NSW Roads and Maritime Services

WOOLGOOLGA TO BALLINA | PACIFIC HIGHWAY UPGRADE

THREATENED INVERTEBRATES MANAGEMENT PLAN

Version 1.0

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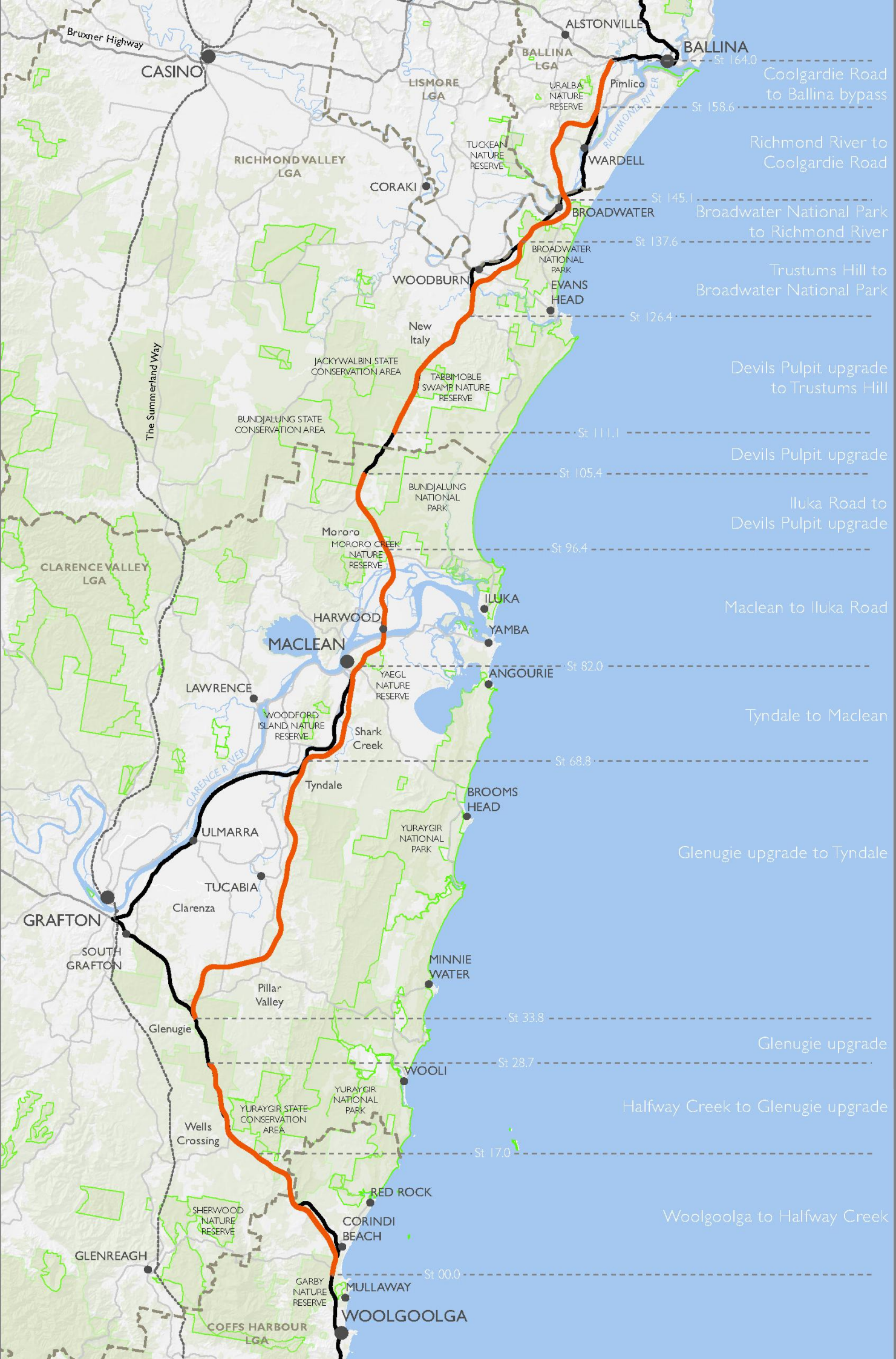
Bruxner Highway
CASINO
ALSTONVILLE
BALLINA
BALLINA LGA
LISMORE LGA
URALBA NATURE RESERVE
Pimlico
RICHMOND RIVER
St 164.0
Coolgardie Road to Ballina bypass
11
St 158.6
Richmond River to Coolgardie Road
10
TUCKEAN NATURE RESERVE
WARDELL
RICHMOND VALLEY LGA
CORAKI
St 145.1
BROADWATER
Broadwater National Park to Richmond River
9
St 137.6
BROADWATER NATIONAL PARK
WOODBURN
EVANS HEAD
Trustums Hill to Broadwater National Park
8
St 126.4
New Italy
JACKYWALBIN STATE CONSERVATION AREA
TABBIMOBLE SWAMP NATURE RESERVE
Devils Pulpit upgrade to Trustums Hill
7
The Summerland Way
BUNDJALUNG STATE CONSERVATION AREA
St 111.1
Devils Pulpit upgrade
St 105.4
BUNDJALUNG NATIONAL PARK
Iluka Road to Devils Pulpit upgrade
6
Mororo
MORORO CREEK NATURE RESERVE
St 96.4
CLARENCE VALLEY LGA
ILUKA
HARWOOD
YAMBA
MACLEAN
Maclean to Iluka Road
5
ANGOURIE
St 82.0
YAEGL NATURE RESERVE
LAWRENCE
WOODFORD ISLAND NATURE RESERVE
Shark Creek
Tyndale to Maclean
4
St 68.8
CLARENCE RIVER
Tyndale
BROOMS HEAD
YURAYGIR NATIONAL PARK
ULMARRA
Glenugie upgrade to Tyndale
3
TUCABIA
Clarenza
GRAFTON
SOUTH GRAFTON
MINNIE WATER
Pillar Valley
St 33.8
Glenugie
Glenugie upgrade
St 28.7
WOOLI
YURAYGIR NATIONAL PARK
YURAYGIR STATE CONSERVATION AREA
Halfway Creek to Glenugie upgrade
2
Wells Crossing
St 17.0
RED ROCK
SHERWOOD NATURE RESERVE
CORINDI BEACH
Woolgoolga to Halfway Creek
1
GLENREAGH
St 00.0
GARBY NATURE RESERVE
MULLAWAY
WOOLGOOLGA
COFFS HARBOUR LGA

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1. Introduction

1.1 Project overview

NSW Roads and Maritime Services (Roads and Maritime) is seeking approval for the Woolgoolga to Ballina (W2B) Pacific Highway upgrade project (the project / the action), on the NSW North Coast. The approval is sought under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The location of the project is shown in the figure above.

Since 1996, both the Australian and NSW governments have contributed funds to the upgrade of the 664-kilometre section of the Pacific Highway between Hexham and the Queensland border, as part of the Pacific Highway Upgrade Program.

Both governments have a shared commitment to finish upgrading the highway to a four-lane divided road as soon as possible. However, the actual timing of construction, opening to traffic and completion is dependent on funding negotiations between the Australian and NSW governments. Assessments would be adjusted accordingly based on actual opening dates, for example noise and traffic predictions.

The project would upgrade around 155 kilometres of highway and represents the last priority (known as 'Priority 3' in the upgrade program) in achieving a four-lane divided road between Hexham and the NSW/Queensland Border. The project therefore forms a major part of the overall upgrade program and when constructed, would complete the four-lane divided road program.

The project would be jointly funded by the NSW and Australian governments.

The project does not include the Pacific Highway upgrades at Glenugie and Devils Pulpit, which are located between Woolgoolga and Ballina. These are separate projects, with Glenugie now complete and Devils Pulpit under construction. Altogether, these three projects would upgrade 164 kilometres of the Pacific Highway. The project does include a partial upgrade of the existing dual carriageways at Halfway Creek.

A more detailed description of the Woolgoolga to Ballina Pacific Highway upgrade is found in the Pacific Highway upgrade: Woolgoolga to Ballina Environmental Impact Statement prepared by Roads and Maritime in December 2012.

1.2 Purpose and objectives

This threatened invertebrates management plan addresses the potential and residual impacts of the upgrade on Southern Pink Underwing Moth *Phyllodes imperialis smithersi* (listed as Endangered under the EPBC Act and NSW *Threatened Species Conservation Act* (TSC Act)), and Atlas Rainforest Ground Beetle *Nurus atlas* (listed as Endangered under the TSC Act) and potential habitat for these species. Both of these invertebrate species and the moth host plant have been confirmed to occur in the vicinity of the road corridor in project Section 10 and Section 11.

This plan identifies the proposed mitigation measures to be implemented for threatened invertebrates and a program for monitoring the effectiveness of these measures.

The objectives of the plan include:

- A summary of the locations where threatened invertebrates and their host plants have been identified.
- A description of the areas relevant to the threatened invertebrates and their host plants that would be impacted by the project within Section 10 and 11 and the areas to be retained adjacent to the project.
- Details of the targeted methods for identifying locations of threatened invertebrate populations impacted by the project prior to construction, as well as recommendations for rehabilitation of threatened invertebrate habitat.
- A description of the management and mitigation measures, as well as potential corrective actions, that would be implemented during construction and operation of project Section 10 and 11 for the protection of Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle populations, as well as *in-situ* host plants for the moth.
- A description of the monitoring program that would be implemented during construction and operation of project Section 10 and 11 to assess the effectiveness of the proposed mitigation measures and provides input into adaptive management.
- Strategies to trial re-establishment of threatened invertebrate host plant species, including propagation, with supplementary planting in areas of suitable habitat, in rainforest revegetation areas.

1.3 Management structure and plan updates

Management structure

This species management plan provides a framework for any part of the proposed upgrade between Woolgoolga to Ballina. This plan would be updated during detailed design or pre-construction stage of any proposal that may affect threatened species relevant to this plan. The final management plan would be specific to the project section, stage, program of works or singular element of infrastructure which makes-up the overall Woolgoolga to Ballina upgrade. The plan would operate in conjunction with the Construction Environmental Management Plan (CEMP) and project specific flora and fauna management plan (FFMP), or may be incorporated into a wider framework that includes such plans.

Roads and Maritime would finalise this plan in consultation with the NSW Department of Planning and Infrastructure (DP&I) and NSW Office of Environment and Heritage (OEH).

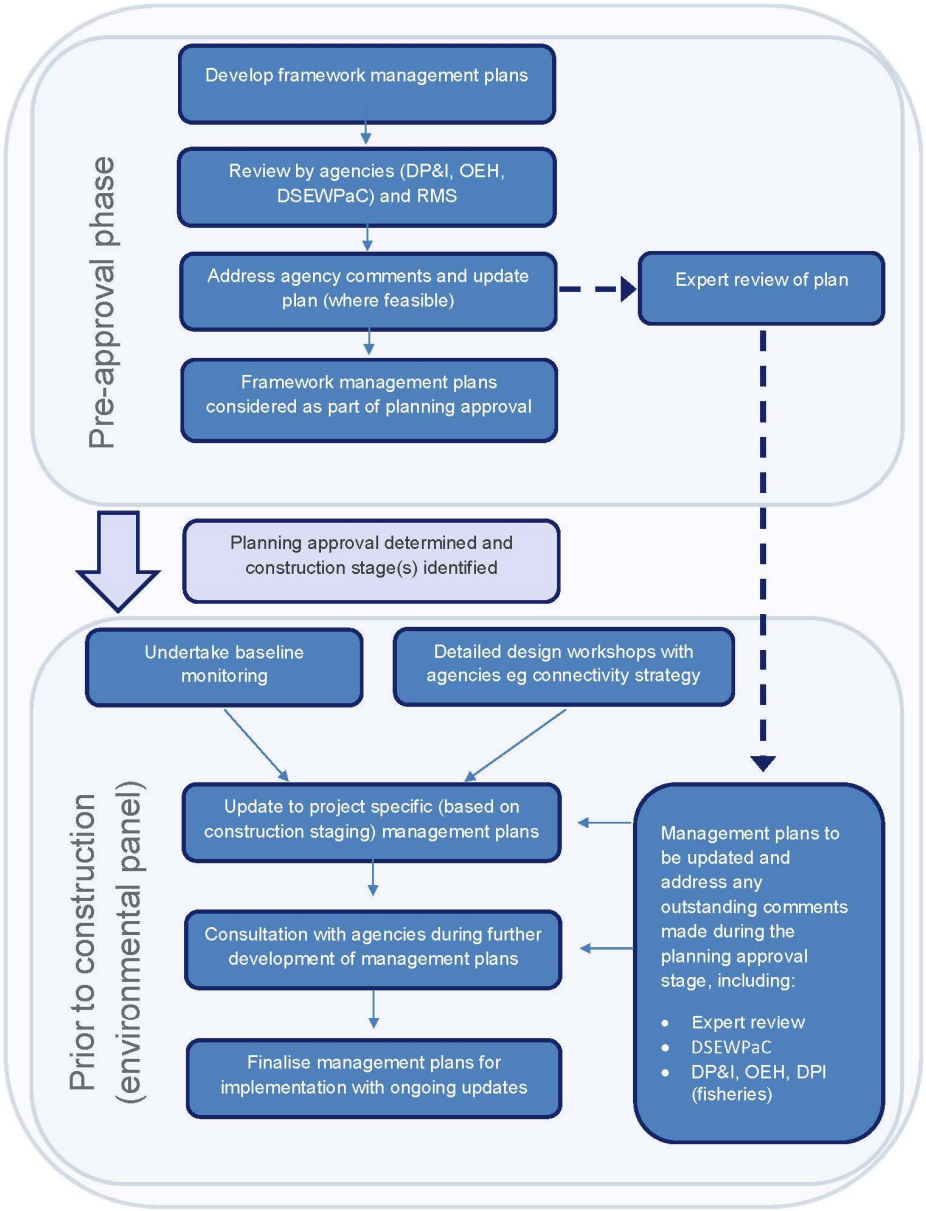
General responsibilities for environmental management would be outlined in the CEMP and FFMP. Responsibilities for implementation of this plan have been described throughout and summarised in Chapter 8. Following approval of the plan, the construction contractor and the contractors ecologist engaged for the relevant project sections would be responsible to oversee implementation of the plan

Plan updates

The plan is intended to be a dynamic document subject to continual improvement. The management plan would be updated as required to meet the mitigation and management measures committed to in the EIS and PIR reports and any Condition of Approval (CoA) for the project. Prior to implementation, the plan would be updated following independent expert review to incorporate any necessary changes that arise from that review. The process for the update of the plan is illustrated in Figure 1-1 below.

