Woolgoolga to Ballina Pacific Highway upgrade

Threatened Rainforest Communities and Rainforest Plants Monitoring Program

Annual Report 2019

Construction Phase Report

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Woolgoolga to Ballina Pacific Highway Upgrade, Sections 10 & 11, Threatened Rainforest Communities and Rainforest Plants, Annual Monitoring Report # 3 (2019)

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Executive Summary

As part of the rainforest management plan for the W2B project (Roads and Maritime 2015), a monitoring programme was implemented to record potential changes to threatened rainforest communities and threatened plants during the construction and operation phases on Sections 10 and 11 of the W2B project. Permanent plots were established to monitor changes in the composition and structure of rainforest communities. Threatened rainforest plants were also tagged to record changes in their growth and condition. The rainforest plots consisted of Impact and Control pairs and were located in four types of rainforest. Impact sites were positioned next to the highway and Control sites further back inside the rainforest. Threatened plants closest to the highway and further inside the rainforest were monitored. A total of 14 Impact and Control rainforest community plots and 213 threatened rainforest plants were included in the monitoring program.

Baseline data were recorded in February 2014 (EMM 2014). Construction phase monitoring was carried out 2017 to 2019 by Ecos Environmental Pty Ltd. This annual monitoring report describes the results of the final year of construction phase monitoring in 2019. Three years of operational phase monitoring is planned from 2020 after the highway opens.

Rainforest community plot data were analysed using ordination and data summary methods. PCA ordination found that the rate of vegetation change from February 2014 until spring 2019 at the Impact plots did not increase consistently relative to Control plots during construction, nor was it greatest in subplot a, closest to the highway. Results therefore provided no support for the hypothesis that vegetation changes would be greater in the Impact monitoring plots due to edge effects. This in turn implied that floristic changes occurring during construction were very minor.

Species-level examination of the data found there were increases in the number and/or abundance of exotic species at some of the Impact sites, but this also occurred at Control sites, suggesting that edge effects related to vegetation clearing were not necessarily the cause. Species richness at the subplot level stayed relatively constant or increased slightly over three years, again indicating that the rainforest communities remained relatively stable in species composition during the construction phase.

Only one threatened rainforest plant mortality was recorded in the first two years of monitoring. This year (Jan 2020) there was a marked increase in the number of monitored plants showing substantial foliage browning off and leaf fall, in some cases complete defoliation and possible mortality. This was most likely due to the very dry conditions in 2019, one of the driest years on record for the Ballina locality.

Although there may be a perception that the effects of the 2019 were increased by edge effects caused by clearing of the highway corridor, the monitoring data and general observation indicated that browning off and leaf fall were general throughout rainforest vegetation and not concentrated on the edge of rainforest next to the highway, therefore were unrelated to construction. Overall, the effects of the drought did not appear to greatly change rainforest species composition or the integrity and intactness of rainforest communities. The results of the forthcoming Spring 2020 monitoring will show whether any significant short-term changes in rainforest composition and structure have occurred.

1 Introduction

Roads and Maritime Services (Roads and Maritime) aims to minimise impacts on threatened rainforest communities and rainforest plant species during construction and operation of Sections 10 and 11 of the Woolgoolga to Ballina (W2B) upgrade of the Pacific Highway. 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 changes in species composition and condition. These are set out in the Woolgoolga to Ballina Threatened Rainforest Communities and Rainforest Plants Management Plan (Roads and Maritime 2015). Further information on the monitoring methodology is given in the baseline monitoring report - Rainforest Communities and Threatened Rainforest Plants Preconstruction Targeted Surveys and Baseline Monitoring Report (EMM 2014).

The objective of monitoring is 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 (Roads and Maritime 2015).

The monitoring program includes three years of construction phase monitoring. The first two years of monitoring was undertaken in 2017-18 during construction activities on Sections 10 and 11. The results are described in two annual monitoring reports (Ecos Environmental 2017 and 2018).

Herein we present the findings of year 3 (2019) of construction phase monitoring of threatened rainforest communities and rainforest plant species on Sections 10 and 11 of the W2B project. The contents of this report have been set out as follows:

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

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 1999 (EPBC Act) listed Lowland Rainforest of Subtropical Australia, which has the status of critically endangered ecological community (CEEC); and

- Littoral Rainforest in the South East Corner, Sydney Basin and NSW North Coast Bioregions (herein referred to as Littoral Rainforest) - listed under the BC 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 EMM rainforest survey in 2014 (see below) 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, or sub-forms of, 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 Environmental (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 between Lumleys Lane and Whytes Lane on Section 10-11 (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 (Roads and Maritime 2015). Impact sites were located as close as possible to the clearing boundary. The Impact sites are potentially subject to the indirect impacts of clearing such as changes in microclimate, weed invasion, protracted waterlogging, soil nutrient increase and other habitat changes. 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 1a, 1b, 1c and 1d, etc. The long edge of each subplot was aligned parallel with the clearing boundary (Figure 2). Subplot a was always closest to the clearing boundary and sub-plot d was placed furthest from the boundary.

GPS coordinates and photographs were taken at the south-east corner 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 subplot.

Within each of the four subplots, the following data were recorded:

- The general health of plants
- Any disturbances or weed invasion
- General landscape features (slope, aspect, soil, etc)
- 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.

Species abundance was recorded as crown-cover, which can be defined as the percentage of the plot area (or subplot 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. The area estimate is made visually, using as guide that 1 x 1 m^2 = 1% of the sub-plot (5 m x 20 m) area, 5 m x 5 m = 25%, etc. Species with less than 1% cover were recorded as 0.5%. Species crown cover was recorded for each height stratum. For further details and results of the baseline survey see EMM (2014).

<u>Monitoring Schedule (Construction Phase)</u>

Rainforest communities – twice a year (Autumn and Spring) for 3 years.

Rainforest plant species – 4 times in year 1 (Summer, Autumn, Winter and Spring), twice in year 2 (Autumn and Spring), and once in year 3 (end of year)

<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 (Table 3).

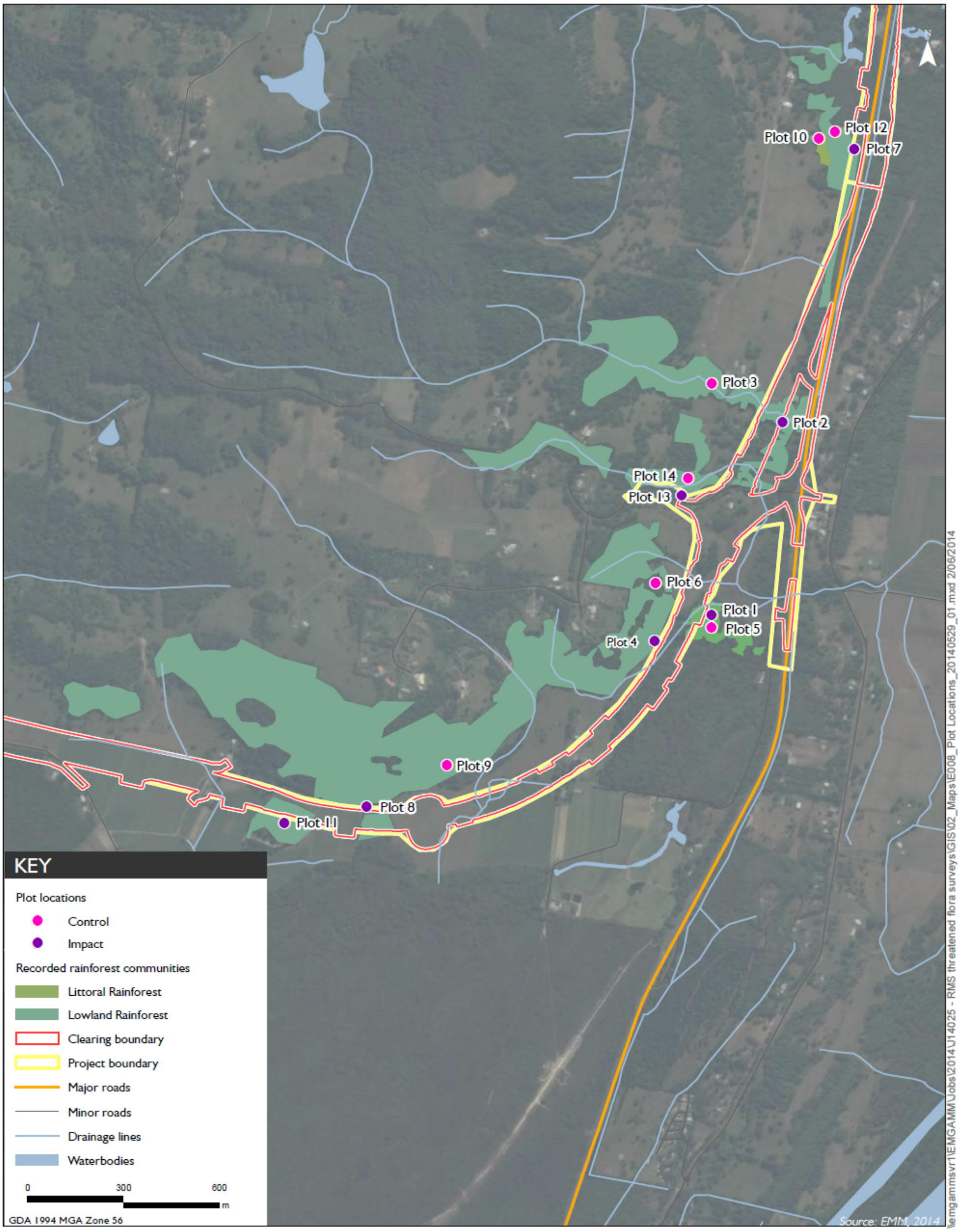

Figure 1: Monitoring plots in relation to W2B Pacific Highway upgrade project boundary and threatened rainforest communities. Map is sourced from EMM (2014).

