Converting stands of camphor laurel to rainforest

What are the costs and outcomes of different control methods?

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Regrowth dominated by the exotic tree camphor laurel (*Cinnamomum camphora*) covers large areas of former rainforest land in subtropical Australia

Rainforest plants regenerating under dead camphor laurels, eight years after the camphor trees were killed, Rocky Creek Dam, northern New South Wales, Australia

Summary

Subtropical rainforests in Australia have been extensively cleared for agriculture, with adverse impacts on biodiversity. Over the past few decades, large areas of this agricultural land have been colonised by the exotic tree camphor laurel (*Cinnamomum camphora*: Lauraceae). While camphor laurel does provide habitat for a range of rainforest plants and animals, in many circumstances it may be desirable to replace stands of camphor laurel with rainforest, using one of the following methods:

1. **Clear and replant** with rainforest trees (a proven method, but expensive, and unsuitable for some sites).
2. **Do nothing** and wait for camphor to be replaced by rainforest trees, dispersed to camphor stands by birds and bats attracted to eat the abundant camphor fruit crop (a cheap method, but one that may not be effective. Furthermore, control of camphor laurel is a legal requirement in some shires).
3. **'Camphor conversion'**: i.e., strategically kill camphors to promote the growth and regeneration of rainforest plants that have recruited to camphor stands, or that are present in the soil seed bank. This is a relatively new approach, trialled at a limited number of sites over the last decade. It takes advantage of the presence of rainforest plants in camphor stands, is often cheaper than replanting, and can be used on steep or riparian sites where camphor removal is not a feasible option.

This document summarises the costs and outcomes of the two main methods of camphor conversion: 'staged' and 'patch' removal, using information obtained from practitioners and from surveys of treated sites.

Staged removal involves progressively killing a proportion of mature camphor trees in a stand (e.g., 30% at a time), with months to years between stages.

Patch removal involves killing all mature camphor trees in patches, 0.5 – 1 ha in size, at one time.

Both methods also require the control of understorey weeds, initially at the time that camphor trees are killed and then for the following 1 - 5 years, depending on the amount of regeneration of rainforest plants.

Advantages and disadvantages of the two camphor conversion methods. Proponents of **staged remova**l say it maintains a shaded, structurally complex habitat during treatment, minimises the risk that sites will revert to weeds if work is interrupted, and reduces the risk of erosion on steep sites. However, staged removal can be relatively slow. It may take years to kill all the mature camphors in a stand, during which time rainforest plants face competition from retained camphors. The shaded conditions maintained by this method may also not strongly stimulate the recruitment of rainforest pioneers from the seed bank.

Proponents of the **patch removal** method say it promotes the vigorous regeneration of rainforest pioneers from the seed bank, stimulates the growth of existing rainforest plants by removing competition from all camphor trees, and has the potential to be used as a rapid, large-scale conversion method. However, patch removal requires intensive follow-up weed control, and can create a structurally-simple "bare" habitat for one or more years after treatment, particularly at sites where the regeneration of rainforest plants is limited.

Costs of treatment are similar for both removal methods. 'Average' costs in 2007 were around AUD$10K per ha, but vary considerably (from $5 – 30K/ ha) with the abundance of weeds at a site. About 80% of the costs are labour. Most costs are incurred during primary treatment (killing mature camphors and understorey weeds); these costs are spread over a longer period in staged than in patch removal. Follow-up weed control may comprise 20 – 40% of total costs, with higher costs on sites with poor regeneration of rainforest plants.

Comparison of the outcomes of staged and patch removal. Surveys of 19 treated camphor sites showed that both removal methods can convert stands of camphor laurel to regenerating rainforest. Staged removal tends to maintain a more rainforest-like structure during the first few years of treatment. However, after about 4 – 6 years, both staged and patch removal methods produce similar outcomes in terms of vegetation structure and the number of rainforest tree species regenerating at treated sites. The success of removal methods in promoting rainforest regeneration is likely to be influenced by the proximity of treated sites to remnant rainforest, the age of camphor stands, weather conditions during treatment, and wallaby browsing.

What is the best removal method? As the costs and outcomes of the two removal methods appear similar, the choice of method for a particular site may depend primarily on logistical issues such as the availability of resources for follow-up weed control. Patch removal may suit large or small-scale restoration projects with guaranteed resources for follow-up weed control. Staged removal may suit small-scale projects with limited or irregular labour supply (e.g., 'backyard' projects), as well as projects where there is a desire to maintain shaded conditions and/ or a more forest-like structure during the initial stages of treatment.

Caveats: The information presented in this document is based on surveys of treated sites in the 'Big Scrub' region of northern New South Wales, Australia. The outcomes of camphor conversion projects may be different in other regions and ecological situations. A rigorous comparison of the two removal methods will require standardised experimental trials and subsequent long-term monitoring of outcomes.

Contents

Young camphor laurel trees growing in abandoned pasture. Over time, these trees will form a patch of regrowth forest, with a dense canopy that shades out grasses and creates conditions more suitable for the recruitment of rainforest plants.

Native rainforest plants growing under mature camphor laurel trees. Rainforest plants and fleshy-fruited weeds are dispersed to camphor stands by birds and bats that eat the abundant and reliable camphor fruit crop.

Introduction: rainforest loss and restoration

The subtropical rainforests of Australia have exceptional biodiversity values. Over the past 150 years, subtropical rainforests have been extensively cleared for agriculture, reducing populations of rainforest plants and animals, causing local extinctions and altering ecological processes in remnant forests.[1, 3]

Subtropical rainforest, Australia

In recent decades, community concern has led to the conservation of remaining subtropical rainforests, and attempts to restore rainforest to areas of cleared land.[1, 4, 6] However, rainforest restoration is expensive, and only small areas of land have been replanted with rainforest trees.[2, 3.]

