Woolgoolga to Ballina Pacific Highway upgrade

Threatened Rainforest Communities and Rainforest Plants Monitoring Program

Annual Report 2022

Year 3 Operation Phase Report

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Woolgoolga to Ballina Pacific Highway Upgrade, Sections 10 & 11, Threatened Rainforest Communities and Rainforest Plants, Annual Monitoring Report # 6 (2022)

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Executive Summary

As part of the rainforest management plan for the Woolgoolga to Ballina (W2B) Pacific Highway upgrade (Roads and Maritime 2015), a monitoring program was implemented to record potential impacts to threatened rainforest communities and threatened rainforest plants during the construction and operation phases of Sections 10 and 11. Permanent plots were established to monitor changes in the composition and structure of rainforest communities. The rainforest plots consisted of Impact and Control pairs and were located in four types of rainforest. Impact plots were positioned immediately adjacent the highway at the edge of clearing and Control plots away from the highway inside the forest. Threatened rainforest species were also monitored for changes in growth and condition. Threatened plants close to the highway and further inside the rainforest were found during surveys and tagged for monitoring. A total of 14 Impact and Control rainforest community plots and 210 threatened rainforest plants were included in the monitoring program.

EMM and Ecos Environmental recorded baseline data for the monitoring program in February 2014 before construction of Sections 10 and 11 began (see EMM 2014 for results). During construction, Ecos Environmental carried out monitoring in 2017, 2018 and 2019 (see Ecos 2017, 2018 and 2019 for results). The operation phase of the monitoring program began in 2020 when Sections 10 and 11 opened to traffic. Ecos Environmental carried out monitoring during spring 2020 and 2021 (see Ecos 2020 and 2021 for results). This was followed by monitoring during September 2022 which marks year 6 of the monitoring program (year 3 operation), the results of which are described in this report.

Ordination of the plot data revealed that the rate of vegetation change (from February 2014 to spring 2022) at the Impact sites was not consistently greater compared to the Control sites, suggesting no/minimal edge effects from vegetation clearing. There has been increases in the abundance of exotic species at some of the Impact sites since 2014, however this has also occurred at Control sites, suggesting edge effects were likely not the cause.

Since monitoring of the threatened rainforest plants began in 2014, there has been six plant mortalities - one White Laceflower, four Smooth Davidsonia, and one Green-leaved Rose Walnut. These plants died or declined in 2019, which was one of the driest years on record, and so it is likely that moisture stress was the cause.

Some of the threatened rainforest plants went backwards in the 2019 drought but resumed growing in 2020 and continued in 2021 and 2022. Surprisingly most plants continued to grow through 2019 despite the extreme conditions.

There were major floods in March 2022 on the NSW North Coast, which may explain the dieback or lack of growth (through waterlogging) observed for some of the threatened species growing adjacent watercourses. On the other hand, Rough-shelled Bush Nut appeared to respond positively to the above average rainfall, with a large portion of individuals flowering/fruiting.

The results of the operation phase monitoring after three years suggest that the W2B project has not resulted in significant indirect impacts to adjacent threatened rainforest communities and species compared with baseline (pre-construction) data. The increase in weed cover in some of the monitoring plots most likely reflects historical disturbances

rather than clearing-related edge effects. The Monitoring data showed that the exotic species canopy of Camphor Laurel, Large-leaved Privet and native vines growing on poor metasediment derived soils was assisting recruitment of many native rainforest species, and that formation of canopy gaps by poisoning the two exotic trees had an adverse effect on rainforest regeneration by facilitating the spread of aggressive exotic vines and reversing gain of rainforest structure.

1 Introduction

1.1 Overview

Transport for New South Wales (TfNSW) aims to minimise impacts on threatened rainforest communities and threatened rainforest plant species during construction and operation of Sections 10 and 11 of the Woolgoolga to Ballina (W2B) Pacific Highway upgrade. To achieve this aim, a management plan was prepared specifically for threatened rainforest communities and species, which included methods for monitoring the potential impacts of highway construction and operation, resulting in changes in species composition and condition. For details see *Woolgoolga to Ballina Threatened Rainforest Communities and Rainforest Plants Management Plan* (RMS 2015). TfNSW prepared this management plan based on data collected in preconstruction surveys and baseline monitoring by EMM and Ecos Environmental (see EMM 2014 for details).

The objective of the monitoring program was to determine the effectiveness of mitigation measures in avoiding direct and indirect impacts and maintaining the condition of threatened rainforest communities and species during highway construction and operation (RMS 2015).

The schedule for the monitoring program includes three years of construction phase monitoring and three years of operation phase monitoring. The results of the construction phase monitoring are described in three annual monitoring reports (Ecos 2017, 2018 and 2019). The operation phase of the monitoring program began in 2020 when Sections 10 and 11 opened to traffic. Ecos Environmental carried out operation phase monitoring during spring 2020 and 2021 (see Ecos 2020 and 2021 for results). This was followed by monitoring during September 2022 which marks year 6 and the third year of the operational phase monitoring program, the results of which are described in this report. The contents of this annual monitoring report are set out as follows:

- Section 2: methods, data analysis and results of the threatened rainforest communities component of the monitoring program
- Section 3: methods, data analysis and results of the threatened rainforest plants component of the monitoring program, and
- Section 4: conclusion and recommendations.

1.2 Performance Criteria

The management plan (RMS 2015) requires that mitigation measures implemented to protect threatened rainforest communities and species during highway construction of operation be assessed for effectiveness against performance criteria, using the results of monitoring.

This monitoring report is concerned with management of in situ vegetation and threatened plant species – i.e., those naturally occurring and remaining in situ in the road reserve after the finish of clearing. Relevant performance criteria are those relating to management of in situ threatened rainforest communities and in situ threatened rainforest plant species during the operation phase of ecological monitoring (lasting for three years).

Objectives of rainforest management during the operation period are given in Section 8.2 of the management plan (RMS 2015). Similarly, the objectives of rainforest monitoring are given in Sections 9.2 and 9.3 of the management plan. Although performance criteria may not be specifically stated in some cases, stated objectives or management goals can be considered as equivalent to performance criteria, and are provided in relevant sections of the plan. Specific performance criteria for threatened rainforest communities and species during the operation monitoring period lasting for three years, include:

- Zero mortality of retained in situ threatened plant populations has occurred during construction and for three consecutive monitoring periods post-construction and 80 per cent survival of tree, shrub and herbaceous perennials after three years
- At least 90 per cent of the plants planted as part of the revegetated areas have survived after the first year and 80 per cent after three consecutive monitoring events
- Less than five per cent weed cover at retained in situ threatened flora sites (after three years).

See also Sections 9.2 and 9.3 which describe the objectives of monitoring and is reproduced below:

9.2 In situ threatened rainforest plants
Retained in situ threatened flora species/populations within the project area would be monitored during and post-construction until the mitigation measures have been proven successful for three consecutive monitoring periods. Post construction monitoring of in situ rainforest plant and rainforest communities will be undertaken annually. A particular focus would be to identify any changes in health and condition which require management actions for remediation.

9.2.1 Monitoring goals
All retained in situ threatened rainforest plants have survived during construction and for three consecutive monitoring periods post-construction and 80 per cent survived after three years, especially for trees, shrubs and large vines.
Species may differ in resilience, longevity and sensitivity to disturbance. Plant health may seasonally fluctuate in its natural environment depending on the species (e.g. shade loving species would need more attention to buffering disturbances, particularly in the understorey). These factors would need to be considered.

9.3 Rainforest communities
Monitoring sites of the Lowland and Littoral rainforest communities in Sections 10 and 11 of the project have been established by EMM (2014) and focus on patches within 50 metres of the project where access is achievable. The monitoring includes an assessment of habitat condition within remnant patches. Control sites have also

been selected to monitor natural variation within the habitat condition which are not attributable to the impacts associated with the project.

9.3.1 Monitoring goals

Monitoring would provide reliable information such that sound conclusions can be drawn in relation to the management of rainforest communities. The overall monitoring objectives include:

- *Evaluating the success of mitigation measures, including protection of in situ rainforest communities*
- *Evaluating any impacts to rainforest communities as a result of the project (e.g., edge effects, weed incursion, changes in microclimate)*
- *Evaluating the success of weed control.*

Performance Criteria (including management objectives and goals) provided in the management plan (RMS 2015) for assessing the effectiveness of mitigation measures in protecting threatened rainforest species and rainforest communities during highway operation are summarised below:

Rainforest Species
Objective/Performance Criteria (see MP Table 8.3, Section 8.4): • 80% survival of threatened species after three years • 80% of plants planted in revegetated areas (translocation sites) have survived after three years • <5% weed cover at in situ threatened flora sites.
Rainforest Communities
Objective/Performance Criteria (see MP Section 9.3): • Evaluating any impacts to rainforest communities as a result of the project (e.g., edge effects, weed incursion, changes in microclimate) • Evaluating the success of weed control • Evaluating the success of mitigation measures, including protection of rainforest communities adjacent to the clearing extents and in situ threatened rainforest plant populations.
Rainforest Communities – General
The objective of the monitoring program was to determine the effectiveness of mitigation measures in avoiding direct and indirect impacts and maintaining the condition of threatened rainforest communities and species during highway construction and operation (RMS 2015).

