Woolgoolga to Ballina Pacific Highway upgrade

Invertebrate Monitoring Program Annual Report 2020

Year 3 Construction Phase Report

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Project Manager/s: Dr Penn Lloyd

Client: Jacobs on behalf of Pacific Complete

Project Title: Woolgoolga to Ballina Pacific Highway Upgrade Invertebrate Monitoring Program Annual Report 2020, Year 3 Construction Phase Report

Project Author/s: Dr Penn Lloyd

Project Summary: This report presents the results of the third 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 in November and December 2019 for comparison with baseline pre-construction monitoring results.

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Signed on behalf of Date: 10/03/2020

Biodiversity Assessment and Management Pty Ltd

Director

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 third construction phase survey and monitoring for two threatened invertebrate species for the Woolgoolga to Ballina Pacific Highway Upgrade Project. Construction activity concluded in late December 2019, with operation expected to commence in mid-2020. Therefore, monitoring was undertaken up until December 2019 to conclude the construction phase monitoring reported in this report. The next phase of monitoring will commence once the project is in operation. The objectives of the study are to:

1. Undertake two monthly monitoring surveys (November, December) for Southern Pink Underwing Moth *Phyllodes imperialis smithersi* eggs and larvae during daylight hours at a network of monitoring sites, including two control transect sites, five impact transect sites and 11 additional impact sites close to the highway construction footprint.
2. Undertake two monthly monitoring surveys (November, December) for Atlas Rainforest Ground Beetle *Nurus atlas* populations at two control transect sites and five impact transect sites.
3. 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. Monitoring of Southern Pink Underwing Moth larval abundance, which is indicative of breeding activity was conducted once each month in November and December 2019 (two survey events) and involved searching for eggs and larvae on the foliage of the species' host plant *Carronia multisepalea*. Monthly monitoring for Atlas Rainforest Ground Beetle (two survey events) involved: (1) searching during daylight hours for burrows consistent with those constructed and maintained by Atlas Rainforest Ground Beetle within a 50 x 20 m transect at each monitoring site; and (2) returning in the early evening to all burrows found during the daytime survey, to confirm whether the burrows were occupied by Atlas Rainforest Ground Beetles, which typically only become active at their burrow entrances at night.

Results and Discussion

A single 3rd instar Pink Underwing Moth larva was found at control site C1 (Davis Scrub Nature Reserve) during the November survey, but no larvae were found during the December survey.

No Atlas Rainforest Ground Beetle activity was detected during the extremely dry prevailing conditions in November 2019, but increased activity was detected during the December 2019 survey following some rainfall. During the two surveys, the greatest numbers of Atlas Rainforest Ground Beetles confirmed at burrow entrances along monitoring transects were as follows: T1 (0 beetles, 2 burrows), T5 (1 beetle, 1 burrow), between T1 and T5 (0 beetles, 3 burrows) and C1 in Davis Scrub NR (10 beetles in 20 burrows checked, with up to 37 burrows detected on the 50 x 20m transect). These are all locations where Atlas Rainforest Ground Beetle has been confirmed on previous surveys. No burrows consistent with Atlas Rainforest Ground Beetle were found at any of the other monitoring sites, which is consistent with the results of previous surveys.

A single Richmond Birdwing larva *Ornithoptera richmondia* was found at each of site 11 and in planted host vines near site C2 in Victoria Park Nature Reserve in November 2019, but no larvae were found at any of the monitoring sites in December 2019.

Although formal surveys of habitat condition and host plant abundance were not conducted due to the shortened duration of monitoring, no evidence of change in habitat condition or host plant populations since the Year 2 construction phase survey was apparent.

Conclusions

The timing of breeding and the relative abundance of Southern Pink Underwing Moth larvae during each breeding event are variable, but the environmental factors responsible for inter-annual and intra-seasonal variation in breeding activity remain poorly understood. The finding of relatively large numbers of Southern Pink Underwing Moth larvae during the construction Year 2 and earlier surveys confirms that the study area is a significant breeding area for Southern Pink Underwing Moth, particularly during favourable seasonal rainfall conditions. The abundance of Southern Pink Underwing Moth larvae across the network of impact monitoring sites during the first two construction-year survey periods was equivalent to or greater than larval abundance during the pre-construction surveys. This result demonstrates that the initial construction works on the highway upgrade had no indirect impact on the breeding success of Southern Pink Underwing Moth in retained rainforest habitats close to the highway construction footprint. Due to the short duration of monitoring in Year 3 of the construction phase, which covered only the early portion of the species' potential breeding season, as well as the prevailing dry conditions that may have inhibited early-season breeding, it is not possible to make meaningful comparisons with previous seasons. Notwithstanding this, there is no evidence of an impact of construction phase activities on Southern Pink Underwing Moth.

A low-density population of Atlas Rainforest Ground Beetle occurs in retained rainforest habitats close the highway construction footprint. There was no evidence of a decline in beetle abundance in this population during the first two years of highway construction in comparison with pre-construction abundance. Atlas Rainforest Ground Beetle apparent abundance was substantially reduced at both impact and control sites during the Year 3 monitoring, but this was likely due to the prevailing extremely dry conditions following substantially below average rainfall.

