A total of 10,938 seeds germinated from the 17 study sites, and 10,226 were exotic. Exotics represented 328 germinants and 40 species of remnant rainforest sites; 4,864 germinants and 34 species of adjacent rehabilitated sites; and 5,034 germinants and 31 species of isolated rehabilitated sites. There were no significant differences in number of exotic seeds and species between the adjacent and isolated rehabilitated sites, which indicate that distance from seed source did not affect the exotic composition of rehabilitated sites. The exotic species found in the soil seed banks were herbs and grasses. Herbs and grasses had a significant positive correlation with wind dispersal, small sized seeds, and early successional species.

A total of 238 seeds were native recruits. Native recruits represented 120 germinants and 20 species of remnant rainforest sites, 33 germinants and 5 species of adjacent rehabilitated sites, and 85 germinants and 4 species of isolated rehabilitated sites. There were no significant differences in native recruit germinants among the remnant rainforest sites, the adjacent rehabilitated sites and the isolated rehabilitated sites; however, there were significant differences in the number of native species recruited between the three rainforest site types. There were significantly more species recruited to the remnant rainforest sites than the adjacent rehabilitated sites. However, the results indicate that location of rehabilitation planting (adjacent or isolated) does not affect native species recruitment. The native recruited species were shrubs and trees. There was a significant positive association between life form and wind dispersal, small sized seeds, and early successional stage.

The soil seed bank composition suggests that 10 – 12 years following weed control, exotic species may germinate after a disturbance and establish the rehabilitated sites. These results have significant implications for future rehabilitation efforts on the Atherton Tableland due to evidence of exotic herbaceous dominance, which requires longer and more intense management.

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Glossary

Active seed bank	A collection of seeds comprised of non-dormant, short-lived seeds that germinate shortly after arrival to the seed bank (Harper 1977; Garwood 1989)
Adjacent rehabilitated sites	Rehabilitated sites 12 – 15 years old that are planted directly next to remnant rainforest
Climax species	Long – lived native plant species characteristic of primary forests. Climax species have irregular fruiting patterns and have large seeds and fruits that are non-dormant and short lived (Whitmore 1990; Richards 1996)
Diversity	The variety of life forms, the ecological roles they perform, and the genetic diversity they contain (Wilcox 1984 cited in Murphy 1988)
Dormant seed bank	A collection of seeds that remain viable below the soil surface (Harper 1977)
Edge effect	Alters the condition of the rainforest site because of exposure to conditions experienced in the surrounding ecosystems. Changes include air temperature, light, air and soil moisture, species abundance and composition, species interactions, competition, herbivory, pollination, and seed dispersal (1995)
Enforced dormancy	Dormancy maintained by the absence of germination requirements (Harper 1977)
Exotic species	Plant species introduced from a country outside Australia, and also includes herbs and grasses native to Australia
Fragmentation	Replacement of native forest by other ecosystems leaving isolated rainforest patches (Murcia 1995)
Induced dormancy	Dormancy state in which seed has altered dormancy because of an environmental factor (i.e. drought, increased carbon dioxide) (Harper 1977)
Innate dormancy	Dormancy from a genetic requirement (Harper 1977)

Isolated rehabilitated sites	Rehabilitated sites 12 – 15 years old planted in isolation (500 – 1,800 m) from remnant rainforest
Native species	Plant species originating from Australia, excluding herbs and grasses
Pioneer species	Light-demanding, short-lived trees that dominate early and intermediate stages of secondary succession
Recruitment	The occurrence of plant species on rehabilitated sites not originally planted but rather introduced by natural dispersal mechanisms
Rehabilitation	The re-creation, direction, and acceleration of natural processes to repair damaged ecosystem functions (Goosem and Tucker 1995)
Remnant rainforest sites	Rainforests that have not been destroyed by logging or farming and are at least 80 years old
Resilience	Ability to withstand disturbance in the rainforest
Seed rain	Newly dispersed seeds not yet incorporated below the soil surface
Seed shadow	The area within which seed from an individual plant falls (Richards 1996)
Seedling bank	Established, suppressed seedlings in the forest understorey
Self sustainability	Maintaining an ecological balance without human interference
Soil seed bank	Collection of seeds that can remain dormant in or on the soil (Simpson *et al.* 1989)
Wet Tropics	900,000 ha of tropical rainforest extending from Cooktown to Townsville listed as World Heritage area in 1988 by United Nations Educational, Scientific, and Cultural Organization (UNESCO)

Introduction

Over recent history many tropical rainforests throughout the world, including rainforests in tropical northeast Queensland, have changed from large continuous areas of rainforest to small fragmented rainforests. For example, the tropical rainforests of northeast Queensland have decreased in size from 780,150 ha to 594,436 ha in approximately 200 years (Winter *et al.* 1987). The rainforests of northeast Queensland have much plant and animal diversity. However, increase in loss of rainforest areas consequently results in the loss of biological diversity of the area.

Awareness of the loss of habitat and biological diversity has prompted the World Heritage listing of the tropical rainforests of northeast Queensland by the United Nations Educational, Scientific, and Cultural Organization (UNESCO). Heightened international attention has caused government agencies, local conservation groups, and individuals to rebuild and rehabilitate tropical rainforests on the Atherton Tableland. However, current rehabilitation practices have been based on experience rather than scientific study, and only minimal monitoring has been conducted to ensure that rehabilitated sites are a self-functioning ecosystem.

Currently, rainforest rehabilitation monitoring is limited to two to three years, which does not allow sufficient time to determine whether the rehabilitated sites are achieving aims that include catalysing natural successional processes and native species recruitment. One method to identify species composition and predict future successional patterns is to investigate the composition of the soil seed bank. The soil seed bank offers information on species accumulation at the rainforest site, and what species have the potential to germinate and establish a site. This study seeks to determine whether soil seed bank examination is a suitable alternative to current tropical rainforest rehabilitation monitoring. Included in this overall aim are specific aims: What is the soil seed bank composition of remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites? Does distance from remnant rainforest affect the composition of the soil seed bank? Lastly, is native species recruitment occurring in the soil seed banks of rehabilitated sites?

This study will investigate whether the soil seed bank reflects the desired outcome of rehabilitation practice; i.e. has rehabilitation attracted new plant species via successful seed dispersal across landscapes? Chapter 1 describes the biology and ecology of soil seed banks. Chapter 2 gives a broad overview of forest rehabilitation on the Atherton Tableland as well as detailed descriptions of the study sites used, the methodology for assessing the soil seed bank, and the data analysis. Chapter 3 investigates the composition of germinating seeds in the soil seed bank in remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites. The composition of seeds in the soil seed bank has been separated into native and exotic to investigate whether distance from remnant rainforest sites influences the exotic component of the soil seed bank. Chapter 4 focuses on native species recruitment to determine whether distance from remnant rainforest sites impacts native species recruitment. Since the recruitment of native woody plant species is a primary objective of rehabilitation practices, it is important to examine whether these sites are meeting these aims. Lastly, Chapter 5 discusses methods to measure success of rehabilitation plantings, and predicts future outcomes for rehabilitated sites on the Atherton Tableland.

Chapter 1: Tropical rainforests and the role of the soil seed bank

1.1 Tropical forest fragmentation and conservation

1.1.1 Rainforest fragmentation

Tropical rainforests are the source of biological diversity that is essential for the maintenance of a sustainable environment. Tropical rainforests contain the most diverse ecosystems in the world (Whitmore 1990; Richards 1996; Goldsmith 1998). Although rainforests cover approximately 7% of the earth's surface, they hold approximately two-thirds of all known organisms (Raven 1988). Estimates of the number of organisms in tropical rainforests range from 3 million to 30 million (Raven 1988). Specifically, the tropical rainforests of northeast Queensland contain 30% of Australia's total marsupial species, 58% of bat species, 26% of frog species, 17% of reptile species, 58% of butterfly species, 48% of bird species (Department of Environmental Heritage 2004). Tropical rainforests of northeast Queensland also have much plant diversity. For example, approximately 3,000 plant species from 210 families are found in the rainforests of northeast Queensland. More than 700 of these species are endemic to northeast Queensland. Thirteen of the world's 19 families of primitive flowering plants are found in this area, and within these families, at least 50 species are endemic (Department of Environmental Heritage 2004). In addition to the biological diversity and endemism, many threatened animals and plants species are located in northeast Queensland. For example, 350 species of plants in the tropical rainforests of northeast Queensland are considered 'rare or very restricted', 74 plant species are considered 'threatened', and 25 species of animals are considered 'very rare' (Department of Environmental Heritage 2004).

Despite efforts to protect the biological diversity of tropical rainforests, humans have accelerated tropical deforestation by clearing and burning land for economic gain such as logging, mining, and farming (Whitmore 1997). Although deforestation may produce a short-term economic benefit, the long term cost is significant. The widespread destruction of tropical rainforests and increased fragmentation has global consequences including loss of biological diversity (Wilson 1988) and increase in atmospheric carbon dioxide and other greenhouse gasses (Houghton 1995; Phillips *et al.* 1998).

Rainforest fragmentation (isolated rainforest patches in the midst of tropical deforested land) (Murcia 1995) is a product of tropical deforestation and results in the reduction of rainforest area and habitat size. This reduction may result in simplified ecological systems (Terborgh *et al.* 1997), and ultimately cause the extinction of some species (Hobbs and Saunders 1993; Murcia 1995). Fragmentation alters the condition of the rainforest site because it exposes sites to conditions experienced in the surrounding ecosystems. These changes are commonly termed 'edge effects' (Murcia 1995; Whitmore 1997). Three types of edge effects may result from fragmentation: 1. abiotic edge effect (changes in environmental condition such as air temperature, light, air and soil moisture); 2. direct biological edge effect (changes in species abundance and composition); and 3. indirect biological effect (changes in species interactions, competition, herbivory, pollination, and seed dispersal) (Murcia 1995).

In order to repair these fragmented landscapes and mitigate the negative edge effects that result from rainforest fragmentation, rainforest rehabilitation techniques have been employed in tropical locations that include: Australia, Brazil, Costa Rica, Philippines, Puerto Rico, and Uganda (Aide *et al.* 1995; Butterfield 1996; Lamb *et al.* 1997; Parrotta *et al.* 1997; Tucker 2001; Blakesley *et al.* 2002; Camargo *et al.* 2002; Duncan and Chapman 2003; Carpenter *et al.* 2004; Goltenboth and Hutter 2004). Rainforest rehabilitation attempts to accelerate natural successional processes by planting native species in a degraded area. Rainforest rehabilitation is a necessary tool to help these areas become re-established as self-sustaining, functional ecosystems (Lamb *et al.* 1997; Reay and Norton 1999).

1.1.2 Rainforest rehabilitation

Rehabilitation attempts to re-establish degraded areas by planting species native to the area. On the Atherton Tableland of northeast Queensland, approximately 16 government and local agencies have been formed to identify and administer support to restore tropical degraded land (Bushcare 2003). This support includes growing trees, planning projects, preparing sites, planting trees, and monitoring rehabilitated land.

Rainforest rehabilitation practices are not universal and vary from one project to the next. For example, two common aims of rehabilitation in northeast Queensland include accelerating the rate of natural succession, and encouraging the recruitment of native plants and animals from surrounding, undisturbed rainforests. Although much money and human effort is put into site preparation and planting, there is little focus on long-term monitoring to determine whether the sites continue to meet the aims of the planting.

An important method of evaluating rehabilitation achievements is to investigate the composition of native species in the site to identify whether acceleration of natural successional processes are occurring. Currently the composition of native species is assessed by examining the seed rain, which can be defined as newly dispersed seeds not yet incorporated below the soil surface (Tucker and Murphy 1997; Benitez-Malvido *et al.* 2001; McKenna 2001; Benitez-Malvido and Martinez-Ramos 2003). Another method investigates the composition of the seedling bank, which are established, suppressed seedlings in the understorey (Garwood 1989; White *et al.* 2004).

1.2 Soil seed bank

1.2.1 Definition

The soil seed bank, which may be defined as a "collection of seeds that can remain dormant in or on the soil" (Simpson *et al.* 1989), may be another method to investigate the native species composition and 'success' of rehabilitation plantings. Species composition of the soil seed bank may offer information on species that have the potential to establish the rehabilitated site, particularly following a disturbance. Species that produce soil-stored seeds that germinate quickly after disturbance might increase in abundance at a location if disturbances become more frequent or intense (Hall and Swaine 1980; Uhl *et al.* 1981; Hopkins and Graham 1984 a; Putz and Appanah 1987; Young *et al.* 1987; Garwood 1989; Hopkins 1990; Dupuy and Chazdon 1998). Species in the soil seed bank may influence regeneration because, for example, a high concentration of exotic, herbaceous species in the soil seed bank may germinate following a disturbance, in which case, natural forest succession may retard and the area revert back to a pre-rehabilitated state. Alternatively, the germination of native species may indicate that the rainforest is capable of succeeding toward an older, more complex forest (Kellman 1978; Warr *et al.* 1993).

1.2.2 Seed Dispersal

The process of the development of soil-stored seed bank population dynamics begin when seeds enter an area via the seed rain. Seeds may originate from plants in the immediate area and neighbouring rainforests, and may be dispersed by water, animals, birds, wind, or gravity (Hall and Swaine 1980; Quintana-Ascencio *et al.* 1996; Richards 1996). The nature of dispersal implies seeds are not dispersed uniformly. Rather, as distance from the parent plant increases, seed dispersal declines exponentially, which is called a seed shadow (Janzen 1970; Richards 1996). Flemming and Heithaus (1981) (cited in Howe 1986) offer a hypothetical relationship between seed dispersal and distance. As distance from a seed source increases, seed density exponentially decreases, and seedling mortality decreases. In addition, Saluei and Swaine (1988) evaluated the seeds of gap dependent species and found that seeds of pioneer species decreased exponentially as distance from parent increased. Therefore, areas close to seed sources will have a larger number of seeds and species than areas more distant from seed sources.

1.2.3 Seed dormancy and germination

Once a seed has left the parent plant and arrived safely on the forest floor, the seed may undergo predation, germinate immediately (transient seed bank) to become a seedling, or become incorporated into the dormant (or persistent) seed bank. Seeds may be integrated into the soil seed bank by burial from animals such as rodents and worms, or by physical processes such as wind, rain, and erosion (Richards 1996). Once a seed is incorporated into the dormant seed bank it may follow one of two pathways: death by decay and senescence, or is stimulated to become a component of the active seed bank (Harper 1977).

Prior to stimuli, seeds remain in a dormant state. Three major types of dormancy effect seed germination: innate, induced, and enforced dormancy (Harper 1977). Innate dormancy is dormancy from a genetic requirement (MacKay 1972; Harper 1977). This dormancy state prevents seeds from germinating while connected to the parent plant

(Rees 1997). Induced dormancy occurs when the seed has changed its dormancy state because of an environmental condition, such as drought or carbon dioxide increase (Harper 1977). Enforced dormancy is maintained by absence of germination requirements, such as moisture, oxygen, or light (Harper 1977; Rees 1997). For example, water uptake is determined by seed coat composition, seed coat permeability, and water availability. Seeds also differ in their germination response to temperature. For example, lettuce germinates at temperatures of 20˚C or below, and is dormant at high temperatures (Toole *et al.* 1956, cited in (Pollock 1972). Light also effects germination; red light promotes germination and blue light inhibits germination (Mayer and Poljakoff-Mayber 1989). Once dormancy is broken, seeds become incorporated into the active seed bank, where seeds germinate to become seedlings.

1.2.4 Dormant and active seed bank

Differences between species' dormancy types, and triggers required to initiate seed germination (see above), results in a range of dormancy periods. For example, hard-shelled legumes and pioneer species (light demanding, short lived trees that dominate early and intermediate stages of secondary succession) (Richards 1996), have longer dormancy than most other seeds (Vazquez-Yanes and Smith 1982; Hopkins and Graham 1987). One study of dormancy in tropical plant species of Australia (Hopkins and Graham 1987) showed that some seeds of pioneer species, i.e. *Solanum mauritianum* (Solanaceae), *Trema aspera* (Ulmaceae), and *Acacia celsa* (Mimosaceae), remained viable in the soil for up to two years, compared to late successional species that remained viable for six weeks or less, i.e. *Cryptocarya hypospodia* (Lauraceae), *Flindersia acuminata* (Rutaceae), and *Syzygium endophloim* (Myrtaceae). In addition, Holthuijzen and Boerboom (1982) tested for seed viability of the pioneer/light demanding genus *Cecropia* (Cecropiaceae) in Surinam by burying seeds of two species: *C. sciadophylla* and *C. obtusa* in earthenware pots. These two species remained viable up to 62 months. Lastly, three gap dependent species in Costa Rica, *Phytolacca rivinoides* (Phytolaccaceae), *Witheringia solanacea* (Solanaceae), and *W. coccoloboides* (Solanaceae), were able to remain viable in the soil seed bank up to 27 months (Murray 1988).

Seeds that have the ability to remain viable in the soil until suitable germination conditions arise are a component of the dormant (persistent) seed bank (Harper 1977; Cook 1980; Garwood 1989). Generally, these species also exhibit a suite of life history traits that include: they are short-lived, fast growing, wind-dispersed seeds that fruit every year or continuously throughout the year, and have a steep dispersal curve, weak competitive ability, and low decay rates of seed population in soil (Harper 1977; Cook 1980; Hall and Swaine 1980; Whitmore 1990). Following disturbances that cause the formation of canopy gaps, many of these pioneer species germinate and replace the forest floor area that was once exposed to light (Guevara and Gomez-Pompa 1972; Cheke *et al.* 1979; Cook 1980; Hall and Swaine 1980; Holthuijzen and Boerboom 1982; Hopkins and Graham 1983; Putz and Appanah 1987; Young *et al.* 1987; Garwood 1989). Worldwide examples of these pioneer species include *Acacia celsa* (Mimosaceae), *Alphitonia petriei* (Rhamnaceae), *Annona sp.* (Annonaceae), *Cecropia sp.* (Cecropiaceae), *Dendrocnide moroides* (Urticaceae), *Euodia elleryana* (Rutaceae), *Melia azedarach* (Meliaceae), *Palicourea sp.* (Rubiaceae), *Solanum mauritianum* (Solanaceae), and *Trema sp.* (Ulmaceae) (Hall and Swaine 1980; Hopkins and Graham 1983, 1987; Dalling *et al.* 1998; Dalling and Hubbell 2002).

In contrast, non-dormant, short-lived seeds that germinate shortly after arrival in the seed bank are a component of the active (transient) seed bank (Harper 1977; Garwood 1989). These seeds usually form seedling banks rather than seed banks. The life history traits of these species include: large seeds and fruits, long-lived plants, low relative growth rate, strong competitive ability, high decay rates of seed populations in soil, and flat dispersal curve (Cook 1980). They have irregular fruiting patterns and may fruit every three to seven years (Putz and Appanah 1987). Some of these species include climax species (long–lived native plant species characteristic of primary forests) such as *Syzygium sp.* (Myrtaceae), *Endiandra sp.* (Lauraceae), *Calamus australis* (Arecaceae), *Acmena sp.* (Myrtaceae), and *Myristica insipida* (Myristicaceae) (Hopkins and Graham 1987; Graham and Hopkins 1990).

1.2.5 Soil seed bank composition in tropical rainforests

Because pioneer species have the ability to remain viable in the soil seed bank, it is expected that more pioneer species than climax species will be present in the soil seed bank. For example, tropical soil seed bank studies found that pioneer species (including herbs and grasses) dominated the soil seed bank of primary and secondary rainforests (Guevara and Gomez-Pompa 1972; Cheke *et al.* 1979; Hall and Swaine 1980; Hopkins and Graham 1983, 1984 a, 1984 b; Graham and Hopkins 1990; Quintana-Ascencio *et al.* 1996; Tucker and Murphy 1997; Dupuy and Chazdon 1998). In addition, Dupuy and Chazdon (1998) found that herbs, shrubs, and vines represented more than 75% of species in the soil seed bank in the rainforests of Costa Rica.

In a review of temperate and tropical soil seed bank literature and sampling techniques, Warr *et al.* (1993) explained that woody plants dominated the soil seed bank of tropical soil seed banks. This finding is not universal, however, because other tropical soil seed bank studies reported that herbs and grasses dominated the soil seed bank (Uhl and Clark 1983; Young *et al.* 1987; Chandrashekara and Ramakrishnan 1993; Tucker and Murphy 1997). On the Atherton Tableland, the soil seed bank composition of recently rehabilitated and heavily disturbed sites are composed predominately of exotic herbaceous species (Hopkins and Graham 1984 a; Hopkins *et al.* 1990; Tucker and Murphy 1997), which may be a reflection of the species present on the site prior to rehabilitation (Hall and Swaine 1980; Holthuijzen and Boerboom 1982; Hopkins and Graham 1983; Enright 1985; Epp 1987).

1.3 Major themes in soil seed bank research

Temperate and tropical soil seed bank research topics include composition, vegetation responses (particularly in response to disturbance), and regeneration following disturbance (natural and man-made). Table 1.1 illustrates major themes in temperate and tropical soil seed bank research.

Table 1.1: Common themes of soil seed bank research in temperate and tropical climates

Theme	*Temperate or Tropical*	*Author*
Species composition and germination	Temperate and Tropical	(McClanahan 1986; Valbuena and Trabaud 1995; Ashton *et al.* 1998; Jankowska-Blaszczuk *et al.* 1998; Tierney and Fahey 1998; Halpern *et al.* 1999; King and Buckney 2001; Holmes 2002).
Vegetation responses	Tropical	(Campos and de Souza 2003)
Forest regeneration	Temperate and Tropical	(Young *et al.* 1987; Graham and Hopkins 1990) and succession (Oosting and Humphreys 1940; Olmstead and Curtis 1947; Champness and Morris 1948; Livingston and Allessio 1968; Donelan and Thompson 1980; Hopkins and Graham 1983; Hopkins 1990; Dupuy and Chazdon 1998)
Germination following disturbances	Temperate and Tropical	(Hall and Swaine 1980; Ewel *et al.* 1981; Uhl *et al.* 1981; Hopkins and Graham 1984 a; Putz and Appanah 1987; Young *et al.* 1987; Garwood 1989; Dupuy and Chazdon 1998; Kalamees and Zobel 2002)

1.3.1 Regeneration following disturbance

Species composition that contributes to regeneration after a disturbance is a common theme in tropical soil seed bank research (Table 1.1). At high levels of disturbance, the soil seed bank, rather than the seed rain, may account for rainforest regeneration because increased light and temperature that results from a disturbance triggers germination from soil-stored seeds (Cheke *et al.* 1979; Uhl and Clark 1983; Putz and Appanah 1987; Garwood 1989; Hopkins 1990; Chandrashekara and Ramakrishnan 1993). In addition, large disturbances result in the loss of trees and therefore the loss of seeds from the seed rain. For example, Putz and Appanah (1987) found that seven times more seeds germinated from the seed bank than from the seed rain following a disturbance in a tropical rainforest in Malaysia. Although in cases of high levels of disturbance, the seed rain does not contribute to as many seeds as seeds present in the seed bank, the seed rain is also an important component in generating diversity. For example, as an abandoned pasture succeeded into rainforest in Puerto Rico, Campos and de Souza (2003) found that seed rain played a larger role in rainforest regeneration than the soil seed bank. In addition, Benitez-Malvido *et al.* (2001) noted that the seed rain contributed more late successional species than the seed bank in primary rainforests and pastures, and the seed bank contributed more early successional species than the seed rain in secondary rainforests.

Canopy gaps are common in tropical rainforests (Hopkins and Graham 1984 b; Denslow 1987; Brandani *et al.* 1988; Lawton and Putz 1988; Hopkins 1990; Whitmore 1990; Chandrashekara and Ramakrishnan 1993; Richards 1996; Kapos *et al.* 1997; Dalling *et al.* 1998; Dalling and Hubbell 2002). The size of the canopy gap may determine rainforest regeneration. For example, some tropical soil seed bank studies illustrated that larger canopy gaps may be more important in initiating recruitment from the soil seed bank than smaller canopy gaps because larger canopy gaps allow more sunlight and subsequent heat to the soil surface, both of which act as triggers for germination in soil-stored seeds (Garwood 1989; Hopkins 1990). However, Hopkins and Graham (1984 b) investigated the influence of canopy gap size on seed germination from the soil seed bank in Queensland, Australia, and discovered that the large gaps did not contain the largest number of germinated seeds. Rather, medium-sized canopy gaps contained the greatest number of germinated seeds, followed by edge canopy gaps, large gaps, small canopy gaps, and below remnant rainforest canopy.

Studies, in addition to those on canopy gaps, have emphasized the importance the soil seed bank may play on regeneration following disturbances. Young *et al.* (1987) studied tropical rainforests over a variety of successional stages in Costa Rica. They discovered that within one year following a disturbance, the soil seed bank decreased dramatically due to seed germination, indicating the importance of the seed bank for vegetation response to disturbance. The soil seed bank began to accumulate in the following years to reach a peak at four to seven years, when it slowly declined and reached a density of its pre-disturbed state. To further support the claim of Young *et al.* (1987), two studies in India and Puerto Rico also reported that soil seed banks in recent disturbances appeared to be lower in seed abundance and species richness than sites that had not been recently disturbed, which suggests increased recruitment is occurring from the soil seed bank following disturbances (Chandrashekara and Ramakrishnan 1993; Cubina and Aide 2001).

1.3.2 Seed Density

Another common topic of soil seed bank research is seed density. Seed density varies greatly within the tropical soil seed bank studies (Table 1.2). Primary tropical rainforests have low seed densities compared with secondary rainforests (Guevara and Gomez-Pompa 1972; Hall and Swaine 1980; Hopkins and Graham 1983; Uhl and Clark 1983; Putz and Appanah 1987; Young *et al.* 1987; Warr *et al.* 1993; Quintana-Ascencio *et al.* 1996; Butler and Chazdon 1998; Dupuy and Chazdon 1998). For example, Graham and Hopkins (1990) studied a primary rainforest in Australia and found 84 seeds m^{-2}, while Hopkins and Graham (1984 a) studied a secondary rainforest in Australia and found 1,300 – 1,400 seeds m^{-2}. The large difference in density may be explained by species present in surrounding areas. Species in secondary rainforests may have life history traits that include fruiting annually. However, climax species found in primary rainforests have irregular fruiting patterns, and few fruits are generally produced. Other differences may be dependent on the surface vegetation history and age of the seeds within the soil (Cook 1980).

Table 1.2: Tropical soil seed bank studies illustrating seed density variation of primary and secondary rainforests

Rainforest Type	*Seeds m^{-2}*	*Location*	*Year*	*Author*
Primary forest	85	Australia	1990	(Graham and Hopkins 1990)
Primary forest	50 -700	Ghana	1980	(Hall and Swaine 1980)
Primary forest	132	Malaysia	1987	(Putz and Appanah 1987)
Primary forest, 3 yr, 6 yr	180-200	Brazil	1983	(Uhl and Clark 1983)
Primary forest	330 – 1,090	Panama	1997	(Dalling *et al.* 1997)
Primary forest	8,331 – 14,535	Surinam	1982	(Holthuijzen and Boerboom 1982)
Secondary forest	391 – 7,807	Ethiopia	2000	(Tekle and Bekele 2000)
70 yr old secondary forest	2,236± 440	Costa Rica	1985	(Young 1985)
15-20 yr secondary forest, selectively logged, and primary forest	2,258 – 2,659 and 8,331 – 14,535	Panama	1998	(Dupuy and Chazdon 1998)
16 yr old secondary forest	4,535 – 5,476	Costa Rica	1998	(Butler and Chazdon 1998)
3 yr, 11 yr, 75 yr forest	6,800-9,500	Costa Rica	1987	(Young *et al.* 1987)
Degraded grasslands	2,000-3,000	Australia	1984	(Hopkins and Graham 1984 a)
Pastures and cornfields	9,800-12,960	Belize	1978	(Kellman 1978)

1.3.3 Representation of standing vegetation in seed bank

Generally, the soil seed bank does not represent the standing vegetation of primary rainforests (Cheke *et al.* 1979; Hall and Swaine 1980; Hopkins and Graham 1983; Hopkins *et al.* 1990). However, the soil seed bank is more representative of the standing vegetation in secondary rainforests (Hopkins and Graham 1983, 1984 a; Putz and Appanah 1987; D'Angela *et al.* 1988; Tekle and Bekele 2000; Dalling and Hubbell 2002). For example, primary rainforests contained 10% of species representative of the overstorey vegetation (Hopkins and Graham 1983). In contrast, in a study of the soil seed bank composition of secondary rainforests, Hopkins and Graham (1984 a) found 45% - 85% of the soil seed bank to be representative of the overstorey vegetation. The difference in rainforest stages may be due to the germination characteristics of the species. Pioneer species are characteristic of widespread dispersal and dormancy (Hall and Swaine 1980; Dalling *et al.* 1997). Some germination requirements include light and changes in soil temperature (Holthuijzen and Boerboom 1982; Hopkins and Graham 1983, 1984 b; Richards 1996). Primary species may not remain dormant in the soil, but germinate soon after arrival to incorporate the seedling bank. Since these species may not be commonly found in the soil seed bank, they will not represent the standing vegetation of primary forests.

1.4 Gaps in research

Despite the current research of soil seed bank dynamics in tropical ecosystems, little work has been conducted in investigating soil seed bank composition and species recruitment of rehabilitated sites. Soil seed banks may play a role in tropical rehabilitation regeneration and succession (Butler and Chazdon 1998) by the germination of native recruited species to increase diversity or by the germination of exotic herbs and grasses to inhibit rainforest succession. Therefore, understanding processes that operate within these rehabilitated sites to determine species composition patterns could produce predictions of the potential future forest composition (Tucker and Murphy 1997). Moreover, such understanding is necessary to identify whether rehabilitated sites require further management.

Chapter 2: Forest rehabilitation and research design of study sites on the Atherton Tableland

2.1 Conservation of tropical rainforests of northeast Queensland, Australia

2.1.1 Forest rehabilitation

To reverse the deforestation that occurred on the Atherton Tableland and to conserve the tropical rainforest under the World Heritage listing (Wet Tropics World Heritage Area), degraded land has been rehabilitated. Although there are many reasons for rehabilitation, i.e. forestry farms and commercial plantations, this study focuses on rehabilitation for ecological purposes. Such rehabilitation may be defined as the re-creation, direction, and acceleration of natural processes to repair damaged ecosystem functions (Goosem and Tucker 1995). Ecological rehabilitation includes planting wildlife corridors, creating suitable habitat for wildlife, and generating native species diversity.

2.1.2 Protection and management of tropical rainforests of northeast Queensland

The land in the Atherton Tableland in need of rehabilitation has been extensively logged and cleared for farming since the late 1800s (Frawley 1991). It has been documented that 19% of the 965,000 ha of rainforest in the Wet Tropics has been cleared by humans (Winter *et al.* 1987). Much of the cleared land had been used for farming because the areas had gentle slopes (Tucker *et al.* 2004) and rich soil (Frawley 1991).

Increasing awareness of the consequences of deforestation and rainforest fragmentation, and of the tropical rainforest diversity and endemism has led to the protection of the tropical forests of northeast Queensland. In 1988, the area became listed and protected as a World Heritage site by the United Nations Educational, Scientific, and Cultural Organization (UNESCO). For a location to be listed as World Heritage, it must fulfil at least one of ten criteria. The four natural criteria that the rainforests of tropical northeast

Queensland fulfil are: 1. “outstanding example representing the major stages of Earth's history, including the record of life, and significant ongoing geological processes in the development of landforms, or significant geomorphic or physiographic features; or 2. outstanding example representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals; or 3. contains superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; or 4. contains the most important significant habitats for in situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation (UNESCO 2005).”

2.1.3 Organisation involvement in tropical rainforest conservation

Following the World Heritage listing numerous government and local groups have formed to initiate forest rehabilitation. On the Atherton Tableland, there are currently six nurseries that raise trees for forest rehabilitation (Bushcare 2003). Two examples of groups that have rehabilitated land on the Atherton Tableland are Trees for the Evelyn and Atherton Tablelands (TREAT), and Wet Tropics Management Authority (WTMA). TREAT is a community group formed in 1982 to plant native trees in the Evelyn and Atherton Tablelands, assist landholders with rehabilitation projects, raise awareness of the need of planting trees for environmental purposes, and work with other government agencies in tree rehabilitation projects (Murphy and Tucker 2000). A government agency, WTMA, was created to manage the land under World Heritage listing. A conservation scheme, The Wet Tropics Tree Planting Scheme (WTTPS) was formed in 1988 to conduct rehabilitation projects in the Atherton Tableland and currently management by shire councils.

2.2 Rehabilitation in the Atherton Tableland

2.2.1 Aims of Rehabilitation

Two principal and inter-related aims of rainforest rehabilitation are to accelerate the natural successional processes and, while doing so, to recruit native species. Initial natural successional processes are accelerated by planting trees of different successional stages and dispersal mechanisms to initiate rainforest establishment. Accordingly, native species are planted to ensure that the composition of planted trees resembles the composition of naturally occurring rainforests in surrounding areas (Goosem and Tucker 1995). These native species also are attractive to dispersal vectors, such as mammals and birds that may, in turn, disperse native seeds originating from neighbouring rainforests and further increase diversity.

Although these two concepts are applied in many rehabilitation projects, approaches must be site specific and unique to particular locations. Examples of site specific aims include restoring derelict land to forest (Bradshaw 1983), creating rainforest to surround parks and recreational areas (Robertson 2003 pers. comm.), creating wildlife corridors (Cairns 1988; Tucker 2001), planting for economical use, preventing erosion, improving water quality (Cairns 1988), and adding wildlife habitat (Goosem and Tucker 1995).

2.2.3 Framework species method and maximum diversity method

The two principal methods of rehabilitation conducted in the Atherton Tableland are the framework species method and the maximum diversity method (Goosem and Tucker 1995). Rehabilitation plantings investigated in this study were planted according to the framework species method. This method utilizes pioneer species that grow quickly to create a canopy to out shade weeds. Selections of pioneer species that produce bird-dispersed seeds are planted on the rehabilitated sites. The aim of this method is to attract birds, which will then disperse seeds of native species from neighbouring areas. The framework species method is commonly used in rehabilitation sites near existing forests since it relies on local seed sources to increase diversity (Goosem and Tucker 1995).