This plan identifies the general locations proposed for conducting monitoring and the methods, variables and timing of the proposed monitoring program. Details have been provided on the parameters for the selection of the final monitoring sites, both impact and control sites. It is not possible to pre-select the monitoring sites at this point in the planning and design process, as this requires consultation with affected landowners. The final selection of monitoring sites would be subject to further interrogation through the implementation of targeted surveys (refer to section 4.3.2) and confirmation of landowner access and would be presented in the first annual monitoring report with the intention of repeated sampling to be conducted at these locations.

Figure 1-1 Process to develop management plan



1.4 Plan authors and expert review

Authors

This management plan was prepared by Dr Lindsay Popple of Biodiversity Assessment and Management Pty Ltd (BAAM) in liaison with Chris Thomson of Sinclair Knight Merz (SKM). Lindsay holds a PhD in entomology and has co-ordinated flora and fauna surveys across Australia since 1997. He has more than 10 years research experience in the field of entomology, with specialist expertise in the taxonomy, ecology, phylogenetics and biogeography of animals and plants, and has published in a wide range of peer-reviewed journals. Since joining BAAM in 2011, Lindsay has prepared species management programs for both large and small scale projects.

Chris Thomson has a Bachelor of Applied Science and Graduate Certificate in Natural Resources with seventeen years professional experience in the fields of ecology and natural resource management. He is highly experienced in the design and implementation of ecological monitoring programs, flora and fauna surveys, threatened fauna management plans and ecological impact assessment, having completed numerous studies for clients such as the Roads and Maritime and Department of Defence. Chris has considerable experience assisting clients with meeting project Conditions of Approval in relation to managing and monitoring impacts on biodiversity. This includes the preparation and implementation of species specific management plans and monitoring programs. In particular Chris has comprehensive knowledge of fauna monitoring programs, having coordinated numerous targeted fauna surveys and monitoring programs throughout the Northern Rivers, Riverina, the ACT, Sydney Basin and the Hunter Valley.

Expert review

An expert review of the plan was undertaken in August 2013 by Dr DPA Sands. Don Sands is an insect taxonomist and ecologist and has a long research career with CSIRO. He has published more than 120 scientific papers and five books. As a Post-retirement Fellow he wrote two major works, *Biological Control of Arthropods in Australia* (with Dr DF Waterhouse, ACIAR) and *The Action Plan for Australian Butterflies* (with Prof. TR New), the latter to review the conservation status of all Australian butterflies.

Don's conservation research and concerns began in the 1990s (e.g. Richmond birdwing butterfly, *Ornithoptera richmondia*) and was followed by a research project on the Queen Alexandra's Birdwing Butterfly (*Ornithoptera alexandrae*), a large and spectacular threatened species of international concern. His studies with CSIRO on fruit piercing moths led to the discovery in 1987 of the Pink Underwing Moth (southern subspecies), subsequently recognised as endangered (EPBC Act and TSC Act). Most recently Don published the description of this moth and provided a name for this new and unnamed sub-species, the Southern Pink Underwing Moth (*Phyllodes imperialis smithersi*).

Curricula vita for Dr Sands is provided in Appendix A and a copy of his review of the management plan is attached as Appendix B. The recommendations provided in this review have been summarised in Table 1-1. The table also identifies how each of the recommendations have been addressed. Recommendations have been addressed in one of three ways:

- Adopted - plan updated.
- Adopted - plan to be updated prior to implementation.
- To be reviewed - recommendation to be reviewed further by Roads and Maritime prior to implementation.

Table 1-1 Summary of recommendations from the expert review and how addressed in the plan

ID No	Recommendation	How recommendation is to be addressed
TIMP1	Mapping of Wardell Site. The surveyed site and other rainforest ecosystems along the Richmond River have been referred to in past times as the 'Big Scrub'. To place emphasis on the importance of threatened species and ecosystems, in the Introduction it would be helpful to refer to the site as a remnant of the Big Scrub, indicate remaining intact areas, and those nearby protected (by tenure) as national parks.	Adopted- plan to be updated prior to implementation.
TIMP2	A Map to show areas proposed for clearing ('before' revision) and 'after' revision of boundaries would be helpful to readers to reflect commitment to avoiding damage to protected species habitats. Show current locations of food plants for the two (Lepidoptera) species of conservation concern, *Carronia multisepalea* and *Pararistolocia praevenosa.*	To be reviewed prior to implementation
TIMP3	Early in section 2.2.1 note the habitats occupied by the two targeted insect species (+ Richmond birdwing butterfly) are defined as threatened *Lowland Rainforest of Subtropical Australia,* by Federal and NSW Governments.	Adopted- plan updated
TIMP4	Pink Underwing Moth - name. Add "Southern" (to common name); update scientific name for subspecies (i.e. *Phyllodes imperialis smithersi).* Integrate in text: 'larvae of the southern subspecies of moth are dependent on one food plant vine, *Carronia multisepalea*, found only in rainforests of north-eastern NSW and south-eastern Queensland" or similar….	Adopted- plan updated
TIMP5	In section 2.3 Add "Fragmentation of habitats from disturbance may result in in-breeding depression".	Adopted- plan updated
TIMP6	*Acknowledge State Agency* for issue of 'permits to collect' (for protected insect surveys).	Adopted- plan to be updated prior to implementation.
TIMP7	*Conservation status update.* Threatened species should be reviewed (by agency) every 3 years to take account of new information. Appendix B, pp. 35-	Adopted- plan updated.
TIMP8	Add weeds to Threats. List local invasive weeds so that appropriate agencies and their control methods (e.g. herbicides) can be identified (e.g. green panic, molasses grass, lantana, camphor laurel) and included in lists of threats for the overall ecosystem. Avoid using exotic grasses to re-enforce road edge embankments (common practice in Qld). Some (e.g. signal grass) are known to repel indigenous insects	Adopted- plan updated
TIMP9	*Fruiting plants for adult moths.* Plants suitable for adult food and species that fruit during flight seasons for the moths (e.g. November – March) include: Lillypillies, *Syzygium australe*, *S. smithii* and other local species; *Waterhousea floribunda*, *Ficus* spp., including *F. opposita*, *F. coronata*.	Adopted- plan to be updated prior to implementation.
TIMP10	*Translocation of moth eggs and larvae* (from site of disturbance). Doubtful conservation value unless stages are present on targeted vines, and can be moved prior to clearing. Pupae likely to be present on nearby plants are at risk but are very difficult to locate.	To be reviewed prior to implementation
TIMP11	*Translocation of vine* Carronia multisepalea (no longer proposed). Doubtful value, doubtfully achievable. However, attempts might be made to propagate plants by using rhizomes removed from the path of disturbance.	To be reviewed prior to implementation
TIMP12	Plants to minimise edge effects. Soil-binding (& fire retardant) plants for embankments and vine to stabilise edge effects (First check that Wardell, NSW is within the native range for each species): *Lomandra hystrix, L. longifolia* (moist woodland form), *Rubus spp.*: (e.g. *R. parvifolius, R. moluccanus, R. risifolius, R. probus, R. moorei*) (especially useful for steep embankment / moist slopes), *Carex apressa, other Carex spp. Solanum spp. Ficus coronate,* Cordyline spp. Vine: *Pandorea jasminiodes*	Adopted- plan to be updated prior to implementation
TIMP13	Control sites. Nearby sites of little value when comparing undisturbed habitats with disturbed areas unless positive results are obtained. More distant sites monitored are of value to indicate: (i) presence, number and persistence of breeding in nearby sites, (ii) seasonal patterns, and when stages are most likely to be present and (iii) whereabouts of meta-populations likely to influence colonising of disturbed and re-planted (with vine) areas. As very few vines and patches of vines are used even in undisturbed areas, negative results (no eggs or larvae seen) are likely to be frequent.	Adopted- plan to be updated prior to implementation
TIMP14	Pre-clearing surveys An indication of vines (C*arronia multisepalea, Pararistolocia praevenosa*) that have been removed or destroyed, and as a % of the overall food plants in the area would provide a useful record. The Reviewer is of the opinion that the site once disturbed is unlikely to support breeding by the moth until vegetation has matured and providing deep shade for at least 10 or more years	To be reviewed prior to implementation

ID No	Recommendation	How recommendation is to be addressed
TIMP15	*Rehabilitation of breeding sites for the moth*. *Investigate opportunities to rehabilitate off-site habitats*. for both moth and beetle, e.g. (i) private covenants, nature refuges and other tenures; (ii) buy-back of private land for add to local national parks (they do not need to share boundaries). *Re-vegetation*. If continued for more than 2 years, local community groups can be invited to participate in a coordinated program. Local Landcare groups actively rehabilitate sites in northern NSW (e.g. 'Rainforest Rescue'). Local members could be encouraged to take "ownership" of their efforts to 'save the endangered moth'. Most Incorporated groups are 'not-for-profit' organisations but they always need financial assistance to support operating costs (e.g. herbicides) and other activities for rehabilitating bushlands. *Habitat rehabilitation for the Atlas Ground Beetle.* Very little is known about the ecology of this beetle and it is therefore difficult to assess the potential for rehabilitation of sites to make them suitable for the beetle and its prey. Information from the surveys would indicate that burrow need some overhang, protection (e.g. overhanging log) or embankment and it is possible that these micro-habitats can be simulated in areas rehabilitated. Use of night vision glasses in surveys could contribute to information about nocturnal activity away from burrows, prey, ground shelters and any particular plants used for making burrows (other than While Cedar). *Security for rehabilitation sites*. Signage for sites (+ protected species) is desirable but security needs to be considered. The tenure needs clarification so that protection can be seen as a long term commitment. The moth has potential $$ value for trade (especially for overseas collectors of specimens) but 'collecting' is not known to be a threat at present.	To be reviewed prior to implementation.
TIMP16	*Support for 'Feasibility Study to develop a Recovery Plan'* Recommend support be provided to an appropriate nursery for propagation studies on *Carronia multisepalea* (e.g. *Dorrigo Environment Watch Inc.*) and develop methods to propagate the vine. *Community workshops*. Community workshops can also be included in any local program and by providing support funds. A community workshop on the Southern Pink Underwing Moth was run for Barung Landcare (May 2008) at Maleny (Mary Cairncross Scenic Reserve; cost: ca $2,000. The venue was provided by Council. Community participation was encouraged using the Richmond Birdwing Butterfly Conservation program	To be reviewed prior to implementation.
TIMP17	*Lighting*. Lights and their wattage to be minimised; lights mounted as low as possible, and limited where possible to road & signage illumination. Avoid mercury vapour lights; sodium vapour may need evaluation (effects on target species not known). • Avoid penetration by lights into forest or water courses to avoid disruption of flight behaviour, flight paths, host and mate-finding by the moths. • No disturbance to southern (and northern ssp.) pink underwing moth behaviour (flight, feeding, avoidance) has been seen (using night vision glasses) at localities in Queensland when lights are 500 m or further from habitat. It is not possible to predict how longer-term exposure to lights will influence moth behaviour without experiments or observations. Sometimes insects will 'condition' themselves to light disturbance. • Studies on longer-term exposure light requires more research; this may justify use of night vision glasses for a monitoring program.	To be reviewed prior to implementation
TIMP18	*Other edge effects.* • Dust management in construction and diesel exhausts may have an impact on the larvae of the moth • Monitoring of dust settlement on foliage may provide an indication of impacts on larvae feeding. • The recommendation that disturbance should not occur within 500m of breeding sites appears impractical. Therefore an attempt at no disturbance within 100 of breeding sites appears more feasible.	Adopted- plan updated.
TIMP19	*Methods for Trapping and Monitoring* Southern Pink Underwing Moth • Monitoring eggs and larvae for numbers and distribution are appropriate methods for determining presence or absence, health of habitat, season and suitability of plant phenotype when stages are present. • Correct identification of eggs and moth larvae requires experienced personnel. Similar common moth species (e.g. *Eudocima*	Adopted- plan to be updated prior to implementation