At the same time, changes in land use have led to the development of extensive stands of regrowth on marginal farmland. In former rainforest landscapes in subtropical Australia, this regrowth is often dominated by the exotic tree camphor laurel (*Cinnamomum camphora*).[10, 11]

Although camphor laurel stands can provide habitat for some rainforest plants and animals [9, 10], it is generally desirable to replace stands of camphor laurel with rainforest, particularly where the intention is to manage the land for conservation purposes (e.g., on steep slopes, in wildlife corridors, along creeks, or near remnants).

Replacing camphor with rainforest

There are three main options for replacing camphor stands with rainforest (Table 1):[9, 10, 11]

1. clear and replant with rainforest trees;

2. do nothing, and wait for rainforest plants to eventually dominate the site (most stands of camphor laurel also support some rainforest plants, dispersed by birds and bats which eat the fruit of camphor laurel) [9, 10]; and

3. 'camphor conversion': strategically kill camphor laurels and other weeds to promote the growth of rainforest plants that have recruited to camphor stands. At present, most conversion projects target mature (20 - 30 yr old) camphors.

Table 1. Replacing stands of camphor laurel with rainforest

Option	Costs*	Advantages	Disadvantages
1. Clear and replant with rainforest trees	$30 - 50K/ ha for site preparation, planting and maintenance. Costs vary with planting density and species used. Clearing costs are additional.	Proven method that can rapidly (3 – 5 years) establish a young rainforest stand given appropriate species selection, site preparation and maintenance.	Expensive. May not utilise existing regeneration under camphors. Mechanised clearing may be inappropriate on steep slopes, in riparian areas or if regeneration under camphor includes rare and threatened species.
2. Do nothing	Nothing.	Cheap. A diverse range of rainforest plants occur in many mature camphor stands, dispersed by birds and bats.[8]	It is not known if rainforest will naturally replace camphor stands, but if so, that may take hundreds of years. Camphor control is also a legal requirement in some shires.
3. 'Camphor conversion': kill camphor trees and other weeds, to promote the regeneration and growth of rainforest plants	$5 - 30K/ ha, depending on the types and abundance of weeds at a site. Involves primary treatment (killing camphors and other weeds), plus follow-up weed control and maintenance.	Likely to be cheaper than planting in many sites, provided there is sufficient natural regeneration following treatment. Takes advantage of existing regeneration, which may be of high conservation value, and can be used on steep or riparian sites.	A relatively recent approach, so far trialled on a limited number of sites. May not be suited to young camphor stands, or to sites distant from remnant forest, without supplementary planting. There is a risk of failure if maintenance is not sufficiently resourced over a long-enough period, or if natural regeneration is limited at a site.

* $AUD in 2007. Costs are indicative only, and will vary between sites and practitioners.

Camphor conversion methods

Two main methods of 'camphor conversion' are currently practiced: staged and patch removal (Table 2).[7, 12] In staged removal, camphor trees are progressively killed at a site (e.g., 30% of trees at a time), with months to years between stages. In patch removal, all camphor trees are killed at once, in 0.5 – 1 ha patches. Both methods require the intensive control of understorey weeds during primary treatment and in the following years (the duration of follow-up treatment may vary from 1 – 5 years, depending on the removal method and the amount of regeneration at a site), and then maintenance weed control in subsequent years. Both approaches use herbicide to kill camphors and other weeds, often using methods developed through trial and error by practitioners. Details of various control methods are given in the references.[1, 7, 11, 12]

Table 2. Overview of the 'staged' and 'patch' camphor removal methods

Description	Staged removal	Patch removal
Overview of approach	Mature camphor trees are progressively killed at a site, with months to years between stages. Camphors with good regeneration of rainforest plants are targetted first for control. Understorey weeds are killed in first stage of treatment. Follow-up weed control may require 2 - 3 sprays in the first year after treatment, then 1 - 2 sprays/ year until a rainforest canopy is established. Subsequently, treated areas only require maintenance weed control.	All mature camphor trees and understorey weeds are killed in patches (typically, 0.5 – 1 ha in size) in a single season. Intensive follow-up weed control is required in first year (4 or 5 repeat sprays). On sites with a good regeneration of rainforest plants, only maintenance weed control may be required in following years; otherwise, treated sites may require 2 - 3 repeat sprays/ year for 3 - 5 years, until a rainforest canopy is established.
Response of rainforest plants to treatment	Rainforest pioneers and weeds recruit under killed camphors from the soil seed bank. Rainforest trees already present in the stand may respond to reduced competition from mature camphors, particularly in the later stages of treatment. After several years, the regenerating rainforest trees may form a closed canopy. Late successional rainforest trees become more prominent in the regrowth over time.	Rainforest pioneers and weeds recruit in large numbers from the soil seed bank. Existing late successional rainforest trees usually persist at the treated site, except perhaps in very hot/ dry conditions, but are overtopped by fast-growing pioneers. A closed canopy may form within 1 - 2 years on sites with good regeneration, or 3 - 5 years where regeneration is sparse. Late successional rainforest trees become more prominent in the regrowth over time.
Potential advantages, according to proponents	Maintains shaded and structurally complex 'rainforest-like' habitat during treatment. Follow-up treatment is less intensive than required in patch removal. Treated sites will not completely revert to weed-dominated regrowth if work is interrupted before completion. May reduce the risk of erosion from killing all camphor trees on steep or riparian sites.	Promotes the vigorous regeneration of rainforest pioneers from the seed bank. Stimulates the growth of mature phase species by removing competition from camphor trees for light, nutrients and water. Is potentially a rapid, large-scale conversion method, if sufficient resources are available for follow-up treatment.
Potential disadvanages	Treatment may be relatively slow, because: (i) it can takes years to complete primary weed control; and (ii) the early stages of treatment may not strongly stimulate the recruitment of rainforest pioneers from the seed bank, or release rainforest plants from competition. The effort required to control camphor seedlings may be high for several years due to seed dropped by retained camphors.	Can create a structurally-simple and "bare" habitat for several years on treated sites. May require substantial follow-up weed control and/ or enrichment planting if the regeneration of rainforest plants is limited by site or environmental conditions. Treated sites could revert to weed-dominated regrowth if work is interrupted after primary treatment. Regeneration may favour wallaby browsing.
Examples of projects using method	Projects seeking to maintain shaded and complex habitat and/ or to minimise erosion during treatment *(see Case studies 3 & 4)*	Large-scale restoration projects with sufficient resources a for intensive follow-up weed control *(see Case studies 1 & 2)*

Staged removal of camphor laurel, one year after commencement of treatment, near Alstonville, northern NSW. This method involves progressively killing mature camphor trees over a period of months to years, along with all understorey weeds, to promote the growth of rainforest plants. In this example, one third of mature camphor trees at the site have been poisoned in the initial stage of treatment.