The framework species has been successful in accelerating native species recruitment on the Atherton Tableland. For example, White *et al.* (2004) found that an adjacent rehabilitated site recruited 95% of native species in a site planted under the framework species method on the Atherton Tableland. Lamb *et al.* (1997) suggested that the framework species method was a better approach to restoring “poorly dispersed, rare species” than the natural re-growth (allow natural successional processes to restore the forest community while protecting the site from disturbances), or mono-culture approaches (planting one species in an area).

Despite these attractions, the framework species method has some disadvantages. One disadvantage is the high cost of planting compared with other methods (Tucker *et al.* 2004). The high expense comes from the cost of seedlings, cost of site preparation, cost of staff, and site management. Due to this large relative outlay, only small areas have been rehabilitated using this method.

Another method for rehabilitating land on the Atherton Tableland described by Goosem and Tucker (1995) is the maximum diversity method. This method involves planting climax species and excluding fast growing pioneer species. The climax canopy species are slow growing and therefore slow to form a canopy to out shade weeds. However, the maximum diversity method involves planting many climax species to create diversity, rather than relying on outside seed sources. This method is not as common as the framework species method since mature phase species are slower growing and more management is required to reduce weeds before canopy formation (Goosem and Tucker 1995).

Before either rehabilitation method is implemented, site preparation must first take place. Site preparation includes spraying the site with herbicide to reduce weeds, after which trees are commonly planted 1.5 metres apart to create a canopy. The area is covered by hay or newspaper to further reduce weeds. Management is conducted for the first two years and weeds are controlled every two months by herbicide spray (Murphy and Tucker 2000; Robertson 2003 pers. comm.). However, current management has some disadvantages. It does not take into consideration long-term changes in forest structure or whether natural successional processes and native species recruitment achieve their aims. To attempt to determine the success of these methods, soil seed bank composition and native species recruitment were examined in rehabilitated sites on the Atherton Tableland.

2.3 Research design

2.3.1 Site description

The study was conducted on the Atherton Tableland, northeast Queensland, Australia (between 17˚14'S, 145˚34'E to 17˚25'S 145˚38'E). The Atherton Tableland is a mid-elevation (600-900m) plateau, with a wet season from January to April (Tracy 1982). Monthly precipitation for January 2003 was 253 mm, and 29.2 mm in June 2003. Total monthly precipitation recorded at Malanda during January 2003 was 298.9 mm and 84.4 mm in June 2003. Maximum and minimum temperatures in January 2003 were 27.2˚C and 17.7˚C, and 23.0˚C and 13.6˚C in June 2003 (Bureau of Meteorology 2004).

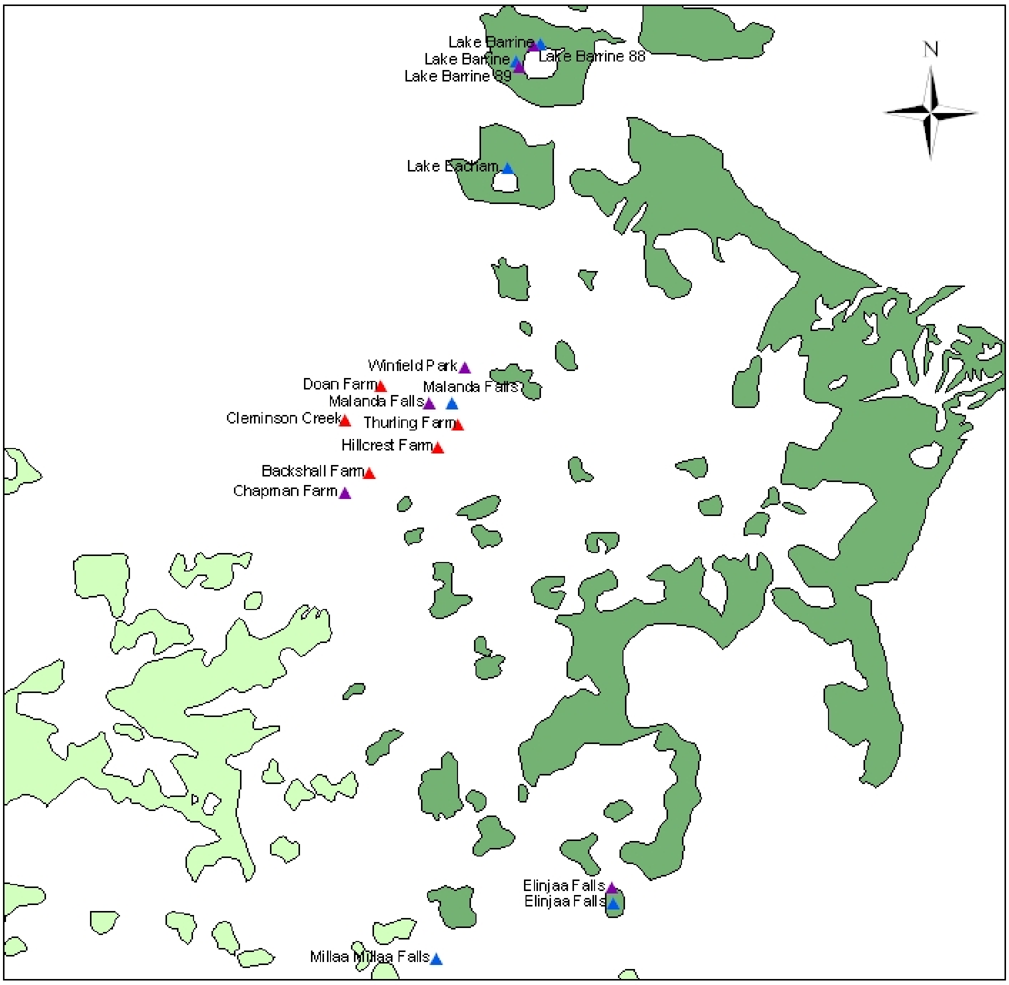
There were many possible rehabilitation sites to choose from on the Atherton Tableland. However, previous analysis of 12 selected sites showed large differences in rehabilitated sites in the following factors: isolation from seed source, planting age, planting area, planting shape ratio, and landscape matrix (variegated, fragmented, or relictual) (McKenna 2001). Rather than potentially confound results by selecting sites that differed in many respects, sites were selected to control as best as possible for age, forest classification, and soil type. In this way, all sites were 12 – 15 years old and previously had been either one of two forest types. Twelve to 15 year old rehabilitated sites were chosen because this allowed the largest number of replicates in each forest category while limiting the age interval between any two sites to a maximum of three years. The two forest types chosen were Complex Mesophyll Vine forest (1b) and Complex Notophyll Vine Forest (5a) (Tracy 1982). These were studied because much of the rainforest in the Atherton Tableland comprised these forest types before deforestation (Tracy 1982).

Complex Mesophyll Vine forest (1b) is classified as 'wet and wet cloudy uplands on basalt soil.' Forest type 1b is confined to small National Parks around Lake Barrine and Lake Eacham (Tracy 1982) and occurs on PinGin (Pg) soil. The landscape has gently (3-10%) sloping rises to moderately (10-32%) sloping low hills. The soil is deep, acid, pedal, and uniform fine texture profile, and is derived from basalt (Malcolm *et al.* 1999). Complex Notophyll Vine Forest (5a) is classified as 'cloudy wet highlands; [with] very limited areas of basalt and basic rocks' (Tracy 1982). These sites are on

Maalan (Mn) soil derived from basaltic rocks. They are deep, acid, pedal, uniform, fine texture and located on moderately (10-32%) to steeply (>32%) sloping hills and low hills (Malcolm *et al.* 1999).

Based on the above classification, 17 sites were selected (Map 2.1 and Table 2.1). Six sites were remnant rainforest sites, which can be defined as forests that have not been destroyed by logging and are at least 80 years old. The six remnant rainforest sites were: Lake Barrine National Park (two sites) (Barrine 1 and 2), Lake Eacham National Park (Eacham), Millaa Millaa Falls Scenic Reserve (Millaa), Elinjaa Falls Scenic Reserve (Elinjaa), and Malanda Falls Environmental Park (Malanda). Six sites were adjacent rehabilitated sites, which are sites planted directly next to remnant rainforest sites. The six adjacent rehabilitated sites were: Winfield Park (Winfield), Chapman Farm (Chapman), Malanda Falls Environmental Park (Malanda Rehab.), Lake Barrine National Park (two sites) (Barrine 88 and 89) and Elinjaa Falls Scenic Reserve (Elinjaa Rehab). Five sites were isolated rehabilitated sites, which are sites planted within 500-700, and 1800 metres from remnant rainforest sites. The five isolated rehabilitated sites were: Hillcrest Farm (Hillcrest), Cleminson Creek (Cleminson), Thurling Farm (Thurling), Doan Farm (Doan), and Backshall Dairy Farm (Backshall).

Map 2.1: Study Sites on the Atherton Tableland



Legend

- Adjacent
- Isolated
- Remnant
- Forest Type 1b
- Forest Type 5a

Map created by Andrea L. Pullo
7 April 2005
Map identifying 17 study sites on the Atherton Tableland
highlighting forest sites and Tracy/Webb
forest classification 1b and 5a
Data source projection by Wet Tropics Management Authority
Cairns, Australia

0 2.5 5 10 15 Kilometers

1:175,000

Table 2.1: Description of study sites illustrating age, size, location, forest type and number of species planted

Site	Property	Location	Forest type	Species planted	Year planted	Approximate area (dimension)	Agency
Remnant Rainforest Sites	Barrine 1	Lake Barrine National Park	1b	N/A	N/A	408.10 ha	ESC [1]
	Barrine 2	Lake Barrine National Park	1b	N/A	N/A	408.10 ha	ESC
	Eacham	Lake Eacham National Park	1b	N/A	N/A	646.80 ha	ESC
	Millaa	Evelyn Rd.	5a	N/A	N/A	53.7 ha	ESC
	Elinjaa	Theresa Creek Rd.	1b	N/A	N/A	7.32 ha	ESC
	Malanda	Malanda	5a	N/A	N/A	13.74 ha	QPWS [2]
Adjacent Rehab. Sites	Winfield	Glen Allyn Rd.	1b	61	1992	3 ha	WTTPS[3]/ ECS
	Malanda Rehab.	Malanda	1b	86	1991-1992	0.6 ha (200 x 30 m)	WTTPS/ ESC
	Chapman	Malanda	1b	30-40	1990	0.9 ha (150 x 600 m)	WTTPS
	Barrine 88	Lake Barrine National Park	1b	38	1988	0.3 ha	QPWS
	Barrine 89	Lake Barrine National Park	1b	45	1989	0.5 ha	QPWS
	Elinjaa Rehab.	Theresa Creek Rd.	1b	95	1993	3 ha	WTTPS/ ESC
Isolated Rehab Sites	Hillcrest	Glen Allyn Rd.	1b	152	1992/1993	10 ha	QPWS
	Doan	Cleminson Ck, Malanda	1b	125	1992/1993	10 - 20 ha (50-100 x 2000m)	WTTPS
	Cleminson	Atherton Rd.	1b	30-40	1992/1993	4 ha	QPWS
	Thurling	Glen Allyn Rd.	1b	50+	1989-1992	4-5 ha	QPWS
	Backshall	Meragallan Rd. Malanda	1b	45	1990/1991	0.37 ha (75 x 500 m)	QPWS

[1] Eacham Shire Council [2] Queensland Park and Wildlife Service [3] Wet Tropics Tree Planting Scheme

2.3.2 Soil collection and sampling justification

At each site, a 20 metre transect was positioned along the forest floor. The origin of the transect was positioned at a 90 degree angle from the forest edge and began 10-20 metres from the forest edge to reduce influences of edge effects (Chapter 1 Section 1.1.1). A single soil sample, including leaf litter (Simpson *et al.* 1989), was collected using a steel core (60 x 60 x 50 mm deep) at each one metre interval along the transect (20 samples per site). All soil cores for each site were pooled by mixing in plastic bags, and were then labelled. To identify recruits, and overrepresentation of species in the soil seed bank, overstorey species that occurred within 1 metre on either side of the transect were recorded (Appendix B).

A large number of small samples were collected in order to increase the accuracy of obtaining representative samples of species in the soil. The spatial heterogeneity of seeds in the soil seed bank makes it difficult to capture all species of seeds present in the soil seed bank (Benitez-Malvido 1998; Butler and Chazdon 1998). The depth of 50 mm was chosen because seed density and discovery decreases with increasing soil depth and the discovery of additional species would be unlikely (Chippendale and Milton 1934; Guevara and Gomez-Pompa 1972; Moore and Wein 1977; Kellman 1978; Cheke *et al.* 1979; Holthuijzen and Boerboom 1982; Hopkins and Graham 1983; Putz and Appanah 1987; Dalling *et al.* 1997; Singhakumara *et al.* 2000). For example, Holthuijzen & Boerboom (1982) found seeds up to 20 cm in the soil, but most were in 0-1 cm of the soil.

2.3.3 Seed germination

Following seed collection all samples were taken to the Commonwealth Scientific & Industrial Research Organisation (CSIRO) Tropical Forest Research Centre (TFRC), Atherton. The seedling emergence method was applied in this study. A 10 mm layer of soil was spread onto 25 mm of medium grain vermiculite for germination. Although Dalling *et al.* (1994) recommended spreading soil to 5 mm, it was not possible due to the thick clay nature of the soil. The soil for each site was spread evenly among five trays. A similar quantity of sterilised potting soil was spread onto 17 germination trays to act as controls for seed contamination detection. Nine tables were set up in the glasshouse for the soil trays. Ten trays of soil samples and two control trays were placed randomly on each table. There were a total of 102 germination trays, 85 soil samples and 17 control trays.

Trays were watered for 10 minutes twice daily using a timed mist watering system. Seedlings were monitored weekly or fortnightly to ensure that the water regime was adequate. Trays were set on tables randomly and shuffled at every monitoring interval. Seedling emergence was monitored continuously for three months (Graham 2003 pers. comm.) (Appendix A).

The two most common methods to evaluate soil seed banks are direct counting and seedling emergence methods. The direct counting method consists of sieving soil to extract seeds. The seeds are commonly divided into categories, counted and identified. A disadvantage of this method is that small seeds may be lost during the sieving process (Warr *et al.* 1993) and subsequently species numbers may be underestimated (Tekle & Bekele 2000). Also, seed counting does not identify seed viability (Warr *et al.*1993) and therefore seed germination is necessary, which makes this method time consuming (Warr *et al.*1993).

Seedling emergence method consists of seed germination in the soil. Soil is usually spread onto trays and put into a greenhouse or other protected environment. Commonly, the two germination requirements applied are increased light and temperature. If species in the soil are known, other requirements such as scarification may be used. A disadvantage of this method is that species specific germination requirements cannot be used because species present in the soil are unknown (Warr *et al.* 1993). Some difficulties include keeping the seedlings viable for identification, and providing adequate greenhouse space for seed germination (Warr *et al.* 1993). Seedling emergence is the most common technique since it considers only viable seeds, and common germination requirements are used (increased light and temperature). For these reasons, the seedling emergence method was used in this study.

Seedlings were identified to species level at each census interval. If identification was unknown, the specimens were tagged and left in the germination tray or re-potted until they had grown to a stage when reliable identification was possible. After seedling identification, the life history traits of each species were collected. Life history traits included: life form, successional stage, dispersal mechanism, seed size, and origin (native or exotic). Life form included: tree, shrub, vine, grass, herb, and fern. Successional stage was categorized into: early, intermediate, and late. Dispersal mechanism was categorized into: animal, flight, cassowary, varied (more than one primary dispersal mechanisms), and wind. Seed size was divided into: small (0-10 mm), and intermediate (11-20 mm). Life history trait information came from published sources (Francis 1981; Turner and McMahon 1989; Cooper and Cooper 1994; Tucker and Murphy 1997; Tucker 2001; Hyland *et al.* 2003; Wrigley and Fagg 2003).

Ferns were also seen emerging in the germination trays. Because of their size and abundance, it was impossible to count them individually. To assess the contribution of the potential fern composition, overall abundance was estimated. Abundance was recorded by placing a soil core on the germination tray. All individual ferns were counted within the 60 mm x 60 mm core. The number of ferns was multiplied by 12 to create a total number of ferns per germination tray. Further, two common nursery weeds, silver fern (*Pityrogramma calomelanos*; family Pteridaceae) and military fern (*Pilea microphylla*; family Urticaceae) were found in the control trays. They were the only two species that emerged in the control trays. Abundances of *Pityrogramma calomelanos* and *Pilea microphylla* were excluded from all analyses because it could not be determine whether all trays were contaminated.

2.4 Data Analysis

Collecting soil samples is problematic because seed shadows suggest that seeds are not distributed evenly on the forest floor (Chapter 1 Section 1.2.2). Seeds may be underrepresented in some soil samples, and over-represented in others. Kellman (1978) noted that tropical soil seed banks have a large degree of spatial variability (see also review by Warr *et al.* 1993). Due to this spatial variability, it is unlikely that the frequency distribution of seeds will conform to a normal distribution (Warr *et al.* 1993).

To accommodate this irregular distribution, non-parametric statistical tests were used (Townend 2002).

To test for significant differences in the medians between: 1. species germinated; 2. number of individuals germinated; and 3. life history traits between remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites, the parametric ANOVA was replaced by the non-parametric Kruskal-Wallis ANOVA, which compares the medians of populations rather than the means. Where significant differences were detected across all site types, combinations for all possible 2-way tests for differences between medians (Mann-Whitney *U*-test) were used to isolate which forest site types were statistically different from others. For all Mann-Whitney *U*-tests, the Bonferroni corrected *p*-value of 0.016 (0.05/3 = 0.016) was used, since three *U*-tests were conducted for the three site combinations: remnant rainforest sites and adjacent rehabilitated sites, remnant rainforest sites and isolated rehabilitated sites, and adjacent and isolated rehabilitated sites. However, in some instances, the Kruskal-Wallis ANOVA may detect a *p*-value < 0.05, yet the Mann-Whitney *U*-test results in *p*-values > 0.016. In these cases, since the Kruskal-Wallis ANOVA identified a significant difference, the Mann-Whitney *U*-test *p*-value closest to the reduce level of 0.016 was detected as significant.

Since life history traits are not independent of one another, they may have positive or negative associations. The non-parametric Spearman's Rank Correlation Coefficient (r_s) was used to detect these associations. Spearman's Rank Correlation Coefficient accounts for irregular distribution by placing the observations as ranks and measures how closely two sets of rankings agree with each other.

All statistical tests were performed in SPSS 12.0 (SPSS 2003). These statistical tests are applied in the following chapters.

Chapter 3: Exotic species dominance in the soil seed bank of rehabilitated sites

3.1 Soil seed bank contribution to rainforest rehabilitation

3.1.1 Recruitment

A common aim of rainforest rehabilitation is to promote the re-establishment of plant species diversity in areas in which previous land practices have removed existing vegetation (Lamb *et al.* 1997; Tucker and Murphy 1997). Generally, rehabilitation seeks to plant a group of species that possess different dispersal mechanisms in order to increase natural levels of seed dispersal, and to encourage continued recruitment of new cohorts of native species (Tucker and Murphy 1997, Tucker 2001, White *et al.* 2004, McKenna 2001). Underlying this methodology is the assumption that following tree planting, the rehabilitated sites will attract native plant species of different successional stages, life forms, and dispersal mechanisms. Naturally dispersed seeds will then germinate, grow, and reproduce and in turn, native plant species recruitment will increase.

However, recruitment is not limited to native species, and exotic species also disperse to rehabilitated sites. Exotic species are considered a threat to rehabilitated sites because they have the potential to retard native species recruitment (Holzner 1978; Ashton *et al.* 1997; Groves and Willis 1999). If exotic species germinate, fruit, and dominate rehabilitated sites, then rehabilitation practices have not fulfilled their aim because the sites are not catalysing natural successional processes and the vegetation will not progress toward community composition similar to remnant rainforest.

3.1.2 Effect of distance on rehabilitation plantings

One principle factor limiting the efficacy of rehabilitation plantings is the location in which rehabilitation work is conducted. Previous decisions about the location of rehabilitation sites have been based on attempts to increase forest size, create forest buffers (Hobbs *et al.* 1993), and create larger habitat for wildlife (Robertson 2003 pers.

comm.). The result is that much of the forest rehabilitation conducted on the Atherton Tableland has occurred on land adjacent to remnant rainforest sites. In contrast, rehabilitated sites isolated from remnant rainforest are less common, and occur only on smaller scales and on private farming properties. Isolated rehabilitated sites are not as common because they are more susceptible to wind disturbance, microclimate change, and weed invasion (Laurance 1997). Therefore, recruitment to isolated rehabilitated sites may differ significantly from rehabilitated sites adjacent to remnant rainforest. Furthermore, isolation from remnant rainforests may exert a large influence on the identities of species that can successfully be recruited to the isolated sites.

One of the principal mechanisms limiting species recruitment to isolated rehabilitated sites is seed dispersal. Many seeds are not developed for dispersal over long distances (Takahashi and Kamitani 2004) and rely on local dispersal. For example, in northeast Queensland, many native rainforest species are limited to specific dispersers, including the flightless bird, the southern cassowary (*Casuarius casuarius*) (Crome and Moore 1990). The southern cassowary is the largest specialist seed disperser in tropical northeast Queensland, and is the only dispersal vector for over 100 species of native rainforest plants that have large fruits with big seeds (Crome and Bentrupperbaumer 1993). These birds require large continuous rainforest for survival and are unlikely to travel to small isolated rehabilitated sites. Therefore, seeds of some plant species may never disperse to rehabilitation sites isolated from remnant rainforest. Conversely, many isolated rehabilitated sites are surrounded by pastures, with abundant exotic species that produce many small highly-mobile wind-dispersed seeds. Therefore, isolated rehabilitated sites may have a higher concentration of exotics than remnant rainforest sites or adjacent rehabilitated sites (McKenna 2001; White *et al.* 2004).

3.1.3 Soil seed bank

Previous studies of the efficiency of rehabilitation practices at meeting their stated goals have generally considered only the above-ground recruits to the seedling banks of northeast Queensland (Tucker and Murphy 1997; McKenna 2001; Tucker 2001; White *et al.* 2004). Yet, full understanding of recruitment to rehabilitation sites may only be gained from consideration of all types of recruited seeds. The soil seed bank may provide additional information on species composition and recruitment not obtained by an above ground survey (Tucker and Murphy 1997). Therefore, knowledge of the composition of the soil seed bank is essential to determine whether the rehabilitated sites are catalysing natural successional processes.

Knowledge of seeds in the soil seed banks can be used to predict vegetation dynamics and community-level changes in species composition and relative abundances (Campos and de Souza 2003). Studies of soil seed bank composition have been used to investigate forest regeneration and succession (Kellman 1978; Hopkins and Graham 1983; Young *et al.* 1987; Graham and Hopkins 1990; Hopkins *et al.* 1990; Warr *et al.* 1993; Dupuy and Chazdon 1998; Walker and del Moral 2003). Specific studies have also examined regeneration in response to disturbance events (Guevara and Gomez-Pompa 1972; Hall and Swaine 1980; Hopkins and Graham 1983, 1984 a; Putz and Appanah 1987; Young *et al.* 1987; Garwood 1989; Dupuy and Chazdon 1998). For example, disturbances to above-ground vegetation can cause a reduction in established plant composition (Hopkins 1990), and increased light levels on the forest floor (Hopkins 1990; Whitmore 1990), which favour germination and establishment of light dependent species.

The disturbance events may potentially cause rehabilitation systems to divert from the trajectory of increasing native species diversity to its exotic herbaceous pre-rehabilitated state since exotic species have a high resilience to disturbance. In contrast, a high concentration of native seeds from diverse plant species of various successional stages may indicate that the rainforest site is resilient to disturbance, and re-establishment processes may be expected to follow processes of remnant rainforest, succeeding toward an older, more complex forest (Kellman 1978; Warr *et al.* 1993).

3.2 Aim

In this chapter, the composition of soil-stored seed banks at rehabilitated sites adjacent to and isolated from, remnant rainforest sites is examined. The soil seed bank composition of rehabilitated sites is compared with the soil seed bank of remnant rainforest sites. Of principle interest are the relative size and composition of the exotic species component.

Specifically, the aims of this study were to:

1. Determine the soil seed bank composition of remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites; and
2. Investigate if distance from remnant rainforest sites influences the exotic component of the soil seed bank

3.3 Research design

Refer to Chapter 2 Sections 2.3.1 – 2.3.3

3.3.1 Isolation of Exotics

To determine whether distance from remnant rainforest sites influences the exotic component of the soil seed bank, species were categorized as either native (all native trees, shrubs, vines), or exotic (all exotics, including native and exotic herbs, grasses, and ferns).

3.4 Data Analysis

To investigate whether the composition of the soil seed banks differed at varying distances from remnant rainforest, differences in the number of seeds germinated, number of species, abundance of species, and life history traits were tested using the Kruskal – Wallis ANOVA. Where significant differences were detected, the Mann-Whitney *U*-test was used to isolate which forest sites were statistically different. The Bonferroni corrected *p*-value of 0.016 (0.05/3) was used for the Mann-Whitney *U*-test. As explained in Chapter 2 Section 2.4, there were instances where the Kruskal-Wallis ANOVA detected a significance of $p < 0.05$, yet the Mann-Whitney *U*-test did not detect a significance of $p < 0.016$. In these cases, since the Kruskal-Wallis ANOVA identified a significant difference, the Mann-Whitney *U*-test *p*-value closest to the reduced level of $p = 0.016$ will be detected as significant.

Spearman's Rank Correlation Coefficient (r_s) was used to detect positive and negative associations among life history traits of exotic species. For example, small sized seeds may have a positive association with wind dispersed seeds, since seeds must be small in order for wind to transport the seeds.

All statistical analysis was conducted using SPSS 12.0 (SPSS 2003). For a more detailed explanation of these tests, refer to Chapter 2 Section 2.4.

3.5 Results

3.5.1 Soil seed bank composition

Across the 17 study sites, a total of 10,938 seeds were germinated from the soil seed bank (Appendix D). However, the total number of germinants was not consistent across rainforest sites. The soil seed banks of remnant rainforest sites were smallest, having 496 germinated seeds. The rehabilitated sites yielded more germinated seeds: 5,078 seeds in adjacent rehabilitated sites, and 5,364 seeds in isolated rehabilitated sites (Figure 3.1). There was a significant difference in the median number of germinants recorded between sites (Kruskal-Wallis $\chi^2 = 11.129$, d.f. = 2, $p = 0.004$). In general, more germinants were recorded in samples from adjacent and isolated rehabilitated sites than were recorded in samples from remnant rainforest sites. For example, significantly more seeds germinated in adjacent rehabilitated sites than remnant rainforest sites (Mann-Whitney U = 0, d.f. = 1, $p = 0.004$). Significantly more seeds germinated in isolated rehabilitated sites than remnant rainforest sites (Mann-Whitney U = 0, d.f. = 1, $p = 0.006$). However, there were no differences in the median number of seeds germinated between the adjacent and isolated rehabilitated sites (Mann-Whitney U = 15, d.f. = 1, $p = 1.000$).

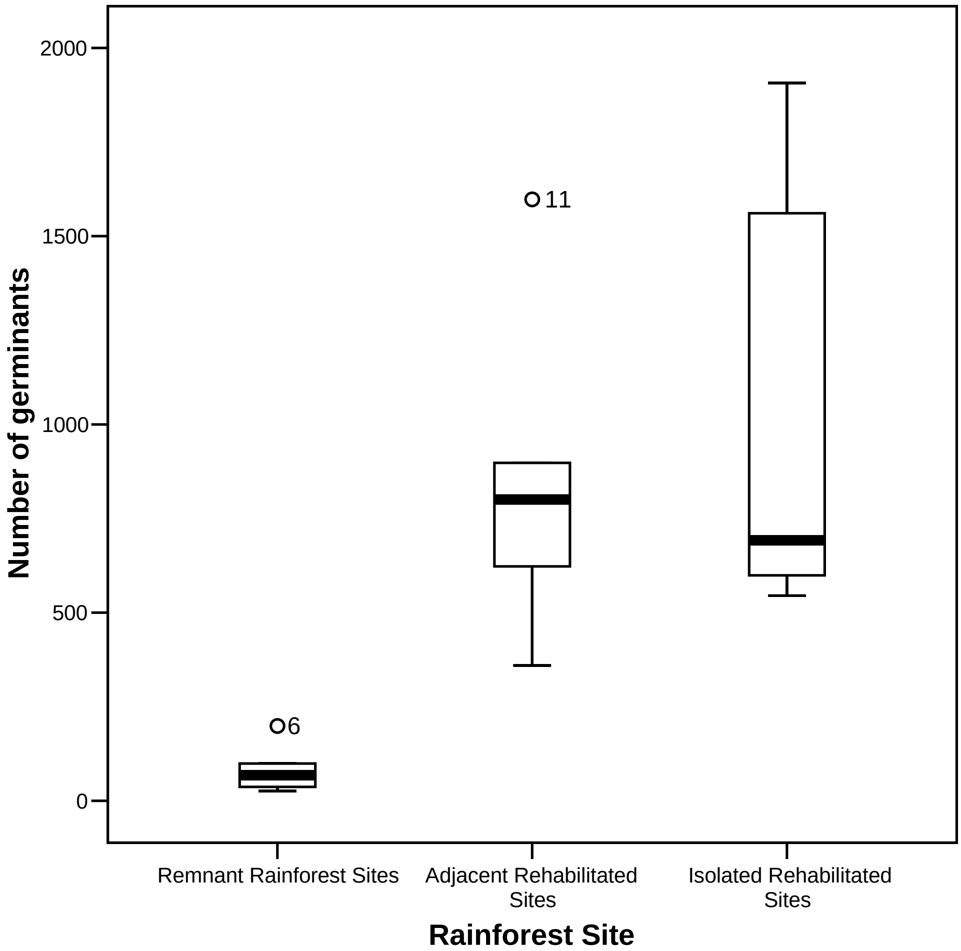


Figure 3.1: Box plot of median and range of total number of seeds germinated in remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites (outliers refer to two sites that produced a much larger number of germinated seeds)

3.5.2 Exotic Composition

The pattern shown in total germinants was largely the product of differences in the exotic component between rainforest site types. Across the 17 sites, a total of 10,226 exotic seeds were recorded. A total of 328 exotic seeds germinated in the remnant rainforest sites; 4,864 exotic seeds germinated in the adjacent rehabilitated sites; and 5,054 exotic seeds germinated in the isolated rehabilitated sites. Thus, the exotic component of the total germinants samples was 93% (10,226/10,938). Not surprisingly, the distribution of exotic species closely reflected the pattern for total germinants. When analysed alone, similar patterns of differences between site types were evident (compare Figure 3.1 and Figure 3.2). Significant differences in the median number of exotic germinants were detected between sites (Kruskal-Wallis $\chi^2 = 11.017$, d.f. = 2, $p = 0.004$). For example, significantly more exotic seeds germinated in adjacent rehabilitated sites than in remnant rainforest sites (Mann-Whitney $U = 0$, d.f. = 1, $p = 0.006$). Significantly more seeds germinated in isolated rehabilitated sites than in remnant rainforest sites (Mann-Whitney $U = 0$, d.f. = 1, $p = 0.004$). Again, there were no significant differences in the median number of exotic seeds germinating from the soil seed bank of adjacent or isolated rehabilitated sites (Mann-Whitney $U = 14$, d.f. = 1, $p = 0.855$).

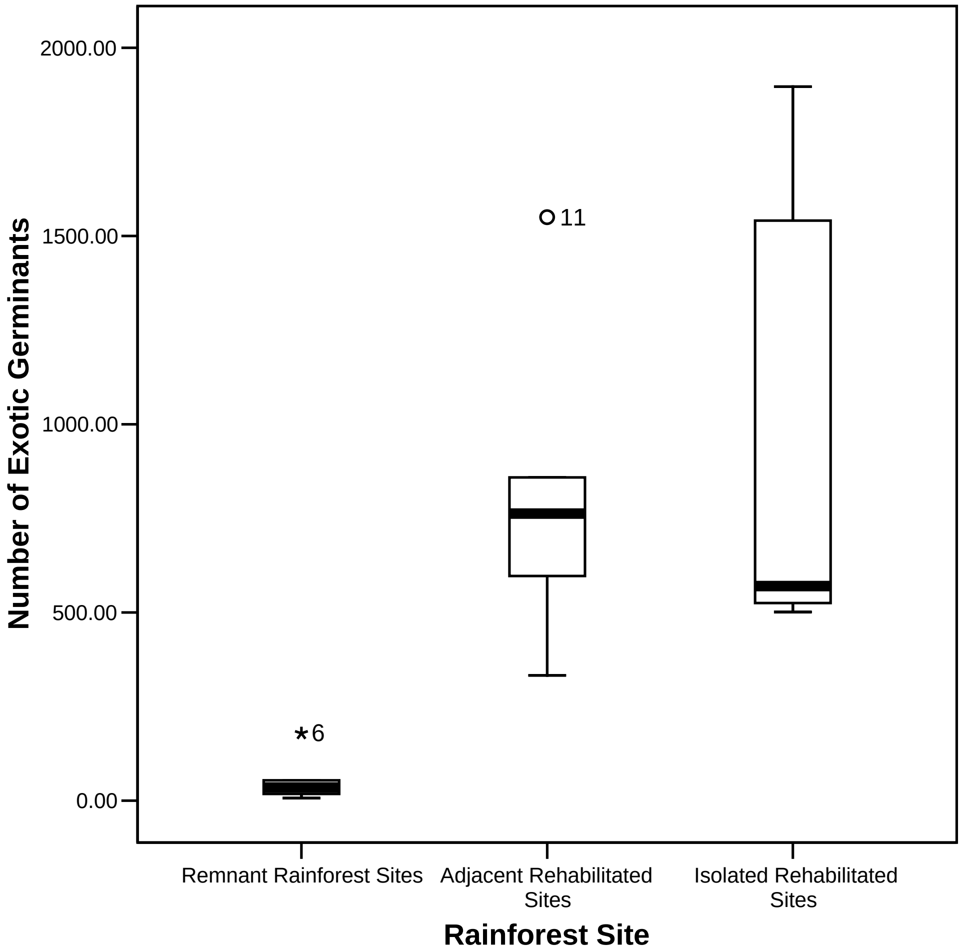


Figure 3.2: Boxplot of median and range of number of exotic seeds germinated in remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites

3.5.3 Species composition

A total of 56 species germinated in the 17 study sites. The largest number of species was found in the remnant rainforest sites. For example, 40 species were recorded from remnant rainforest sites, 34 species from adjacent rehabilitated sites, and 31 species from isolated rehabilitated sites (Table 3.1). There was no significant difference between the median number of species in each rainforest site (Kruskal-Wallis χ^2 = 3.491, d.f. = 2, p = 0.175). Some of the species were representative of all three rainforest site types, while others were exclusive to remnant rainforest, adjacent rehabilitated or isolated rehabilitated sites. For example, 17 species were common across all sites. Sixteen species were exclusive to remnant rainforest sites, three species were exclusive to adjacent rehabilitated sites, and five species were exclusive to isolated rehabilitated sites. Six species were represented in the remnant rainforest sites and the adjacent rehabilitated sites, one species was represented in the remnant rainforest sites and isolated rehabilitated sites, and nine species were found only in rehabilitated sites (Table 3.1).