ID No	Recommendation	How recommendation is to be addressed
	fullonia) utilise the same food plant as used by *P. imperialis smithersi.* • Monitoring adults with lights is likely to be of little value for highly mobile moths; they are rarely seen unless feeding. Lights occasionally attract moths but traps have proven (in SE Qld) to be ineffective and may disrupt normal flight behaviour of the target species. • Lights and light traps (in the forest) may have unwanted impacts on non-target species and disturb the behaviour of other species. • Fruit baited (e.g. with over-ripe bananas) traps can useful for determining presence/absence of pink underwing moths, especially if mounted in-flight paths. • Cameras are unlikely to distinguish differences between many species of large night-flying moths (e.g. large silk moths) that occur in the area. • Night vision glasses are useful research tools for observing host plant selection by female moths, feeding by adults (e.g. on hanging fruit) and flight behaviour. Doubtful value for this – essentially a monitoring project	
TIMP20	Atlas Rainforest Ground Beetle • *Expert with most experience:* Dr Geoff Monteith (retired Hon. Scientist) Queensland Museum. • *Monitoring:* Correctly identifying burrows made by the Atlas Beetle would appear to be the best method. • *Traps.* Pitfall traps may be useful for determining presence/absence of beetles but the method can also be considered destructive, even when beetles are released, depending on their densities per area of habitat. • Experienced surveyors are needed to identify burrows and avoid misidentifying burrows of other related beetles in an area. • Flight? If the beetle is nocturnal or it can fly, night vision glasses may be useful for monitoring beetles when they leave their burrows. • Off site monitoring of burrows and at control sites need first to establish the identity of this species. Persistence of the beetle after nearby disturbance may be of value in assessing impacts on beetles populations. • Light interference. Comments on possible effects of lights on the moth's behaviour may apply to beetle behaviour if it can fly.	Adopted- plan to be updated prior to implementation

2. Invertebrate populations

2.1 Background

The threatened invertebrate species relevant to and referred in this plan are listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act) and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as follows:

- Southern Pink Underwing Moth (*Phyllodes imperialis smithersi*) — Endangered under the EPBC Act and TSC Act.
- Atlas Rainforest ground Beetle (*Nurus atlas*) — Endangered under the TSC Act.

2.2 Existing knowledge

2.2.1 Habitat requirements

The following provides a brief description of the species and habitat requirements. Further detail is provided in the species profile in Appendix B. Note the known and potential habitats for these species, Lowland Rainforest, is also listed as a critically endangered ecological community (EPBC Act) and endangered ecological community (TSC Act). Additional mitigation and monitoring for this endangered community is provided in the Rainforest Communities and Rainforest Plants Management Plan.

Southern Pink Underwing Moth

The Pink Underwing Moth (*Phyllodes imperialis*) is known from Papua New Guinea, the Solomon Islands, Vanuatu, New Britain, New Ireland, New Caledonia and eastern Australia (Sands 2012). The southern subspecies (*Phyllodes imperialis smithersi*) is restricted to subtropical eastern Australia from near Gympie in Queensland south to near Urunga in New South Wales (Sands 2012). Breeding (i.e. records of the larval form) has been recorded from Mary Cairncross (Sands 2012) and Witta (Herbison-Evans *et al.* 2011) in south-east Queensland, and from Middle Pocket (Herbison-Evans *et al.*2011) and near Ballina (refer to Section 2.2.2) in northern NSW. Whilst this project has revealed the second only breeding record of the species in NSW, it should be noted that Sands (2012) also states that "larvae or adults have been photographed or collected" at several additional locations. These include Border Ranges, Richmond Range, Richmond River, Billinudgel, Dorrigo, Rosewood River, Bellingen, Huonville and Bellinger Island (Sands 2012). This suggests that one or more of these locations also contain breeding records. Nevertheless, it is acknowledged that the revelation of a breeding record in association with the area of this project is a significant finding.

The known distribution of the Southern Pink Underwing Moth is identical to that of its larval food plant (host plant), the vine *Carronia multisepalea*. Larvae of the southern subspecies of moth are dependent on one food plant vine, Carronia multisepalea, found only in rainforests of north-eastern NSW and south-eastern Queensland. In discussing the moth's habitat requirements, Sands (2012) notes that it "is confined to notophyll vine forest where the food plant, *C. multisepalea*, is an uncommon endemic vine in eastern Australia, growing on rich volcanic slopes and riparian or alluvial soils." Unlike other fruit-piercing moths, Southern Pink Underwing Moth lacks the adaptation to pierce fruit directly. Instead, it is known to feed on damaged fruit, including *Ficus* sp. and a *Syzygium* sp. (Sands 2012), and has been photographed feeding on a damaged Custard Apple (Herbison-Evans *et al.*2011).

Atlas Rainforest Ground Beetle

Until recently, Atlas Rainforest Ground Beetle (*Nurus atlas*) was known only from the Alstonville-Lismore district, which has been considered to be the last refuge of what was presumably a wider distribution in association with the Big Scrub (DECC 2012). More recently it was also discovered in an area of mature rainforest just outside of the project to the north of Wardell; a minor range extension (refer to Section 2.2.2). It is a flightless, predatory beetle that occurs in association with rainforest on rich red volcanic soils (DECC 2012; Monteith and Turco n. d.). Adult beetles build characteristic burrows under rocks, logs and tree roots. Both sexes remain in their burrows for much of the year, although evidence from pitfall trapping suggests that males become more mobile in the wet season (Monteith and Turco n. d.). The life cycle of this species and especially the larval stage, are essentially unknown.

2.2.2 Known or expected occurrence in the project

Southern Pink Underwing Moth

Surveys were undertaken to identify if Southern Pink Underwing Moth was located within the project and in areas up to 400 metres from the project (BAAM 2012, 2013). During the surveys, meandering searches were conducted within each of the relevant vegetation polygons, with the aim of identifying presence/absence of the moth and its host plant (*Carronia multisepalea*). Several occurrences of the host plant were identified within the survey area, along with multiple records of the immature stages of the moth. This allowed polygons of known and potential habitat to be identified into three categories. These were:

1) Known breeding habitat for Southern Pink Underwing Moth where host plant and larval records occur and where the moth is considered likely to occur throughout the polygon.
2) Potential breeding habitat for Southern Pink Underwing Moth where the host vine, *Carronia multisepalea*, has been detected, but where moth larvae have not been recorded.
3) Potential foraging habitat for Southern Pink Underwing Moth where the moth and host vine have not yet been detected (i.e. potential foraging habitat for the moth, but not potential breeding habitat due to the absence of the host plant).

Records of Southern Pink Underwing Moth are restricted to rainforest outside and to the west of Section 10 of the project (refer to Figure 2-1) in rainforest between Coolgardie Road and Wardell. The area, mapped under the category of known breeding habitat, is restricted to two large rainforest polygons covering 33.2 hectares. One hundred and eighteen records of the host plant and 78 records of Southern Pink Underwing Moth have been obtained in this area from the separate surveys (refer to Figure 2-1) (BAAM 2012, 2013).

Vegetation mapped as potential habitat (where the moth has not yet been detected) extends north from the vicinity of Coolgardie Road in Section 10 to just east of Uralba Nature Reserve in Section 11 (refer to Figure 2-1) (57.3 hectares in total). This includes 18.1 hectares of habitat where the host plant has been detected and 39.2 hectares where the host plant was not encountered.

Atlas Rainforest Ground Beetle

Surveys were undertaken to identify if Atlas Rainforest Ground Beetle was located within the project and in areas up to 400 metres from the project.

Records of Atlas Rainforest Ground Beetle are restricted to rainforest outside and to the west of Section 10 of the project (refer to Figure 2-2), in a contiguous patch of rainforest between Coolgardie Road and Wardell. This comprises the only area of known and potential habitat for the beetle in the vicinity of the project (refer to Figure 2-2).

2.3 Threats

Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle

The decline of Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle populations may be attributed to loss and fragmentation of habitat due to land development. Other specific potential threats to the moth and/ or its habitat associated with development include:

- Dispersal across fragmented landscapes.
- Disruption of movements or general disorientation due to artificial lighting.
- Increased weed invasion leading to habitat degradation.
- Fragmentation of habitats from disturbance may result in in-breeding depression.

There is no published information on the extent to which each of the above potential threats may contribute to a decline in either species. At this stage, the ecology and distribution of both species remains relatively poorly understood. However, impacts of artificial lighting would likely pose a greater threat to Southern Pink Underwing Moth than the flightless Atlas Ground Beetle.

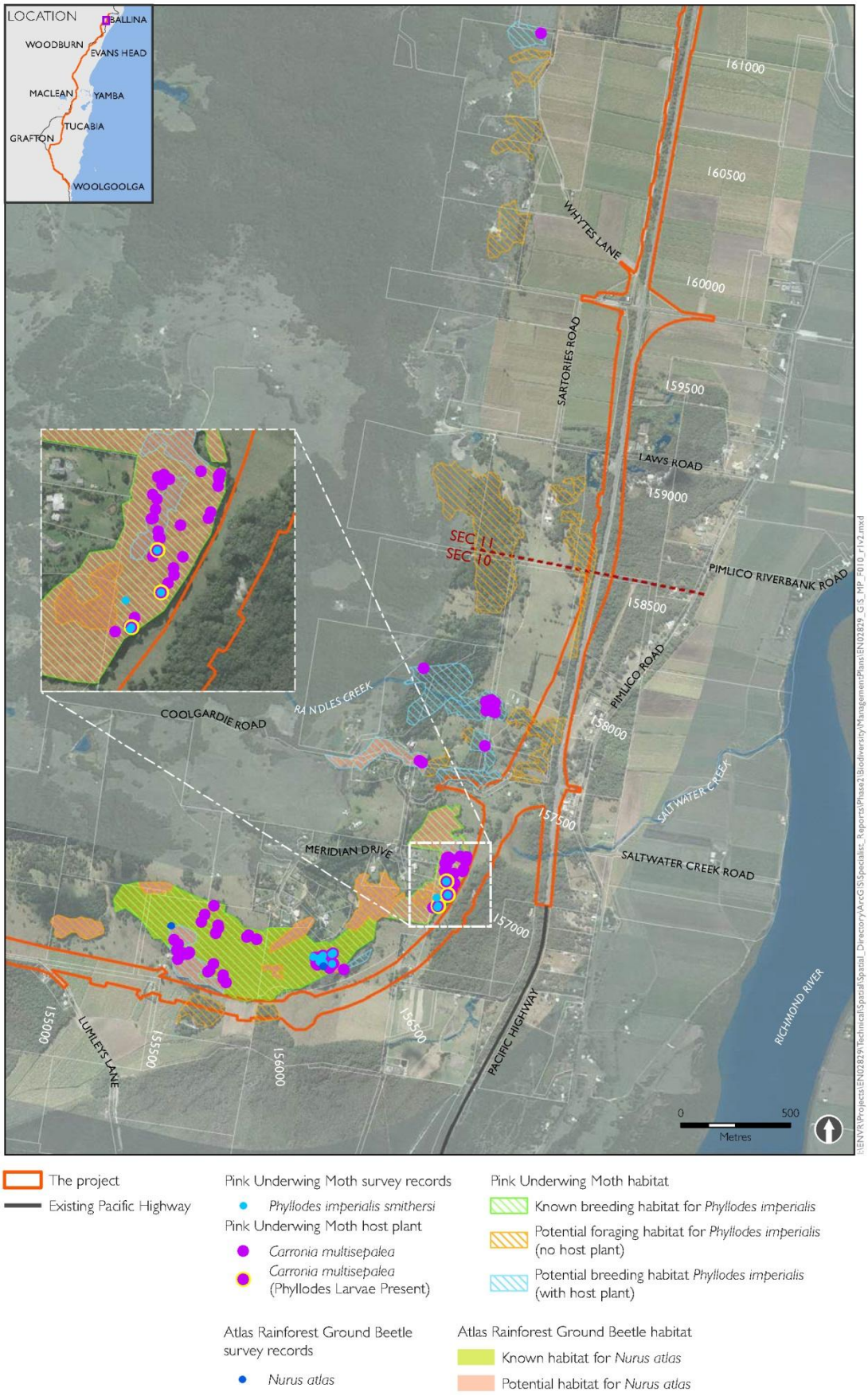


Figure 2-1 Records and location of potential habitat for Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle.

3. Potential impacts and mitigation approach

The following chapter provides a brief overview of the potential impacts to the threatened invertebrate populations with reference to the more detailed impact assessment presented in the biodiversity working paper. It describes the potential impacts to the species at specific locations along the upgrade and during the pre-construction, construction and post-construction (operational) stages of the project. The mitigation approach presented in the EIS and documented in Chapters 4 to 6 of the management plan target the predicted impacts.

3.1 Potential impacts associated with the project

Southern Pink Underwing Moth

Targeted surveys for Southern Pink Underwing Moth conducted in February to March 2012 and February 2013, and were successful in locating both the moth and its host plant in rainforest habitat within 400 metres of the project. This has led to the identification of known and potential habitat for the moth, based on (1) the confirmed presence of larvae/eggs, (2) presence/absence of the host plant, and (3) the occurrence of soft-fruiting rainforest trees, which may provide foraging habitat for the moth (BAAM 2013). These areas of habitat have been categorised as follows:

- Known breeding habitat for Southern Pink Underwing Moth where host plant and larval records occur and where the moth is considered likely to occur throughout the polygon (33.2 hectares identified).
- Potential breeding habitat for Southern Pink Underwing Moth where the host plant has been detected, but where moth larvae have not been recorded (18.1 hectares identified).
- Potential foraging habitat for Southern Pink Underwing Moth where the moth and host vine have not yet been detected (39.2 hectares identified).