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 Randell's 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 Çoolgardie Rd.
14	Control		~50m north

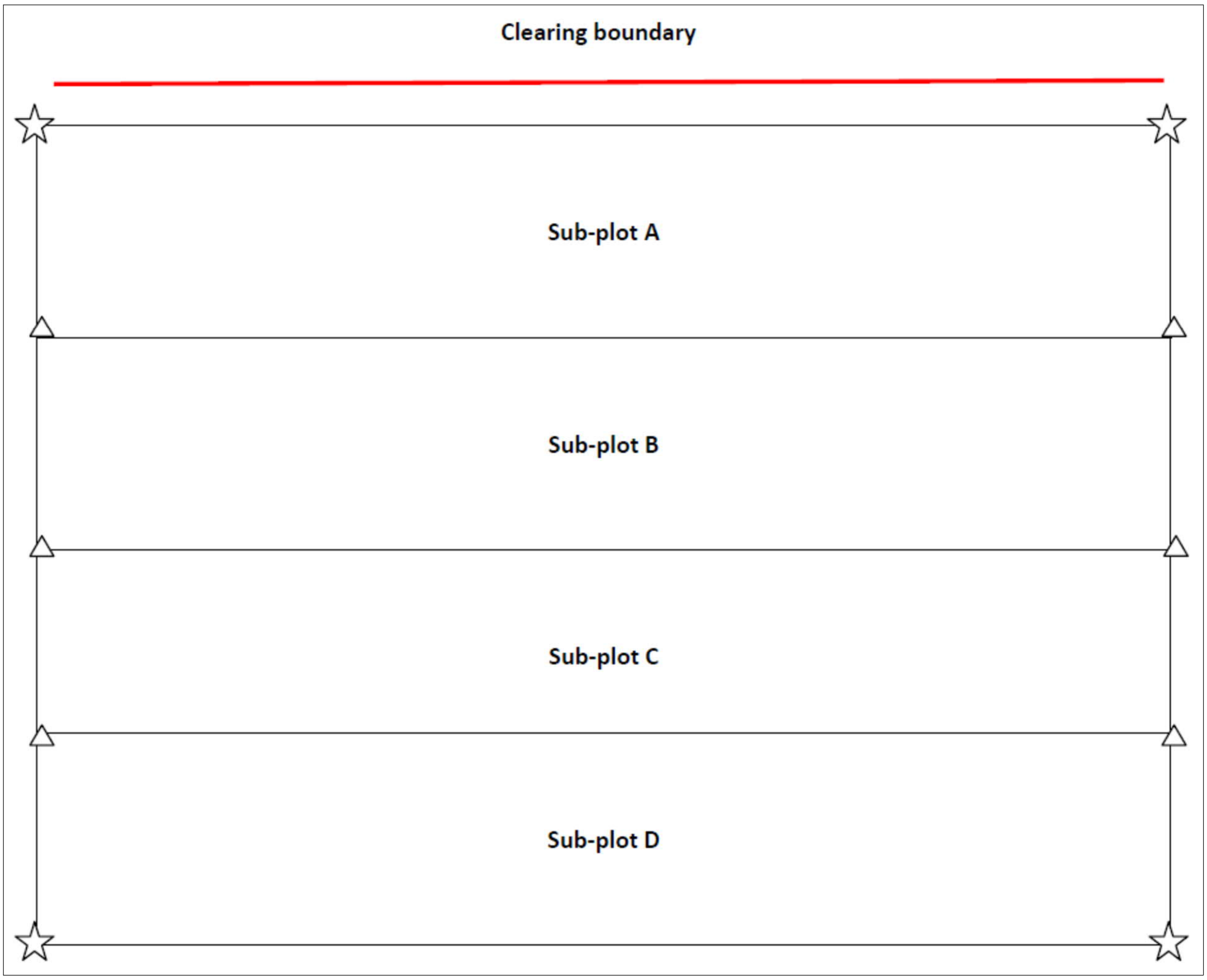

Figure 2: Plot layout for threatened rainforest communities monitoring. Plots were 20 m x 20 m and divided into four 20 m x 5 m sub-plots. Diagram is sourced from EMM (2014).

2.2 Data Analysis

2.2.1 Ordination and point sequences

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 predictions about how the vegetation at the monitoring sites will change following construction and operation of the highway, such as:

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

To test these predictions, the following data analysis method was used, which is taken from Chapter 7 of Data Analysis In Vegetation Ecology (Wildi 2017) and is used for detecting and investigating temporal trends in vegetation.

An excel spreadsheet containing the baseline data (Autumn 2014) for subplot a of each site and the Autumn 2019 data for sub-plot a of each site was imported into a data matrix object in the statistical software R (R Core Team 2018). Principal Component Analysis (PCA) was performed on all the sites and then separately on each pair of Control and Impact sites (e.g. Plot 2 and Plot 3, Plot 1 and Plot 5, etc) using the pcaser function in the dave package (Wildi 2017). Like all ordination methods, PCA enables complex multivariate datasets to be arranged in two-dimensional space where the closer samples (represented by points) are to each other, the more similar (in terms of the variables measured) they are. To make it clearer to see trends in ordination space, only the baseline data and the autumn 2019 data for subplot a of each site were analysed. Note, that the rate of vegetation change at the impact sites is expected to be greatest at subplot a as it is closest to construction.

2.2.2 Number, abundance and recruitment of exotic species

Number of exotic species and abundance of exotic species were used as indicators of rainforest condition. An increase in either of these indicators was interpreted as a decline in vegetation condition. Number of exotic species per plot was derived by counting the number of exotic species in each sub-plot and then averaging across the four sub-plots. The abundance of exotic species per plot was derived in the same way.

2.2.3 Native species diversity

Native species diversity was also used as an indicator of rainforest condition. More or less constant species richness was considered an indicator that rainforest was not declining in condition.

Species richness per plot was derived by counting the number of species in each subplot and then averaging across the four subplots.

2.3 Results

2.3.1 Weather Conditions

Table 2 shows the annual rainfall at Ballina between 2010 and end of 2019. Baseline data for the rainforest monitoring was collected in 2014 and early works construction started in 2015. Clearing of the highway corridor through Sections 10-11 started in late 2017.

Mean rainfall at Ballina for the last ten years is 1733.92 mm. Mean annual rainfall at Ballina over 25 years (i.e. all the data available on BoM website) is 1789 mm, therefore indicating a decline in rainfall over the last 10 years.

It can be seen from Table 2 that three out of the last 10 years had rainfall substantially below average – 2014, 2016 and 2019 . The current year (2019) was particularly dry, although data going back to 1885 at Woodburn (http://www.bom.gov.au/climate/data/) indicates two or three years in the period between 1900 and 1920 were as dry or drier than 2019. Table 2 also shows that six out of the last ten years had an annual rainfall above average.

In the last ten years there appears to have been a shift in the amount of rain received in different seasons. An inspection of Figure 3, which plots mean and actual monthly rainfall, shows that rainfall was below average during the spring to summer period every year from 2012 to 2019 (i.e. for almost eight years). In contrast, higher than average monthly rainfall often occurred in the wet season, including March/2017 which recorded the second highest monthly rainfall on record (after March 1974). (This is based on 25 years of rainfall data, the maximum amount of data available on BoM website for Ballina.)

Overall the weather pattern during the last 10 years, and particularly 2014-2019, appeared to be characterised by greater variability than usual. The net result for plants, particularly rainforest plants was probably greater stress, either from longer and more intense dry periods and higher temperatures in the dry season, or more flash flooding and long periods of waterlogged soil in the rainy season.

Table 2: Total annual rainfall (mm) at Ballina 2010-2019

2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
2239	1912.8	1905	1967.8	1279	2024.4	1225.2	2165.2	1649.2	971.6

