Woolgoolga to Ballina Pacific Highway upgrade

Threatened Rainforest Communities and Rainforest Plants Monitoring Program

Annual Report 2018

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 # 2 (2018)

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Executive Summary

The W2B rainforest monitoring program includes three years of construction phase monitoring from 2017 until the end of 2019. As part of the second year of construction phase monitoring, 14 Impact and Control rainforest community plots and 213 threatened rainforest plants were monitored biannually in 2018.This yearly monitoring followed on from baseline monitoring conducted in February 2014 (EMM 2014) and the first year of construction phase monitoring undertaken in 2017 (Ecos Environmental 2017).

Rainforest community plot data were analysed using ordination and data summary methods. PCA ordination of the data revealed that the rate of vegetation change (from February 2014 until spring 2018) at the impact sites did not increase after construction of Sections 10 and 11 began, nor was it greatest at subplot a (closest to the highway) within the impact monitoring plots (as would be expected if there were edge effects).There has been 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 have also 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. Some native tree species that would have once been common in the rainforest communities (before European settlement) have not been recorded in the 0-1 m stratum throughout the monitoring program, suggesting little or no recruitment of these species.

The rainforest monitoring program has yielded interesting information, particularly on the plant species dynamics occurring in a major area of regenerating rainforest on the Blackwall Range in Ballina Shire.

No major changes in plant condition were evident in threatened plants at the end of the second year of construction. One mortality, an *Archidendron hendersonii* tree, was most likely unrelated to construction and due to natural causes.

Some decline in the condition of threatened rainforest communities was evident due to increases in exotic species. Corrective action was recommended to address this issue, as follows:-

Recommendation No.	Recommendation	Roads and Maritime response	Status
1	Weed management as part of the landscape maintenance period during and post construction should identify areas for intervention in the vicinity of Coolgardie Rd and should focus on Ochna, Small-leaved Privet and Asparagus Fern to reduce impacts on adjacent threatened rainforest communities and rainforest plants.	Adopted	Current

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 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 *Rainforest Communities and Threatened Rainforest Plants Preconstruction Targeted Surveys and Baseline Monitoring Report* (EMM 2014), the baseline monitoring report.

The objective of monitoring is to determine the effectiveness of mitigation measures in avoiding direct and indirect impacts and maintaining the condition of rainforest communities and species (after clearing) during highway construction and operation (Roads and Maritime 2015).

The monitoring program includes three years of construction phase monitoring. The first year of construction phase monitoring was undertaken in 2017 when construction activities began on Sections 10 and 11. The results of the first year construction monitoring are described in *Woolgoolga to Ballina Pacific Highway Upgrade Sections 10 & 11 Threatened Rainforest Communities and Rainforest Plants Annual Monitoring Report # 1* (Ecos Environmental 2017).

Herein we present the findings of year 2 (2018) 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 are set out as follows:

- Section 2: methods and results for the threatened rainforest communities component of the monitoring program
- Section 3: methods, data analysis and results for 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 synonymous 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); and

- 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, synonymous with the EPBC Act listed Littoral Rainforest and Coastal Vine Thickets of Eastern Australia, which is listed as a CEEC.

In addition to these 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, whereas the other three are equivalent to, or sub-forms of the EEC Lowland Rainforest. This initial classification of rainforest types occurring on Sections 10 and 11 of W2B, based on observation of the rainforest flora and habitat in the field, has subsequently been confirmed by ordination and 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 established 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 is defined as the percentage of the plot area (subplot in the case of this monitoring program) covered by the vertical projection onto the ground of the perimeter or outline of plant crowns. All the area within the crown perimeter contributes to crown cover regardless of spaces between leaves – i.e. the crown area is treated as opaque. The estimate is made visually, where 1 x 1 m^2 of cover = 1% of the plot 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 2018</u>

The monitoring procedure for the second year of construction was the same as in 2017. The 14 plots were visited in autumn and spring, and full floristics were recorded and habitat condition noted. As in 2017, abundance estimates were made without referring back to the previously recorded data to ensure samples were independent (statistically speaking). Additionally, 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).

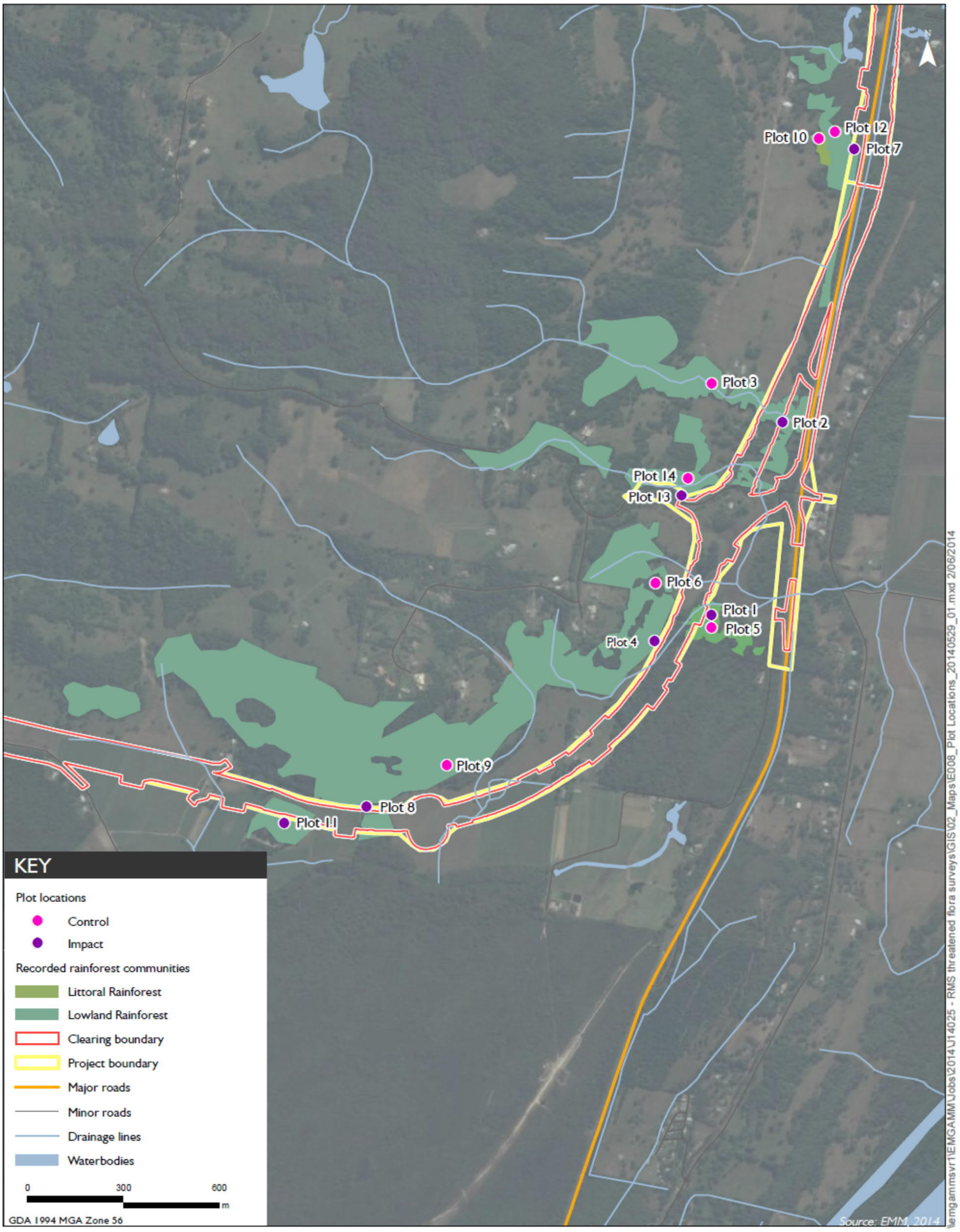

Figure 1. Monitoring plots in relation to W2B Pacific Highway upgrade project boundary and threatened rainforest communities. Map is sourced from EMM (2014).