A population of Southern Pink Underwing Moth has been confirmed to occur in larger rainforest remnants to the south of Coolgardie Road and west of the existing Pacific Highway adjacent to Section 10 of the project. The 33.2 hectare area of known breeding habitat occurs in two large remnant blocks (25.5 hectares and 7.6 hectares respectively). Potential breeding and foraging habitat for the moth has also been identified in the surrounding landscape (refer to Figure 2-1). During the February 2013 survey for this species, 45 larvae and nine eggs were recorded in the most southerly area of known breeding habitat, an area where host vine density was >10 plants per hectare. Despite multiple surveys in smaller fragments of potential habitat where the vines are present across two years during the breeding season of the moth, no larvae were found in these fragments.

The project would not impact directly upon known breeding habitat or potential breeding habitat for Southern Pink Underwing Moth and would pass adjacent to the eastern and southern edges of polygons containing habitat in these categories (refer to Figure 2-1). However, about 2.4 hectares of potential foraging habitat for the moth would be impacted directly by the project and require removal. Removal of this habitat would not be expected to fragment the remaining potential moth habitat as:

- The 2.4 hectares of potential foraging habitat to be removed lie to the south and east of the remaining areas of moth habitat in the three categories above. Therefore, only a small amount of isolated potential foraging habitat would be removed.
- About 54.9 hectares of potential moth habitat would remain in the vicinity of the project, including 18.1 hectares of potential breeding and foraging habitat (i.e. no direct impact) and 36.8 hectares of potential foraging habitat.

Potential indirect impacts to Southern Pink Underwing Moth and host plant may include impacts from a variety of 'edge effects', such as artificial lighting, road noise, dust and weeds. As noted in Section 2.3 above, there is no published information on the extent to which these potential threats may contribute to a decline in this species (or the Atlas Rainforest Ground Beetle). However, impacts of artificial lighting would likely pose the greatest threat to Southern Pink Underwing Moth. As such, artificial lighting from the project may attract or result in general disorientation of the nocturnal adult moth, which could disrupt the movement of individuals and lead to mortality. Other artificial light sources, such as car headlights are not expected to pose a significant threat to the moth, as these are transient rather than fixed. These may disorientate insects directly crossing the highway; however, Southern Pink Underwing Moth is not expected to cross the project on any regular basis, as no known or potential habitat for the moth has been identified on the eastern side of the project.

Another potential indirect impact that could affect populations of Southern Pink Underwing Moth includes exposure to increased natural light penetration and increased predation associated with newly formed habitat 'edges'. However, the area surrounding the known breeding habitat for the moth is a paddock and; therefore, already an edge. In the area adjacent to this known breeding habitat, the project would be sited within the paddock and as a consequence, no new edge would be created. As no changes to the current habitat edge are anticipated, no significant impacts associated with natural light penetration or predation would be expected.

Hydrological changes and soil desiccation are also not considered likely to be significant impacts, as all known breeding habitat for the moth is sited upslope relative to the project.

Atlas Rainforest Ground Beetle

The project has been sited so that it would avoid direct impacts to areas that have been identified as known or potential habitat for Atlas Rainforest Ground Beetle. Impacts to Atlas Rainforest Ground Beetle may involve disruption of movement corridors or general disorientation due to artificial lighting, as well as the potential compromise of areas of known habitat adjacent to the project through a variety of indirect 'edge effects' (including, but not limited to, artificial lighting, road noise, dust and weeds).

3.2 Mitigation and monitoring approach

A number of measures to mitigate and monitor the impact of the project on threatened invertebrates during construction and operation of the project were suggested in the EIS (biodiversity working paper). In general these measures related to:

- Development of a sound methodological approach for undertaking pre-clearing surveys.
- Provision of exclusion fencing to protect areas of invertebrate habitat during construction.
- A staged habitat removal process.
- A method for the re-use of woody debris and bedrock (habitat for Atlas Rainforest Ground Beetle).
- Identification of procedures for habitat rehabilitation and revegetation of suitable habitat near the project including the planting of the host plant for Southern Pink Underwing Moth to minimise the potential for indirect impacts and inform the design of appropriate buffers between the habitat and the project.
- A monitoring program for rehabilitation areas and retained habitat in the vicinity of the project.
- A suitable fauna handling procedure.

Measures for mitigating edge effects, such as noise, dust and invasive species, which impact upon ecological values in general, would be included in the CEMP.

3.3 Detailed design considerations

An objective of the detailed design for Section 10 and 11 would be to avoid unnecessary direct impacts to potential foraging habitat for Southern Pink Underwing Moth. Another objective would be to reduce the indirect impacts of road noise, dust, weeds and particularly artificial light spill on surrounding known and potential habitat for Southern Pink Underwing Moth and Atlas Rainforest Beetle.

To meet these objectives it is recommended that the majority of the project, in the vicinity of habitat for threatened invertebrates be unlit, except where lighting would be an essential requirement for road safety on round-a-bouts. Where lighting has been identified as required for road safety, lighting recognised as having a low attractiveness for insects is recommended for use. High pressure sodium or LED lamps wherever the project falls within 100 metres of known or potential habitat for Southern Pink Underwing Moth are therefore recommended for use. These types of lamp are widely used in street lighting and have been demonstrated to attract far fewer insects than other viable options, such as metal halide lamps (Eisenbeis, G. and F. Hassel 2000).

Modelling of a combination of the above lamp types in preliminary designs of lighting for the project suggest that the planned position of street lighting would not lead to light spill entering directly into areas of threatened invertebrate habitat. The modelling suggests that light spill would only affect areas 150 metres away from the edge of known threatened invertebrate habitat, Where particularly bright light sources have been identified as required (notably the Coolgardie interchange), shielding is recommended for each light source to shield the light from areas of threatened invertebrate habitat, whilst allowing the required illumination of the road surface for road safety. Consideration is recommended for the following shielding options:

- Physical barrier to horizontal light spill the pole structure.
- Physical barriers (similar to noise barriers) on the edges of the road boundary.
- Thick plantings of vegetation along the road margin to reduce light penetration.

Implementation of these recommendations for the artificial lighting design near known breeding habitat and host plants would be expected to result in insignificant impacts from the project on both Southern Pink Underwing Moth and Atlas Rainforest Beetle.

3.4 Effectiveness of mitigation measures

A summary of the proposed threatened invertebrates specific mitigation measures and evaluation of their effectiveness based on past experience with other highway upgrades is described in Table 3-1 below.

3.5 Adaptive management approach

The management plan has been presented using an adaptive management approach based on firstly identifying specific goals for the management and implementation of management actions followed by monitoring of the performance of these measures against the goals and identified thresholds. As a final step the monitoring would evaluate the effectiveness of the management measures using identified thresholds for performance and implement corrective actions to improve mitigation where required.

To ensure the success of this approach the management goals presented in the plan were based on the following SMART principles:

- **S**pecific.
- **M**easurable.
- **A**chievable.
- **R**esults-based.
- **T**ime-based.

Table 3-1. Mitigation measures and evaluation of their effectiveness

Issue	Mitigation measure	History of success	Effectiveness rating
The host plant and threatened invertebrates are difficult to detect and host plants may be accidentally removed during clearing.	Installation of temporary fencing to exclude construction activities from known threatened invertebrate habitat areas.	Temporary exclusion fencing used in association with all Pacific Highway upgrade over the last 10 years.	High
	Pre-clearing and clearing procedures.	A standard procedure has been developed by Roads and Maritime and documented in the Biodiversity Guidelines for Construction (RTA 2011). The guidelines were developed in consultation with the NSW Office of Environment and Heritage (OEH), NSW Department of Primary Industries (DPI) (Fisheries), biodiversity specialists and Roads and Maritime staff including project managers, construction personnel and designers. Consultation was facilitated through a number of workshops carried out in 2009. These procedures have been developed using knowledge gained from a long history of upgrades on the Pacific Highway and other road projects in NSW.	High
	Translocation of Southern Pink Underwing Moth if any are encountered on each day prior to any clearing in areas of potential habitat. A species profile is provided in Appendix B.	The New South Wales National Parks and Wildlife Service has a Policy for the Translocation of Threatened Fauna in New South Wales (NPWS 2001), which applies to all fauna, including invertebrates. Roads and Maritime has previously funded studies into the translocation of threatened invertebrates (e.g. Translocation of threatened species and rehabilitation of key habitat (Purple Copper Butterfly – *Paralucia spinifera*).	Unknown; monitor development of immature stages for three weeks following translocation.
Impact to threatened invertebrate habitat outside the construction zone.	Identification of exclusion zones and limits of clearing.	Identification of exclusions zones and limits of clearing has for a number of Roads and Maritime Pacific Highway projects managed the removal of vegetation within designated areas and avoided unnecessary vegetation removal. Exclusions zones are generally marked on plans, outlined in inductions and pegged out on site.	High
Movement disruption and or disorientation of threatened invertebrates due to use of artificial lighting.	Minimise use of artificial lighting; use lamps with low attractiveness; use lighting shields to block bright lights at interchanges where lighting is required to address road safety requirements.	A rigorous and detailed study of the attractiveness of different artificial light sources to insects was completed by Eisenbeis and Hassel (2000). Information from this study has been used to inform the choice of lamps in design considerations for the project.	Unknown; monitor moth activity at light via a remote camera and implement corrective actions and provisional measures as required.
Increased incursion of invasive weeds.	Weeds managed in accordance with procedures in the CEMP	Roads and Maritime have developed standard procedures for weeds on construction sites as part of the CEMP process with a long history of success as reported in auditing reports.	High
Dust and noise impacting on habitat use.	Dust and noise managed in accordance with procedures in the CEMP	Roads and Maritime have developed standard procedures for dust and noise management on construction sites as part of the CEMP process with a long history of success as reported in auditing reports.	High

Issue	Mitigation measure	History of success	Effectiveness rating
Propagation of Southern Pink Underwing Moth host plant	Propagation trials for the host plant for Southern Pink Underwing Moth (*Carronia multisepalea*)	There is no documented evidence that translocation of *Carronia multisepalea* has been undertaken previously.	Unknown; monitor as outlined in Chapter 7.

4. Pre-construction measures

4.1 Potential impacts during pre-construction phase

- The location of infrastructure within ancillary facility sites including heavy vehicle access have the potential to impact threatened invertebrate habitat.

4.2 Main goals for management

- Map the distribution and abundance and identify suitable locations adjacent to the project (outside of the road reserve) for habitat rehabilitation.
- No impact to threatened invertebrate habitat outside of the project including designated work areas for ancillary facilities within in Section 10 and 11 during the pre-construction planning phase.
- Trial a host plant propagation strategy.

4.3 Management measures

Details on the site specific performance indicators and mitigation measures for Southern Pink Underwing Moth and Atlas Rainforest Beetle to be implemented during the pre-construction phase are detailed below and summarised in Table 3-2 along with performance thresholds and corrective actions.

4.3.1 Targeted baseline survey

Prior to construction, follow up targeted surveys would be conducted for Southern Pink Underwing Moth and its host plant, as well as Atlas Rainforest Ground Beetle, during late summer or early autumn using active searching techniques as per BAAM (2012, 2013). These surveys would be performed to map the distribution and abundance of the two invertebrate species and identify suitable locations adjacent to the project (at least 100 metres outside of the road reserve) for habitat rehabilitation. The surveys would also inform the construction mitigation measures in terms of protecting local populations of host plants and invertebrates in-situ, where applicable. Final alignment surveys would be required once the construction corridor has been established and pegged out.

These surveys would also record the current condition of the threatened invertebrate habitat that would remain in the vicinity of the project. Such data would form the baseline for the monitoring program and inform the habitat structure and plant species diversity at known sites as a benchmark for development of revegetation or offset sites.

For retained habitat patches, establishment of photographic reference points of edge zone condition and evidence of host plant recruitment events would be conducted.

4.3.2 Identification and marking

The objective of the pre-clearance survey would be to:

- Accurately identify and quantify individual host plants in habitat areas adjacent to the impact areas and/or project.
- Record the presence of individual host plants adjacent to the impact areas and/or project and collect propagules for later planting.
- Identify locations where any threatened invertebrates have been encountered are found or have been encountered within 20 metres of the project.
- Identify habitat features suitable for Atlas Rainforest Ground Beetle within the project that would be removed to adjacent habitat.

- Identify suitable sites for relocation of adult beetles and moth larvae / pupae (if required).
- Clearly identify and map habitat edges as far as possible, to enable avoidance or implementation of edge protection;
- Each individual host plant to be retained within 5 to 10 metres of the project would be marked in the field using flagging tape, survey pegs and a GPS location.

A field inspection would be undertaken by an experienced ecologist to ensure that no host plants fall within the limits of the project once it has been accurately defined and marked in the field with survey pegs.

4.3.3 Temporary exclusion fencing

Exclusion fencing would be established prior to clearing in proximity to known threatened invertebrate habitat to ensure protection of vegetation immediately adjacent to the project. Additional high visibility fencing may be required in proximity to ancillary areas (laydown, construction tracks, car parks, works sites, etc).