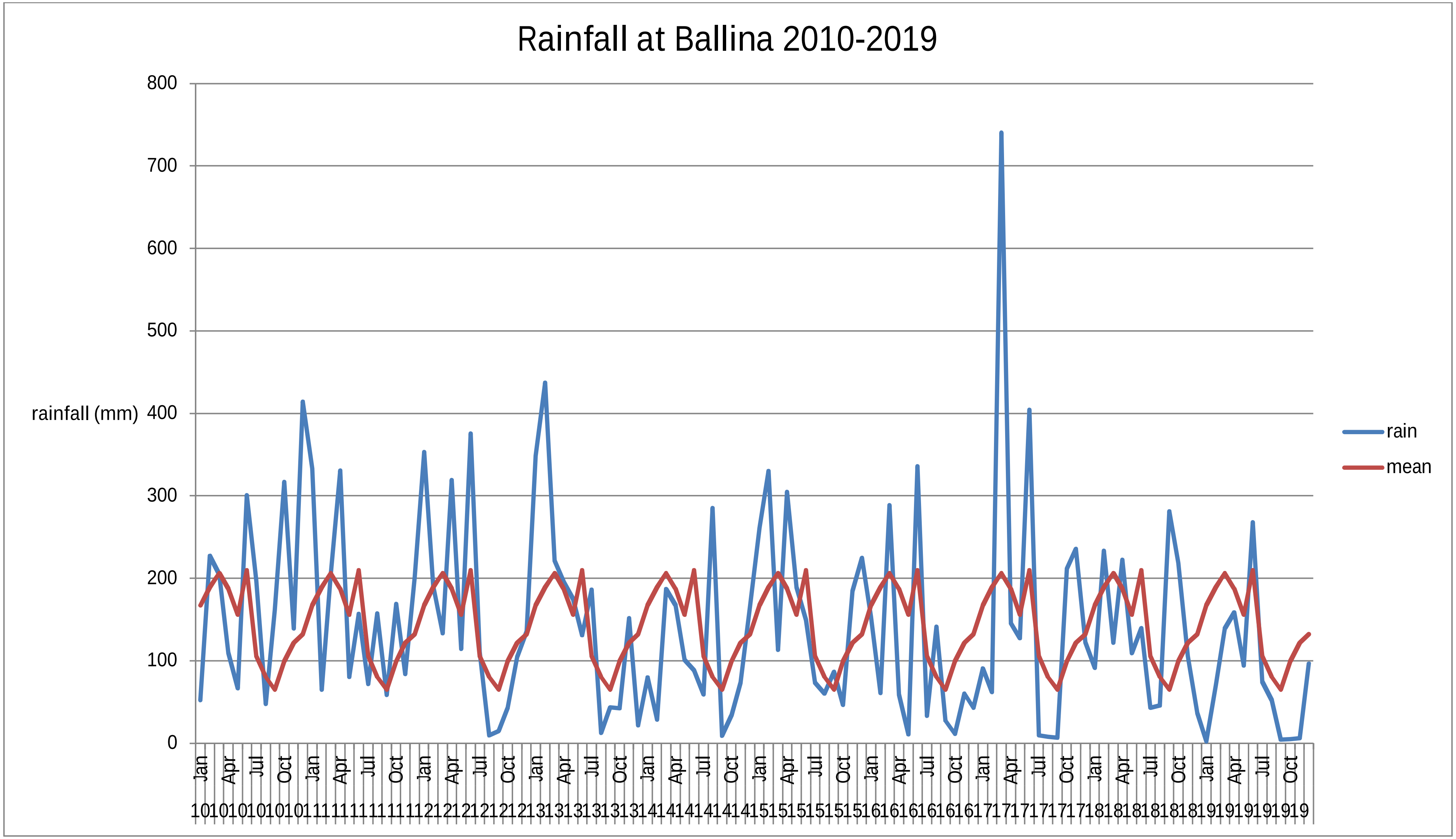

Figure 3: Average monthly and actual monthly rainfall at Ballina between 2010 and 2019, the closest station to the Sections 10 and 11.

2.3.2 Ordination and point sequences

Each PCA graph showed the rate of vegetation change at subplot a of each pair of Control and Impact sites (Figure 4 and 5). In each PCA graph the length of the line connecting the two points in the time series indicates the rate of change, i.e. the longer the line, the greater the rate of change. If the highway upgrade has negatively affected the adjacent rainforest communities through edge effects, we would expect the rate of change at the Impact sites to be greater than at the Control sites. This was the case for some areas, for example, Plot 2 and Plot 3. Subplot 2a (Impact) has changed more than subplot 3a (Control) (Figure 4). However, for other areas, the Control site has changed more than the Impact site, for example, Plot 8 and Plot 9 (Figure 5). 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 about the impact of the highway upgrade on the neighbouring rainforest communities.

The PCA graphs for the other paired sites are included in Appendix 3.

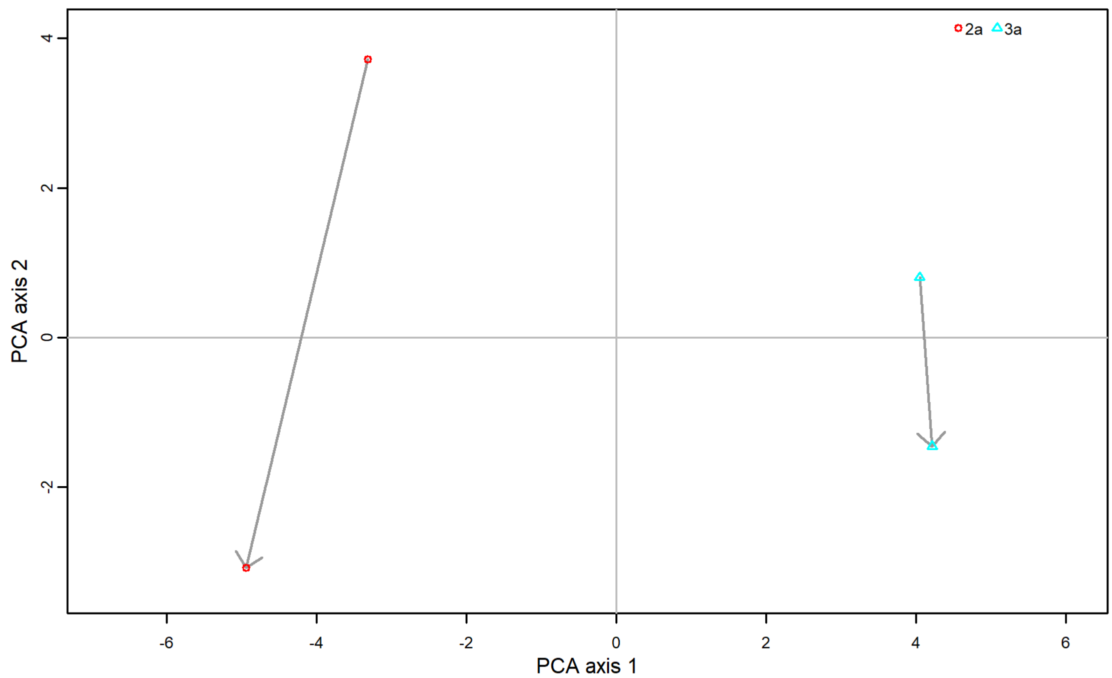

Figure 4: PCA ordination graph of a time series of subplot 2a (Impact) and subplot 3a (Control). The arrow points from the beginning state (i.e. Autumn 2014) to the end state (i.e. Autumn 2019). Note that the rate of vegetation change is greater at the Impact site.

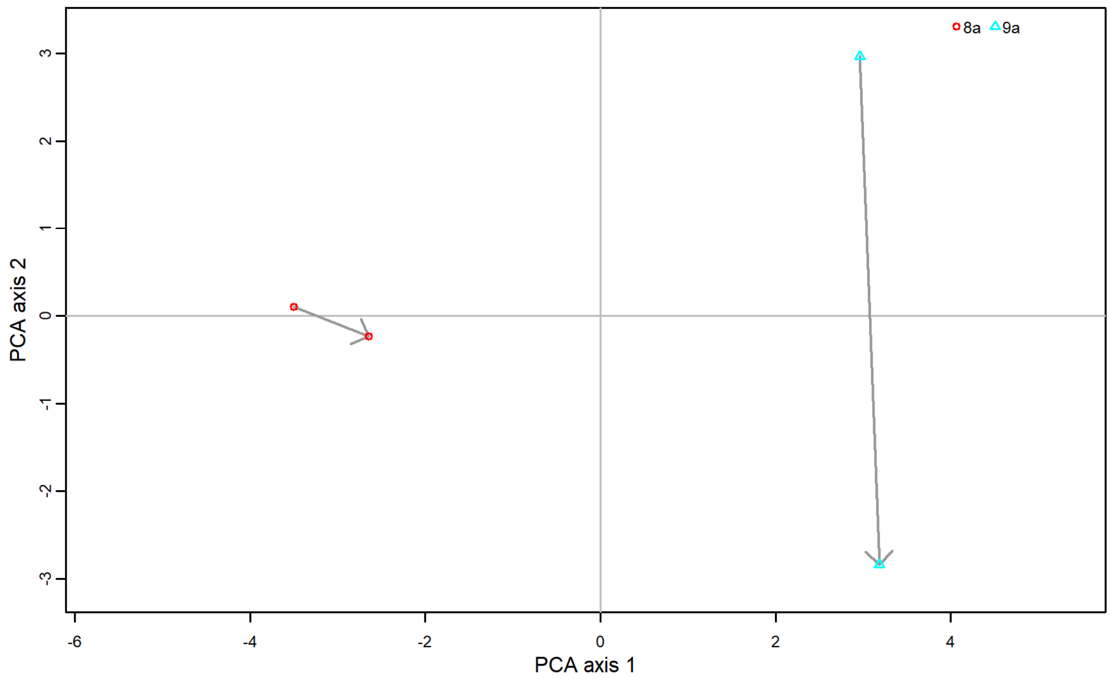

Figure 5: PCA ordination graph of a time series of subplot 8a (Impact) and subplot 9a (Control). The arrow points from the beginning state (i.e. Autumn 2014) to the end state (i.e. Autumn 2019). Note that the rate of vegetation change is greater at the control site.

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 five years (2014-2019), 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 3). 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 3: 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

Impact plot	Approx. distance of plot to edge of clearing/ construction	Effective/ineffective clearing
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 generally extended no 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 according to the former study would be unlikely to register a significant increase in weediness due to reduced distance to the forest edge.

Positioning of the Impact plots away from the actual edge of clearing was unavoidable as they were installed in 2014 and relied on early models of the road design and construction footprint.

Ordination methods are useful for simplifying complex datasets and detecting overall tends 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 forms or strata within the plant community) as described below.

2.3.3 Exotic species – changes in abundance

A total of 40 exotic species were recorded in the rainforest plots. The great majority of these were common herbaceous weeds of minor concern ecologically. About 10 species were environmental weeds that can build up large infestations in native bushland.

The average number of exotic species per subplot has fluctuated across monitoring events but overall remained about the same (Table 4). Since Spring 2017, noticeable changes have occurred at Plot 2 – rising from three exotic species per subplot to eight – and Plot 13 – rising from six exotic species per subplot to nine. This may be evidence of an edge effect, as construction began in 2017 and both Plot 2 and 13 are impact sites less than 10 m from the edge of clearing. The additional exotic species included short-lived species of little concern, but perennials such as Asparagus Fern and Ochna pose a potential threat to the integrity of the rainforest communities.

In terms of species abundance or crown cover, there has been about an 80% increase in exotic species from February 2014 to Spring 2019 (Table 5). Exotic species abundance, however, has increased in both the control and impact sites, and was increasing before construction began in 2017. This suggests that edge effects resulting from clearing for the highway upgrade are not the cause. This trend was noted in the first monitoring report and removal of cattle, which were grazing the forest along the alignment in 2014 (pers. obs.), was suggested as the possible cause.