The species that dominated the soil seed bank were representative of exotic families or native families favoured by disturbance. The five most common families present in the soil seed bank ranked by number of germinants/number of species were Asteraceae (6,034/6), Malvaceae (2,162/2), Poaceae (465/5), Solanaceae (210/5), and Euphorbiaceae (73/2).

Table 3.1: Species and abundance germinated in soil seed banks of remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites

Family	Species	Native (N)[1] Exotic (E)[2]	Site		
			Remnant	Adjacent	Isolated
Amaranthaceae	*Alternanthera bettzichiana*	N	0	0	2
Anacardiaceae	*Euroschinus falcata*	N	1	0	0
Apiaceae	*Hydrocotle acutiloba*	E	22	54	102
Apocynaceae	*Alstonia scholaris*	N	0	1	0
Araliaceae	*Polyscias murrayi*	N	1	2	0
Aristolochiaceae	*Aristolochia sp.*	N	1	0	0
Asteraceae	*Ageratum conyzoides*	E	49	2,181	3,537
	Conyza canadensis	N	0	7	15
	Crassocephalum crepidioides	E	14	70	127
	Gnaphalium	E	0	8	7
	Sonchus oleraceus	E	0	4	1
	Tridax procumbens	E	0	1	2
Brassicaceae	*Cardamine hirsuta*	E	43	26	20
Campanulaceae	*Wahlenbergia sp.*	E	1	109	0
Caryophyllaceae	*Drymaria cordata*	E	0	32	82
Cyperaceae	*Cyperus rotundus*	E	6	617	48
Elaeagnaceae	*Elaeagnus triflora*	N	9	0	0
Euphorbiaceae	*Homalanthus novo-guineensis*	N	10	12	10
	Phyllanthus lamprophyllus	N	0	35	6
Fabaceae	*Glycine cyrtoloba*	N	0	13	1
Lamiaceae	*Plectranthus sp.*		7	0	0
Lauraceae	*Lindera queenslandica*	N	25	0	6
Malvaceae	*Urena lobata*	E	1	0	0
	Sida rhombifolia	E	13	1,421	727
Meliaceae	*Melia azedarach*	N	7	0	0
Mimosaceae	*Acacia celsa*	N	2	9	2
Moraceae	*Ficus congesta*	N	21	16	1
	Ficus copiosa	N	2	0	0

Family	Species	Native (N)[1]/ Exotic (E)[2]	Site		
			Remnant	Adjacent	Isolated
Moraceae	*Ficus fraserii*	N	1	1	0
	Ficus sp.	N	1	0	0
Myrtaceae	*Rhodamnia sessiliflora*	N	2	0	0
	Rhodomyrtus pervagata	N	2	0	0
Oragraceae	*Ludwigia sp.*	E	0	7	2
Oxalidaceae	*Oxalis corniculata*	E	2	82	66
Pittosporaceae	*Hymenosporum flavum*	N	1	0	0
Poaceae	*Axonopus compressus*	E	6	69	107
	Brachiaria decumbens	E	0	67	0
	Cynadon dactylon	E	0	47	129
	Oplismenis aemulus	E	2	27	6
Rhamnaceae	*Alphitonia petriei*	N	15	55	55
Rosaceae	*Rubus alceifolius*	E	3	15	0
	Rubus moluccanus	N	2	5	1
Rubiaceae	*Richardia brasiliensis*	E	0	0	2
Rutaceae	*Melicope elleryana*	N	2	0	0
Solanaceae	*Physalis minima*	E	8	7	78
	Solanum dallachii	N	4	0	0
	Solanum mauritianum	E	8	42	43
	Solanum seaforthianum	E	1	16	0
	Solanum torvum	E	0	0	3
Thymelaeaceae	*Wikstroemia indica*	N	0	1	0
Tiliaceae	*Triumfetta rhomboidea*	E	0	0	1
Urticaceae	*Dendrocnide moroides*	N	19	0	0
	Dendrocnide photinophylla	N	18	5	0
Zingiberaceae	*Alpinia caerulea*	N	2	0	0
	Fern	E	134	0	0
	Grass 3	E	0	0	5

[1] all native trees, shrubs, vines [2] all exotic herbs, grasses, trees, shrubs, vines, including native herbs and grasses

Species did not germinate in equal numbers among sites, and the soil seed bank of each site type was dominated by a total of four species. For example, ferns dominated the soil seed banks of remnant rainforest sites (Figure 3.3). *Ageratum conyzoides* (Asteraceae), *Sida rhombifolia* (Schrophulariaceae), and *Cyperus rotundus* (Cyperaceae) dominated the soil seed banks of adjacent rehabilitated sites (Figure 3.4). *A. conyzoides* and *S. rhombifolia* dominated the soil seed banks of isolated rehabilitated sites (Figure 3.5).

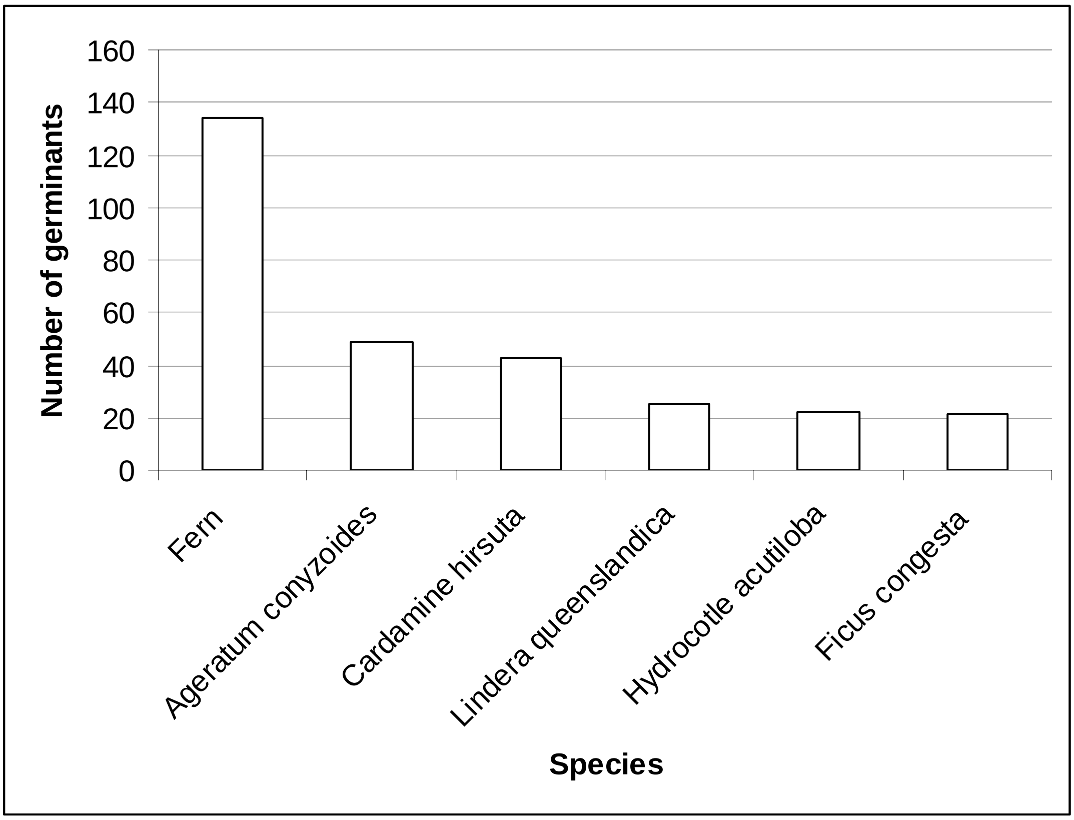


Figure 3.3: Bar graph showing species abundance > 20 germinants in remnant rainforest sites

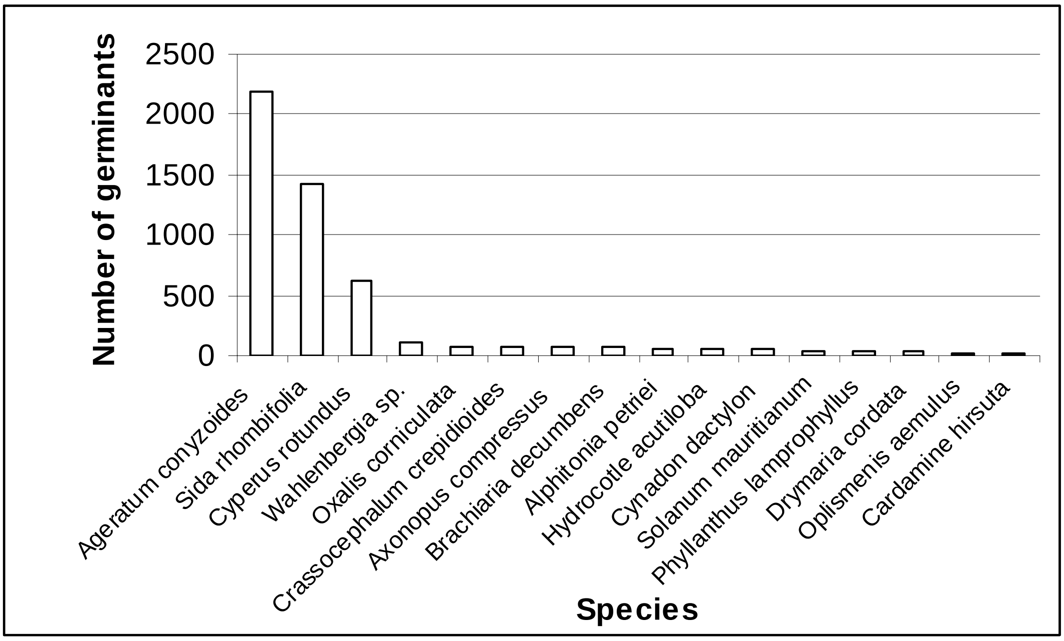


Figure 3.4: Bar graph of species abundance > 20 germinants in adjacent rehabilitated sites

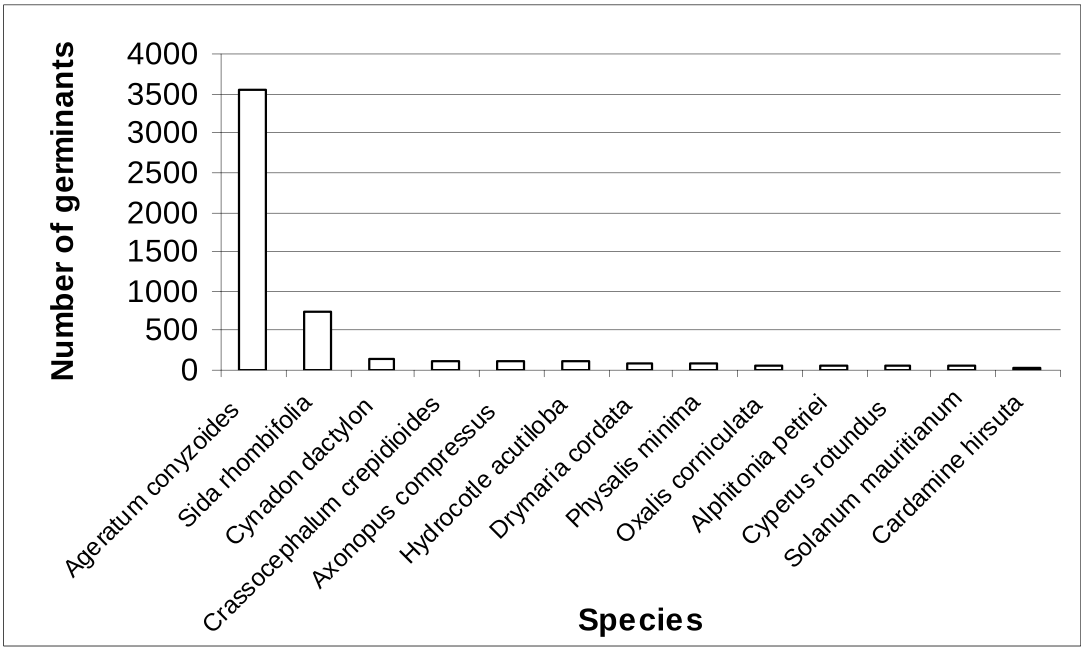


Figure 3.5: Bar graph of species abundance > 20 germinants in isolated rehabilitated sites

Of the 11 exotic species that occurred across all three rainforest site types, there were significant differences in the medians of four exotic species: *Ageratum conyzoides* (Asteraceae) (Kruskal-Wallis χ^2 = 11.705, d.f. = 2, p = 0.003), *Crassocephalum crepidioides* (Asteraceae) (Kruskal-Wallis χ^2 = 10.342, d.f. = 2, p = 0.006), *Oxalis corniculata* (Oxalidaceae) (Kruskal-Wallis χ^2 = 6.641, d.f. = 2, p = 0.036), and *Physalis minima* (Solanaceae) (Kruskal-Wallis χ^2 = 7.511, d.f. = 2, p = 0.023) (Appendix G). There were significantly more germinants of *A. conyzoides* in adjacent rehabilitated sites than in remnant rainforest sites (Mann-Whitney U = 0, d.f. = 1, p = 0.004). Significantly more *A. conyzoides* germinated in isolated rehabilitated sites than in remnant rainforest sites (Mann-Whitney U = 0, d.f. = 1, p = 0.006). However, no significant differences were detected in the median number of *A. conyzoides* between the adjacent rehabilitated sites and the isolated rehabilitated sites (Mann-Whitney U = 8, d.f. =- 1, p = 0.201). In addition, there were significantly more *C. crepidioides* in isolated rehabilitated sites than in remnant rainforest sites (Mann-Whitney U = 0, d.f. = 1, p = 0.006). However, no significant differences were detected in the median number of *C. crepidioides* between adjacent rehabilitated sites and remnant rainforest sites (Mann-Whitney U = 4.5, d.f. = 1, p = 0.029) and between adjacent rehabilitated sites and isolated rehabilitated sites (Mann-Whitney U = 5, d.f. = 1, p = 0.067). Significantly more germinants of *O. corniculata* germinated in adjacent rehabilitated sites than in remnant rainforest sites (Mann-Whitney U = 4, d.f. = 1, p = 0.020). However, no differences were detected between isolated rehabilitated sites and remnant rainforest sites (Mann-Whitney U = 4, d.f. = 1, p = 0.034), and between adjacent rehabilitated sites and isolated rehabilitated sites (Mann-Whitney U = 13.5, d.f. = 1, p = 0.783). There were significantly more germinants of *P. minima* present in isolated rehabilitated sites than remnant rainforest sites (Mann-Whitney U = 2, d.f. = 1, p = 0.016). However, there were no significant differences in the medians of *P. minima* between the adjacent rehabilitated sites and the remnant rainforest sites Mann-Whitney U = 17.5, d.f. = 1, p = 0.933), and between the isolated rehabilitated sites and the remnant rainforest sites (Mann-Whitney U = 2.5, d.f. – 1, p = 0.021).

3.5.4 Life history traits

All of the exotic seeds that germinated in the soil seed bank were small (0-10 mm) and early successional. They represented the life forms of herbs, grasses, ferns, trees, shrubs, and vines. Significant differences in the median number of exotic herbs were detected between sites (Kruskal-Wallis χ^2 = 12.210, d.f. = 2, p = 0.004). Herbs dominated the soil seed banks of rehabilitated sites. For example, significantly more herbs were present in the adjacent rehabilitated sites than in the remnant rainforest sites (Mann-Whitney U = 0, d.f. = 1, p =0.004). Significantly more herbs were present in the isolated rehabilitated sites than in the remnant rainforest sites (Mann-Whitney U = 0, d.f. = 1, p = 0.006). However, no significant differences were detected in the median between the adjacent and isolated rehabilitated sites (Mann-Whitney U = 11, d.f. = 1, p = 0.465). Due to the associations between life form and other life history traits, herbs were positively associated with wind dispersal (r_s = 0.934, n = 17, p < 0.001), and varied dispersal (r_s = 0.617, n = 17, p < 0.001), and negatively associated with trees (r_s = -0.651, n = 17, p = 0.005) (Figures 3.6 A,B,C) (Appendix E).

Grasses were also present in large abundances in the sites. Significant differences in the median number of grasses were detected between sites (Kruskal-Wallis χ^2 = 7.725, d.f. = 2, p = 0.021). Significantly more grasses occurred in the isolated rehabilitated sites than in the remnant rainforest sites (Mann-Whitney U = 0, d.f. = 1, p = 0.006). However, no significant differences in the medians were detected between remnant rainforest sites and adjacent rehabilitated sites (Mann-Whitney U = 5.5, d.f. = 1, p = 0.045) and adjacent and isolated rehabilitated sites (Mann-Whitney U = 10.5, d.f. = 1, p = 0.410). Due to the associations between life form and other life history traits, grasses were positively associated with wind dispersal (r_s = 0.527, n = 17, p = 0.03), and varied dispersal (r_s = 0.624, n = 17, p = 0.007) (Figure 3.6 A,B,C).

Significant differences in the median number of exotic vines were detected among sites (Kruskal-Wallis χ^2 = 7.352, d.f. = 2, p = 0.025). There were significantly more vines in the adjacent rehabilitated sites than in the remnant rainforest sites (Mann-Whitney U = 3.5, d.f. = 1, p = 0.013). However, no significant differences occurred between the isolated rehabilitated sites and the remnant rainforest sites (Mann-Whitney U = 3.5, d.f. = 1, p = 0.022) and the adjacent and isolated rehabilitated sites (Mann-Whitney U = 15, d.f. = 1, p = 1.000). Vines were positively associated with varied dispersal (r_s = 0.807, n = 17, p < 0.001) (Figure 3.6 A,B,C).

Fig. 3.6 A

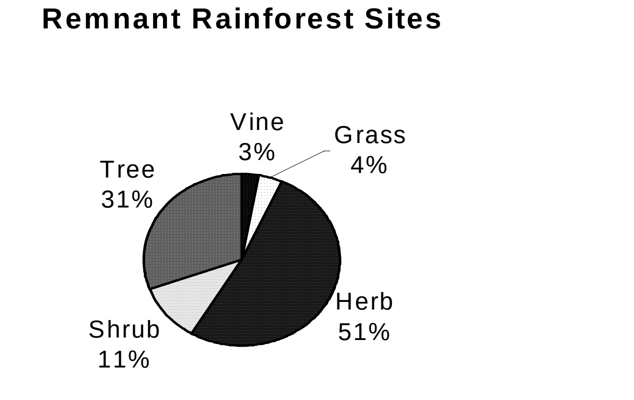


Fig. 3.6 B

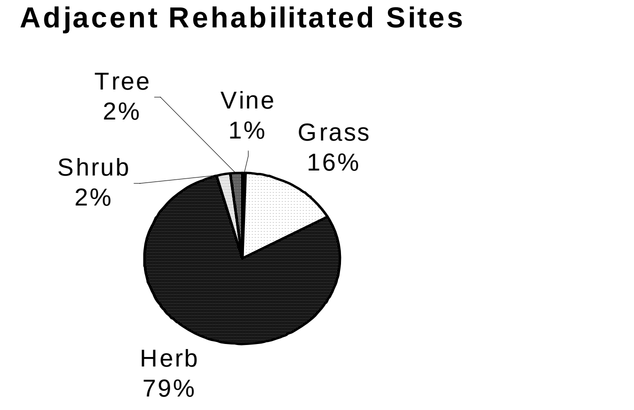


Fig. 3.6 C

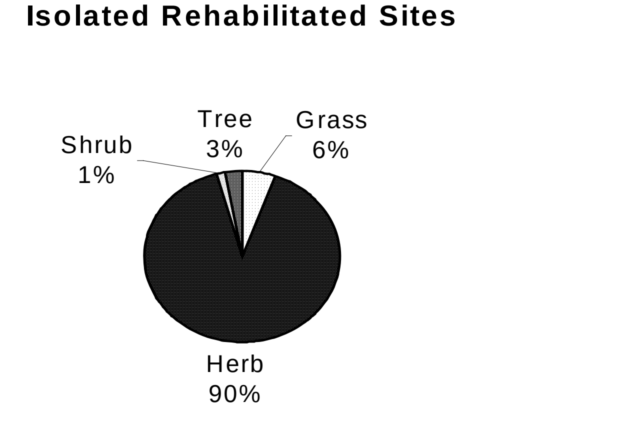
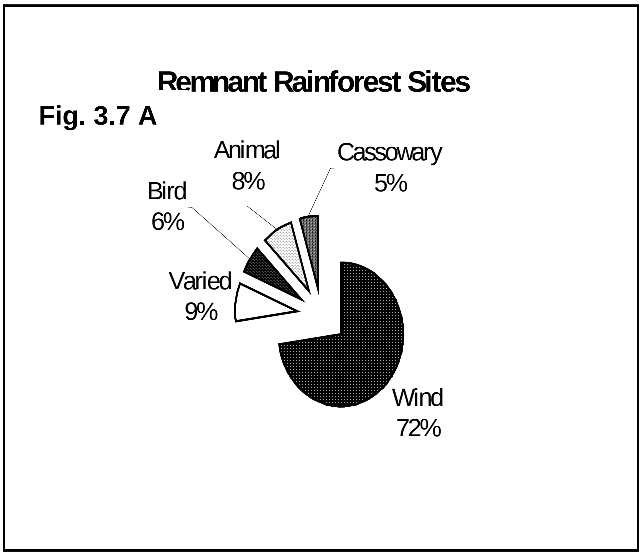
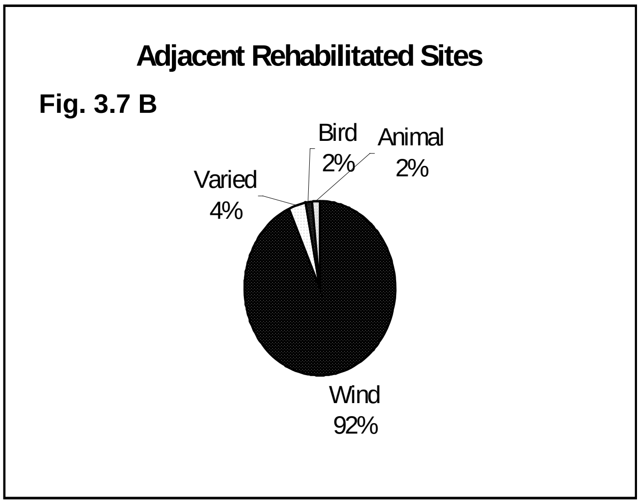


Figure 3.6 A,B,C: Pie charts illustrating percentage of life history trait distribution between remnant rainforest sites (A), adjacent rehabilitated sites (B), and isolated rehabilitated sites (C)

The representation of life history traits between different site types followed identical patterns to life form differences discussed above. The seeds were dispersed by flight, wind, and varied dispersal. There were significant differences among wind and varied dispersal mechanisms. Significant differences in the median number of wind dispersed seeds were detected between sites (Kruskal-Wallis $\chi^2 = 11.014$, d.f. = 2, $p = 0.004$). Significantly more wind dispersed seeds were present in the adjacent rehabilitated sites than in the remnant rainforest sites (Mann-Whitney $U = 0$, d.f. = 1, $p = 0.004$). Significantly more wind dispersed seeds were present in the isolated rehabilitated sites than in the remnant rainforest sites (Mann-Whitney $U = 0$, d.f. = 1, $p = 0.006$). However no differences in the medians number of wind dispersed seeds were detected between the adjacent and isolated rehabilitated sites (Mann-Whitney $U = 14$, d.f. = 1, $p = 0.855$). Due to the associations between dispersal mechanism and other life history traits, wind dispersal was positively associated with herbs ($r_s = 0.934$, $n = 17$, $p < 0.001$), grass ($r_s = 0.527$, $n = 17$, $p = 0.03$), and negatively associated with trees ($r_s = -0.635$, $n = 17$, $p = 0.006$) (Figure 3.7 A,B,C).

Significant differences in the median number of varied dispersed seeds were detected between sites (Kruskal-Wallis $\chi^2 = 11.313$, d.f. = 2, $p = 0.003$). Adjacent rehabilitated sites revealed significantly more varied dispersed seeds than the remnant rainforest sites (Mann-Whitney $U = 0$, d.f. = 1, $p = 0.004$). Isolated rehabilitated sites, however, yielded significantly more varied dispersed seeds than the remnant rainforest sites (Mann-Whitney $U = 0$, d.f. = 1, $p = 0.006$). Interestingly, no significant differences were detected between the adjacent and isolated rehabilitated sites (Mann-Whitney $U = 11$, d.f. =1, $p = 0.460$). Due to the associations between dispersal mechanism and other life history traits, varied dispersal was positively associated with the life forms: herbs ($r_s = 0.617$, $n = 17$, $p = 0.008$), grasses ($r_s = 0.624$, $n = 17$, $p = 0.007$), shrubs ($r_s = 0.707$, n = 17, $p = 0.002$), and vines ($r_s = 0.807$, $n = 17$, $p < 0.001$) (Figure 3.7 A,B,C).





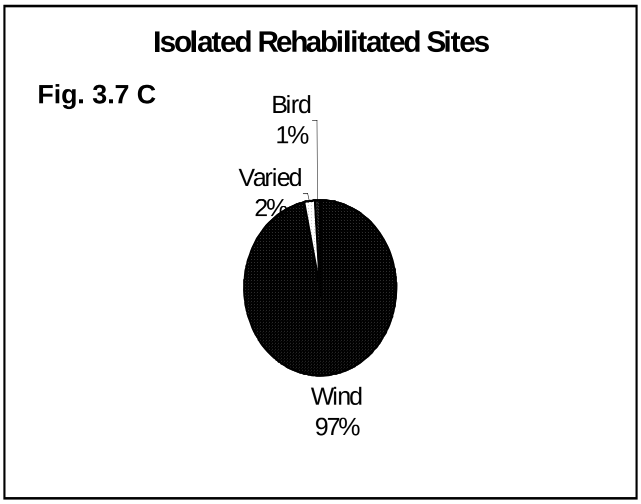


Figure 3.7 A,B,C: Pie charts illustrating percentage of dispersal mechanism distribution between remnant rainforest sites (A), adjacent rehabilitated sites (B), and isolated rehabilitated sites (C)

3.6 Discussion

3.6.1 Species composition

The seeds that germinated in the soil seed banks were represented predominantly by five families. These families comprised exotic species and native species characteristic of disturbance: Asteraceae, Poaceae, Solanaceae, Euphorbiaceae, and Malvaceae. Asteraceae has 900 genera, 13,000 species, and 200 genera occur in Australia (Hyland *et al.* 2003). All the species in Asteraceae that germinated in the soil seed bank were exotic, herbaceous species. Species in Asteraceae can remain dormant in the soil seed bank, but once germination conditions are met, three to seven days are required for germination (Wrigley and Fagg 2003). Poaceae consists of 620 genera and 9,000 – 10,000 species and 150 genera appear in Australia (Hyland *et al.* 2003). Species in Poaceae are native and exotic grasses. Solanaceae consists of 90 genera and 2,600 species and 12 genera occur in Australia (Hyland *et al.* 2003). Species in Solanaceae are native and exotic herbs and shrubs. Euphorbiaceae has 300 genera and 7,500 species and 50 – 55 genera grow in Australia. Species in Euphorbiaceae are native trees favoured by disturbance (Hyland *et al.* 2003). Malvaceae consists of 75 genera and 1,000 – 1,500 species and 20 genera occur in Australia. Species in Malvaceae are native shrubs favoured by disturbance (Hyland *et al.* 2003).

Of the 11 species representative of all three rainforest site types, there were significantly more seeds of *Ageratum conyzoides* (Asteraceae), *Crassocephalum crepidioides* (Asteraceae), *Oxalis corniculata* (Oxalidaceae), and *Physalis minima* (Solanaceae) in rehabilitated sites than in remnant rainforest sites. *A. conyzoides* (Blue Top) is an exotic annual or short-lived perennial, which has the ability to grow under low light conditions, and is considered to be a common weed (Turner and McMahon 1989). *C. crepidioides* (Thick Head) is an exotic annual herb (Turner and McMahon 1989). *O. corniculata* (Creeping Oxalis) is an annual or perennial herb and is common throughout Australia (Lamp and Collet 1999). *P. minima* (Wild Gooseberry) is an annual herb and is a common weed of New South Wales and Queensland (Lamp and Collet 1999). The dominance of these exotic herbaceous species may inhibit the growth and survival of woody species (Dupuy and Chazdon 1998) by covering the forest floor and hoarding light, moisture, and nutrients and so preventing the germination of native species.

3.6.2 Dominance of exotics

Investigating the composition of the soil seed bank is necessary to identify the species pool from which new seedlings may potentially germinate at a particular site (Kellman 1978; Hopkins and Graham 1983; Young *et al.* 1987; Graham and Hopkins 1990; Hopkins *et al.* 1990; Warr *et al.* 1993; Dupuy and Chazdon 1998; Walker and del Moral 2003). This study demonstrated that the soil seed banks of rehabilitated sites yielded a significantly larger number of seeds than the soil seed banks of remnant rainforest sites. More importantly, most of these seeds were from exotic species.

Unsurprisingly, rehabilitated sites have high concentrations of exotic seeds. Land surrounding the rehabilitated sites contained exotic species. Because of the life history traits of these seeds (small, wind dispersed seeds), many seeds may disperse into the area, become incorporated into the soil seed bank, and germinate in favourable conditions. Exotic species produce seeds with characteristics that often result in them dominating the soil seed banks. These characteristics include small size and hard coated seed conditions. These seeds have the ability to remain dormant for extended periods until suitable conditions for germination occur (see Chapter 1 Section 1.2.3). Exotic species also produce many wind-borne seeds annually, which travel to and either germinate or become incorporated into the soil seed bank. The exotic, wind-dispersed seeds present in the soil seed bank were also early successional species. The presence of early successional species was expected since climax species do not remain dormant in the soil seed bank, but germinate immediately to establish the seedling bank (Hopkins and Graham 1987; Whitmore 1990). For example, Hopkins and Graham (1987) investigated germination of rainforest species and found that climax species remained dormant in the soil seed bank for six weeks or less. This finding confirms studies of remnant rainforest sites that found the soil seed banks were dominated by early successional species and the absence of late successional species (Guevara and Gomez-Pompa 1972; Cheke *et al.* 1979; Hall and Swaine 1980; Quintana-Ascencio *et al.* 1996; Dupuy and Chazdon 1998).

3.6.3 Exotics and distance from remnant rainforest

The dominance of exotic germinants in rehabilitated sites compared to remnant forest sites is consistent with past studies. Previous investigations of the soil seed banks of remnant rainforest sites found a small proportion of exotic herbs and grasses (Guevara and Gomez-Pompa 1972; Hopkins and Graham 1983; Young *et al.* 1987). Conversely, two studies of the soil seed banks of five-year old rehabilitated sites or disturbed sites found a high concentration of exotic herbs and grasses (Hopkins and Graham 1983; Tucker and Murphy 1997). Although the exotic component was significantly greater between remnant rainforest sites and adjacent rehabilitated sites, exotics did not differ based on distance, either adjacent to, or isolated from remnant rainforest sites. This result differs from another study of the Atherton Tableland that found rehabilitated sites isolated from remnant rainforests had a significantly larger number of exotic species than rehabilitated sites adjacent to remnant rainforest (White *et al.* 2004). Since rehabilitated sites are not different in species composition, it appears that distance from remnant rainforest does not influence soil seed bank composition.

3.6.4 Factors affecting species composition

One factor that may have influenced the species composition in soil seed bank samples is the differences in the number and types of seed predators present at the sites. Predators may have eaten seeds on the forest floor before they were incorporated into the soil and collected. For example, the white-tailed rat (*Uromys caudimaculatus*) is a common predator of rainforest seeds (Harrington *et al.* 1997) and may have eaten seeds that had fallen on the forest floor. These seeds may be underrepresented in the soil seed bank.

Another factor that may have affected species richness is the germination technique used. In this study, seed germination took place in a glasshouse rather than in a natural environment. More seeds may have germinated in glasshouse conditions than in the natural environment since seeds were not competing with overstorey species for light and nutrients (Henry *et al.* 2004). In addition, seeds in the soil seed banks are difficult to measure because of the different germination requirements. The seedling emergence method used in this study collects soil and germinates seeds by increased light and temperature (Sutherland 1996) (Chapter 2 Section 2.3.3). This method fails to include seeds that do not germinate under these conditions. It also omits seeds that do not remain dormant in the soil, but germinate immediately. Seeds may have been present in the soil that had other methods of dormancy, which did not germinated under light and temperature. Further research is needed to determine the maximum number of species present in the soil seed bank by germination techniques other than by increased light and temperature.

Spatial heterogeneity of seeds in the soil and seasonality are two other factors that may have influenced the species composition in the soil seed bank. As explained in Chapter 1 Section 1.2.4, seeds do not fall uniformly on the forest floor. The methodology to collect a large number of small samples attempts to maximize the number of species. However, it is unlikely that soil samples included the total species of seeds under the soil surface of the rainforest sites. Seasonality may also affect the composition of the seeds within the soil seed bank. Some trees fruit at different times of the year, and may be present in the soil seed bank at different seasons (Guevara and Gomez-Pompa 1972). This study sampled the soil once during the year, and not at different time intervals. Therefore, the seeds in the soil seed bank are only a snapshot of the soil seed bank at one time during the year. In order to collect a more thorough representation of species within the soil seed bank, soil collection could occur at intervals throughout the year.

3.6.5 Role of Disturbance

The species in the soil seed bank have been found to play an important part in forest regeneration following disturbance (Ewel *et al.* 1981; Uhl and Clark 1983; Hopkins and Graham 1984 b; Putz and Appanah 1987; Young *et al.* 1987). The results from this study indicate that, after a disturbance, exotic herbs and grasses may germinate and establish in the rehabilitated sites. Once established, the exotic herbs and grasses may prevent other native species from germinating. Exotics are highly resilient to disturbance, are prolific seed producers and are capable of long dormancy; all these factors illustrate that these species pose a threat to the re-establishment of native species to rehabilitated sites.