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

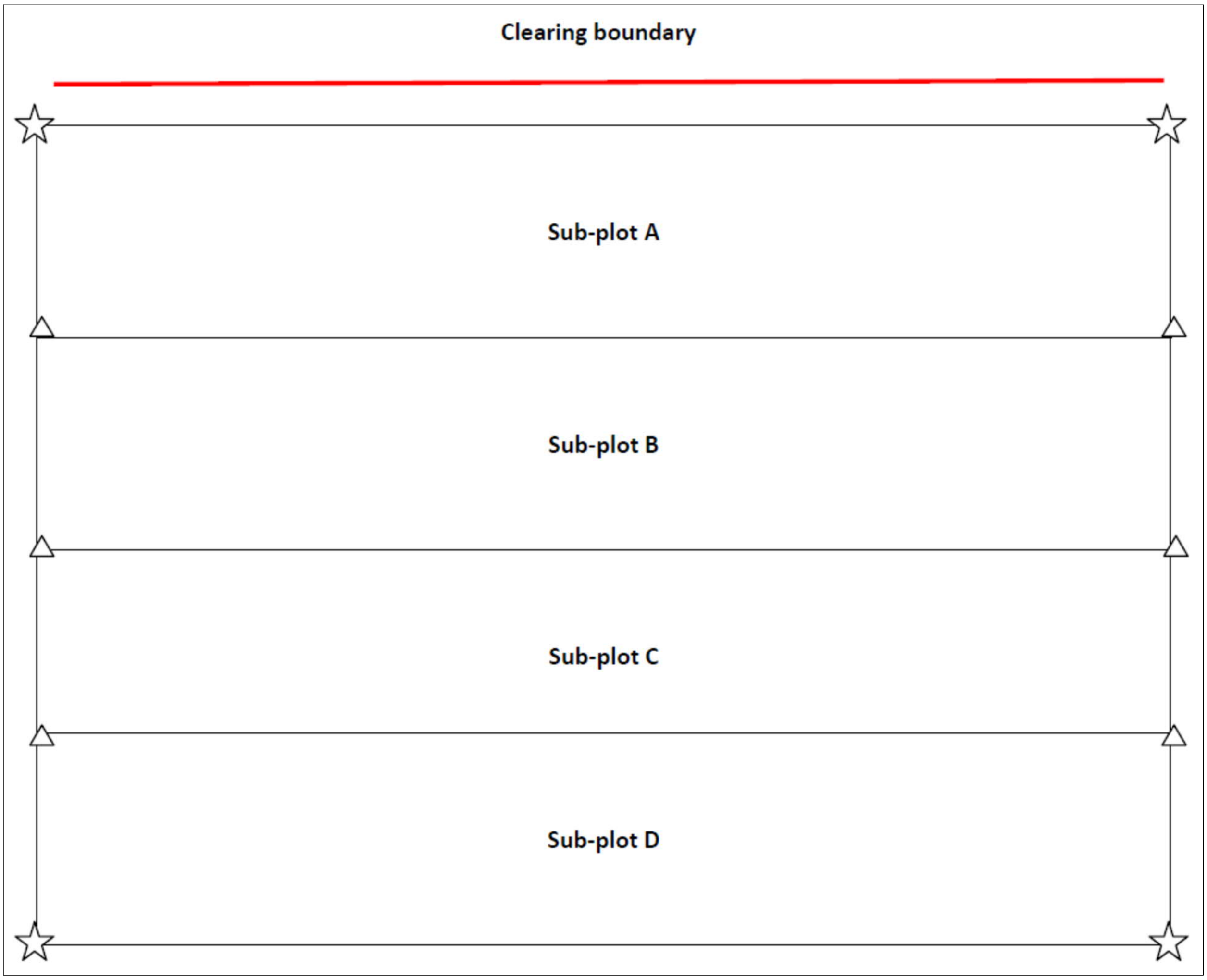

Figure 2: Plot layout for threatened rainforest communities monitoring. Plots were 20 m x 20 m and divided into four 20 m x 5 m sub-plots. Diagram is sourced from EMM (2014).

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, and

The rate of vegetation change at each impact site will be greatest in subplot a (closest to forest edge and project boundary).

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 all the data (i.e. from 2014, 2017, and 2018) was imported into a data matrix object in the statistical software R (R Core Team 2018). Principal Component Analysis (PCA) was then performed separately on the subplots of 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.

The PCA results were plotted using the 'plot' function (R Core Team 2018). The 'pcaser' function allows the user to draw lines connection points in a time series and arrows pointing from the beginning to the end state. A line was inserted connecting the same subplots – thus showing a time series – and an arrow was drawn from the beginning state (i.e. 2014) to the end state (i.e. spring 2018) to show the order of the time series. When this was done with all five monitoring events, it was difficult to separate the points in ordination space. Therefore, the autumn 2018 monitoring event was removed from the dataset, which made each point sequence easier to interpret.

The PCA graphs allowed us to visualise the change of subplots through time to see if there was a temporal trend – whereby each state in a time series is sequential – and if so, assess whether the rate of change varied among sites and subplots.

2.2.2 Number, abundance and recruitment of exotic species

Number and abundance of exotic species were used as indicators of rainforest condition. An increase in the number and abundance of exotics was interpreted as a deterioration in 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 subplots. The abundance of exotic species per plot was derived by summing the abundance values of exotic species for each subplot and then averaging across the four subplots.

In the 0-1 m stratum, Camphor Laurel (*Cinnamomum camphora*) and Broad-leaved Privet (*Ligustrum lucidum*) were the most frequent exotic species. To assess the recruitment dynamics of these tree weed species, their frequency in each stratum were calculated and plotted as a stem chart.

2.2.3 Species richness and native tree recruitment

Species richness was also used as an indicator of rainforest condition. Increase in richness was interpreted as improving condition; decrease in richness was interpreted as declining condition. Species richness per plot was derived by counting the number of species in each subplot and then averaging across the four subplots.

Native tree recruitment was used as an indicator of rainforest resilience. For each native tree species, a tree recruitment index was derived by calculating their frequency in the 0-1 m stratum. Additionally, for the ten highest recruiting species, frequency in each stratum was calculated and plotted as a stem chart.

2.3 Results

2.3.1 Ordination and point sequences

PCA ordination of each pair of sites through time generally did not reveal a strong temporal trend, and therefore, it was difficult to determine whether the rate of change differed among plots and subplots. The PCA graph for Plot 1 and Plot 5 (Figure 3) is a typical example. If we look at subplot 5c, we can see that the distance from the initial state (February 2014) increases with each time step until the third point (Spring 2017) in the time series. Therefore, between February 2014 and Spring 2017 we could say that there was a temporal trend – perhaps 5c was undergoing succession and moving (in time) towards a climax state. The next and final state in the time series, however, is more similar to the initial state. There has been a step backwards so to speak. We would not expect this for Plot 5 as it is a control site and there has been no disturbance since the monitoring program began. The point sequences for the other subplots also show a somewhat random pattern.