Incidental observations of Richmond Birdwing 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 Richmond Birdwing Vine *Pararistolochia praevenosa*.

The construction phase monitoring conducted to date has not identified an exceedance of any trigger for corrective action; consequently, no corrective actions are triggered. Since no indirect impacts of the Project on any threatened invertebrate species have been detected, adaptive management of the mitigation measures set out in the TIMP is not required. The revised monitoring approach for Southern Pink Underwing Moth implemented through the 2018/19 and 2019/20 seasons has increased the effectiveness of monitoring intra-seasonal variation in breeding activity and larval abundance in this species. The revised monitoring approach has also increased the effectiveness of searching for Atlas Rainforest Ground Beetle burrows during the day.

INVERTEBRATE MONITORING PROGRAM ANNUAL REPORT 2020
YEAR 3 CONSTRUCTION PHASE REPORT

WOOLGOOLGA TO BALLINA PACIFIC HIGHWAY UPGRADE

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Table of Terms and Abbreviations

BAAM	Biodiversity Assessment and Management Pty Ltd
BC Act	New South Wales *Biodiversity Conservation Act 2016*
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
TIMP	Woolgoolga to Ballina Threatened Invertebrate Management Plan

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 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 third year of the construction phase. Construction activity concluded in late December 2019, with operation expected to commence in mid-2020. Therefore, monitoring was undertaken up until December 2019 to conclude the construction phase monitoring reported in this report. The next phase of monitoring will commence once the project is in operation. The scope of work also required 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 (TIMP) (NSW Roads and Maritime Services 2015), which prescribes management and monitoring approaches for values protected by the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the *Biodiversity Conservation Act 2016* (BC Act). Key objectives of the TIMP with regards to monitoring include the following:

- Monitor breeding activity, age (eggs, larvae, adults) and numbers of Southern Pink Underwing Moth *Phyllodes imperialis smithersi* sufficient to detect population change in comparison with the baseline population, including whether a decline in numbers occurs over a three-year post-construction survey period, controlling for natural seasonal variability
- Monitor the presence and abundance of Atlas Rainforest Ground Beetle *Nurus atlas* in known and potential habitat areas sufficient to detect population change in comparison with the baseline population, including whether a decline in numbers occurs over a three-year post-construction survey period, controlling for natural seasonal variability
- Monitor habitat condition for Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle in known habitat retained outside the project clearing boundary sufficient to detect change in habitat condition in comparison with the baseline condition, including whether a decline in habitat condition occurs after each monitoring event
- Monitor the abundance of host plants for Southern Pink Underwing Moth larvae in known habitat retained outside the project clearing boundary sufficient to detect change in host plant abundance in comparison with the baseline abundance, including whether a decline in host plant abundance occurs after each monitoring event.

To meet the monitoring objectives of the TIMP, this study specifically 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 TIMP (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 and an Endangered Ecological Community under the BC 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 to 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).

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 commenced in November 2017. By March 2018 the highway construction footprint had been cleared and substantial road-base had been laid down, and by March 2019 the highway construction was well progressed but not yet complete. The final components of construction were completed in late December 2019, with operation of the highway expected to commence in mid-2020.

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:

- Southern 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 Richmond Birdwing Vine *Pararistolochia praevenosa* (not threatened), were also included as a component of the assessment.

1.5. HABITAT IMPROVEMENT

In January 2020, Pacific Complete introduced five large tree-trunk logs on basaltic soil on sloping terrain at the edges of rainforest regrowth in the study area (see **Figure 3.4** for locations and **Appendix A** for photographs of the logs in situ) as an action to improve habitat for Atlas Rainforest Ground Beetle. This action implements one of the management measures recommended under Section 6.3.7 of the TIMP.

BAAM ECOLOGICAL CONSULTANTS

Client	Jacobs on behalf of Pacific Complete	
Project	Woolgoolga to Ballina Pacific Highway Upgrade Invertebrate Monitoring	
Design	BAAM	4.05.2017
Drawn	Bentline | MP	4.05.2017
Scale	1:600,000	# 0108
Cad File	BAAM_PacHWY01.dwg	NTP 87
Title	Location of the Study Area	FIGURE 1.1

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1.6. MODIFICATIONS TO THE MONITORING METHODOLOGY FOR PINK UNDERWING MOTH

The initial three seasons of monitoring for Southern Pink Underwing Moth between March 2014 and March 2018 incorporated two methods: (1) nocturnal monitoring for adult Southern Pink Underwing Moths attracted to baits of over-ripe bananas placed on transects through each of the five impact and two control monitoring sites, undertaken once per month within the period November to March, including incidental searches for larvae; and (2) habitat assessment and intensive searches for Southern Pink Underwing Moth larvae on host plants at each of 18 habitat assessment sites within the study area, undertaken once each year in February/March.

