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Project Title: Woolgoolga to Ballina Pacific Highway Upgrade Invertebrate Monitoring Program Annual Report 2018, Year 1 Construction Phase Report

Project Author/s: Dr Penn Lloyd, Dr Lindsay Popple and Mr Lui Weber

Project Summary: This report presents the results of the first construction phase season of monitoring for threatened invertebrates for the Woolgoolga to Ballina Pacific Highway Upgrade Project. Monitoring of invertebrate activity and habitat condition was performed for Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle at impact sites close to the construction footprint and at two control sites in Victoria Park Nature Reserve and Davis Scrub Nature Reserve monthly from November 2017 to March 2018 for comparison with baseline pre-construction monitoring results.

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# EXECUTIVE SUMMARY

## Background and objectives

Biodiversity Assessment and Management (BAAM) has prepared this report for Jacobs on behalf of Pacific Complete to document the results of the first construction phase survey and nocturnal monitoring for two threatened invertebrate species for the Woolgoolga to Ballina Pacific Highway Upgrade Project. The objectives of the study are to:

1. Monitor Southern Pink Underwing Moth *Phyllodes imperialis smithersi* and Atlas Rainforest Ground Beetle *Nurus atlas* populations at five established monitoring transects close to Section 10 of the Project (referred to as 'impact sites' due to their potential to experience indirect impacts due to their close proximity to the highway construction footprint) and two nearby control sites
2. Monitor habitat condition for the moth and beetle at the monitoring transects and additional nearby sites
3. Monitor host plant populations (and their condition) for the moth at the monitoring transects and additional nearby sites
4. Check the outcomes of the monitoring against the performance measures relevant to construction outlined in the Threatened Invertebrates Management Plan (TIMP) for the Project.

## Methodology

The methodology used in this study was designed to be consistent with the approach and objectives outlined in the TIMP. Nocturnal monitoring for Pink Underwing Moth and Atlas Rainforest Ground Beetle was performed for one night monthly from November 2017 to March 2018 (six monitoring events) at each of five impact site transects and two control site transects. Fruit (banana) baits were deployed on each occasion to attract Southern Pink Underwing Moths. Searches for Atlas Rainforest Ground Beetles were reliant on active observation and the identification and examination of their distinctive burrows.

A habitat assessment survey, conducted over three days 6-8 March 2018, included assessment of habitat condition at a network of habitat assessment sites for each of the two invertebrate species as well as searches for Southern Pink Underwing Moth larvae and Atlas Rainforest Ground Beetle burrows. The habitat assessment sites included the five impact transect sites, two control transect sites and additional sites (11 for Southern Pink Underwing Moth and eight for Atlas Rainforest Ground Beetle) located more broadly in rainforest habitats close to the highway construction footprint.

## Results and Discussion

No adult Southern Pink Underwing Moths were detected during any nocturnal monitoring event; however, a variety of other moth species were detected feeding at the baits. No larvae of Southern Pink Underwing Moth were detected during the first four monitoring events November 2017 to January 2018. Five weeks after the January survey, 27 Southern Pink Underwing Moth larvae were found at four of the five impact transect sites and at the Davis Scrub Nature Reserve control transect site on 20th February during relatively short surveys of host plants along the nocturnal monitoring transects. During the March habitat assessment survey at a broader network of sites, 75 Southern Pink Underwing Moth larvae of various ages were found, including at four of the five impact transect monitoring sites, one of the two control transect monitoring sites and at eight of the nine other monitoring sites with host plants present. Larvae were also found at six of eight additional sites where host plants were found. Overall, Southern Pink Underwing Moth larvae were found at 79% of sites with host plants present. No previous

survey for the species conducted anywhere across its range has located as many larvae as the March 2018 survey in the study area.

Patches of the Southern Pink Underwing Moth larval host plant *Carronia multisepalea* were re-surveyed at all habitat monitoring sites where the host plant had been previously recorded ie the five impact transect sites, two control transect sites and nine of the 11 additional habitat assessment sites located more broadly near the highway construction footprint. Patches of host plant were also detected at an additional eight sites. Host plant population sizes at each of the monitoring sites were generally stable or had increased since the preconstruction baseline surveys. The extent of known habitat for the species close to the construction footprint has increased from 33.2ha to 43.9ha following confirmation of use of additional habitat areas by the species for breeding in. The presence of a large number of *Carronia multisepalea* host plant populations that contain mature vines and exhibit substantial recent recruitment, together with the finding of relatively large numbers of larvae of the moth during the current and earlier surveys confirms that the rainforest habitats close to the construction footprint are a significant breeding area for Southern Pink Underwing Moth, particularly during favourable seasonal rainfall conditions. The condition of the supporting habitat appears to be slowly improving as the process of succession in regrowth areas advances. The results demonstrate that the early construction works on the highway upgrade have had no indirect impact on the breeding success of Southern Pink Underwing Moth in rainforest habitats close to the highway construction footprint.

Atlas Rainforest Ground Beetle was detected on all nocturnal surveys; its activity was generally greater on calm nights after recent rainfall, and least during dry spells. The surveys detected more Atlas Rainforest Ground Beetles at more locations than previous surveys, confirming the presence of small numbers of beetles at three different locations at or close to the T1 and T5 impact monitoring sites, and the continuing good health of a larger population at Davis Scrub Nature Reserve control site. However, the small number of beetles located at Victoria Park Nature Reserve control site during previous surveys in March 2014 and 2017 had disappeared, and no new burrows were located at the site. These results confirm that a low density population of Atlas Rainforest Ground Beetle continues to persist in rainforest habitats close the highway construction footprint. The results also demonstrate that the early construction works on the highway upgrade have had no indirect impact on the occupancy of rainforest habitats close to the highway construction footprint by Atlas Rainforest Ground Beetle.

**Recommendations for Future Monitoring**

The Threatened Invertebrates Management Plan is intended to be a dynamic document subject to continual improvement. The construction phase monitoring conducted to date has not identified any indirect impacts of the Project on any threatened invertebrate species; therefore adaptive management of the mitigation measures set out in the TIMP is not required. Three seasons of trialling the nocturnal monitoring method for Southern Pink Underwing Moth, whereby over-ripe banana baits are visited at night to try to detect moths attracted to the baits, has shown the method to be ineffective. It is therefore recommended that this monitoring method be discontinued and the survey effort previously expended on this method be allocated to improving the survey effort coverage of larval-stage monitoring. Recommendations for a revised survey approach are as follows:

- Four monthly surveys (November, December, January, February) for Southern Pink Underwing Moth larvae and Atlas Rainforest Ground Beetle burrows during daylight hours at an expanded network of monitoring sites, including the two control transect sites, five impact transect sites and 11 additional sites close to the highway construction footprint; this network of sites accounted for 79% of the host plant availability in habitats close to the highway construction footprint and 87% of the larvae recorded during the March 2018 survey.

- A single habitat assessment survey in March, including a survey for Southern Pink Underwing Moth larvae and Atlas Rainforest Ground Beetle burrows during daylight hours at all habitat assessment monitoring sites, as well as a survey for Southern Pink Underwing Moth larvae at an additional eight sites identified during the March 2018 survey. This survey replicates the habitat assessment survey as originally outlined in the TIMP, but expands the number of Southern Pink Underwing Moth larvae monitoring sites for the assessment of total larval population size.
- Five monthly surveys (November to March) conducted at night at each of the two control and seven impact transect monitoring sites, visiting all potential Atlas Rainforest Ground Beetle burrows identified and marked during the daytime surveys to determine if these burrows are indeed occupied by the species. This survey replicates the Atlas Rainforest Ground Beetle monitoring survey method as originally outlined in the TIMP.

# INVERTEBRATE MONITORING PROGRAM ANNUAL REPORT 2018
# YEAR 1 CONSTRUCTION PHASE REPORT

# WOOLGOOLGA TO BALLINA PACIFIC HIGHWAY UPGRADE

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## *Table of Appendices*



## *Table of Terms and Abbreviations*

| | |
|---|---|
| BAAM | Biodiversity Assessment and Management Pty Ltd |
| Conservation significant | Includes species listed as Critically Endangered, Endangered, Vulnerable and Near Threatened under the EPBC Act and/or TSC Act and species listed as Regionally Significant under the Byron Biodiversity Conservation Strategy, which have been identified in association with rainforest communities in the Study Area |
| EPBC Act | Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* |
| RMS | Roads and Maritime Services |
| SKM | Sinclair Knight Merz |
| Study Area | The area encompassing a network of monitoring sites close to the Woolgoolga to Ballina Pacific Highway Upgrade Corridor between Pimlico and Buckombil Mountain southwest of Ballina, northern New South Wales |
| TSC Act | New South Wales *Threatened Species Conservation Act 1995* |

# 1.0 INTRODUCTION

## 1.1. BACKGROUND AND PURPOSE

Biodiversity Assessment and Management (BAAM) has prepared this report for Jacobs on behalf of Pacific Complete to document the results of surveys and nocturnal monitoring for conservation significant invertebrates on properties close to Section 10 of the Woolgoolga to Ballina Pacific Highway Upgrade at Coolgardie Road near Wardell in northern New South Wales during the first year of the construction phase. The scope of work also required nocturnal monitoring at control locations in two national park estates to the north-west of Section 10 for comparative purposes.

This report fulfils obligations specified under the Woolgoolga to Ballina Threatened Invertebrate Management Plan (NSW Roads and Maritime Services 2015), which prescribes management practices for values protected by the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the *Threatened Species Conservation Act 1995* (TSC Act). More specifically, this study aims to:

- Monitor Southern Pink Underwing Moth *Phyllodes imperialis smithersi* and Atlas Rainforest Ground Beetle *Nurus atlas* populations at five established monitoring transects close to Section 10 of the Project (referred to as 'impact sites' due to their potential to experience indirect impacts due to their close proximity to the highway construction footprint) and two nearby control sites
- Monitor habitat condition for the moth and beetle at the monitoring transects and additional nearby sites
- Monitor host plant populations (and their condition) for the moth at the monitoring transects and additional nearby sites
- Check the outcomes of the monitoring against the performance measures relevant to construction outlined in the Threatened Invertebrates Management Plan (NSW Roads and Maritime Services 2015).

The area encompassing the complete network of impact and control monitoring sites included in this study is hereafter referred to as the 'study area'.

## 1.2. SITE DESCRIPTION

The portion of the Woolgoolga to Ballina Pacific Highway Upgrade that passes through the study area partially follows the footprint of the existing Pacific Highway near Pimlico in the north, then diverting to the west from the intersection of Coolgardie Road southwest to Lumleys Lane, Wardell (**Figure 1.1**). The five impact transect monitoring sites as well as other habitat monitoring sites are located in vegetation types that include Lowland Rainforest of Subtropical Australia, listed as a Threatened Ecological Community (TEC) under the EPBC Act, as well as rainforest regrowth that does not meet the condition thresholds for recognition as the TEC (BAAM 2012, 2013). The rainforest regrowth includes patches dominated by Camphor Laurel *Cinnamomum camphora*, an introduced tree species. Almost all patches of these habitats close Section 10 are restricted to steep rocky slopes or lower slopes on dark basaltic soils (Sheringham *et al.* 2008). However, red basaltic soils transition abruptly to lighter coloured soils, presumably kurosols derived from metamorphic rocks (Jenkins and Morand 2002) on some parts of Buckombil Mountain. Furthermore, one habitat monitoring site north of Coolgardie Road occurs in rainforest on the alluvial plain.