This monitoring report does not address mitigation measures and objectives aimed at revegetation, which is also identified as a mitigation measure in the rainforest management plan (RMS 2015). For example:

- *Revegetation with native species reflective of the local area and pre-disturbed vegetation communities where possible will occur post construction. Revegetation design of areas adjacent to in situ threatened plant populations will ensure the plantings will not impact on the species (e.g., will not compete for light or moisture) and are consistent with their habitat requirements. Further details of areas for revegetation and native species to be used, will be provided in the Urban Design and Landscape Plan (UDLP) for each section of the project.*

Revegetation and habitat restoration were carried out by Ecos Environmental at the two rainforest translocation sites (Lumleys Lane and Coolgardie Rd). Results are described in the relevant annual translocation monitoring reports and again address general objectives and goals rather than specific performance criteria. Other revegetation work was carried out adjoining the Coolgardie Road interchange by another contractor.

2 Threatened Rainforest Communities

2.1 Methods

2.1.1 Identification of rainforest types

Two threatened rainforest communities occur within and adjacent to sections 10 and 11 of the W2B Pacific Highway upgrade:

- Lowland Rainforest of the NSW North Coast and Sydney Basin Bioregion - an Endangered Ecological Community (EEC) listed under the NSW *Biodiversity Conservation Act 2016* (BC Act). This community is equivalent with the Commonwealth *Environment Protection and Biodiversity Conservation Act 199*9 (EPBC Act) listed Lowland Rainforest of Subtropical Australia, which has the status of critically endangered ecological community (CEEC)

- Littoral Rainforest in the South East Corner, Sydney Basin and NSW North Coast Bioregions (herein referred to as Littoral Rainforest) - listed under the TSC Act as an EEC, equivalent with the EPBC Act listed Littoral Rainforest and Coastal Vine Thickets of Eastern Australia, which is listed as a CEEC.

In addition to the two listed threatened rainforest types, the preconstruction survey carried out in 2014 (EMM 2014) identified four rainforest types as present in the study, as follows:

- Littoral rainforest
- Swamp rainforest
- Rainforest on alluvium
- Hillside rainforest regrowth.

The first community is equivalent to the EEC *Littoral Rainforest* and the other three are equivalent to the EEC *Lowland Rainforest*. This initial classification of rainforest types by EMM was subsequently confirmed by cluster analysis of plot data, as described in Ecos (2017).

2.1.2 Data collection at control and impact sites

A total of 14 Control and Impact monitoring sites were positioned in the four different rainforest types within and adjacent to Sections 10 and 11 of the highway upgrade (Figure 1). Each Impact site was paired with a Control site in the same rainforest type, as indicated in Table 1. Control sites were located at a minimum of 20 m from the clearing boundary and within 100 m of the project boundary, as specified in the management plan (RMS 2015). Impact sites were located as close as possible to the clearing boundary. The Impact sites are potentially subject to negative edge effects such as elevated light intensity, higher temperatures, lower moisture availability, stronger wind, weed invasion and lower seedling survival due to branch fall. Control sites are expected to be unaffected by highway construction and operation.

Each monitoring plot was 20 m x 20 m and divided into four 20 m x 5 m sub-plots, labelled *a*, *b*, *c* and *d*. The long edge of each sub-plot was aligned parallel with the clearing boundary (Figure 2). Sub-plot *a* was always closest to the clearing boundary and subplot *d* was placed furthest from the boundary.

GPS coordinates and photographs were taken at the corners of each plot. 1.2 m hardwood stakes were used to mark the corners of each plot, while smaller 60 cm stakes were used to mark the ends of each sub-plot.

Within each of the four sub-plots, the following data were recorded:

- All species and their abundance in five fixed vertical height strata or layers: 0-1 m, 1-5 m, 5-10 mm, 10-20 m, and 20+ m
- The general health of plants
- Any disturbances or weed invasion
- General landscape features (slope, aspect, soil, etc).

Species abundance was recorded as crown-cover, which can be defined as the percentage of the plot area (or sub-plot in the case of this monitoring program) covered by the vertical projection onto the ground of the perimeter or outline of plant crowns. The area within the crown perimeter contributes to crown cover regardless of spaces between leaves. As a guide, in this monitoring study a plant crown covering 1 m x 5 m of the sub-plot was equal to a crown cover of 5%, a plant crown covering 2 m x 5 m of the sub-plot was equal to a crown cover of 10%, etc. Species crown cover was recorded for each height stratum.

<u>Distance from forest edge/clearing</u>

The distance from each Impact plot to the forest edge was recorded to assess which Impact plots are most likely to be susceptible to edge effects.

<u>Monitoring Schedule</u>

The third annual operation phase monitoring of the rainforest communities was carried out during September (Spring) 2022 (Table 2).

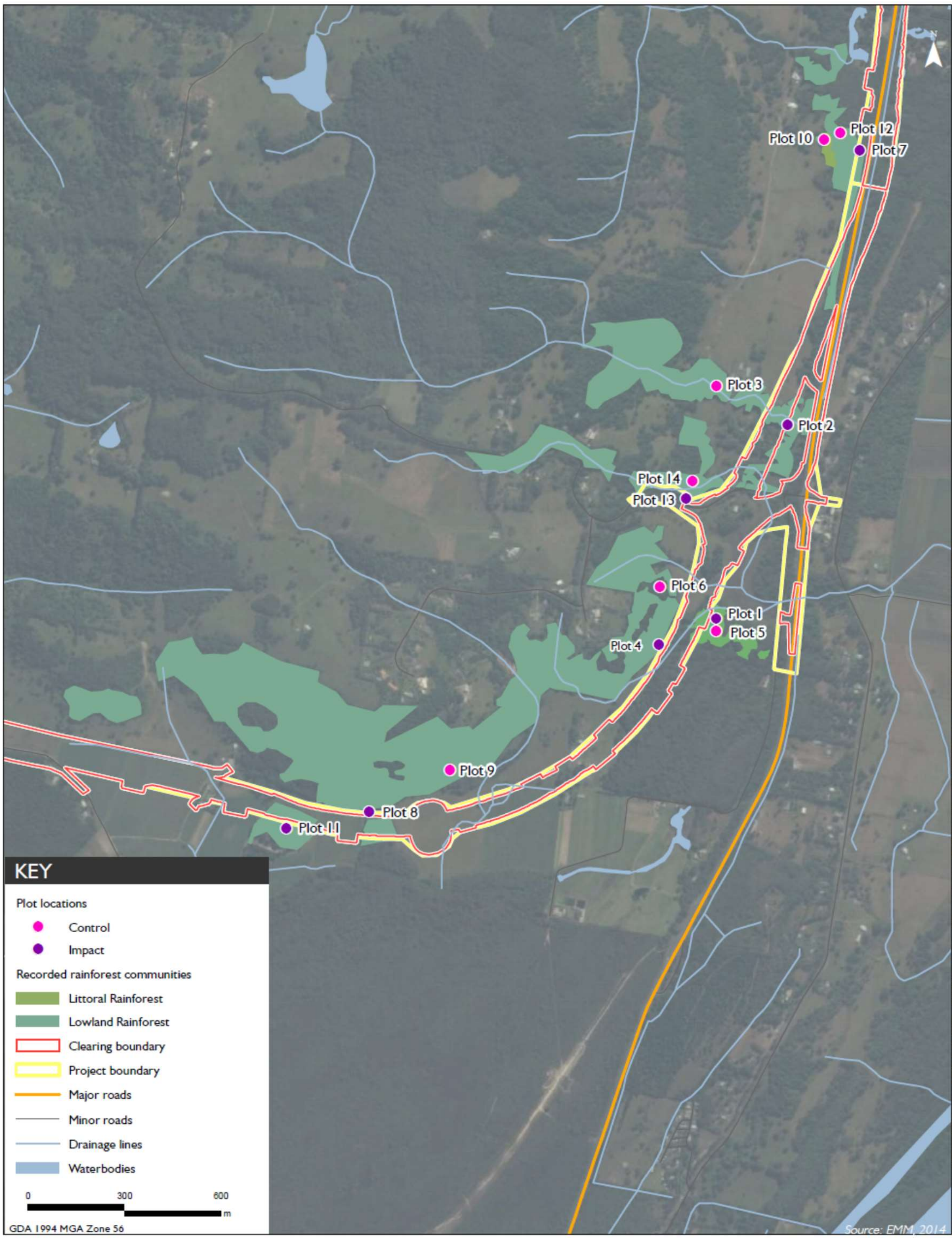

Figure 1. Monitoring plots in relation to W2B Pacific Highway upgrade project boundary and threatened rainforest communities. Map is sourced from EMM (2014).

Table 1. Details and habitat description of paired Impact and Control monitoring plots.