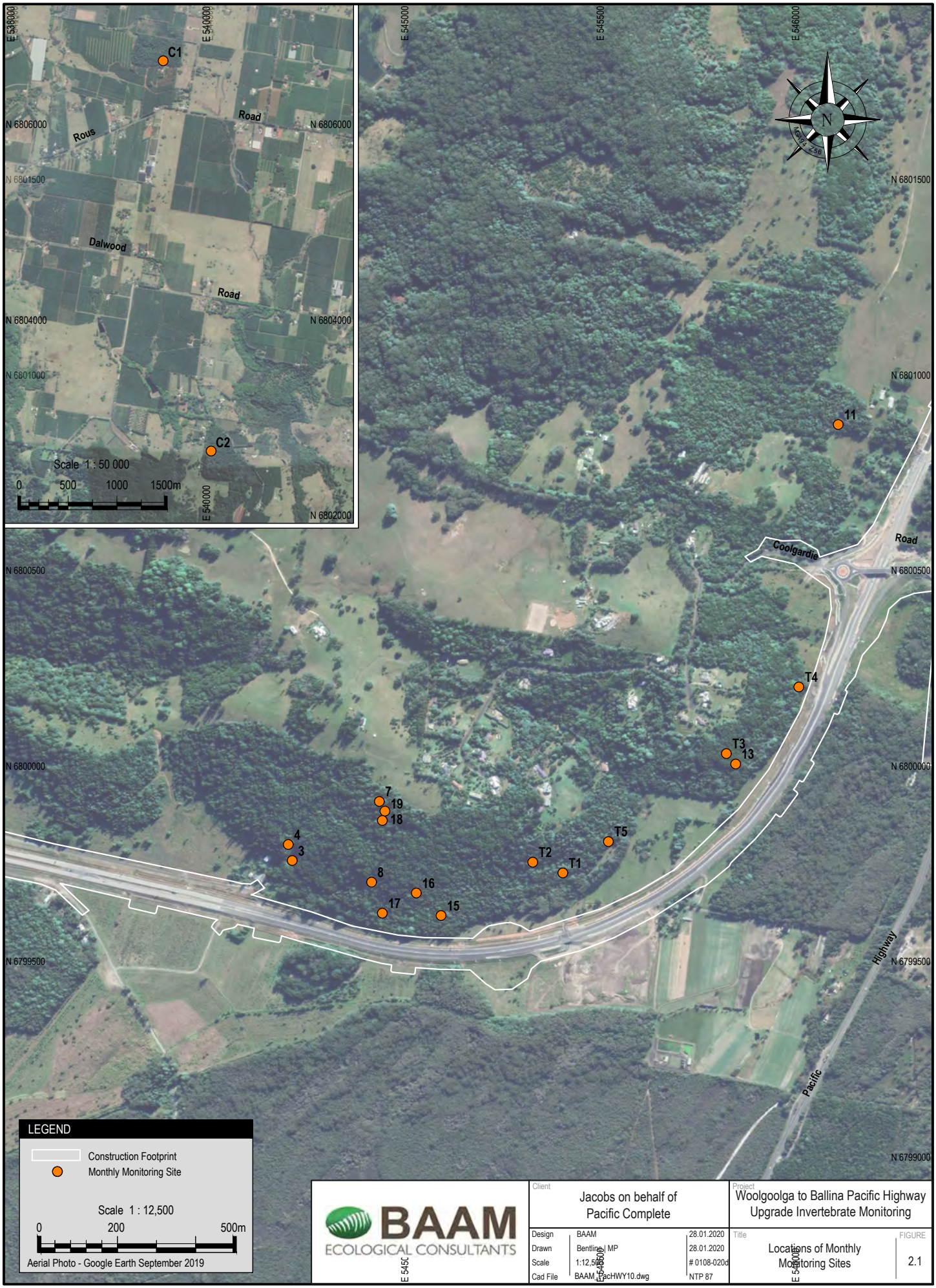
While a variety of moth species that feed on ripe fruit were detected during the nocturnal monitoring surveys between March 2014 and March 2018, no Southern Pink Underwing Moth adults were positively detected despite considerable survey effort (588 bait-nights) and evidence of extensive breeding by the species in the study area (BAAM 2014, 2017, 2018). This led to the conclusion that the nocturnal monitoring method is ineffective in detecting adult Southern Pink Underwing Moths due to the high mobility, unpredictability and apparent rarity of the adult moths (BAAM 2018). A recommendation was made to modify the monitoring approach for Pink Underwing Moth to provide more effective monitoring of habitat use, breeding activity and population change (BAAM 2018). The recommended change to the monitoring approach was to discontinue the monitoring of adult moths and allocate the survey effort previously expended on this method to improving the survey effort coverage of larval-stage monitoring. Larval surveys offer the best method for monitoring habitat use and population change in Southern Pink Underwing Moth due to 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. Recommendations for a revised survey approach for Southern Pink Underwing Moth were as follows (BAAM 2018):

- Four monthly surveys (November, December, January, February) for Southern Pink Underwing Moth eggs and 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.
- A single habitat assessment survey in March, including a survey for Southern Pink Underwing Moth larvae 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.

The recommended revision to the survey approach for Southern Pink Underwing Moth was adopted by NSW Roads and Maritime Services prior to the start of Year 2 of the construction phase. The recommended revised approach is therefore implemented in this report as set out in the following section.

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). Since construction was completed in late December 2019, with operation expected to commence in mid-2020, only two monthly threatened invertebrate monitoring surveys (November, December), not including a habitat assessment survey, were conducted during Year 3 of the construction phase that is reported on here. Surveys were performed by Dr Penn Lloyd and Shelley Trevaskis on 26 November and 17 December 2019. All surveys were performed under BAAM's NSW Scientific Licence number SL100704.