The two control sites are situated north-west of Section 10, in Victoria Nature Reserve and Davis Scrub Nature Reserve. Both these reserves contain remnant Lowland Rainforest on rich red ferrosols formed on a basaltic plateau (Jenkins and Morand 2002).

Figure 1.1 Location of the Study Area

### 1.3. CONSTRUCTION WORK

The highway upgrade will build a partly raised, multi-lane highway, with interchanges, lighting and temporary construction infrastructure located at appropriate points. This development requires clearing of vegetation and earthwork along a linear corridor through the study area; however, the position of the road corridor has been sited to avoid direct impact to rainforest habitats close to the road corridor that contain populations of the conservation significant invertebrates targeted in this study. More specific details on the Project are available in NSW Roads and Maritime Services (2013). The start of vegetation clearing for the highway upgrade close to the impact monitoring sites coincided with the start of monitoring in November 2017. By March 2018 the highway construction footprint had been cleared and substantial road-base had been laid down.

### 1.4. TARGET SPECIES

The target species for this monitoring program are the two threatened invertebrate species that are known to occur in rainforest habitats in the study area:

- Pink Underwing Moth *Phyllodes imperialis smithersi* (listed as endangered under the EPBC Act and the TSC Act) and its host plant *Carronia multisepalea* (not threatened)
- Atlas Rainforest Ground Beetle *Nurus atlas* (listed as endangered under the TSC Act).

Incidental observations of a third species, Richmond Birdwing *Ornithoptera richmondia*, listed as Regionally Significant under the Byron Biodiversity Conservation Strategy, and its host plant *Pararistolochia praevenosa* (not threatened), were also included as a component of the assessment.

## 2.0 METHODOLOGY

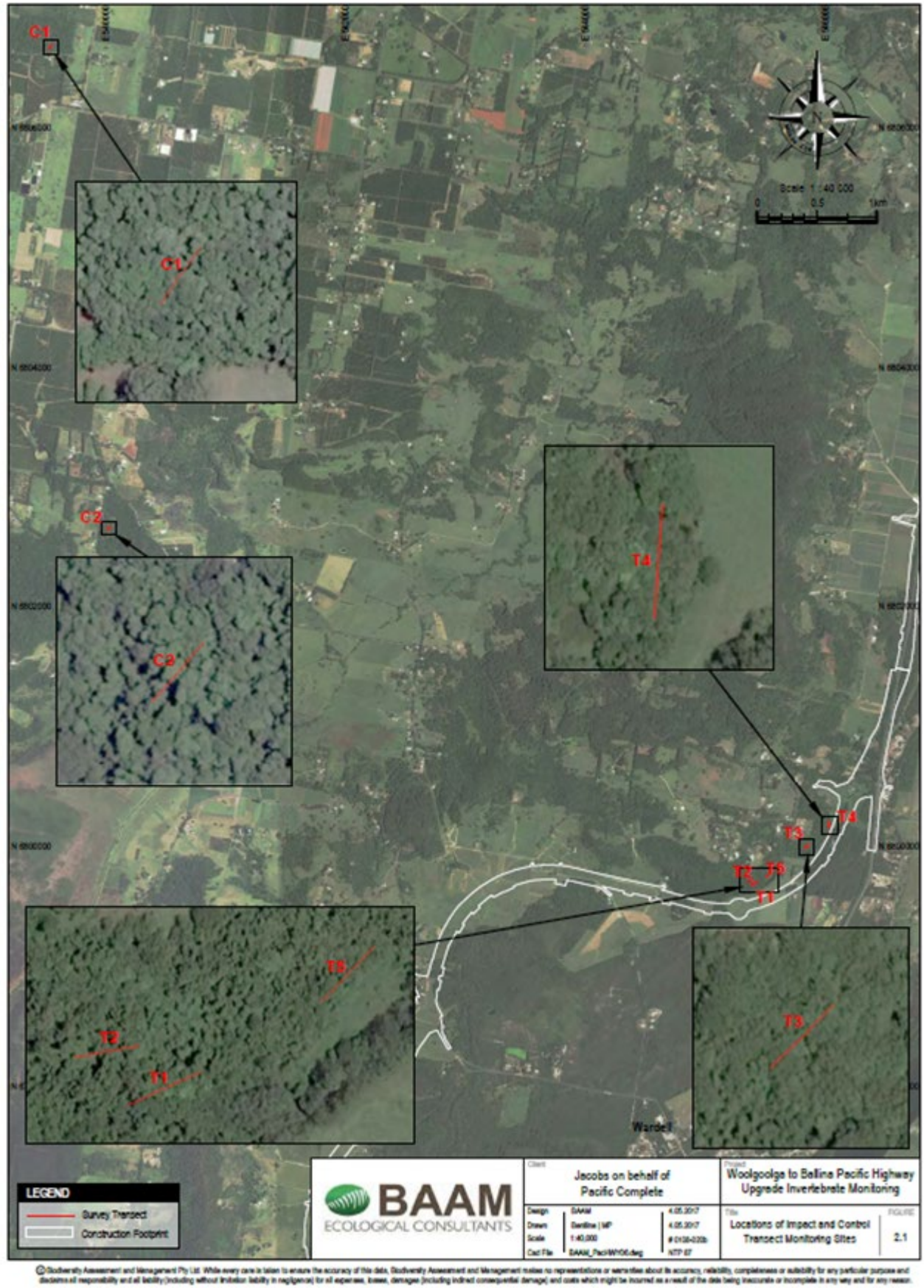
The methodology used in this study was designed to be consistent with the approach and objectives outlined in the Threatened Invertebrates Management Plan (NSW Roads and Maritime Services 2015). It included nocturnal monitoring of threatened invertebrates and host plants during the months November 2017 to March 2018 (six nocturnal monitoring events in total), and a single habitat assessment survey in March 2018. Surveys were performed by Dr Lindsay Popple and Shelley Trevaskis on 8 November, by Dr Lindsay Popple and Dr Penn Lloyd on 11 November and 19 December, by Dr Penn Lloyd and Shelley Trevaskis on 16 January and 20 February, and by Dr Penn Lloyd and Lui Weber on 6-8 March. All surveys were performed under BAAM's NSW Scientific Licence number SL100704.

### 2.1. NOCTURNAL MONITORING OF THREATENED INVERTEBRATES AND HOST PLANTS ALONG TRANSECTS

Nocturnal monitoring for Pink Underwing Moth and Atlas Rainforest Ground Beetle was performed at each of the five impact site transects and the two control site transects identified during the initial preconstruction baseline survey. The locations of the monitoring transects are shown in **Figure 2.1**. A description of each of the five impact site and two control site transects is provided in **Appendix A**. Each transect was 50 m in length, with some deviation from a straight line to improve detection of Atlas Rainforest Ground Beetle in areas of potentially suitable microhabitat. The start and end of each transect was recorded by GPS. Flagging tape was used to mark 10 m intervals along each transect to facilitate the deployment of baits for Pink Underwing Moth.

Nocturnal monitoring occurred for one night each month from November 2017 to March 2018. Baits were prepared and deployed during the afternoon before each monitoring session, each bait comprising a one-third portion of over-ripe banana placed into a nylon-string bag (see **Photos 3.1** and **3.2**). A single bait was suspended from a tree branch within arm's reach at each 10 m interval along each 50 m transect (six baits per transect).

Figure 2.1 Location of impact and control transect monitoring sites



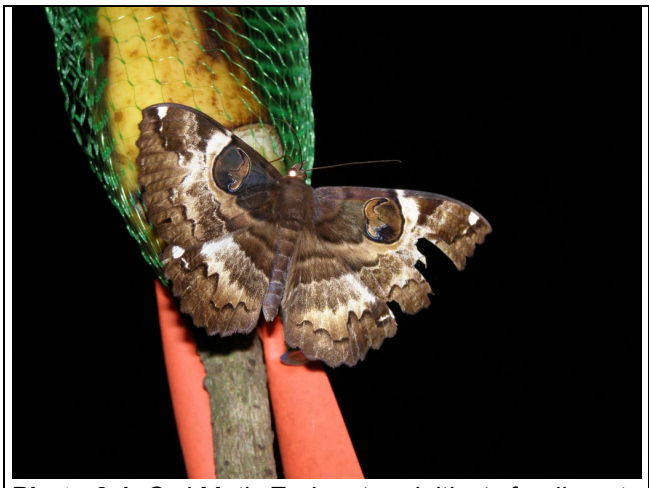


**Photo 3.1.** Owl Moth *Erebus terminitincta* feeding at a banana bait.

**Photo 3.2.** Common Fruit Piercing Moth *Eudocima fullonia* feeding at a banana bait.

Monitoring started approximately 45 minutes after sunset and lasted approximately 20 minutes along each transect, typically ending between 10.30 pm and 11:30 pm. Night vision goggles and a night vision LED torch were used to scan each bait for signs of moth activity. Small LED flashlights were used to negotiate areas of difficult terrain along each transect and during transit. Use of these torches was kept to a minimum to minimise light disturbance prior to the checking of each bait. Baits were removed sequentially after being checked. Thereafter, LED flashlights were used to search the ground and any previously identified burrows in the vicinity of each transect for signs of Atlas Rainforest Ground Beetle activity. The foliage of any host plants encountered along each transect was also briefly checked for any signs of moth larvae. Notes on the invertebrate activity and weather conditions were kept for each transect during each weekly monitoring event.