Chapter 4: Native recruitment to the soil seed banks of selected rehabilitated sites

4.1 Native species recruitment as an aim of rainforest rehabilitation

4.1.1 Recruitment and diversity

As stated in Chapter 3 Section 2.1.1, the principal aim of forest rehabilitation initiatives on the Atherton Tableland is to foster the recruitment of native species (Tucker and Murphy 1997; Murphy and Tucker 2000; McKenna 2001; Tucker 2001; White *et al.* 2004). In this context, recruitment is best defined as the occurrence of plant species on rehabilitated sites that were not originally planted. The underlying assumption in rehabilitation initiatives is an increase of 'natural' dispersal rates across fragmented landscapes. Therefore, recruitment to rehabilitated sites should include native species that were not part of the original planting scheme.

Successful dispersal across landscapes increases plant species diversity at rehabilitated sites. Diversity is important when forest rehabilitated sites are managed because diversity is vital to the long term survival of species (Goosem and Tucker 1995; Austrheim and Eriksson 2003). For example, diversity generates increases in the number and types of plant-animal interactions. Diversity may also increase the rate of forest succession by attracting late successional native woody plants that are dispersed by animals attracted to rehabilitated areas. In contrast, when natural dispersal is limited, areas can become dominated by a few species (of single life form or successional stage) and prevent native species from establishing. For example, Ashton *et al.* (1997) found that the dominance of Guinea Grass, *Panicum maximum* (Poaceae), which is highly resilient to disturbance, can out-compete the establishment of native species. Dominance of a single or few species results in low levels of habitat heterogeneity, and increases the chance of arrested succession (Hopkins 1990).

4.1.2 Isolation and the soil seed bank

In order to minimize species dominance, delimit forest fragmentation, and utilize seed sources available from remnant rainforests, rehabilitated sites are often planted adjacent to remnant rainforests (Lamb *et al.* 1997; Laurance 1997). Adjacent rehabilitated sites may attract a diverse range of seeds of different successional staged species and with a range of dispersal mechanisms. However, isolated sites may not benefit from these species since they are secluded from outside seed sources (Lamb *et al.* 1997). Therefore, native species recruitment may differ between rehabilitated sites based on distance from remnant rainforest. Little work has been conducted to investigate how the composition of native species in the soil seed bank responds to isolation, although evidence from seed rain and seedling bank studies shows a strong influence of isolation (Tucker and Murphy 1997; McKenna 2001; Tucker 2001; White *et al.* 2004). For example, McKenna (2001) showed that isolation has a strong negative influence on native seedling species richness. The greater the distance between rehabilitated plot and potential source of native seeds, the less diverse the native component of recruited seedlings. In his study, distance accounted for a much greater proportion of variance in native seedling recruits between sites than other site parameters such as age and plot shape. However, only one study has looked at the native species recruitment to the soil seed bank (Tucker and Murphy 1997). They investigated young (6 year) rehabilitated sites and found that the soil seed bank comprised 10% native species recruits and the remaining seeds were representative of exotic species. The soil seed bank may illustrate native species recruitment and indicate if these species will germinate following a disturbance in the canopy.

4.2 Aim

The composition of native species recruited to the soil seed bank of rehabilitated sites adjacent and isolated from remnant rainforest sites is examined. Native species recruitment to the soil seed bank of rehabilitated sites is compared with remnant rainforest sites. Of principle interest are the relative size, composition, and life history traits of the native recruited species.

Specifically, the aims of this study were to:

1. Investigate if native species recruitment is occurring on rehabilitated sites on the Atherton Tableland; and
2. Determine if distance from remnant rainforest sites influence the number of native seeds and species recruited to the rehabilitated sites on the Atherton Tableland.

4.3 Methods

4.3.1 Research design

See Chapter 2 Sections 2.3.1 – 2.3.3

4.3.2 Isolation of native recruited species

Recruited species were defined as those plant species on rehabilitated sites that were not originally planted. In order to isolate the component of the total species identified as native recruited species (Chapter 2 Sections 2.3.2 – 2.3.3), existing information about identities of planted species was used. Species lists of all trees planted as part of rehabilitation programs were available from the tree planting agencies Wet Tropics Tree Planting Scheme (WTTPS) and Eacham Shire Council (ESC) to five sites: Winfield Park (adjacent), Malanda Falls Environmental Park (adjacent), Hillcrest Farm (isolated), Elinjaa Falls Scenic Reserve (adjacent), and Doan Farm (isolated) (Appendix C). However, an organized system of recording species names was not created at the time of rehabilitation works for the other 12 sites: Lake Barrine National Park 1988 and 1989 (adjacent), Chapman Farm (adjacent), Cleminson Creek (isolated), Thurling Farm (isolated) and Backshall (isolated). For these sites, overstorey species lists were created during data collection (Chapter 2 Section 2.3.2) (Appendix A). For all rehabilitated sites species germinated from the soil seed bank study were compared either to the planted species lists or to the overstorey species lists. All native species found in the soil seed bank study but not occurring on either list were classified ‘recruits’. To compare rehabilitated and remnant rainforest sites, overstorey species lists were also generated from remnant rainforest sites and an identical process of identification was used to generate a list of ‘recruits’ in remnant rainforest sites.

4.4 Data analysis

Kruskal-Wallis ANOVA and Mann-Whitney *U*-tests were used to detect significant differences in native seedlings and species recruited to sites, and differences in life history traits. The Bonferroni corrected *p*-value of 0.016 (0.05/3) was used for the Mann-Whitney *U*-test. In the instances where the Kruskal-Wallis ANOVA detected a significance of $p < 0.05$, yet the Mann-Whitney *U*-test did not detect a significance of $p < 0.016$, the Mann-Whitney *U*-test *p*-value closest to the reduce level of $p = 0.016$ will be detected as significant.

To investigate the life history traits of the native recruitment occurring in these sites, Spearman's Rank Correlation Coefficient was used to measure associations between the seed characteristics and to illustrate whether some seed characteristics had strong positive or negative associations.

These tests were performed in SPSS 12.0 (SPSS 2003).

4.5 Results

4.5.1 Native recruitment

Of the 10,938 seeds that germinated in the 17 study sites, 462 germinated seeds were native, and 238 native seeds were identified as 'recruits'. A total of 120 native seeds were recruited to the remnant rainforest sites; 33 native seeds to the adjacent rehabilitated sites; and 85 native seeds to the isolated rehabilitated sites. The number of recruited native seeds was consistent across the rainforest sites. There were no significant differences in the median number of native recruited seeds between rainforest site types (Kruskal-Wallis $\chi^2 = 0.233$, d.f. = 2, $p = 0.890$) (Figure 4.1).

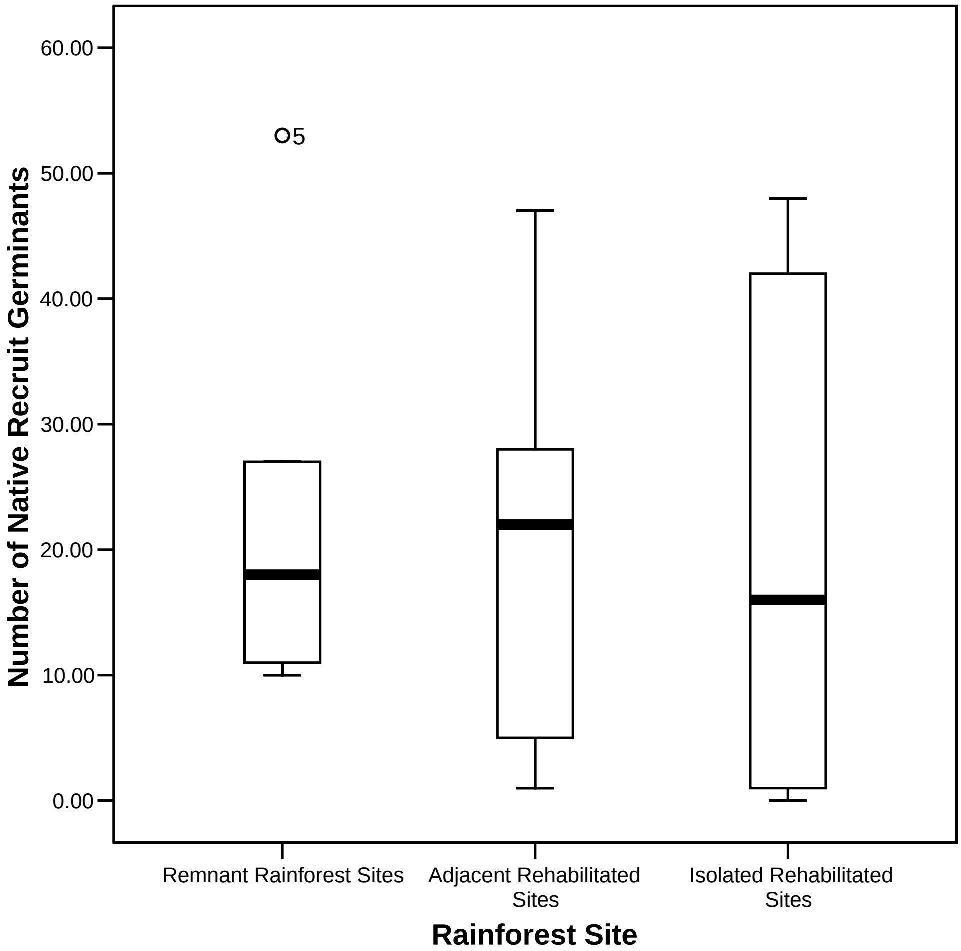


Figure 4.1: Boxplot showing median and range of native seeds recruited to the remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites

4.5.2 Native species composition

A total of 29 native species were recruited to the soil seed banks of the three rainforest site types (Table 4.1). The largest number of recruited native species occurred on remnant rainforest sites (20 native species), and six species represented more than five individuals. Five species were recruited to the adjacent rehabilitated sites. Four species were recruited to the isolated rehabilitated sites. There was no significant difference in the median number of native species recruited to the three rainforest site types (Kruskal-Wallis $\chi^2 = 0.517$, d.f. = 2, p = 0.772) (Figure 4.5) (Appendix H).

Table 4.1: Native species recruited to the soil seed banks of remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites

Family	Species	Site		
		Remnant	Adjacent	Isolated
Anacardiaceae	*Euroschinus falcata*	1	0	0
Aristolochiaceae	*Aristolochia sp.*	1	0	0
Elaeagnaceae	*Elaeagnus triflora*	1	0	0
Euphorbiaceae	*Homalanthus novoguineensis*	10	9	6
Lauraceae	*Lindera queenslandica*	25	0	77
Meliaceae	*Melia azedarach*	6	0	0
Mimosaceae	*Acacia celsa*	2	0	0
Moraceae	*Ficus congesta*	18	16	1
	Ficus copiosa	2	0	0
	Ficus fraserii	1	1	0
	Ficus sp.	1	0	0
Myrtaceae	*Rhodamnia sessiflora*	2	0	0
Myrtaceae	*Rhodomyrtus pervagata*	2	2	0
Pittosporaceae	*Hymenosporum flavum*	1	0	0
Rosaceae	*Rubus moluccanus*	2	0	1
Rutaceae	*Melicope elleryana*	2	0	0
Solanaceae	*Solanum dallachii*	4	0	0
Urticaceae	*Dendrocnide moroides*	19	0	0
	Dendrocnide photinophylla	18	5	0
Zingiberaceae	*Alpinia caerulea*	2	0	0

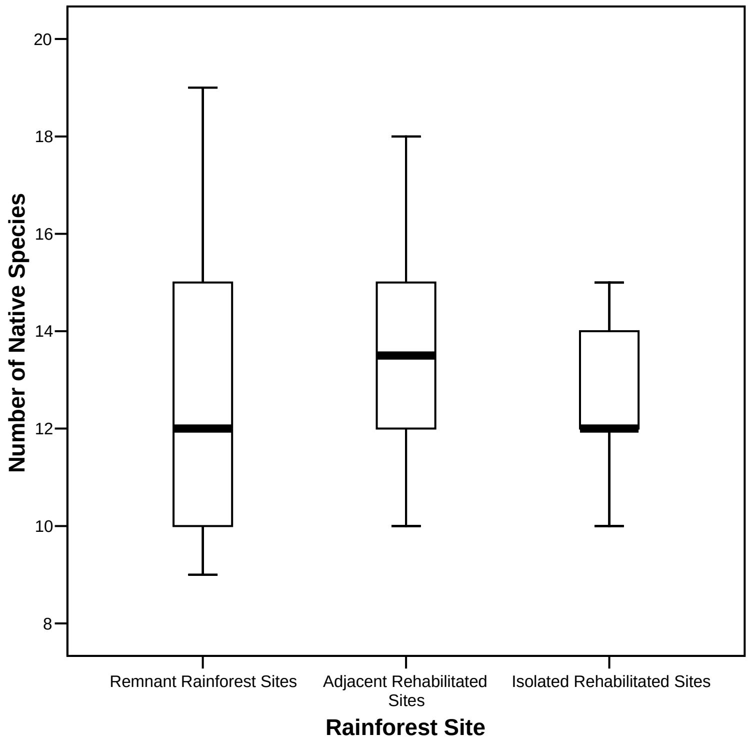


Figure 4.5: Boxplot showing median and range number of native germinated seeds recruited to the remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites

The recruited native species were site specific. Eleven species were exclusive to the remnant rainforest sites. Two species were recruited to all three rainforest site types. Out of the two species recruited to all three rainforest site types, there were no significant differences in the median number of *Homalanthus novoguineensis* (Euphorbiaceae) (Kruskal-Wallis χ^2 = 0.796, d.f. = 2, p = 0.672), or *Ficus copiosa* (Moraceae) (Kruskal-Wallis χ^2 = 1.833, d.f. = 2, p = 0.400). The four most common families recruited to the rainforest sites types ranked by number of germinants/number of species were: Lauraceae (102/1), Moraceae (35/1), Euphorbiaceae (25/1), and Urticaceae (23/1).

4.5.3 Life history traits

The life forms of the native species recruits were of trees and shrubs. These species had seed dispersal by wind, flight, varied, animal, and cassowary. The seeds were small (0-10 mm) and intermediate (11-20 mm) sized, and were early and intermediate successional staged species.

There were no significant differences in the median number of trees (Kruskal-Wallis $\chi^2 = 2.176$, d.f. = 2, $p = 0.337$), and shrubs (Kruskal-Wallis $\chi^2 = 1.054$, d.f. = 2, $p = 0.590$) between rainforest site types (Figure 4.6 a and b). Due to the association with life form and other life history traits, trees were positively associated with varied dispersal ($r_s = 0.591$, $n = 17$, $p = 0.013$), small sized seeds ($r_s = 0.824$, $n = 17$, $p < 0.001$), and intermediate successional species ($r_s = 0.735$, $n = 17$, $p = 0.001$). Shrubs were positively associated with wind dispersal ($r_s = 0.638$, $n = 17$, $p = 0.006$), small sized seeds ($r_s = 0.620$, $n = 17$, $p = 0.008$), and early successional species ($r_s = 0.978$, $n = 17$, $p < 0.001$) (Appendix F).

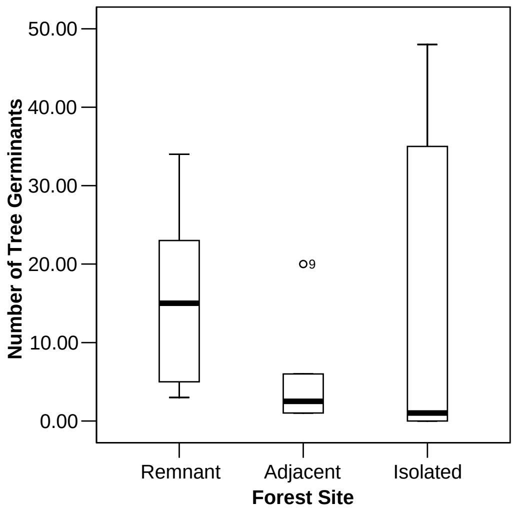


Figure 4.6 a

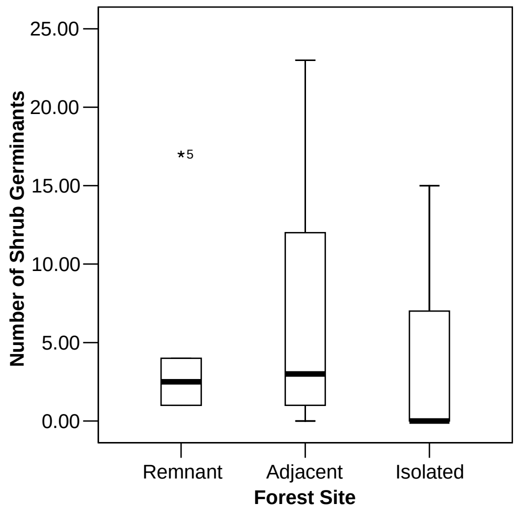


Figure 4.6 b

Figure 4.6 a and b: Boxplot showing median and range of native recruited germinants of trees and shrubs in remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites

All but three seeds recruited to the soil seed bank were small sized seeds. No significant differences occurred in median number of small sized seeds between rainforest site types (Kruskal-Wallis $\chi^2 = 0.459$, d.f. = 2, $p = 0.795$). Due to the associations between seed size and other life history traits, small sized seeds are positively associated with early successional species ($r_s = 0.559$, $n = 17$, $p = 0.020$), with intermediate successional species ($r_s = 0.544$, $n = 17$, $p = 0.024$), and with shrubs ($r_s = 0.620$, $n = 17$, $p = 0.008$). Intermediate sized seeds are positively associated with intermediate successional species ($r_s = 0.589$, $n = 17$, $p = 0.013$).

All but three seeds were representative of early successional species. The remaining three were representative of intermediate successional species. There were no significant differences in the median number of early successional seeds between the rainforest site types (Kruskal-Wallis $\chi^2 = 0.899$, d.f. = 2, $p = 0.638$) and intermediate successional seeds between the rainforest site types (Kruskal-Wallis $\chi^2 = 6.347$, d.f. = 2, $p = 0.042$). Due to the associations between successional stage and other life history traits, early successional seeds were positively associated with wind dispersal ($r_s = 0.603$, $n = 17$, $p = 0.010$), small sized seeds ($r_s = 0.591$, $n = 17$, $p < 0.05$), and with shrubs ($r_s = 0.978$, $n = 17$, $p < 0.001$). Intermediate successional seeds were positively associated with animal dispersal ($r_s = 0.561$, $n = 17$, $p = 0.019$), varied dispersal ($r_s = 0.734$, $n = 17$, $p = 0.001$), cassowary dispersal ($r_s = 0.572$, $n = 17$, $p = 0.016$), small sized seeds ($r_s = 0.544$, $n = 17$, $p = 0.024$), intermediate sized seeds ($r_s = 0.589$, $n = 17$, $p = 0.013$), and trees ($r_s = 0.735$, $n = 17$, $p = 0.001$).

The dispersal mechanisms representative of native recruits were wind, flight, animal, cassowary, and varied. Wind dispersal was the most common between the two rehabilitated site types (65% wind dispersal in adjacent rehabilitated sites, 33% wind dispersal in isolated rehabilitated sites), but wind dispersal was absent in the remnant rainforest site. However, there were no significant differences in the median number of wind dispersed seeds between the rainforest site types (Kruskal-Wallis $\chi^2 = 5.253$, d.f. = 2, $p = 0.072$). Flight dispersal represented 12% of recruits in remnant rainforest sites, 3% of isolated rehabilitated sites, and was absent from adjacent rehabilitated sites. There was a significant difference detected in the median number of flight dispersed seeds between the three rainforest site types (Kruskal-Wallis $\chi^2 = 6.884$, d.f. = 2, $p = 0.032$). Remnant rainforest sites showed significantly more flight dispersal than adjacent rehabilitated sites (Mann-Whitney $U = 6$, d.f. = 1, $p = 0.022$). However, no significant differences were detected in the median number of flight dispersed seeds between remnant rainforest sites and isolated rehabilitated sites (Mann-Whitney $U = 6.5$, d.f. = 1, $p = 0.089$), and between adjacent and isolated rehabilitated sites (Mann-Whitney $U = 12$, d.f. = 1, $p = 0.273$). Varied dispersal was most common in the isolated rehabilitated sites (21%), remnant rainforest sites (20%), and adjacent rehabilitated sites (12%). No significant differences were detected in the median number of varied dispersed seeds (Kruskal-Wallis $\chi^2 = 3.036$, d.f. = 2, $p = 0.219$). Dispersal by cassowary accounted for approximately the same abundance of recruited seeds between remnant rainforest sites (24%), and adjacent rehabilitated sites (23%), but was absent from isolated rehabilitated sites. No differences were detected in the median number of cassowary-dispersed seeds between rainforest site types (Kruskal-Wallis $\chi^2 = 0.636$, d.f. = 2, $p = 0.728$) (Table 4.2).

Animal dispersal was the most common in remnant rainforest sites (43%), and adjacent rehabilitated sites (7%) but was absent from isolated rehabilitated sites. There were, however, significant differences in the median number of native animal dispersed seeds between sites (Kruskal-Wallis $\chi^2 = 10.936$, d.f. = 2, $p = 0.004$) (Table 4.2 and Figure 4.7). Significantly more native animal dispersed seeds in remnant rainforest sites than in isolated rehabilitated sites (Mann-Whitney $U = 0$, d.f. = 1, $p = 0.004$), due to the absence of animal dispersed seeds in isolated plots. Yet, there were no significant differences between remnant rainforest sites and adjacent rehabilitated sites (Mann-Whitney $U = 4$, d.f. = 1, $p = 0.023$), and adjacent rehabilitated sites and isolated rehabilitated sites (Mann-Whitney $U = 7.5$, d.f. = 1, $p = 0.080$). Animal dispersal was positively associated with intermediate successional species ($r_s = 0.561$, $n = 17$, $p = 0.019$). Varied dispersal was also positively associated with intermediate successional species ($r_s = 0.734$, $n = 17$, $p = 0.001$) as well as trees ($r_s = 0.591$, $n = 17$, $p = 0.013$). Wind dispersal was positively associated with early successional species ($r_s = 0.603$, $n = 17$, $p = 0.010$), and shrubs ($r_s = 0.638$, $n = 17$, $p = 0.006$). Cassowary dispersal was positively associated with intermediate successional species ($r_s = 0.572$, $n = 17$, $p = 0.016$).

Table 4.2: Table illustrating dispersal mechanisms of native recruited species in remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites

Site	*Wind dispersal*	*Flight dispersal*	*Varied dispersal*	*Cassowary dispersal*	*Animal dispersal*
Remnant	0	12%	20%	24%	43%
Adjacent	58%	0	12%	23%	7%
Isolated	72%	3%	21%	3%	0

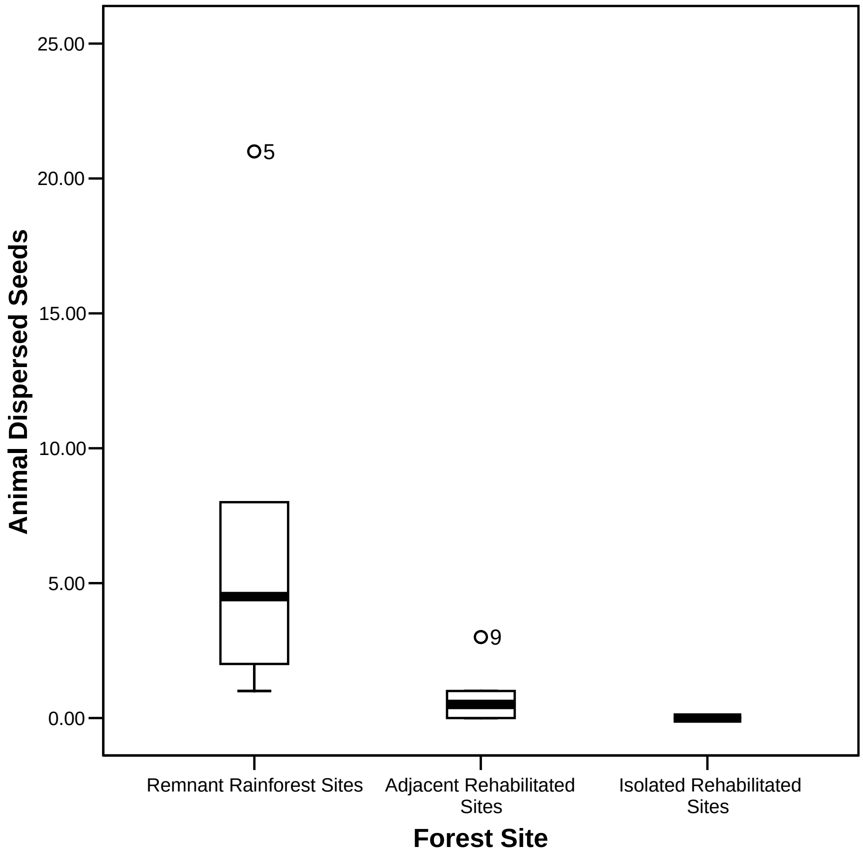


Figure 4.7: Boxplot showing median and range of native animal dispersed seeds recruited to remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites

4.6 Discussion

4.6.1 Native recruitment

Studying native species recruitment to rehabilitated sites may indicate that the site has increased in forest diversity (Goosem and Tucker 1995; Austrheim and Eriksson 2003).

This study found that little native species recruitment (4.6%) occurred to the three rainforest site types. No significant difference was detected in the median number of native seeds and species germinating from the soil seed bank. This result suggests that native species recruitment is occurring independent of distance from rehabilitated sites either adjacent to, or isolated from remnant rainforests. This result is in contrast to previous works. Studies investigating native seed and seedling recruitment to rehabilitated sites on the Atherton Tableland have determined that distance from remnant rainforest has a large effect on native species recruitment to the seed rain and seedling bank (McKenna 2001; White *et al.* 2004). For example, a study by White *et al.* (2004) showed that adjacent rehabilitated sites recruited significantly more native seedlings than two rehabilitated sites at varying distances (600 m and 1,200 m) from remnant rainforest. Further research that includes another isolation category (2,000 metres) may show a difference in native species recruitment.

4.6.2 Site specific species

Recruited native species were site specific. For example, 11 species were restricted to remnant rainforest sites. These species were: *Euroshinus falcata* (Anacardiaceae), *Hymenosporum flavum* (Pittosporaceae), *Rhodamnia sessiliflora* (Myrtaceae), *Acacia celsa* (Mimosaceae), *Melicope elleryana* (Rutaceae), *Alpinia caerulea* (Zingiberaceae), *Solanum dallachii* (Solanaceae), *Melia azedarach* (Meliaceae), and *Dendrocnide moroides* (Urticaceae). *Euroshinus falcata* (Pink Poplar), *Hymenosporum flavum* (Native Frangipani), and *Rhodamnia sessiliflora* (Iron Malletwood) are trees endemic to Australia and found in a variety of well developed rainforests (Hyland *et al.* 2003).

However, the remaining eight species are favoured by disturbance and are more characteristic of rainforest regrowth. *Acacia celsa* (Black Wattle) is a tree endemic to Queensland. *A. celsa* is a fast growing species favoured by disturbance and characteristic of regrowth (Hyland *et al.* 2003). The apparent recruitment of *A. celsa* only to remnant rainforest sites is probably an artefact because *A. celsa* was planted in many rehabilitated plantings and therefore not recognised by them as a recruit. Furthermore, the presence of *A. celsa* in rehabilitated sites increases the probability that *A. celsa* seeds may have been dispersed into the remnant rainforest sites from the adjacent rehabilitated sites where they were planted. *Melicope elleryana* (Pink Euodia) occurs in northeast Queensland as well as Western Australia, Northern Territory, and Cape York Peninsula. The tree grows in well developed rainforest and is favoured by disturbance (Hyland *et al.* 2003). The shrub *Alpinia caerulea* (Native Ginger) is endemic to Australia and found in northeast Queensland, Cape York Peninsula, and south to coastal New South Wales. It grows in disturbed areas in well developed lowland and upland rainforest (Hyland *et al.* 2003). *Solanum dallachii* (Nightshade) is a shrub endemic to northeast Queensland and is found in disturbed areas in well developed lowland and upland rainforest (Hyland *et al.* 2003). *Melia azedarach* (White Cedar) is a tree found in northeast Queensland, Cape York Peninsula, Northern Territory, Western Australia, and south to coastal New South Wales. It also occurs in Asia, Malaysia, and the Solomon Islands. *M. azedarach* is a component of regrowth and favoured by disturbance (Hyland *et al.* 2003). *Dendrocnide moroides* (Stinging Bush) is a shrub that appears in northeast Queensland, Cape York Peninsula, and northeast New South Wales. It grows on disturbed areas in lowland and upland rainforest (Hyland *et al.* 2003).

The four most common families of native recruited species were Lauraceae, Euphorbiaceae, Moraceae, and Urticaceae. The species recruited in Lauraceae is *Lindera queenslandica*. Lauraceae consists of 50-55 genera with over 3 000 species. Eight genera naturally occur in Australia. The species recruited to Euphorbiaceae is *Homalanthus novo-guineensis.* There are 300 genera and 7,500 species in the family Euphorbiaceae. Fifty to 55 genera occur naturally in Australia. Species recruited in Moraceae are figs *Ficus congesta, F. copiosa, F. fraserii,* and an unknown fig. Moraceae consists of 53 genera and 1,400 species. Seven genera occur naturally in Australia. *Dendrocnide moroides* and *D. photinophylla* were representative of Urticaceae. There are 52 genera and 1,900 species in the family Urticaceae. Eleven genera occur naturally in Australia (Hyland *et al.* 2003).

4.6.3 Life history traits

The life forms representative of native species recruitment to the soil seed bank were trees and shrubs. No significant differences occurred among the rainforest site types, which indicate that distance from remnant rainforest sites does not influence recruitment of native trees and shrubs to the soil seed bank. The small number (301 germinants) of native woody plant recruits agrees with an earlier study investigating the soil seed bank composition of rainforest sites at varying ages and disturbances (Hopkins and Graham 1983). Hopkins and Graham (1983) found that disturbed rainforest sites (comparable to rehabilitation sites) contributed to a small percentage of native woody plant species (10%), and may be indicative of the germination technique for successful establishment. More exotic herbs and grasses have the ability to remain dormant in the soil seed bank until suitable germination conditions occur. Many native rainforest tree species are not capable of remaining dormant in the soil seed bank, but rather germinate immediately (up to six weeks) (Hopkins and Graham 1987).

All but three seeds that were recruited to the soil seed bank were small. The dominance of small-sized seeds in the soil seed bank is comparable to seeds found in the seedling bank. For example, McKenna (2001) found that most seeds representing species in the seedling bank were small. Tucker and Murphy (1997) also found mostly small-sized seeds in both the seedling bank and soil seed bank. These results suggest that such seeds are characteristic of rehabilitation sites, and may be due to some trade-offs between seed size and seed number, and weight and dispersal vector (Crawley 1997).

In addition, most small-seeded native tree and shrub recruits were representative of early successional species. This result is consistent with Tucker and Murphy (1997) who found that most species present in the soil seed bank were early successional species. Late successional species were absent from the soil seed banks of the three rainforest site types. The reason may be that many intermediate to late successional native species do not remain dormant in the soil, but germinate soon after dispersal (Hopkins and Graham 1987). Additionally, late successional species do not fruit annually, but rather every 3 – 7 years (Whitmore 1990) or during different seasons. Therefore, some of these species and may not have fruited during soil collection and not be represented in the soil seed bank. Further research should be conducted to collect soil seed bank samples throughout the year to determine whether seasonality influences species recruitment to the soil seed bank.

The recruited species had similar life history traits to the exotic seeds present in the soil seed bank (see Chapter 3). Both native and exotic seeds were small sized, early successional and predominantly wind-dispersed. This study demonstrates that these life history traits are advantageous to the success of seeds that remain dormant in the soil seed bank.

4.6.4 Dispersal mechanisms

The native species recruited species were typical of wind, flight, varied, cassowary, and animal dispersal mechanisms. There was a significant difference in flight dispersal, and more flight dispersal occurred in remnant rainforest sites but was absent in adjacent rehabilitated sites. Although the value of the presence of flight dispersal has been documented in adjacent and isolated rehabilitated sites (Tucker and Murphy 1997; White *et al.* 2004), flight dispersal was found in small numbers in seed recruitment to the soil seed bank.

There were significantly more animals-dispersed seeds recruited to remnant rainforest sites than to isolated rehabilitated sites. This result was due to the absence of animal dispersal in isolated rehabilitated sites. The result was not surprising because in general, rainforest animals live in large areas of rainforest, rather than in isolated patches (Laurance 1997). Animals may not travel to the isolated sites for foraging (Willson and Crome 1989; Dennis 2003; Dennis *et al.* 2003). For example, the musky rat-kangaroo (*Hypsiprymnodon moschatus*) disperse fruit close by the parent plant or, if they travel greater than 5 m, within an average distance of 16.51 $\pm$ 2.7 metres (Dennis 2003). They are important dispersers because they eat the fruit of 40 native plant species (Dennis 2003). However, it is less likely that animals travel and disperse seeds in isolated patches.

Large-seed regeneration is dependent on animal dispersal, which is largely influenced by fragmentation (Harrington *et al.* 1997). Absence of animal dispersed species in isolated sites is problematic because animals do not disperse native rainforest species to isolated rehabilitated sites. As a result, isolated rehabilitated sites may experience long term decrease in diversity, and perhaps arrested succession (Tucker and Murphy 1997).

In order for these species to arrive at isolated sites, the sites may have to rely on human intervention such as direct seeding, in which seeds are collected and dispersed by humans rather than animals or other means (Kanowski *et al.* 2003a).

Chapter 5: Soil seed bank and the success of rainforest rehabilitation

5.1 Overview

This study has investigated the composition of the soil seed bank in relation to meeting the rehabilitation aims of catalysing natural successional processes and recruitment of native species. This chapter investigates the factors that consider whether rehabilitation has been successful or not. In addition, this chapter investigates additional methods that have also been employed to assess the success of rehabilitation. Current management is discussed and further management is suggested in order to assure that rehabilitation aims are met. Lastly, the results from this study form the basis for a suggestion for the future composition of rehabilitated sites.