BAAM ECOLOGICAL CONSULTANTS

Client	Jacobs on behalf of Pacific Complete	
Project	Woolgoolga to Ballina Pacific Highway Upgrade Invertebrate Monitoring	
Design	BAAM	28.01.2020
Drawn	Bentling, MP	28.01.2020
Scale	1:12,500	# 0108-020d
Cad File	BAAM_PacHWY10.dwg	NTP 87
Title	Locations of Monthly Monitoring Sites	FIGURE 2.1

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2.1. MONITORING SOUTHERN PINK UNDERWING MOTH LARVAL ABUNDANCE

Monitoring of Southern Pink Underwing Moth larval abundance, which is indicative of breeding activity, was conducted at a network of 18 monitoring sites, including two control transect sites (C1 and C2), five impact transect sites (T1 to T5) and 11 other impact sites in retained habitat close to the highway construction footprint. The locations of the monthly monitoring sites are shown in Figure 2.1.

During each monitoring event, the undersides of the leaves and stems of most of the *Carronia multisepalea* host plants present at each site were searched for eggs and larvae during daylight hours. Wherever eggs or larvae were found, the position of the observation was recorded using a hand-held GPS and the number and age of the larvae were noted. Larval ages were characterised on the basis of the five stages of growth that larvae (caterpillars) go through, referred to as larval instars, between the time they hatch from eggs and the time they become a pupa. These stages are illustrated in the photos below. Incidental searches for Southern Pink Underwing Moth adults were also undertaken during the nocturnal surveys for Atlas Rainforest Ground Beetle described in the next section.

Photo 2.1. Pink Underwing Moth egg.

Photo 2.2. Pink Underwing Moth 1st instar larva (reproduced from Sands (2012)).

Photo 2.3. Pink Underwing Moth 2nd instar larva.

Photo 2.4. Pink Underwing Moth 3rd instar larva.

Photo 2.5. Pink Underwing Moth 4th instar larvae.

Photo 2.6. Pink Underwing Moth 5th instar larva.

2.2. MONITORING ATLAS RAINFOREST GROUND BEETLE ABUNDANCE

Monitoring of Atlas Rainforest Ground Beetle abundance was conducted in conjunction with the Southern Pink Underwing Moth monitoring. This monthly monitoring was conducted at an expanded network of monitoring sites, including two control transect sites (C1 and C2), five impact transect sites (T1 to T5) and 11 additional impact sites close to the highway construction footprint. Each monitoring survey involved: (1) searching during daylight hours for burrows consistent with those constructed and maintained by Atlas Rainforest Ground Beetle within a 50 x 20 m transect at each monitoring site; and (2) returning in the early evening to all burrows found during the daytime survey, to confirm whether the burrows were occupied by Atlas Rainforest Ground Beetles, which typically only become active at their burrow entrances at night. During each nocturnal survey starting approximately 45 minutes after sunset, burrows were approached as quietly as possible and LED head-torches were used to first check for the presence of a beetle at each burrow entrance from a short distance away before shining the torch down the burrow to check for the presence of a beetle deeper in the burrow.

2.3. MONITORING HABITAT CONDITION

Due to the abbreviated duration of monitoring in Year 3 of the construction phase and the absence of any notable change in habitat condition since the Year 2 construction phase survey, monitoring of habitat condition was not conducted. Monitoring of habitat condition will resume during Year 1 of the operation phase.

2.4. MONITORING HOST PLANT POPULATIONS

Due to the abbreviated duration of monitoring in Year 3 of the construction phase and the absence of any notable change in host plant populations since the Year 2 construction phase survey, monitoring of host plant populations was not conducted. Monitoring of host plant populations will resume during Year 1 of the operation phase.

2.5. OPPORTUNISTIC SURVEY FOR RICHMOND BIRDWING

Opportunistic observations and records of Richmond Birdwing butterflies and larvae were made during each of the monthly daytime surveys. This included searching the foliage of host plants (Richmond Birdwing Vine *Pararistolochia praevenosa*) for the distinctive Richmond Birdwing larvae.

3.0 RESULTS AND DISCUSSION

3.1. RAINFALL CONDITIONS DURING THE MONITORING PERIOD

Rainfall in the few months prior to and during the monitoring surveys was substantially below average (**Figure 3.1**). Prior to the 26 November 2019 survey, only 12 mm of rainfall had fallen over the previous three months, resulting in extremely dry conditions during the survey. Prior to the 17 December 2019 survey, a total of approximately 58 mm had fallen since the November survey, including 36 mm two weeks prior.