Patch removal of camphor laurel, three years after treatment, near Fernleigh, northern NSW. This method involves killing all camphor trees in patches at one time, along with all understorey weeds, to promote the growth of rainforest plants. In this example, the treated patch is around 0.5 ha in size.

Costs of camphor conversion

1. Camphor conversion involves the following activities:

   (i) primary treatment (killing mature camphors and understorey weeds);

   (ii) intensive follow-up weed control until canopy closure; and

   (iii) subsequent maintenance weed control.

2. 'Average' costs of conversion are around $10K per ha in 2007 (but range from $5 – 30K per ha, according to the abundance and types of weeds at a site). Costs are similar for both removal methods. Most costs (around 80%) are labour; other costs are herbicide and use of equipment.

3. The main costs of camphor conversion are associated with primary treatment. On sites with a dense weedy understorey, around two-thirds of the costs of primary treatment may be from killing understorey weeds, and the remainder from killing mature camphors. These costs do not vary between removal methods, and in both cases are mostly incurred in the first year. However, there is a greater spread of costs over the first few years of treatment in staged than patch removal.

Practitioner Tim Roberts surveys his handiwork: a patch of camphor laurel treated six months previously

4. Follow-up weed control can comprise around 20 - 40% of the costs of camphor conversion. The effort required for follow-up weed control is highest on sites where the regeneration of rainforest plants is sparse and weeds are abundant. The total costs of camphor conversion on these sites may be 20% higher than on sites with a good regeneration of rainforest plants.

5. Maintenance weed control is required at least annually for several years after canopy closure, and less frequently thereafter, depending on the abundance and types of weeds at a site.

Table 3. Indicative work schedule and costs for converting camphor stands to rainforest.*

Year	Staged removal	Patch removal
1	• Kill 30% of mature camphors • Kill all understorey weeds • Follow-up weed control: 2 – 3 sprays** **Cost year 1 = $5350 - $5600**	• Kill all mature camphors • Kill all understorey weeds • Follow-up weed control: 4 – 5 sprays** **Cost year 1 = $7500 - $7750**
2	• Kill 50% remaining mature camphors • Follow-up weed control: 1 – 3 sprays** **Cost year 2 = $1100 - $1600**	• Follow-up weed control: 1 – 3 sprays** **Cost year 2 = $250 - $750**
3	• Kill all remaining mature camphors • Follow-up weed control: 1 – 3 sprays** **Cost year 3 = $1100 - $1600**	• Follow-up weed control: 1 – 3 sprays** **Cost year 3 = $250 - $750**
4	• Follow-up weed control: 1 – 2 sprays** **Cost year 4 = $250 - $500**	• Follow-up weed control: 1 – 3 sprays** **Cost year 3 = $250 - $750**
5	• Maintenance weed control: 1 spray **Cost year 5 = $250**	• Maintenance weed control: 1 spray **Cost year 5 = $250**
1 - 5	**Total cost = $8050 - $9550**	**Total cost = $8500 - $10250**

* Costs per ha, $AUD in 2007, derived from interviews with practitioners and landholders. Costs are indicative only, and may vary by a factor of 2 - 3 between sites, depending on the type and abundance of weeds.

** The amount of follow-up weed control required depends on the regeneration of rainforest plants and weeds at a site.

Outcomes of camphor conversion

To compare the ecological outcomes of the different camphor conversion methods, surveys were conducted at 19 treated camphor stands. Eight stands were treated by staged removal, and 11 by patch removal. Sites were located on 10 different properties in the 'Big Scrub' region of northern NSW. Surveys were conducted in 2007.

All sites originally supported subtropical rainforest, and 20 – 40 year old regrowth dominated by camphor laurel at the time of treatment. Some of the properties were located close to remnant rainforest, while others were more isolated, but this did not differ systematically between the two removal methods. Proximity to remnant rainforest is important because it may influence the dispersal of rainforest plants and hence the amount of regeneration at treated sites.[3, 8, 9, 10]

To evaluate outcomes on treated sites, surveys were also conducted in six untreated stands of camphor laurel and six sites in remnant rainforest. These sites were also located in the Big Scrub region and surveyed between 2003 and 2007.

Methodology

At each site, vegetation structure and tree species composition were surveyed on one to two 50 x 10 m transects, using published protocols.[5] Results were standardised by survey effort. Vegetation structure included attributes such as canopy cover and height, the density of woody stems, woody debris, ground cover and special life forms (vines, epiphytes, etc). These structural attributes are known to be associated with the use of reforested sites by rainforest wildlife.[3, 5]

To compare the outcomes of the two removal methods, trends in floristic and structural attributes were plotted against time since treatment. The comparison focussed on broad trends in the results, as outcomes for particular sites will reflect site- and time-specific factors such as distance to remnant forest, weather conditions during treatment, or wallaby browsing.