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 forest as a result of cattle foraging but as long as cattle continue to graze the forest the weeds are controlled. An increase in weediness at control and impact sites suggests that cattle removal during construction may be the causal factor, as both control and impact sites were previously grazed. (Prior to construction, cattle were grazed along a cleared corridor at the base of the Blackwall Range and adjoining areas of forest by two or three farmers).

In Spring and Summer 2019 there was evidence of cattle grazing in the forest again. Fencing off the highway has allowed farmers to restock paddocks next to the highway again. This may help to control increasing populations of environmental weed in some areas, although only about a quarter of the sites had evidence of grazing at the end of 2019.

The last monitoring report discussed how the two exotic trees Cinnamomum camphora (Camphor Laurel) and Ligustrum lucidum (Broad-leaved Privet) have played a key role in enabling the regeneration of subtropical rainforest on the Blackwall Range by acting as a initial nursery layer to enable the seedlings of native species dispersed by birds to become established. On the rocky slopes of the Blackwall Range escarpment upslope of the new highway, rainforest regrowth is dominated by Camphor Laurel and Privet, but native trees, shrubs, ferns and herbs are establishing in the lower strata of the forest, and native vines are already abundant and co-dominant in much of the regenerating rainforest canopy, also playing a key role in rainforest regeneration.

Table 4: Average number of exotic species per subplot for each plot through time. Averages rounded to the nearest one.

		February 2014	Autumn 2017	Spring 2017	Spring 2018	Spring 2019
1	Impact	3	3	4	4	4
5	Control	4	2	4	4	4
2	Impact	4	2	3	8	8
3	Control	4	3	4	6	6
4	Impact	6	3	5	5	5
6	Control	6	4	6	5	5
7	Impact	3	2	1	3	4
12	Control	2	1	1	1	2

		February 2014	Autumn 2017	Spring 2017	Spring 2018	Spring 2019
8	Impact	5	3	4	4	6
9	Control	4	3	3	4	5
11	Impact	4	4	5	6	7
10	Control	4	3	3	2	4
13	Impact	7	6	6	9	9
14	Control	4	3	4	4	5
Overall av Impact		5	3	4	6	6
Overall av Control		4	3	4	4	5

Table 5: Average abundance of exotic species across the four subplots of each plot, through time. 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	Autumn 2017	Summer 2017	Summer 2018	Summer 2019
1	Impact	2	4	14	12	11
5	Control	12	10	18	25	22
2	Impact	11	36	18	35	30
3	Control	4	7	7	18	15
4	Impact	61	81	102	106	95
6	Control	28	41	37	57	52
7	Impact	2	1	1	2	1
12	Control	1	1	<0.5	1	1
8	Impact	103	92	127	114	117
9	Control	68	42	63	73	72

		February 2014	Autumn 2017	Summer 2017	Summer 2018	Summer 2019
11	Impact	4	12	19	12	10
10	Control	4	2	2	4	5
13	Impact	38	54	37	92	81
14	Control	5	2	6	9	6
Overall average Impact		32	40	45	53	49
Overall average Control		17	15	22	27	25

2.3.4 Native Species Diversity

A total of 255 native plant species were recorded in the rainforest plots, along with 40 exotic species.

Species diversity at the monitoring sites expressed as the average number of species per subplot has remained more or less constant with an overall average of 31-33 species per subplot between 2014 and 2019.

At Plot 2 (Impact) and Plot 3 (Control), however, there were relatively large increases from 26 to 37, and 43 to 52, respectively.

Table 6: Average species richness (including native and exotic species) per subplot for each plot through time.

		February 2014	Autumn 2017	Spring 2017	Spring 2018	Spring 2019
1	Impact	23	26	29	31	30
5	Control	24	19	19	25	26
2	Impact	26	25	27	37	37
3	Control	43	35	52	50	52
4	Impact	28	26	30	30	29
6	Control	29	24	30	27	25

		February 2014	Autumn 2017	Spring 2017	Spring 2018	Spring 2019
7	Impact	22	23	19	27	29
12	Control	18	16	14	16	17
8	Impact	35	25	24	32	30
9	Control	42	33	35	35	37
10	Impact	26	23	27	22	21
11	Control	39	35	39	44	41
13	Impact	42	31	33	39	38
14	Control	39	29	40	40	40
Overall average		31	26	31	33	32

2.3.5 Effect of 2019 drought

Rainforest community monitoring was carried out in Spring 2019 before the effects of the 2019 drought became very pronounced. To assess the general effects of the drought on vegetation at the peak of drought, an inspection of plots was carried out in January 2020, during the threatened plant monitoring. Observations at each plot are summarised in Table 7 below.

The main findings were as follows:

- A few large native trees had died, or were completely defoliated, including Guioa semiglauca, but other than that there was no evidence of widespread tree death.
- Vine dieback was noticeable, particularly Whip Vine (Flagellaria indica) and Cissus species.
- Dieback of ground ferns was widespread and quite severe, often 100%.
- Leaf fall throughout rainforest areas was high with a thick layer of recently shed leaves on the forest floor; the overall effect of the drought was to cause substantial leaf fall in normally evergreen subtropical rainforest species.
- Defoliation of Camphor Laurel was widespread; many trees had lost over half their leaves.
- Some defoliation of small trees and saplings was evident but not very great.
- A significant percentage of threatened plants were affected by drought, as detailed below.

Table 7: Drought effects observed at rainforest monitoring plots in January 2020

Paired sites	Impact/ Control	Rainforest Type	Drought Effects
1	Impact	Littoral rainforest	Litsea australis foliage browning off (25-50%) particularly on the forest edge
5	Control	Littoral rainforest	No drought stress evident
2	Impact	Floodplain STRF	Little evidence of drought effect apart from possible increased leaf fall
3	Control	Floodplain STRF	Little drought effect, some minor wilting, no trees dead or defoliated; some saplings defoliated including White Laceflower
4	Impact	Hillside STRF	No dieback apart from Camphor shedding 50-75% of foliage
6	Control	Hillside STRF	Flagellaria 100% brown off, Camphor dropped 50-75% of foliage, otherwise not much evidence of drought, other trees and saplings ok
7	Impact	Swamp STRF	Some fern dieback, otherwise no drought effect
12	Control	Swamp STRF	Some fern dieback, otherwise no drought effect
8	Impact	Hillside STRF	No evidence of drought effect
9	Control	Hillside STRF	Fern die back, heavy leaf fall on ground, but canopy still intact and most trees appear unaffected.
10	Impact	Littoral rainforest	Fern die back, Pellaea 60% dieback, Litsea dieback 50% lot of leaflets on ground, otherwise no other noticeable effects
11	Control	Littoral rainforest	Drought affected understory vines and tree saplings:- Smilax dieback, Alpinia dieback 50%; some Litsea saplings 100% dieback, Livistona seedlings brown-off; Diploglottis 75% dieback, Stenocarpus 75% dieback, Syzygium oleosum dieback, Calamus dieback. Saplings generally about 1/3 defoliated. All ferns died off; thick leaf litter, Bridelia defoliated, but overall, effects minor and limited to small saplings and ferns, and increased leaf fall.

Paired sites	Impact/ Control	Rainforest Type	Drought Effects
13	Impact	Hillside STRF	Large Guioa tree 100% defoliated possibly dead; vines have shed 50-25% of leaves; Camphor Laurel heavy leaf fall, thick deposit of leaves on the ground.
14	Control	Hillside STRF	Flagellaria 100% brown-off, Brush Kurrajong and Mallotus philippinensis 80-100% defoliated, tall vines heavily defoliated, Calamus brown-off, Camphor 80% defoliated, heavy leaf litter layer

3 Threatened Rainforest Plant Monitoring

3.1 Species included 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 located adjacent the construction corridor and potentially affected by construction activities were included in the monitoring program:

- 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 the first monitoring report (Ecos Environmental 2017).

3.2 Data collection and analysis

A total of 213 plants were monitored between 2017 and 2019 (Figure 6). They were initially tagged and recorded in Feb/2014 then relocated and recorded again in 2017 (Ecos Environmental 2017).

The following plant attributes were recorded: plant condition on a scale of 0-5 (Table 8), 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.

To assess rates of growth between 2017 and 2019, only plants measured with the tape measure were included in the data analysed. These results are shown in Figure 7 below. Note – EMM did not record plant height in 2014.

Rainforest plant species were monitored 4 times in year 1 (2017), twice in year 2 (2018) and once in year 3 (2019).

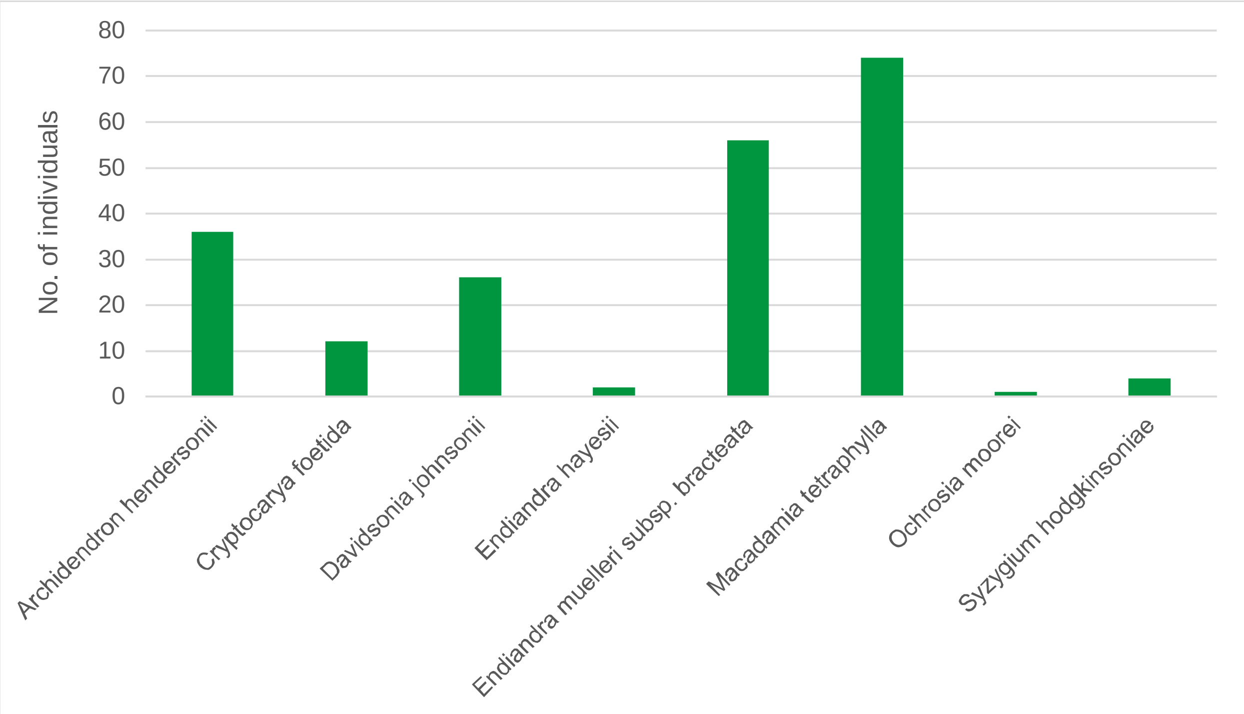

Figure 6: Species and numbers of individuals included in the monitoring program. Total number of individuals is 213.