5.2 Measures of tropical rehabilitation success

Ecologists suggest methods including self-sustaining vegetation, restoring forest structure, and increasing biodiversity to measure the success of rehabilitation plantings. However, there is no consensus as to whether rehabilitated sites have been successful, and no agreement about the ways to measure rehabilitation success. Current approaches do not describe practical management techniques that will indicate whether the forest is a successful rehabilitation planting. For example, one suggestion to maximize the success of rehabilitation plantings is to create a cover of self-sustaining vegetation (Hobbs *et al.* 1993). This method involves changing the land type from degraded to restored, while creating a self-sustaining ecosystem. However, this method does not indicate practical measures to determine what a restored area is, or to determine whether a site is self-sustainable or not.

Another method estimates success by recolonizing species and increasing diversity. However, success should be looked at as a continuum (Reay and Norton 1999). If the beginning stages of the continuum are termed a success, the later stages have a greater change of also being successful. Specifically, the study investigated rehabilitated sites in New Zealand and regarded success as the creation of a fully restored structure and composition as mature forests. The results indicate that the rehabilitated sites were not successful. However, since the authors suggest outcomes should be considered as a continuum, success may change over time, which implies further monitoring should be conducted over the long-term to determine long-term success (Reay and Norton 1999).

Cairns (1993) suggest there are three factors to measure the success of a rehabilitation site: there should be no observable negative effects, the site must be self sustainable for "some time" and lastly, the outcomes should meet the goals of the rehabilitation agency (Cairns 1993). This suggestion is entirely hypothetical and offers no practical examples or methods to determine whether a rehabilitated site is successful.

This study implemented Tucker and Murphy's (1997) proposal, which stated that a successful rehabilitation project is one that demonstrates native species recruitment and the ability to sustain new life forms. This study applied this method by measuring the exotic species component and the native recruited component.

5.3 Additional methods of evaluating ecological processes on rehabilitated sites

Although examination of the soil seed bank was implemented to assess Tucker and Murphy (1997) determination of success as native species recruitment, other methods have also been used to evaluate ecological processes occurring in rehabilitated sites. These methods include investigating the presence of mammal and birds as dispersers (Murray 1988; Tucker 2001; Dennis *et al.* 2003); examining the presence of specialized invertebrates occurring at rehabilitated sites (Jansen 1997; Blanche 2003; Nakamura *et al.* 2003); and analysing the composition of seed rain and newly established seedlings (Tucker and Murphy 1997; McKenna 2001; White *et al.* 2004).

For example, studies of the presence of mammal and birds at rehabilitated sites have shown that more mammal and bird dispersers forage on rehabilitated sites planted adjacent to remnant rainforests than on rehabilitated sites planted in isolation from remnant rainforests (Dennis *et al.* 2003). Two important rainforest seed dispersers, the musky rat-kangaroo and the southern cassowary, do not disperse seeds over long distances, but disperse seeds locally (Crome and Moore 1990; Dennis 2003). The dispersal patterns of mammals and birds may indicate the species diversity on a rehabilitated site, and on adjacent rehabilitated sites, may be more diverse than on isolated rehabilitated sites. However, the soil seed bank study detected no significant difference between animal and bird dispersed seeds at either adjacent or isolated rehabilitated sites.

Ecologists currently examine the species composition of the seed rain or seedling bank to determine whether rehabilitated sites recruit native species, and to determine preferred rehabilitation planting locations. Studies investigating seed rain, or seedling banks have demonstrated that rehabilitated sites adjacent to remnant rainforest sites recruit native plants with a variety of dispersal mechanisms, successional stages, and life forms (Tucker and Murphy 1997; McKenna 2001; White *et al.* 2004). These studies suggest that rehabilitation plantings should be conducted at sites adjacent to remnant rainforests. However, the soil seed bank suggests that species composition is not influenced by distance from remnant rainforest. The two different results suggest that a successful rehabilitation project is determined by which method is employed. Although the soil seed bank studied independently of other methods does not provide a complete picture of ecological processes, it should be an added component to rehabilitation research based on the new information it provides.

5.4 Management of rainforest rehabilitation sites

Sustained management practices are essential to maximize the success of rehabilitation plantings. Specifically, on the Atherton Tableland, WTTPS has carried out on-site management, including weed control for 2 – 3 years. Herbicide should be used with caution because, although it may be effective in the short-term, it but must be accompanied by rapid regrowth of native canopy to be successful (Hobbs *et al.* 1993). The current management regime does not does not take into consideration that weeds may germinate after two years. Additionally, this method does not evaluate the goals of the plantings, the function of the forest, or whether the site is becoming self-sustainable. This study investigated rehabilitated sites 10 – 12 years following weed control and the sites showed a dominance of exotic herbs and grasses. Exotic dominance suggests current rehabilitation management is not sufficient. For these reasons Walker and del Moral (2003) recommend long term monitoring and maintenance. To reduce the exotic component of the soil seed bank, a more rigid management regime should be implemented including longer weed management, reduction of exotic seeds in the soil, and weed control of surrounding pasture (Hobbs *et al.* 1993).

The soil seed bank offers a better understanding of management regimes than looking only at above ground species. For example, an increase in native species may indicate whether rehabilitated sites are undergoing natural succession without human intervention. In addition, if native species dominate recruitment, and exotic species are absent, no further management may be necessary. This study demonstrated that 4.5% of all seeds in the soil seed bank were native recruits, which indicates that native species recruitment is not occurring at a high rate in the soil seed banks of remnant rainforest sites or rehabilitated sites. To increase native species recruitment, human intervention may be necessary. Direct seeding, which is defined as scattering seeds by humans, may be necessary to increase native species recruitment and diversity.

5.5 Future of Rehabilitation Sites on the Atherton Tableland

What the sites will look like in the future is a question to consider following the current monitoring and management of rehabilitated sites. As discussed in Chapter 1, the soil seed bank plays a large role in forest regeneration following a disturbance. In the short term, many of the overstorey species are young and may live many years before they die and create a gap in the canopy. The chance of a disturbance in the canopy due to tree mortality is small. However, once the canopy is disturbed by storms or fire, the rehabilitated sites are threatened. The results from this study propose that following a disturbance, the exotic herbs and grasses will germinate and become established on the rehabilitated sites, so adjacent and isolated rehabilitated sites may not have the ability to replace themselves due to the large number of exotic herbs and grasses present in the soil seed bank.

As Kanowski, *et al.* (2003b) state, the "nature of rainforests is its ability to become self-sustainable, replace themselves, recolonise and establish and persist in the face of colonisation by introduced species." The results from the soil seed bank study suggest that the rehabilitation sites are not yet a 'rainforest' because of the high probability that exotic herbaceous species will germinate following a disturbance. More human intervention is needed to further catalyse successional processes.

5.6 Conclusions

Much emphasis has been placed on rehabilitating degraded land on the Atherton Tableland. However, little has been done to ensure the aims are being met. Although there are many hypothetical suggestions to measure the success of rehabilitated sites, this study investigated whether rehabilitated sites were catalysing natural successional processes or increasing in native species recruitment. The composition of the soil seed bank was examined because the soil seed bank offers information on the future vegetation processes that may occur on a site.

According to the soil seed bank, rehabilitated sites are not catalysing natural successional processes since native species recruitment is small and the soil seed banks are dominated by early successional, wind-dispersed herbs and grasses. Without increased human intervention (weed control, direct seeding), the rehabilitated sites will face the risk of exotic species germinating and dominating the rehabilitated sites.

In addition, although much emphasis has been placed on planting sites adjacent to remnant rainforests, the soil seed bank does not detect a difference in the composition of soil-stored seeds. This result suggests that rehabilitated sites can be planted either adjacent to – or isolated from – remnant rainforests. Since this information is not found in above ground surveying, the soil seed bank should be an added component to soil rainforest rehabilitation management.

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Appendices

Appendix A: Germination length of seeds germinating in a glasshouse environment

A.1 Soil seed bank methodology

Soil collection for the 17 study sites were expected to occur over two days. However, after the soil collection of 5 study sites, it began to rain and it continued for three months. The soil collection for the remaining 12 sites was postponed until the rain subsided. In the meantime, data was collected for the five study sites. Therefore, data was collected for the entire seven months for the five study sites in glasshouse conditions. This information means that soil seed bank germination duration could be analysed to determine if three month germination time was an accurate representation of seeds in the soil seed bank. Of particular interest was the exotic component and native recruits since those factors were directly related to the aims of this project.

Three month germination duration was chosen for this project for three reasons. First, pioneer species are expected to dominate the soil seed banks (Hopkins and Graham 1983) and germinate by increased light and temperature. It was expected that three months is sufficient for pioneer species to germinate. Second, germination times were compared with the relevant tropical soil seed bank research, and three months was an average time for seed germination. Third, three months deemed suitable to permit germination and still fit within the timeframe of a Masters project.

Although methodology varies in many ways including sample size and seasonality, this chapter focuses specifically on germination duration. This variable must be taken into consideration when creating a suitable sampling regime. As explained in Chapter 1, seeds have three types of dormancy: innate, induced and enforced (Harper 1977). Germination time may influence when some seeds germinate. However, little information in known about the germination requirement of tropical rainforest seeds, and some seeds may require specific light, temperature, and scarification conditions in order to germinate successfully (Hopkins and Graham 1987).

A.2 Aim

This study looked at seeds from 0 – 3 months, however, it was necessary to determine if species composition differed if germination technique continued for seven months. Of particular interest was the composition of exotics and native recruits.

Specifically the aim of this chapter was to:

1. Determine whether the seeds germinated in the soil seed bank from 4 – 7 months differed significantly in number of seeds and species from seeds germination in the soil seed bank from 0 – 3 months.

A.3 Methods

Refer to Chapter 2, section 2.3.1 – 2.3.3

A.4 Data Analysis

The non-parametric Kruskal Wallis ANOVA and Mann-Whitney *U*-tests were used to detect significant differences in number of seeds and species composition from months 4 – 7. The Mann-Whitney U-test was also used to detect significant differences between species, number of germinants, exotics, and native recruits from months 0 – 3 and 4 – 7 for remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites. The Bonferroni corrected *p*-value of 0.016 (0.05/3) was used for the Mann-Whitney *U*-test since three separate tests were conducted for each characteristic: remnant rainforest sites and adjacent rehabilitated sites, remnant rainforest sites and isolated rehabilitated sites, and adjacent and isolated rehabilitated sites. In the instances where the Kruskal-Wallis ANOVA detected a significance of < 0.05, and the Mann-Whitney *U*-test did not detect a significance of < 0.016, the Mann-Whitney *U*-test *p*-value closest to the reduce level of 0.016 will be detected as significant.

A.5 Results

A.5.1 Comparison of months 0 – 3 and 4 – 7

Remnant rainforest sites and rehabilitated sites showed significant differences in the median number seeds/spores that germinated between 0 – 3 months and 4 – 7 months (Kruskal-Wallis χ^2 = 16.069, d.f. = 5, p = 0.007) (Figure A.1). Significantly more seeds/spores germinated in remnant rainforest sites in 4 – 7 months than 0 – 3 months (Mann-Whitney $U = 0$, d.f. = 1, $p = 0.021$). No significant differences were detected in number of seeds/spores germinated between 0 – 3 months and 4 – 7 months in adjacent rehabilitated sites (Mann-Whitney $U = 6$, d.f. = 1, $p = 0.564$) or isolated rehabilitated sites (Mann-Whitney $U = 1$, d.f. = 1, $p = 0.127$).

Differences were noted not only in seeds/spores, but also in the median number of species germinating between the three site types between months 0 – 3 and 4 – 7 (Kruskal-Wallis $\chi^2 = 15.103$, d.f. = 5, $p = 0.010$) (Figure A.2). For example, significantly more species germinated in the adjacent rehabilitated sites during months 4 – 7 than 0 – 3 (Mann-Whitney $U = 0$, d.f. = 1, $p = 0.020$). However, no significant differences were detected in the median number of species germinating in the remnant rainforest sites from 0 – 3 months and 4 – 7 months (Mann-Whitney $U = 7$, d.f. = 1, $p = 0.766$), or the isolated rehabilitated sites between 0 – 3 months and 4 – 7 months (Mann-Whitney $U = 1$, d.f. =1, $p = 0.127$) (Appendix I).

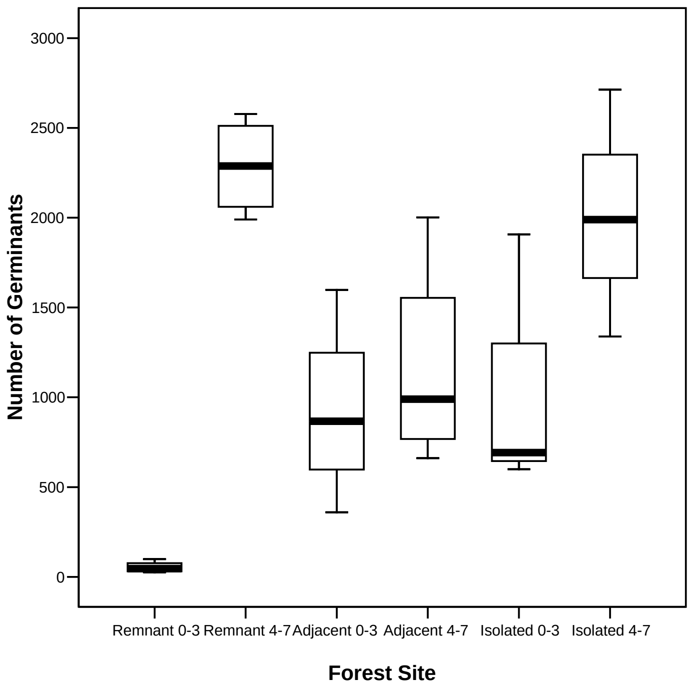

Figure A.1: Boxplot showing median and range of seeds germinating from 0 - 3 months, and 4 - 7 months in remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites

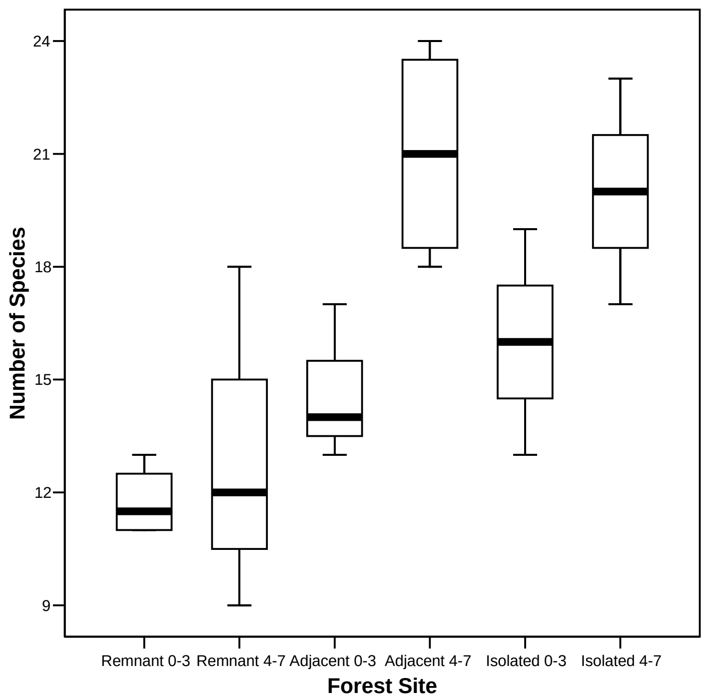

Figure A.2: Boxplot showing median and range of species germinating 0 - 3 months and 4 - 7 months in remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites

Figure A.3 illustrates the addition of new species from 0-7 months for remnant rainforest sites, adjacent, and isolated rehabilitated sites. No new species were detected after six months.

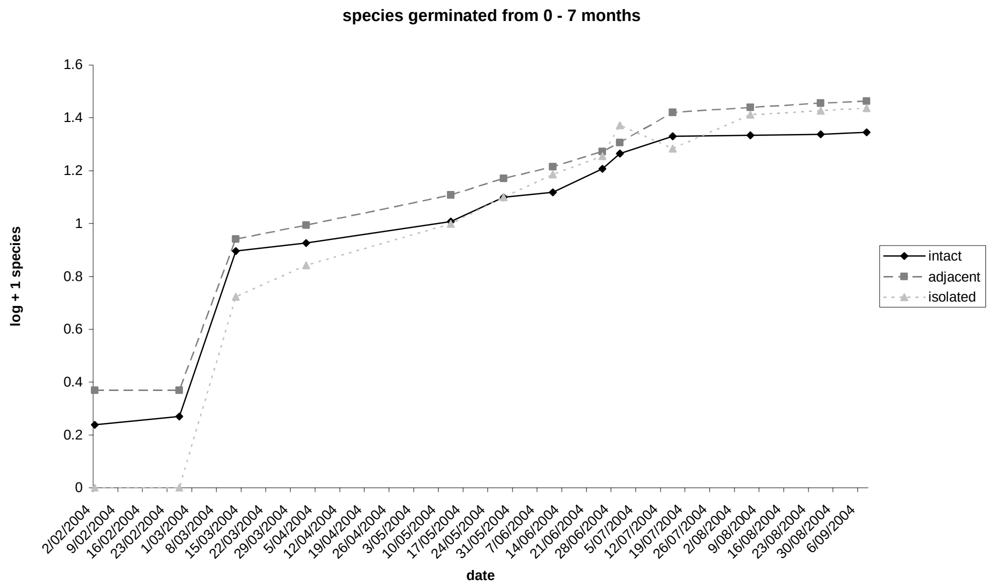

Figure A.3: Species germinated from 0 - 7 months in remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites

More new species germinated during months 0 – 3 than 4 – 7. For example, 22 species germinated during 0 – 3 months, and 16 species germinated only during 4 – 7 months (Table A.1).

Table A.1: table illustrating species germinating between 0 - 3 months, or between 4 - 7 months

Family	Name	0-3 months	4-7 months
Amaranthaceae	*Alternanthera bettzichiana*	X	
Anacardiaceae	*Euroschinus falcata*	X	
Apocynaceae	*Alstonia scholaris*	X	
Araliaceae	*Polyscias murrayi*	X	
Arecaceae	*Calamus moti*		X
Aristolochiaceae	*Aristolochia sp.*	X	
Asteraceae	*Helichrysum rupestris*		X
	Sonchus oleraceus	X	
Caryophyllaceae	*Drymaria cordata*	X	
Euphorbiaceae	*Breynia stipata*		X
	Homalanthus novo-guineensis	X	
	Mallotus mollissimus		X
Fabaceae	*Glycine cyrtoloba*	X	
Lamiaceae	*Plectranthus sp.*	X	
Malvaceae	*Urena lobata*	X	
Meliaceae	*Melia azedarach*	X	
Moraceae	*Ficus copiosa*	X	
	Ficus lepticlada		X
	Ficus obliqua		X
	Ficus waterhausia		X
Myrtaceae	*Pilidiostigma tropicum*		X
	Rhodamnia sessiliflora	X	
	Rhodomyrtus pervagata	X	
Oragraceae	*Ludwigia sp.*	X	
Passifloraceae	*Passiflora adulis*		X
Phytolaccaceae	*Phytolacca octundra*		X
Pittosporaceae	*Hymenosporum flavum*	X	
Rhamnaceae	*Alphitonia petriei*	X	
Rosaceae	*Rubus moluccanus*		X
Rubiaceae	*Psychotria sp.*		X
	Richardia brasiliensis	X	
Solanaceae	*Solanum dallachii*	X	
	Solanum discolour		X
Thymelaeaceae	*Wikstroemia indica*	X	
Tiliaceae	*Trichospermum pleiostigma*		X
	Triumfetta rhomboidea	X	
Verbenaceae	*Callicarpa pedunculata*		X
Vitaceae	*Cissus antarctica*		X

A.5.2 Exotics germinants and native recruits

There were no significant differences in the median number of native recruits arriving at the sites between 0 – 3 months and 4 – 7 months (Kruskal-Wallis χ^2 = 1.165, d.f. = 5, p = 0.948). However, a significant difference was detected in the median of number of exotic seeds/spores germinated from 0 – 3 and 4 – 7 months (Kruskal-Wallis χ^2 = 15.211, d.f. = 5, p = 0.009) (Figure A.4). Significantly more exotic seeds/spores germinated in the remnant rainforest sites between 4 – 7 months than 0 – 3 months (Mann-Whitney U = 0, d.f. = 1, p = 0.021). However, there were no differences in number of exotics that germinated in the rehabilitated sites during the 7 month germination period. For example, no significant differences were detected in the median number of exotic seeds/spores in adjacent rehabilitated sites between 0 – 3 months and 4 – 7 months (Mann-Whitney U = 5, d.f. = 1, p = 0.386), and in isolated rehabilitated sites between 0 – 3 months and 4 – 7 months (Mann-Whitney U = 2, d.f. = 1, p = 0.275).

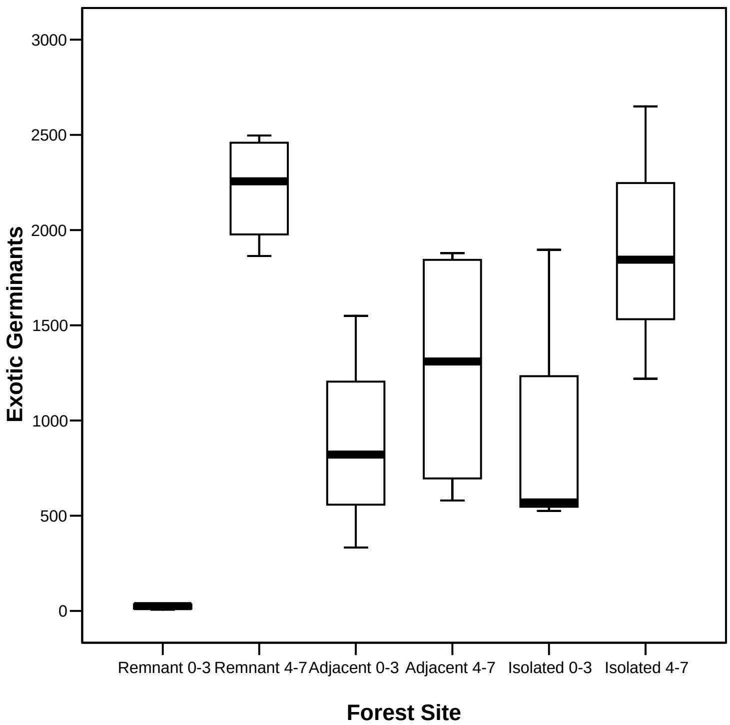

Figure A.4: Boxplot showing median and range of exotic germinants from 0 - 3 months and 4 - 7 months in remnant rainforest sites, adjacent rehabilitated sites, and isolated rehabilitated sites

A.6 Discussion/Recommendations

This study focused on differences to the soil seed bank in germinants and species of exotics and native recruits. Significantly more exotic seeds/spores germinated in remnant rainforest sites between months 4 – 7 than months 0 – 3. This result is explained by the large number of ferns that germinated in the remnant rainforest sites germination trays during months 4 – 7. The dominance of ferns in the germination trays may have prevented other native seeds from germinating because they may have occupied most of the light and moisture. The larger number of exotics in remnant rainforests during months 4 – 7 does not suggest germinating seeds longer than three months because ferns were observed at month 3. The component that changed was the abundance of ferns present in the germination trays of remnant rainforests.

No significant differences occurred in recruited native seeds germinating from the soil seed bank between the two time periods. It was expected that seeds continued to germinate during the entire seven months. The number of seeds in the soil is unknown, so the germination time was unclear. Although some native species were present in the 4 – 7 months germination time and absent from the 0 – 3 month germination time i.e. *Calamus moti, Helichrysum rupestris, Breynia stipata, Ficus lepticlada, Ficus obliqua, Ficus waterhousia, Psychotria sp., Trichospermum pleiostigma, Callicarpa pedunculate,* and *Cissus antarctica*, the overall number of germinate seedlings were not significantly different and therefore, does not suggest that germination should continue for longer than 3 months.

Although some species germinated during one time or the other (see Table A.1), herbs germinated throughout the entire 7 months germination period. Herbs may be able to germinate continuously because of the number of seeds herbs produce and because of the germination conditions occurred, i.e. the increased light and temperature conditions. For example, Hopkins and Graham (1984 a) found that herbs germinated throughout their experiment. They credited this result to the soil disruption when seedlings were removed, and to the high light and seeds/spores moisture availability.

Although this study looked exclusively at germination duration, many other methodology considerations should be evaluated, which include time of year for soil collection, the number of samples collected and the depth of soil collection. Due to the importance of standardized methodology for comparison of results and applications, further research should investigate suitable methodology that investigates seasonality, number of samples and soil depth.

A.7 Conclusion

This study demonstrated that three months is a suitable time for seeds to germinate in a glasshouse environment. Specifically this study was interested in the exotic component and native species recruits to the soil seed bank. Since this study found no differences in the number of exotics and native species recruits during the two time periods, three months was a suitable time for seed germination. Due to the importance of standardized methodology in comparing results, three month germination duration should be applied for other soil seed bank studies in the Atherton Tableland.

Appendix B: Species list of overstorey or natural regeneration within 1 metre of transect line

Site: Barrine Remnant (1988)

Family	Genus	Species	Overstorey or Natural regeneration
Annonaceae	*Haplostichanthus*	*johnsonii*	Natural regeneration
Arecaceae	*Calamus*	*moti*	Overstorey
Euphorbiaceae	*Codiaeum*	*variegatum*	Overstorey
	Macaranga	*subdentata*	Natural regeneration
Eupomatiaceae	*Eupomatia*	*laurina*	Overstorey
Fabaceae	*Derris*	*trifoliata*	Natural regeneration
Lauraceae	*Cryptocarya*	*mackinnoniana*	Overstorey
Meliaceae	*Aglaia*	*tomentosa*	Overstorey
	Toona	*ciliata*	Overstorey
Monimiaceae	*Doryphora*	*aromatica*	Natural regeneration
	Doryphora	*aromatica*	Overstorey
Myristicaceae	*Myristica*	*insipida*	Overstorey
Myrtaceae	*Austromyrtus*	*dallachiana*	Overstorey
	Rhodamnia	*sessiflora*	Overstorey
Sapindaceae	*Harpullia*	*rhyticarpa*	Natural regeneration
	Mischocarpus	*macrocarpus*	Overstorey
Sterculiaceae	*Argyrodendron*	*peralatum*	Overstorey
Verbenaceae	*Faradaya*	*splendida*	Natural regeneration
Zingiberaceae	*Alpinia*	*caerulea*	Natural regeneration
Zingiberaceae	*Alpinia*	*modesta*	Natural regeneration

Site: Barrine Remnant (1989)

Family	Genus	Species	Overstorey or Natural regeneration
Apocynaceae	*Melodinus*	*australis*	Natural regeneration
Arecaceae	*Calamus*	*australis*	Overstorey
	Calamus	*moti*	Natural regeneration
Aspleniaceae	*Asplenium*	*australiasicum*	Overstorey
Elaeocarpaceae	*Elaeocarpus*	*angustifolius*	Overstorey
Euphorbiaceae	*Breynia*	*stipitata*	Overstorey
Lauraceae	*Cryptocarya*	*mackinnoniana*	Natural regeneration
	Cryptocarya	*triplinervis*	Natural regeneration
	Litsea	*leefeana*	Overstorey
	Neolitsea	*dealbata*	Overstorey
Meliaceae	*Aglaia*	*sapindina*	Overstorey
	Aglaia	*tomentosa*	Overstorey
	Dysoxylum	*rufum*	Overstorey
Monimiaceae	*Doryphora*	*aromatica*	Overstorey

Appendix B cont.: Species list of overstorey or natural regeneration within 1 metre of transect line

Site: Barrine Remnant 1989 cont.

Family	***Genus***	***Species***	**Overstorey or Natural regeneration**
Myristicaceae	*Myristica*	*insipida*	Overstorey
Myrtaceae	*Pilidiostigma*	*tropicum*	Overstorey
Poaceae	*Oplismenis*	*aemulus*	Natural regeneration
Podocarpaceae	*Sundacarpus*	*amara*	Overstorey
Rutaceae	*Acronychia*	*acidula*	Overstorey
Sapindaceae	*Mischocarpus*	*pyriformis*	Overstorey
	Toechima	*erythrocarpum*	Overstorey
Sterculiaceae	*Argyrodendron*	*peralatum*	Overstorey
Thymelaeaceae	*Phaleria*	*clerodendron*	Natural regeneration
	Phaleria	*clerodendron*	Overstorey

Site: Eacham Remnant

Family	***Genus***	***Species***	**Overstorey or Natural regeneration**
Annonaceae	*Haplostichanthus*	*johnsonii*	Overstorey
Apocynaceae	*Alstonia*	*meulleriana*	Overstorey
Arecaceae	*Calamus*	*caryotoides*	Overstorey
Blechnaceae	*Blechnum*	*cartilagineum*	Overstorey
Dichapetalaceae	*Dichapetalum*	*papuanum*	Overstorey
Elaeagnaceae	*Elaeagnus*	*triflora*	Natural regeneration
Euphorbiaceae	*Codiaeum*	*variegatum*	Overstorey
	Mallotus	*polyadenos*	Overstorey
Lauraceae	*Cryptocarya*	*mackinnoniana*	Natural regeneration
	Cryptocarya	*mackinnoniana*	Overstorey
	Cryptocarya	*melanocarpa*	Natural regeneration
	Cryptocarya	*triplinervis*	Natural regeneration
	Cryptocarya	*triplinervis*	Overstorey
Meliaceae	*Aglaia*	*tomentosa*	Natural regeneration
Myrtaceae	*Acmena*	*divaricata*	Natural regeneration
	Acmena	*divaricata*	Overstorey
	Austromyrtus	*dallachiana*	Overstorey
	Austromyrtus	*minutiflora*	Natural regeneration
	Syzygium	*wesa*	Overstorey
Proteaceae	*Alloxylon*	*flammeum*	Overstorey
	Darlingia	*darlingiana*	Natural regeneration
	Darlingia	*darlingiana*	Overstorey
	Helicia	*nortoniana*	Overstorey
Rubiaceae	*Canthium*	*coprosmoides*	Overstorey
Sapindaceae	*Mischocarpus*	*grandissimus*	Overstorey
	Mischocarpus	*lachnocarpus*	Overstorey
	Mischocarpus	*pyriformis*	Overstorey
	Sarcotoechia	*serrata*	Overstorey
Sterculiaceae	*Argyrodendron*	*peralatum*	Natural regeneration

Appendix B cont.: Species list of overstorey or natural regeneration within 1 metre of transect line

Site: Eacham Remnant cont.

Family	***Genus***	***Species***	**Overstorey or Natural regeneration**
Sterculiaceae	*Argyrodendron*	*peralatum*	Overstorey
	Argyrodendron	*trifoliolata*	Natural regeneration
	Argyrodendron	*trifoliolata*	Overstorey
	Fern		Natural regeneration
	Fern		Overstorey

Site: Elinjaa Falls Remnant

Family	***Genus***	***Species***	**Overstorey or Natural regeneration**
Annonaceae	*Haplostichanthus*	*johnsonii*	Overstorey
Araceae	*Alocasia*	*brisbanensis*	Natural regeneration
	Pothos	*longipes*	Overstorey
Araliaceae	*Schefflera*	*actinophylla*	Overstorey
Arecaceae	*Calamus*	*australis*	Overstorey
	Calamus	*moti*	Overstorey
Asclepidiaceae	*Hoya*	*australis*	Overstorey
Blechnaceae	*Blechnum*	*orientalis*	Natural regeneration
Elaeocarpaceae	*Sloanea*	*australis*	Overstorey
Euphorbiaceae	*Macaranga*	*subdentata*	Natural regeneration
	Macaranga	*subdentata*	Overstorey
Lauraceae	*Beilschmiedia*	*bancroftii*	Natural regeneration
	Endiandra	*acuminata*	Natural regeneration
	Litsea	*leefeana*	Natural regeneration
	Litsea	*leefeana*	Overstorey
	Neolitsea	*dealbata*	Natural regeneration
Meliaceae	*Aglaia*	*tomentosa*	Overstorey
	Synoum	*muelleri*	Overstorey
Monimiaceae	*Wilkiea*	*angustifolius*	Natural regeneration
	Wilkiea	*angustifolius*	Overstorey
Myristicaceae	*Myristica*	*insipida*	Overstorey
Myrtaceae	*Syzygium*	*gustavioides*	Overstorey
Piperaceae	*Piper*	*novo-hollandiae*	Overstorey
Proteaceae	*Cardwellia*	*sublimis*	Natural regeneration
Rutaceae	*Euodia*	*xanthoxyloides*	Natural regeneration
	Flindersia	*brayleyana*	Overstorey
Sapindaceae	*Guioa*	*lasioneura*	Natural regeneration
	Guioa	*lasioneura*	Overstorey
Verbenaceae	*Faradaya*	*splendida*	Overstorey
Vitaceae	*Cissus*	*hypoglauca*	Overstorey
Zingiberaceae	*Alpinia*	*caerulea*	Natural regeneration

Appendix B cont.: Species list of overstorey or natural regeneration within 1 metre of transect line

Site: Malanda Falls Remnant

Family	Genus	Species	Overstorey or Natural regeneration
Annonaceae	Haplostichanthus	johnsonii	Natural regeneration
	Melodorum	leichhardtii	Natural regeneration
Apocynaceae	Melodinus	australis	Overstorey
Araceae	Alocasia	brisbanensis	Natural regeneration
Arecaceae	Calamus	australis	Natural regeneration
	Calamus	caryotoides	Natural regeneration
Dichapetalaceae	Dichapetalum	papuanum	Overstorey
Elaeagnaceae	Elaeagnus	triflora	Natural regeneration
	Elaeagnus	triflora	Overstorey
Fabaceae	*Castanospermum*	*australe*	Overstorey
	Derris	*trifoliolata*	Natural regeneration
Lauraceae	*Cryptocarya*	*triplinervis*	Natural regeneration
	Litsea	*leefeana*	Overstorey
	Neolitsea	*dealbata*	Overstorey
Meliaceae	*Amoora*	*ferruginea*	Overstorey
	Dysoxylum	*rufum*	Overstorey
Myristicaceae	*Myristica*	*insipida*	Overstorey
Myrtaceae	*Pilidiostigma*	*tropicum*	Natural regeneration
	Pilidiostigma	*tropicum*	Overstorey
Rutaceae	Acronychia	acidula	Overstorey
Sapindaceae	*Castanospora*	*alphandii*	Overstorey
Sterculaceae	*Argyrodendron*	*peralatum*	Natural regeneration

Site: Millaa Millaa Falls Remnant

Family	*Genus*	*Species*	Overstorey or Natural regeneration
Annonaceae	*Haplostichanthus*	*johnsonii*	Overstorey
Araceae	*Pothos*	*longipes*	Overstorey
Araliaceae	*Polyscias*	*elegans*	Overstorey
Arecaceae	*Calamus*	*moti*	Overstorey
Elaeocarpaceae	*Sloanea*	*australis*	Overstorey
Euphorbiaceae	*Codiaeum*	*variegatum*	Overstorey
	Codiaeum	*variegatum*	Natural regeneration
Eupomatiaceae	*Eupomatia*	*laurina*	Overstorey
Lauraceae	*Cryptocarya*	*melanocarpa*	Overstorey
	Cryptocarya	*murrayi*	Overstorey
	Cryptocarya	*mackinnoniana*	Overstorey
	Endiandra	*sankeyana*	Overstorey
	Neolitsea	*dealbata*	Natural regeneration
	Neolitsea	*dealbata*	Overstorey
Meliaceae	*Aglaia*	*tomentosa*	Natural regeneration
	Aglaia	*tomentosa*	Overstorey

Appendix B cont.: Species list of overstorey or natural regeneration within 1 metre of transect line
Site: Millaa Millaa Falls Remnant cont.