## 2.2. HABITAT ASSESSMENTS

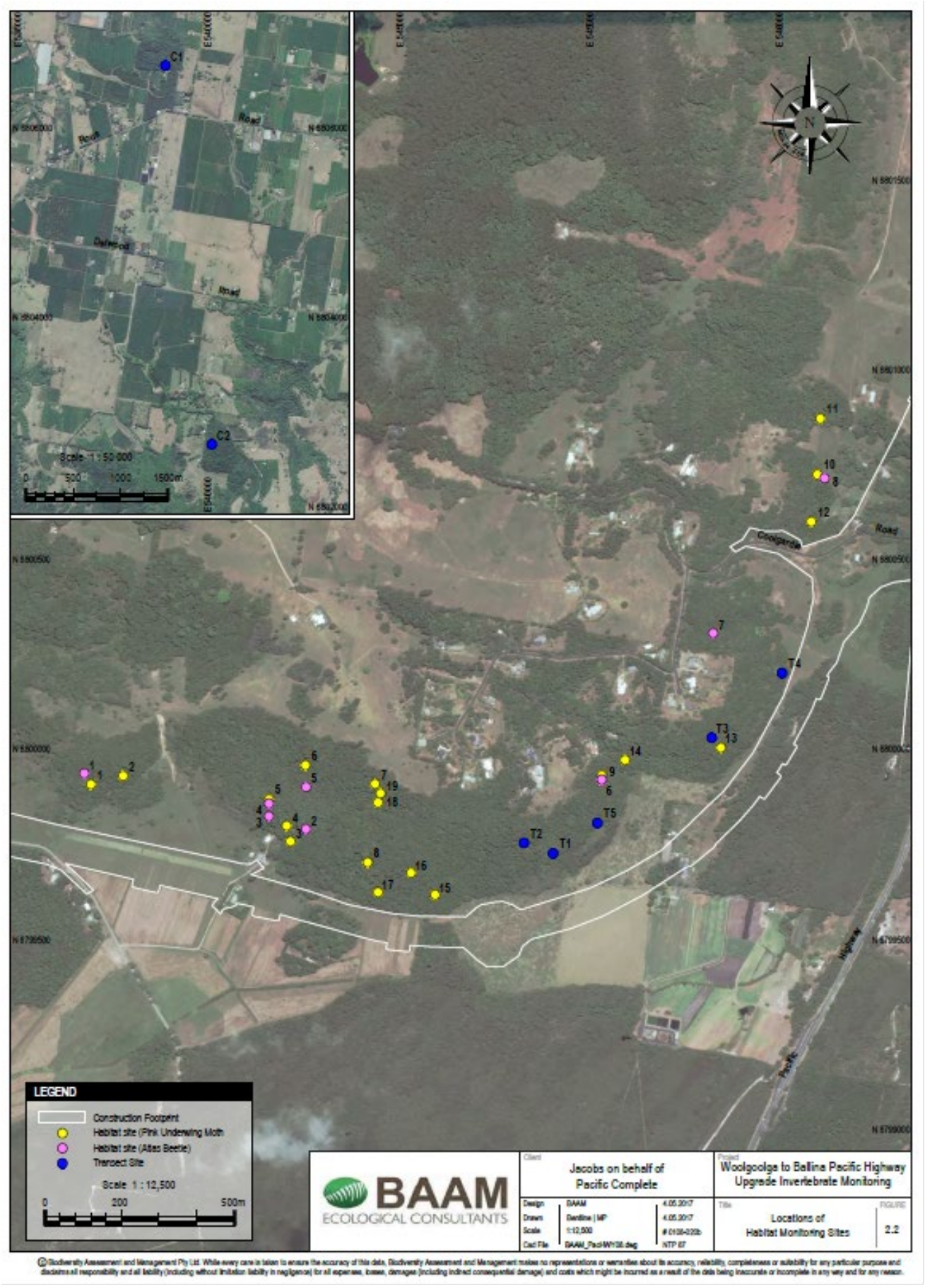
The habitat assessment survey, conducted over three days 6-8 March 2018, included assessment of habitat condition at a network of habitat assessment sites for each of the two invertebrate species as well as searches for Southern Pink Underwing Moth larvae and Atlas Rainforest Ground Beetle burrows. The habitat assessment sites included the five impact transect sites, two control transect sites and additional sites (11 for Southern Pink Underwing Moth and eight for Atlas Rainforest Ground Beetle) located more broadly within the study area close to the highway construction footprint (**Figure 2.2**). The habitat assessment methods for each of the two invertebrate species are outlined in the following two sections.

### *2.2.1. Southern Pink Underwing Moth*

In accordance with the preconstruction survey, the following data were collected at each of the 18 fixed habitat assessment sites for Southern Pink Underwing Moth:

- Total number, sex (where apparent) and form (seedling, shrub or vine) of *Carronia multisepalea* plants
- Dominant leaf characteristics (broad-leaved or narrow-leaved) of *Carronia multisepalea* plants at the site, including presence of soft, pale, new leaf growth, and any evidence of leaf damage consistent with the feeding of Southern Pink Underwing Moth larvae
- Presence, total number and age of any Southern Pink Underwing Moth eggs or larvae found on *Carronia multisepalea* host plants
- Number of fleshy-fruited native tree species in the habitat surrounding the site
- Percent cover of native and exotic plant species in each stratum of the habitat surrounding the site
- Percent canopy cover of the habitat surrounding the site.

Figure 2.2


C1
C2
Road
Scale 1 : 50 000
0 500 1000 1500m
Coopernook Road
Pacific Highway
LEGEND
Construction Footprint
Habitat site (Pink Underwing Moth
Habitat site (Atlas Beetle)
Transect Site
Scale 1 : 12,500
0 200 500m
BAAM
ECOLOGICAL CONSULTANTS
Jacobs on behalf of Pacific Complete
Woolgoolga to Ballina Pacific Highway Upgrade Invertebrate Monitoring
Locations of Habitat Monitoring Sites
2.2

At each of the five impact site transects and two control site transects, photographs were taken at each cardinal compass point at the centre of each transect for comparison with baseline condition photographs.

Wherever additional patches of *Carronia multisepalea* were encountered during meandering traverses of the study area between the previously identified fixed monitoring sites, the total number and form of host plants in the patch were recorded, the coordinates of the patch were recorded via hand-held GPS and the foliage of the plants was thoroughly searched to identify the presence, total number and age of any Southern Pink Underwing Moth eggs or larvae. Searches for eggs and larvae included turning over the leaves of the host plant to search the undersides of leaves for eggs and early-instar (ie younger) larvae, particularly the foliage of plants showing leaf damage consistent with the feeding of Southern Pink Underwing Moth larvae.

#### *2.2.2. Atlas Rainforest Ground Beetle*

In accordance with the preconstruction survey, the following data were collected at each of the 15 fixed habitat assessment sites for Atlas Rainforest Ground Beetle:

- Percentage cover of rocks in the ground layer
- Percentage cover of logs in the ground layer
- Percentage cover of overhangs in the ground layer
- Total number of active burrows consistent with the size and shape of those inhabited by Atlas Rainforest Ground Beetle found during a meandering search in areas of suitable habitat at the site, searching the bases of rocks, logs and plant roots for burrow entrances; surveys focussed particularly on areas where burrows have previously been recorded.

#### *2.2.3. Richmond Birdwing*

Opportunistic observations and records of Richmond Birdwing butterflies and larvae were made during the survey and throughout the monitoring.

### 2.3. HABITAT MAPPING AND CONDITION SCORES FOR SOUTHERN PINK UNDERWING MOTH

The first preconstruction survey (BAAM 2014) mapped patches of habitat for Southern Pink Underwing Moth into three categories:

1. Known habitat where the host plant occurs and the adult moth or larvae have been recorded
2. Potential habitat where the host plant occurs but the adult moth or larvae have not been recorded
3. Potential habitat where neither the host plant nor the adult moth or larvae have yet been detected.

Areas of potential and known habitat were scored by 'habitat condition' relative to the ecological requirements of Southern Pink Underwing Moth as far as they are understood. Polygons were given a score of between 0 and 6, with a point being awarded for each one of these criteria (modified from BAAM 2013):

- Host plant (*Carronia multisepalea*) was detected during the surveys
- Number of native fleshy-fruited tree species detected during the survey was >20
- Patch exhibited natural canopy gaps, allowing for potential recruitment of the host plant
- Canopy cover comprised >50% native species
- Number of rainforest indicator species (from TSSC 2011) was >30
- Included areas where canopy cover was dominantly ≥65%.

This mapping was designed to be updated based on the survey results following each year of monitoring. The second preconstruction survey in March 2017 (BAAM 2017) did not detect Southern Pink Underwing Moth adults or larvae; therefore no mapping update was performed. The present study amended the mapping based on the application of the criteria listed above.

### 2.4. INVESTIGATING THE FEASIBILITY OF CAMERA MONITORING OF MOTHS

Due to the ongoing lack of success in detecting Southern Pink Underwing Moths using the nocturnal monitoring survey methodology, the feasibility of using remote cameras for monitoring moth activity was investigated through a review of any published information on nocturnal monitoring of moths using remote cameras as well as testing a remote camera commonly used for nocturnal monitoring of larger vertebrate animals. The latter test involved setting up a Reconyx HC500 Hypefire camera at a distance of 30 cm from an over-ripe banana bait. The camera was set to high sensitivity and to take three rapid-fire pictures per trigger with no delay after being triggered and no quiet period. The camera was in place for two consecutive nights, with the bait refreshed after the first night.

## 3.0 RESULTS

### 3.1. RAINFALL CONDITIONS DURING THE MONITORING PERIOD

Rainfall prior to the start of the monitoring surveys was substantially above-average during late summer to mid-winter 2017, but substantially below average over the three months July to September 2017 (**Figure 3.1**). Above average rainfall then occurred through the summer of 2017/18.

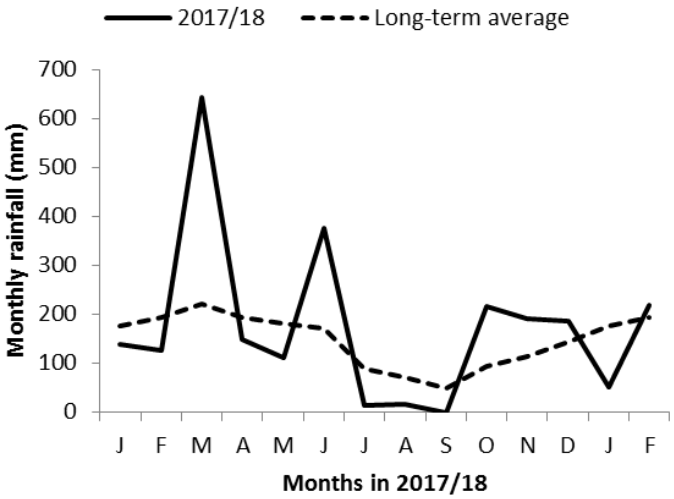



**Figure 3.1.** Monthly rainfall between January 2017 and February 2018 at Meerschaum Vale Weather Station compared to the long-term average. Data from http://www.bom.gov.au/climate/data/.

### 3.2. NOCTURNAL MONITORING

#### *3.2.1. Southern Pink Underwing Moth*

A summary of the monthly nocturnal monitoring results is provided in **Table 3.1**. Notably, no adult Southern Pink Underwing Moths were detected during any nocturnal monitoring event; however, a variety of other moth species were detected feeding at the baits (**Photos 3.1** to **3.2**). No larvae of Southern Pink Underwing Moth were detected during the first four monitoring events on 8 November, 24 November,19 December and 16 January. Five weeks after the 16 January survey, a total of 27 Southern Pink Underwing Moth larvae of various ages, including well-developed fifth instar larvae were found at four of the five impact transect sites and at the Davis Scrub Nature Reserve control transect site on 20 February during relatively short surveys of host plants along the nocturnal monitoring transects (see **Table 3.2** for further details). In light of this result, the final

survey, which included the broader habitat and population assessments was brought forward a week to 6-8 March to try to ensure the broader survey for larvae occurred at a time when larvae were likely to be at peak abundance. Southern Pink Underwing Moth larvae of various ages were again detected during the nocturnal survey of 7 March following more comprehensive surveys conducted during the day as part of the habitat assessment survey reported under **Section 3.3** below.