4.3.4 Host plant propagation trial strategy

Collection of seeds was considered to be an impractical option for the host plant of Southern Pink Underwing Moth, as the seeds of *Carronia multisepalea* tend to form quite high in the canopy, making them difficult to source. Instead, propagation from cuttings would be trialled as a priority measure. There is no documented evidence to suggest that successful propagation of *Carronia multisepalea* has been undertaken previously. Therefore, a trial program would provide baseline information into the usefulness of propagation in the rehabilitation of rainforest, including habitat for Southern Pink Underwing Moth. Plants propagated by cutting would be placed in areas where rainforest rehabilitation would take place to increase the value of these areas as habitat for the moth. As an additional strategy, opportunistic collection of seeds would be conducted in areas adjacent to the road corridor in mid-summer (corresponding with the seeding time of the vine). In cases where seeds have been collected, these would be propagated for supplementary planting.

4.3.4.1 Propagation from cuttings

The objective of this action would be to provide details of best practice procedures for cutting collection and propagation to provide a source of new host plants for the revegetation program and maintain the current genetic diversity and resilience of the host plant and Southern Pink Underwing Moth populations in the vicinity of the project.

The propagule collection program would be initiated prior to clearing activities. Cutting collection would be limited to no more than two cuttings per adult plant to maximise the chance of maintaining genetic diversity. The propagule collection program for revegetation would be initiated at the earliest possible opportunity.

Collection, storage and propagation of cuttings would be undertaken by an experienced ecologist/ horticulturalist sourced from the north coast region so that propagules would remain within climatic zones representative of their natural habitat. The areas of the population restricted to the western side of the project were considered an appropriate source for cutting collection.

The cutting collection and propagation activities would aim to match the density of vines present in areas of habitat where the moth is known to occur (i.e. a minimum of 10 plants per hectare).

An experimental trial would be undertaken with half of the plants grown from cuttings placed in commercial potting mix and the remainder in a mix containing the natural soil type from the site. Transplanting to the natural soil type would be carried out when vine propagules reach 15-30 centimetres long. The trial would aim to examine the effect of the potting medium on growth and establishment of plants in the field. As the host species typically grows in nutrient-rich soils derived from basalt, all propagules would be planted with a slow release fertiliser to improve chances of establishment.

The above experimental trial treatments would provide useful information for future management and mitigation of the vines with regards to the effect of nursery soil medium and establishment of propagated plants introduced to the wild; a factor that remains poorly understood.

Propagule collection, storage and propagation follow Greening Australia guidelines are located online on the Greening Australia website (http://www.greeningaustralia.org.au/uploads//Our Solutions – Toolkit pdfs/NT_8_Undertake_Propagation_Web.pdf). Table 4-1 summarises the basic methods for collection, propagation and storage of cut plant material.

Table 4-1: Cutting collection, storage and propagation methods

Process	Method
Cutting collection	▪ Cuttings would be collected early in the day, when conditions are cool and moist. ▪ Take cuttings from the upper part of healthy plants, growing in shrub form (rather than vine form), from relatively new growth formed in the current or immediately past season. ▪ Single cuttings would be 8-12 cm in length and the cut should be performed just below the node, avoiding material with flower buds. ▪ Cuttings would be from the end of the stem, with the option for a longer cutting to be broken into two separate cuttings if necessary. ▪ Cuttings would preferentially be taken from plants that show signs of moth larval feeding activity; however cuttings would not be taken from branches where moth eggs are present ▪ Plants would be checked for moth larvae and eggs prior to taking each cutting and any sections of plant with larvae or eggs would be avoided.
Cutting storage	The basic requirements for good storage are to ensure the following: ▪ Leaves would be removed from the bottom of the cutting. ▪ Remaining leaves would be cut in half to reduce water loss. ▪ Cuttings would be stored in water, or wrapped in wet paper or a plastic bag, in a cool place. ▪ Accurate record keeping would be implemented including collection data, a unique plant number and the associated GPS location of the source plant.
Cutting propagation	▪ Most of the propagules would be planted out in the field when they reach 30 cm in length. If landscaping activities become delayed some plants would be potted into larger pots and grown further.

4.4 Performance thresholds and corrective actions

Table 4-2 summarises the pre-construction environmental planning measures for threatened invertebrates that would be completed prior to the commencement of construction. A hold would be placed on the commencement of construction activities until all pre-clearance surveys have been completed and mitigation measures have been implemented.

Table 4-2 Mitigation measures, performance measures and corrective actions

Main goals for mitigation	Proposed mitigation measure	Monitoring/timing frequency	Performance threshold	Corrective actions
Map the extent of the local populations of threatened invertebrates and identify suitable locations adjacent to the project (outside of the road reserve) for habitat rehabilitation.	Targeted baseline survey.	Pre-construction.	Pre-construction review of compliance shows that targeted baseline survey has not been undertaken.	Delay construction until targeted baseline survey has been undertaken.
No impact to threatened invertebrate habitat outside of the project including designated work areas for ancillary facilities within in Section 10 and 11 during the pre-construction planning phase	Identification and marking including pre-clearance survey and demarcation of exclusion zones. Temporary exclusion fencing to be established prior to clearing in proximity to known threatened invertebrate habitat.	Pre-construction and report results as per the CEMP requirements.	Inspection of clearing boundary reveals gaps or inappropriate placement of fencing.	Ensure that clearing boundary is physically defined prior to clearing works.
Trial a host plant propagation strategy	Implementation of the trial propagation strategy.	Pre-construction	Propagation trial is not successful, ie does not result in propagation of host plant.	Re-trial using different method and techniques using remaining plant material collected.

5. Construction management measures

5.1 Potential impacts during construction phase

- Impacts during clearing of vegetation.
- Disturbance and degradation of adjacent known invertebrate habitat.
- Movement disruption and or disorientation of threatened invertebrates due to the use of artificial lighting.
- Dust and noise impacting on invertebrates and habitats.
- Increased incursion of invasive weeds due to edge effects.

5.2 Goals for management

- No direct impact to known threatened invertebrate habitat outside of the project and/or impact areas within Section 10 and 11 during construction.
- No direct impact to known threatened invertebrates or host plants during clearing of vegetation in Section 10.
- No displacement of threatened invertebrates in Section 10 and 11 due to artificial lighting during the construction phase.
- Dust and noise managed in accordance with the CEMP to minimise impacts on invertebrates.
- Weeds managed in accordance with the CEMP to minimise impacts on invertebrates.
- Rehabilitation of known threatened invertebrate habitat areas adjacent to the project (outside of the road reserve) to be commenced during the construction phase.

5.3 Management measures

5.3.1 Construction work method statements

Construction work method statements (CMSCWMS) would be prepared for all activities adjacent to or directly affecting Southern Pink Underwing Moth habitat to ensure sound environmental practices are implemented and to minimise the risk of environmental incidents or system failures, in accordance with the CEMP. This management plan would be included as an annexure to the project CEMP.

CMSCWMSs would be prepared to address all construction threatened invertebrate management requirements for construction in consultation with relevant agencies, Roads and Maritime and the relevant Project Environmental Management Representative prior to the commencement of identified activities.

5.3.2 Construction induction and training

Induction training would be conducted with all contractors and other staff that would be working in the areas of known and potential threatened invertebrate habitat and distribution in Section 10 and 11 of the upgrade. This training would identify threatened invertebrate habitat, and crossing zones and key threats. The importance of following the clearing and rehabilitation protocols would be made clear for any personnel that require access to the site.

5.3.3 Temporary exclusion fencing

Exclusion fencing would be established prior to clearing in proximity to known threatened invertebrate habitat to ensure protection of vegetation immediately adjacent to the project. Additional high visibility fencing may be required in proximity to ancillary areas (laydown, construction tracks, car parks, works sites, etc).

Any host plants identified within 10 metres of the project would be marked by GPS and flagged with high visibility fencing/tape and 'no-go' signage to ensure that their location has been identified and understood by construction contractors and that the plants are not disturbed. The retention of flagged host plants would be checked on the day following clearing.

5.3.4 Clearing protocol

The Roads and Maritime biodiversity guideline (2011) outlines the standard clearing protocol that would be followed. The clearing area would be minimised and vegetation protection/no go areas would be established.

An ecologist would check potential habitat for Southern Pink Underwing Moth within the project on each day prior to commencement of any clearing activity to ensure that no host plants or individuals of the moth fall within the clearing zone. This survey, immediately before clearing commences, would be aimed at reducing the risk of mortality of threatened invertebrates during clearing activities.

No host plants of Southern Pink Underwing Moth have been identified within the project in the surveys undertaken to date, so it would not be expected that the moth or its host plant would be encountered during clearing. However; if a case arises where individuals of Southern Pink Underwing Moth are found, they would be relocated by an ecologist to areas of suitable habitat more than 20 metres outside of the road boundary. Larvae, eggs or pupae in particular would be relocated to another host plant vine (*Carronia multisepalea*) in each case with a preference for a plant positioned under the protection of the rainforest canopy that has ample foliage and at least some evidence of host use by the moth (e.g. recent feeding activity; or 1–2 larvae already present). The development of any relocated immature stages would be monitored for three weeks following translocation.

A copy of the species profile in Appendix B would be provided to the ecologist to assist with searches and identification of the host plant and the moth.

5.3.5 Installation of street lighting

The project would be largely unlit; however some areas of lighting would be installed in association with interchange roundabouts and merge and diverge traffic lanes in the vicinity of known and potential habitat for threatened invertebrates. No disturbance to southern (and northern ssp.) pink underwing moth behaviour (flight, feeding, avoidance) has been seen (using night vision glasses) at localities in Queensland when lights are 500 m or further from habitat (Dr Sands pers.comm). It is not possible to predict how longer-term exposure to lights will influence moth behaviour without experiments or observations. Sometimes insects will 'condition' themselves to light disturbance.

Potential impacts of lighting on the moth are considered unlikely (Dr Sands pers.comm). As a precautionary measure wherever possible, the use of lighting in the vicinity of known moth habitat would be avoided. In cases where lighting is essential, the project would consider the use of non-standard forms of lighting to minimise attraction and displacement of adult Southern Pink Underwing Moth, as well as potential disorientation of Atlas Rainforest Ground Beetle. Any bright lighting that has the potential to be directly visible from areas of threatened invertebrate habitat would be shielded, as described in Section 3.3. The following specific measures apply to the project:

- Lights and their wattage to be minimised.
- Lights mounted as low as possible, and limited where possible to road & signage illumination.
- Avoid mercury vapour lights; sodium vapour may need evaluation (effects on target species not known).
- Avoid penetration by lights into forest or water courses to avoid disruption of flight behaviour, flight paths, host and mate-finding by the moths.

5.3.6 Minimising dust and noise

Dust and noise impacts would be managed in accordance with the CEMP and would include the implementation of dust suppression measures and construction noise limits. The monitoring program in Chapter 7 aims to monitor the impacts of dust on rainforest habitat near the project and in particular impacts on the host plant Carronia multisepalea where this species occurs in edge areas. Where impacts are noted from dust, vertical shade cloth would be erected adjacent to the plants during construction. This would be in the form of temporary screening.

5.3.7 Weed Management

Details of the weed management plan would follow the broad approaches outlined in the FFMP and CEMP and follow the Roads and Maritime biodiversity guidelines requirements (Roads and Maritime 2011). This plan would focus on weeds identified in the recovery plan relevant to the section where works are being undertaken, particularly the Camphor Laurel, which is invasive in the habitat occupied by both threatened invertebrates. The management of such specific weeds in habitat for threatened invertebrates would be conducted as specified in the Rainforest communities and threatened rainforest plants management plan (currently in draft).

5.3.8 Revegetation and habitat improvement procedures

Given the limited distribution of remaining known or potential (rainforest) habitat for Southern Pink Underwing Moth and Rainforest Atlas Ground Beetle within the NSW North Coast, management measures would encompass a mix of improved management of existing rainforest patches and the establishment of new areas of rainforest with the aim of recreating habitat suitable for the moth and the beetle, and minimise the overall impact of edge effects on the remaining rainforest patches.

Revegetation for the moth would be focused towards management of its host plant and also retention or establishment of rainforest food trees that are recognised to provide suitable resources for the adult moth. These include *Ficus* spp. and *Syzygium* spp. (Sands 2012).

Habitat improvement for the beetle would include the provision of microhabitat features such as; plant roots (via revegetation), large rocks and logs (Monteith and Turco n. d.). Revegetation would include large-buttressed local plant species such as *Ficus* spp., *Elaeocarpus* spp., *Sloanea* spp. and *Melia azedarach*, which would provide habitat for the beetle. Other important features including rocks and logs would be sourced from within the project as per Roads and Maritime biodiversity guidelines (2011). These would be placed on basaltic soil on sloping terrain to provide shelter and the best opportunity for beetle colonisation.

The exact location(s) of revegetation projects has yet to be identified. It is anticipated that this would be proposed and confirmed (following approval), during development of the offset strategy.

5.4 Performance thresholds and corrective actions

Table 5-1 summarises the construction environmental planning measures for Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle and corrective actions if the measure deviates from the performance criteria.