Table 8: 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

3.4 Results

3.4.1 Summary

In the period between 2014 and 2018, a single mortality was recorded among 213 threatened plants - a White Laceflower tree near Plot 1, Kays Lane. This appeared to be a natural tree death, as the tree was already in poor condition in 2017.

In Jan 2019, substantial numbers of plants of five of the eight threatened species being monitored were showing leaf browning-off and leaf fall. This was due to a long period of below average monthly rainfall in 2019, compounded by drier than usual preceding years (see Section 2.3.1). Plants showing leaf browning-off and leaf fall that affected more than half the plants foliage was considered to be strongly affected by drought and in poor condition. The impact of the drought was most evident in Smooth-leaved Davidsonia where 38% of stems were leafless and appeared to be dead.

Height measurements of plants <3.5 m high showed that all but one species increased in mean height between 2017 and 2019 (Table 9; Figure 7). So despite the increase in the percentage of plants in poor condition in 2019, species had still grown and increased in height over three years.

Table 9: Results of threatened plant monitoring for plants less than 3.5 m high, showing the percentage of each species in poor condition in Jan 2020, and change in plant height between 2017 and Jan 2020. Plants <3.5 m high were measured with a tape measure.

Threatened Species	% of plants strongly affected by drought – i.e. in poor condition	% change in mean height from 2017 to Jan 2020
White Laceflower	22% (mostly seedlings)	15%
Stinking Cryptocarya	25% (one out of 4)	3%
Smooth-leaved Davidsonia'	38%	-1%
Rusty Rose Walnut	12%	13%
Rough-shelled Bush Nut	6%	18%
Red Lilly Pilly	0%	31%
Southern Ochrosia	0%	6%
Velvet Laurel	50% (one out of 2)	13%

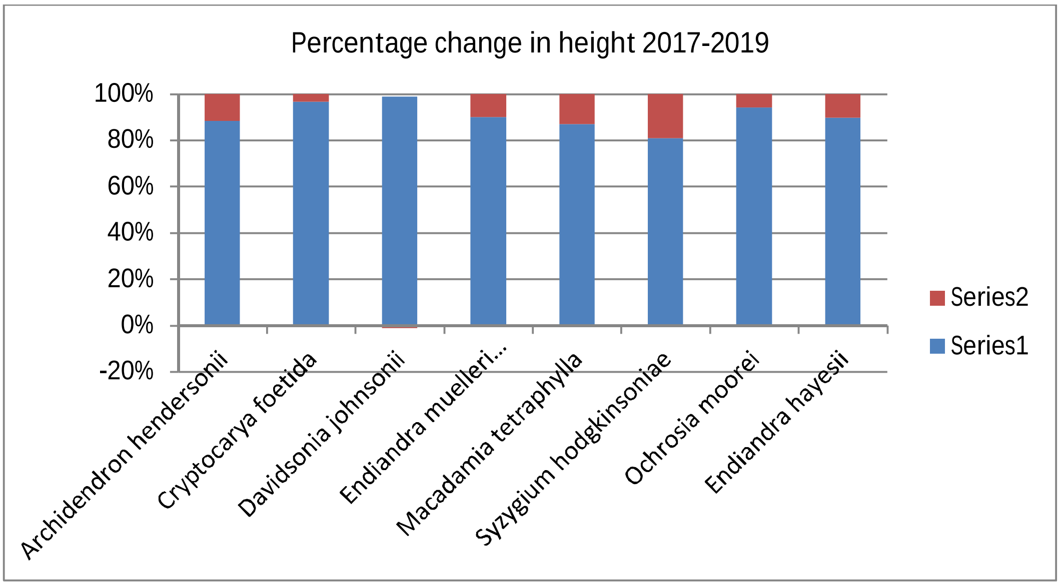

Figure 7: Percentage change in average plant height in threatened species between 2017 and 2019. Series 1 = height 2017; series 2 = height increment 2017-2019 (Jan 2020).

3.4.2 Condition of Threatened Species 2019

<u>Rough-shelled Bush Nut (Macadamia tetraphylla)</u>

Survival/condition: 5 individuals with at least 50% of leaves browned off, representing 6% of the total monitored (i.e. 94% showing no ill effects of drought); no browning off at this level was recorded in previous years.

Growth: average 18% increase in height over 3 years in plants under 3.5 m high. Very little active shoot growth at last monitoring.

Reproduction: 4 individuals recorded with small numbers of nuts, many others had flowered but not set seed, as indicated by dead floral axes

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

Survival/condition: 7 individuals heavily defoliated, representing 12% of the total being monitored; some individuals were 100% defoliated but reshooting at base. No defoliation recorded in previous years.

Growth: average 13% increase in height over 3 years in plants under 3.5 m. Very few new shoots recorded.

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

White Lace Flower (Archidendron hendersonii)

Survival/condition: 8 individuals dead or defoliated, representing 18% of the total monitored, although half of these were seedlings. Two larger plants appear to be dead. One probably died last year and did not reshot.
Growth: 15% increase in height over 3 years in plants under 3.5 m. Very few new shoots recorded.

Reproduction: a few orange pods were present on one tree, representing the end of the season.

Rusty Rose Walnut (Endiandra hayesii)

Survival/condition: 1 individual (out of two) heavily defoliated

Growth: 13% increase in height over 3 years in plants under 3.5 m. Very few new shoots recorded.

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

Stinking Cryptocarya (Cryptocarya foetida)

Survival/condition: 1 individual broken off by fallen limb. (Note – number less than originally recorded as several individuals appear to be Cryptocarya microneura.)

Growth: 3% increase in height over 3 years in plants under 3.5 m. Very few new shoots recorded.

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

Southern Ochrosia (Ochrosia moorei)

Survival/condition: single tree being monitored was in good condition

Growth: 6% increase in height over 3 years.

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

Red Lilly Pilly (Syzygium hodgkinsoniae)

Survival/condition: all individuals in good condition, no evidence of significant defoliation.

Growth: 31% increase in height over 3 years.

Reproduction: a few flower buds were observed 2019.

Smooth Davidsonia (Davidsonia johnsonii)

Survival/condition: 38% of stems dead in January 2020

Growth: negaive growth (just) recorded in last three years

Reproduction: nil

Velvet Laurel (Endiandra hayesii)

Survival/condition: one tree was partly defoliated in January 2020

Growth: 13% increase in height over 3 years.

Reproduction: nil

3.4.3 Weed Spraying, Access Tracks and Threatened Species

There was evidence of roadside herbicide spraying having affected the threatened species Native Guava (Rhodomyrtus psidioides). This species has recently been listed as Critically Endangered due to a dramatic decline in populations caused by the introduced disease Myrtle Rust.

The affected plants were recorded between Plot 11 and the highway footprint, amongst Lantana which had been sprayed. The plants were reshooting and appear to have been defoliated by the herbicide, but not killed (see Plates 1-3).

Native Guava (Rhodomyrtus psidioides) also occurs in Plot 10 on private property north of Coolgardie Road and near Plots 1 and 2 off Kays Lane, near the highway footprint.

A mature White Laceflower (Archidendron hendersonii) tree next to the highway just north of Lumleys Lane has produced several large root sucker shoots on a sandy track that appears to be used as an access for maintenance and monitoring work. We marked the plants on the track with stakes and pink tape with threatened species written on it, but an alternative access needs to be worked out so they are not damaged by accident in future (see Plates 4-5).

Table 10: Location of additional White Laceflower requiring management actions

Tag	Coordinates	Comments
AHN6	28.93166 153.46205	Large White Laceflower on corner of rainforest block next to track, unmarked before we put pink flagging tape on it. Seeding, end of season. Height 9.5 m, diameter 50 cm
AHN1	28.93157 153.462127	Root sucker shoots growing from AHN6 on sandy track, leaf tufts to 70 cm high
AHN2		
AHN3		
AHN4		
AHN5		

Also, a founder population of the environmental weed Giant Devils Fig (Solanum chrysotrichum), a vigorous invader of native bush, was observed next to the fauna fence in the Lumleys Lane area. This should be eradicated as soon as possible and any fruit on the plants collected and destroyed (see Plate 6).

Plate 1: Roadside bush near rainforest community Plot 11 showing ground layer die-off from herbicide spraying.

Plate 2: Regrowth in the ground layer at the site in Plate 1, two shoots of Native Guava (Rhodomyrtus psidiodes) with pink tape. The grass is Broad-leaved Paspalum an environmental weed that reshot after being sprayed.

Plate 3: Dead Lantana in the same area, which has been over-sprayed probably with a spray gun. Spray drift has affected the adjoining littoral rainforest edge containing the Critically Endangered species Native Guava (Rhodomyrtus psidiodes), see Plates 1 and 2.