### *3.2.2. Atlas Rainforest Ground Beetle*

Atlas Rainforest Ground Beetle was detected on all nocturnal surveys (**Table 3.1**); the activity of this species was generally greater on calm nights after recent rainfall, and least during dry spells. At impact site T1, a burrow previously active at the western edge of the transect in March 2017 had been taken over by ants, but a single new active burrow was located nearby in March 2018 (**Photo 3.4**). Up to two active burrows were identified at impact site T5, the first record of the species at this transect (**Photo 3.3**), and up to four active burrows were located at the rainforest edge approximately 45 m east of impact site T1 for the first time. No beetle burrows were detected at the other impact sites or at the Victoria Park control site C2. Up to nine active beetle burrows were detected on most surveys at Davis Scrub Nature Reserve control site C1.

**Photo 3.3.** Atlas Rainforest Ground Beetle outside its burrow under a root at impact site T5.

**Photo 3.4.** Atlas Rainforest Ground Beetle at the entrance to its burrow under a root at impact site T1.

## 3.3. HABITAT ASSESSMENTS

The habitat assessment survey, which included more comprehensive searches for Southern Pink Underwing Moth larvae and Atlas Rainforest Ground Beetle burrows at a broader network of impact monitoring sites was performed over three days 6-8 March 2018. Detailed data from the habitat assessments are presented in **Appendix B**; measures of habitat condition remain unchanged since the March 2017 preconstruction survey, with no evidence of any habitat degradation or damage since the previous baseline surveys.

### *3.3.1. Southern Pink Underwing Moth*

Patches of the host plant *Carronia multisepalea* were re-located at all Southern Pink Underwing Moth habitat monitoring sites where the host plant had been previously recorded ie the five impact transect sites, two control transect sites and nine of the 11 additional habitat assessment sites located more broadly near the highway construction footprint. No host plants were located at the two habitat assessment sites where host plants have not previously been detected. Patches of host plant within between 1 and 72 plants were also detected at an additional eight sites (**Figure 3.2**).

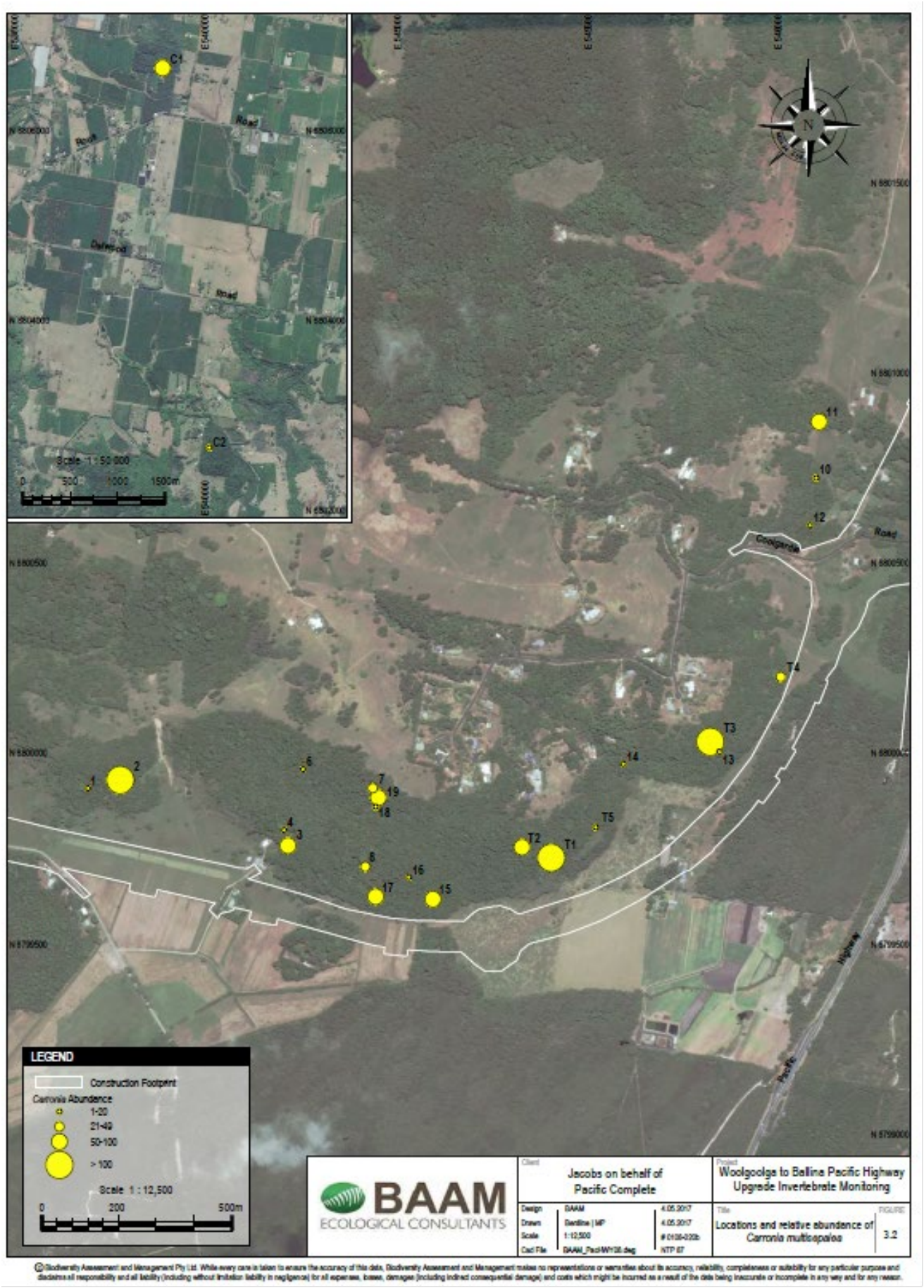
Host plant population sizes at each of the monitoring sites were generally stable or had increased since the preconstruction surveys (**Figure 3.3**); some increases in the total counts may be due to either larger areas being covered or difficulties in establishing the number of individual plants from the number of stems emerging from the ground, since individual plants can have multiple stems that can be difficult to separate from other plants.

**Table 3.1. Summary of the results of nocturnal monitoring for Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle during the 2017/18 season.**

| Date | Rainfall | General Notes | Atlas Rainforest Ground Beetle | Pink Underwing Moth |
|---|---|---|---|---|
| 8 November 2017 | Over 125 mm over three days prior to survey, following a prolonged spell of dry conditions. | Cool night, with some precipitation at control transect C2, moderate humidity and little invertebrate activity. A tree cricket was observed on transect T1. A likely Owl Moth *Erebus terminitincta* was observed feeding briefly at a bait in transect T5. A cockroach attended a bait on control transect C1. | The burrow identified at transect T1 during the previous season was inspected and may be active. Six burrows observed on control transect C1 were presumed to be active. No beetles were observed at burrow entrances. | No activity or possible signs of adult Pink Underwing Moth were found at any of the impact or control transects. |
| 24 November 2017 | 44.8 mm over four days prior to survey. | Warm night, with moderate humidity but no precipitation. A single Owl Moth was observed at baits in each of transects T1 and T5. A Raspy Cricket and a Sugar Ant were observed attending baits at control site C2. | The burrow identified at transect T1 during the previous season was inspected but no beetle was observed. A new localised cluster of several burrows, all with beetles near the entrances was found ~30 m east of transect T1. A total of nine active burrows with beetles at entrances were found at control transect C1. No burrows were found at C2. | No activity or possible signs of adult Pink Underwing Moth were found at any of the impact or control transects. |
| 19 December 2017 | A total 31.2 mm in early December. 0 mm in week prior to survey. | Warm evening, with low–moderate humidity and no precipitation. A Raspy Cricket was observed feeding on a bait in transect T4, a single Owl Moth was observed above a bait in transect T3, a Longhorn Beetle was found on a bait in transect T2 and a Common Fruit-piercing Moth was observed feeding at a bait in transect T1. Scutigerid centipedes were observed at several baits in transects 1–5. A Green Fruit-piercing Moth was observed feeding at bait in control site C1 and a Sugar Ant were observed attending baits at control site C2. | The burrow identified at transect T1 during the previous season was discovered to have been abandoned by the resident Atlas Rainforest Ground Beetle and had been re-occupied by Sugar Ants. A new localised cluster of several burrows, all with beetles near the entrances was found ~45 m east of transect T1. A total of nine active burrows with beetles at entrances were found at control transect C1. No burrows were found at C2. | No activity or possible signs of adult Pink Underwing Moth were found at any of the impact or control transects. |

| Date | Rainfall | General Notes | Atlas Rainforest Ground Beetle | Pink Underwing Moth |
|---|---|---|---|---|
| 16 January 2018 | A total of 70 mm in the first 4 days of January, dry thereafter. | Warm, dry evening with relatively strong winds. | Two new burrows with a beetle each at the burrow entrance identified on transect T5, the first records of the beetle at this transect location. No active beetles observed at C1 or at any other transect monitoring site. | No adult Pink Underwing Moth found during the nocturnal monitoring. Caronia plants showing signs of insect feeding damage, but only larvae of species in the family Geometridae were found on Carronia leaves during brief searching of plants on monitoring transects during the nocturnal survey. |
| 20 February 2018 | A total of 91 mm in January and a further 120 mm in the first week of February but relatively dry thereafter. | Warm, overcast, relatively calm evening with scattered light showers towards the end of the evening. Green Fruit-piercing Moth *Eudocima salaminia* seen feeding at two banana baits, as well as two other moth species. | Two active burrows re-located below transect T1, and one active burrow with a beetle re-located at transect T5. Three active burrows observed at C1, but no activity an any other transect monitoring site. | No adult Pink Underwing Moth found during the nocturnal monitoring, but 27 larvae of various ages found at T1, T2, T3, T5 and C1 during relatively short surveys of Carronia plants along the nocturnal monitoring transects (see additional details and photos in table below). Also one egg consistent with the species observed under a Carronia leaf in T5. |
| 6-8 March 2018 | A total of 91 mm in January, 234 mm in February and 25 mm in March prior to the survey, including 117 mm over the 2 weeks since the previous survey 2 weeks prior. Many Carronia plants showed fresh growth in response to the good summer season rainfall. | Light rain throughout the first day of the survey, mild, partly cloudy and windy thereafter. Fruit-piercing Moth *Eudocima salaminia* seen feeding at banana baits, as well as Owl Moth *Erebus crepuscularis*, *Achaea* moths and an unidentified moth species. In addition to 75 Pink Underwing Moth larvae found on Carronia leaves, 5 *Eudocima fullonia* larvae and one larva in the family Limacodidae were found on Carronia leaves and 1 Richmond Birdwing Butterfly *Ornithoptera richmondia* larva and one adult female butterfly were observed at site PUM3. | One active burrow with a beetle located on transect T1, four active burrows with beetles re-located below T1, one active burrow with a beetle re-located at transect T5, eight active burrows observed at C1, but no activity an any other transect monitoring site and no burrows consistent with the species detected at the other annual monitoring sites. | No adult Pink Underwing Moth found during the nocturnal monitoring, but a total of 75 larvae of various ages (instars 2 to 5) found on Carronia leaves at T1, T2, T3, T5 and C1 transect sites, at PUM1-3, 6-8, and 10-11 annual monitoring sites, and at several other locations between the annual monitoring sites. |