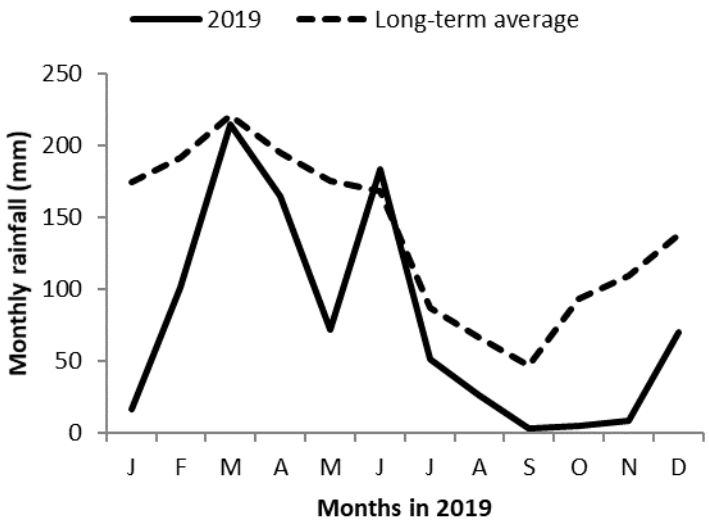


Figure 3.1. Monthly rainfall at Meerschaum Vale weather station during 2019 compared to the long-term average (BoM 2020).

3.2. SOUTHERN PINK UNDERWING MOTH ABUNDANCE

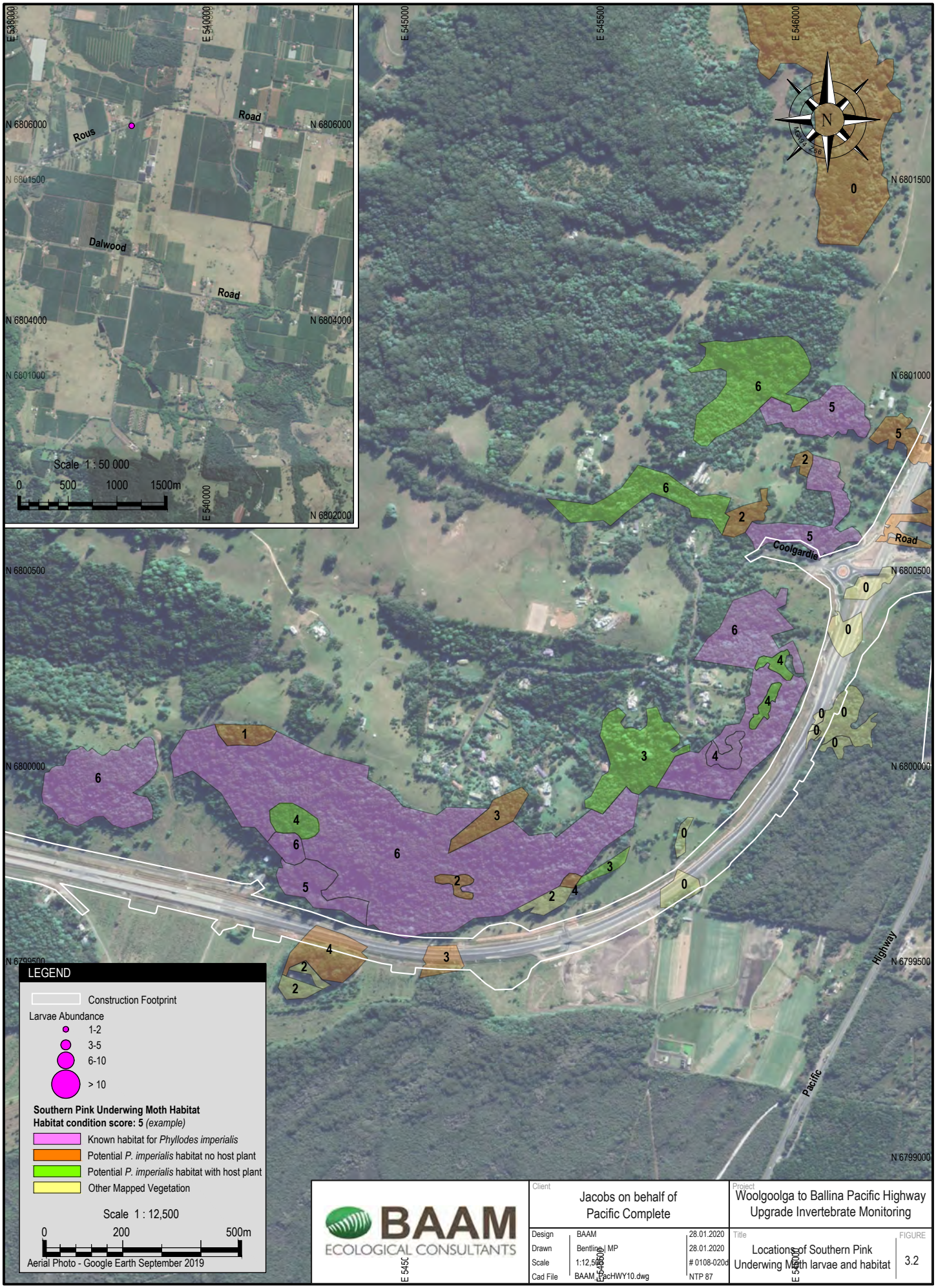
A summary of the monthly monitoring results is provided in **Table 3.1**. During the November survey, a single 3rd instar Pink Underwing Moth larva was found at control site C1 (Davis Scrub Nature Reserve) (**Figure 3.2**, **Photo 3.1**). No larvae were found during the December survey. No larvae of fruit-piercing moth species were found during either of the two surveys. No adult Pink Underwing Moths were observed during the nocturnal monitoring for Atlas Rainforest Ground Beetle.