Family	Genus	Species	Overstorey or Natural regeneration
Meliaceae	*Amoora*	*ferruginea*	Natural regeneration
Myristicaceae	*Myristica*	*insipida*	Overstorey
Myrtaceae	*Pilidiostigma*	*tropicum*	Overstorey
	Syzygium	*gustavioides*	Overstorey
Rutaceae	*Zanthoxylum*	*veneficum*	Natural regeneration
Stangeriaceae	*Bowenia*	*spectabilis*	Natural regeneration
Sterculiaceae	*Franciscodendron*	*laurifolium*	Overstorey
Symplocaceae	*Symplocos*	*cochinchinensis spp. thwaitesii var. pilosiuscula*	Natural regeneration

Site: Barrine Adjacent 1988

Family	Genus	Species	Overstorey or Natural regeneration
Anacardiaceae	*Blepharocarya*	*involucrigera*	Overstorey
Annonaceae	*Melodorum*	*leichhardtii*	Natural regeneration
Apocynaceae	*Alstonia*	*meulleriana*	Overstorey
	Alstonia	*scholaris*	Overstorey
Araliaceae	*Polyscias*	*elegans*	Overstorey
Arecaceae	*Calamus*	*australis*	Natural regeneration
Aspleniaceae	*Asplenium*	*nidus*	Natural regeneration
Caryophyllaceae	*Drymaria*	*cordata*	Natural regeneration
Combretaceae	*Terminalia*	*seriocarpa*	Overstorey
Elaeagnaceae	*Elaeagnus*	*triflora*	Natural regeneration
Euphorbiaceae	*Aleurites*	*rockinghamensis*	Natural regeneration
	Mallotus	*philippensis*	Natural regeneration
Fabaceae	*Neonotonia*	*wightii*	Natural regeneration
Lauraceae	*Cryptocarya*	*triplinervis*	Natural regeneration
	Neolitsea	*dealbata*	Overstorey
Meliaceae	*Aglaia*	*sapindina*	Natural regeneration
	Dysoxylum	*muelleri*	Natural regeneration
	Toona	*ciliata*	Natural regeneration
Mimosaceae	*Acacia*	*celsa*	Overstorey
Moraceae	*Maclura*	*cochinchinensis*	Natural regeneration
	Streblus	*brunonianus*	Natural regeneration
Myrtaceae	*Acmena*	*resa*	Natural regeneration
	Rhodamnia	*sessiflora*	Natural regeneration
	Syzygium	*sayeri*	Natural regeneration
Oleaceae	*Olea*	*paniculata*	Natural regeneration
Piperaceae	*Piper*	*caninum*	Natural regeneration
Rhamnaceae	*Rhamnus*	*napalensis*	Natural regeneration
Rutaceae	*Flindersia*	*acuminata*	Overstorey
	Flindersia	*bourjotiana*	Overstorey
	Melicope	*elleryana*	Overstorey
Sapindaceae	*Mischocarpus*	*macrocarpus*	Natural regeneration
Solanaceae	*Solanum*	*seaforthianum*	Natural regeneration

Appendix B cont.: Species list of overstorey or natural regeneration within 1 metre of transect line

Site: Barrine Adjacent 1988 cont.

Family	*Genus*	*Species*	Overstorey or Natural regeneration
Ulmaceae	*Aphananthe*	*philippinensis*	Natural regeneration
Urticaceae	*Dendrocnide*	*photinophylla*	Natural regeneration

Site: Barrine Adjacent 1989

Family	*Genus*	*Species*	Overstorey or Natural regeneration
Anacardiaceae	*Acronychia*	*acidula*	Overstorey
Annonaceae	*Melodorum*	*leichhardtii*	Natural regeneration
	Melodorum	*uhrii*	Natural regeneration
Apocynaceae	*Alstonia*	*meulleriana*	Overstorey
Araliaceae	*Polyscias*	*elegans*	Natural regeneration
Arecaceae	*Calamus*	*moti*	Natural regeneration
Davidsoniaceae	*Davidsonia*	*pruriens*	Natural regeneration
Dilleniaceae	*Tetracera*	*nordtiana*	Natural regeneration
Elaeocarpaceae	*Elaeocarpus*	*angustifolius*	Overstorey
Euphorbiaceae	*Breynia*	*oblongifolia*	Natural regeneration
Fabaceae	*Castanospermum*	*australe*	Natural regeneration
Lauraceae	*Cryptocarya*	*mackinnoniana*	Natural regeneration
	Litsea	*leefeana*	Natural regeneration
	Neolitsea	*dealbata*	Natural regeneration
Meliaceae	*Aglaia*	*sapindina*	Natural regeneration
	Dysoxylum	*muelleri*	Natural regeneration
	Dysoxylum	*parasiticum*	Natural regeneration
	Toona	*ciliata*	Overstorey
Menispermaceae	*Stephania*	*japonica*	Natural regeneration
Mimosaceae	*Acacia*	*celsa*	Overstorey
Myrtaceae	*Acmenosperma*	*claviflorum*	Overstorey
	Austromyrtus	*minutiflora*	Natural regeneration
Piperaceae	*Piper*	*novo-hollandiae*	Natural regeneration
Poaceae	*Oplismenis*	*aemulus*	Natural regeneration
Rhamnaceae	*Alphitonia*	*petriei*	Overstorey
Rubiaceae	*Canthium*	*coprosmoides*	Natural regeneration
Rutaceae	*Flindersia*	*bourjotiana*	Overstorey
	Flindersia	*brayleyana*	Overstorey
	Zanthoxylum	*veneficum*	Natural regeneration
Sapindaceae	*Castanospora*	*alphandii*	Overstorey
	Guioa	*acutifolia*	Natural regeneration
	Sarcopteryx	*martyana*	Natural regeneration
Sapotaceae	*Pouteria*	*obovoidea*	Overstorey

Appendix B cont.: Species list of overstorey or natural regeneration within 1 metre of transect line

Site: Chapman Farm Adjacent

Family	***Genus***	***Species***	**Overstorey or Natural regeneration**
Annonaceae	*Melodorum*	*uhrii*	Natural regeneration
Araceae	*Alocasia*	*brisbanensis*	Natural regeneration
Caryophyllaceae	*Drymaria*	*cordata*	Natural regeneration
Elaeagnaceae	*Elaeagnus*	*triflora*	Natural regeneration
Elaeocarpaceae	*Elaeocarpus*	*angustifolius*	Natural regeneration
	Sloanea	*australis*	Natural regeneration
Elaeagnaceae	*Elaeagnus*	*angustifolius*	Overstorey
Euphorbiaceae	*Breynia*	*odorata*	Natural regeneration
Fabaceae	*Austrosteeinsia*	*blackii*	Natural regeneration
Lauraceae	*Cryptocarya*	*onoprienkoana*	Natural regeneration
	Cryptocarya	*triplinervis*	Natural regeneration
	Litsea	*leefeana*	Natural regeneration
	Neolitsea	*dealbata*	Natural regeneration
Moraceae	*Ficus*	*superba*	Natural regeneration
Myrsinaceae	*Embelia*	*grayi*	Natural regeneration
Myrtaceae	*Pilidiostigma*	*tropicum*	Overstorey
	Rhodamnia	*sessiflora*	Natural regeneration
	Syzygium	*cormiflorum*	Overstorey
	Syzygium	*johnsonii*	Overstorey
	Xanthostemon	*chrysanthus*	Natural regeneration
Poaceae	*Axonopus*	*edulis*	Natural regeneration
	Oplismenus	*aemulus*	Natural regeneration
Proteaceae	*Cardwellia*	*sublimis*	Overstorey
	Carnarvonia	*araliifolia*	Natural regeneration
	Carnarvonia	*araliifolia*	Overstorey
	Darlingia	*darlingiana*	Natural regeneration
	Grevillea	*baileyana*	Natural regeneration
Rhamnaceae	*Alphitonia*	*petriei*	Overstorey
Rutaceae	*Flindersia*	*brayleyana*	Overstorey
	Flindersia	*pimentiliana*	Overstorey
	Melicope	*elleryana*	Natural regeneration
Sapindaceae	*Castanospora*	*alphandii*	Natural regeneration
	Guioa	*lasioneura*	Natural regeneration
	Mischocarpus	*lachnocarpus*	Natural regeneration
	Mischocarpus	*lachnocarpus*	Overstorey
	Sarcopteryx	*martyana*	Natural regeneration
Thymelaeaceae	*Wikstroemia*	*indica*	Natural regeneration

Appendix B cont.: Species list of overstorey or natural regeneration within 1 metre of transect line

Site: Elinjaa Falls Adjacent

Family	*Genus*	*Species*	Overstorey or Natural regeneration
Apocynaceae	*Alstonia*	*scholaris*	Overstorey
Araliaceae	*Polyscias*	*elegans*	Natural regeneration
Cunoniaceae	*Geissois*	*biagiana*	Overstorey
Euphorbiaceae	*Glochidion*	*hylandii*	Natural regeneration
	Homalanthus	*novoguineensis*	Overstorey
Lauraceae	*Cryptocarya*	*hypospodia*	Overstorey
	Neolitsea	*dealbata*	Natural regeneration
	Neolitsea	*dealbata*	Overstorey
Mimosaceae	*Acacia*	*celsa*	Natural regeneration
Myrtaceae	*Pilidiostigma*	*tropicum*	Natural regeneration
	Psidium	*cattleianum*	Natural regeneration
	Rhodamnia	*sessiflora*	Natural regeneration
	Syzygium	*papyraceum*	Overstorey
Proteaceae	*Helicia*	*nortoniana*	Natural regeneration
Rhamnaceae	*Alphitonia*	*petriei*	Overstorey
Rosaceae	*Rubus*	*alceifolius*	Natural regeneration
	Rubus	*moluccanus*	Natural regeneration
Rutaceae	*Euodia*	*xanthoxyloides*	Natural regeneration
	Flindersia	*brayleyana*	Overstorey
	Flindersia	*pimentiliana*	Overstorey
Sapindaceae	*Guioa*	*lasioneura*	Natural regeneration
	Mischocarpus	*macrocarpus*	Overstorey
Symplocaceae	*Symplocos*	*cochinchinensis ssp. thwaitesii var. pilosiuscula*	Overstorey
Thymelaeaceae	*Wikstroemia*	*indica*	Natural regeneration

Site: Malanda Falls Adjacent

Family	*Genus*	*Species*	Overstorey or Natural regeneration
Anacardiaceae	*Euroschinus*	*falcata*	Natural regeneration
Annonaceae	*Melodorum*	*uhrii*	Natural regeneration
Apocynaceae	*Alstonia*	*scholaris*	Overstorey
	Melodinus	*australis*	Natural regeneration
Cyperaceae	*Cyperus*	*laxus*	Natural regeneration
Elaeocarpaceae	*Elaeocarpus*	*angustifolius*	Overstorey
Elaeagnaceae	*Elaeagnus*	*triflora*	Natural regeneration
Euphorbiaceae	*Glochidion*	*hylandii*	Natural regeneration
	Homalanthus	*novo-guineensis*	Overstorey
Flacourtiaceae	*Scolopia*	*braunii*	Natural regeneration
	Scolopia	*braunii*	Overstorey
Lauraceae	*Cryptocarya*	*triplinervis*	Natural regeneration
	Endiandra	*insignis*	Overstorey
	Neolitsea	*dealbata*	Natural regeneration
	Neolitsea	*dealbata*	Overstorey

Appendix B cont.: Species list of overstorey or natural regeneration within 1 metre of transect line

Site: Malanda Falls Adjacent cont.

Family	***Genus***	***Species***	**Overstorey or Natural regeneration**
Meliaceae	*Dysoxylum*	*parasiticum*	Natural regeneration
	Toona	*ciliata*	Natural regeneration
Mimosaceae	*Acacia*	*celsa*	Overstorey
Myrsinaceae	*Maesa*	*dependens var. dependens*	Natural regeneration
Myrtaceae	*Acmena*	*resa*	Overstorey
Poaceae	*Oplismenus*	*aemulus*	Natural regeneration
Proteaceae	*Darlingia*	*darlingiana*	Natural regeneration
	Darlingia	*darlingiana*	Overstorey
	Stenocarpus	*sinuatus*	Overstorey
Rhamnaceae	*Alphitonia*	*petriei*	Overstorey
Rutaceae	*Flindersia*	*brayleyana*	Natural regeneration
Sapindaceae	*Guioa*	*acutifolia*	Natural regeneration
	Mischocarpus	*grandissimus*	Overstorey
Thymelaeaceae	*Wikstroemia*	*indica*	Natural regeneration

Site: Winfield Park Adjacent

Family	***Genus***	***Species***	**Overstorey or Natural regeneration**
Anacardiaceae	*Blepharocarya*	*involucrigera*	Overstorey
Apocynaceae	*Alstonia*	*meulleriana*	Overstorey
Araliaceae	*Mackinlaya*	*macrosciadea*	Natural regeneration
	Polyscias	*elegans*	Natural regeneration
Araucariaceae	*Agathis*	*robusta*	Overstorey
	Araucaria	*cunninghamii*	Overstorey
Arecaceae	*Calamus*	*moti*	Natural regeneration
Aristolochiaceae	*Aristolochia*	*sp.*	Natural regeneration
Elaeocarpaceae	*Elaeocarpus*	*angustifolius*	Overstorey
Euphorbiaceae	*Breynia*	*stipitata*	Natural regeneration
Lauraceae	*Cryptocarya*	*mackinnoniana*	Natural regeneration
	Neolitsea	*dealbata*	Natural regeneration
Meliaceae	*Toona*	*ciliata*	Overstorey
Mimosaceae	*Acacia*	*cincinnata*	Overstorey
Myrtaceae	*Acmena*	*resa*	Overstorey
	Rhodamnia	*sessiflora*	Natural regeneration
	Syzygium	*cormiflorum*	Overstorey
Piperaceae	*Piper*	*novo-hollandiae*	Natural regeneration
Poaceae	*Oplismenus*	*aemulus*	Natural regeneration
	Panicum	*maximum*	Natural regeneration
Proteaceae	*Darlingia*	*darlingiana*	Natural regeneration
Rhamnaceae	*Rhamnus*	*napalensis*	Natural regeneration
Rubiaceae	*Canthium*	*coprosmoides*	Natural regeneration
Sapindaceae	*Guioa*	*acutifolia*	Natural regeneration
	Sarcopteryx	*martyana*	Natural regeneration
Sapotaceae	*Pouteria*	*obovoidea*	Overstorey
Symplocaceae	*Symplocos*	*cochinchinensis*	Natural regeneration

Appendix B cont.: Species list of overstorey or natural regeneration within 1 metre of transect line

Site: Backshall Farm Isolated

Family	*Genus*	*Species*	Overstorey or Natural regeneration
Anacardiaceae	*Acronychia*	*acidula*	Overstorey
	Euroschinus	*falcata*	Overstorey
Asteraceae	*Ageratum*	*conyzoides*	Natural regeneration
Caryophyllaceae	*Drymaria*	*cordata*	Natural regeneration
Casuarinaceae	*Casuarina*	*cunninghamii*	Overstorey
Combretaceae	*Terminalia*	*sericocarpa*	Overstorey
Elaeagnaceae	*Elaeagnus*	*angustifolius*	Overstorey
Euphorbiaceae	*Glochidion*	*hylandii*	Natural regeneration
	Macaranga	*tanarius*	Overstorey
Lauraceae	*Cinnamomum*	*camphora*	Natural regeneration
	Litsea	*leefeana*	Overstorey
Malvaceae	*Sida*	*rhombifolia*	Natural regeneration
	Urena	*lobata*	Natural regeneration
Meliaceae	*Dysoxylum*	*muelleri*	Overstorey
Moraceae	*Ficus*	*congesta*	Overstorey
	Ficus	*virgata*	Overstorey
	Ficus	*watkinsiana*	Overstorey
Myrtaceae	*Acmena*	*resa*	Overstorey
	Syzygium	*gustavioides*	Overstorey
	Syzygium	*sayeri*	Overstorey
Poaceae	*Axonopus*	*compressus*	Natural regeneration
Proteaceae	*Cardwellia*	*sublimis*	Overstorey
	Darlingia	*darlingiana*	Natural regeneration
	Darlingia	*darlingiana*	Overstorey
Rosaceae	*Prunus*	*turneriana*	Overstorey
Rutaceae	*Flindersia*	*schottiana*	Overstorey
	Melicope	*elleryana*	Overstorey
Sapindaceae	*Castanospora*	*alphandii*	Overstorey
Solanaceae	*Solanum*	*mauritianum*	Natural regeneration
Thymelaeaceae	*Wikstroemia*	*indica*	Natural regeneration
Verbenaceae	*Lantana*	*camara*	Natural regeneration

Site: Cleminson Creek Isolated

Family	*Genus*	*Species*	Overstorey or Natural regeneration
Araliaceae	*Polyscias*	*elegans*	Overstorey
Aspleniaceae	*Asplenium*	*australiasicum*	Natural regeneration
Euphorbiaceae	*Homalanthus*	*novo-guineensis*	Natural regeneration
	Homalanthus	*novo-guineensis*	Overstorey
Fabaceae	*Castanospermum*	*australe*	Overstorey
Flacourtiaceae	*Scolopia*	*braunii*	Overstorey
Lauraceae	*Litsea*	*leefeana*	Natural regeneration

Appendix B cont.: Species list of overstorey or natural regeneration within 1 metre of transect line

Site: Cleminson Creek Isolated cont.

Family	***Genus***	***Species***	**Overstorey or Natural regeneration**
	Litsea	*leefeana*	Overstorey
	Neolitsea	*dealbata*	Natural regeneration
	Neolitsea	*dealbata*	Overstorey
Meliaceae	*Dysoxylum*	*rufum*	Natural regeneration
Mimosaceae	*Acacia*	*cincinnata*	Overstorey
Myrtaceae	*Acmena*	*divaricata*	Overstorey
	Acmena	*smithii*	Overstorey
	Pilidiostigma	*tropicum*	Overstorey
	Psidium	*cattleianum*	Natural regeneration
	Syzygium	*wilsonii ssp. crytophlebium*	Overstorey
Oleaceae	*Ligustrum*	*sinense*	Natural regeneration
Poaceae	*Oplismenus*	*aemulus*	Natural regeneration
Polypodiaceae	*Belvisia*	*mucronata*	Natural regeneration
Proteaceae	*Darlingia*	*darlingiana*	Overstorey
Rutaceae	*Flindersia*	*bourjotiana*	Overstorey
Sapindaceae	*Castanospora*	*alphandii*	Overstorey
	Guioa	*lasioneura*	Overstorey
	Mischocarpus	*macrocarpus*	Overstorey
Verbenaceae	*Lantana*	*camara*	Natural regeneration

Site: Doan Isolated

Family	***Genus***	***Species***	**Overstorey or Natural regeneration**
Anacardiaceae	*Acronychia*	*acidula*	Overstorey
Asteraceae	*Ageratum*	*houstonianum*	Natural regeneration
Caryophyllaceae	*Drymaria*	*cordata*	Natural regeneration
Combretaceae	*Terminalia*	*sericocarpa*	Overstorey
Commelinaceae	*Tradescantia*	*sp.*	Natural regeneration
Cyatheaceae	*Cyathea*	*cooperi*	Overstorey
Elaeagnaceae	*Elaeagnus*	*triflora*	Natural regeneration
	Elaeagnus	*angustifolius*	Overstorey
Euphorbiaceae	*Aleurites*	*rockinghamensis*	Overstorey
	Mallotus	*philippensis*	Overstorey
	Omalanthus	*novoguineensis*	Overstorey
Fabaceae	*Desmodium*	*sp.*	Natural regeneration
	Castanospermum	*australe*	Overstorey
Lauraceae	*Litsea*	*leefeana*	Overstorey
Meliaceae	*Dysoxylum*	*muelleri*	Natural regeneration
Mimosaceae	*Acacia*	*cincinnata*	Overstorey
Myrtaceae	*Xanthostemon*	*chrysanthus*	Overstorey
Oleaceae	*Chionanthus*	*ramiflora*	Overstorey
	Ligustrum	*lucidum*	Natural regeneration
	Ligustrum	*sinense*	Natural regeneration
Phytolaccaceae	*Rivina*	*humilis*	Natural regeneration
Rhamnaceae	*Alphitonia*	*petriei*	Overstorey

Appendix B cont.: Species list of overstorey or natural regeneration within 1 metre of transect line

Site: Doan Isolated cont.

Family	*Genus*	*Species*	Overstorey or Natural regeneration
Rutaceae	*Flindersia*	*bourjotiana*	Overstorey
	Flindersia	*schottiana*	Overstorey
	Melicope	*elleryana*	Overstorey
Sapindaceae	*Guioa*	*lasioneura*	Natural regeneration
	Rhysotoechia	*robertsonii*	Overstorey
Solanaceae	*Solanum*	*mauritianum*	Natural regeneration
Sterculaceae	*Argyrodendron*	*peralatum*	Overstorey
Symplocaceae	*Symplocos*	*cochinchinensis*	Natural regeneration
Thymelaeaceae	*Wikstroemia*	*indica*	Natural regeneration

Site: Hillcrest Farm Isolated

Family	*Genus*	*Species*	Overstorey or Natural regeneration
Anacardiaceae	*Acronychia*	*acidula*	Natural regeneration
Apiaceae	*Centella*	*asiatica*	Natural regeneration
Araliaceae	*Polyscias*	*australiana*	Natural regeneration
Asteraceae	*Ageratum*	*conyzoides*	Natural regeneration
	Crassocephalum	*crepidioides*	Natural regeneration
Euphorbiaceae	*Aleurites*	*rockinghamensis*	Overstorey
	Mallotus	*mollissimus*	Overstorey
	Mallotus	*paniculata*	Overstorey
Fabaceae	*Castanospermum*	*australe*	Overstorey
Flacourtiaceae	*Scolopia*	*braunii*	Overstorey
Lauraceae	*Cinnamomum*	*camphora*	Natural regeneration
	Litsea	*leefeana*	Natural regeneration
Malvaceae	*Urena*	*lobata*	Natural regeneration
Mimosaceae	*Acacia*	*celsa*	Natural regeneration
	Acacia	*celsa*	Overstorey
Myrsinaceae	*Rapanea*	*porosa*	Natural regeneration
Myrtaceae	*Acmena*	*smithii*	Overstorey
	Pilidiostigma	*tropicum*	Overstorey
	Rhodamnia	*sessiflora*	Natural regeneration
Oleaceae	*Chionanthus*	*ramiflora*	Overstorey
Pittosporaceae	*Pittosporum*	*venulosum*	Overstorey
Podocarpaceae	*Sundacarpus*	*amara*	Overstorey
Proteaceae	*Cardwellia*	*sublimis*	Overstorey
Rutaceae	*Flindersia*	*bourjotiana*	Overstorey
	Flindersia	*brayleyana*	Overstorey
	Melicope	*elleryana*	Natural regeneration
Sapindaceae	*Diploglottis*	*smithii*	Overstorey
	Guioa	*acutifolia*	Natural regeneration
	Mischocarpus	*microphylla*	Overstorey
Sterculaceae	*Argyrodendron*	*peralatum*	Overstorey
Thymelaeaceae	*Wikstroemia*	*indica*	Natural regeneration

Appendix B cont.: Species list of overstorey or natural regeneration within 1 metre of transect line

Site: Hillcrest Farm Isolated cont.

Family	***Genus***	***Species***	**Overstorey or Natural regeneration**
Verbenaceae	*Lantana*	*camara*	Natural regeneration
Xanthophyllaceae	*Xanthophyllum*	*octandrum*	Natural regeneration

Site: Thurling Farm Isolated

Family	***Genus***	***Species***	**Overstorey or Natural regeneration**
Apocynaceae	*Alstonia*	*scholaris*	Overstorey
Araucariaceae	*Agathis*	*robusta*	Overstorey
Dilleniaceae	*Hibbertia*	*scandens*	Natural regeneration
Elaeagnaceae	*Elaeagnus*	*triflora*	Natural regeneration
Elaeocarpaceae	*Elaeocarpus*	*angustifolius*	Overstorey
	Sloanea	*macbrydei*	Overstorey
Euphorbiaceae	*Aleurites*	*rockinghamensis*	Overstorey
Fabaceae	*Castanospermum*	*australe*	Overstorey
Lauraceae	*Beilschmiedia*	*obtusifolia*	Natural regeneration
	Cryptocarya	*mackinnoniana*	Overstorey
Lauraceae	*Litsea*	*leefeana*	Natural regeneration
Meliaceae	*Toona*	*ciliata*	Overstorey
Moraceae	*Maclura*	*cochinchinensis*	Natural regeneration
Myrtaceae	*Eucalyptus*	*grandis*	Overstorey
	Syzygium	*cormiflorum*	Overstorey
Ochnaceae	*Ochna*	*serrulata*	Natural regeneration
Pandanaceae	*Freycinetia*	*scandens*	Natural regeneration
	Freycinetia	*scandens*	Overstorey
Proteaceae	*Cardwellia*	*sublimis*	Natural regeneration
	Darlingia	*darlingiana*	Overstorey
	Grevillea	*robusta*	Overstorey
	Lomatia	*fraxinifolia*	Natural regeneration
	Stenocarpus	*sinuatus*	Natural regeneration
	Stenocarpus	*sinuatus*	Overstorey
Rhamnaceae	*Alphitonia*	*petriei*	Overstorey
Rutaceae	*Flindersia*	*acuminata*	Overstorey
	Flindersia	*bourjotiana*	Natural regeneration
Sapindaceae	*Guioa*	*lasioneura*	Overstorey
	Guioa	*lasioneura*	Natural regeneration

Appendix C: Species lists of rehabilitation plantings

Site: Doan Isolated

Family	Genus	Species
Anacardiaceae	*Acronychia*	*acidula*
	Acronychia	*chooreechillum*
	Euroschinus	*falcata*
Casuarinaceae	*Casuarina*	*cunninghamii*
Combretaceae	*Terminalia*	*seriocarpa*
Cunoniaceae	*Ceratopetalum*	*succirubrum*
Elaeocarpaceae	*Elaeocarpus*	*angustifolius*
	Elaeocarpus	*coorangooloo*
	Sloanea	*macbrydei*
Euphorbiaceae	*Aleurites*	*moluccans*
	Glochidion	*hylandii*
	Glochidion	*philippicum*
	Mallotus	*philippensis*
	Homalanthus	*novoguineensis*
Fabaceae	*Castanospermum*	*australe*
Flacourtiaceae	*Casearia*	*dallachii*
Hamamelidaceae	*Ostrearia*	*australiana*
Himantandraceae	*Galbulimima*	*belgraveana*
Lauraceae	*Beilschmiedia*	*bancroftii*
	Beilschmiedia	*collina*
	Cinnamomum	*laubatii*
	Cryptocarya	*angulata*
	Cryptocarya	*hypospodia*
	Cryptocarya	*oblata*
	Cryptocarya	*triplinervis*
	Endiandra	*bessaphila*
	Endiandra	*globosa*
	Endiandra	*monothyra*
	Endiandra	*montana*
	Endiandra	*sankeyana*
	Endiandra	*wolfei*
	Litsea	*leefeana*
	Neolitsea	*dealbata*
Meliaceae	*Dysoxylum*	*muelleri*
	Synoum	*muelleri*
	Toona	*australis*
Mimosaceae	*Acacia*	*celsa*
	Archidendron	*vaillantii*
	Pararchidendron	*pruinosum*
Monimiaceae	*Hedycarya*	*loxocarya*
	Daphnandra	*repandula*
	Tetrasynandra	*pubescens*
Moraceae	*Ficus*	*destruens*
	Ficus	*pleurocarpa*
Myrtaceae	*Acmena*	*graveolens*
	Acmena	*hemilampra*
	Acmena	*smithii*

Appendix C cont.: Species lists of rehabilitation plantings

Site: Doan Isolated cont.

Family	Genus	Species
Myrtaceae	*Acmenosperma*	*claviflorum*
	Callistemon	*viminalis*
	Pilidiostigma	*tropicum*
	Syzygium	*alliiligneum*
	Syzygium	*angophoroides*
	Syzygium	*australe*
	Syzygium	*canicortex*
	Syzygium	*cormiflorum*
	Syzygium	*endophloium*
	Syzygium	*erythrocalyx*
	Syzygium	*gustavioides*
	Syzygium	*kuranda*
	Syzygium	*leuhmannii*
	Syzygium	*papyraceum*
	Syzygium	*sayeri*
	Syzygium	*wesa*
	Syzygium	*wilsonii ssp. crytophlebium*
	Syzygium	*wilsonii ssp. wilsonii*
	Waterhousea	*unipunctata*
	Xanthostemon	*chrysanthus*
	Xanthostemon	*whitei*
Oleaceae	*Chionanthus*	*ramiflora*
Pittosporaceae	*Hymenosporum*	*flavum*
	Pittosporum	*ferruginea*
Proteaceae	*Alloxylon*	*flammeum*
	Athertonia	*diversifolia*
	Buckinghamia	*celsissima*
	Cardwellia	*sublimis*
	Carnarvonia	*araliifolia*
	Darlingia	*darlingiana*
	Darlingia	*ferruginea*
	Helicia	*lamingtoniana*
	Helicia	*nortoniana*
	Lomatia	*fraxinifolia*
	Macadamia	*whelanii*
	Musgravea	*heterophylla*
	Opisthiolepis	*heterophylla*
	Placospermum	*coriaceum*
	Stenocarpus	*sinuatus*
Rhamnaceae	*Alphitonia*	*petriei*
	Emmenosperma	*alphitoniodes*
Rosaceae	*Prunus*	*turneriana*
Rubiaceae	*Gardenia*	*winfrenii*
Rutaceae	*Euodia*	*bonwickii*
	Euodia	*elleryana*
	Evodiella	*muelleri*
	Flindersia	*bourjotiana*
	Flindersia	*brayleyana*

Appendix C cont.: Species lists of rehabilitation plantings

Site: Doan Isolated cont.

Family	Genus	Species
Rutaceae	*Flindersia*	*laevicarpa*
	Flindersia	*oppositifolia*
	Flindersia	*pimentiliana*
	Flindersia	*schottiana*
	Halfordia	*scleroxyla*
	Zanthoxylum	*ovalifolium*
Sapindaceae	*Arytera*	*lautererana*
	Arytera	*pauciflora*
	Castanospora	*alphandii*
	Cupaniopsis	*dallachyi*
	Cupaniopsis	*foveolata*
	Diploglottis	*bracteata*
	Diploglottis	*diphyllostegia*
	Guioa	*acutifolia*
	Guioa	*lasioneura*
	Mischocarpus	*lachnocarpus*
	Mischocarpus	*pyriformis ssp. pyriformis*
	Rhysotoechia	*robertsonii*
	Sarcotoechia	*serrata*
	Synima	*macrophylla*
Sapotaceae	*Planchonella*	*queenslandica*
Sterculaceae	*Argyrodendron*	*peralatum*
	Argyrodendron	*trifoliolatum*
	Franciscodendron	*laurifolium*
	Brachychiton	*acerifolius*
Symplocaceae	*Symplocos*	*cochinchinensis*
Verbenaceae	*Gmelina*	*fasciculiflora*
Winteraceae	*Drimys*	*piperita*
Xanthophyllaceae	*Xanthophyllum*	*octandrum*

Site: Elinjaa Falls Adjacent

Family	Genus	*Species*
Apocynaceae	*Alstonia*	*scholaris*
Araucariaceae	*Araucaria*	*bidwillii*
Combretaceae	*Terminalia*	*seriocarpa*
Corynocarpaceae	*Corynocarpus*	*cribbianus*
Cunoniaceae	*Ceratopetalum*	*succirubrum*
	Geissois	*biagiana*
	Pullea	*stutzeri*
Elaeocarpaceae	*Elaeocarpus*	*angustifolius*
	Elaeocarpus	*largiflorens*
Euphorbiaceae	*Homalanthus*	*novoguineensis*
Hamamelidaceae	*Ostrearia*	*australiana*
Himantandraceae	*Galbulimima*	*belgraveana*
Lauraceae	*Beilschmiedia*	*tooram*
	Cinnamomum	*laubatii*

Appendix C cont.: Species lists of rehabilitation plantings

Site: Elinjaa Falls Adjacent cont.