Figure 3.2


C1
C2
Scale 1:50 000
0 500 1000 1500m
Road
Coolgarda
Pacific
Highway
LEGEND
Construction Footprint
Carronia Abundance
1-20
21-40
50-100
> 100
Scale 1 : 12,500
0 200 500m
BAAM
ECOLOGICAL CONSULTANTS
Jacobs on behalf of Pacific Complete
Woolgoolga to Ballina Pacific Highway Upgrade Invertebrate Monitoring
Locations and relative abundance of Carronia multispalva
3.2

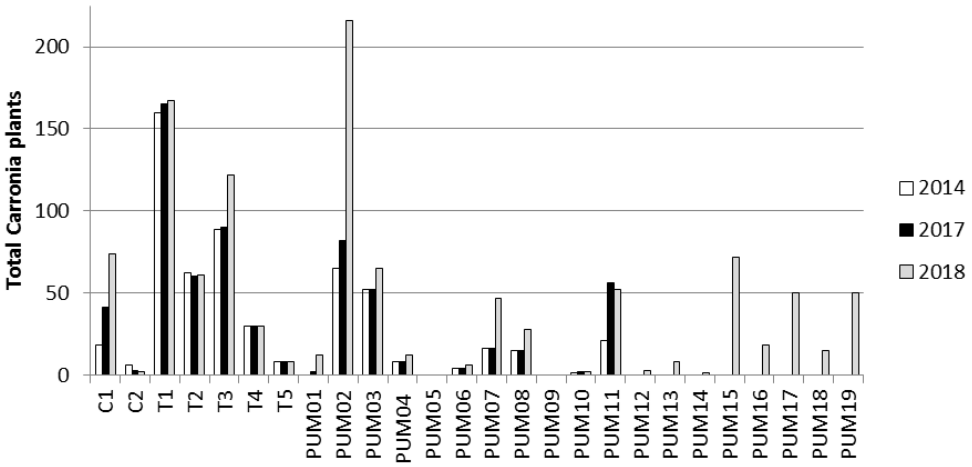



**Figure 3.3.** Comparison of *Carronia multisepalea* counts between surveys.

Host plants in all populations were found to be in good health, typically with signs of substantial new growth and recent recruitment of new seedlings following above-average summer rainfall. A few plants at most locations showed signs of recent or old herbivory consistent with moth larval activity (potentially Southern Pink Underwing Moth or other fruit-piercing moths).

A total of 75 Southern Pink Underwing Moth larvae of various ages from second to fifth instar were found during the survey (**Photos 3.5** to **3.8**), including at four of the five impact transect monitoring sites, one of the two control transect monitoring sites and at eight of the nine other monitoring sites with host plants present (see **Table 3.2** and **Figure 3.4** for details). Southern Pink Underwing Moth larvae were also found at six of eight additional sites where host plants were found (**Figure 3.4**). Overall, Southern Pink Underwing Moth larvae were found at 79% of sites with host plants present. Only six fruit piercing moth larvae were found, all of which were Common Fruit Piercing Moth *Eudocima fullonia* (**Photo 3.9**).

**Photo 3.5.** Pink Underwing Moth second instar larva.

**Photo 3.6.** Pink Underwing Moth third instar larva.

**Photo 3.7.** Pink Underwing Moth fourth instar larvae.

**Photo 3.8.** Pink Underwing Moth fifth instar larva.

**Photo 3.9.** Common Fruit Piercing Moth larva.

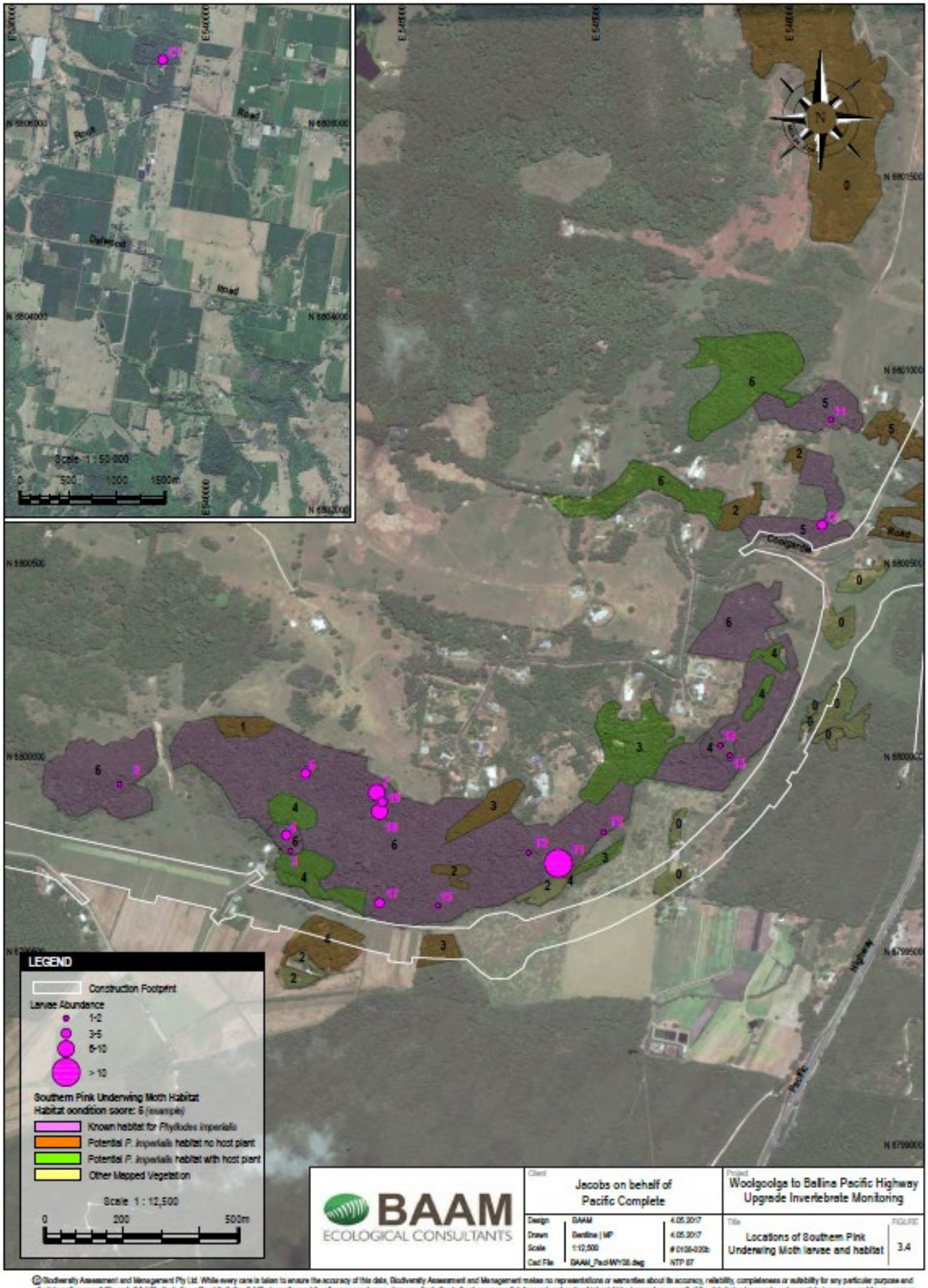
**Photo 3.10.** Richmond Birdwing larva.

**Table 3.2. Summary of the total number of Southern Pink Underwing Moth larvae found during a transect survey on 20 February and the broader population assessment survey of 6-8 March 2018.**

| Type | Site | 2nd | 3rd | 4th | 5th | Total | Total Carronia plants |
|---|---|---|---|---|---|---|---|
| **20 February 2018** | | | | | | | |
| Impact | T1 | 3 | | 3 | 4 | 10 | |
| Impact | T2 | 2 | | | 1 | 3 | |
| Impact | T3 | 1 | | | | 1 | |
| Impact | T4 | | | | | 0 | |
| Impact | T5 | 1 | | | 1 | 2 | |
| Impact | PUM13 | 2 | | | | 2 | |
| Control | C1 | 1 | | 2 | | 3 | |
| Control | C2 | | | | | 0 | |
| | ***Total*** | ***10*** | | ***5*** | ***6*** | ***21*** | |
| **6-8 March 2018** | | | | | | | |
| Impact | T1 | | 11 | 3 | 4 | 18 | 167 |
| Impact | T2 | | | | 1 | 1 | 61 |
| Impact | T3 | | | 1 | | 1 | 122 |
| Impact | T4 | | | | | 0 | 30 |
| Impact | T5 | | 1 | | 1 | 2 | 8 |
| Impact | PUM01 | | | | | 0 | 12 |
| Impact | PUM02 | | | 1 | | 1 | 216 |
| Impact | PUM03 | 1 | | | | 1 | 65 |
| Impact | PUM04 | 3 | | 2 | | 5 | 12 |
| Impact | PUM05 | | | | | 0 | 0 |
| Impact | PUM06 | | 4 | | | 4 | 6 |
| Impact | PUM07 | | 4 | 3 | | 7 | 47 |
| Impact | PUM08 | | 2 | 2 | 2 | 6 | 28 |
| Impact | PUM09 | | | | | 0 | 0 |
| Impact | PUM10 | | | | | 0 | 2 |
| Impact | PUM11 | | | | 2 | 2 | 52 |
| Impact | PUM12 | | | 2 | 3 | 5 | 3 |
| Impact | PUM13 | | | 1 | | 1 | 8 |
| Impact | PUM14 | | | | | 0 | 1 |
| Impact | PUM15 | | | 1 | 1 | 2 | 72 |
| Impact | PUM16 | | | | | 0 | 18 |
| Impact | PUM17 | 1 | | 3 | | 4 | 50* |
| Impact | PUM18 | 2 | 4 | | 1 | 7 | 15 |
| Impact | PUM19 | | 3 | | | 3 | 50* |
| Control | C1 | 2 | 1 | 2 | | 5 | 74 |
| Control | C2 | | | | | 0 | 2 |
| | ***Total*** | ***9*** | ***30*** | ***21*** | ***15*** | ***75*** | ***1121*** |

* Recorded as large patches of host plant, so population size assumed to be at least 50 plants.

Figure 3.4



### *3.3.2. Atlas Rainforest Ground Beetle*

No burrows consistent with those of Atlas Rainforest Ground Beetle were found at any of the annual monitoring sites for this species, not including the nocturnal monitoring transect sites discussed under **Section 3.2.2** above. Habitat condition for the species has remained unchanged since the 2017 preconstruction survey. The locations and maximum numbers of active of Atlas Rainforest Ground Beetle burrows are shown in **Figure 3.5**.