Photo 3.1. Southern Pink Underwing Moth 3rd instar larva at site C1.

Photo 3.2. Richmond Birdwing larva at site 11.

Table 3.1. Summary of the results of nocturnal monitoring for Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle.

Date	Rainfall	General Notes	Atlas Rainforest Ground Beetle	Southern Pink Underwing Moth
26 November 2019	12 mm of rainfall over the previous 3 months, and annual rainfall to date (843 mm) substantially less than the long-term average of 1,550 mm.	Hot, extremely dry and windy conditions during the survey.	Burrows consistent with Atlas Rainforest Ground Beetle were found during the day at T1 (2 burrows), T5 (1 burrow), between T1 and T5 (3 burrows in a tight cluster) and C1 (37 burrows within 50x10 m plot). However, there was no beetle activity at burrow entrances during the evening survey i.e. no beetles in all the burrows at T1, T5, between T1 and T5 and a sample of 24 burrows checked at C1. The lack of beetle activity is most likely due to the prevailing drought conditions.	A single 3rd instar Pink Underwing Moth larva was found at C1 (Davis Scrub Nature Reserve). No larvae of fruit-piercing moth species were found. A single Richmond Birdwing larva was found at each of site 11 and in planted host vines near site C2 in Victoria Park Nature Reserve.
17 December 2019	A total of approximately 58 mm since the previous survey, including 36 mm two weeks prior.	Mild, dry conditions.	Burrows consistent with Atlas Rainforest Ground Beetle were found during the day at T1 (2 burrows), T5 (1 burrow), between T1 and T5 (2 burrows) and C1 (30 burrows within 50x10 m plot). Beetles were detected at burrow entrances during the evening survey in the burrow at T5, and in 10 of 20 burrows checked as a sample at C1.	No Pink Underwing Moth larvae detected at any of the monitoring sites. No larvae of fruit-piercing moth species were found. No Richmond Birdwing larvae detected.



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The finding of relatively large numbers of Southern Pink Underwing Moth larvae during the construction Year 2 and earlier surveys (see **Table 3.3** for a summary) confirms that the study area is a significant breeding area for Southern Pink Underwing Moth, particularly during favourable seasonal rainfall conditions. 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 3.3. 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
Pre-construction: 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.
Pre-construction: 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.
Pre-construction: 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 in late March at Davis Scrub Nature Reserve control site C1.
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.
Pre-construction: 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.
Construction Year 1: 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 (BAAM 2018).	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.
Construction Year 2: Six monthly surveys between 27 November 2018 and 5 March 2019 at impact and control sites (BAAM 2019).	A total of **41 larvae** found in late November, **14 larvae** in mid-December, **3 larvae** in early February and **18 larvae** in early March, all at impact sites.
Construction Year 3: Two monthly surveys 26 November and 17 December 2019 at impact and control sites (this study).	A **single larva** found in November at Davis Scrub Nature Reserve control site C1; no larvae found at impact monitoring sites.

The surveys conducted to date show that both the timing of breeding and the relative abundance of larvae during each breeding event are variable (**Table 3.3, Figure 3.3**). While at least some Southern Pink Underwing Moth larvae appear to be consistently produced in February/March each year, a larger number of larvae were produced in November than in February/March in the study area during the 2018/19 season. The environmental factors responsible for inter-annual and intra-seasonal variation in breeding activity remain poorly understood; while the November 2018 early-season breeding followed above-average rainfall in September-October after below-average rainfall through winter, similar conditions the previous year did not result in early-season breeding.