Results

1. Vegetation structure

In many respects, the vegetation structure of camphor laurel regrowth is remarkably similar to subtropical rainforest (Figure 1). Killing camphor laurels and understorey weeds dramatically simpifies the vegetation structure of regrowth sites in the first few years after treatment, particularly on patch removal sites. However, after 4 – 6 years, most structural attributes appear to be developing on a trajectory towards rainforest conditions. This trajectory is similar for sites treated with staged and patch removal methods.

Values of canopy cover, tree basal area and overall site structural condition at treated sites were still below the condition of rainforest 10 – 12 years after treatment. In contrast, treated sites had a much higher basal area of stags (dead trees) than rainforest, and exceeded rainforest conditions in stem density and volume of woody debris withing a few years of treatment. Competition between regenerating rainforest trees and the collapse of dead camphors cause stem density and stag basal area to return towards rainforest conditions by 10 - 12 years after treatment, but the volume of woody debris was still increasing on treated sites 10 – 12 years after treatment.

2. Floristic composition

Camphor laurel regrowth has a relatively impoverished floristic composition compared with subtropical rainforest (Figure 2). Killing camphor laurels and understorey weeds has a positive impact on the number of rainforest tree species at treated sites, starting shortly after treatment, and the number of species continues to increase towards rainforest conditions over time. This trajectory is broadly similar for sites treated with staged and patch removal methods, whether all tree species or just late successional species (characteristic of intact rainforest) are considered.

Treated sites tend to be dominated by early successional species, when compared with rainforest. Early successional species are especially prominent in patch removal sites 5 - 9 years after treatment, but by 10 – 12 years, numbers of these species have declined towards rainforest conditions. The number of late successional species on patch removal sites increases progressively after formation of a closed canopy (around 4 - 6 years after treatment).

In terms of overall tree species composition, treated sites increase in similarity to rainforest shortly after treatment, due to the removal of exotic plants and the recruitment of pioneers. Patch removal sites may then decline in similarity to rainforest for a few years, perhaps due to the abundant recruitment of pioneers, but after 4 – 6 years, patch removal sites again increase in similarity to rainforest. After this time, both staged and patch removal sites appear to follow a similar trajectory towards rainforest conditions. Ten to 12 years after treatment, treated sites are moderately similar in tree species composition to rainforest reference sites.

From what is known of rainforest dynamics, treated sites may take many decades to approach intact rainforest in species composition. Over this time, pioneer species will senesce and additional later successional trees recruit to treated sites. It is possible that certain species (e.g., those with large seeds, or dispersed by wind) may need to be planted at treated sites isolated from remnant forest, because they may not be readily dispersed to isolated sites by natural processes.[8]