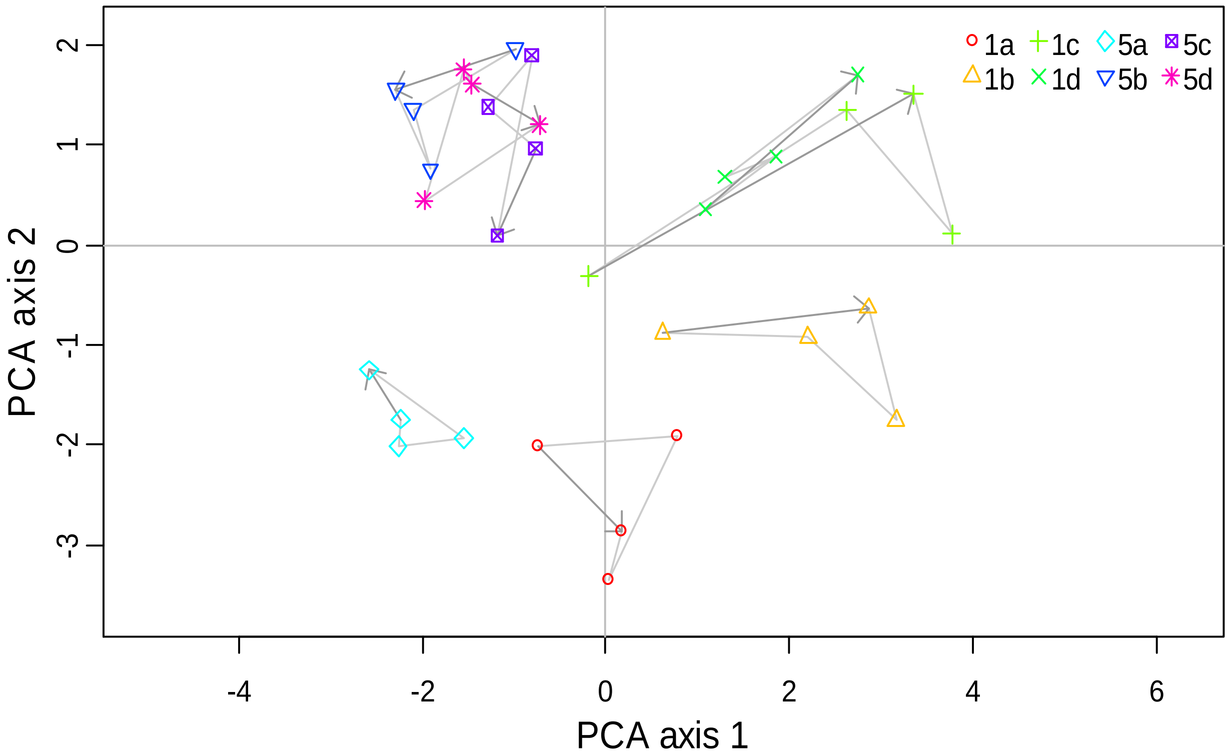

Figure 3. Principal Component Analysis (PCA) of subplots of Plot 1 (impact) and Plot 5 (control), sampled February 2014, autumn 2017, spring 2017 and spring 2018. Lines connect points of the same time series and an arrow points from the initial state (February 2014) to the final state (spring 2018). Eigenvalues for axis 1 and axis 2 are 22.72 and 14.56, respectively. Eigenvalues are the amount of variance captured by each axis. In other words, they tell us how well the data is represented in two-dimensional space. For this data, 37.28% of the variance is explained by the first two axes. For the sample size of this data, 37.28% explained variance is generally acceptable for a two-dimensional ordination.

Unavoidable imprecision in the estimates of cover abundance may be contributing 'noise' (statistically speaking) to the data and blurring temporal patterns that may be present. A certain lack of precision is inherent in visual estimation of abundance, but it is the only practical method available if recording large numbers of species and is usually adequate for detecting marked shifts in species composition. Other measures than crown cover can be applied by visual estimation, such as foliage projective cover, but they have the same limitation, or are even more prone to observer variation. One way to ensure estimations are precise is to put in place quality control measures. For example, in this monitoring program, observer variation was minimised by having the same observer record data for each monitoring event or calibrating other observers to ensure crown cover was estimated in the same way.

Another 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 (2014-2018), which is a small time-scale in the context of ecological succession.

Looking at the rate of change in Figure 3– represented in ordination space by the distance between points in a time series – it appears that, overall, Plot 1 has changed more than Plot 5. The rate of change for Plot 1, however, did not increase after construction of the highway began and is not greatest in subplot *a*. Therefore, predictions 1 and 2 in *Section 2.2.1* of this report are not supported.

A factor worth considering, however, is that some of the impact plots are not situated directly beside the forest edge (edge of clearing) and therefore, are not expected to be subject to strong edge effects (Table 2). 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 2. 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)	15 m	ineffective

Monitoring of roadside threatened plant habitat conducted by Ecos Environmental for the Brunswick Heads to Yelgun project (Ecos Environmental 2006) found that weed incursion into threatened species habitat generally extended no more than 10 metres inside newly created forest edges. Five of the seven impact monitoring plots for this study are 10 metres 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 off the actual edge of clearing was unavoidable as they were installed in 2014 and relied on early models of the construction footprint and hand-held GPS which is not highly accurate.

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. specific growth forms or strata within the plant community) as described below.

The PCA graphs for the other paired sites are included in Appendix 3. They are not included here because they generally show the same pattern as Figure 3.

2.3.2 Number, abundance and recruitment of exotic species

The average number of exotic species per subplot of each plot has fluctuated across monitoring events but overall has remained about the same (Table 3). 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. The additional exotic species, however, are short-lived annuals that do not pose a serious threat to the integrity of the rainforest communities.

In terms of the abundance of exotic species (estimated by crown cover), there has been overall about an 80% increase from February 2014 to Spring 2018 (Table 4). Exotic species abundance, however, has increased in both the control and impact sites and had been steadily 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.) – suggested as the possible cause.

Cattle like to graze within forest and it is generally recognised that removal of cattle from forest where they formerly grazed is followed by an increase in weediness. Weeds may become established in forest as a result of cattle foraging but as long as cattle continue to graze the forest they are controlled. A similar increase in weediness at control and impact sites suggests that cattle removal is 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). Although not directly related to clearing as such, increase in exotics could be considered an indirect impact of highway construction on rainforest communities, as cattle were removed to prepare the site for construction.

Figure 4 shows the frequency of different size classes of *C. cinnamomum* (Camphor Laurel) and *L. lucidum* (Broad-leaved Privet) in each stratum, providing insight into the recruitment dynamics of these major weed species in the rainforest communities. *C. cinnamomum* is frequent in the 0-1 m and 10-20 m strata but is under-represented in the two mid-strata. This suggests that mature individuals in the 10-20 m stratum are the source of seedlings in the 0-1 m stratum, and that few seedlings are establishing and growing to reach the mid-strata. This indicates that *C. cinnamomum* does not recruit successfully under a closed forest canopy. The abundance of individuals in the 10-20 m stratum suggests that there was a burst of recruitment in the past, most likely about 50 years ago (based on size and growth rate of *C. cinnamomum*) when the forest canopy was more open. The 1960s was the start of the decline of cattle grazing in northern NSW, which may have been a factor in this burst of *C. cinnamomum* recruitment, as the monitoring sites have a history of grazing and cattle are known to graze *C. cinnamomum*.

L. lucidum (Broad-leaved Privet) on the other hand, is frequent in all strata – except 20+ m as *L. lucidum* does not grow this tall – suggesting that recruitment of this species is continuous and ongoing. Unlike *C. cinnamomum*, *L. lucidum* may be able to recruitment successfully under a closed forest canopy.

It is likely that exotic trees have played a key role in rainforest regrowth in the study area by acting as a nursery layer or protection for seedlings of native species. For example, on rocky slopes of the escarpment (the Blackwall Range) above the highway upgrade, rainforest regrowth is dominated by *C. cinnamomum* and *L. lucidum* but there are also native vines in the canopy and native trees, shrubs, ferns and herbs have colonised below. If not for *C. cinnamomum* and *L. lucidum*, regrowth would probably consist of a low Lantana dominated scrub with lower native species diversity.

Table 3. Average number of exotic species per subplot for each plot through time. Averages rounded to the nearest one.