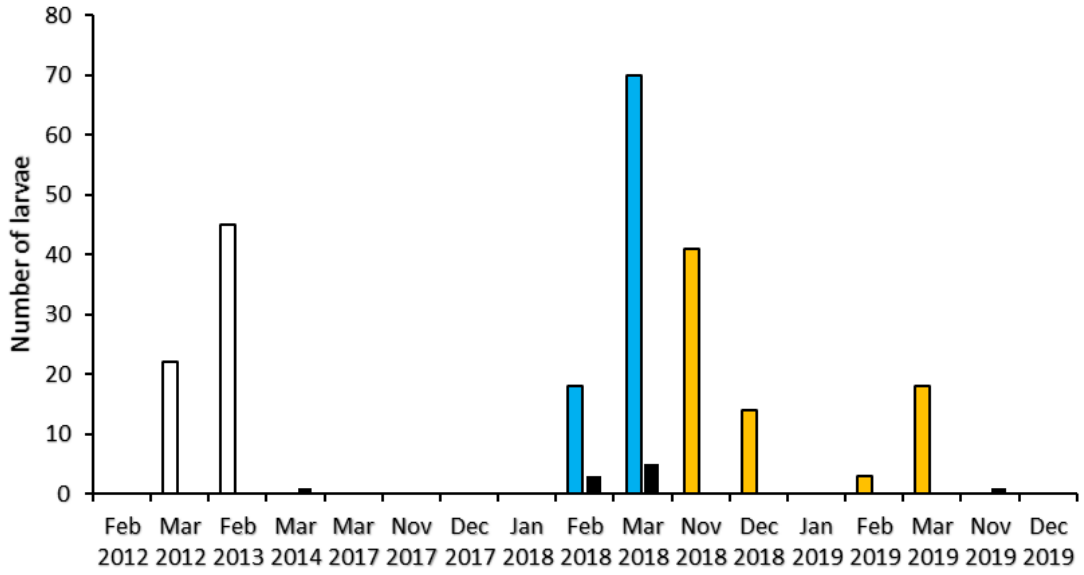

Figure 3.3. Southern Pink Underwing Moth total larval abundance at impact monitoring sites during pre-construction (February 2012 to March 2017, white bars), construction year 1 (November 2017 to March 2018, blue bars), construction year 2 (November 2018 to March 2019, orange bars) and construction year 3 (November to December 2019) surveys. Black bars show total larval abundance at control sites.

The abundance of Southern Pink Underwing Moth larvae across the network of impact monitoring sites during the first two construction-year survey periods was equivalent to or greater than larval abundance during the pre-construction surveys (**Figure 3.3**). This result demonstrates that the initial two years of construction works on the highway upgrade had no indirect impact on the breeding success of Southern Pink Underwing Moth in retained rainforest habitats close to the highway construction footprint. Due to the short duration of monitoring in Year 3 of the construction phase, which covered only the early portion of the species' potential breeding season, as well as the prevailing dry conditions that may have inhibited early-season breeding, it is not possible to make meaningful comparisons with previous seasons.

3.3. ATLAS RAINFOREST GROUND BEETLE ABUNDANCE

No Atlas Rainforest Ground Beetle activity was detected during the extremely dry prevailing conditions in November 2019, but increased activity was detected during the December 2019 survey following some rainfall (**Table 3.1, Figure 3.4**). This pattern of activity is consistent with the results of previous surveys where the activity of this species was minimal on dry, windy evenings, but much greater after recent rainfall. During the two surveys, the greatest numbers of Atlas Rainforest Ground Beetles confirmed at burrow entrances along monitoring transects were as follows: T1 (0 beetles, 2 burrows), T5 (1 beetle, 1 burrow), between T1 and T5 (0 beetles, 3 burrows) and C1 in Davis Scrub NR (10 beetles in 20 burrows checked, with up to 37 burrows detected on the 50 x 20m transect). These are all locations where Atlas Rainforest Ground Beetle has been confirmed on previous surveys. No burrows consistent with Atlas Rainforest Ground Beetle were found at any of the other monitoring sites, which is consistent with the results of previous surveys.

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The 2018/19 surveys detected similar numbers of Atlas Rainforest Ground Beetles at the impact monitoring sites as were found during 2017/18 (**Table 3.4, Figure 3.5**), confirming the presence of small numbers of beetles at three different locations at or close to the T1 and T5 impact monitoring sites. The increase in the total number of beetles at Davis Scrub Nature Reserve control site C1 is largely due to the changed Southern Pink Underwing Moth survey protocol that allows more time for searching for beetle burrows during the day.

Table 3.4. 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 (BAAM 2018).	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.
Six daytime and nocturnal monitoring surveys between 29 November 2018 and 5 March 2019 and a broader habitat and population assessment survey 12-13 December 2018 at impact and control sites (BAAM 2019).	Up to **44 beetles** at C1, no burrows found at C2 but up to eight beetles in burrows nearby**, two beetles** at T1, **three beetles** at T5 and **three beetles** between T1 and T5.
Two daytime and nocturnal monitoring surveys 26 November and 17 December 2019 (this study).	Up to 37 burrows with 50% confirmed activity (**19 beetles**) at C1, no burrows at C2, 2 burrows (no beetles) at T1, 1 burrow (**1 beetle**) at T5 and 3 burrows (no beetles) between T1 and T5.

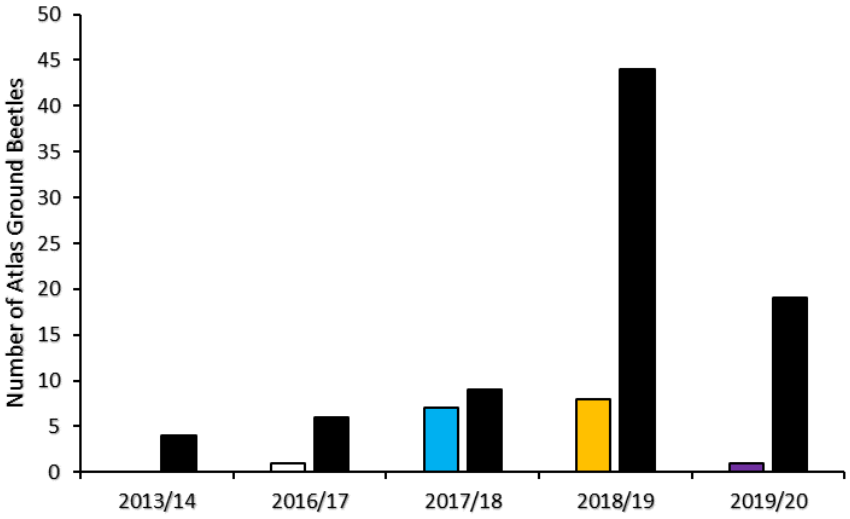

Figure 3.5. Atlas Rainforest Ground Beetle total maximum abundance at impact monitoring sites during pre-construction (2013/14 and 2016/17, white bars), construction year 1 (2017/18, blue bar), construction year 2 (2018/19, orange bar) and construction year 3 (2019/20, purple bar) surveys. Black bars show maximum beetle abundance at control sites.