Paired sites	Impact/ Control	Rainforest type/subtype	Habitat/Location
1	Impact	Littoral rainforest	Flat, Pleistocene sand bench, off Kays Rd
5	Control		~20m east
2	Impact	Lowland Rainforest on creek alluvium	Both plots on Randles Creek
3	Control	Disturbed, mostly open canopy	~300m upstream
4	Impact	Rainforest regrowth on rocky hillside	Regrowth, weedy, lower slope
6	Control		~300m north
7	Impact	Swamp rainforest – Bangalow Palm	Flat floodplain swale, flood-prone, peaty soil
12	Control		~100m apart very similar
8	Impact	Rainforest regrowth on rocky hillside	Regrowth, weedy, lower to mid slope
9	Control		~300m north
11	Impact	Littoral rainforest/Lowland Rainforest	Flat Pleistocene sand merging with bedrock hillslope
10	Control		~2.5km north; not merging with bedrock
13	Impact	Rainforest regrowth on hillside	Lower slope, north of Coolgardie Rd.
14	Control		~50m north

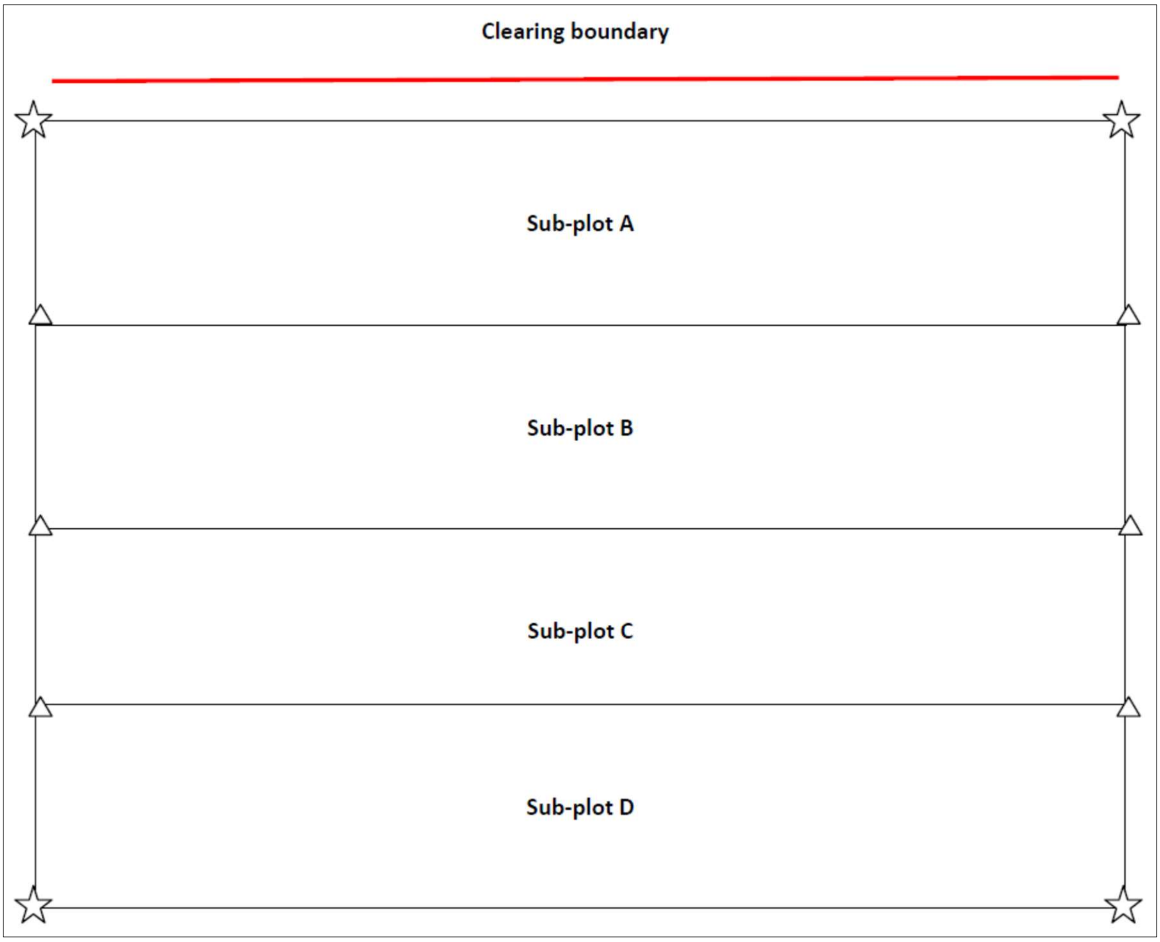

Figure 2. Plot layout for threatened rainforest communities monitoring plots. Plots were 20 m x 20 m and divided into four 20 m x 5 m sub-plots. Diagram is sourced from EMM (2014).

Table 2. Schedule for W2B Threatened Rainforest Plants and Rainforest Communities monitoring program. Table sourced RMS (2015).

Monitoring	Year	Phase	Section
1st quarter - Rainforest Plant Monitoring	1	Construction	S10-11
2nd quarter - Rainforest Plant Monitoring	1	Construction	S10-11
3rd quarter -Rainforest Plant Monitoring	1	Construction	S10-11
4th quarter - Rainforest Plant Monitoring	1	Construction	S10-11
Autumn - Rainforest Community Monitoring	1	Construction	S10-11
Spring - Rainforest Community Monitoring	1	Construction	S10-11
1st half - Rainforest Plant Monitoring	2	Construction	S10-11
2nd half - Rainforest Plant Monitoring	2	Construction	S10-11
Autumn - Rainforest Community Monitoring	2	Construction	S10-11
Spring - Rainforest Community Monitoring	2	Construction	S10-11
Annual monitoring - Rainforest Plants	3	Construction	S10-11
Autumn - Rainforest Community Monitoring	3	Construction	S10-11
Spring - Rainforest Community Monitoring	3	Construction	S10-11
Annual monitoring - Rainforest Plants	4	Operation	S10-11
Annual monitoring - Rainforest Communities	4	Operation	S10-11
Annual monitoring - Rainforest Plants	5	Operation	S10-11
Annual Monitoring - Rainforest Communities	5	Operation	S10-11
Annual monitoring - Rainforest Plants	6	Operation	S10-11
Spring - Rainforest Community Monitoring	6	Operation	S10-11

2.2 Data Analysis

2.2.1 Ordination

The perceived threat of the highway upgrade to the adjacent threatened rainforest communities is that it will cause edge effects resulting in a decrease in habitat condition (through weed invasion and death of plants due to exposure to harsher abiotic factors). Based on this assumption we can make the following prediction about how the vegetation at the monitoring sites will change:

- After construction begins, the rate of vegetation change at the Impact sites will be greater than at the Control sites.

Ordination is a multivariate data analysis technique that plant ecologists often use to simplify and visualize complex vegetation data, whereby sites are plotted so that the more similar they are (in terms of species present and amount of each species) the closer they will be to one another. Ordination was used to visualise the 2014 baseline data vs the 2022 operation phase data to see if the Impact sites changed more than the Control sites (as would be expected if the rainforest communities suffered from edge effects post-construction).

Ordination of the data was performed in R (R Core Team 2022) using the *vegan* package. The function *metaMDS* was used, which performs non-metric multidimensional scaling (NMDS), and the distance measure was set to Bray-Curtis. For vegetation data, Bray-Curtis distance is preferred because it is compatible with different measures of cover-abundance, and multidimensional scaling (MDS) is preferred because it assumes the relationship between environmental variables and species abundances is non-linear (Austin 2013). To reduce clutter in the ordination graph, only subplot *a* from each site was analysed. These subplots were chosen for analysis because they are positioned closest to the edge of clearing, and therefore, are most likely subject to edge effects.

2.2.2 Abundance of exotic species

The abundance of exotic species was used as an indicator of rainforest condition. An increase in the abundance of exotic species was interpreted as a decline in vegetation condition. The abundance of exotic species per plot was derived by summing the crown cover of each sub-plot and then averaging across the four sub-plots.

It is noted that following recommendations in the last monitoring report, a Rainforest Weed Management Plan was prepared by Jacobs and implemented in 2021. According to information supplied by Pacific Complete, Bushland Restoration Services (BRS) carried out weed control work in relation to the Weed Plan during February-March 2021. This was followed by further work by GMC Environmental Consulting in August 2021. Further exotic species removal in the area relevant to the Weed Plan was carried out by Ecos Environmental surrounding the Coolgardie Rd translocation area in 2021.

2.2.3 Native tree recruitment

Native tree recruitment was used as an indicator of overall rainforest condition and recovery (following historical disturbances). Recruitment was calculated by counting the number of subplots each tree species was recorded in in the 0-1 m stratum.

2.3 Results

2.3.1 Description of rainforest communities monitoring plots spring 2022

<u>Plot 1 and Plot 5</u>

Located close to each other and capture littoral rainforest vegetation dominated by *Litsea australis, Flindersia bennettii* and *Endiandra sieberi*. Since the monitoring program began there has been a slow but steady growth of these species with other natives persisting but growing little. Plot 1 (Impact) receives more sunlight (due to its proximity to the edge of clearing) and more plant growth is apparent, particularly *L. australis* that is reproducing via root-suckering and has high stem density. Weeds such as *Ochna serrulata, Ardisia crenata* and *Asparagus plumosus* had low abundances at the time of baseline monitoring but were steadily increasing until weed control work was carried out at the site, and there has since been a decrease in weed cover.

See Appendix 1 for photos of rainforest communities monitoring plots.

<u>Plot 2 and Plot 3</u>

Occur on creek alluvium along Randles Creek. Most of Plot 2 (Impact) is heavily shaded by a dense canopy of Bangalow Palm that has changed little in terms of floristics, albeit the north-eastern corner which is more open and is separated from the highway by a strip of exotic vegetation (Plates 1 and 2). There has been increases in exotic cover in this north-eastern corner since baseline monitoring, but weeds have not penetrated further into the forest. Plot 3 (Control) samples a vegetation patch with high conservation value as it has high native species richness and several threatened flora and host plants for threatened invertebrates. Most native flora have seen a slow but steady increase in cover since baseline monitoring. Weeds are confined to subplot *a* where has been a tree fall in the past and Lantana has subsequently invaded.

<u>Plot 4 and Plot 6</u>

Located on the rocky slopes of the Blackwall Range and sample regrowth rainforest that is partly dominated by the exotic trees Camphor Laurel and Large-leaved Privet. Plot 4 (Impact) is located along the western edge of the highway and has more disturbed vegetation. Weed cover was high during baseline monitoring and has continued increasing throughout the monitoring program (see Plates 1 and 2). Plot 6 (Control) has remained relatively unchanged throughout the monitoring program, albeit in subplot *a* where there is an *Ochna serrulata* infestation that has steadily grown.