Plot No.	**Impact/ Control**	**Average number of exotics per subplot**			
		February 2014	**Autumn 2017**	**Spring 2017**	**Spring 2018**
1	Impact	3	3	4	4
5	Control	4	2	4	4
2	Impact	4	2	3	8
3	Control	4	3	4	6
4	Impact	6	3	5	5
6	Control	6	4	6	5
7	Impact	3	2	1	3
12	Control	2	1	1	1
8	Impact	5	3	4	4
9	Control	4	3	3	4
11	Impact	4	4	5	6
10	Control	4	3	3	2
13	Impact	7	6	6	9
14	Control	4	3	4	4

Overall average	4	3	4	5
Overall av control	4	3	4	4
Overall av impact	5	3	4	6

Table 4. Average abundance (%) of exotic species per subplot for each plot through time. Abundance was estimated by crown cover. Values can be higher than 100% because abundance values for each stratum were summed. Averages rounded to the nearest one.

Paired sites	**Impact/ Control**	**Average abundance (%) of exotics per subplot**			
		February 2014	**Autumn 2017**	**Spring 2017**	**Spring 2018**
1	Impact	2	4	14	12
5	Control	12	10	18	25
2	Impact	11	36	18	35
3	Control	4	7	7	18
4	Impact	61	81	102	106
6	Control	28	41	37	57
7	Impact	2	1	1	2
12	Control	1	1	<0.5	1
8	Impact	103	92	127	114
9	Control	68	42	63	73
11	Impact	4	12	19	12
10	Control	4	2	2	4
13	Impact	38	54	37	92
14	Control	5	2	6	9
Overall average		24	27	31	40
Overall average control		17	15	22	27
Overall average impact		32	40	45	53

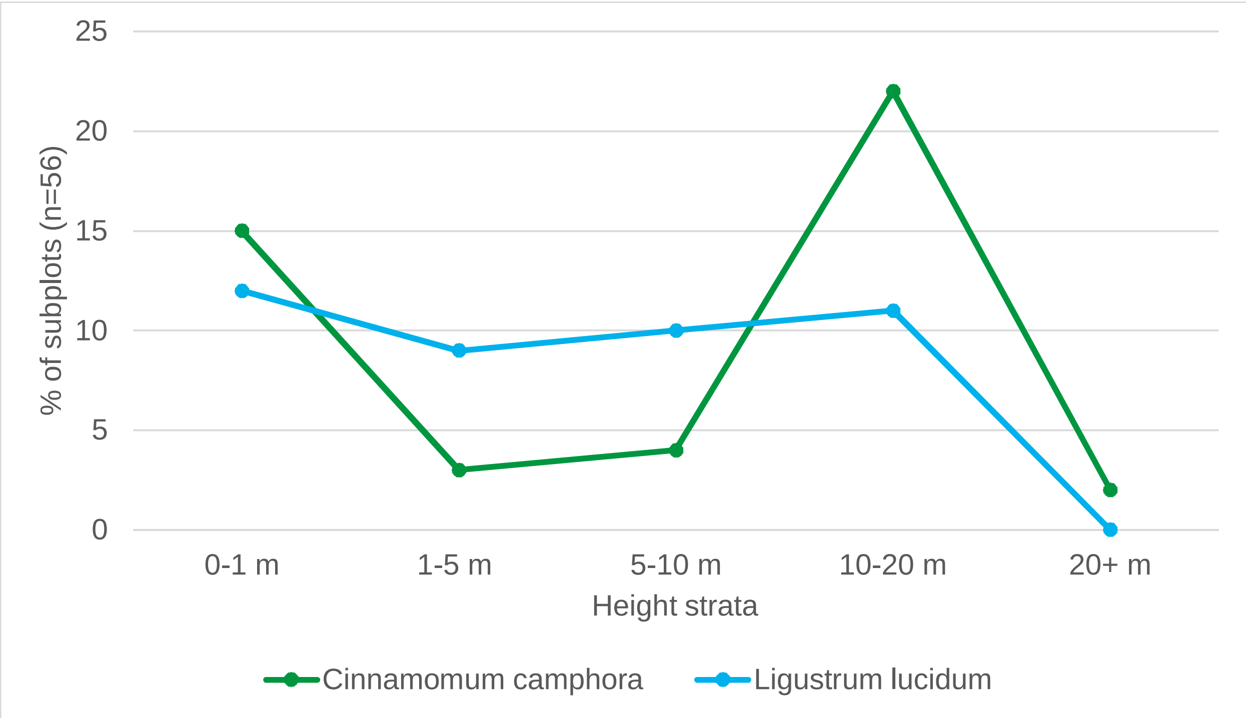

Figure 4. Frequency of Camphor Laurel (*Cinnamomum oliveri*) and Broad-leaved Privet (*Ligustrum lucidum*) in each height stratum, recorded in Spring 2018.

2.3.3 Species richness and native tree recruitment

Species richness at the monitoring sites – expressed as the subplot average – has overall slightly increased from 31 species in February 2014 to 33 species in spring 2018 (Table 5). For most sites, species richness has fluctuated across monitoring events but generally remained the same. At Plot 2 (Impact) and Plot 3 (Control), however, there has been relatively large increases from 26 to 37, and 43 to 50, respectively. In Plot 2, exotic species that were recorded in spring 2018 contributed to this increase.

In spring 2018, the ten native tree species with the highest frequency of active recruitment (i.e. present in 0-1 m stratum) were Tuckeroo (*Cupaniopsis anacardioides*), Three-veined Laurel (*Cryptocarya triplinervis*), Foambark Tree (*Jagera pseudorhus*), Rough-leaved Elm (*Aphananthe philippinensis*), Guoia (*Guioa semiglauca*), Pepperberry Tree (*Cryptocarya obovata*), Bangalow Palm (*Archontophoenix cunninghamiana*), Red Kamala (*Mallotus phillippensis*), Bollywood (*Litsea australis*), and Steelwood (*Sarcopteryx stipata*) (Table 6). Generally, these were also the ten most actively recruiting species in Spring 2017 but in a different order. By comparison, *C. cinnamomum* and *L. lucidum*, even though dominating the canopy, were less frequent in the 0-1 m stratum than the top ten actively recruiting native tree species (Table 6).

Figure 6 shows the frequency of these ten native tree species in each stratum. All species except *A. cunninghamiana* appear to be common in the lower two strata but progressively less frequent in the mid and high strata. From this we can infer that either there has been a relatively recent burst of recruitment in the rainforest communities or saplings are not surviving to reach the mid and high stratum, which . We can also infer that either reproductively mature individuals in the 1-5 m stratum are mostly the source of seedlings in the 0-1 m stratum, or seed is coming from larger trees outside the monitoring plots. As there are no mature stands of rainforest in the study area, the latter explanation seems unlikely so young trees in the 1-5m stratum, just reaching maturity, must be the source. As stands of *A. cunninghamiana* (Bangalow Palm) were rarely harvested for timber, it is not surprising that this species is still common in the 10-20 stratum in swamp rainforest plots.

Of the 141 native tree species, 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. In the latter category were several species that would have once been common in the rainforest communities (before European settlement) including Australia Teak (*Flindersia australis*), White Booyong (*Argyrodendron trifoliatum*), Rose Satinash (*Syzygium crebrinerve*) and White Beach (*Gmelina leichhardtiana*), which now persist 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 or very rare with little evidence of recent recruitment.