Plate 4: White Laceflower (Archidendron hendersonii) tree previously unmarked north of Lumleys Lane.

Plate 5: White Laceflower (Archidendron hendersonii) root sucker shoots on a sandy access track next to a fauna underpass tunnel just north of Lumleys Lane. The shoots are coming from the tree in Plate 4 above.

 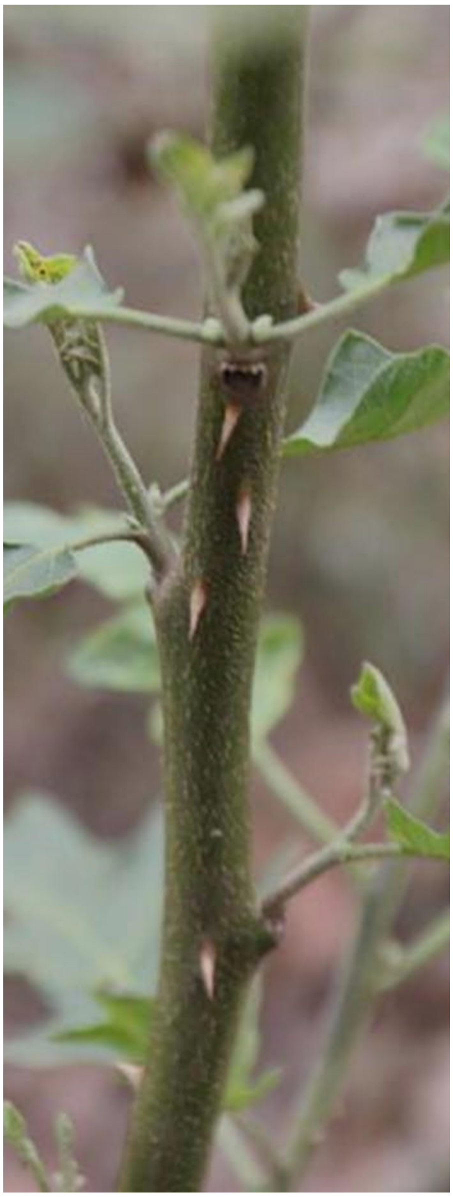

Plate 6: Giant Devils Fig (Solanum chrysotrichum). This tall solanum with sharp thorns on its stems is an environmental weed in NSW and Qld. It invades most types of native forest and forms dense stands impossible to walk through because of the thorny stems. It is expanding its range in NSW and is presently not common south of the Tweed valley.

A few plants were seen on the edge of the highway in the Lumleys Lane area on the northern side of the alignment about 50 m west of rainforest plot 8. These plants should be killed as soon as possible to prevent them spreading into subtropical rainforest regrowth on the Blackwall Range next to the highway.

4 Conclusion and recommendations

4.1 Main Findings

The main findings of the third year of construction phase monitoring of the threatened rainforest communities were:

- PCA ordination of the monitoring data revealed that the rate of vegetation change (from February 2014 to Spring 2019) 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 number of exotic species at some of the Impact sites but these are mostly short-lived annuals that do not threaten the integrity of the rainforest communities
- There has been increases in the abundance of exotic species at some of the Impact sites but this has also occurred at Control sites, suggesting edge effects are not necessarily the cause
- Species richness (natives and exotics) at the subplot level has overall slightly increased
- Evidence of the impact of the 2019 drought on vegetation was observed in January 2019, mostly as partial defoliation of trees, vines and saplings, and browning off of ferns in the ground layer. There was no evidence that drought die-off was exacerbated by clearing of the highway corridor, such as increased browning-off of vegetation along the edge of the highway. Overall, despite the severity of the drought and the large amount of leaf fall, death of trees and canopy vines appeared to be rare. Most affected plants are likely to recover during the rainy season.

Ongoing monitoring of the threatened rainforest communities for indirect impacts will gauge longer-term effects as operation of the highway upgrade begins.

4.2 Threatened rainforest plant species

The 2019 drought had a negative impact on threatened plants in six out of the eight species being monitoring, causing browning-off and whole or partial defoliation. Again, this was primarily a natural phenomenon related to severe water stress due to the rainfall in 2019 being well below the average. There was no evidence that drought effects were exacerbated by clearing and construction of the highway.

Most of the defoliated or partly defoliated threatened plants are likely to recover by reshooting as the drought breaks and the rainy season begins. Translocation work with most of the species being monitored has shown these species have the capacity to regenerate following severe physical disturbance and defoliation (i.e. transplanting and 100% pruning), conditions that are analogous to the physiological impact of severe drought.

There was no evidence of construction activity having a direct adverse impact on the condition of threatened plant species remaining in situ adjacent to the highway corridor.

Opening of new forest edges adjacent to in situ threatened flora has produced some increase in exotic species and the potential to act as an entry point for new environmental weeds (e.g. Giant Devils Fig), but there was no evidence of increased sun or wind burn impacting threatened rainforest plant species.

Several environmental weeds including Ochna, Small-leaved Privet and Asparagus Fern have increased since the start of construction, including on RMS land. This indirect impact of the highway project on rainforest communities is of concern because of the likelihood of an ongoing increase in the weediness of lowland rainforest regrowth (a listed EEC) adjacent to the new highway.

Adaptive management to mitigate this threat, in the form of a weed control program targeting invasive environmental weeds, implemented by a bush regeneration specialist, would be an appropriate response measure.

4.3 Recommendations

Based on the findings of this monitoring program, we suggest the following adaptive management actions to mitigate indirect impacts:

Table 11: Recommendations following 2019 monitoring and response from TfNSW

Recommendation Number	Recommendation	TfNSW response
1	Develop a targeted strategy for eradicating environmental weeds within the project corridor and on RMS property, focusing on Ochna, Asparagus Fern and Small-leaved Privet. Camphor Laurel and Large-leaved Privet should not be priority weeds as they play a key 'nursery role' in facilitating rainforest regeneration	Adopted - Weed management as part of the landscape maintenance will focus on Ochna, Asparagus Fern and Small-leaved Privet. This report will be provided to the contractor responsible for weed management in the vicinity of rainforest communities.
2	Utilise professional bush regenerators to carry out weed eradication work in threatened plant communities (i.e. rainforest) and near threatened plant species.	Adopted – Contractor responsible for weed management within project boundary around rainforest communities has been provided advice from an experienced ecologist/botanist.

Recommendation Number	Recommendation	TfNSW response
3	Make the eradication of Giant Devils Fig a high priority (include removal of any fruits)	Adopted – Weed management contractor will be provided with this report and to carry out removal of Giant Devils Fig.
4	Identify and clearly mark occurrences of the Critically Endangered Species Native Guava (Rhodomyrtus psidiodes) within the project boundary and on adjacent RMS property.	Adopted – Native Guava within project boundary as identified in this report have been flagged. Where individuals are known on adjacent RMS property they will also be flagged
5	Fence off and protect White Laceflower (Archidendron hendersonii) vegetative recruitment on sandy track (see Plates 5 & 6).	Adopted – Contractor responsible for weed management will investigate the feasibility of fencing off White Laceflower on access track. If fencing is not feasible, individuals will be flagged.

5 References

Ecos Environmental (2006) 'Monitoring of Roadside Threatened Plant Species for Brunswick Heads to Yelgun Pacific Highway upgrade, Year 4'. Report prepared for Roads and Traffic Authority, Grafton.

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Roads and Maritime Services (2015) 'Woolgoolga to Ballina Threatened Rainforest Communities and Rainforest Plants Management Plan'. (Department of Roads and Maritime Services) Available at https://www.rms.nsw.gov.au/documents/projects/northern-nsw/woolgoolga-to-ballina/woolgoolga-ballina-threatened-invertebrates-management-plan-2015-07.pdf [Verified 18 October 2018].

Wildi O (2017) 'Data Analysis In Vegetation Ecology 3rd Edition'. (CABI: Oxfordshire, UK).

Appendix 1:

Photos of Rainforest Community Monitoring Plots 1 to 14, November 2019

Plate 1: Plot 1, littoral rainforest Impact Plot

Plate 2: Plot 2, alluvial rainforest Impact Plot

Plate 3: Plot 3, hillside rainforest Control Plot

Plate 4: Plot 4, hillside rainforest Impact Plot

Plate 5: Plot 5, littoral rainforest Control Plot

Plate 6: Plot 6, hillside rainforest Control Plot

Plate 7: Plot 7, swamp rainforest Control Plot

Plate 8: Plot 8, hillside rainforest Impact Plot

Plate 9: Plot 3, hillside rainforest Control Plot

Plate 10: Plot 10, littoral rainforest Control Plot

Plate 11: Plot 11, littoral rainforest Impact Plot

Plate 12: Plot 12, swamp rainforest Impact Plot

Plate 13: Plot 13, hillside rainforest Impact Plot

Plate 14: Plot 11, hillside rainforest Control Plot

Appendix 2:

Photos – A Selection of Threatened Rainforest Plants Being Monitored, January 2020

Plate 1: White Laceflower (Archidendron hendersonii) no. 73 near Plot 6. Showing no ill effects of the drought.

Plate 2: White Laceflower (Archidendron hendersonii) no. 73 near Plot 6. Foliage crown a bit sparse due to the drought.

Plate 3: White Laceflower (Archidendron hendersonii) no. 73 near Plot 6. Showing no ill effects of the drought.

Plate 4 & 5: Stinking Cryptocarya (Cryptocarya foetida) no. 5 broken off by a fallen tree (above) and no 227. Both showing no obvious ill effects of the drought.

Plate 6: -Smooth-leaved Davidsonia (Davidsonia johnsonii) no. 159. Part of a copse of more than 30 stems, some showing effects of drought dieback.

Plate 7: -Southern Ochrosia (Ochrosia moorei) – leaves low down and thinner grey main stem going up. Showing no ill effects of drought.