Table 5-1 Mitigation measures, performance measures and corrective actions

Main goals for management	Management measure	Monitoring/timing frequency	Performance threshold	Corrective actions
No direct impact to known threatened invertebrate habitat outside of the project and/or impact areas within Section 10 and 11 during construction.	• Temporary exclusion fencing to be established prior to clearing in proximity to known threatened invertebrate habitat. • Additional high visibility fencing may be required in proximity to ancillary areas (laydown, construction tracks, car parks, works sites, etc). • Any host plants adjacent to the project would be flagged and their retention in Section 10 would be confirmed on the day following clearing activity.	• Prior to clearing near known invertebrate habitat areas. • Report results as per the CEMP requirements. • Biannual surveys to monitor threatened invertebrate habitat condition within 100 m of the project for three years commencing from the start of the construction phase.	Evidence of direct impact to known invertebrate habitat outside of the project.	Incident investigation to identify cause and appropriate mitigation measures to avoid no further removal of host plants or harm to threatened invertebrates outside the project. Supplementary revegetation of disturbed habitat and monitor recovery for period of 12 months
No direct impact to known threatened invertebrates or host plants during clearing of vegetation in Section 10.	• Documented procedure for clearing of vegetation. • Ecologist to check areas to be cleared for threatened invertebrates and host plants prior to clearing	• Threatened invertebrate incident reporting to be maintained on a monthly basis as per FFMP. • Biannual surveys to monitor threatened invertebrate activity in known habitats in the vicinity of the project for three years commencing from the start of the construction phase.	Evidence of direct disturbance to known invertebrate habitat found outside of the project.	Incident investigation to identify cause and appropriate mitigation measures to avoid no further removal of host plants or harm to threatened invertebrates outside the project. Supplementary revegetation of disturbed habitat and monitor recovery for period of 12 months.
No displacement of threatened invertebrates in Section 11 due to artificial lighting during the construction phase.	• Street lighting within 100 m of invertebrate habitat would use high-pressure sodium or LED lamps, which have a low attractiveness for invertebrates. • Lighting at interchanges in Section 10 would be shielded so that they would not be directly visible to areas of threatened invertebrate habitat.	• Biannual monitoring of threatened invertebrate activity to commence at start of construction phase. Monitoring of moth activity at lights via remote camera to detect presence of large moths.	Evidence of activity of large moths detected on remote cameras installed at lights within 200 m of threatened invertebrate habitat. Evidence of a reduction in threatened invertebrate activity in areas of known habitat during biannual monitoring.	Investigate potential adaptive changes to the monitoring program, as well as potential design changes to lights, including lamp type, design of shields and potential implementation of filters, as required.
Dust and noise managed in accordance with the CEMP to minimise impacts on invertebrates.	• Implement dust and noise management procedures as outlined in the CEMP.	• Measures to be implemented in response to weather and construction conditions/activities. • Monthly reporting as part of CEMP including updates on the effectiveness of dust and noise control measures.	Inspections and monitoring indicate a decline in the condition score of any threatened invertebrate habitat polygons within 100 m of the project. Evidence of a reduction in threatened invertebrate activity in	Investigate potential causes and manage in accordance with the CEMP, including review of the dust and noise management measures.

Main goals for management	Management measure	Monitoring/timing frequency	Performance threshold	Corrective actions
		• Biannual monitoring of threatened invertebrate habitat condition and activity to commence at start of the construction phase. • Installation of dust gauges in representative areas adjacent to known and potential moth habitat.	areas of known habitat during biannual monitoring.	
Weeds managed in accordance with the CEMP to minimise impacts on invertebrates.	• Implement weed management procedures as outlined in the CEMP.	• Measures to be implemented in accordance with the CEMP. • Monthly reporting as part of CEMP including updates on the effectiveness of weed control measures. • Biannual monitoring of threatened invertebrate habitat condition and activity to commence at start of the construction phase.	Inspections and monitoring indicate a decline in the condition score of any threatened invertebrate habitat polygons within 100 m of the project due to an increase in weeds (refer Chapter 7).	Investigate potential causes and manage in accordance with the CEMP, including review of the weed management measures.
Rehabilitation of known threatened invertebrate habitat areas outside of the project to be commenced during the construction phase.	• Plantings in threatened invertebrate habitat (Section 10 and 11) to be undertaken as per the Threatened Lowland Rainforest and Rainforest species management plan. • Propagation trials to be undertaken for the host plant of Southern Pink Underwing Moth.	• Propagation trail results as per reporting in the CEMP. • Construction and operational audits, with specific review of the landscape design. • Biannual monitoring of threatened invertebrate habitat condition and activity to commence at start of the construction phase.	No evidence of threatened invertebrate habitat revegetation captured in the landscape design and/or audits. Inspections and monitoring indicate a decline in the condition score of any threatened invertebrate habitat polygons within 100 m of the project (refer Chapter 7). Evidence of a reduction in threatened invertebrate activity in areas of known habitat during biannual monitoring.	Update landscape design accordingly.

6. Operational management measures

6.1 Potential impacts during operational phase

- Movement disruption and or disorientation of threatened invertebrates due to the permanent presence of artificial lighting outside of daylight hours.
- Degradation of threatened invertebrate habitat revegetated areas.

6.2 Goals for management

- No substantial reduction in activity of threatened invertebrates in Section 10 and 11 due to the introduction of artificial lighting.
- To maintain and improve areas of threatened invertebrate habitat outside of the project in Section 10 and 11 during operation.

6.3 Management measures

6.3.1 Street lighting

The project would be largely unlit; however some areas of lighting would be installed in association with interchange roundabouts and merge and diverge traffic lanes in the vicinity of known and potential habitat for threatened invertebrates. The potential impacts of lighting on the moth in particular pose a threat to the long term persistence of the population. Wherever possible, the use of lighting in the vicinity of known moth habitat would be avoided. In cases where lighting is essential, the project would use high-pressure sodium or LED lighting (low UV output) to minimise attraction and displacement of adult Southern Pink Underwing Moth, as well as potential disorientation of Atlas Rainforest Ground Beetle. Any bright lighting that has the potential to be directly visible from areas of threatened invertebrate habitat would be shielded, as described in Chapter 3.

A remote camera would be installed at each light positioned within 200 metres of known moth habitat for three years post construction. Each camera would monitor moth activity at the lights and would provide valuable information on the effectiveness of the lighting design.

6.3.2 Revegetation / landscaping

Revegetation would commence during construction and continue during operation in any areas within the road reserve adjacent to existing known or potential habitat patches or conditions considered suitable for threatened invertebrate species and their host plants. It would be important that those areas near known and potential habitat are revegetated using locally collected plant propagules (within the extent of the former big scrub) and are revegetated with the aim of extending and enhancing the adjacent habitat.

The exact areas of revegetation and landscaping would be determined during the detailed design phase. Areas for rehabilitation may include suitable areas within or outside the road reserve. Consultation with adjacent landowners would also be undertaken if opportunity to revegetate rainforest as an offset on private land exists.

Inspection, monitoring and maintenance requirements for threaten invertebrate habitat revegetation areas and threatened invertebrate barrier areas would be specified in the landscape design. The recommended monitoring and maintenance schedule for the revegetated areas in the first year is outlined in Table 6-1.

Table 6-1 Monitoring and maintenance schedule first year

Monitoring	Timing	Maintenance
Site preparation	Commencement	Weeds and grass controlled within 2 metres of planting locations.
Watering weekly	First month	No plants wilting or with dried foliage.
Monitoring weeds and plant health	3 months	Weeds not smothering plants, plants healthy with active growth, replanting required if plant survival not at required percentage.
Weed control Mulching and fertilising of plants	3 Months	Weeds and grass controlled within 2 metres of planting locations, all plants mulched and fertilised.
Monitoring weeds and plant health	6 months	Weeds not smothering plants, plants healthy with active growth, replanting required if plant survival not at required percentage.
Weed control Mulching and fertilising of plants	6 months	Weeds and grass controlled within 2 metres of planting locations, all plants mulched and fertilised.
Monitoring weeds and plant health	9 months	Weeds not smothering plants, plants healthy with active growth, replanting required if plant survival not at required percentage.
Weed control Mulching and fertilising of plants	9 months	Weeds and grass controlled within 2 metres of planting locations, all plants mulched and fertilised.
Monitoring weeds and plant health	12 months	Weeds not smothering plants, plants healthy with active growth, replanting required if plant survival not at required percentage.
Weed control Mulching and fertilising of plants	12 months	Weeds and grass controlled within 2 metres of planting locations, all plants mulched and fertilised.

6.3.3 Weed management

Details of the weed management plan would follow the general approaches outlined in the FFMP and CEMP and follow the Roads and Maritime biodiversity guidelines (Roads and Maritime 2011) requirements. Focus would be on weeds identified in recovery plans (for example Lantana and Camphor Laurel). The management of specific weeds in habitat for threatened invertebrates would be conducted as specified in the Rainforest communities and threatened rainforest plants management plan (currently in draft). The need for ongoing weed management would be informed by the condition monitoring program.

6.4 Performance measures and corrective actions

Table 6-2 summarises the operational environmental planning measures for Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle and corrective actions if the measure deviates from the performance criteria.

Table 6-2 Mitigation measures, performance measures and corrective actions

Main goals for management	Management measure	Monitoring/timing frequency	Performance threshold	Corrective actions
No substantial reduction in activity of threatened invertebrates in Section 10 and 11 due to the introduction of artificial lighting.	• Street lighting within 100 m of invertebrate habitat would use high-pressure sodium or LED lamps, which have a low attractiveness for invertebrates. • Lighting at interchanges in Section 10 would be shielded so that light would not be directly visible to areas of threatened invertebrate habitat.	Biannual monitoring of threatened invertebrate habitat condition and activity to commence at start of the construction phase. Monitoring of moth activity at lights via remote camera to detect presence of large moths.	Evidence of activity of large moths detected on remote cameras installed at lights within 200 m of threatened invertebrate habitat. Evidence of a reduction in threatened invertebrate activity in areas of known habitat during biannual monitoring.	Investigate changes to the monitoring program, as well as potential design changes to lights, including lamp type, design of shields and potential implementation of filters, as required.
To maintain areas of threatened invertebrate habitat outside of the project in Section 10 and 11 for three years post-construction.	• Revegetation of areas within the road reserve adjacent to known or potential habitat patches or conditions considered suitable for threatened invertebrate species and their host plants as per the landscape design. • Inspect, monitor and maintain revegetated areas for a period of three years post-construction.	Biannual monitoring of threatened invertebrate habitat condition and activity to commence at start of the construction phase.	Inspections and monitoring and maintenance requirements not undertaken. Inspections and monitoring indicate a decline in the condition score of any threatened invertebrate habitat polygons within 100 m of the project (refer Chapter 7).	Review requirements and update mitigation measures as required. For example the maintenance period may be increased to five years for Section 10 and 11.

7. Monitoring program

The monitoring program would follow the progress of the threatened invertebrate habitat patches and threatened invertebrate populations that have been identified adjacent to the alignment and document the effectiveness of mitigation measures. Monitoring would be undertaken at each threatened invertebrate location and any additional rehabilitation sites. The monitoring program would be refined if new locations are found following the final targeted survey.

7.1 Goals for monitoring

Monitoring would be conducted over a period of three years post-construction and would be aimed at providing reliable information such that sound conclusions could be drawn in relation to management of Southern Pink Underwing Moth and Atlas Rainforest Ground Beetle and their habitats. The overall monitoring objectives would be to:

- Evaluate the success of mitigation measures.
- Further understand the habitat requirements of the threatened invertebrate species in the vicinity of the project.
- Determine the extent of indirect impacts of the proposal on the habitat and threatened invertebrate and host plant populations and identify any additional mitigation measures that may minimise these impacts.
- Evaluate the viability of the threatened invertebrate populations in the long-term.

This monitoring can be refined, subject to progress against the above matters. In order to fulfil these objectives a number of ecological variables would be monitored, with each variable discussed below.

7.2 Southern Pink Underwing Moth

7.2.1 Habitat condition assessment

A pre-clearing survey would allow habitat condition to be scored relative to the ecological requirements of Southern Pink Underwing Moth as far as they are understood. Following the procedure of BAAM (2013), polygons would be given a score of between 0 and 5, with a point being awarded for each one of the following criteria:

- Host plant (*Carronia multisepalea*) was detected during the surveys.
- Diversity 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.

Habitat condition monitoring using the above scoring criteria would be conducted for each accessible patch located in proximity to the project and to monitor the success of revegetation endeavours post construction. The aim of this exercise would be to ensure that habitat polygons either retain or achieve a higher habitat condition score relative to the scores attributed prior to construction. All polygons of known and potential habitat, including rehabilitation areas, would be monitored biannually, with an initial scoring to be undertaken prior to commencement of pre-construction activities. Any polygons of known or potential moth habitat within 500 metres of the project that fall below their pre-construction condition score during the monitoring would be used as a trigger for corrective actions.

7.2.2 Moth populations

Monitoring of continued breeding activity of moth populations in adjacent to the project would follow the approach taken during previous targeted surveys. For each separate area of habitat, biannual surveys would be conducted during the construction period and for three years post-construction. The presence, age and abundance of Southern Pink Underwing Moth would be recorded, as well as any potentially influential factors. Each survey would include at least two control sites, one at Victoria Park (known breeding habitat identified by BAAM (unpublished); within 15 kilometres of the project) and another location to be determined. One survey would be performed between February and April, which corresponds with a peak time of breeding activity for the moth, based on previous surveys (BAAM 2012, 2013). Another survey would be conducted during November to January, which would focus on detecting adult moths during the peak fruiting season. These surveys would be conducted in conjunction with and monitoring events for Atlas Rainforest Ground Beetle. The results would be documented in an annual monitoring and research report for threatened invertebrate and host plant populations.