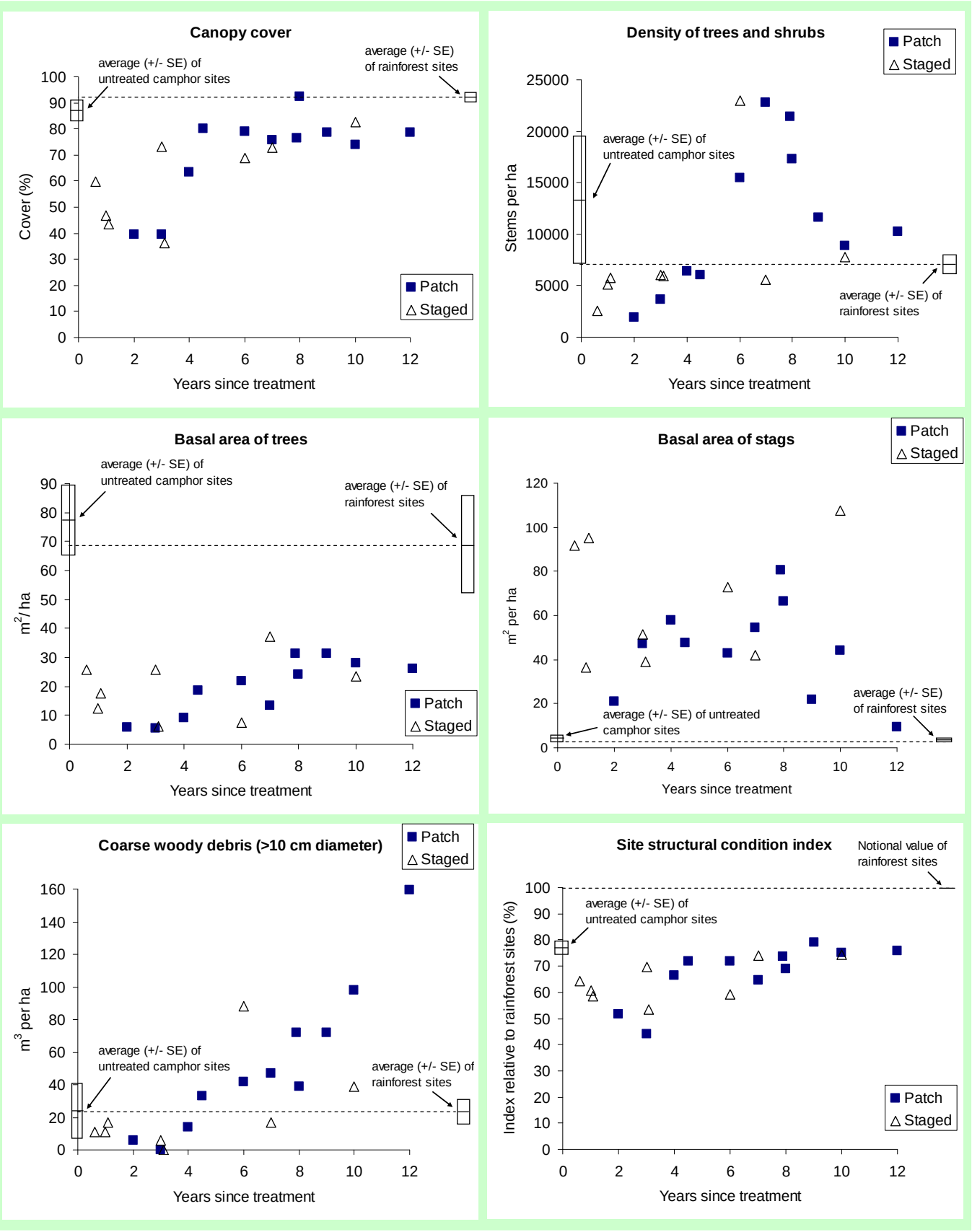


Figure 1. Vegetation structure of treated camphor sites, plotted against years since treatment. Patch removal = squares, staged removal = triangles. 'Basal area' is the combined cross-sectional area of woody stems (stags = dead trees). 'Site structural condition index' is a measure of the average value of selected structural attributes (canopy cover, canopy height, stem density, stem diversity, tree basal area, stag basal area, woody debris, and indices of ground cover, special life forms and forest structure) in treated sites relative to mean values in rainforest reference sites.[5] Data are from one or two 50 x 10 m transects per site.

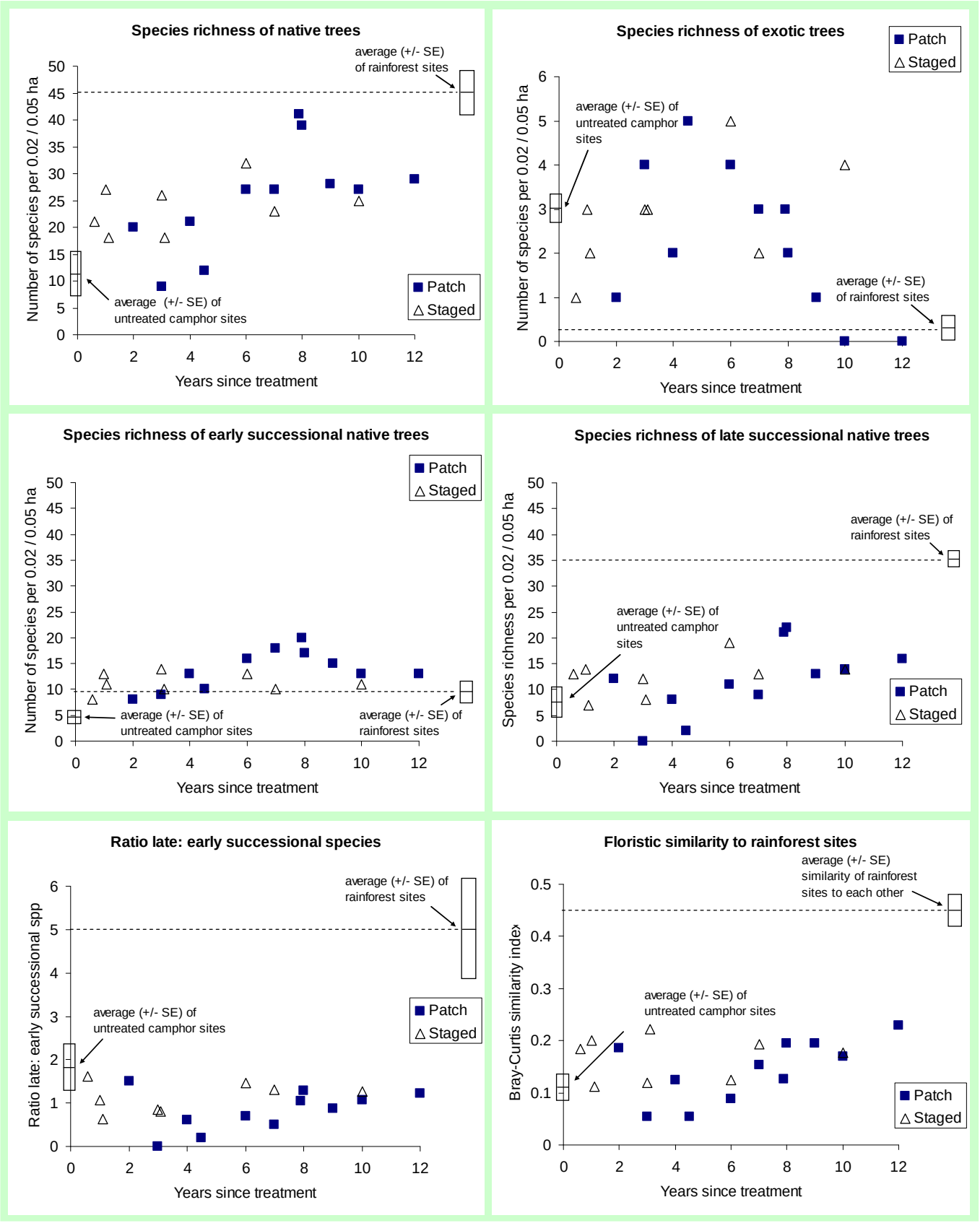


Figure 2. Floristic composition of treated camphor sites, plotted against years since treatment. Patch removal = squares, staged removal = triangles. Species are categorised by successional stage as per Kooyman (1996) [6]: early successional = pioneer and early secondary; late successional = late secondary and mature phase. Floristic similarity is based on the average Bray-Curtis similarity of a site to rainforest reference sites. 'Species richness' = number of species. Data are from surveys of trees and shrubs on a 50 x 4 m transect (for stems >0.5 m high, <10 cm dbh) or 50 x 10 m transect (for stems >10 cm dbh) per site.

Case studies

The four case studies presented in the following pages provide additional information on the camphor conversion projects which were surveyed for this study.

Case study 1: Rocky Creek dam

Attributes of site: A former grazing property, acquired for construction of Rocky Creek dam in the 1950s, then colonised by camphor laurel, privet, lantana and rainforest regrowth. About 30 ha of the site have been subject to systematic restoration since the late 1980s. The property is favourably located for the dispersal of rainforest plants, as it is adjacent to the extensive forests of the Nightcap Range.