Plate 8: Rusty Green-leaved Rose Walnut (Endiandra muelleri subsp. bracteata) no.35 near Plot 6. The thinner main stem in front of buttressed, larger tree. Showing no ill effects of the drought.

Plate 9: Rusty Green-leaved Rose Walnut (Endiandra muelleri subsp. bracteata) no.83 near Plot 2. A small juvenile plant showing no ill effects from the drought.

Plate 10: Rusty Green-leaved Rose Walnut (Endiandra muelleri subsp. bracteata) no.274 near Plot 2. A small juvenile plant showing leaf browning and leaf fall due to the drought.

Plate 11: Rusty Green-leaved Rose Walnut (Endiandra muelleri subsp. bracteata) no.91 near Plot 2. Small tree showing no ill effects from the drought.

Plate 12: Rusty Green-leaved Rose Walnut (Endiandra muelleri subsp. bracteata) no.124 near Plot 11. The main stem has died and it has live coppice shoot around the base.

Plate 13: Rough-shelled Bush Nut (Macadamia tetraphylla) no.24 near Plot 13. A small juvenile plant showing no ill effects of the drought.

Plate 14: Rough-shelled Bush Nut (Macadamia tetraphylla) no. 72 near Plot 6. A small tree showing no ill effects of the drought.

Plate 14: Rough-shelled Bush Nut (Macadamia tetraphylla) no. 45 near Plot 3. A small tree showing no ill effects of the drought.

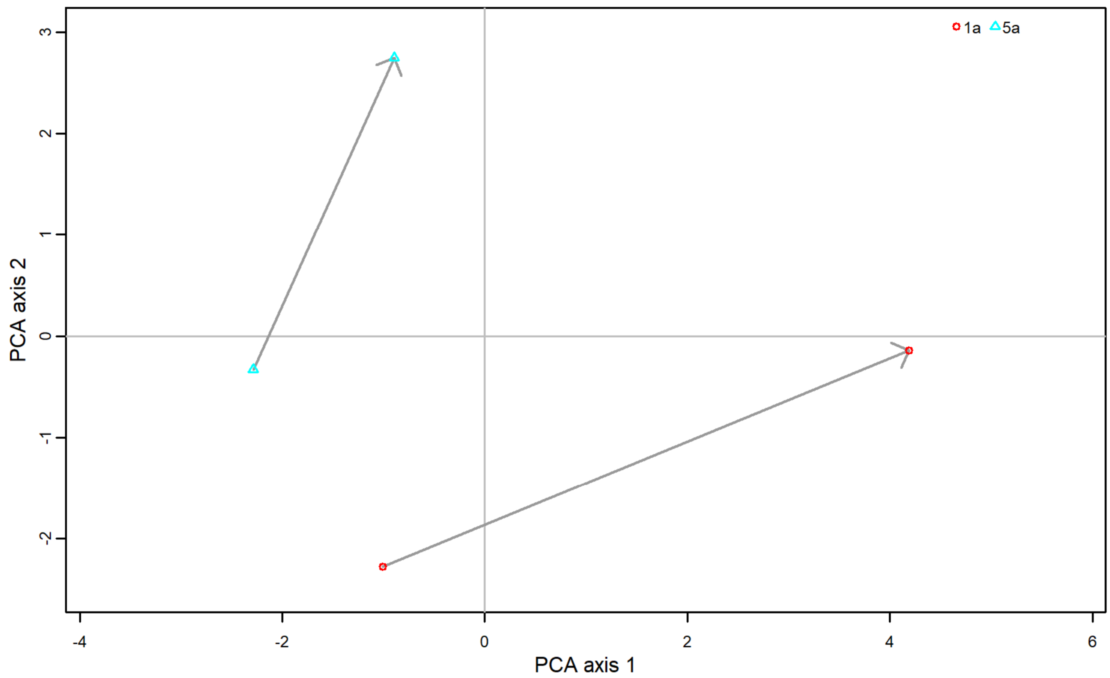
Plate 15: Rough-shelled Bush Nut (Macadamia tetraphylla) no. 386 near Plot 4. A mature tree showing no ill effects of the drought.

Plate 16: Rough-shelled Bush Nut (Macadamia tetraphylla) no. 170 near Plot 10. This mature individual made up of 50 or more coppice stems is showing canopy dieback from several years of below average rainfall.

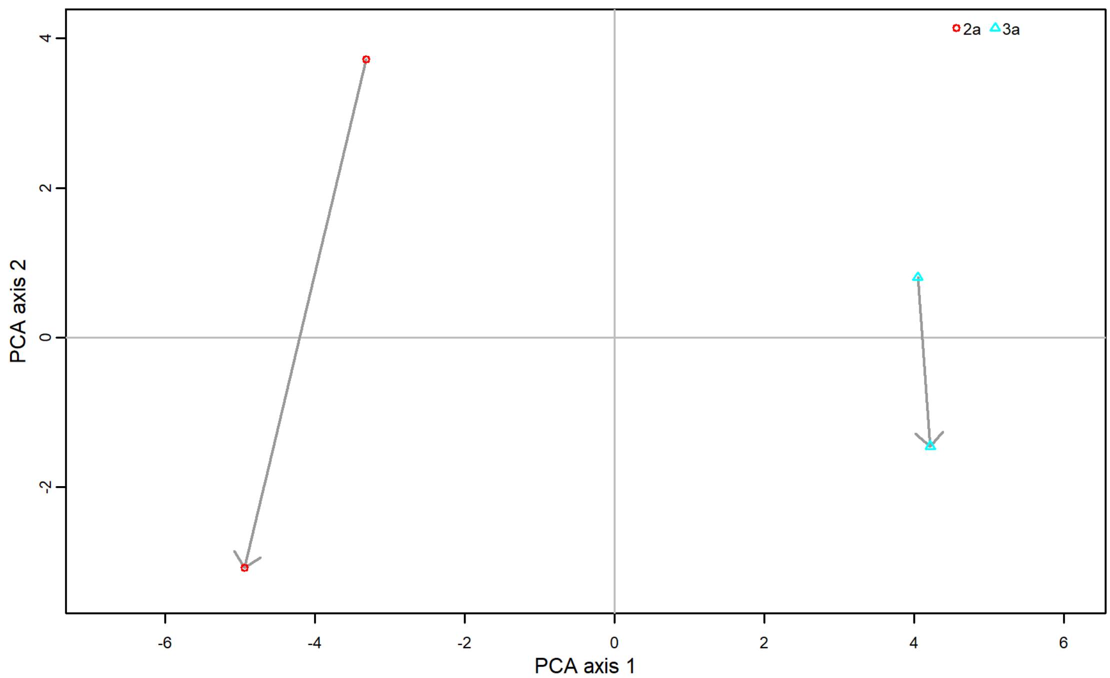
Plate 17: Rough-shelled Bush Nut (Macadamia tetraphylla) no. 166 near Plot 10. Small numbers of seed were present on larger macadamia including this multi-stemmed tree near the one above in Plate 16.

Appendix 3:

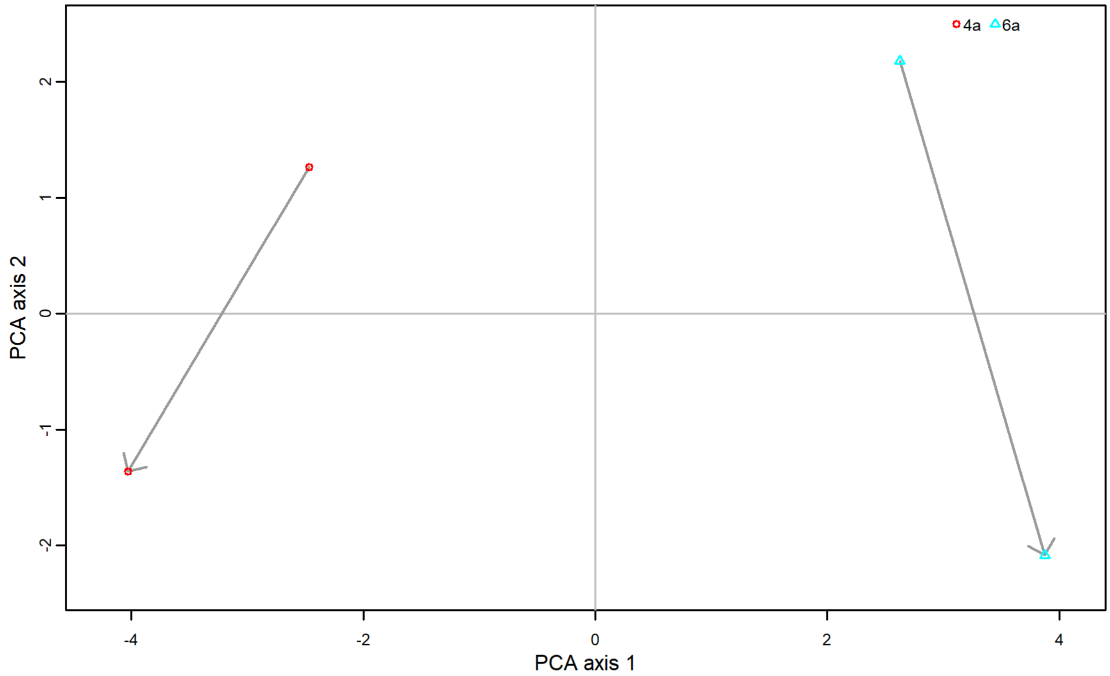
Ordination outputs – Comparison of Floristics in Impact and Control Plots.