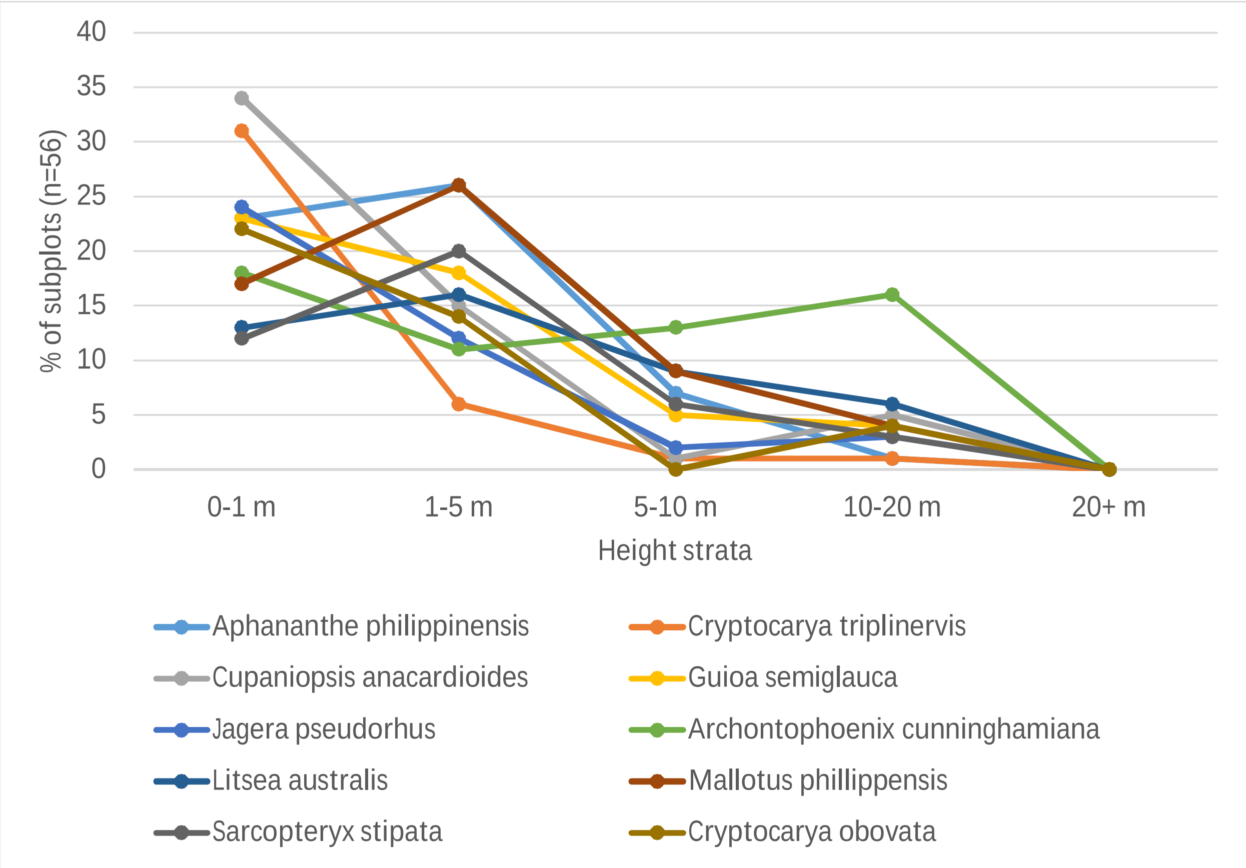

Figure 6. Frequency of the ten most actively recruiting native tree species in each height stratum. Data recorded Spring 2018.

Table 5. Average species richness (including native and exotic species) per subplot for each plot through time. Averages rounded to the nearest one.

Paired sites	**Impact/ Control**	**Average Species Richness per subplot**			
		Feb 2014	**Autumn 2017**	**Spring 2017**	**Spring 2018**
1	Impact	23	26	29	31
5	Control	24	19	19	25
2	Impact	26	25	27	37
3	Control	43	35	52	50
4	Impact	28	26	30	30
6	Control	29	24	30	27
7	Impact	22	23	19	27
12	Control	18	16	14	16
8	Impact	35	25	24	32
9	Control	42	33	35	35
10	Impact	26	23	27	22
11	Control	39	35	39	44
13	Impact	42	31	33	39
14	Control	39	29	40	40
Overall average		31	26	31	33

Table 6: The 10 most frequent native tree species in 0-1 m height stratum, recorded in Spring 2017 and Spring 2018. Percentages rounded to the nearest one.

Spring 2017		Spring 2018	
Native tree species	**Percentage of subplots (n = 56)**	**Native tree species**	**Percentage of subplots (n = 56)**
Cryptocarya triplinervis	48	*Cupaniopsis anacardioides*	61
Archontophoenix cunninghamiana	43	*Cryptocarya triplinervis*	55
Cryptocarya obovata	40	*Jagera pseudorhus*	43
Cupaniopsis anacardioides	40	*Aphananthe philippinensis*	41
Aphananthe philippinensis	32	*Guioa semiglauca*	41
Jagera pseudorhus	32	*Cryptocarya obovata*	39
Guioa semiglauca	28	*Archontophoenix cunninghamiana*	32
Litsea australis	27	*Mallotus phillippensis*	30
Sarcopteryx stipata	25	*Litsea australis*	23
Flindersia schottiana	23	*Sarcopteryx stipata*	21
Exotic tree species			
**Cinnamomum camphora*	20	*Cinnamomum camphora*	27
**Ligustrum lucidum*	18	*Ligustrum sinense*	21

3 Threatened Rainforest Plant Monitoring

3.1 Species included in 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).

The plants being monitored are located on Sections 10 and 11 of the highway upgrade, within and up to 100 m from the project boundary. Section 10 extends from the Richmond River north to Coolgardie Rd and Section 11 from Coolgardie Rd north to the Ballina bypass tie-in.

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

3.2 Previous monitoring – 2014 and 2017

In February 2014, EMM collected baseline data for 261 individuals of the eight threatened species. The condition of each plant was recorded and plants were tagged and recorded with a GPS for ongoing monitoring. The tags were small plastic buttons pre-inscribed with a number and chosen at random as each plant was tagged (i.e. numbers non-sequential).

In 2017 when construction of Sections 10 and 11 began, Ecos Environmental resurveyed the plants tagged by EMM in 2014. Not all 261 plants could be recorded, as some tags had disappeared (the wire attaching the tags had rusted), some plants had been translocated, and others were given identical numbers in the report. In addition, about 20 plants with tags were found in the field that were not included in the EMM report. These were added to the current monitoring program. The overall result was a total of 213 plants were recorded in 2017 and included in the current monitoring program (Figure 7).

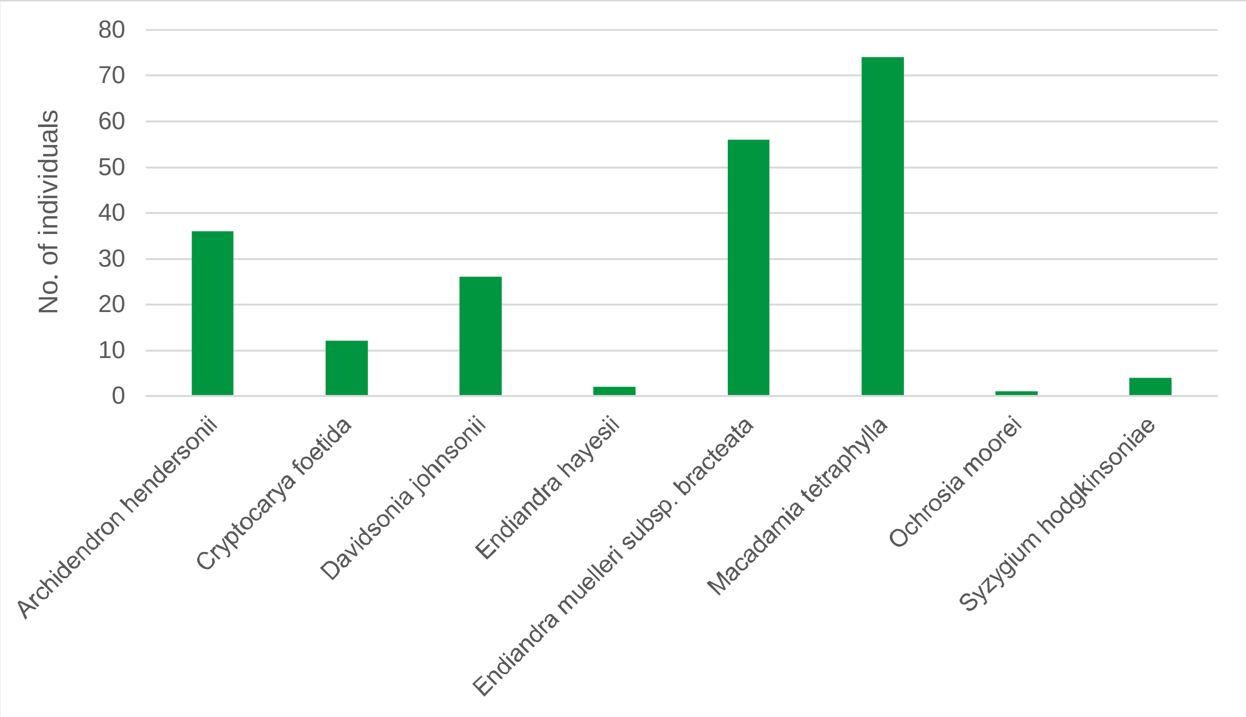

Figure 7. Number of individuals per threatened species in the monitoring program. Total number of individuals is 213.