Camphor conversion approach used on site: Patch removal

Practitioner: Ralph Woodford

Details of approach: Primary treatment involved the spraying of all understorey weeds in winter, followed by the poisoning of mature camphor trees, in patches of 0.5 – 1 ha, in spring. In the first summer following treatment, 4 – 5 follow-up sprays of the germinating weed seedbank were required. One year after treatment, the regenerating rainforest pioneer species had formed a closed canopy, and only maintenance weed control was required in subsequent years.

Treated camphor sites surveyed for this study: Five sites, aged 7 – 12 years since treatment.

Comments: The patch removal method has been very successful in restoring rainforest cover to this site. The diversity of regenerating rainforest plants reflects the proximity of the site to remnant rainforests. Since about 1997, the site has been subject to high levels of herbivory from wallabies, which appear to have reduced the abundance and diversity of regeneration in subsequent years of treatment.

More information: Woodford, R. 2000. Converting a dairy farm back to rainforest: the Rocky Creek Dam Story. *Ecological Management and Restoration* 1: 83–92.

Former camphor laurel regrowth at Rocky Creek Dam, treated by the patch removal method. The patch on the left was treated seven years ago, and still has a relatively simple structure. The patch on the right was treated 12 years ago, and is more complex, with a good representation of late successional rainforest trees. Both patches are only a few hundred metres from the largest remnant of the former Big Scrub rainforest.

Case study 2: Tongmar and Nash properties, Fernleigh

Attributes of sites: Former grazing properties colonised by camphor laurel, privet and some early successional rainforest species over the past 20 - 30 years. Both sites are in an extensively cleared section of the 'Big Scrub' region. Land-cover types around the properties include grazing, macadamia plantations and camphor laurel regrowth; there are also some small rainforest remnants scattered across the landscape.

Camphor conversion approach used on sites: Patch removal

Practitioner: Ralph Woodford, assisted by landholders

Details of approach: Systematic restoration work using the patch removal method began on the Tongmar property in 2000. Primary treatment was completed in 2004 and most of the intensive follow-up work finished by 2006. Systematic restoration treatment began on the Nash property in 2003 and is continuing, along with follow-up weed control. Primary treatment and initial follow-up weed control were conducted as per Rocky Ck dam (see Case Study 1), in patches 0.3 – 1.8 ha in size. Because the regeneration of rainforest plants at both sites has not been as abundant as at Rocky Ck dam, it has been necessary to continue follow-up weed control (2 – 3 sprays per year) for 3 – 4 years after treatment, until the achievement of canopy closure. In subsequent years, only maintenance weed control is required.

Treated camphor sites surveyed for this study: Five sites, aged 2 – 6 years since treatment.

Comments: At first glance, the camphor-dominated regrowth sites at these properties would have seemed unlikely candidates for conversion to rainforest, as their understories were thick with privet and they supported few seedlings of rainforest plants. Nevertheless, the patch removal method has been successful in stimulating the recruitment of rainforest pioneers from the seed bank at both sites, although less abundantly than at Rocky Ck dam. Regeneration is likely to have been limited by the relative isolation of the sites from rainforest remnants, as well as by the generally dry weather conditions prevailing at the time of treatment. Regeneration on both sites has also been subject to intense browsing by wallabies.

More information: Newsletter, Big Scrub Rainforest Landcare Group, November 2006 (URL: www.bigscrubrainforest.org.au/news/article1168121140.html).

Former camphor laurel regrowth on Tongmar's property, treated by the patch removal method. The patch on the left was treated three years ago, and still requires moderately intensive follow-up weed control. The site on the right was treated six years ago, and has a good cover of rainforest plants. The property is located in an extensively cleared part of the former Big Scrub region, isolated from remnant rainforests.

Case study 3: Brockley

Attributes of site: Former grazing property, now mostly planted with macadamias. The property is in an extensively cleared part of the 'Big Scrub' region, but includes two sizable rainforest remnants and some areas of camphor laurel regrowth.

Camphor conversion approaches used on site: Both staged and patch removal have been used.

Practitioners: Stephanie Lymburner, Julian Lymburner and Tim Roberts, assisted by landholders

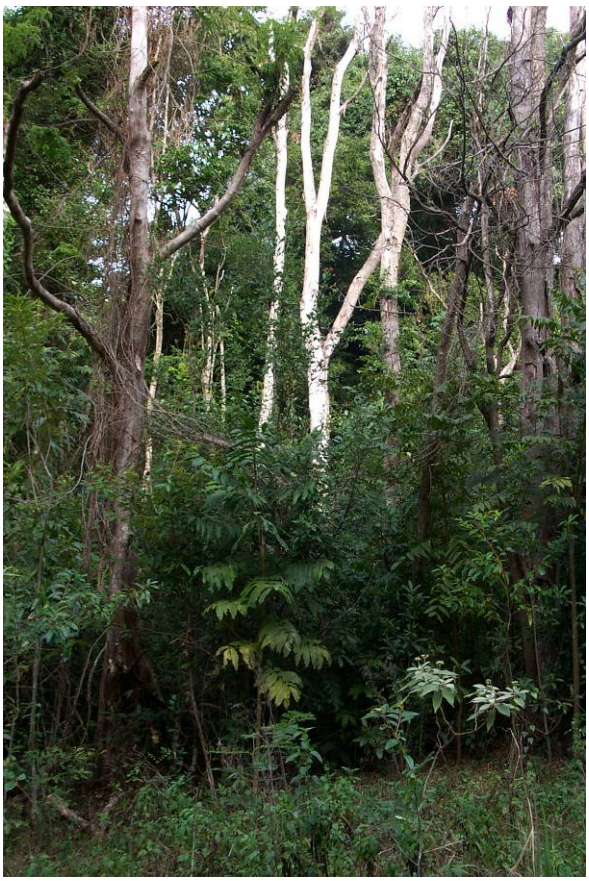
Details of approach: *1. Staged removal.* Primary treatment involved killing mature camphors in three stages. Camphor trees with the most regeneration of rainforest plants under them were killed first. All understorey weeds were also killed. In the first year following treatment, 2 sprays of germinating weeds were required, with hand-weeding around native plants. The second year, half the remaining mature camphors were poisoned, followed by another 1 - 2 sprays of germinating weeds. In the third year, the last of the mature camphors were poisoned. Subsequently, only maintenance weed control has been required.