Family	Genus	*Species*
Lauraceae	*Cryptocarya*	*angulata*
	Cryptocarya	*grandis*
	Cryptocarya	*hypospodia*
	Cryptocarya	*lividula*
	Cryptocarya	*mackinnoniana*
	Cryptocarya	*oblata*
	Cryptocarya	*onoprienkoana*
	Cryptocarya	*triplinervis*
	Endiandra	*hypotephra*
	Endiandra	*montana*
	Endiandra	*sankeyana*
	Litsea	*leefeana*
	Neolitsea	*dealbata*
Meliaceae	*Dysoxylum*	*pettigrewianaum*
	Synoum	*muelleri*
Mimosaceae	*Acacia*	*celsa*
	Pararchidendron	*pruinosum*
Monimiaceae	*Doryphora*	*aromatica*
Moraceae	*Ficus*	*destruens*
	Ficus	*obliqua var.*
	Ficus	*pleurocarpa*
	Ficus	*racemosa*
Myrtaceae	*Acmena*	*resa*
	Acmena	*smithii*
	Pilidiostigma	*tropicum*
	Rhodomyrtus	*trineura*
	Syzygium	*alliiligneum*
	Syzygium	*australe*
	Syzygium	*canicortex*
	Syzygium	*cormiflorum*
	Syzygium	*endophloium*
	Syzygium	*erythrocalyx*
	Syzygium	*gustavioides*
	Syzygium	*kuranda*
	Syzygium	*leuhmannii*
	Syzygium	*papyraceum*
	Syzygium	*sayeri*
	Syzygium	*trachyphloium*
	Syzygium	*wesa*
	Syzygium	*wilsonii var. crytophlebium*
	Xanthostemon	*octandrum*
	Xanthostemon	*whitei*
Podocarpaceae	*Podocarpus*	*dispermus*
Proteaceae	*Austromuellera*	*trinervia*
	Cardwellia	*sublimis*
	Carnarvonia	*araliifolia*
	Darlingia	*darlingiana*
	Darlingia	*ferruginea*

Appendix C cont.: Species lists of rehabilitation plantings

Site: Elinjaa Falls Adjacent cont.

Family	**Genus**	***Species***
Proteaceae	*Helicia*	*lamingtoniana*
	Helicia	*nortoniana*
	Lomatia	*fraxinifolia*
	Stenocarpus	*sinuatus*
Rhamnaceae	*Alphitonia*	*petriei*
	Emmenosperma	*alphitoniodes*
Rosaceae	*Prunus*	*turneriana*
Rutaceae	*Acronychia*	*acidula*
	Euodia	*bonwickii*
	Euodia	*elleryana*
	Euodia	*xanthoxyloides*
	Flindersia	*acuminata*
	Flindersia	*bourjotiana*
	Flindersia	*brayleyana*
	Flindersia	*pimentiliana*
	Halfordia	*scleroxyla*
Sapindaceae	*Arytera*	*divaricata*
	Arytera	*lautererana*
	Castanospora	*alphandii*
	Cupaniopsis	*dallachyi*
	Diploglottis	*diphyllostegia*
	Diploglottis	*smithii*
	Guioa	*acutifolia*
	Guioa	*lasioneura*
	Mischocarpus	*grandissimus*
	Mischocarpus	*lachnocarpus*
	Mischocarpus	*stipitata*
	Rhysotoechia	*robertsonii*
	Synima	*macrophylla*
	Toechima	*erythrocarpum*
Sapotaceae	*Pouteria*	*castanosperma*
Sterculaceae	*Argyrodendron*	*peralatum*
	Brachychiton	*acerifolius*
Symplocaceae	*Symplocos*	*cochinchinensis*

Site: Hillcrest Farm Adjacent

Family	**Genus**	***Species***
Anacardiaceae	*Acronychia*	*acidula*
	Acronychia	*crassipetala*
	Blepharocarya	*involucrigera*
	Euroschinus	*falcata*
Annonaceae	*Polyalthia*	*michaelii*
Apocynaceae	*Alstonia*	*scholaris*
Araliaceae	*Polyscias*	*australiana*
Araucariaceae	*Agathis*	*robusta*
Caesalpiniaceae	*Pilidiostigma*	*tropicum*
Clusiaceae	*Calophyllum*	*sil*

Appendix C cont.: Species lists of rehabilitation plantings

Site: Hillcrest Farm Isolated cont.

Family	**Genus**	***Species***
Combretaceae	*Terminalia*	*sericocarpa*
Corynocarpaceae	*Corynocarpus*	*cribbianus*
Cunoniaceae	*Caldcluvia*	*australiensis*
	Ceratopetalum	*succirubrum*
	Ceratopetalum	*virchowii*
	Geissois	*biagiana*
	Pullea	*stutzeri*
Davidsoniaceae	*Davidsonia*	*pruriens*
Elaeocarpaceae	*Elaeocarpus*	*angustifolius*
	Elaeocarpus	*coorangooloo*
	Peripentadenia	*mearsii*
Euphorbiaceae	*Aleurites*	*moluccana*
	Glochidion	*hylandii*
	Glochidion	*philippicum*
	Macaranga	*subdentata*
	Mallotus	*philippensis*
	Homalanthus	*novoguineensis*
Fabaceae	*Castanospermum*	*australe*
Flacourtiaceae	*Casearia*	*dallachii*
	Scolopia	*braunii*
Grossulariaceae	*Polyosma*	*alangiacea*
Hamamelidaceae	*Ostrearia*	*australiana*
Himantandraceae	*Galbulimima*	*belgraveana*
Lauraceae	*Beilschmiedia*	*bancroftii*
	Beilschmiedia	*obtusifolia*
	Cinnamomum	*laubatii*
	Cryptocarya	*angulata*
	Cryptocarya	*hypospodia*
	Cryptocarya	*lividula*
	Cryptocarya	*mackinnoniana*
	Cryptocarya	*oblata*
	Cryptocarya	*triplinervis*
	Endiandra	*wolfei*
	Litsea	*leefeana*
	Neolitsea	*dealbata*
Meliaceae	*Aglaia*	*sapindina*
	Amoora	*ferruginea*
	Dysoxylum	*muelleri*
	Dysoxylum	*pettigrewianaum*
	Dysoxylum	*rufum*
	Synoum	*muelleri*
	Toona	*ciliata*
Mimosaceae	*Acacia*	*celsa*
	Pararchidendron	*pruinosum*
Monimiaceae	*Doryphora*	*aromatica*
	Hedycarya	*loxocarya*
	Daphnandra	*repandula*
	Tetrasynandra	*pubescens*

Appendix C cont.: Species lists of rehabilitation plantings

Site: Hillcrest Farm Isolated cont.

Family	**Genus**	***Species***
Moraceae	*Ficus*	*destruens*
	Ficus	*obliqua var. petiolaris*
	Ficus	*pleurocarpa*
	Ficus	*superba var. ?*
Myrtaceae	*Acmena*	*hemilampra*
	Acmena	*resa*
	Acmena	*smithii*
	Acmenosperma	*claviflorum*
	Rhodomyrtus	*trineura*
	Syzygium	*alliiligneum*
	Syzygium	*angophoroides*
	Syzygium	*australe*
	Syzygium	*canicortex*
	Syzygium	*cormiflorum*
	Syzygium	*endophloium*
	Syzygium	*gustavioides*
	Syzygium	*kuranda*
	Syzygium	*leuhmannii*
	Syzygium	*papyraceum*
	Syzygium	*tierneyanum*
	Syzygium	*wesa*
	Syzygium	*wilsonii sp. crytophlebium*
	Syzygium	*wilsonii ssp. wilsonii*
	Waterhousea	*unipunctata*
	Xanthostemon	*chrysanthus*
Myristicaceae	*Myristica*	*insipida*
Oleaceae	*Chionanthus*	*ramiflora*
Pittosporaceae	*Hymenosporum*	*flavum*
	Pittosporum	*ferruginea*
	Pittosporum	*melanospermum*
	Pittosporum	*revolutum*
Podocarpaceae	*Podocarpus*	*dispermus*
	Prumnopitys	*amara*
Proteaceae	*Alloxylon*	*flammeum*
	Athertonia	*diversifolia*
	Buckinghamia	*celsissima*
	Cardwellia	*sublimis*
	Carnarvonia	*araliifolia*
	Darlingia	*darlingiana*
	Darlingia	*ferruginea*
	Helicia	*nortoniana*
	Lomatia	*fraxinifolia*
	Musgravea	*heterophylla*
	Musgravea	*stenostachya*
	Opisthiolepis	*heterophylla*
	Placospermum	*coriaceum*
	Stenocarpus	*sinuatus*
Rhamnaceae	*Alphitonia*	*petriei*

Appendix C cont.: Species lists of rehabilitation plantings

Site: Hillcrest Farm Isolated cont.

Family	**Genus**	***Species***
Rhamnaceae	*Alphitonia*	*whitei*
	Emmenosperma	*alphitoniodes*
Rosaceae	*Prunus*	*turneriana*
Rubiaceae	*Guettarda*	*tenuiflora*
Rutaceae	*Euodia*	*bonwickii*
	Euodia	*sp.*
	Evodiella	*muelleri*
	Flindersia	*acuminata*
	Flindersia	*bourjotiana*
	Flindersia	*brayleyana*
	Flindersia	*ifflaiana*
	Flindersia	*laevicarpa*
	Flindersia	*pimentiliana*
	Flindersia	*schottiana*
	Halfordia	*scleroxyla*
	Harpullia	*frutescens*
	Harpullia	*pendula*
	Melicope	*elleryana*
	Melicope	*vitiflora*
	Zanthoxylum	*ovalifolium*
Sapindaceae	*Arytera*	*divaricata*
	Arytera	*lautererana*
	Castanospora	*alphandii*
	Cupaniopsis	*dallachyi*
	Cupaniopsis	*flagelliformis*
	Cupaniopsis	*foveolata*
	Diploglottis	*bracteata*
	Diploglottis	*diphyllostegia*
	Diploglottis	*smithii*
	Guioa	*acutifolia*
	Guioa	*lasioneura*
	Mischocarpus	*lachnocarpus*
	Mischocarpus	*pyriformis*
	Mischocarpus	*stipiatus*
	Rhysotoechia	*robertsonii*
	Sarcotoechia	*serrata*
	Synima	*cordierorum*
	Synima	*macrophylla*
	Toechima	*erythrocarpum*
Sapotaceae	*Planchonella*	*obovoidea*
Sterculaceae	*Argyrodendron*	*peralatum*
	Argyrodendron	*trifoliolatum*
	Franciscodendron	*laurifolium*
	Brachychiton	*acerifolius*
Verbenaceae	*Gmelina*	*fasciculiflora*
Winteraceae	*Tasmannia*	*membranea*
Xanthophyllaceae	*Xanthophyllum*	*octandrum*

Appendix C cont.: Species lists of rehabilitation plantings

Site: Malanda Falls Adjacent

Family	***Genus***	***Species***
Anacardiaceae	*Acronychia*	*acidula*
	Euroschinus	*falcata*
Apocynaceae	*Alstonia*	*scholaris*
Araucariaceae	*Agathis*	*robusta*
Caesalpiniaceae	*Pilidiostigma*	*tropicum*
Corynocarpaceae	*Corynocarpus*	*cribbianus*
Cunoniaceae	*Ceratopetalum*	*succirubrum*
	Geissois	*biagiana*
	Pullea	*stutzeri*
Davidsoniaceae	*Davidsonia*	*pruriens*
Elaeocarpaceae	*Elaeocarpus*	*angustifolius*
	Elaeocarpus	*coorangooloo*
	Sloanea	*macbrydei*
Euphorbiaceae	*Aleurites*	*moluccana*
	Mallotus	*philippensis*
	Homalanthus	*novoguineensis*
Fabaceae	*Castanospermum*	*australe*
Flacourtiaceae	*Casearia*	*dallachii*
	Scolopia	*braunii*
Hamamelidaceae	*Ostrearia*	*australiana*
Lauraceae	*Beilschmiedia*	*bancroftii*
	Beilschmiedia	*obtusifolia*
	Beilschmiedia	*tooram*
	Cinnamomum	*laubatii*
	Cryptocarya	*corrugata*
	Cryptocarya	*hypospodia*
	Cryptocarya	*mackinnoniana*
	Cryptocarya	*oblata*
	Cryptocarya	*triplinervis*
	Endiandra	*sankeyana*
	Litsea	*leefeana*
Lauraceae	*Neolitsea*	*dealbata*
Meliaceae	*Dysoxylum*	*muelleri*
	Dysoxylum	*pettigrewianaum*
	Toona	*australis*
Mimosaceae	*Acacia*	*celsa*
	Acacia	*cincinnata*
Monimiaceae	*Doryphora*	*aromatica*
Moraceae	*Ficus*	*destruens*
	Ficus	*pleurocarpa*
	Ficus	*obliqua var.*
Myrtaceae	*Acmena*	*resa*
	Syzygium	*canicortex*
	Syzygium	*cormiflorum*
	Syzygium	*endophloium*
	Syzygium	*gustavioides*
	Syzygium	*johnsonii*
	Syzygium	*kuranda*

Appendix C cont.: Species lists of rehabilitation plantings

Site: Malanda Falls Adjacent

Family	***Genus***	***Species***
Myrtaceae	*Syzygium*	*leuhmannii*
	Syzygium	*papyraceum*
	Syzygium	*sayeri*
	Syzygium	*wilsonii ssp. crytophlebium*
	Xanthostemon	*whitei*
Proteaceae	*Athertonia*	*diversifolia*
	Buckinghamia	*celsissima*
	Cardwellia	*sublimis*
	Carnarvonia	*araliifolia*
	Darlingia	*darlingiana*
	Darlingia	*ferruginea*
	Helicia	*nortoniana*
	Stenocarpus	*sinuatus*
Rhamnaceae	*Alphitonia*	*petriei*
	Emmenosperma	*alphitoniodes*
Rosaceae	*Prunus*	*turneriana*
Rutaceae	*Euodia*	*elleryana*
	Euodia	*xanthoxyloides*
	Flindersia	*acuminata*
	Flindersia	*bourjotiana*
	Flindersia	*brayleyana*
	Flindersia	*pimentiliana*
	Halfordia	*scleroxyla*
Sapindaceae	*Arytera*	*divaricata*
	Arytera	*lautererana*
	Castanospora	*alphandii*
	Cupaniopsis	*flagelliformis*
	Cupaniopsis	*foveolata*
	Diploglottis	*diphyllostegia*
	Diploglottis	*smithii*
	Guioa	*lasioneura*
	Mischocarpus	*grandissimus*
	Mischocarpus	*stipiatus*
	Rhysotoechia	*robertsonii*
	Toechima	*erythrocarpum*
Sterculaceae	*Argyrodendron*	*peralatum*
	Argyrodendron	*trifoliolatum*
Sterculiaceae	*Brachychiton*	*acerifolius*
Symplocaceae	*Symplocos*	*cochinchinensis*
Thymelaeaceae	*Oreodendron*	*biflorum*
Verbenaceae	*Gmelina*	*fasciculiflora*

Site: Winfield Park Adjacent

Family	***Genus***	***Species***
Anacardiaceae	*Acronychia*	*acidula*
	Blepharocarya	*involucrigera*
Araliaceae	*Mackinlaya*	*sp.*

Appendix C cont.: Species lists of rehabilitation plantings

Site: Winfield Park Adjacent

Family	***Genus***	***Species***
Araucariaceae	*Agathis*	*robusta*
Araucariaceae	*Araucarias*	*cunninghamii*
Caesalpiniaceae	*Pilidiostigma*	*tropicum*
Combretaceae	*Terminalia*	*seriocarpa*
Cunoniaceae	*Gillbeea*	*adenopetala*
Davidsoniaceae	*Davidsonia*	*pruriens*
Ebenaceae	*Diospyros*	*pentamera*
Elaeocarpaceae	*Elaeocarpus*	*angustifolius*
	Elaeocarpus	*sericopetalus*
Flacourtiaceae	*Scolopia*	*braunii*
Lauraceae	*Cryptocarya*	*triplinervis*
Lauraceae	*Neolitsea*	*dealbata*
Meliaceae	*Dysoxylum*	*sp.*
Mimosaceae	*Pararchidendron*	*pruinosum*
Myrtaceae	*Acmena*	*divaricata*
	Acmena	*hemilampra*
	Acmena	*smithii*
	Acmenosperma	*claviflorum*
	Backhousia	*hughesii*
	Callistemon	*viminalis*
	Syzygium	*alliiligneum*
	Syzygium	*australe*
	Syzygium	*canicortex*
	Syzygium	*cormiflorum*
	Syzygium	*erythrocalyx*
	Syzygium	*leuhmannii*
	Syzygium	*papyraceum*
	Syzygium	*resa*
	Syzygium	*wilsonii*
	Xanthostemon	*chrysanthus*
Pittosporaceae	*Pittosporum*	*ferrugineum*
Proteaceae	*Athertonia*	*diversifolia*
	Buckinghamia	*celsissima*
	Darlingia	*darlingiana*
	Darlingia	*ferruginea*
	Lomatia	*fraxinifolia*
	Placospermum	*coriaceum*
	Stenocarpus	*sinuatus*
Rhamnaceae	*Alphitonia*	*petriei*
	Emmenosperma	*alphitoniodes*
Rutaceae	*Euodia*	*elleryana*
	Evodiella	*muelleri*
	Flindersia	*bourjotiana*
	Flindersia	*brayleyana*
	Flindersia	*pimentiliana*
	Flindersia	*schottiana*
Sapindaceae	*Arytera*	*divaricata*
	Castanospora	*alphandii*

Appendix C cont.: Species lists of rehabilitation plantings

Site: Winfield Park Adjacent cont.

Family	***Genus***	***Species***
Sapindaceae	*Cupaniopsis*	*flagelliformis*
	Guioa	*acutifolia*
	Mischocarpus	*lachnocarpus*
	Mischocarpus	*stipitatus*
	Rhysotoechia	*robertsonii*
Sapotaceae	*Planchonella*	*sp.*
Sterculaceae	*Argyrodendron*	*sp.*
	Brachychiton	*acerifolius*
Ulmaceae	*Trema*	*orientalis*

Appendix D: Species germination lists for 17 study sites

Site: Elinjaa Falls Scenic Reserve Remnant

Family	Genus	Species	Life Form	Native/ Exotic[1]	Successional Stage	Dispersal Mechanism	Seed Size[2]
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small
Brassicaceae	*Cardamine*	*hirsuta*	Herb	Exotic	Early	Wind	Small
Lamiaceae	*Plectranthus*	*sp.*	Shrub	Native	Early	Wind	Small
Moraceae	*Ficus*	*congesta*	Tree	Native	Early	Cassowary	Small
	Ficus	*copiosa*	Tree	Native	Early	Cassowary	Small
	Ficus	*sp.*	Tree	Native	Early	Varied	Small
Myrtaceae	*Rhodamnia*	*sessiliflora*	Tree	Native	Early	Bird	Small
Pittosporaceae	*Hymenosporum*	*flavum*	Tree	Native	Early	Bird	Intermediate
Rosaceae	*Rubus*	*alceifolius*	Vine	Exotic	Early	Bird	Small
	Rubus	*moluccanus*	Vine	Native	Early	Bird	Small
Solanaceae	*Solanum*	*mauritianum*	Shrub	Exotic	Early	Varied	Small
Zingiberaceae	*Alpinia*	*caerulea*	Shrub	Native	Early	Varied	Small

Site: Lake Barrine 1988 Remnant

Family	Genus	Species	Life Form	Native/ Exotic[1]	Successional Stage	Dispersal Mechanism	Seed Size[2]
Apiaceae	*Hydrocotle*	*acutiloba*	Herb	Exotic	Early	Wind	Small
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small
Cyperaceae	*Cyperus*	*rotundus*	Grass	Exotic	Early	Wind	Small

Appendix D cont.: Species germination lists for 17 study sites

Site: Lake Barrine 1988 Remnant cont.

Family	Genus	Species	Life Form	Native/ Exotic[1]	Successional Stage	Dispersal Mechanism	Seed Size[2]
Elaeagnaceae	*Elaeagnus*	*triflora*	Vine	Native	Intermediate	Varied	Intermediate
Euphorbiaceae	*Homalanthus*	*novoguineensis*	Tree	Native	Early	Varied	Small
Malvaceae	*Sida*	*rhombifolia*	Herb	Exotic	Early	Wind	Small
Meliaceae	*Melia*	*azedarach*	Tree	Native	Early	Bird	Small
Rhamnaceae	*Alphitonia*	*petriei*	Tree	Native	Early	Bird	Small
Rutaceae	*Melicope*	*elleryana*	Tree	Native	Early	Bird	Small
Solanaceae	*Physalis*	*minima*	Shrub	Exotic	Early	Wind	Small
Urticaceae	*Dendrocnide*	*moroides*	Shrub	Native	Intermediate	Varied	Small
	Dendrocnide	*photinophylla*	Tree	Native	Early	Varied	Small

Site: Lake Barrine 1989 Remnant

Family	Genus	Species	Life Form	Native/ Exotic[1]	Successional Stage	Dispersal Mechanism	Seed Size[2]
Apiaceae	*Hydrocotle*	*acutiloba*	Herb	Exotic	Early	Wind	Small
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small
Euphorbiaceae	*Homalanthus*	*novoguineensis*	Tree	Native	Early	Varied	Small
Malvaceae	*Sida*	*rhombifolia*	Herb	Exotic	Early	Wind	Small
Meliaceae	*Melia*	*azadirach*	Tree	Native	Early	Bird	Small
Poaceae	*Oplismenis*	*aemulus*	Grass	Exotic	Early	Varied	Small
Rhamnaceae	*Alphitonia*	*petriei*	Tree	Native	Early	Bird	Small
Solanaceae	*Physalis*	*minima*	Shrub	Exotic	Early	Wind	Small

	Solanum	*mauritianum*	Shrub	Exotic	Early	Varied	Small
Urticaceae	*Dendrocnide*	*moroides*	Shrub	Native	Intermediate	Varied	Small

Appendix D cont.: Species germination lists for 17 study sites
Site: Lake Eacham National Park Remnant

Family	**Genus**	**Species**	**Life Form**	**Native/ Exotic[1]**	**Successional Stage**	**Dispersal Mechanism**	**Seed Size[2]**
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
Elaeagnaceae	*Elaeagnus*	*triflora*	Vine	Native	Intermediate	Varied	Intermediate
Malvaceae	*Sida*	*rhombifolia*	Herb	Exotic	Early	Wind	Small
Meliaceae	*Melia*	*azedarach*	Tree	Native	Early	Bird	Small
Mimosaceae	*Acacia*	*celsa*	Tree	Native	Early	Animal	Small
Oxalidaceae	*Oxalis*	*corniculata*	Herb	Exotic	Early	Varied	Small
Rhamnaceae	*Alphitonia*	*petriei*	Tree	Native	Early	Bird	Small
Urticaceae	*Dendrocnide*	*moroides*	Shrub	Native	Intermediate	Varied	Small

Site: Malanda Falls Environmental Park Remnant

Family	**Genus**	**Species**	**Life Form**	**Native/ Exotic[1]**	**Successional Stage**	**Dispersal Mechanism**	**Seed Size[2]**
Apiaceae	*Hydrocotle*	*acutiloba*	Herb	Exotic	Early	Wind	Small
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small
Campanulaceae	*Wahlenbergia*	*sp.*	Herb	Exotic	Early	Wind	Small
Cyperaceae	*Cyperus*	*rotundus*	Grass	Exotic	Early	Wind	Small
Euphorbiaceae	*Homalanthus*	*novoguineensis*	Tree	Native	Early	Varied	Small
Lauraceae	*Lindera*	*queenslandica*	Shrub	Native	Early	Wind	Small
Malvaceae	*Sida*	*rhombifolia*	Herb	Exotic	Early	Wind	Small
Rhamnaceae	*Alphitonia*	*petriei*	Tree	Native	Early	Bird	Small
Solanaceae	*Physalis*	*minima*	Shrub	Exotic	Early	Wind	Small
	Solanum	*dallachii*	Shrub	Native	Early	Varied	Small
	Solanum	*mauritianum*	Shrub	Exotic	Early	Varied	Small
Urticaceae	*Dendrocnide*	*moroides*	Shrub	Native	Intermediate	Varied	Small

	Dendrocnide	*photinophylla*	Tree	Native	Early	Varied	Small

Appendix D cont.: Species germination lists for 17 study sites

Site: Millaa Millaa Falls Scenic Reserve Remnant

FAMILY	Genus	Species	Life Form	Native/ Exotic[1]	Successional Stage	Dispersal Mechanism	Seed Size[2]
Anacardiaceae	*Euroschinus*	*falcata*	Tree	Native	Early	Wind	Small
Araliaceae	*Polyscias*	*murrayi*	Tree	Native	Early	Bird	Small
Aristolochiaceae	*Aristolochia*	*sp.*	Shrub	Native	Intermediate	Wind	Intermediate
Asteraceae	*Sonchus*	*oleraceus*	Herb	Exotic	Early	Wind	Small
Brassicaceae	*Cardamine*	*hirsuta*	Herb	Exotic	Early	Wind	Small
Caryophyllaceae	*Drymaria*	*cordata*	Herb	Exotic	Early	Wind	Small
Malvaceae	*Sida*	*rhombifolia*	herb	Exotic	Early	Wind	Small
Moraceae	*Ficus*	*congesta*	Tree	Native	Early	Cassowary	Small
	Ficus	*fraseri*	Tree	Native	Early	Varied	Small
Myrtaceae	*Rhodamnia*	*sessiliflora*	Tree	Native	Early	Bird	Small
	Rhodomyrtus	*pervagata*	Tree	Native	Early	Wind	Small
Oxalidaceae	*Oxalis*	*corniculata*	Herb	Exotic	Early	Varied	Small
Poaceae	*Axonopus*	*compressus*	Grass	Exotic	Early	Wind	Small
	Oplismenis	*aemulus*	Grass	Exotic	Early	Varied	Small
Rhamnaceae	*Alphitonia*	*petriei*	Tree	Native	Early	Bird	Small
Rosaceae	*Rubus*	*alceifolius*	Vine	Exotic	Early	Bird	Small
Solanaceae	*Solanum*	*mauritianum*	Shrub	Exotic	Early	Varied	Small
	Solanum	*seaforthianum*	Vine	Exotic	Early	Varied	Small
Urticaceae	*Dendrocnide*	*photinophylla*	Tree	Native	Early	Varied	Small

Appendix D cont.: Species germination lists for 17 study sites

Site: Chapman Farm Adjacent

FAMILY	Genus	Species	Life Form	Native/ Exotic[1]	Successional Stage	Dispersal Mechanism	Seed Size[2]
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
	Conyza	*canadensis*	Shrub	Exotic	Early	Wind	Small
	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small
Caryophyllaceae	*Drymaria*	*cordata*	Herb	Exotic	Early	Wind	Small
Cyperaceae	*Cyperus*	*rotundus*	Grass	Exotic	Early	Wind	Small
Euphorbiaceae	*Homalanthus*	*novoguineensis*	Tree	Native	Early	Varied	Small
Malvaceae	*Sida*	*rhombifolia*	herb	Exotic	Early	Wind	Small
	Urena	*lobata*	Shrub	Exotic	Early	Wind	Small
Moraceae	*Ficus*	*congesta*	Tree	Native	Early	Cassowary	Small
	Ficus	*fraserii*	Tree	Native	Early	Varied	Small
Myrtaceae	*Rhodomyrtus*	*pervagata*	Tree	Native	Early	Wind	Small
Oxalidaceae	*Oxalis*	*corniculata*	Herb	Exotic	Early	Varied	Small
Poaceae	*Axonopus*	*compressus*	Grass	Exotic	Early	Wind	Small
	Cynodon	*dacytlon*	Grass	Exotic	Early	Wind	Small
Rhamnaceae	*Alphitonia*	*petriei*	Tree	Native	Early	Bird	Small
Rosaceae	*Rubus*	*alceifolius*	Vine	Exotic	Early	Bird	Small
Solanaceae	*Solanum*	*mauritianum*	Shrub	Exotic	Early	Varied	Small
Urticaceae	*Dendrocnide*	*photinophylla*	Tree	Native	Early	Varied	Small

Appendix D cont.: Species germination lists for 17 study sites

Site: Elinjaa Falls Scenic Reserve Adj.

FAMILY	**Genus**	**Species**	**Life Form**	**Native/ Exotic**[1]	**Successional Stage**	**Dispersal Mechanism**	**Seed Size**[2]
Apiaceae	*Hydrocotle*	*acutiloba*	Herb	Exotic	Early	Wind	Small
Apocynaceae	*Alstonia*	*scholaris*	Tree	Native	Early	Wind	Small
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
	Conyza	*canadensis*	Shrub	Exotic	Early	Wind	Small
	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small
	Tridax	*procumbens*	Herb	Exotic	Early	Wind	Small
Brassicaceae	*Cardamine*	*hirsuta*	Herb	Exotic	Early	Wind	Small
Caryophyllaceae	*Drymaria*	*cordata*	Herb	Exotic	Early	Wind	Small
Euphorbiaceae	*Homalanthus*	*novoguineensis*	Tree	Native	Early	Varied	Small
Moraceae	*Ficus*	*congesta*	Tree	Native	Early	Cassowary	Small
Oxalidaceae	*Oxalis*	*corniculata*	Herb	Exotic	Early	Varied	Small
Poaceae	*Axonopus*	*compressus*	Grass	Exotic	Early	Wind	Small
	Cynadon	*dactylon*	Grass	Exotic	Early	Wind	Small
	Oplismenis	*aemulus*	Grass	Exotic	Early	Varied	Small
Rhamnaceae	*Alphitonia*	*petriei*	Tree	Native	Early	Bird	Small
Rosaceae	*Rubus*	*alceifolius*	Vine	Exotic	Early	Bird	Small
	Rubus	*moluccanas*	Vine	Native	Early	Bird	Small
Solanaceae	*Solanum*	*mauritianum*	Shrub	Exotic	Early	Varied	Small
Thymelaeaceae	*Wikstroemia*	*indica*	Shrub	Native	Early	Bird	Small

Appendix D cont.: Species germination lists for 17 study sites

Site: Lake Barrine 1988 Adjacent

FAMILY	Genus	Species	Life Form	Native/ Exotic[1]	Successional Stage	Dispersal Mechanism	Seed Size[2]
Apiaceae	*Hydrocotle*	*acutiloba*	Herb	Exotic	Early	Wind	Small
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
	Conyza	*canadensis*	Shrub	Exotic	Early	Wind	Small
	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small
	Gnaphalium	*sp.*	Herb	Native	Early	Wind	Small
	Sonchus	*oleraceus*	Herb	Exotic	Early	Wind	Small
Campanulaceae	*Wahlenbergia*	*sp.*	Herb	Exotic	Early	Wind	Small
Cyperaceae	*Cyperus*	*rotundus*	Grass	Exotic	Early	Wind	Small
Euphorbiaceae	*Homalanthus*	*novoguineensis*	Tree	Native	Early	Varied	Small
Fabaceae	*Glycine*	*cyrtoloba*	Vine	Native	Early	Wind	Small
Malvaceae	*Sida*	*rhombifolia*	Herb	Exotic	Early	Wind	Small
Mimosaceae	*Acacia*	*celsa*	Tree	Native	Early	Animal	Small
Poaceae	*Brachiaria*	*decumbens*	Grass	Exotic	Early	Wind	Small
Rhamnaceae	*Alphitonia*	*petriei*	Tree	Native	Early	Bird	Small
Solanaceae	*Physalis*	*minima*	Shrub	Exotic	Early	Wind	Small
	Solanum	*mauritianum*	Shrub	Exotic	Early	Varied	Small
	Solanum	*seaforthianum*	Vine	Exotic	Early	Varied	Small

Site: Lake Barrine 1989 Adjacent

FAMILY	Genus	Species	Life Form	Native/ Exotic[1]	Successional Stage	Dispersal Mechanism	Seed Size[2]
Apiaceae	*Hydrocotle*	*acutiloba*	Herb	Exotic	Early	Wind	Small
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small

	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small

Appendix D cont.: Species germination lists for 17 study sites
Site: Lake Barrine 1989 Adjacent cont.

FAMILY	Genus	Species	Life Form	Native/ Exotic[1]	Successional Stage	Dispersal Mechanism	Seed Size[2]
Euphorbiaceae	*Homalanthus*	*novoguineensis*	Tree	Native	Early	Varied	Small
	Phyllanthus	*lamprophyllus*	Shrub	Native	Early	Wind	Small
Malvaceae	*Sida*	*rhombifolia*	Herb	Exotic	Early	Wind	Small
Mimosaceae	*Acacia*	*celsa*	Tree	Native	Early	Animal	Small
Oxalidaceae	*Oxalis*	*corniculata*	Herb	Exotic	Early	Varied	Small
Poaceae	*Oplismenis*	*aemulus*	Grass	Exotic	Early	Varied	Small
Rhamnaceae	*Alphitonia*	*petriei*	Tree	Native	Early	Bird	Small
Solanaceae	*Physalis*	*minima*	Shrub	Exotic	Early	Wind	Small
	Solanum	*mauritianum*	Shrub	Exotic	Early	Varied	Small

Site: Malanda Falls Environmental Park Adjacent

FAMILY	Genus	Species	Life Form	Native/ Exotic[1]	Successional Stage	Dispersal Mechanism	Seed Size[2]
Apiaceae	*Hydrocotle*	*acutiloba*	Herb	Exotic	Early	Wind	Small
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small
	Sonchus	*oleraceus*	Herb	Exotic	Early	Wind	Small
Campanulaceae	*Wahlenbergia*	*sp.*	Herb	Exotic	Early	Wind	Small
Caryophyllaceae	*Drymaria*	*cordata*	Herb	Exotic	Early	Wind	Small
Cyperaceae	*Cyperus*	*rotundus*	Grass	Exotic	Early	Wind	Small
Euphorbiaceae	*Phyllanthus*	*lamprophyllus*	Shrub	Native	Early	Wind	Small
Malvaceae	*Sida*	*rhombifolia*	Herb	Exotic	Early	Wind	Small
Oxalidaceae	*Oxalis*	*corniculata*	Herb	Exotic	Early	Varied	Small

Poaceae	*Brachiaria*	*decumbens*	Grass	Exotic	Early	Wind	Small

Appendix D cont.: Species germination lists for 17 study sites

Site: Malanda Falls Environmental Park Adjacent cont.