3.3 Current monitoring 2018

In 2018 – the second year of construction phase monitoring – all 213 plants recorded in 2017 were located and monitored. The same attributes were recorded as in 2017 – 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. The threatened plants were recorded twice in 2018 (autumn and spring).

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

3.4 Results

A single mortality was recorded out of the 213 threatened plants being monitored. This was a White Laceflower (*Archidendron hendersonii*) tree about 6 m high, which was already in poor condition with crown dieback at the start of 2017 before vegetation clearing started. There was no evidence that the apparent death of this tree was related to effects of highway construction such as increased edge exposure or damage to roots. The tree located about 10m from the edge of clearing with several other White Laceflowers. Long spring-summer dry periods during the last two summers may have caused its decline. The tree has a lignotuber so it is possible it will reshoot from the base.

No adaptive management is proposed for this individual, as this is only required if mortality is considered due to construction impacts (RMS 2015, Section 9.7.2).

General results for the eight species being monitored are described below.

Rough-shelled Bush Nut (*Macadamia tetraphylla*)

This species has a substantial number of small, but reproductively mature individuals in the vicinity of the highway corridor. Flowering and seed production were recorded on a large proportion of individuals being monitored in 2017 and 2018. Most individuals appear to produce small quantities of seed (<20 per plant). Only one or two small seedlings were observed, indicating high loss of seed to animals such as introduced rats. Active shoot growth was observed each year and there was no evidence of disease or excessive grazing by insects or other animals. An increase in exotics was evident at some sites. The overall picture is one of slow increase in population size and potential for gradual species recovery.

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

This species also has a substantial number of small, but reproductively mature individuals in the vicinity of the highway corridor. A small amount of flowering was recorded in 2017 and 2018, but no seed production observed. A few seedlings were observed, indicating low rates of seed production and recruitment. Active shoot growth was observed each year and there was no evidence of disease or excessive grazing by insects or other animals. An increase in exotics was evident at some sites.

White Lace Flower (*Archidendron hendersonii*)

This species occurs sporadically on the project corridor. Most significant is a large tree just north of Lumleys Lane. This tree has not been observed to flower or produce seed, but probably reproduces intermittently. The tree appears to be in good health with no evidence of disease or over grazing by insects. Seedlings (supressed juveniles) underneath the tree indicate occasional heavy seed crops. These seedlings are being monitored and show a high survival rate but very slow growth (virtually non-existent in two years). One tree appears to have died in the group being monitored off Kays Lane. The tree was already in poor condition at the start of 2017 before vegetation clearing so the decline is unlikely to be related to highway construction.

Rusty Rose Walnut (*Endiandra hayesii*)

This species appears to be present but hybridising with *Endiandra muelleri subsp bracteata.* Similar comments apply to both species.

Stinking Cryptocarya (*Cryptocarya foetida*)

Several saplings of this species continue to be in good condition and maintaining slow growth. A few seedlings were also observed so there may be some seed production occurring (although intermittently). Active shoot growth was observed each year and there was no evidence of disease or excessive grazing by insects or other animals. An increase in exotics was evident at some sites.

Southern Ochrosia (*Ochrosia moorei*)

The single medium sized individual of this species continues to be in reasonable condition. No flowering or seed production have been observed. Active shoot growth was observed each year and there was no evidence of disease or excessive grazing by insects or other animals. An increase in exotics was evident at the single location.

Red Lilly Pilly (*Syzygium hodgkinsoniae*)

The single occurrence of this species is in good condition. Flowering was observed in 2017 and 2018 and production of a few fruits. Active shoot growth was observed each year and there was no evidence of disease or excessive grazing by insects or other animals.

Smooth Davidsonia (*Davidsonia johnsonii*)

The population being monitored continues to be in reasonable condition. No flowering or seed production has been observed. Active shoot growth was observed each year and there was no evidence of disease or excessive grazing by insects or other animals.

4 Conclusion and recommendations

4.1 Threatened rainforest communities

The major findings of the second year of construction phase monitoring of the threatened rainforest communities were:

- PCA ordination of the monitoring data indicated that the rate of vegetation change (from February 2014 to Spring 2018) at the impact sites did not increase after construction of Sections 10 and 11 began, nor was it greater at subplot a (the side of the plot closest to the edge of clearing)
- There has been 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
- Some native tree species that would have once been common in the rainforest communities (before European settlement) have not been recorded in the 0-1 m stratum throughout the monitoring program, suggesting little or no recruitment of these species.

Ongoing monitoring of the threatened rainforest communities for indirect impacts will be important as construction of Sections 10 and 11 continues and operation of the highway upgrade begins.

4.2 Threatened rainforest plant species

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 so far produced only a minor increase in exotic species and no evidence of sun or wind burn of threatened rainforest plant species.

However, due to the removal of cattle, which the monitoring data indicate supressed exotic species such as Ochna, Small-leaved Privet and Asparagus Fern prior to the start of construction, there has been a steady increase in exotic species cover-abundance since baseline monitoring was carried out in 2014. 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.

4.3 Performance Criteria

Sections 9.1 and 9.2.1 of the Threatened Rainforest Communities and Rainforest Plants Management Plan (RMS 2015) specify that Performance goals should be 100% survival of all in-situ threatened plants during construction and then 80% survival in 3 consecutive years post-construction.

After two years of construction, there were no construction related mortalities of threatened rainforest plants. One White Laceflower (Archidendron hendersonii) has apparently died but this was most likely the result of natural causes (see Sec 3.4)

The main indirect impact of the project on rainforest that poses a threat to the condition of adjacent threatened rainforest communities and rainforest plants, is an increase in exotic species. Corrective actions to control and limit the increase of exotic species are recommended below.

4.4 Recommendations

Based on the findings of this monitoring program, we suggest the following adaptive management action:

Recommendation No.	Recommendation	Roads and Maritime response	Status
1	Weed management as part of the landscape maintenance period during and post construction should identify areas for intervention in the vicinity of Coolgardie Rd and should focus on Ochna, Small-leaved Privet and Asparagus Fern to reduce impacts on adjacent threatened rainforest communities and rainforest plants.	Adopted	Current

5 References

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Appendix 1: Photos of rainforest monitoring plots