Plate 1. Large-leaved Privet dominate in Plot 4, spring 2022.

Plate 2. *Ochna serrulata* dominate in Plot 4, spring 2022.

<u>Plot 7 and Plot 12</u>

Located in the north of the project area and sample swamp rainforest dominated by Bangalow Palm, *Melaleuca quinquenervia* and *Melicope elleryana*. There have been small increases in the exotics *Ipomoea cairica* and *Ligustrum sinense* in Plot 7 (Impact) at the edge of clearing but further into the forest weeds are mostly absent. In Plot 12 (Control) there has been a large tree fall since the last monitoring event (Plate 3). The increase in light availability has not yet lead to noticeable floristic changes in the plot.

Plate 3. Large *Melaleuca quinquenervia* tree fall in Plot 12, spring 2022.

Plot 8 and Plot 9

Located on the rocky slopes of the Blackwall Range (SW of Plots 4 and 6). The weeds Camphor Laurel, Large-leaved Privet and Small-leaved Privet have high cover in Plot 8 (Impact), particularly in subplot *a* at the edge of clearing, but have not increased markedly since monitoring began. Weed control has recently been carried out in Plot 9 (Control). Large Camphor Laurel and Large-leaved Privet have been poisoned and they have since died, opening up the canopy and letting in more sunlight (see Plates 4-6). Native vines have also been chopped back, as is standard for bush regenerators, the aim of which is to prevent vines from smothering tree seedlings and saplings following removal of exotic canopy trees and increased light availability, and to improve access for subsequent work. The aggressive exotic vine *Ipomoea cairica* has increased in the plot since the Camphor Laurel and Large-leave Privet was poisoned, as is often the case when one weed is removed another weed takes its place. If allowed to expand *Ipomoea cairica* will likely smother regeneration of native species and it can be extremely difficult to eradicate once established due to its underground system of rhizomes and high tolerance to herbicides. Retention of Camphor Laurel and Large-leaved Privet, which create an understory microclimate promoting native rainforest species regeneration (see Sect. 2.3.5) as well avoiding formatoin of canopy gaps, combined with removal of understory weeds such as Ochna (*Ochna serrulata*) and Asparagus Fern (*Protoasparagus plumosus* and *P. sprengeri*) may have been a better approach to managing the site. This is discussed further in Section 2.3.5 of this report.

Plate 4. Poisoned Large-leaved Privet with now open canopy, Plot 9, spring 2022.

Plate 5. Chopped native vines in Plot 9, spring 2022.

Plate 6. *Ipomoea cairica* infestation in Plot 9 following poisoning of exotic canopy trees, spring 2022.

Plot 10 and Plot 11

Located at opposite ends of the project area but both occurring on Pleistocene sand and sampling vegetation with littoral rainforest elements. Plot 11 (Impact) had low weed cover when it was first monitored in 2014. Following construction there was a slight increase in weed cover but weed control work was subsequently carried out and weed cover has since remained low. Plot 10 (Control) have remained relatively weed-free throughout the monitoring program and floristic changes have been minimal.

Plot 13 and Plot 14

Located on the slower slopes of the Blackwall Range, adjacent to Coolgardie Rd. Plot 13 (Impact) has several aggressive weed species including *Anredera cordifolia*, *Asparagus plumosus*, *Ipomoea cairica* and *Ligustrum sinense*, and there has been a steady increase in weed cover throughout the monitoring program, particularly of *L. sinense* (Plate 7). Weed cover in Plot 14 has remained low throughout the monitoring program and the native species composition and structure have changed little.

Plate 7. *Ligustrum sinense* (exotic) dominating the ground and shrub layers in Plot 13, spring 2022.

2.3.2 Ordination

The ordination graph below (Figure 3) shows subplot *a* for each monitoring site. For each subplot there is a point for baseline (2014) and spring 2022 monitoring. The further points are apart in ordination space, the more different they are in terms of the variables measured (i.e., species present and their cover). If the highway upgrade negatively affected the adjacent rainforest communities through edge effects, we would expect vegetation change to be greater at the impact sites compared to the control sites, and this would be reflected in ordination space by the distance between baseline and spring 2022 monitoring being greater for Impact sites compared to Control sites. This is the case if we make comparisons among some pairs of Control and Impact sites, for example 1a (Impact) has changed more than 5a (Control), but other pairs contradict this, for example, 7a (Impact) has changed less than 12a (Control). As the rate of vegetation change is not consistently greater at the Impact sites compared to the Control sites, it is difficult to draw conclusions through multivariate analysis about the impact of the highway upgrade on the neighbouring rainforest communities.

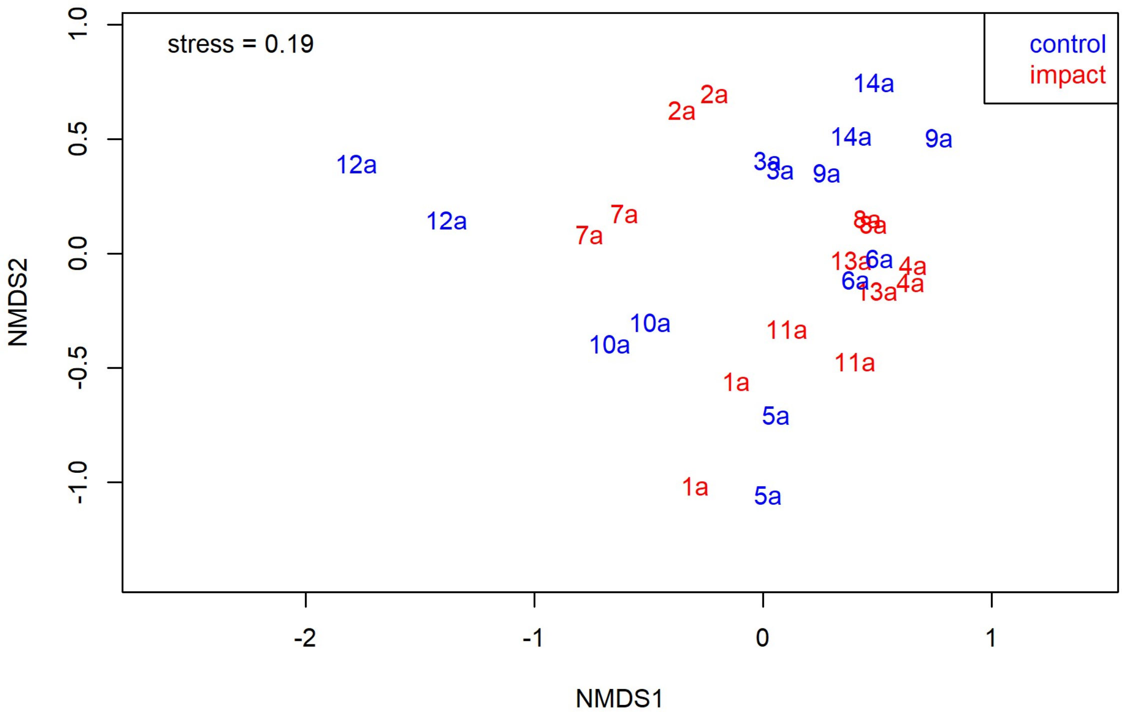

Figure 3. Ordination graph of subplot *a* for each monitoring site. For each subplot there is a point for baseline (2014) and spring 2022 monitoring. How well the data is graphically represented in 2- or 3-dimensional space is indicated by the stress value. If the stress value is <0.2 then there is good representation; if it is >0.2 then the plot should be interpreted with caution (Clarke 1993). The stress value = 0.19, meaning there is good representation in 2-dimentional space.

One possible explanation for the absence of a temporal trend is that not enough time has elapsed for one to emerge. So far, the rainforest plots have been monitored for nine years (2014-2022), which is a small time-scale in the context of ecological succession.

A factor worth considering, however, is that some of the Impact plots were not situated directly beside the forest edge (edge of clearing) and therefore, are not expected to be subject to strong edge effects (Table 4). For some Impact plots the forest edge has become closer due to clearing for the highway upgrade, while the distance to the forest edge has not changed for others as there was a cleared edge already, at the start of construction.

Table 4. Variable distance of Impact plots from edge of clearing or construction and whether clearing was effective or ineffective. Effective clearing is where clearing of forest took place next to the plot and ineffective clearing is where clearing (of the construction footprint) next to the plot did not result in removal of forest, only pasture.

Impact plot	Approx. distance of plot to edge of clearing/ construction	Effective/ineffective clearing
1 (LRF Kays Ln)	15 m	Effective
2 (STRF Randall's Ck)	0 m	Effective
4 (RF rocky)	10 m	Ineffective
7 (Swamp RF)	0 m	Effective
8 (RF rocky)	10 m	Ineffective
11 (LRF Lumleys)	10 m	Effective
13 (Coolgardie Rd)	5 m	Ineffective

Previous monitoring studies of the impact of clearing on threatened rainforest flora found that weed incursion into threatened species habitat rarely extends more than 10 m inside newly created forest edges (Ecos Environmental 2006). Four of the seven impact monitoring plots for this study are 10 m or more from the edge of clearing and therefore, based on Ecos Environmental (2006), would be unlikely to register a significant increase in weediness due to reduced distance to the forest edge.