These results confirm that a low-density population of Atlas Rainforest Ground Beetle occurs in retained rainforest habitats close the highway construction footprint. There was no evidence of a decline in beetle abundance in this population during the first two years of highway construction in comparison with pre-construction abundance (**Figure 3.5**). Atlas Rainforest Ground Beetle apparent abundance was substantially reduced at both impact and control sites during the Year 3 monitoring, but this was likely due to the prevailing extremely dry conditions following substantially below average rainfall.

3.4. RICHMOND BIRDWING

A single Richmond Birdwing larva was found at each of site 11 and in planted host vines near site C2 in Victoria Park Nature Reserve in November 2019 (**Photo 3.2**), but no larvae were found at any of the monitoring sites in December 2019 (**Table 3.1**). Many host plant vines showed signs of desiccation in the prevailing dry conditions. The locations of these observations are shown in **Figure 3.4**.

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, 2018, 2019). The 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.

3.5. CONCLUSIONS ON OUTCOMES RELATIVE TO PERFORMANCE INDICTORS

The Threatened Invertebrates Management Plan (TIMP) is intended to be a dynamic document subject to continual improvement (NSW Roads and Maritime Services 2015). The TIMP specifies performance indicators and corrective actions if monitoring finds poor outcomes, as outlined in **Table 3.6** below. Also included in **Table 3.6** is an assessment of whether corrective actions are triggered by the monitoring results of the 2019/20 season.

The construction phase monitoring conducted to date has not identified an exceedance of any trigger for corrective action; consequently, no corrective actions are triggered (**Table 3.6**). Since no indirect impacts of the Project on any threatened invertebrate species have been detected, adaptive management of the mitigation measures set out in the TIMP is not required. The revised monitoring approach for Southern Pink Underwing Moth implemented through the 2018/19 and 2019/20 seasons has increased the effectiveness of monitoring intra-seasonal variation in breeding activity and larval abundance in this species. The revised monitoring approach has also increased the effectiveness of searching for Atlas Rainforest Ground Beetle burrows during the day.

Table 3.6. Summary of monitoring outcomes relative to the performance indicators and corrective actions specified in the TIMP.

Monitoring element	Trigger for corrective action	Corrective actions	Assessment of 2019/20 monitoring outcomes
Southern Pink Underwing Moth annual surveys Atlas Rainforest Ground Beetle annual surveys	Evidence of a decline in numbers over a three-year post-construction survey period.	• If decline is noted in invertebrate numbers at a monitoring event from the baseline evaluate potential causes. • Review monitoring locations and cross reference with monitoring results of rehabilitation areas and monitoring of Lowland Rainforest communities in Section 10 and Section 11. • Evaluate population numbers at the control sites and investigate additional areas of habitat beyond the project and consider options to improve habitat condition and connectivity. • If a decline is still noted after three consecutive years of monitoring engage with OEH and EPA and consider provisional measures. • This may include a review and update of the monitoring program to consider more intense monitoring or different techniques to identify if the decline is as a result of the Project. • If there is an additional residual impact to threatened invertebrates Roads and Maritime will evaluate the need for additional offsets.	No evidence of a decline attributable to the project in numbers of either Southern Pink Underwing Moth or Atlas Rainforest Ground Beetle during the construction phase. No corrective actions triggered.
Invertebrate habitat condition monitoring (known habitat retained outside the project clearing boundary)	Evidence of a decline in habitat condition after each monitoring event. Less than 100% survival rate of retained host plants.	• Evaluate reasons for the decline such as weed incursion, edge effects or natural event. • Review and revise management techniques as appropriate. • Continue monitoring program to evaluate effectiveness of revised management actions.	No evidence of a decline in invertebrate habitat condition or survival of retained host plants. No corrective actions triggered.
Host plant condition monitoring	Evidence of a decline in host plant quantity or habitat condition.	• If decline in host plant numbers or habitat condition is noted during any annual period of monitoring, review and revise management techniques as appropriate. • Erect temporary shade cloth adjacent to host plants where these occur in edge areas to minimise dust impacts and increased exposure until plants have stabilised. • If decline noted after three years post-construction monitoring, cross reference with monitoring of threatened invertebrates. • Investigate additional areas of habitat beyond the project and consider options to improve habitat condition and connectivity. • If decline still noted in subsequent two monitoring periods engage with OEH and consider provisional measures. • Further monitoring of provisional measures would be planned at this stage.	No evidence of a decline in host plant condition. No corrective actions triggered.

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APPENDIX A

Photographs of logs introduced to improve habitat for Atlas Rainforest Ground Beetle

Table A.1. Photographs of logs introduced to improve habitat for Atlas Rainforest Ground Beetle.


Log 1


Log 2


Log 3


Log 4


Log 5