Impact and Control pairs

Spring 2018

Plate 1: Plot 1 (Impact) – Littoral rainforest

Plate 2: Plot 5 (Control) – Littoral rainforest

Plate 3: Plot 2 (Impact) – alluvial rainforest, Randle's Creek

Plate 4: Plot 2 (Control) – alluvial rainforest, Randle's Creek

Plate 5: Plot 4 (Impact) - Rainforest regrowth on rocky hillside

Plate 6: Plot 6 (Control) - Rainforest regrowth on rocky hillside

Plate 7: Plot 8 (Impact) - Rainforest regrowth on rocky hillside

Plate 9: Plot 9 (Control) - Rainforest regrowth on rocky hillside

Plate 10: Plot 11 (Impact) – Littoral rainforest

Plate 11: Plot 10 (Control) – Littoral rainforest

Plate 12: Plot 13 (Impact) – Rainforest regrowth on rocky hillside

Plate 13: Plot 14 (Control) – Rainforest regrowth on rocky hillside

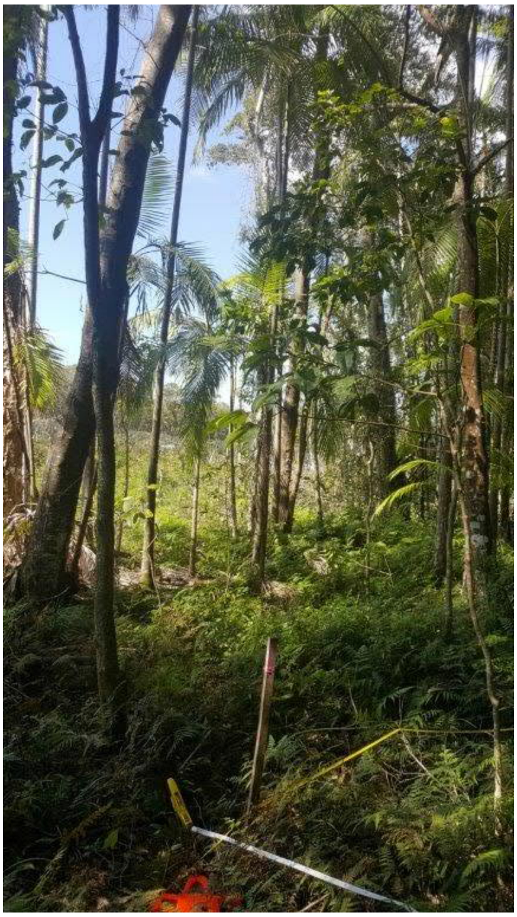

Plate 13: Plot 7 (Impact) – Swamp/Bangalow Palm Rainforest

Plate 14: Plot 12 (Control) – Swamp/Bangalow Palm Rainforest

Appendix 2: Photos of threatened rainforest species

Spring 2018


Plate 15: Macadamia tetraphylla no.23,rocky hillside rainforest regrowth near impact plot 13

Plate 16: Macadamia tetraphylla no.29,rocky hillside rainforest regrowth near impact plot13

Plate 17: Macadamia tetraphylla no. x in flower near control plot 10, Whytes Lane

Plate 18: Macadamia tetraphylla no. x in flower near impact plot13

Plate 19: Ochrosia moorei in alluvial rainforest on Randle Creek near Control plot 2

Appendix 3: PCA ordination of rainforest monitoring plots through time

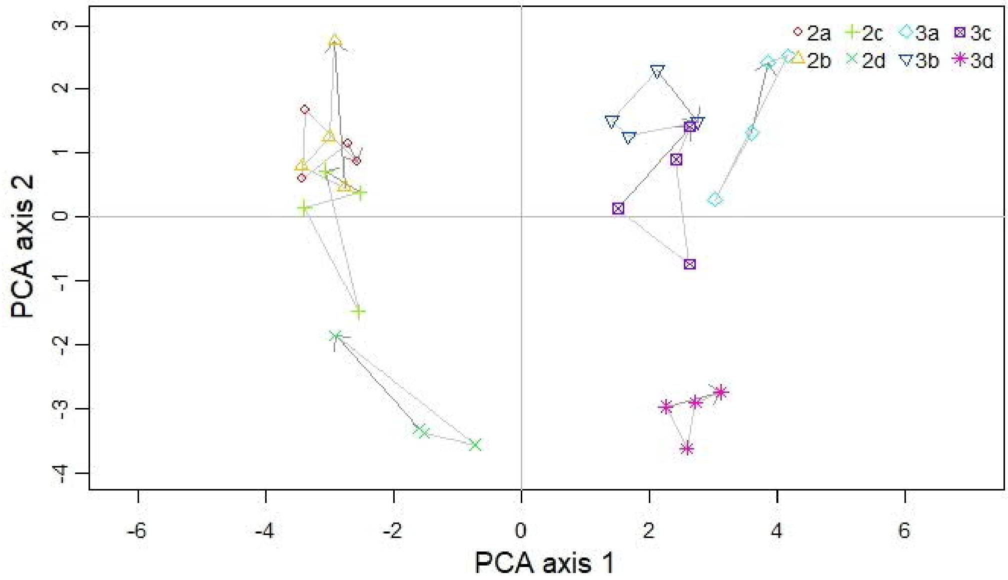

Figure 1. Principal Component Analysis (PCA) of subplots of Plot 2 (impact) and Plot 3 (control), sampled February 2014, autumn 2017, spring 2017 and spring 2018. Lines connect points of the same time series and an arrow points from the initial state (February 2014) to the final state (spring 2018).

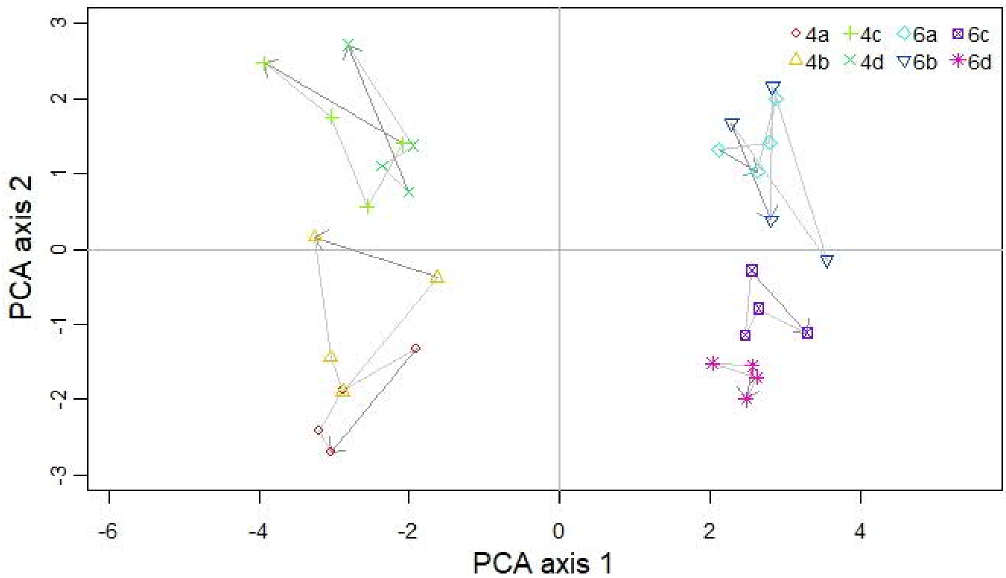

Figure 2. Principal Component Analysis (PCA) of subplots of Plot 4 (impact) and Plot 6 (control), sampled February 2014, autumn 2017, spring 2017 and spring 2018. Lines connect points of the same time series and an arrow points from the initial state (February 2014) to the final state (spring 2018).