It should be noted that positioning of the Impact plots at the immediate edge of clearing during the pre-construction (baseline) phase was difficult as they were installed in 2014 when only early models of the road design and construction footprint were available. In future, such plots should be installed directly after clearing, to record the true edge effect.

Ordination methods are useful for simplifying complex datasets and detecting overall trends in plant communities. A limitation of this approach, however, is that common or abundant species in plant communities can mask small but important changes occurring among less frequent species. Therefore, it is important to also investigate trends that may be occurring at the species level or among certain components of the flora (e.g., exotic species, specific growth or strata within the plant community) as described below.

2.3.3 Abundance of exotic species

A total of 30 exotic species were recorded in spring 2022 across the 14 monitoring plots. Like in previous monitoring events, most were common garden escapees or herbaceous annuals that do not pose a serious threat to the integrity of rainforest communities. Eleven species were recorded that are considered serious weeds in rainforest communities, these were Madeira Vine, Climbing Asparagus Fern, Camphor Laurel, Coastal Morning Glory, Large-leaved Privet, Ochna, Broad-leaved Paspalum, Devil's Fig, Winter Senna and Crofton Weed. Of these eleven weed species, Camphor Laurel, Large-leaved Privet, Broad-leaved Paspalum, Climbing Asparagus Fern and Ochna were most common among the monitoring plots.

Exotic abundance averaged across the seven Impact plots has increased from 32% crown cover in February 2014 to 58% crown cover in Spring 2022 (Table 5). Impact plots 2, 4 and 13 had the largest increases in exotic abundance since February 2014 (11%->48%, 61%->135%, and 38%->100%, respectively). The other Impact plots either had small increases in exotic abundance or remained relatively unchanged.

The increase in exotic abundance in the Impact plots could be indicative of detrimental edge effects (i.e., an increase in light availability favouring weed species), however, there has also been an increase in exotic abundance in the Control plots. Exotic abundance averaged across the seven Control plots has increased from 17% crown cover in February 2014 to 25% crown cover in spring 2022. In all of the Control plots there has been increases in exotic abundance throughout the monitoring program of greater than 5%, however, due to bush regeneration work some Control plots have recently seen declines in weed cover.

Weeds establish in rainforest where there is increased light availability, which can either be at the edge of the rainforest or underneath canopy gaps as a result of tree fall. In the rainforests of north-eastern Queensland, Pohlman (2006) found that weeds were confined exclusively to the forest edge or where there were large canopy gaps. Once some rainforest weeds are established however, they can continue to grow in low light conditions. This is true for the weed species Climbing Asparagus, Madeira Vine and Ochna (Darren Bailey pers. comm.). The finding in this monitoring study that there has been an increase in weed abundance at both the Impact and Control plots suggests that weed abundance has increased not because of construction-related edge effects but because weeds were established at the plots prior to the monitoring study commencing, and have continued to grow regardless of increased light availability from clearing.

Another factor that may explain the increase in weed abundance is the removal of cattle grazing. The monitoring sites have a history of cattle grazing and it is generally recognised that removal of cattle from forest where they formerly grazed is followed by an increase in weediness. Weeds can become established in a forest as a result of cattle foraging but as long as cattle continue to graze the forest the weeds are controlled. Removing cattle to restore natural conditions can have the opposite effect by encouraging weed growth and necessitate expensive weed control programs.

The monitoring sites that are positioned on the rocky slopes of the Blackwall Range (Plots 4, 8, 9 and 13) have a canopy dominated by Broad-leaved Privet and to a lesser extent

Camphor Laurel. These exotic species are often the first trees to establish in cleared areas that previously had rainforest and a range of birds feed on these species fruit. Although Broad-leaved Privet and Camphor Laurel are aggressive competitors, they may serve as an initial nursery layer that enables native species dispersed by birds to establish. Indeed, Plots 4, 8, and 13 all had native trees, shrubs, ferns and herbs establishing in the lower canopy strata, and native vines were already abundant in the higher strata.

Some of the current weed infestations at the monitoring sites are more likely to cause a reduction in rainforest condition and a loss of biodiversity in the future. This is the case for infestations at sites 4, 6, 7, 9 and 13. At sites 4 and 6 there are Ochna infestations that have expanded and will likely continue to increase as this weed species can grow in low light conditions underneath rainforest canopies. Ochna is difficult and time-consuming to treat as it has a high tolerance to herbicide, meaning substantial time and resources are required to control large infestations.

At sites 7, 9 and 13, Coastal Morning Glory was observed to establish on the edge of clearing during 2020-2022and spread into adjoining forest. Weed control work carried out at these sites by Ecos Environmental as part of annual maintenance in 2021-2022 was successful in reducing the cover of Coastal Morning Glory to less than 1% at these sites. This species may spread in future from private property into the project boundary, but this is largely out of the project' control and is not considered a significant risk in the near future.

2.3.4 Native tree recruitment

Of the 141 native tree species recorded in the monitoring program, 74 species were present in the 0-1 m height stratum indicating active recruitment and 40 species were absent from this stratum indicating little or no recruitment. Of the species with no active recruitment were several that would have once been common in the rainforest communities before European settlement, including Australian Teak (*Flindersia australis*), White Booyong (*Argyrodendron trifoliatum*), Rose Satinash (*Syzygium crebrinerve*), White Beach (*Gmelina leichhardtiana*) and Rosewood (*Dysoxlum fraserianum*), which persist in the study area as a few stunted, remnant trees. Many other species such as the large figs *Ficus macrophylla, F. watkinsiana, F. virens* and *F. superba* almost certainly present in the original rainforest, were also absent and no evidence of recolonization was seen.

In spring 2022, the ten native tree species with the highest frequency of active recruitment (i.e. present in 0-1 m stratum) were Three-veined Laurel (*Cryptocarya triplinervis*), Tuckeroo (*Cupaniopsis anacardioides*), Guoia (*Guioa semiglauca*), Bangalow Palm (*Archontophoenix cunninghamiana*), Bollywodd (*Litsea australis*), Rough-leaved Elm (*Aphananthe philippinensis*), Foambark Tree (*Jagera pseudorhus*), Flindersia bennettii (Bennett's Ash), Steelwood (*Sarcopteryx stipata*), Pepperberry Tree (*Cryptocarya obovata*) (Table 6). Generally, these were also the ten most actively recruiting species in spring 2017 and in 2014 (baseline monitoring) but in a different order.

These recruits were growing under a closed rainforest-like canopy dominated by Camphor Laurel, Large-leaved Privet and native vine species (e.g. Cissus antarctica and C. hypoglauca), and occasional trees of native rainforest species. The humid, shaded microclimate formed by the exotic species canopy was clearly facilitating recruitment of native rainforest species, which were mainly species with succulent fruits or arils surrounding the seed, and probably dispersed by frugivorous birds.

2.3.5 Importance of exotic trees and native vines in rainforest regrowth

Exotic trees dominate the canopy of subtropical rainforest regrowth between Lumleys Lane and Coolgardie Rd (and elsewhere on the Blackwall Range) and appear to have been pivotal in facilitating rainforest regeneration, because of their ability to colonise cleared open sites. Some native species can do this such as Cheese Tree and Brush Kurrajong, but they are relatively scarce locally and the two exotic trees Camphor Laurel (*Cinnamomum camphora*) and Large-leaved Privet (*Ligustrum lucidum*) dominate regrowth. The monitoring method, which recorded species abundance against five vertical height strata, showed that these species are facilitating colonisation by native rainforest species, the majority of which are mainly present as seedlings, saplings and young trees under the exotic species dominated canopy. Also recorded was a general absence or scarcity of seedlings and young plants of the two exotics, indicating they do not recruit well in a forest, but require relatively open conditions to do this (perhaps formed by elephants and rhinoceros in the countries they originally came from).

The exotic trees are playing a key role in restoring rainforest ecosystem functions, by creating a suitable microclimate for native species to regenerate and by building up biomass and organic matter in the soil. Without this, the rainforest ecosystem would not have enough nutrient cycling between soil and vegetation to grow into a tall rainforest and would likely remain low in stature due to the nutrient poor, metasediment derived soil (with some basal colluvium from upslope).

Vines are also common in the rainforest regrowth and form a main component of the forest canopy, enhancing the protected microclimate below and also adding substantial amounts of biomass to the ecosystem. There is a common perception that vines hold back the development of rainforest, which is a misconception. Ecologically, vines are essential for development and maintenance of rainforest. The most southerly occurrences of subtropical rainforest in eastern Australia which are in East Gippsland consist of gully vine thickets with a few vines and one or two tree species, demonstrating the important colonising role played by vines in maintenance of this ecosystem. The large vines seen in rainforest do not grow up and strangle the forest canopy, but start in canopy gaps or rainforest edges and are often carried up by growing trees.

There was no evidence the exotic canopy trees and native vines were suppressing native species, more the contrary.

The importance of exotic trees and vines in rainforest regrowth is pointed out because landowners with good intentions, but mis-understanding the ecological role of these species, are engaging bush regenerators to poison and cut them out of rainforest regrowth. This approach for rainforest restoration should be discouraged, or at least implemented scientifically with control and treatment plot or areas, to compare their effect on the rainforest as it continues to regenerate.

Ecos Environmental recommends that bush regenerators focus on removing weed species from the understory of rainforest regrowth such as Asparagus Fern, Small-leaved Privet and Ochna. Removal of large exotic trees such as Camphor Laurel and Large-leaved Privet should only be carried out if there is funding for frequent follow-up weed control 1-2 years after primary work, and subsequent regular maintenance work until resultant canopy gaps have closed. What has been observed in Plot 9 is that poisoned Camphor Laurel and Large-leaved Privet are being replaced by more aggressive and harder to control weeds such as Coastal Morning Glory.

