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.