### *3.3.3. Richmond Birdwing*

Two incidental observations of Richmond Birdwing were made during the survey, a female butterfly seen feeding on flowering Lantana *Lantana camara* at PUM03 and a single larva on a host plant at PUM04 (**Photo 3.10, Figure 3.5**). Casual observation of host plant vines suggests they are healthy and undergoing recruitment.

## 3.4. HABITAT MAPPING AND CONDITION SCORES

Southern Pink Underwing Moth larvae were recorded at more sites than during several baseline preconstruction surveys. Consequently, the extent of known habitat for the species has increased from 33.2ha to 43.9ha following confirmation of use of the habitat areas by the species for breeding in. **Table 3.4** summarises the extents of known and potential habitat scored and ranked based on habitat condition (with a score of "6" being the highest ranking of habitat condition). The habitat condition scores remain unchanged since the previous habitat condition assessment in March 2017 (BAAM 2017). The habitat mapping and condition scores for Southern Pink Underwing Moth are presented in **Figure 3.4**.

**Table 3.4. Extent of known or potential habitat for Southern Pink Underwing Moth ranked according to condition.**

| Habitat condition ranking (see Section 2.3) | Area (hectares) | | |
|---|---|---|---|
| | Known habitat | Potential habitat (where host plant is present) | Potential habitat (where host plant was not detected) |
| 0 | 0 | 0 | 0.3 |
| 1 | 0 | 0 | 3.7 |
| 2 | 0 | 0 | 1.2 |
| 3 | 0 | 3.9+ | 3.0 |
| 4 | 0.5 | 4.7 | 4.2 |
| 5 | 4.8 | 0 | 11.6 |
| 6 | 38.6 | 7.8 | 0 |
| No ranking[1] | 0 | 0 | 16.6 |
| **TOTAL AREA** | 43.9 | 16.4 | 40.6 |

[1] Rankings were allocated only to polygons visited as part of this study or previous surveys (BAAM 2012, 2013, 2014, 2017)

## 3.5. FEASIBILITY OF CAMERA MONITORING OF MOTHS

### *3.5.1. Review of published information*

The review of published information identified two types of camera monitoring of moths, developed as technologies for monitoring insect species that are agricultural pests: a camera pre-programmed to take photographs during daylight hours of insects trapped in a pheromone-baited trap (Trapview 2018), and closed-circuit television (CCTV) cameras with infrared light-emitting diodes (LEDs) to supply illumination (Adams *et al.* 2015; Young 2016). The Trapview system is unsuitable for monitoring moths at night. The disadvantages of CCTV cameras for wildlife monitoring include: their requirement for 12 volts DC power supply that is typically supplied via a mains power source, which restricts the distance that a CCTV camera can be deployed from the nearest mains power source; and requirement for a separate recorder connected to the camera to record the video footage. While most CCTV cameras will work with batteries such as rechargeable 12 V lithium batteries or rechargeable 12 V DC lead acid batteries, the recording device typically requires a mains power source. Consequently, the CCTV system is relatively expensive and difficult to deploy in field situations that are typically remote from a mains power source.

Figure 3.5

A third type of camera, known as a wildlife camera, has been used extensively to remotely monitor and photograph warm-blooded vertebrate animals. A wildlife camera is triggered by a combination of heat and motion. A passive infrared (PIR) sensor in the camera measures infrared light emitted from objects in its field of view, especially objects that generate heat, and therefore infrared radiation. The sensor is actually split into two halves so as to detect not the infrared radiation itself, but the change in condition that occurs when a target enters its field. Wildlife cameras have not been used to monitor cold-blooded animals or invertebrates, because such animals are thought not to cause as much of a differential in infrared radiation when they enter the camera's field of view. Nevertheless, large moths produce large increases in their body temperature (up to 20-30°C above ambient temperature) through the movement of their wing muscles to increase their body temperature up to a maximum of 40-45 °C while flying (Heinrich 1974), with some species regulating their body temperature within the range 34-38 °C when active (Heath and Adams 1967). Therefore, a large moth such as Southern Pink Underwing Moth has the potential to trigger a wildlife camera at close range.

### *3.5.2. Field test using a wildlife camera*

The wildlife camera that was deployed for two consecutive nights at a distance of 30 cm from a bait was triggered only once, capturing a sequence of three images of a Green Fruit Piercing Moth (*Eudocima salaminia*) landing on the banana bait at 8:24pm when the ambient temperature was recorded by the camera as 19°C (**Photo 3.11**). While the wildlife camera captures only black-and-white images using an infrared LED flash, the species could be reliably identified based on the contrasting colour-pattern of the wings (compare **Photos 3.11** and **3.12**). Since the Southern Pink Underwing Moth is larger and has a similarly contrasting and distinctive colour-pattern on its wings, it should similarly be identifiable if photographed by a wildlife camera at night.


**Photo 3.11.** Green Fruit Piercing Moth at a banana bait photographed via an infrared motion-triggered wildlife camera with infrared LED flash.

**Photo 3.12.** Green Fruit Piercing Moth at a banana bait photographed manually using a standard camera with white-light flash.

# 4.0 DISCUSSION

## 4.1. HABITAT CONDITION WITHIN THE STUDY AREA

### *4.1.1. Southern Pink Underwing Moth*

The study area next to the highway construction footprint contains 43.9ha of lowland rainforest (including regrowth rainforest) that is recognised as known habitat for Southern Pink Underwing Moth. The presence of a large number of *Carronia multisepalea* host plant populations that contain mature vines and exhibit substantial recent recruitment, together with the finding of relatively large numbers of larvae of the moth during the current and earlier surveys (see **Table 4.1** for a summary) confirms that the study area is a significant breeding area for Southern Pink Underwing Moth, particularly during favourable seasonal rainfall conditions. No previous survey for the species conducted anywhere across its range has located as many larvae as the March 2018 survey in the study area (**Table 4.1**). The large and dispersed population of *Carronia multisepalea* plants at impact sites T1 and T2 have consistently supported the greatest numbers of Southern Pink Underwing Moth larvae in different seasons.

**Table 4.1. Summary of the numbers of Southern Pink Underwing Moth larvae found during recent targeted surveys for the species in north-eastern NSW.**

| Survey | Summary of larvae found |
|---|---|
| Six days 6-10 February and four days 13-16 March 2012, focussed on habitats close to the highway construction footprint, including sites further north and south of the current monitoring area (BAAM 2012). | No larvae found during the February survey but **22 larvae** found during the March survey, 15 at what later became monitoring site T1 and 7 around T3. |
| A broader habitat and population assessment survey 11-15 February 2013 at impact sites (BAAM 2013) | A total of **45 larvae** and **9 eggs** recorded, all at sites T1 and T2. |
| Six nocturnal monitoring surveys between 5 March and 9 April and a broader habitat and population assessment survey 18-20 March 2014 at impact and control sites (BAAM 2014). | No larvae found at impact monitoring sites but **one larva** found at Davis Scrub Nature Reserve control site C1 during the habitat assessment survey. |
| Two surveys 5-9 December 2016 and 19-24 February 2017 at 63 sites with host plant populations across north-eastern NSW between Tweed Heads and Wardell (Richards and Andren 2017). | A total of **56 larvae** recorded from 22 sites at seven discrete localities, 9 during the early December survey and 47 during the late February survey, but none at Davis Scrub or Victoria Park Nature Reserves. |
| Two nocturnal monitoring surveys 1 and 30 March 2017 and a broader habitat and population assessment survey 28-31 March 2017 at impact and control sites (BAAM 2017). | No larvae found. |
| Six nocturnal monitoring surveys between 8 November 2017 and 7 March 2018 and a broader habitat and population assessment survey 6-8 March 2018 at impact and control sites (this survey). | No larvae found November to January but **21 larvae** and **1 egg** found during brief surveys on 20 February and **75 larvae** found during more extensive survey 6-8 March, including 70 at impact sites and 5 at Davis Scrub Nature Reserve control site C1. |

The paucity or absence of larvae in March 2014 and March 2017 may have been due to the substantially below average rainfall that was experienced in the area during the summers of 2013/14 and 2016/17, or perhaps by earlier breeding in those seasons, since larvae have been found as early as November (Richards and Andren 2017) and many host plants showed signs of old herbivory consistent with Southern Pink Underwing Moth or fruit-piercing moths in both March 2014 and March 2017, years in which surveys earlier in summer were not conducted. The condition of the supporting habitat appears to be slowly improving as the process of succession in regrowth areas advances. These results demonstrate that the early construction works on the highway upgrade have had no indirect impact on the breeding success of Southern Pink Underwing Moth in rainforest habitats close to the highway construction footprint.

### *4.1.2. Atlas Rainforest Ground Beetle*

The current surveys detected more Atlas Rainforest Ground Beetles at more locations than previous surveys, confirming the presence of small numbers of beetles at three different locations at or close to the T1 and T5 impact monitoring sites, and the continuing good health of a larger population at Davis Scrub Nature Reserve control site (**Table 4.2**). However, the small number of beetles located at Victoria Park Nature Reserve during previous surveys in March 2014 and 2017 had disappeared, and no new burrows were located at the site.

**Table 4.2. Summary of the numbers of Atlas Rainforest Ground Beetles or burrows found during surveys for the species in the study area.**

| Survey | Summary of beetles or burrows found |
|---|---|
| Six days 6-10 February and four days 13-16 March 2012, focussed on habitats close to the highway construction footprint, including sites further north and south of the current monitoring area (BAAM 2012). | **One beetle** in a burrow at what later became monitoring site T1. |
| Six nocturnal monitoring surveys between 5 March and 9 April and a broader habitat and population assessment survey 18-20 March 2014 at impact and control sites (BAAM 2014). | Up to **three beetles** in burrows at Davis Scrub Nature Reserve control site C1, **one beetle** in a burrow at Victoria Park control site C2, many more potential burrows at C1 and C2, one potential burrow at T3. |
| Two nocturnal monitoring surveys between 1 and 30 March 2017 and a broader habitat and population assessment survey 28-31 March 2017 at impact and control sites (BAAM 2017). | Up to six beetle burrows with up to **four beetles** at C1, up to **two beetles** at C2, and **one beetle** at T1. |
| Six nocturnal monitoring surveys between 8 November 2017 and 7 March 2018 and a broader habitat and population assessment survey 6-8 March 2018 at impact and control sites (this survey). | Up to **nine beetles** at C1 but no burrows found at C2, **one beetle** at T1 and two new locations with up to **two beetles** at T5 and up to **four beetles** 45m south-east of T1. |

These results confirm that a low-density population of Atlas Rainforest Ground Beetle continues to persist in rainforest habitats close the highway construction footprint. The results also demonstrate that the early construction works on the highway upgrade have had no indirect impact on the occupancy of rainforest habitats close to the highway construction footprint by Atlas Rainforest Ground Beetle.