This approach should be specified in any future Biodiversity Stewardship Agreement sponsored by TfNSW and communicated to Ballina Shire Council.

Table 5. The abundance of exotic species of each pair of Control and Impact plots, compared across monitoring events. Abundance is percentage crown cover. Values can be higher than 100% because species abundance values were summed for the five strata. Averages rounded to the nearest integer.

		February 2014	Spring 2017	Spring 2018	Spring 2019	Spring 2020	Spring 2021	Spring 2022
1	Impact	2	14	12	11	18	15	7
5	Control	12	18	25	22	25	26	12
2	Impact	11	18	35	30	42	50	48
3	Control	4	7	18	15	24	34	34
4	Impact	61	102	106	95	113	121	135
6	Control	28	37	57	52	67	90	94
7	Impact	2	1	2	1	4	4	5
12	Control	1	<0.5	1	1	1	1	2
8	Impact	103	127	114	117	108	108	109
9	Control	68	63	73	72	71	71	17
11	Impact	4	19	12	10	9	9	4
10	Control	4	2	4	5	5	4	5
13	Impact	38	37	92	81	90	95	100

14	Control	5	6	9	6	10	16	11
Overall Impact		32	45	53	49	55	57	58
Overall Control		17	22	27	25	29	35	25

Table 6. The 10 most frequent native tree species in 0-1 m height stratum, recorded in 2014 (baseline), spring 2017 (first year of construction phase monitoring) and spring 2022.

Baseline 2014		**Spring 2017**		**Spring 2022**	
Native tree species	**Percentage of subplots (n = 56)**	**Native tree species**	**Percentage of subplots (n = 56)**	**Native tree species**	**Percentage of subplots (n = 56)**
Cryptocarya triplinervis	26	*Cryptocarya triplinervis*	48	*Cryptocarya triplinervis*	27
Cupaniopsis anacardioides	24	*Archontophoenix cunninghamiana*	43	*Cupaniopsis anacardioides*	23
Aphananthe philippinensis	23	*Cryptocarya obovata*	40	*Guioa semiglauca*	18
Archontophoenix cunninghamiana	22	*Cupaniopsis anacardioides*	40	*Archontophoenix cunninghamiana*	15
Cryptocarya obovata	22	*Aphananthe philippinensis*	32	*Litsea australis*	15
Guioa semiglauca	20	*Jagera pseudorhus*	32	*Aphananthe philippinensis*	14
Litsea australis	20	*Guioa semiglauca*	28	*Jagera pseudorhus*	12
Jagera pseudorhus	19	*Litsea australis*	27	*Flindersia bennettiana*	11
Sarcopteryx stipata	17	*Sarcopteryx stipata*	25	*Sarcopteryx stipata*	10
Flindersia schottiana	12	*Flindersia schottiana*	23	*Cryptocarya obovata*	9

3 Threatened Rainforest Species

3.1 Species in Monitoring Program

The threatened rainforest plants being monitored are located on Sections 10 and 11 of the highway upgrade. Section 10 extends from the Richmond River north to Coolgardie Rd and Section 11 from Coolgardie Rd north to the Ballina bypass tie-in. Individuals closest to the forest edge as well as a selection of plants further back inside the forest were included in the monitoring program.

The following eight threatened rainforest plant species are located adjacent to Sections 10 and 11 of the W2B Pacific Highway upgrade and are being monitored as part of the *Woolgoolga to Ballina Threatened Rainforest Communities and Rainforest Plants Management Plan* (RMS 2015):

- Rough-shelled Bush Nut (*Macadamia tetraphylla*) (vulnerable under the Biodiversity Conservation Act, 2016 (BC Act) & Environment Protection and Biodiversity Conservation Act (EPBC Act)
- Green-leaved Rose Walnut (*Endiandra muelleri* subsp. *bracteata*) (endangered under the BC Act)
- White Lace Flower (*Archidendron hendersonii*) (vulnerable under the BC Act)
- Rusty Rose Walnut (*Endiandra hayesii*) (vulnerable under the BC Act & EPBC Act)
- Stinking Cryptocarya (*Cryptocarya foetida*) vulnerable under the BC Act & EPBC Act)
- Southern Ochrosia (*Ochrosia moorei*) (endangered under the BC Act & EPBC Act)
- Red Lilly Pilly (*Syzygium hodgkinsoniae*) (vulnerable under the BC Act & EPBC Act)
- Smooth Davidsonia (*Davidsonia johnsonii*) (endangered under the BC Act & EPBC Act).

Streblus brunonianus and *Acronychia littoralis* were included in the initial monitoring program (EMM 2014) but have since been removed. *Streblus brunonianus* was taken out as it is no longer listed as a threatened species and *Acronychia littoralis* was removed due to misidentification. For further details see Ecos (2017).

3.2 Data Collection and Analysis

A total of 210 plants were tagged and recorded in the baseline monitoring and pre-construction survey in February 2014 (Table 6). The tagged plants were positioned close to the highway construction footprint and further back inside the forest.

The following plant attributes were recorded: plant condition on a scale of 0-5 (Table 7), height and girth, presence of flowers or fruit, any insect/grazing damage, evidence of disease, and signs of recruitment.

Plant height was recorded with a tape measure for plants up to about 3.5 m high and visually estimated for taller plants.

Plant height was averaged across individuals of the same species and compared across monitoring events. Heights that were visually estimated (i.e., individuals higher than 3.5 m) were excluded from averaging. Averages were not calculated for Rusty Rose Walnut and Southern Ochrosia because there is only one plant being monitored for each species.

The tagged plants were monitored quarterly in year 1 (2017), biannually in year 2 (2018) and annually in years 3 to 6 (2019 - 2022) (Table 2).

Table 7. Condition scores applied to threatened rainforest plant species.

Score	Condition
0	Dead
1	Leafless, possibly still alive and may reshoot
2	Small (<0.7- 1m), seedling or sapling, reasonably healthy; or taller plant that has dieback but still has some leaves
3	Sapling or small tree, healthy, evidence of recent new growth, not reproductively mature; or tree showing evidence of minor dieback
4	Reproductively mature, healthy but relatively small for the species
5	Reproductively mature, healthy, good size

3.3 Results

3.3.1 Summary

Since monitoring of the threatened rainforest plants began in 2014, there have been six plant mortalities – one White Laceflower, four Smooth Davidsonia, and one Green-leaved Rose Walnut (Table 8). In 2019, six Smooth Davidsonia appeared dead but in 2020 one reshot and another one in 2021. Survival for Stinking Cryptocarya, Rough-shelled Bush Nut, Rusty Rose Walnut, Southern Ochrosia and Red Lilly Pilly was 100% in 2022.

Figure 5 shows the average height of plants below 3.5 m for each species during 2017-2022. Note, Rusty Rose Walnut and Southern Ochrosia were not included in the graph because there is only one plant being monitored for these species.

The 2019 drought was one of the driest years on record (Figure 6). It was not surprising that some individuals went backwards in 2019 or did not grow. This was true for plants of the species White Laceflower, Rough-shelled Bush Nut, Smooth Davidsonia and Green-leaved Rose Walnut (Figure 7). The year 2020 had above average rainfall as did 2021 and most of the drought-affected plants resumed growing.

It was surprising that most of the individuals continued to grow in 2019, despite the extreme conditions. Most of the plants that went backwards resumed growing in 2020. Our data suggest that subtropical rainforest species are better adapted to drought than one might expect.

There were major floods in March 2022 on the NSW North Coast, which likely affected the threatened species in different ways. Two *S. hodgkinsoniae* growing at the water's edge along Randles Creek have recently browned-off (leaves brown/dead), which may be due to flooding and waterlogging. On the other hand, *M. tetraphylla* had a large flowering/fruiting event in spring 2022 (31 of 74 tagged plants had flowers and/or fruit), may be as a result of the above average rainfall.

Table 8. The number of plants being monitored for each threatened species and their survival for the years 2017, 2019, 2021 and 2022.

Species	No. of plants monitored	Survival (%) 2017	Survival (%) 2019	Survival (%) 2021	Survival (%) 2022
Archidendron hendersonii	36	100	94	97	97
Cryptocarya foetida	12	100	100	100	100
Davidsonia johnsonii	26	100	77	81	85
Endiandra hayesii	1	100	100	100	100

Endiandra muelleri subsp. bracteata	56	100	100	98	98
Macadamia tetraphylla	74	100	100	100	100
Ochrosia moorei	1	100	100	100	100
Syzigium hodgkinsoniae	4	100	100	100	100