7.2.3 Host plant populations

The monitoring methodology follows that provided for threatened plants and includes the following:

1) Propagules within each of the treatments (2–4 treatments) would be clearly identified in each of the different plantings areas, comprising commercial potting medium with fertiliser application.
2) The health and development of plantings, including the height and girth of individuals in each of the treatments, are to be measured, photographed and recorded at six monthly intervals.
3) The condition and success of the planting trial would be monitored at six monthly intervals.
4) Post-construction monitoring would focus on flowering and fruit production within planted areas and possibly the establishment of seedlings and any suckering of individuals. It is envisaged that post-construction monitoring would be able to determine if the plantings are developing into viable populations.
5) Biannual monitoring would be conducted in conjunction with threatened invertebrate surveys and annual reports are to be prepared, which would cover threatened invertebrate and host plant populations.

7.2.4 Performance indicators

The baseline targeted survey (BAAM 2012), subsequent targeted survey (BAAM 2013) and pre-clearing survey data would provide the information necessary for comparison through the construction and post-construction monitoring periods. These would be used as an indicator of change in condition at impact sites in conjunction with the habitat condition scoring. Control sites (>50 metres from the construction corridor with similar microhabitat characteristics) would be implemented during the monitoring phase. The exact location of these sites would be confirmed following approval and property acquisition.

7.2.5 Offset and revegetation sites

Depending on the condition of the vegetation at offset sites, additional ecological restoration may be required. Revegetation of threatened invertebrate habitat may also occur in the road reserve post-construction. In these instances the habitat condition scoring methodology would also be used at offset revegetation sites to monitor the success of the revegetation. These data would be compared with the pre-construction data collected during the original habitat condition assessment. The number of condition assessments at revegetation sites and offset sites would be relative to the number of independent vegetation polygons present.

7.2.5.1 Performance indicators

The habitat condition score would be used as an indicator of change in revegetation sites. Changes to scores within any given polygon would be monitored as a measure of success.

7.3 Atlas Rainforest Ground Beetle

The objective of the monitoring program would be to monitor the habitat adjacent to the construction corridor with a particular focus on retaining and potentially enhancing the value of rainforest habitat for the known population of Atlas Ground Beetle that occurs in this area.

7.3.1 Beetle populations

A monitoring program would be implemented during construction and post-construction to assess the presence and abundance of Rainforest Atlas Beetle within offset sites and revegetation sites. This would adopt a similar approach to that outlined in the targeted surveys of BAAM (2012). The approach entails an ecologist traversing areas of rainforest habitat and checking carefully and thoroughly under rocks, logs and large plant roots for the presence of the burrows that are characteristic of these beetles. The location and number of these burrows would be counted to provide details on presence and abundance. In offset sites and revegetation sites where beetles have not been detected previously, the surveys would focus on identifying potentially new colonisations of these areas.

Monitoring would occur twice annually, with one survey between the height and end of the wet season (Feb-Apr; post beetle dispersal) and another at the commencement of the wet season (November to January), coinciding with monitoring of Southern Pink Underwing Moth and its host plant. Each survey would include at least two control sites, one at Victoria Park (known habitat; Monteith and Turco n. d.) and another location to be confirmed (Davis Scrub or Tregeagle). This monitoring would continue during construction and for three years post-construction. The results would be documented in an annual monitoring and research report for threatened invertebrates.

7.3.2 Performance indicators

The baseline targeted survey (BAAM 2012) focused on revealing potential and known habitat for Atlas Rainforest Ground Beetle along the proposed corridor. A pre-clearing survey would be performed to reveal an estimate of the occurrence and abundance of beetles in the relevant area prior to construction. This would be used as a preliminary reference for indicating potential change in populations at impact sites during the construction and post-construction monitoring phase.

7.4 Rehabilitation areas and host plants

Monitoring of rehabilitation areas and host plants would follow the procedure outlined in the Lowland Rainforest and Threatened Rainforest Plant Management Plan.

7.5 Performance measures and corrective actions

Table 7-1outlines the monitoring program, performance indicators and corrective actions if monitoring finds poor outcomes as measured by performance indicators.

Table 7-1 Performance measures and corrective actions

Monitoring program	Corrective action trigger	Corrective actions	Responsibility
Southern Pink Underwing Moth biannual surveys Atlas Rainforest Ground Beetle biannual surveys	Evidence of a decline in numbers over a three year post-construction survey period.	• If decline noted after 3 years post-construction monitoring, review and update the monitoring program to consider more intense monitoring or different techniques. • Review monitoring locations and cross reference with monitoring of rehabilitation areas. • Investigate additional areas of habitat beyond the project and consider options to improve habitat condition and connectivity. • If decline still noted after a further 2 years monitoring (5 years total post-construction) engage with OEH and consider provisional measures. • Further monitoring of provisional measures would be planned at this stage.	Roads and Maritime
Rehabilitation condition monitoring Host plant condition monitoring	Evidence of a decline in host plant quantity or habitat condition.	• If decline 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 years monitoring (5 years total post-construction) engage with OEH and consider provisional measures. • Further monitoring of provisional measures would be planned at this stage.	Roads and Maritime

7.6 Evaluation, project review and reporting

Annual reports would be prepared outlining the results of any monitoring undertaken pertaining to the project.

7.6.1 Responsibility

The contractor employed to undertake the threatened invertebrate monitoring would be responsible for the evaluation of the monitoring information collected.

7.6.2 Timing

A brief annual report would be prepared by the contractor for distribution to the Roads and Maritime and other relevant government agencies (DoPI, OEH and SEWPaC) regarding the biannual population surveys.

A final report would be prepared at the conclusion of the monitoring period. This report would incorporate all the results of the monitoring and recommend any additional measures (if deemed necessary) to facilitate the long-term survival of the threatened invertebrate populations in the locality.

7.6.3 Adaptive management

There would be potential for natural variation in threatened invertebrate populations for a range of reasons. Further monitoring/assessment would be undertaken if a decline of population numbers has been identified as being attributable to the construction and operation of the project. The monitoring / assessment would identify the cause of the decline and/or remedial actions to be commenced as necessary, taking into account potential causes such as dry seasons, population fluctuations and other natural variation. The monitoring / assessment would be dependent upon the monitoring already conducted prior to the decline being noted. Any contingency measures to be implemented would be agreed to by the relevant regulatory authorities (DoPI, OEH and SEWPaC) prior to being commenced. The following provides an indicative adaptive management strategy for the threatened invertebrates.

Adaptive management is the process of continued site assessment against established performance indicators to determine whether a site is responding positively to management approaches intended to achieve quantifiable ecological improvement targets. Where the site does not respond in a manner desired, the adaptive management framework identifies the need for action to arrest negative responses (such as reduce plant mortality) or encourage positive site responses (such as an increase in watering frequency) to redress the imbalance such that targets would be more likely to be achieved.

A target of 75% survival of tubestock individuals of threatened invertebrate host plants has been set for offset sites and revegetation areas. Where plants have been retained adjacent to the road boundary a target of 100% survival of those plants has been set. Should results of the monitoring indicate a substantial decline in the health or number of individuals below the target rate of each site, adaptive management measures would need to be implemented to ensure there would be no net-loss of individuals as a result of the project.

Implementation of the monitoring program and the development of subsequent management measures based on the monitoring would be developed as part of the monitoring framework, which links with the offset site rehabilitation plans and they would be prepared at the same time. A number of adaptive management responses would be available if monitoring reveals an apparent decline in a population of threatened invertebrate host plants during construction or post-construction. These may include:

- A review of the records of the watering regime and mulch treatment together with the location (particularly in terms of likely hydrological conditions) to determine the most likely cause(s) of the health/mortality issues and subsequent readjustment of maintenance regimes.
- Active weed control to minimise competition.
- Watering of plantings when young whilst becoming established.
- Replacement of any planted individuals that have perished if survival rate below 75% (ecologist/horticulturalist).
- Replacement of any existing retained individuals that have perished due to indirect impacts associated with the proposal such as edge effects and altered hydrology (ecologist/horticulturalist).
- Reporting of losses of host plants and decreases in abundance of threatened invertebrate populations and likely reasons within the annual monitoring reports (ecologist).

If a decline has been identified as proceeding despite all described procedures being enacted, the corrective procedures described in Chapter 7 would be implemented.

8. Summary table and implementation schedule

Table 8.1 provides an overall example summary of the actions proposed in the above plan. It also identifies the person responsible for the actions and the estimated timing of the project.

The program schedule would be updating following a review of the approval and project timelines.

Table 8-1: Summary table and implementation schedule of management plan

No.	Task	Responsibility	Pre-construction	Construction	Operational		
					Year 1	Year 2	Year 3
1. Pre-construction management							
1.1	Undertake targeted baseline survey	Ecologist	X				
1.2	Work logs	Roads and Maritime and contractor	X				
1.3	Identification and marking including pre-clearance survey and demarcation of exclusion zones	Contractor	X				
1.4	Host plant propagation trial strategy	Roads and Maritime	X				
2. Construction management							
2.1	Construction work method statements	Contractor		X			
2.2	Construction induction and training	Contractor		X			
2.3	Temporary exclusions fencing	Contractor		X			
2.4	Vegetation clearing procedure	Ecologist		X			
2.5	Lighting shielding	Contractor		X			
2.5	Ongoing management of dust and noise	Contractor		X			
2.6	Ongoing management of predators	Contractor		X			
2.7	Ongoing management of weeds	Contractor		X			
2.9	Revegetation and habitat improvement procedures	Roads and Maritime and contractor		X			
3. Operational management							
3.1	Revegetation / landscaping	Roads and Maritime			X	X	X
3.2	Weed management	Roads and Maritime			X	X	X
4. Monitoring program							
4.1	Habitat condition assessment for the moth	Ecologist	X	X	X		X
4.2	Monitoring of moth populations	Ecologist	X	X biannual	X		X
4.3	Monitoring host plant populations for the moth	Ecologist	X	6 monthly during propagation	X biannual		X biannual

No.	Task	Responsibility	Pre-construction	Construction	Operational		
					Year 1	Year 2	Year 3
4.4	Habitat revegetation monitoring	Ecologist		X	X		X
4.6	Evaluation and reporting	Ecologist	X	X	X	X	X

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10. Acronyms and abbreviations

Acronym / Abbreviation	Description
BAAM	Biodiversity Assessment and Management Pty Ltd
DoPI	Department of Planning and infrastructure
DSEWPaC	The Department of Sustainability, Environment, Water, Population and Community
OEH	The NSW Office of Environment
NSW	New South Wales
Roads and Maritime	Roads and Maritime Service
SKM	Sinclair Knight Merz

Appendix A – Dr DPA Sands CV

Curriculum Vitae: Dr Donald Sands

Don Sands is an insect taxonomist and ecologist, having specialised in the identities and interactions of predators and parasitoids with their hosts, and how to ensure safety of biological control agents when introduced from overseas in biological control programs. Don's studies sought to distinguish and select those species likely to be efficient for controlling their hosts (plants and insects) from those with benign impacts. His research on insect interactions led more recently to focus on insect conservation issues, particularly beneficial insects in farming systems, as well as 'flagship species' - those charismatic species that can be used as icons for the community, and to involve members in the conservation and rehabilitation of threatened species.

Don joined CSIRO Division of Entomology in Sydney in 1967 to study the biological control of fruit flies and scale insects and in 1972 he transferred to Papua New Guinea to work on agricultural pests, re-joining CSIRO in Port Moresby in 1973 to work on ecology and control of the Old World Screw Worm Fly. In 1978 he returned to Brisbane to work on biological control of the weeds and subtropical pests of horticulture (including fruit-piercing moth *Eudocima* spp.). He applied taxonomic principals to correctly identify and biological control agents in the insect orders Lepidoptera, Coleoptera and Hymenoptera. He developed collaboration with several overseas projects and was involved in the successful biological control of 5 major international weed species and of 6 insect pests. He published more than 120 scientific papers and five books. As a Post-retirement Fellow he wrote two major works, *Biological Control of Arthropods in Australia* (with Dr DF Waterhouse, ACIAR) and *The Action Plan for Australian Butterflies* (with Prof. TR New), the latter to review the conservation status of all Australian butterflies.

Don's conservation research and concerns began in the 1990s (e.g. Richmond birdwing butterfly, *Ornithoptera richmondia*) ands was followed by a research project on the Queen Alexandra's Birdwing Butterfy (*Ornithoptera alexandrae*), a large and spectacular threatened species of international concern. His studies with CSIRO on fruit piercing moths led to the discovery in 1987 of spectacular, non-destructive related Southern Pink Underwing Moth, subsequently recognised as endangered species (Federal, NSW). Most recently Don published the description of this moth and provided a name for this new and unnamed sub-species. This moth, the Southern Pink Underwing Moth (*Phyllodes imperialis smithersi*), is becoming an icon for insect conservation, and is threatened by its dependence on only one endemic vine as a food plant, occurring in threatened fragments of the subtropical rainforests of eastern Australia.

Academic qualifications:

MSc (1976), PhD (1982); *Associate Australian Institute of Medical Science* (1965).