### *4.1.3. Richmond Birdwing*

Previous surveys identified an active breeding population of Richmond Birdwing together with relatively large numbers of its larval host plant *Pararistolochia praevenosa* in rainforest habitats close to the highway construction footprint (BAAM 2012, 2014, 2017). The few incidental observations from the current survey confirm ongoing breeding by the species in the study area, with no evidence of a decline in the population of the species or its host plant.

## 4.2. MONITORING REVIEW

The Threatened Invertebrates Management Plan (TIMP) is intended to be a dynamic document subject to continual improvement (NSW Roads and Maritime Services 2015). The construction phase monitoring conducted to date has not identified any indirect impacts of the Project on any threatened invertebrate species; therefore, adaptive management of the mitigation measures set out in the TIMP is not required. The efficacy of the monitoring methods as specified in the TIMP is reviewed for each species in the following sections.

### *4.2.1. Nocturnal monitoring for Southern Pink Underwing Moth adults*

The method for nocturnal monitoring for Southern Pink Underwing Moth adults, requiring visiting banana baits at night several hours after their deployment to detect moths attracted to the baits,

was formulated as part of the review process during the development of the Woolgoolga to Ballina Threatened Invertebrates Management Plan (NSW Roads and Maritime Services 2015). This survey method, which was a new survey method that had never previously been trialled, has now been implemented on a total of 14 nights over three seasons (6 nights in March-April 2014, 2 nights in March 2017, 6 nights in November-March 2017/18) at each of seven sites, resulting in a total of 588 bait-nights of survey effort. While a variety of moth species that feed on ripe fruit were detected during these surveys, no Southern Pink Underwing Moth was positively detected despite the considerable survey effort and evidence of extensive egg-laying by the species during the 2017/18 season. This negative result may be a consequence of the species' rarity and/or sensitivity to the disturbance from torchlight and movement that unavoidably occurs while conducting the surveys. It is therefore concluded that the nocturnal monitoring method is ineffective in detecting adult Southern Pink Underwing Moths. Consequently, a review leading to recommendations for improving the monitoring approach for this species is warranted. These recommendations are provided in **Section 5** below.

### *4.2.2. Diurnal monitoring for Southern Pink Underwing Moth larvae*

Southern Pink Underwing Moth larvae feed only on the leaves of a single host plant, *Carronia multisepalea*, generally at a height less than 1.5m. Consequently, the larvae were predicted to be relatively easy to detect and therefore monitor using a daytime survey. The March 2018 monitoring survey for Southern Pink Underwing Moth larvae confirmed the effectiveness of this survey technique, detecting larvae at 79% of the 24 sites at which the host plant occurs. This survey method also confirmed the suitability of habitat for the species that was originally identified as potentially suitable habitat based on habitat structure, diversity of fruiting plants and presence of the host plant. Therefore, continuation of this monitoring method is recommended, and indeed recommendations for the expansion of this monitoring method are provided in **Section 5.0** below.

### *4.2.3. Nocturnal monitoring for Atlas Rainforest Ground Beetle*

The results of the 2017/18 nocturnal monitoring for Atlas Rainforest Ground Beetle together with the results of the preconstruction monitoring surveys confirm the effectiveness of nocturnal monitoring for detecting beetles at the entrances to burrows that are identified and marked during daytime surveys or previous surveys. Therefore, continuation of this monitoring method for Atlas Rainforest Ground Beetle is recommended.

## 5.0 RECOMMENDATIONS FOR FUTURE MONITORING

The three seasons of trialling the nocturnal monitoring method for Southern Pink Underwing Moth, whereby over-ripe banana baits are visited at night to try to detect moths attracted to the baits, has shown the method to be ineffective for detecting adult Southern Pink Underwing Moths. It is therefore recommended that this monitoring method be discontinued. While the expert review process during the development of the TIMP identified that cameras were unlikely to distinguish differences between many species of large night-flying moths that occur in the study area (NSW Roads and Maritime Services 2015), the limited trial of using a wildlife camera deployed in front of an over-ripe banana bait suggests that wildlife cameras may have more success than human monitoring of baits; however more extensive trials would be required to prove the reliability of this method.

The selection of monitoring methods should be informed by the objectives or research questions that the monitoring aims to address. The objectives of the TIMP are to monitor the population sizes of Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle, extent of habitat use by these species close to the highway construction footprint and habitat condition in order to detect change in these parameters, controlling for natural annual or seasonal variability. Due to the high mobility, unpredictability and apparent rarity of the adult moths, monitoring the relative abundance of adult moths is not an effective parameter for monitoring population change in Southern Pink Underwing Moth. By contrast, the predictable association of the larval stages with a single host plant species and the relative ease with which larvae can be surveyed on host plants means that

larval surveys offer the best method for monitoring habitat use and population change in Southern Pink Underwing Moth. It is therefore recommended that the monitoring of adult moths be discontinued and the survey effort previously expended on this method be allocated to improving the survey effort coverage of larval-stage monitoring. Currently, intensive larval monitoring across a broad network of sites is restricted a single survey in March (the habitat assessment survey) with only incidental observations at night along the seven transect monitoring sites during the other four monitoring events that take place between November and March. Recommendations for a revised survey approach are as follows:

- Four monthly surveys (November, December, January, February) for Southern Pink Underwing Moth larvae and Atlas Rainforest Ground Beetle burrows during daylight hours at an expanded network of monitoring sites, including the two control transect sites, five impact transect sites and 11 additional sites close to the highway construction footprint (shown in **Figure 5.1**); this network of sites accounted for 79% of the host plant availability in habitats close to the highway construction footprint and 87% of the larvae recorded during the March 2018 survey.
- A single habitat assessment survey in March, including a survey for Southern Pink Underwing Moth larvae and Atlas Rainforest Ground Beetle burrows during daylight hours at all habitat assessment monitoring sites, as well as a survey for Southern Pink Underwing Moth larvae at an additional eight sites identified during the March 2018 survey. This survey replicates the habitat assessment survey as originally outlined in the TIMP, but expands the number of Southern Pink Underwing Moth larvae monitoring sites for the assessment of total larval population size. While larval abundance is typically greatest in March, the timing of the habitat assessment survey should be flexible such that if larvae are detected earlier in the season than normal, then the habitat assessment survey could be switched with one of the monthly surveys to ensure that the habitat assessment survey is conducted at the anticipated time of greatest larval abundance.
- Five monthly surveys (November to March) conducted at night at each of the two control and seven impact transect monitoring sites, visiting all potential Atlas Rainforest Ground Beetle burrows identified and marked during the daytime surveys to determine if these burrows are indeed occupied by the species. This survey replicates the Atlas Rainforest Ground Beetle monitoring survey method as originally outlined in the TIMP. Adult Southern Pink Underwing Moths will be searched for opportunistically during these surveys.

This revised survey approach results in no material change to the original habitat assessment methodology and the monitoring methodology for Atlas Rainforest Ground Beetle, but substantially improves the spatial and temporal coverage of survey effort for Southern Pink Underwing Moth larvae. This is expected to contribute to a better understanding of seasonal variation in the timing and extent of breeding activity by Southern Pink Underwing Moth in the study area.

The responses of Roads and Maritime Services (RMS) to each of these recommendations is summarised in **Tables 5.1** and **5.2** below.

**Table 5.1 Southern Pink Underwing Moth recommendations and RMS responses**.

| ID no | Recommendation | RMS response |
|---|---|---|
| 1 | Discontinue the nocturnal monthly monitoring (November to March) for Southern Pink Underwing Moth adults. | Adopted |
| 2 | Implement four monthly surveys (November, December, January, February) for Southern Pink Underwing Moth larvae during daylight hours at an expanded network of monitoring sites, including the two control transect sites, five impact transect sites and 11 additional sites close to the highway construction footprint. | Adopted |
| 3 | Implement a single habitat assessment survey (nominally in March, but may be exchanged with a monthly larval survey depending on timing of breeding) at all habitat assessment monitoring sites including a survey for Southern Pink Underwing Moth larvae during daylight hours at all habitat assessment monitoring sites and at an additional eight sites. | Adopted |

Figure 5.1

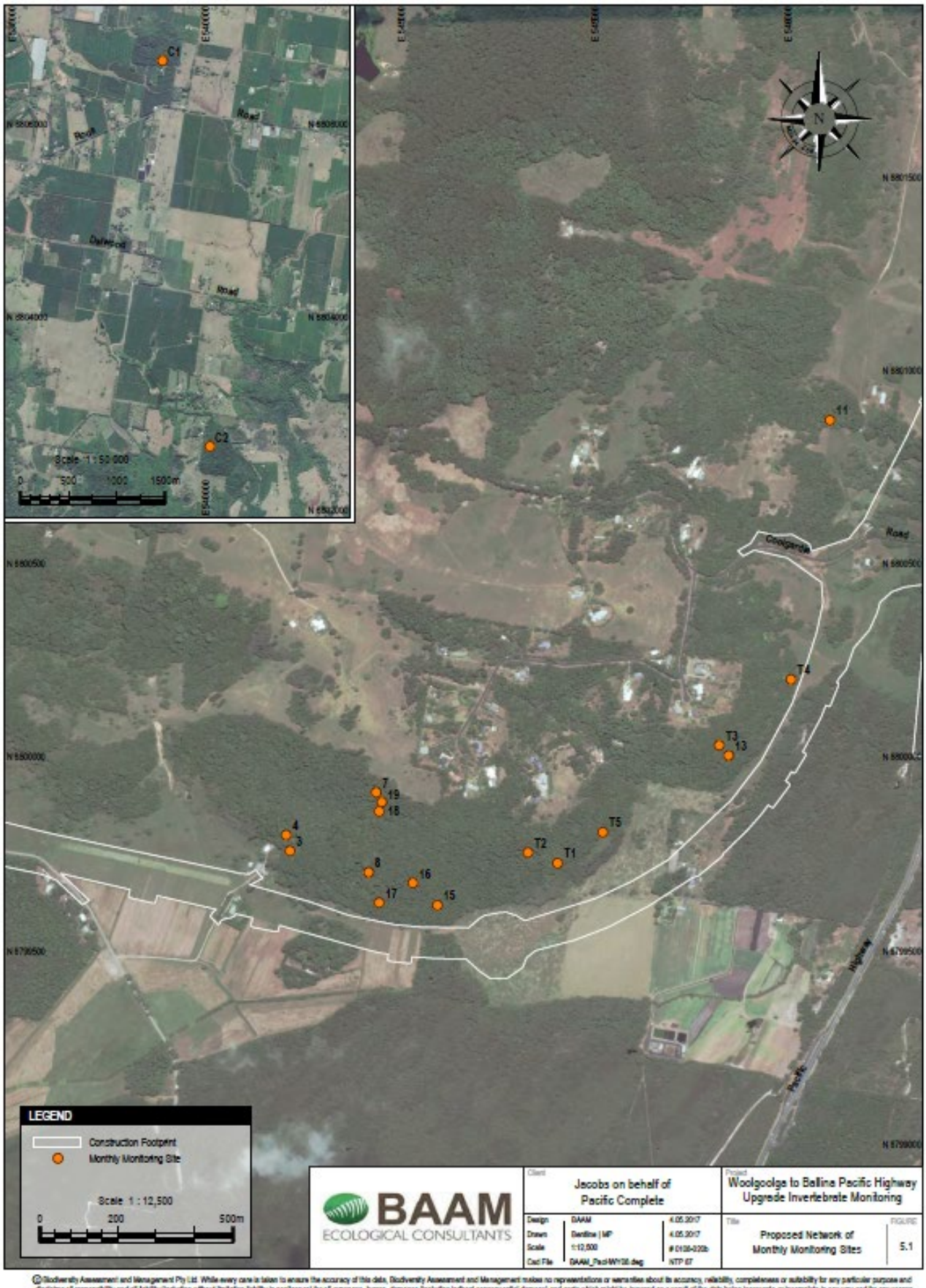


**Table 5.2 Atlas Rainforest Ground Beetle recommendations and RMS responses**.

| ID no | Recommendation | RMS response |
|---|---|---|
| 1 | Implement five monthly surveys (November to March) for Atlas Rainforest Ground Beetle burrows during daylight hours at an expanded network of monitoring sites, including the two control transect sites, five impact transect sites and 11 additional sites close to the highway construction footprint. | Adopted |
| 2 | Implement five monthly surveys (November to March) conducted at night at each of the two control and seven impact transect monitoring sites, visiting all potential Atlas Rainforest Ground Beetle burrows identified and marked during the daytime surveys to determine if these burrows are indeed occupied by the species. | Adopted |