2. Patch removal. Primary treatment involved killing all mature camphors and understorey weeds in one season. Four follow-up sprays of the germinating weeds were required in the first year after treatment. Subsequently, only maintenance weed control has been required**.**

Treated camphor sites surveyed for this study: Two staged removal sites and a patch removal site. The staged sites were aged 3 and 6 years since initial treatment. The older site was in a narrow band of camphors bordering a remnant, and the younger site was on the edge of a more extensive camphor stand about 150 m from a remnant. The patch removal site was 8 years old and located 100 m from a remnant.

Comments: Because both staged and patch removal methods have been used on this property, the outcomes of both methods can be compared directly, without the confounding influence of site-specific ecological factors. Comparison of the 6 year staged and 8 year patch removal sites (Figure 3, below), shows very similar outcomes for the number of rainforest tree species regenerating at the treated sites, including a similar distribution of tree species by successional stage. Both treated sites support around half the number of mature phase rainforest trees recorded in a similar-sized sample of the Brockley rainforest remnant.

More information: Lymburner, S., Handley, C. and Handley, J. 2006. Rainforest rehabilitation on a productive Macadamia property: The Brockley story. *Ecological Management and Restoration* 7:184-196.



Former camphor laurel regrowth at Brockley, treated by the staged removal method, six years after treatment. The regrowth occurred as a narrow band around a patch of remnant rainforest (seen in background).

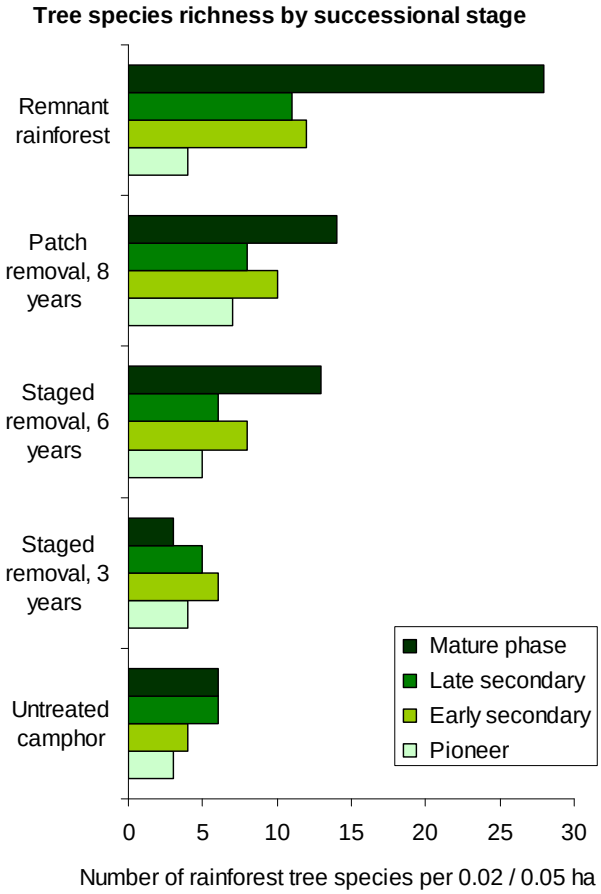


Figure 3: Comparison of the number of rainforest tree species in treated and untreated camphor stands and remnant rainforest at Brockley. Species classified by successional stage as per Kooyman (1996)[6]. For survey details, see Figure 2.

Case study 4: Sites along the southern escarpment of Alstonville plateau, treated by Tim Roberts

Attributes of sites: Mostly steep, rocky sites at the southern edge of the former Big Scrub rainforest. Over the last few decades, much of the escarpment has been colonised by a more or less continuous band of regrowth. To the north, the extensively cleared Alstonville plateau supports a mix of grazing and macadamia plantations; to the south are the lowland forests of the Tuckean swamp and an expanse of canefields. Scattered small remnant patches occur on and adjacent to the escarpment.

Camphor conversion approach used on sites: Staged removal

Practitioner: Tim Roberts

Details of approach: Tim has adopted what he describes as a 'tentative' approach to converting camphor stands to rainforest on these steep escarpment sites, with the intention of minimising the risk of erosion. Primary treatment involved killing a proportion (10 – 50%) of mature camphors, as well as the control of understorey weeds. Camphors with the most regeneration of rainforest plants under them were killed first. In the first couple of years following treatment, germinating weeds have been sprayed several times over the growing season, or as required; followed in subsequent years by maintenance weed control. The remaining mature camphors have been/ or are being killed in stages over 2 – 10 years, depending on site conditions.

Treated camphor sites surveyed for this study: Six sites, aged 1 – 10 years since treatment.

Comments: These sites demonstrate the time and commitment that may be required to convert stands of camphor laurel to rainforest on 'difficult' sites, using a staged approach.

Former camphor laurel regrowth sites on the southern escarpment of the Alstonville plateau, treated by the staged removal method. The site on the left is in the first year of treatment: understorey weeds have been killed, and some of the mature camphors poisoned. Staged treatment of the steeply-sloping site on the right began 10 years ago, and is nearly complete. The site now supports advanced regrowth of rainforest trees, palms, herbs and ferns.

Conclusions

Effectiveness of camphor conversion

- Camphor conversion, using either staged or patch removal methods, can accelerate the replacement of stands of camphor laurel with rainforest.
- At present, most conversion projects target mature (20 - 30 year old) camphor stands whch support some rainforest plants in their understorey. The optimum age of stands for treatment is unknown.