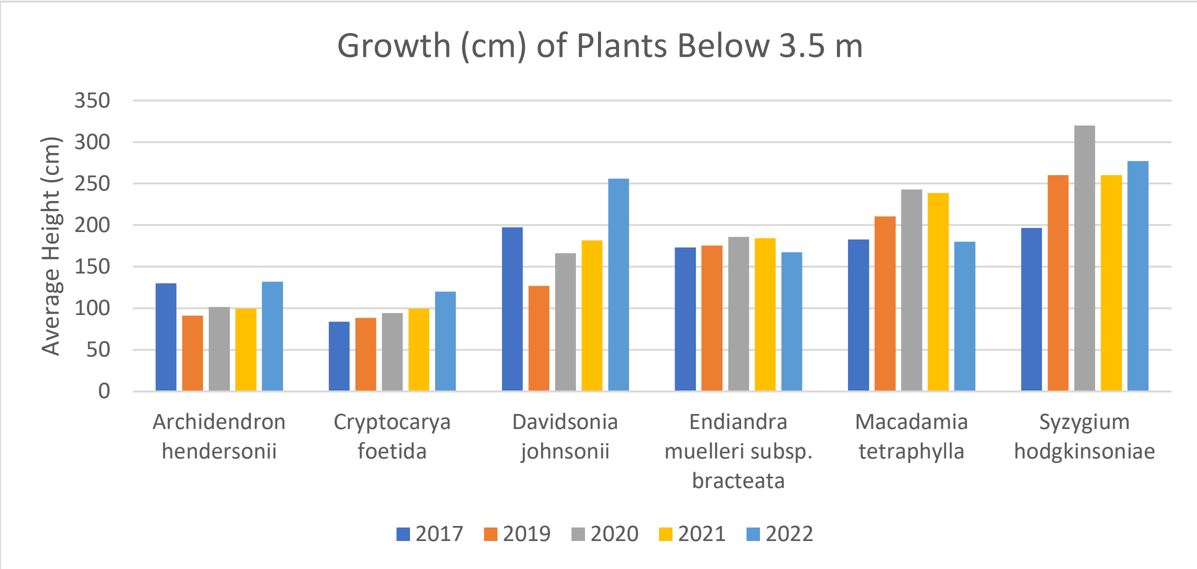

Figure 5. Average plant height (cm) of threatened species in 2017, 2019, 2020, 2021 and 2022 for plants under 3.5 m high. Note, Rusty Rose Walnut and Southern Ochrosia were not included because there is only one individual of each species being monitored and both are greater than 3.5 m in height. Note, the sample for *S. hodgkinsoniae* in 2022 included two plants that had dead/brown leaves; average height next year is likely to be far lower as a result.

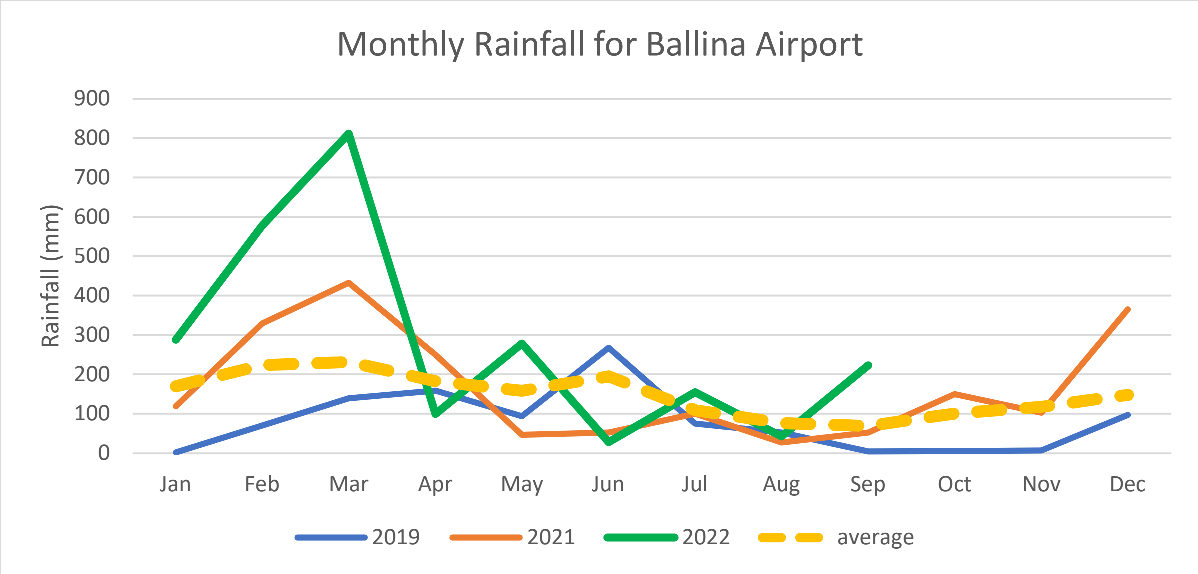

Figure 6. Monthly rainfall for Ballina Airport AWS in 2019, 2021 and 2022, and mean montly rainfall for 21 years (1992-2021). Note the zero rainfal for Sep-Nov during the 2019 drought (blue line) and Feb-March rainfall that far exceeds the average during the 2022 floods (green line).
Data sourced from
http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=139&p_display_type=dataFile&p_startYear=&p_c=&p_stn_num=058198

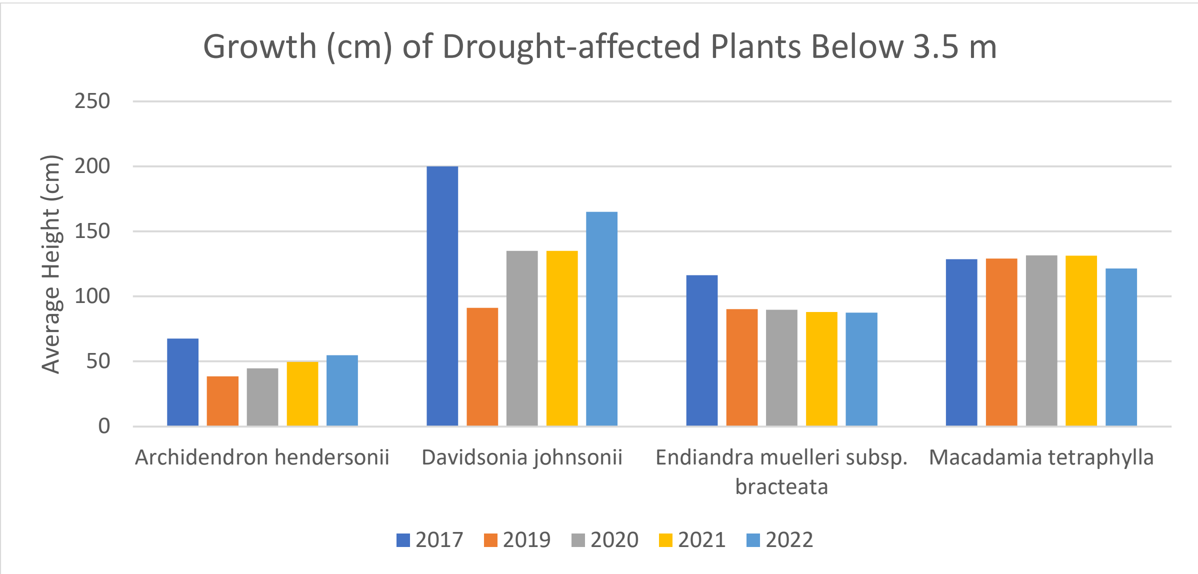

Figure 7. Average plant height (cm) of threatened species in 2017, 2019, 2020, 2021 and 2022 for drought-affected plants under 3.5 m high.

3.3.2 Condition of threatened species 2022

Rough-shelled Bush Nut (*Macadamia tetraphylla*)

Survival/condition: in spring 2022 survival remained at 100%.

Growth: average height for plants under 3.5 m was 180 cm in spring 2022, which is a slight decrease from 239 cm in 2021; this was possibly due to March 2022 flooding and waterlogging which would have a greater impact on smaller plants.

Reproduction: 31 of the 74 plants being monitored were reproductive in 2022 (i.e., flowers and/or fruit present) (e.g., Plate 1, Appendix 2). This was the largest flowering/fruiting event throughout the monitoring program and may be due to the above average rainfall for 2022.

Green-leaved Rose Walnut (*Endiandra muelleri* subsp. *bracteata*)

Survival/condition: survival was 98% at spring 2022 (1 plant mortality). The single plant died during the 2019 drought most likely due to moisture stress.

Growth: some went slightly backwards during the 2019 drought and has remained similar during 2020-2022. In spring 2022, average height under 3.5 m was 168 cm.

Reproduction: one plant was observed flowering in 2022.

White Lace Flower (*Archidendron hendersonii*)

Survival/condition: 97% survival; 2 plants appeared dead in 2019 and 2020 but one reshot in 2021.

Growth: most plants went backwards in 2019 but reshot and grew in subsequent years; for plants under 3.5 m high, average height was 132 cm in 2022, which was an increase from 100cm in 2021.

Reproduction: one plant was observed flowering in 2022.

Rusty Rose Walnut (*Endiandra hayesii*)

Survival/condition: only one plant of this species is being monitored; this plant was healthy in 2022.

Growth: the single plant was approximately 7 m in spring 2022.

Reproduction: no flowers or fruit were recorded in 2022, as in previous years.

Stinking Cryptocarya (*Cryptocarya foetida*)

Survival/condition: survival was 100% in 2022 and plants were in healthy condition.

Growth: most plants continued to grow through the 2019 drought. For plants under 3.5 m high, average height was 120 cm in 2022, which was an increase from 100 cm in 2021.

Reproduction: one plant was observed flowering in 2022.

Southern Ochrosia (*Ochrosia moorei*)

Survival/condition: only one plant of this species is being monitored and this plant was in healthy condition in 2022 (Plate 2, Appendix 2).

Growth: the single plant was approximately 6 m in 2022.

Reproduction: no flowers or fruit were recorded, as in previous years.

Red Lilly Pilly (*Syzygium hodgkinsoniae*)

Survival/condition: four plants of this species are in the monitoring program; in spring 2022 they were all alive but two of the plants that are growing at the water's edge of Randles Creek had dead/brown leaves (Plate 3, Appendix 2), possibly as a result of March 2022 flooding and waterlogging.