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# APPENDIX A

# Descriptions and photo-monitoring results for impact and control site transects

| **Transect name, target species and position** | | **Comparative photographs** | | | |
|---|---|---|---|---|---|
| | | **North** | **East** | **South** | **West** |
| T1. Confirmed location for Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle. Start: 28.9296°S 153.4652°E. End: 28.9294°S 153.4657°E. | 2014 |  |  |  |  |
| | 2017 |  |  |  |  |
| | 2018 |  |  |  |  |
| T2. Confirmed location for Southern Pink Underwing Moth. Suitable for Atlas Rainforest Ground Beetle. Start: 28.9293°S 153.4649°E. End: 28.9292°S 153.4653°E. | 2014 |  |  |  |  |

| Transect name, target species and position | | Comparative photographs | | | |
|---|---|---|---|---|---|
| | | North | East | South | West |
| | 2017 |  |  |  |  |
| | 2018 |  |  |  |  |
| T3. Suitable for Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle. Start: 28.9268°S 153.4698°E. End: 28.9266°S 153.4701°E. | 2014 |  |  |  |  |
| | 2017 |  |  |  |  |

| Transect name, target species and position | | Comparative photographs | | | |
|---|---|---|---|---|---|
| | | **North** | **East** | **South** | **West** |
| | 2018 | Not photographed | | | |
| T4. Confirmed location for Southern Pink Underwing Moth. Suitable for Atlas Rainforest Ground Beetle. Start: 28.9253°S 153.4718°E. End: 28.9248°S 153.4719°E. | 2014 |  |  |  |  |
| | 2017 |  |  |  |  |
| | 2018 | Not photographed | | | |

| Transect name, target species and position | | Comparative photographs | | | |
|---|---|---|---|---|---|
| | | North | East | South | West |
| T5. Suitable for Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle. Start: 28.9286°S 153.4669°E. End: 28.9290°S 153.4665°E. | 2014 |  |  |  |  |
| | 2017 |  |  |  |  |
| | 2018 |  |  |  |  |
| C1. Confirmed site for Atlas Rainforest Ground Beetle. Suitable for Southern Pink Underwing Moth. Start: 28.8665°S 153.4051°E. End: 28.8668°S 153.4048°E. | 2014 |  |  |  |  |

| Transect name, target species and position | | Comparative photographs | | | |
|---|---|---|---|---|---|
| | | North | East | South | West |
| | 2017 |  |  |  |  |
| | 2018 |  |  |  |  |
| C2. Confirmed site for Atlas Rainforest Ground Beetle. Suitable for Southern Pink Underwing Moth. Start: 28.9028°S 153.4102°E. End: 28.9030°S 153.4100°E. | 2014 |  |  |  |  |
| | 2017 |  |  |  |  |

| **Transect name, target species and position** | | **Comparative photographs** | | | |
|---|---|---|---|---|---|
| | | **North** | **East** | **South** | **West** |
| | 2018 |  |  |  |  |

# APPENDIX B

# Monitoring survey data for habitat condition and relevant invertebrates in lowland rainforest habitats in the study area

**Table B.1. Summary of data from Southern Pink Underwing Moth habitat assessment sites close to the highway construction footprint (T1 to T5 and PUM01 to PUM11) and control sites at Davis Scrub Nature Reserve (C1) and Victoria Park Nature Reserve (C2) on 6-8 March 2018.**

| Site name | Photo | Latitude | Longitude | Count of moths | Count of eggs | Count of larval instars | | | | Evidence of eating | Count of Carronia | | | Leaf type | Count of fleshy fruit trees | Percent cover native species | Percent cover exotic | Total percent canopy cover** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2nd | 3rd | 4th | 5th | | Se | Shr | Vine | | | | | |
| T1 | 538 | -28.929457 | 153.465693 | 0 | 0 | | 11 | 3 | 4 | Yes | 60 | 100 | 7 | Mixed | 52 | 30, with 10% canopy Carronia, 35% shrub Carronia | 50 | 80 |
| T2 | 544 | -28.929211 | 153.464903 | 0 | 0 | | | | 1 | Yes | 10 | 40 | 11 | Mixed | 52 | 50, with 3% canopy carronia, 10% shrub Carronia | 15 | 65 |
| T3 | 558 | -28.926688 | 153.469976 | 0 | 0 | | | 1 | | Yes | 10 | 100 | 12 | Mixed | 35 | 15, 5% canopy Carronia, 20% shrub Carronia | 50 | 65 |
| T4 | 554 | -28.925143 | 153.471871 | 0 | 0 | | | | | No | 0 | 27 | 3 | Broad | 35 | 15, 1% canopy Carronia, 10% shrub Carronia | 50 | 65 |
| T5 | 534 | -28.92873 | 153.466887 | 0 | 0 | | 1 | | 1 | Yes | 0 | 4 | 4 | Narrow | 52 | 55, incl. 5% canopy Carronia, 1% young Carronia | 20 | 75 |
| PUM01 | 572 | -28.927856 | 153.453179 | 0 | 0 | | | | | No | 0 | 11 | 1 | Narrow | 34 | 50 | 35 | 85 |
| PUM02 | 577 | -28.927654 | 153.454049 | 0 | 0 | | | 1 | | Yes | 35 | 145 | 36 | Narrow | 34 | 60 | 10 | 70 |
| PUM03 | 579 | -28.929196 | 153.458586 | 0 | 0 | 1 | | | | Yes | 10 | 50 | 5 | Narrow | 0 | 80 | 10 | 90 |
| PUM04 | 583 | -28.928825 | 153.458482 | 0 | 0 | 3 | | 2 | | Yes | 4 | 8 | 0 | Narrow | 29 | 85 | 0 | 85 |
| PUM05 | 587 | -28.9282 | 153.458 | 0 | 0 | | | | | NA | 0 | 0 | 0 | NA | 0 | 70 | 30 | 50 |
| PUM06 | 591 | -28.927382 | 153.458982 | 0 | 0 | | 4 | | | Yes | 0 | 2 | 4 | Narrow | 52 | 95 | 5 | 90 |
| PUM07 | 593 | -28.927823 | 153.460869 | 0 | 0 | | 4 | 3 | | Yes | 13 | 33 | 1 | Narrow | 52 | 95 | 5 | 80 |
| PUM08 | 596 | -28.929688 | 153.460674 | 0 | 0 | | 2 | 2 | 2 | Yes | 15 | 10 | 3 | Narrow | 52 | 90 | 10 | 75 |
| PUM09 | 548 | -28.9276 | 153.467 | 0 | 0 | | | | | NA | 0 | 0 | 0 | NA | 0 | 95 | 5 | 70 |
| PUM10 | 522 | -28.920415 | 153.472801 | 0 | 0 | | | | | No | 0 | 2 | 0 | Narrow | 13 | 50 | 15 | 65 |
| PUM11 | 523 | -28.91908 | 153.472878 | 0 | 0 | | | | 2 | Yes | 0 | 40 | 12 | Broad | 36 | 60 | 0 | 60 |
| C1 | 562 | -28.866728 | 153.405019 | 0 | 0 | 2 | 1 | 2 | | Yes | 46 | 20 | 8 | Narrow | 37 | 75, 2% vine, 8% seedling | 0 | 75 |
| C2 | 570 | -28.902754 | 153.410189 | 0 | 0 | | | | | No | 0 | 1 | 1 | Narrow | 18 | 90, 1% vine Carronia, 1% shrub Carronia | 0 | 90 |

**Table B.2. Summary of data from Atlas Rainforest Beetle habitat assessment sites close to the highway construction footprint (T1 to T5 and PUM01 to PUM11) and control sites at Davis Scrub Nature Reserve (C1) and Victoria Park Nature Reserve (C2) on 6-8 March 2018.**

| Site name | Photo | Latitude | Longitude | Count of Beetle | Count of burrows | % cover logs | % cover rocks | % cover overhangs |
|---|---|---|---|---|---|---|---|---|
| T1 | 541 | -28.9294 | 153.466 | 1 | 1 | 1 | 80 | 3 |
| T2 | 544 | -28.9292 | 153.465 | 0 | 0 | 3 | 70 | 3 |
| T3 | 556 | -28.9265 | 153.47 | 0 | 0 | 1 | 85 | 5 |
| T4 | 555 | -28.9253 | 153.472 | 0 | 0 | 1 | 50-95 | 1 |
| T5 | 537 | -28.9286 | 153.467 | 2 | 2 | 2 | 70 | 0 |
| ARB1 | 572 | -28.9276 | 153.453 | 0 | 0 | 5 | 65 | 2 |
| ARB2 | 580 | -28.9289 | 153.459 | 0 | 0 | 1 | 90 | 1 |
| ARB3 | 582 | -28.9286 | 153.458 | 0 | 0 | 7 | 65 | 5 |
| ARB4 | 586 | -28.9283 | 153.458 | 0 | 0 | 1 | 80 | 10 |
| ARB5 | 589 | -28.9279 | 153.459 | 0 | 0 | 5 | 60 | 10 |
| ARB6 | 548 | -28.9277 | 153.467 | 0 | 0 | 1 | 85 | 10 |
| ARB7 | 551 | -28.9242 | 153.47 | 0 | 0 | 5 | 60 | 5 |
| ARB8 | 522 | -28.9205 | 153.473 | 0 | 0 | 10 | 5 | 0 |
| C1 | 561 | -28.8665 | 153.405 | 9 | 9 | 10 | 1 | 5 |
| C2 | 570 | -28.9028 | 153.41 | 0 | 0 | 10 | 1 | 5 |