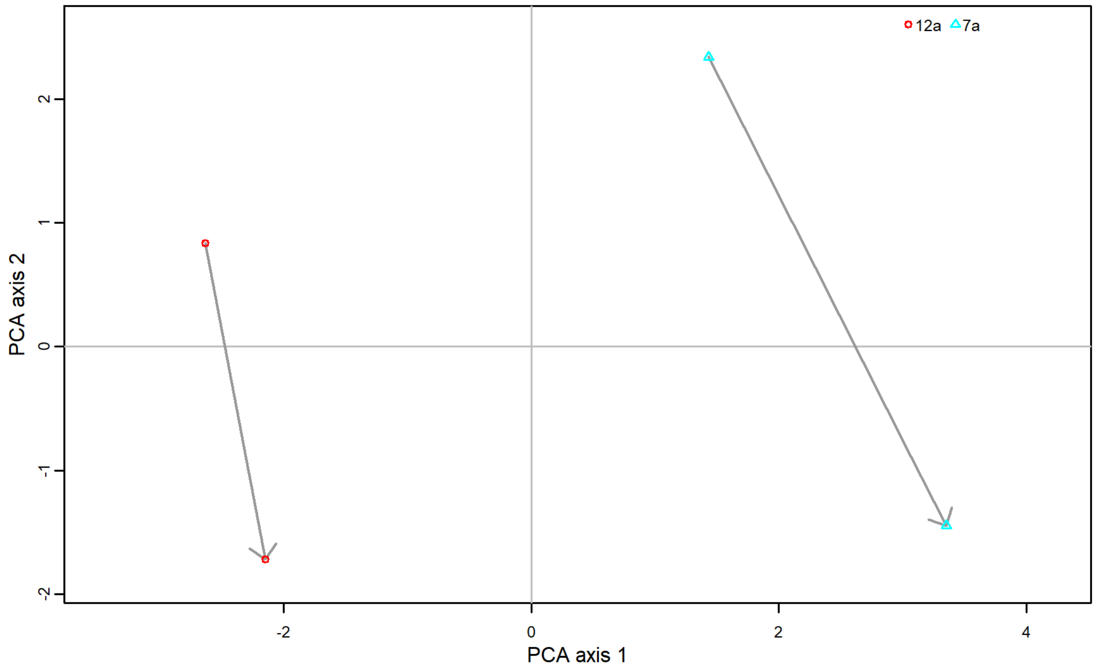
Sites 1a and 5a – Site 1 red = impact; Site 5 blue = control



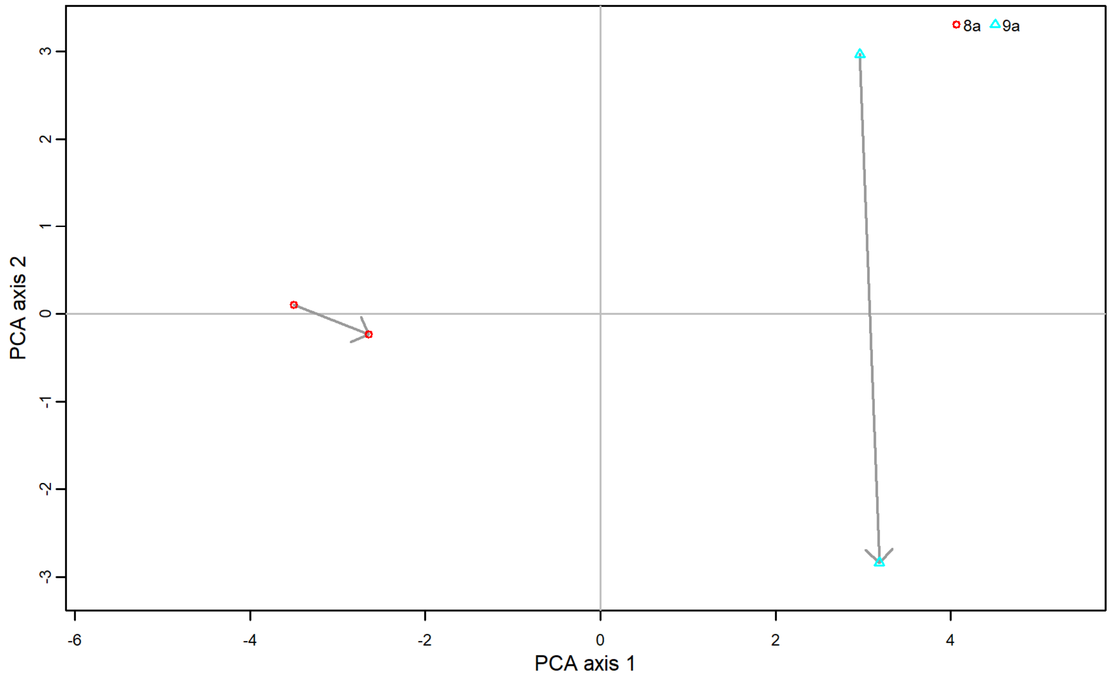
Sites 2a and 3a – Site 2 red = impact; Site 3 blue = control



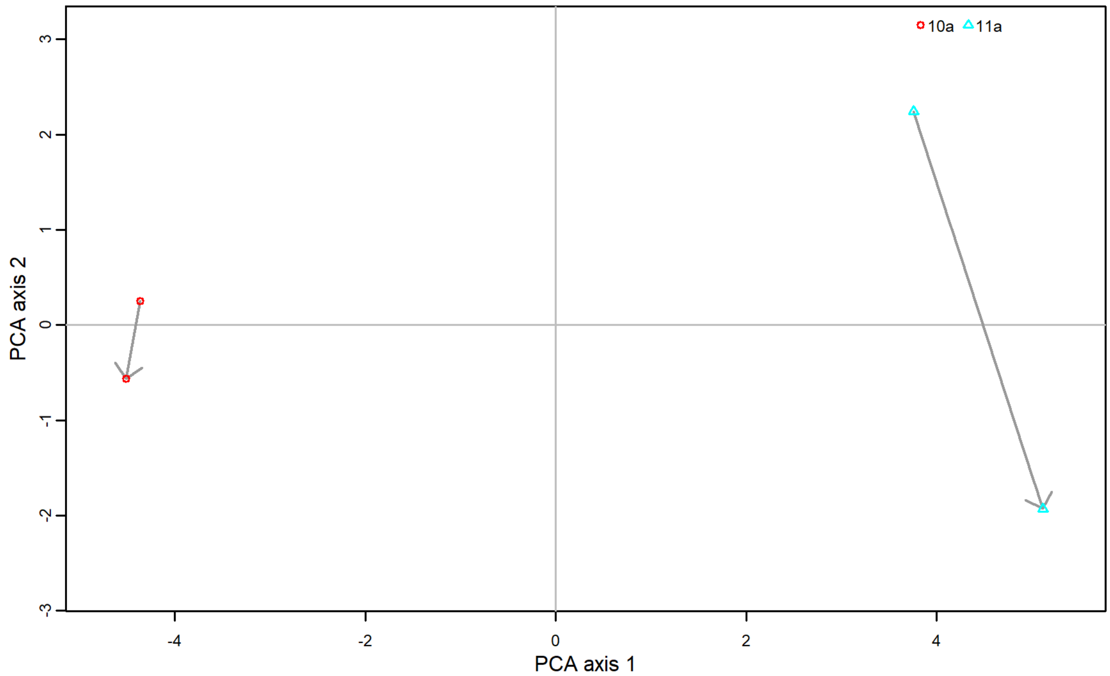
Sites 4a and 5a – Site 4 red = impact; Site 6 blue = control



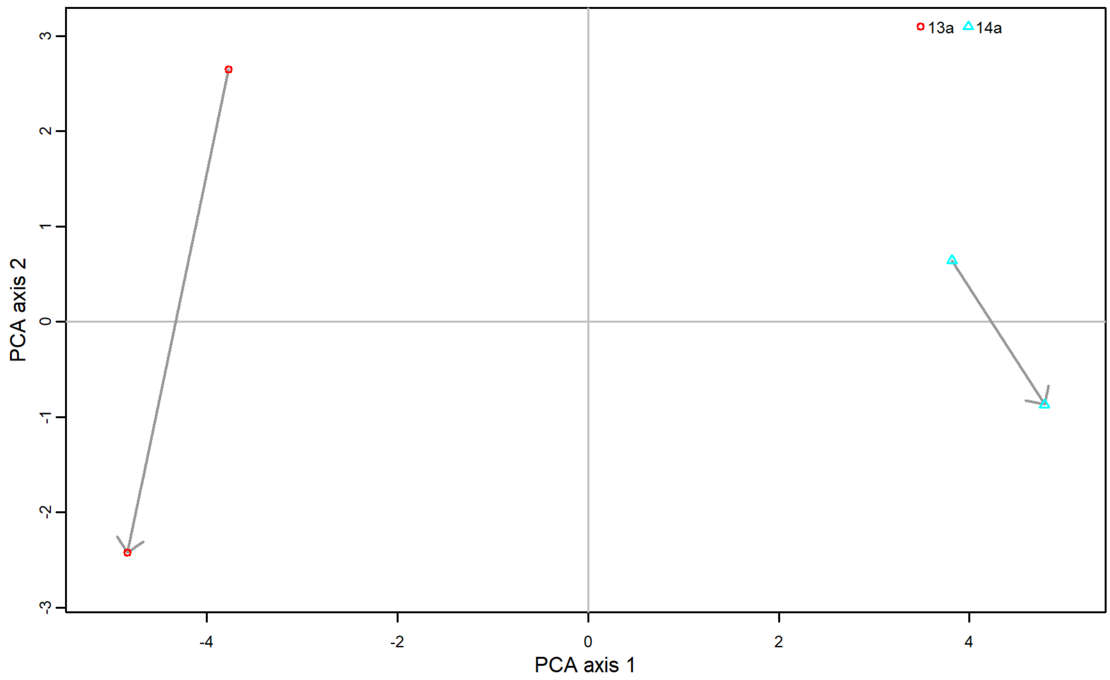
Sites 12a and 7a – Site 12 red = impact; Site 7 blue = control



Sites 8a and 9a – Site 8 red = impact; Site 9 blue = control



Sites 10a and 11a – Site 10 red = impact; Site 11 blue = control



Sites 13a and 14a – Site 13 red = impact; Site 14 blue = control