Growth: in spring 2022, the two larger plants were 3.5 m and 8.2 m in height, with new growth present on the latter; the two smaller plants had recently browned-off but were still alive.

Reproduction: one plant was observed fruiting in 2022 (Plate 4, Appendix 2).

Smooth Davidsonia (*Davidsonia johnsonii*)

Survival/condition: survival was 85% in 2022 (four mortalities). Six plants appeared dead in 2019 but one of these reshot in 2020 and another one in 2021; plants are growing in a clump with other tagged Smooth Davidsonia and it is likely that they are different stems of the same genetic individual as the species reproduces vegetatively via root-suckering (it is the species only known form of reproduction).

Growth: some plants went backwards in the 2019 drought but some continued to grow through 2020-2022. For plants under 3.5 m, average height was 197 cm in 2017 and 256 cm in 2022.

Reproduction: no flowers are fruit were recorded in spring 2022.

4 Conclusion and Recommendations

4.1 Threatened Rainforest Communities

The monitoring program has been running for nine years (since 2014) and has provided an in-depth understanding of the threatened rainforest communities adjacent Sections 10 and 11 of W2B and detected any changes to vegetation integrity that may be due to construction-related edge effects.

The main findings of the monitoring program at spring 2022 (third year of operation) for the threatened rainforest communities were:

- NMDS ordination of the monitoring data revealed that the rate of vegetation change (from February 2014 to Spring 2022) at the Impact sites was not consistently greater compared to the Control sites, suggesting no/minimal edge effects from construction.
- There were increases in the abundance of exotic species at some of the Impact sites but this has also occurred at Control sites, suggesting edge effects were not necessarily the cause.
- There were changes in the composition and structure of the rainforest at the monitoring sites but these changes are most likely due to natural ecosystem processes rather than induced edge effects.
- The rainforest patches in the project area differ in condition as a result of historical disturbances such as clearing, logging and grazing. Some patches have a higher abundance of problematic weeds such as Asparagus Fern, Small-leaved Privet and Ochna and should be the focus of management actions . In most situations, Camphor Laurel and Broad-leaved Privet should be retained for their ecosystem restoration benefits.
- There were no seedlings of key rainforest canopy species that would have been common in the area before European settlement but are now scarce/absent. Management actions for the site should include supplementation of the rainforest patches with these key canopy species (see Appendix 3).

4.2 Threatened Rainforest Species

The monitoring study has helped determine whether construction of Sections 10 and 11 of W2B has had any indirect impacts on the nearby threatened rainforest plants and added to our understanding of each species growth and reproduction. The main findings of the monitoring program at spring 2022 were:

- Survival was 100% for Red Lilly Pilly, 100% for Southern Ochrosia, 100% for Stinking Cryptocarya, 100% for Rough-shelled Bush Nut, 100% for Rusty Rose Walnut, 98% for Green-leaved Rose Walnut (1 mortality), 97% for White Lace Flower (1 mortality), and 85% for Smooth Davidsonia (3 mortalities).
- Individuals of Smooth Davidsonia and White Lace Flower appeared dead in 2019 but reshot and resumed growing in 2020-2022.

- Individuals of Green-leaved Rose Walnut, White Lace Flower and Smooth Davidsonia went backwards in the 2019 drought but resumed growing in 2020-2022.
- Throughout the monitoring program, flowering and/or fruiting was observed frequently for Rough-shelled Bush Nut but was relatively rare for the other threatened species.
- The March 2022 floods appeared to negatively affect some of the tagged plants – for example two Red Lilly Pilly growing beside Randles Creek that had brown/dead leaves, and Rough-shelled Bush Nut <3.5 m in height that had gone backwards in growth compared to 2021 – but had positive effects on others, for example Rough-shelled Bush Nut had the largest flowering/fruiting event during the monitoring program.

4.3 Performance Criteria and Recommendations

Of the Performance Criteria identified in the management plan (RMS 2015) and outlined in Section 1.2 above, all were considered to have been achieved and no corrective actions were required (Table 8).Abundance of exotic species at some sites recorded >5% weed cover, but this also occurred at the control sites and did not appear to be related to highway construction and operation

Table 8: Performance Criteria, Monitoring Results and Corrective Actions

Rainforest Species	**Monitoring Result**	**Corrective Action**	**TfNSW response**
Objective/Performance Criteria (see MP Table 8.3, Section 8.4)			
80% survival of threatened species after three years	85-100% survival of the threatened species after three years of operation monitoring.	Not required.	
<5% weed cover at in situ threatened flora sites.	>5% at some sites, but also at Control sites	Not required	
Rainforest Communities			
Objective/Performance Criteria (see MP Section 9.3)			
Not required	Not required	Not required	Not required
Evaluating the success of weed control program	Weed control work has decreased exotic cover in Plots 1, 5, 9 and 11.	Not required.	

	Plot 9 had large decreases in exotic cover due to poisoning of mature Camphor Laurel and Large-leaved Privet, but the aggressive exotic vine Coastal Morning Glory has since established underneath the resultant canopy gaps.		
Evaluating the success of mitigation measures, including protection of rainforest communities adjacent to the clearing extents and in situ threatened rainforest plant populations	No significant adverse impact detected	Not required	
Rainforest – General			
The objective of the monitoring program was to determine the effectiveness of mitigation measures in avoiding direct and indirect impacts and maintaining the condition of threatened rainforest communities and species during highway construction and operation (RMS 2015)	The majority of threatened rainforest species were in good condition after three years of operation monitoring. Six individuals have died since the monitoring program began, most likely due to moisture stress during the 2019 drought. Four of these six plants were Smooth Davidsonia stems part of the same genetic individual. The rainforest patches had good native species diversity and vegetation structure after three years of		

	operation monitoring. Weed cover differed among sites, which most likely reflects historical disturbances rather than project-related factors. In summary, no significant indirect impacts from the project have been detected throughout the monitoring program.		

5 References

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Appendix 1

Threatened Rainforest Communities Monitoring Plots, Spring 2022

Plot 1, SE corner

Plot 2, SE corner

Plot 3, SE corner

Plot 4, SE corner

Plot 5, SE corner

Plot 6, SE corner

Plot 7, SE corner

Plot 8, SE corner

Plot 9, SE corner

Plot 10, SE corner

Plot 11, SE corner

Plot 12, SE corner

Plot 13, SE corner

Plot 14, SE corner

Appendix 2

Threatened Rainforest Species, Spring 2022

Plate 1. *Macadamia tetraphylla* flowering, Tag ID 71.

Plate 2. *Ochrosia moorei*, tag ID 271.

Plate 3. *Syzygium hodgkinsoniae* with dead leaves most likely due to waterlogging, tag ID 230.

Plate 4. *Syzygium hodgkinsoniae* fruit, tag ID 1.

Appendix 3

Key mature-phase rainforest canopy species, missing from rainforest due to past clearing, recommended for supplementing remnant rainforest within and around the Blackwall Range (Ballina Shire, NSW)

From 2014 until 2022, the rainforest within and around the Blackwall Range (Ballina Shire, NSW) was monitored for changes in species composition, vegetation structure and recruitment success, as part of the Woolgoolga to Ballina (W2B) Pacific Highway upgrade.

One important finding of the monitoring program was that key mature phase canopy species that would have been dominant in the original rainforest (pre-European disturbance) in the area are scare or absent, most likely due to historical clearing and logging combined with poor recruitment success. The following is a list of these key mature phase canopy species that are scare/missing.

To help the rainforest in this area recover to its natural state, restoration activities should include measures to supplement the rainforest with these species. This could be achieved through direct seeding in rainforest canopy gaps or revegetation of cleared land.

For more information on seed collection, propagation and planting of subtropical rainforest species consult *Subtropical Rainforest Restoration* (Big Scrub Landcare 2019) and *Australian Rainforest Seeds* (Chapman et al. 2020).

Table 1: Species recommended for enrichment plantings in regrowth subtropical rainforest between Lumleys Lane to Coolgardie Rd. These species although typical of subtropical rainforest in the local area, are rare or absent from regrowth rainforest, which appears to have been totally cleared in the past.

Common Name	Botanical Name
White Booyong	*Argyrodendron trifoliatum*
Flame Tree	*Brachychiton acerifolium*
Blackbean	*Castanospermum austral*
Olivers Sassafras	*Cinnamomum oliveri*
Churnwood	*Citronella moorei*
Morton Bay Fig	*Ficus macrophylla*
Small-leaved Fig	*Ficus obliqua*
Strangler Fig	*Ficus watkinsiana*
Small-leaved Tamarind	*Diploglottis campbellii*

Yellow Tulipwood	*Drypetes deplanthei*
Rosewood	*Dysoxylum fraserianum*
White Quandong	*Elaeocarpus kirtonii*
Australian Teak	*Flindersia australis*
Cudgerie Tree	*Flindersia schottiana*
White Beech	*Gmelina leichhardtiana*
Silky Oak	*Grevillea robusta*
Alectryon tomentosus	*Hairy Alectryon*
Satinwood	*Harpullia pendula*
Ixora	*Ixora beckleri*
Red Carabeen	*Karabina benthamii*
Brachychiton discolor	*Lacebark*
Crows Ash	*Pentaceras austral*
Pseudoweinmania lachnocarpa	*Rose Marara*
Maidens Blush	*Sloanea australis*
Yellow Carabeen	*Sloanea woollsii*
Sour Cherry	*Syzygium corynanthum*
Coolamon Tree	*Syzygium moorei*
Red Cedar	*Toona ciliata*