Costs of removal methods

- The costs of patch and staged removal methods appear to be similar ('average' costs around $10K per ha, although costs can be 2 – 3 times higher on very weedy sites). Most costs are incurred in primary treatment. The main difference between removal methods is that the costs of primary treatment are spread over a longer period in staged removal than patch removal. Follow-up weed control comprises 20 – 40% of costs and is more expensive on sites where the regeneration of rainforest plants is poor.
- Camphor conversion will often be cheaper than clearing camphor and replanting with rainforest trees.

Outcomes of removal methods

- Both staged and patch removal methods convert stands of camphor laurel to regenerating rainforest. Both treatment methods initially simplify the structure of camphor stands, particularly the patch removal method. However, after 4 – 6 years, both methods result in treated sites developing on a trajectory towards rainforest conditions in terms of vegetation structure and tree species composition.
- The regeneration of rainforest plants at a treated site is likely to be affected by several site- and time-specific factors including the proximity of the site to remnant rainforest, the age of the camphor stand (both these factors are likely to influence the amount of rainforest plants dispersed to a stand), the environmental conditions during treatment and the intensity of browsing by wallabies and other herbivores.

Regenerating rainforest under a patch of treated camphor, Rocky Ck dam, NSW

Choice of removal method for conversion projects

- As the costs and outcomes of the staged and patch removal methods appear to be similar, the choice of method for a particular project may depend primarily on logistical issues such as the availability of resources for follow-up weed control. Patch removal may suit large or small-scale restoration projects with guaranteed resources for follow-up weed control. Staged removal may suit small-scale projects with limited or irregular labour supply (e.g., 'backyard' projects).
- There are two other circumstances where staged removal might be the preferred approach. These are: (i) projects wishing to maintain shaded and/ or structurally complex habitat in the first few years of treatment (e.g., for the benefit of 'sensitive' plants and animals); and (ii) sites with a high risk of erosion if all canopy trees were killed at one time (e.g., very steep sites). Note that these suggestions are based on the reasoned opinion of practitioners using the staged removal method. Determining the relative advantages of the two removal methods on particular types of sites will require further study.

Caveats

- Camphor conversion is a relatively new approach to rainforest restoration, having been trialled on a small number of sites for little over a decade. The long-term response of sites to treatment is unknown.
- The sites surveyed in this study were a subset of the sites where camphor occurs (all were moist ex-rainforest sites on basalt in northern NSW). The response of rainforest plants to camphor conversion may be different in other situations: e.g., on less fertile soils, on drier sites, or in other regions.
- A rigorous understanding of the costs and outcomes of camphor conversion methods, across the range of ecological situations where camphor laurel occurs, will require standardised experimental trials and subsequent monitoring. We encourage practitioners to consider establishing such trials. A suggested experimental and monitoring protocol is available from the authors upon request.

References

1. Big Scrub Rainforest Landcare Group. 2005. *Subtropical Rainforest Restoration: A Practical Manual and Data Source for Landcare Groups, Land Managers and Rainforest Regenerators*. 2nd Edition. Big Scrub Rainforest Landcare Group, Bangalow NSW.
2. Catterall, C. P. and Harrison, D. A. 2006. *Rainforest Restoration Activities in Australia's Tropics and Subtropics.* Cooperative Research Centre for Tropical Rainforest Ecology and Management. Rainforest CRC, Cairns. Available online at: http://www.jcu.edu.au/rainforest/reports.htm.
3. Catterall, C.P., Kanowski, J., Wardell-Johnson, G.W., Proctor, H., Reis, T., Harrison, D. and Tucker, N.I.J. 2004. Quantifying the biodiversity values of reforestation: perspectives, design issues and outcomes in Australian rainforest landscapes. In: Lunney, D. (ed.) *Conservation of Australia's Forest Fauna Volume 2*. Royal Zoological Society of New South Wales, Sydney, pp. 359-393.
4. Joseph, R. 1999. An integrated, systematic approach to rainforest remnant restoration. In: *Rainforest Remnants: A Decade of Growth*. Horton, S. (ed). pp. 168-180. NSW NPWS, Sydney.
5. Kanowski, J. and Catterall, C.P. 2007. *Monitoring Revegetation Projects for Biodiversity in Rainforest Landscapes. Toolkit version 1, revision 1*. available online at: www.rrrc.org.au/publications/report_1.html.
6. Kooyman, R., 1996. *Growing Rainforest: Rainforest Restoration and Regeneration*. Greening Australia Queensland Inc., Brisbane.
7. Lymburner, S., Handley, C. and Handley, J. 2006. Rainforest rehabilitation on a productive Macadamia property: The Brockley story. *Ecological Management and Restoration* 7:184-196.
8. Moran. C., Catterall, C.P., Green, R.J. and Olsen, M.F. 2004. Functional variation among frugivorous birds: implications for rainforest seed dispersal in a fragmented subtropical landscape. *Oecologia* 141, 584-595.
9. Neilan, W., Catterall, C.P., Kanowski, J. and McKenna, S. 2006. Do frugivorous birds assist rainforest succession in weed dominated oldfield regrowth of subtropical Australia? *Biological Conservation* 129, 393-407.
10. Neilan, W., Catterall, C.P. and Kanowski, J. (2005) *A New Role for Weeds in Rainforest Restoration?* Rainforest CRC Issues in Tropical Forest Landscapes Series, No. 4. Available online at: www.griffith.edu.au/centre/cics/.
11. Scanlon, T., and the Camphor Laurel Taskforce, 2000. *Camphor Laurel Kit.* North Coast Weed Advisory Committee. http://www.northcoastweeds.org.au/camphorkit.htm.
12. Woodford, R. 2000. Converting a dairy farm back to rainforest: the Rocky Creek Dam Story. *Ecological Management and Restoration* 1: 83–92.

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