FAMILY	Genus	Species	Life Form	Native/ Exotic[1]	Successional Stage	Dispersal Mechanism	Seed Size[2]
Rhamnaceae	*Alphitonia*	*petriei*	Tree	Native	Early	Bird	Small
Solanaceae	*Physalis*	*minima*	Shrub	Exotic	Early	Wind	Small
Urticaceae	*Dendrocnide*	*photinophylla*	Tree	Native	Early	Varied	Small

Site: Winfield Park Adjacent

FAMILY	Genus	Species	Life Form	Native/ Exotic[1]	Successional Stage	Dispersal Mechanism	Seed Size[2]
Apiaceae	*Hydrocotle*	*acutiloba*	Herb	Exotic	Early	Wind	Small
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small
Caryophyllaceae	*Drymaria*	*cordata*	Herb	Exotic	Early	Wind	Small
Euphorbiaceae	*Phyllanthus*	*lamprophyllus*	Shrub	Native	Early	Wind	Small
Malvaceae	*Sida*	*rhombifolia*	Herb	Exotic	Early	Wind	Small
Mimosaceae	*Acacia*	*celsa*	Tree	Native	Early	Animal	Small
Oragraceae	*Ludwigia*	*octovalvis*	Shrub	Exotic	Early	Wind	Small
Oxalidaceae	*Oxalis*	*corniculata*	Herb	Exotic	Early	Varied	Small
Rhamnaceae	*Alphitonia*	*petriei*	Tree	Native	Early	Bird	Small
Solanaceae	*Physalis*	*minima*	Shrub	Exotic	Early	Wind	Small
Solanaceae	*Solanum*	*mauritianum*	Shrub	Exotic	Early	Varied	Small
Urticaceae	*Dendrocnide*	*photinophylla*	Tree	Native	Early	Varied	Small

Appendix D cont.: Species germination lists for 17 study sites

Site: Backshall Dairy Farm Isolated

FAMILY	**Genus**	**Species**	**Life Form**	**Native/ Exotic**[1]	**Successional Stage**	**Dispersal Mechanism**	**Seed Size**[2]
Amaranthaceae	*Alternanthera*	*bettzichiana*	Herb	Exotic	Early	Wind	Small
Apiaceae	*Hydrocotle*	*acutiloba*	Herb	Exotic	Early	Wind	Small
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
	Conyza	*canadensis*	Shrub	Exotic	Early	Wind	Small
	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small
	Tridax	*procumbens*	Herb	Exotic	Early	Wind	Small
Brassicaceae	*Cardamine*	*hirsuta*	Herb	Exotic	Early	Wind	Small
Caryophyllaceae	*Drymaria*	*cordata*	Herb	Exotic	Early	Wind	Small
Cyperaceae	*Cyperus*	*rotundus*	Grass	Exotic	Early	Wind	Small
Euphorbiaceae	*Phyllanthus*	*lamprophyllus*	Shrub	Native	Early	Wind	Small
Malvaceae	*Sida*	*rhombifolia*	Herb	Exotic	Early	Wind	Small
Oxalidaceae	*Oxalis*	*corniculata*	Herb	Exotic	Early	Varied	Small
Poaceae	*Axonopus*	*compressus*	Grass	Exotic	Early	Wind	Small
	Cyndadon	*dacytlon*	Grass	Exotic	Early	Wind	Small
	Oplismenis	*aemulus*	Grass	Exotic	Early	Varied	Small
Rosaceae	*Rubus*	*moluccanus*	Vine	Native	Early	Bird	Small
Solanaceae	*Physalis*	*minima*	Shrub	Exotic	Early	Wind	Small
	Solanum	*mauritianum*	Shrub	Exotic	Early	Varied	Small
	Solanum	*torvum*	Shrub	Exotic	Early	Varied	Small

Appendix D cont.: Species germination lists for 17 study sites

Site: Cleminson Creek Isolated

FAMILY	**Genus**	**Species**	**Life Form**	**Native/ Exotic**[1]	**Successional Stage**	**Dispersal Mechanism**	**Seed Size**[2]
Apiaceae	*Hydrocotle*	*acutiloba*	Herb	Exotic	Early	Wind	Small
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small
Asteraceae	*Gnaphalium*	*sp.*	Herb	Native	Early	Wind	Small
Euphorbiaceae	*Homalanthus*	*novoguineensis*	Tree	Native	Early	Varied	Small
Fabaceae	*Glycine*	*cyrtoloba*	Vine	Native	Early	Wind	Small
Malvaceae	*Sida*	*rhombifolia*	Herb	Exotic	Early	Wind	Small
Oragraceae	*Ludwigia*	*octovalvis*	Shrub	Exotic	Early	Wind	Small
Poaceae	*Oplismenis*	*aemulus*	Grass	Exotic	Early	Varied	Small
Rhamnaceae	*Alphitonia*	*petriei*	Tree	Native	Early	Bird	Small
Solanaceae	*Physalis*	*minima*	Shrub	Exotic	Early	Wind	Small
	Solanum	*mauritianum*	Shrub	Exotic	Early	Varied	Small
Tiliaceae	*Triumfetta*	*rhomboidea*	Shrub	Exotic	Early	Wind	Small

Site: Doan Farm Isolated

FAMILY	**Genus**	**Species**	**Life Form**	**Native/ Exotic**[1]	**Successional Stage**	**Dispersal Mechanism**	**Seed Size**[2]
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
	Conyza	*canadensis*	Shrub	Exotic	Early	Wind	Small
	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small
Brassicaceae	*Cardamine*	*hirsuta*	Herb	Exotic	Early	Wind	Small
Caryophyllaceae	*Drymaria*	*cordata*	Herb	Exotic	Early	Wind	Small
Cyperaceae	*Cyperus*	*rotundus*	Grass	Exotic	Early	Wind	Small

Euphorbiaceae	*Phyllanthus*	*lamprophyllus*	Shrub	Native	Early	Wind	Small

Appendix D cont.: Species germination lists for 17 study sites

Site: Doan Farm Isolated cont.

FAMILY	**Genus**	**Species**	**Life Form**	**Native/ Exotic[1]**	**Successional Stage**	**Dispersal Mechanism**	**Seed Size[2]**
Lauraceae	*Lindera*	*queenslandica*	Shrub	Native	Early	Wind	Small
Malvaceae	*Sida*	*rhombifolia*	herb	Exotic	Early	Wind	Small
Mimosaceae	*Acacia*	*celsa*	Tree	Native	Early	Animal	Small
Moraceae	*Ficus*	*congesta*	Tree	Native	Early	Cassowary	Small
Oxalidaceae	*Oxalis*	*corniculata*	Herb	Exotic	Early	Varied	Small
Poaceae	*Axonopus*	*compressus*	Grass	Exotic	Early	Wind	Small
	Cynodon	*dacytlon*	Grass	Exotic	Early	Wind	Small
	Oplismenis	*aemulus*	Grass	Exotic	Early	Varied	Small
Rhamnaceae	*Alphitonia*	*petriei*	Tree	Native	Early	Bird	Small
Rubiaceae	*Richardia*	*brasiliensis*	Herb	Exotic	Early	Wind	Small
Solanaceae	*Physalis*	*minima*	Shrub	Exotic	Early	Wind	Small
	Solanum	*mauritianum*	Shrub	Exotic	Early	Varied	Small
Solanaceae	*Solanum*	*torvum*	Shrub	Exotic	Early	Varied	Small

Site: Hillcrest Farm Isolated

FAMILY	**Genus**	**Species**	**Life Form**	**Native/ Exotic[1]**	**Successional Stage**	**Dispersal Mechanism**	**Seed Size[2]**
Apiaceae	*Hydrocotle*	*acutiloba*	Herb	Exotic	Early	Wind	Small
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small
	Gnaphalium	*sp.*	Herb	Native	Early	Wind	Small
	Sonchus	*oleraceus*	Herb	Exotic	Early	Wind	Small
Caryophyllaceae	*Drymaria*	*cordata*	Herb	Exotic	Early	Wind	Small

Malvaceae	*Sida*	*rhombifolia*	Herb	Exotic	Early	Wind	Small

Appendix D cont.: Species germination lists for 17 study sites

Site: Hillcrest Farm Isolated cont.

FAMILY	Genus	Species	Life Form	Native/ Exotic[1]	Successional Stage	Dispersal Mechanism	Seed Size[2]
Mimosaceae	*Acacia*	*celsa*	Tree	Native	Early	Animal	Small
Oxalidaceae	*Oxalis*	*corniculata*	Herb	Exotic	Early	Varied	Small
Poaceae	*Oplismenis*	*aemulus*	Grass	Exotic	Early	Varied	Small
Solanaceae	*Physalis*	*minima*	Shrub	Exotic	Early	Wind	Small

Site: Thurling Farm Isolated

FAMILY	Genus	Species	Life Form	Native/ Exotic[1]	Successional Stage	Dispersal Mechanism	Seed Size[2]
Apiaceae	*Hydrocotle*	*acutiloba*	Herb	Exotic	Early	Wind	Small
Asteraceae	*Ageratum*	*conyzoides*	Herb	Exotic	Early	Wind	Small
	Crassocephalum	*crepidioides*	Shrub	Exotic	Early	Wind	Small
Caryophyllaceae	*Drymaria*	*cordata*	Herb	Exotic	Early	Wind	Small
Euphorbiaceae	*Homalanthus*	*novoguineensis*	Tree	Native	Early	Varied	Small
Malvaceae	*Sida*	*rhombifolia*	Herb	Exotic	Early	Wind	Small
Oragraceae	*Lindera*	*queenslandica*	Shrub	Native	Early	Wind	Small
Oxalidaceae	*Oxalis*	*corniculata*	Herb	Exotic	Early	Varied	Small
Rhamnaceae	*Alphitonia*	*petriei*	Tree	Native	Early	Bird	Small
Solanaceae	*Physalis*	*minima*	Shrub	Exotic	Early	Wind	Small
	Solanum	*mauritianum*	Shrub	Exotic	Early	Varied	Small

[1] = Native: Plant species originating from Australia, excluding herbs and grasses   Exotic: Plant species introduced from a country outside of Australia, and also includes herbs and grasses native to Australia
[2] = Small: 0-10 mm Intermediate: 11-20 mm

Appendix E: Spearman's Rank Correlation Coefficient value for Chapter 3 exotic component

		Inter. seed	Small seed	Wind	Varied	Bird	Animal	Cassowary	Vine	Grass	Shrub
Intermediate seed	Correlation Coefficient	1.000	-.662(**)	-.662(**)	-.521(*)	-.080	.121	.275	.536(*)	-.583(*)	-.287
	Sig. (2-tailed)	.	.004	.004	.032	.761	.644	.285	.027	.014	.265
	N	17	17	17	17	17	17	17	17	17	17
Small seed	Correlation Coefficient	-.662(**)	1.000	.998(**)	.583(*)	.023	-.156	-.160	-.525(*)	.549(*)	.168
	Sig. (2-tailed)	.004	.	.000	.014	.929	.551	.540	.030	.023	.519
	N	17	17	17	17	17	17	17	17	17	17
Wind	Correlation Coefficient	-.662(**)	.998(**)	1.000	.561(*)	.034	-.177	-.189	-.502(*)	.537(*)	.154
	Sig. (2-tailed)	.004	.000	.	.019	.896	.497	.469	.040	.026	.554
	N	17	17	17	17	17	17	17	17	17	17
Varied	Correlation Coefficient	-.521(*)	.583(*)	.561(*)	1.000	-.067	-.078	.007	-.218	.543(*)	.524(*)
	Sig. (2-tailed)	.032	.014	.019	.	.798	.767	.979	.402	.024	.031
	N	17	17	17	17	17	17	17	17	17	17
Bird	Correlation Coefficient	-.080	.023	.034	-.067	1.000	-.121	-.092	.073	.118	-.169
	Sig. (2-tailed)	.761	.929	.896	.798	.	.645	.724	.781	.653	.518
	N	17	17	17	17	17	17	17	17	17	17
Animal	Correlation Coefficient	.121	-.156	-.177	-.078	-.121	1.000	-.169	.367	.085	-.144
	Sig. (2-tailed)	.644	.551	.497	.767	.645	.	.516	.147	.744	.582
	N	17	17	17	17	17	17	17	17	17	17
Cassowary	Correlation Coefficient	.275	-.160	-.189	.007	-.092	-.169	1.000	-.161	.026	.327
	Sig. (2-tailed)	.285	.540	.469	.979	.724	.516	.	.537	.921	.200
	N	17	17	17	17	17	17	17	17	17	17
Vine	Correlation Coefficient	.536(*)	-.525(*)	-.502(*)	-.218	.073	.367	-.161	1.000	-.206	-.265
	Sig. (2-tailed)	.027	.030	.040	.402	.781	.147	.537	.	.427	.303

Appendix E cont.: Spearman's Rank Correlation Coefficient values for Chapter 3 exotic component

		Inter. seed	Small seed	Wind	Varied	Bird	Animal	Cassowary	Vine	Grass	Shrub
	N	17	17	17	17	17	17	17	17	17	17
Grass	Correlation Coefficient	-.583(*)	.549(*)	.537(*)	.543(*)	.118	.085	.026	-.206	1.000	.070
	Sig. (2-tailed)	.014	.023	.026	.024	.653	.744	.921	.427	.	.790
	N	17	17	17	17	17	17	17	17	17	17
Herb	Correlation Coefficient	-.688(**)	.929(**)	.931(**)	.535(*)	-.060	-.280	-.131	-.516(*)	.428	.130
	Sig. (2-tailed)	.002	.000	.000	.027	.818	.276	.617	.034	.086	.620
	N	17	17	17	17	17	17	17	17	17	17
Shrub	Correlation Coefficient	-.287	.168	.154	.524(*)	-.169	-.144	.327	-.265	.070	1.000
	Sig. (2-tailed)	.265	.519	.554	.031	.518	.582	.200	.303	.790	.
	N	17	17	17	17	17	17	17	17	17	17
Tree	Correlation Coefficient	-.103	-.183	-.181	.048	.414	-.126	.283	-.125	.241	.081
	Sig. (2-tailed)	.695	.482	.488	.855	.098	.630	.271	.631	.351	.757
	N	17	17	17	17	17	17	17	17	17	17
early_succ	Correlation Coefficient	-.662(**)	1.000(**)	.998(**)	.583(*)	.023	-.156	-.160	-.525(*)	.549(*)	.168
	Sig. (2-tailed)	.004	.	.000	.014	.929	.551	.540	.030	.023	.519
	N	17	17	17	17	17	17	17	17	17	17
inter_succ	Correlation Coefficient	.499(*)	-.523(*)	-.536(*)	-.274	.313	.036	.491(*)	.154	-.138	.082
	Sig. (2-tailed)	.041	.031	.026	.288	.222	.890	.045	.554	.596	.754
	N	17	17	17	17	17	17	17	17	17	17

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Appendix F: Spearman's Rank Correlation Coefficient value for Chapter 4 native recruits

		Animal	Varied	Wind	Cassowary	Bird	Small seed	Int. Seed	Early Succ.	Inter. Succ	Tree	Shrub
Animal	Correlation Coefficient	1.000	.236	-.283	.260	.316	.297	.467	.150	.561(*)	.366	.235
	Sig. (2-tailed)	.	.361	.270	.313	.217	.247	.059	.565	.019	.149	.363
	N	17	17	17	17	17	17	17	17	17	17	17
Varied	Correlation Coefficient	.236	1.000	-.253	-.039	.211	.421	.417	-.035	.734(**)	.591(*)	-.005
	Sig. (2-tailed)	.361	.	.327	.883	.416	.093	.096	.894	.001	.013	.986
	N	17	17	17	17	17	17	17	17	17	17	17
Wind	Correlation Coefficient	-.283	-.253	1.000	.210	-.307	.276	-.222	.603(*)	-.087	-.055	.638(**)
	Sig. (2-tailed)	.270	.327	.	.418	.231	.284	.392	.010	.741	.835	.006
	N	17	17	17	17	17	17	17	17	17	17	17
Cassowary	Correlation Coefficient	.260	-.039	.210	1.000	-.044	.324	.449	.009	.572(*)	.459	.138
	Sig. (2-tailed)	.313	.883	.418	.	.866	.204	.070	.972	.016	.064	.597
	N	17	17	17	17	17	17	17	17	17	17	17
Bird	Correlation Coefficient	.316	.211	-.307	-.044	1.000	-.024	.470	.119	.109	.063	.106
	Sig. (2-tailed)	.217	.416	.231	.866	.	.926	.057	.649	.678	.811	.686
	N	17	17	17	17	17	17	17	17	17	17	17
Small seed	Correlation Coefficient	.297	.421	.276	.324	-.024	1.000	.142	.559(*)	.544(*)	.824(**)	.620(**)
	Sig. (2-tailed)	.247	.093	.284	.204	.926	.	.587	.020	.024	.000	.008
	N	17	17	17	17	17	17	17	17	17	17	17
Int Seed	Correlation Coefficient	.467	.417	-.222	.449	.470	.142	1.000	-.240	.589(*)	.316	-.096
	Sig. (2-tailed)	.059	.096	.392	.070	.057	.587	.	.354	.013	.216	.714
	N	17	17	17	17	17	17	17	17	17	17	17

Appendix F cont.: Spearman's Rank Correlation Coefficient Chapter 4 native recruits

		Animal	Varied	Wind	Cassowary	Bird	Small seed	Int. Seed	Early Succ.	Inter. Succ	Tree	Shrub
Early Succ	Correlation Coefficient	.150	-.035	.603(*)	.009	.119	.559(*)	-.240	1.000	.038	.184	.978(**)
	Sig. (2-tailed)	.565	.894	.010	.972	.649	.020	.354	.	.886	.479	.000
	N	17	17	17	17	17	17	17	17	17	17	17
Inter Succ	Correlation Coefficient	.561(*)	.734(**)	-.087	.572(*)	.109	.544(*)	.589(*)	.038	1.000	.735(**)	.143
	Sig. (2-tailed)	.019	.001	.741	.016	.678	.024	.013	.886	.	.001	.585
	N	17	17	17	17	17	17	17	17	17	17	17
Tree	Correlation Coefficient	.366	.591(*)	-.055	.459	.063	.824(**)	.316	.184	.735(**)	1.000	.249
	Sig. (2-tailed)	.149	.013	.835	.064	.811	.000	.216	.479	.001	.	.335
	N	17	17	17	17	17	17	17	17	17	17	17
Shrub	Correlation Coefficient	.235	-.005	.638(**)	.138	.106	.620(**)	-.096	.978(**)	.143	.249	1.000
	Sig. (2-tailed)	.363	.986	.006	.597	.686	.008	.714	.000	.585	.335	.
	N	17	17	17	17	17	17	17	17	17	17	17

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Appendix G: Chapter 3 statistical analysis: species and life history traits

Species	***Mean rank***	***K-W ANOVA P value***	***U test Remnant and Adjacent***	***U test Remnant and Isolated***	***U test Adj. and Isolated***
Ageratum conyzoides	Rem. =3.50 Adj.=10.83 Iso.=13.40	P = 0.003 χ^2 = 11.705	P = 0.004 U = 0	P = 0.006 U = 0	P = 0.201 U = 8
Axonopus compressus	Rem. =5.67 Adj.=9.67 Iso.=12.20	P = 0.079 χ^2 = 5.075			
Brachiaria decumbens	Rem. =8.00 Adj.=10.83 Iso.=8.00	P = 0.143 χ^2 = 3.896			
Cardamine hirsuta	Rem. =9.50 Adj.=8.25 Iso.=9.30	P = 0.852 χ^2 = 0.322			
Conyza Canadensis	Rem. =6.50 Adj.=10.25 Iso.=10.50	P = 0.173 χ^2 = 3.509			
Crassocephalum crepidioides	Rem. =4.25 Adj.=9.58 Iso.=14.00	P = 0.006 χ^2 = 10.342	P = 0.029 U = 4.5	P = 0.006 U = 0	P = 0.067 U = 5
Cynadon dactylon	Rem. =6.50 Adj.=9.33 Iso.=11.60	P = 0.114 χ^2 = 4.345			
Cyperus rotundus	Rem. =6.58 Adj.=10.33 Iso.=10.30	P = 0.328 χ^2 = 2.230			
Drymaria cordata	Rem. =5.33 Adj.=10.00 Iso=12.20	P = 0.048 χ^2 = 6.071	P = 0.060 U = 7.5	P = 0.060 U = 7.5	P = 0.402 U = 10.5
Fern	Rem.=10.83 Adj.=8.00 Iso.=8.00	P = 0.143 χ^2 = 3.896			
Glycine cyrtoloba	Rem. =8.00 Adj.=9.50 Iso.=9.60	P = 0.559 χ^2 = 1.163			
Gnaphalium sp.	Rem. =7.50 Adj.=9.08 Iso.=10.70	P = 0.289 χ^2 = 2.481			
Grass 3	Rem. =8.50 Adj.=8.50 Iso.=10.20	P = 0.301 χ^2 = 2.4			
Hydrocotle acutiloba	Rem. =7.25 Adj.=9.92 Iso.=10.00	P = 0.562 χ^2 = 1.151			
Ludwigia sp.	Rem. =8.00 Adj.=9.50 Iso.=9.60	P = 0.559 χ^2 = 1.163			
Oplismenis aemulus	Rem. =7.33 Adj.=9.33 Iso.=10.60	P = 0.490 χ^2 = 1.426			
Oxalis corniculata	Rem. =4.83 Adj.=11.08 Iso.=11.50	P = 0.036 χ^2 = 6.641	P = 0.020 U = 4	P = 0.034 U = 4	P = 0.783 U = 13.5

Appendix G cont.: Chapter 3 statistical analysis: species and life history traits

Species	**Mean rank**	**K-W ANOVA *P* value**	***U* test Remnant and Adj.**	***U* test Remnant and Isolated**	***U* test Adj. and Isolated**
Physalis minima	Rem. =6.83 Adj.=6.92 Iso.=14.10	*P* = 0.023 χ^2 = 2.631	*P* = 0.933 *U* = 17.5	*P* = 0.021 *U* = 2.5	***P* = 0.016** *U* = 2
Polyscias murrayi	Rem.=9.33 Adj.=9.50 Iso.=8.00	*P* = 0.639 χ^2 = 0.896			
Richardia brasiliensis	Rem. =8.50 Adj.=8.50 Iso.=10.20	*P* = 0.301 χ^2 = 2.4			
Rubus alcifolius	Rem.=9.75 Adj.=9.92 Iso.=7.00	*P* = 0.365 χ^2 = 2.016			
Sida rhombifolia	Rem.=6.25 Adj.=10.25 Iso.=10.80	*P* = 0.243 χ^2 = 2.827			
Solanum mauritianum	Rem.=5.50 Adj.=11.33 Iso.=10.40	*P* = 0.096 χ^2 = 4.686			
Solanum seaforthianum	Rem. =9.33 Adj.=9.50 Iso.=8.00	*P* = 0.639 χ^2 = 0.896			
Solanum torvum	Rem.=8.00 Adj.=8.00 Iso.=11.40	*P* = 0.078 χ^2 = 5.10			
Sonchus oleraceus	Rem.=8.33 Adj.=10.00 Iso.=8.60	*P* = 0.713 χ^2 = 0.676			
Tridax procumbens	Rem.=8.00 Adj.=9.33 Iso.=9.80	*P* = 0.540 χ^2 = 1.233			
Triumfetta rhomboidea	Rem.=8.50 Adj.=8.50 Iso.=10.20	*P* = 0.301 χ^2 = 2.400			
Urena lobata	Rem.=8.50 Adj.=9.92 Iso.=8.50	*P* = 0.400 χ^2 = 1.833			
Wahlenbergia sp.	Rem.=8.83 Adj.=10.42 Iso.=7.50	*P* = 0.353 χ^2 = 2.085			
Wikstroemia indica	Rem. =8.50 Adj.=9.92 Iso.=8.50	*P* = 0.400 χ^2 = 1.833			
Number of seeds	Rem. =3.50 Adj.=12.00 Iso.=12.00	*P* = 0.004 χ^2 = 11.129	*P* = 0.004 *U* = 0	*P* = 0.006 *U* = 0	*P* = 1.000 *U* = 15
Number of species	Rem.=6.00 Adj.=10.08 Iso.=11.30	*P* = 0.175 χ^2 = 3.491			
Exotic seed	Rem. =3.50 Adj.=11.67 Iso.=12.40	*P* = 0.004 χ^2 = 11.014	*P* = 0.006 *U* = 0	*P* = 0.004 *U* = 0	*P* = 0.855 *U* = 14

Appendix G cont.: Chapter 3 statistical analysis: species and life history traits

Species	**Mean rank**	**K-W ANOVA *P* value**	***U* test Remnant and Adj.**	***U* test Remnant and Isolated**	***U* test Adj. and Isolated**
Small sized seeds	Rem. =3.50 Adj.=12.00 Iso.=12.00	P = 0.004 χ^2 = 11.000	P = 0.004 U = 0	P = 0.006 U = 0	P = 1.000 U = 15
Animal dispersal	Rem.=10.25 Adj.=11.42 Iso.=4.60	P = 0.057 χ^2 = 5.720			
Flight dispersal	Rem. =8.08 Adj.=11.25 Iso.=7.40	P = 0.386 χ^2 = 1.905			
Cassowary dispersal	Rem. =9.67 Adj.=9.33 Iso.=7.80	P = 0.728 χ^2 = 0.636			
Varied dispersal	Rem. =3.58 Adj.=12.25 Iso.=11.60	P = 0.003 χ^2 = 11.313	P = 0.004 U = 0	P = 0.006 U = 0	P = 0.460 U = 7
Wind dispersal	Rem. =3.50 Adj.=11.83 Iso.=12.20	P = 0.004 χ^2 = 11.014	P = 0.004 U = 0	P = 0.006 U = 0	P = 0.855 U = 14
Early successional seeds	Rem. =3.50 Adj.=12.00 Iso.=12.00	P = 0.004 χ^2 = 11.000	P = 0.004 U = 0	P = 0.006 U = 0	P = 1.000 U = 14
Fern	Rem.=10.83 Adj.=8.00 Iso.=8.00	P = 0.143 χ^2 = 3.896			
Grass	Rem. =4.42 Adj.=11.83 Iso.=11.10	P = 0.021 χ^2 = 7.725	P = 0.045 U = 5.5	P = 0.006 U = 0	P = 0.410 U = 10.5
Herb	Rem. =3.50 Adj.=11.33 Iso.=12.80	P = 0.004 χ^2 = 12.210	P = 0.004 U = 0	P = 0.006 U = 0	P = 0.465 U = 11
Shrub	Rem. =7.33 Adj.=11.08 Iso.=8.50	P = 0.417 χ^2 = 1.750			
Tree	Rem. =8.75 Adj.=8.67 Iso.=9.70	P = 0.934 χ^2 = 0.138			
Vine	Rem.=10.58 Adj.=5.25 Iso.=6.00	P = 0.491 χ^2 = 7.352	P = 0.013 U = 3.5	P = 0.022 U = 3.5	P = 1.000 U = 15

Appendix H: Chapter 4 statistical analysis: species and life history traits

Variable	*Mean Rank*	*K-W ANOVA* **P** *value*	**U**-*test Remnant and Adjacent*	**U**-*test Remnant and Isolated*	**U**-*test Adjacent and Isolated*
Number of species	Rem. =13.42 Adj.=6.92 Iso.=6.20	$P = 0.019$ $\chi^2 = 7.934$	$P = 0.011$ $U = 2.5$	$P = 0.026$ $U = 3$	$P = 0.700$ $U = 13$
Total recruited seeds	Rem. =3.67 Adj.=13.50 Iso. =10.00	$P = 0.890$ $\chi^2 = 0.233$			
Early successional seeds	Rem. =9.08 Adj.= 10.25 Iso.= 7.40	$P = 0.638$ $\chi^2 = 0.899$			
Intermediate successional seeds	Rem. = 12.17 Adj. = 9.50 Iso. = 4.60	$P = 0.042$ $\chi^2 = 6.347$	$P = 0.293$ $U = 11.5$	$P = 0.021$ $U = 2.5$	$P = 0.077$ $U = 5.5$
Shrub	Rem. = 9.58 Adj. = 10.00 Iso. = 7.10	$P = 0.590$ $\chi^2 = 1.054$			
Tree	Rem. = 11.42 Adj. = 7.42 Iso. = 8.00	$P = 0.337$ $\chi^2 = 2.176$			
Flight dispersal	Rem. = 12.42 Adj. = 6.50 Iso. = 7.90	$P = 0.032$ $\chi^2 = 6.884$	$P = 0.022$ $U = 6$	$P = 0.089$ $U = 6.5$	$P = 0.273$ $U = 7.5$
Animal dispersal	Rem. = 13.83 Adj.= 7.92 Iso.= 4.50	$P = 0.004$ $\chi^2 = 10.936$	$P = 0.023$ $U = 4$	$P = 0.004$ $U = 0$	$P = 0.080$ $U = 7.5$
Cassowary dispersal	Rem. = 9.67 Adj.= 9.33 Iso.= 7.80	$P = 0.728$ $\chi^2 = 0.636$			
Varied dispersal	Rem. =11.58 Adj.=8.33 Iso.=6.70	$P = 0.219$ $\chi^2 = 3.036$			
Wind dispersal	Rem. = 5.92 Adj. = 12.08 Iso. = 9.00	$P = 0.072$ $\chi^2 = 5.253$			
Small sized seeds	Rem. = 10.06 Adj. = 8.17 Iso. = 8.70	$P = 0.795$ $\chi^2 = 0.459$			
Acacia celsa	Rem. =9.92 Adj.=8.50 Iso.=8.50	$P = 0.400$ $\chi^2 = 1.833$			
Alpinia caerulea	Rem. =9.92 Adj.=8.50 Iso.=8.50	$P = 0.400$ $\chi^2 =1.833$			
Aristolochia sp.	Rem. =9.92 Adj.=8.50 Iso.=8.50	$P = 0.400$ $\chi^2 = 1.833$			
Dendrocnide photinophylla	Rem. =12.67 Adj.=7.00 Iso.=7.00	$P = 0.012$ $\chi^2 =8.846$	$P = 0.022$ $U = 6$	$P = 0.034$ $U = 5$	$P = 1.000$ $U = 15$
Dendrocnide moroides	Rem. =11.50 Adj.=9.42 Adj.=5.50	$P = 0.083$ $\chi^2 = 4.990$			

Appendix H cont.: Chapter 4 statistical analysis: species and life history traits

Variable	Mean Rank	*K-W* ANOVA P value	U-test Remnant and Adjacent	U-test Remnant and Isolated	U-test Adjacent and Isolated
Elaeagnus triflora	Rem. =9.92 Adj.=8.50 Iso.=8.50	P = 0.400 χ^2 = 1.833			
Euroschinus falcata	Rem. =9.92 Adj.=8.50 Iso.=8.50	P = 0.400 χ^2 = 1.833			
Ficus congesta	Rem. =9.58 Adj.=9.42 Iso.=7.80	P = 0.733 χ^2 = 0.622			
Ficus copiosa	Rem. =9.92 Adj.=8.50 Iso.=8.50	P = 0.400 χ^2 = 1.833			
Ficus fraserii	Rem. =9.42 Adj.=9.42 Iso.=8.00	P = 0.641 χ^2 = 0.889			
Ficus sp.	Rem. =9.92 Adj.=8.50 Iso.=8.50	P = 0.400 χ^2 = 1.833			
Homalanthus novoguineensis	Rem. =9.75 Adj.=9.50 Iso.=7.50	P = 0.672 χ^2 = 0.796			
Hymenosporum flavum	Rem. =9.92 Adj.=8.50 Iso.=8.50	P = 0.400 χ^2 = 1.833			
Lindera queenslandica	Rem. =8.33 Adj.=7.00 Iso.=12.20	P = 0.064 χ^2 = 5.513			
Melia azedarach	Rem. =11.75 Adj.=7.50 Iso.=7.50	P = 0.045 χ^2 = 6.216	P = 0.059 U = 9	P = 0.082 U = 7.5	P = 1.000 U =15
Melicope elleryana	Rem. =9.92 Adj.=8.50 Iso.=8.50	P = 0.400 χ^2 = 1.833			
Rhodamnia sessiflora	Rem. =10.83 Adj.=8.00 Iso.=8.00	P = 0.141 χ^2 = 3.911			
Rhodomyrtus pervagata	Rem. =9.42 Adj.=9.42 Iso.=8.00	P = 0.641 χ^2 = 0.899			
Rubus moluccans	Rem. =9.50 Adj.=8.00 Iso.=9.60	P = 0.559 χ^2 = 1.163			
Solanum dallachii	Rem. =9.92 Adj.=8.50 Iso.=8.50	P = 0.400 χ^2 = 1.833			

Appendix I: Statistical analysis comparing germination of 0 - 3 months and 4 - 7 months

Variable	*Remnant forest sites 0-3, 4-7*	*Adj. 0-3, 4-7*	*Iso. 0-3, 4-7*
Number of germinants	$P = 0.021$ $U = 0$	$P = 0.564$ $U = 6$	$P = 0.127$ $U = 1$
Native germinants	$P = 0.021$ $U = 0$	$P = 0.248$ $U = 4$	$P = 0.050$ $U = 0$
Exotic germinants	$P = 0.146$ $U = 3$	$P = 0.021$ $U = 0$	$P = 0.050$ $U = 0$
Small sized seeds	$P = 0.021$ $U = 0$	$P = 0.149$ $U = 3$	$P = 0.127$ $U = 1$
Intermediate sized seeds	$P = 0.405$ $U = 5.5$	$P = 1.000$ $U = 8$	$P = 1.000$ $U = 4.5$
Early successional seeds	$P = 0.020$ $U = 0$	$P = 0.386$ $U = 5$	$P = 0.275$ $U = 2$
Intermediate successional seeds	$P = 0.180$ $U = 3.5$	$P = 0.468$ $U = 5.5$	$P = 0.275$ $U = 2$
Animal dispersal	$P = 0.309$ $U = 4.5$	$P = 1.000$ $U = 8$	$P = 0.068$ $U = 0.5$
Wind dispersal	$P = 0.021$ $U = 0$	$P = 1.000$ $U = 8$	$P = 0.275$ $U = 2$
Varied dispersal	$P = 0.020$ $U = 0$	$P = 0.083$ $U = 2$	$P = 0.275$ $U = 2$
Flight dispersal	$P = 0.018$ $U = 0$	$P = 0.038$ $U = 1$	$P = 0.513$ $U = 3$
Cassowary dispersal	$P = 0.047$ $U = 2$	$P = 0.014$ $U = 0$	$P = 0.121$ $U = 1.5$
Fern	$P = 0.018$ $U = 0$	$P = 0.047$ $U = 2$	$P = 0.037$ $U = 0$
Vine	$P = 0.752$ $U = 7$	$P = 0.850$ $U = 7.5$	$P = 1.000$ $U = 4.5$
Grass	$P = 0.881$ $U = 7.5$	$P = 0.468$ $U = 5.5$	$P = 0.127$ $U = 1$
Shrub	$P = 0.180$ $U = 3.5$	$P = 0.773$ $U = 7$	$P = 0.127$ $U = 1$
Herb	$P = 0.191$ $U = 3.5$	$P = 0.083$ $U = 2$	$P = 0.050$ $U = 0$
Tree	$P = 0.386$ $U = 5$	$P = 0.885$ $U = 7.5$	$P = 0.827$ $U = 4$
Number of species	$P = 0.766$ $U = 7$	$P = 0.020$ $U = 0$	$P = 0.127$ $U = 1$