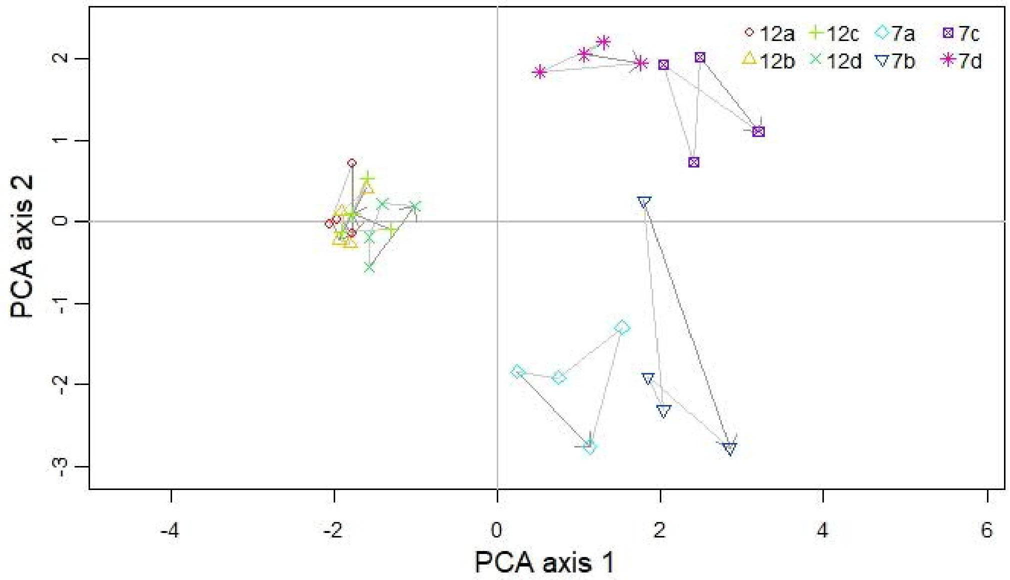

Figure 3. Principal Component Analysis (PCA) of subplots of Plot 7 (impact) and Plot 12 (control), sampled February 2014, autumn 2017, spring 2017 and spring 2018. Lines connect points of the same time series and an arrow points from the initial state (February 2014) to the final state (spring 2018).

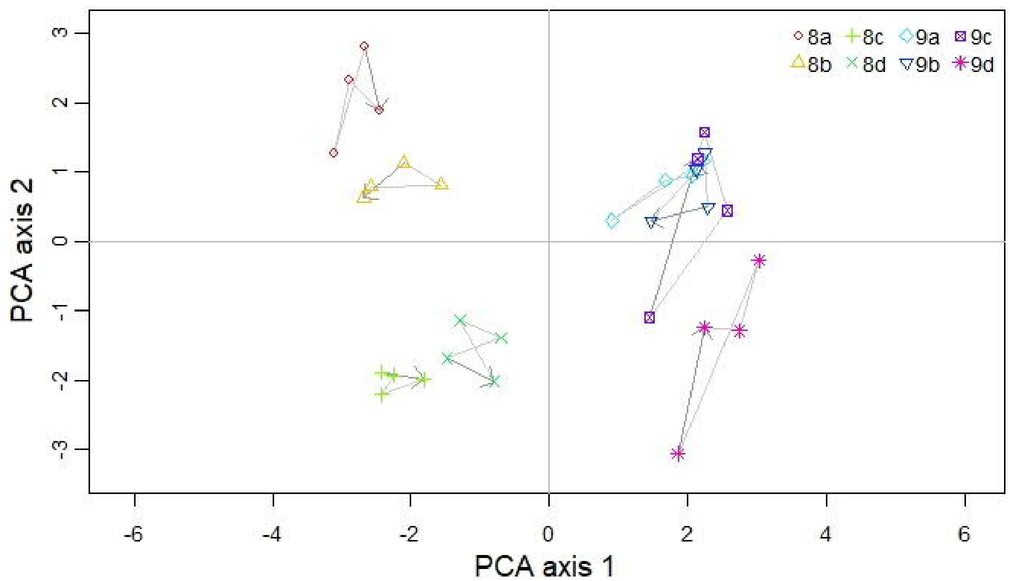

Figure 4. Principal Component Analysis (PCA) of subplots of Plot 8 (impact) and Plot 9 (control), sampled February 2014, autumn 2017, spring 2017 and spring 2018. Lines connect points of the same time series and an arrow points from the initial state (February 2014) to the final state (spring 2018).

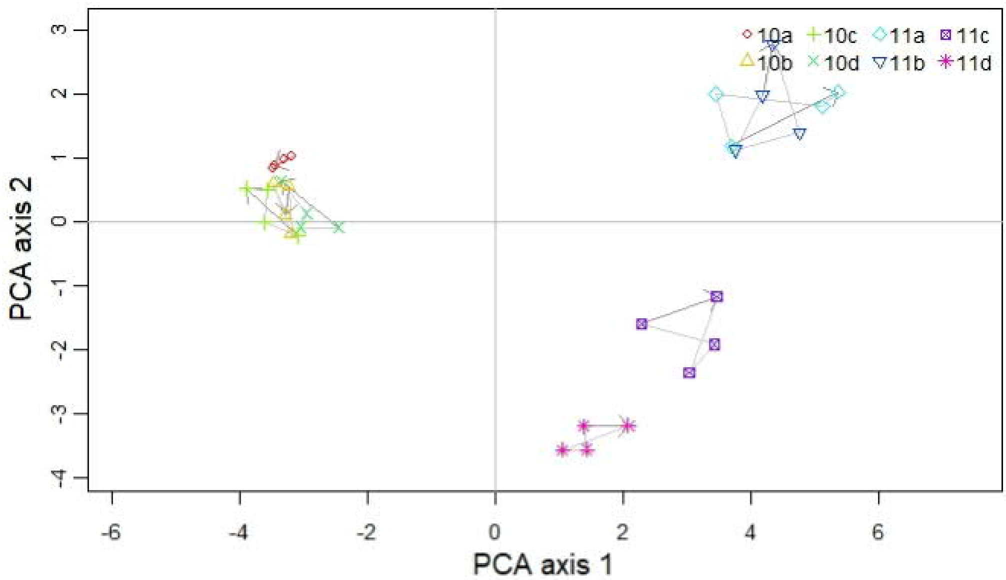

Figure 5. Principal Component Analysis (PCA) of subplots of Plot 10 (control) and Plot 11 (impact), sampled February 2014, autumn 2017, spring 2017 and spring 2018. Lines connect points of the same time series and an arrow points from the initial state (February 2014) to the final state (spring 2018).

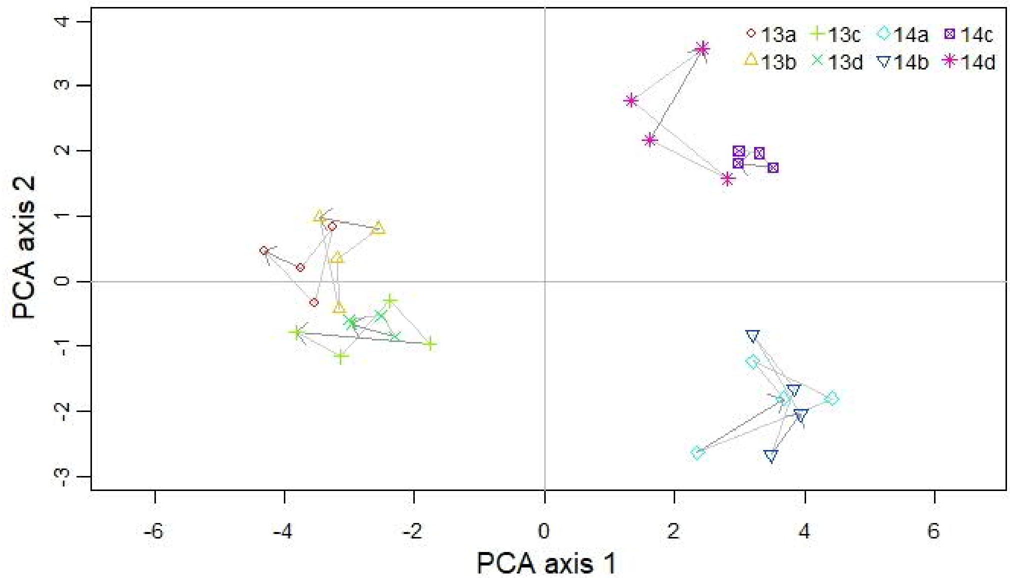

Figure 6. Principal Component Analysis (PCA) of subplots of Plot 13 (impact) and Plot 14 (control), sampled February 2014, autumn 2017, spring 2017 and spring 2018. Lines connect points of the same time series and an arrow points from the initial state (February 2014) to the final state (spring 2018).