Employment & postings:

1967-1972	CSIRO Division of Entomology, Sydney, NSW
1972-1973	Department of Agriculture, Stock and Fisheries, Lae, Papua New Guinea
1973-1978	CSIRO, Division of Entomology, Port Moresby. Papua New Guinea
1978-1997	CSIRO Division of Entomology, Brisbane:
	Experimental Officer 1978-1983,
	Senior Research Scientist 1983-1985,
	Principal Research Scientist 1985-1994,
	Senior Principal Research Scientist 1994-1997; Officer-in-Charge Brisbane 1992 – 1995, Deputy Program Leader 1995 - 1997
1998 -	Post-retired Fellow, Honorary Research Fellow; CSIRO Ecosystem Sciences

Awards

1985. *UNESCO Science Prize* (with CSIRO colleagues). The specific contribution by Sands was identified as "… discovery by Sands of a weevil previously unknown to science;..."

1988. *AIDAB Award for Excellence in Overseas Development Assistance* (shared with colleagues).

1990. *EUREKA POL Prize* (with colleagues). For Environmental Research, hosted by the Australian Museum, Sydney, for "Scientific excellence in research leading to the resolution of an environmental problem".

1990. *ROLEX AWARD FOR ENTERPRISE*, Honourable Mention (with colleagues)

1990. *CSIRO National Incentive Scheme*, for work done in National Interest. Awarded for contributions towards biological control of scale insects.

2001. *Medal of the Order of Australia*. For service to the horticultural industry in Australia and the Pacific region through the development of biological pest control solutions, and to entomology particularly through conservation projects.

2010 *Australian Natural History Medallion*. Nomination by the Australian Entomological Society.

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Appendix B – Dr DPA Sands Review

BALLINA TO WOOLGOOLGA HIGHWAY UPGRADE

A REVIEW OF AN ENVIRONMENTAL IMPACT STATEMENT AND MANAGEMENT PLAN FOR THREATENED INVERTEBRATES AFFECTED BY ROADWORKS

DPA Sands

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1. Summary

This Review is prepared as a consultancy report for Sinclair Knight Merz. It is based on information and reports from NSW Roads and Maritime Services, relating to proposed road works for a highway upgrade near Wardell, NSW (as marked on maps provided). The reports relate to the impacts the roadworks may have an impact on populations and habitats of two endangered insects, the Southern Pink Underwing Moth (*Phyllodes imperialis smithersi*) and the Atlas Rainforest Ground Beetle (*Nurus atlas*). Both insects are listed as Endangered by Federal and NSW Governments and their breeding habitats are plant communities classified as an endangered ecosystem (EPBC 1999 [amended 2011]), and defined as "Lowland Rainforest of Subtropical Australia".

The review focuses primarily on findings from surveys for two rare and threatened species of insects, the Southern Pink Underwing Moth (*Phyllodes imperialis smithersi*) and the Atlas Rainforest Ground Beetle (*Nurus atlas*). More broadly the review discusses their conservation status, food plants and the ecosystems they occupy, as well as touching on other insect species of conservation concern. The latter include two butterflies, the "Laced" Fritillary (*Argreus hyperbius inconstans*; Endangered), the Richmond birdwing butterfly (*Ornithoptera richmondia*; conservation significance under the Byron Biodiversity Conservation Strategy) and the dragonfly, Coastal Petaltail Dragonfly (*Petalura litorea*; Endangered). The Review does not cover these or two other threatened invertebrates listed in the 'Targeted Threatened Invertebrate Study', the Mitchell's Rainforest Snail (*Thersites mitchellae*) and Shorter Rainforest Ground Beetle (*Nurus brevis*), invertebrates currently listed as "threatened" under the appropriate State (NSW) and Federal environmental conservation acts.

The Review is based on documents provided by Sinclair Knight Merz (SKM). Any conclusions or recommendations and experience of this author (Sands) relating to the documents provided, are based on literature (References, e.g. Sands and New 2001) or following his discussions with informed scientists at the Queensland Museum, Brisbane (Dr GB Monteith re. Atlas Rainforest Beetle), the Australian Museum, Sydney (Dr D. Britton re. pink underwing moth in NSW), a Queensland plant ecologist (P. Grimshaw re. insect food plants and regional ecosystems). The author has not recently visited the targeted sites to assess habitats for the moth, their integrity, proximity to breeding sites or to water courses, or rainforest gullies near the areas for moth larvae where landscapes might act as corridors for nocturnal movement by the Moth.

SKM provided the Reviewer with electronic copies of the proposal (received 1/08/2013) and a CD (received 12/08/13) with documents: (i) 'Environment Impact Statement' (TRMS, Executive Summary, December 2012 [including evaluation of Impacts]), (ii) 'Draft Threatened Invertebrates Management Plan' (TRMS, August 2013) and (iii) Report, 'Targeted Threatened Invertebrate Study', prepared by Biodiversity Assessment (BAAM, 11 April 2012) and 'Supplementary Targeted Threatened Invertebrate Study' (BAAM 1 March 2013). The review provided for two, 2-hour teleconferences. The terms, conditions and dates of commencement for this Review and subsequent reviewers' employment, were received on 8 August 2013 (from TECSIDE Personnel) and the agreement was returned to TECSIDE on 13 August 2013. This document was drafted by the reviewer on 22 August 2013 and a second. version was drafted on 2 September 2013.

2. Terms of Reference. The tasks to be addressed by the reviewer were summarised as follows (in letter of 1 August 2013 from Kim Collins):

1. Review background information to the project, including the Environmental Impact Assessment and associated Biodiversity Working Paper.

2. Consider feedback provided from DSEWPaC, DP&I, EPA and DPI on the relevant draft Management Plan.

3. Provide a desktop review of the revised Management Plan from a scientific perspective of the relevant species addressed by the Management Plan.

4. Attend a teleconference debriefing to provide feedback on the Management Plan to Roads and Maritime and the authors.

5. Prepare a written review statement on the Management Plan on letter headed paper. This review should, as a minimum, provide feedback on the following key questions:

a. Is the design of the monitoring project appropriate for the species?

b. Is the frequency and timing of monitoring adequate?

c. Is the Management Plan clear on what basis the monitoring locations would be selected?

d. Are appropriate goals being set?

e. Are the mitigation and management actions sufficiently targeted for the species?

f. Are the objectives, performance measures, corrective actions and thresholds for corrective actions in accordance with SMART principles?

g. Do the management measure objectives, performance indicators, thresholds and corrective actions link sufficiently to allow effective implementation?

h. Has the Management Plan provided sufficient evidence where the proposed mitigation has previously been effective?

i. Does the Management Plan describe and discuss contingencies, should the proposed measures be ineffective?

j. If we can't demonstrate mitigation proposed will be effective, can we demonstrate that corrective actions will be effective?

k. Where there is no known research / evidence of the effectiveness of the specific measure proposed – have relevant alternative contingencies been committed to?

l. Have indirect impacts been addressed in the Management Plan, as relevant?

m. Are qualifications and experience of authors in subject field relevant?

3. Recommendations. Overall the topics and objectives of the Management Plan including mitigation strategies, have been addressed appropriately, with goals outlined clearly and impacts broadly addressed. The surveys for threatened species have been carried out effectively, as shown by the recovery of threatened species in the targeted area. Some finer details and adjustments that follow are recommended for consideration or inclusion in the Management Plan.

Mapping of Wardell Site. The surveyed site and other rainforest ecosystems along the Richmond River have been referred to in past times as the 'Big Scrub'. To place emphasis on the importance of threatened species and ecosystems, in the Introduction it would be helpful to refer to the site as a remnant of the Big Scrub, indicate remaining intact areas, an those nearby protected (by tenure) as national parks.

- A Map to show areas proposed for clearing ('before' revision) and 'after' revision of boundaries would be helpful to readers to reflect commitment to avoiding damage to protected species habitats. Show current locations of food plants for the two (Lepidoptera) species of conservation concern, *Carronia multisepalea* and *Pararistolocia praevenosa*.

Threatened Invertebrates Management Plan

- 2.2.1. *Habitat requirements*. Early in this section note the habitats occupied by the two targeted insect species (+ Richmond birdwing butterfly) are defined as threatened *Lowland Rainforest of Subtropical Australia*, by Federal and NSW Governments.
- *Pink Underwing Moth - name*. Add "Southern" (to common name); update scientific name for subspecies (i.e. *Phyllodes imperialis smithersi*). Integrate in text: 'larvae of the southern subspecies of moth are dependent on one food plant vine, *Carronia multisepalea*, found only in rainforests of north-eastern NSW and south-eastern Queensland" or similar….
- 2.3. *Threats*. Add "Fragmentation of habitats from disturbance may result in in-breeding depression".
- *Acknowledge State Agency* for issue of 'permits to collect' (for protected insect surveys).
- *Conservation status update.* Threatened species should be reviewed (by agency) every 3 years to take account of new information.

  Appendix B, pp. 35-

- *Add weeds to Threats*. List local invasive weeds so that appropriate agencies and their control methods (e.g. herbicides) can be identified (e.g. green panic, molasses grass, lantana, camphor laurel) and included in lists of threats for the overall ecosystem.

  Avoid using exotic grasses to re-enforce road edge embankments (common practice in Qld). Some (e.g. signal grass) are known to repel indigenous insects.

- *Fruiting plants for adult moths.* Plants suitable for adult food and species that fruit during flight seasons for the moths (e.g. November – March) include:

  Lillypillies, *Syzygium australe*, *S. smithii* and other local species; *Waterhousea floribunda*, *Ficus* spp., including *F. opposita*, *F. coronata*.

- *Translocation of moth eggs and larvae* (from site of disturbance). Doubtful conservation value unless stages are present on targeted vines, and can be moved prior to clearing. Pupae likely to be present on nearby plants are at risk but are very difficult to locate.
- *Translocation of vine* Carronia multisepalea (no longer proposed)**.** Doubtful value, doubtfully achievable. However, attempts might be made to propagate plants by using rhizomes removed from the path of disturbance.
- *Plants to minimise edge effects*. Soil-binding (& fire retardant) plants for embankments and vine to stabilise edge effects

  (First check that Wardell, NSW is within the native range for each species)

  Lomandra hystrix

  L. longifolia (moist woodland form)

Rubus spp.: (e.g. *R. parvifolius, R. moluccanus, R. risifolius, R. probus, R. moorei*) (especially useful for steep embankment / moist slopes)

Carex apressa, other *Carex* spp.

Solanum spp.

Ficus coronata

Cordyline spp.

Vine: *Pandorea jasminiodes*

Control sites*.* Nearby sites of little value when comparing undisturbed habitats with disturbed areas unless positive results are obtained. More distant sites monitored are of value to indicate: (i) presence, number and persistence of breeding in nearby sites, (ii) seasonal patterns, and when stages are most likely to be present and (iii) whereabouts of meta-populations likely to influence colonising of disturbed and re-planted (with vine) areas. As very few vines and patches of vines are used even in undisturbed areas, negative results (no eggs or larvae seen) are likely to be frequent.

Pre-clearing surveys An indication of vines (*Carronia multisepalea, Pararistolocia praevenosa*) that have been removed or destroyed, and as a % of the overall food plants in the area would provide a useful record. The Reviewer is of the opinion that the site once disturbed is unlikely to support breeding by the moth until vegetation has matured and providing deep shade for at least 10 or more years

Rehabilitation of breeding sites for the moth. This off-site action can be seen as a positive 'offset' for disturbance of the threatened insect habitats, best done by working with local community groups (collaborating with NPWS).

In a similar project on the Richmond Birdwing butterfly (*Ornithoptera richmondia*) habitat rehabilitation was achieved more that 20 years by involving community groups and schools in propagating and planting food plants (mostly *Pararistolchia praevenosa*) for mass production by nurseries. This food plant vine could be easily included in any replating programmes to help the Richmond Birdwing recolonise. The Richmond Birdwing is currently locally threatened and at the southern edge of its range at Wardell.

Investigate opportunities to rehabilitate off-site habitats. for both moth and beetle, e.g. (i) private covenants, nature refuges and other tenures; (ii) buy-back of private land for add to local national parks (they do not need to share boundaries).

Re-vegetation. If continued for more than 2 years, local community groups can be invited to participate in a coordinated program. Local Landcare groups actively rehabilitate sites in northern NSW (e.g. 'Rainforest Rescue'). Local members could be encouraged to take "ownership" of their efforts to 'save the endangered moth'. Most Incorporated groups are 'not-for-profit' organisations but they always need financial assistance to support operating costs (e.g. herbicides) and other activities for rehabilitating bushlands.

Habitat rehabilitation for the Atlas Ground Beetle

Very little is known about the ecology of this beetle and it is therefore difficult to assess the potential for rehabilitation of sites to make them suitable for the beetle and its prey. Information form the surveys would indicate that burrow need some overhang, protection (e.g. overhanging log) or embankment and it is possible that these micro-habitats can be simulated in areas rehabilitated. Use of night vision glasses in surveys could contribute to information about nocturnal activity away from burrows, prey, ground shelters and any particular plants used for making burrows (other than While Cedar).

Security for rehabilitation sites. Signage for sites (+ protected species) is desirable but security needs to be considered. The tenure needs clarification so that protection can be seen as a long term commitment. The moth has potential $$ value for trade (especially for overseas collectors of specimens) but 'collecting' is not known to be a threat at present.

Support for 'Feasibility Study to develop a Recovery Plan'

Recommend support be provided to an appropriate nursery for propagation studies on *Carronia multisepalea* (e.g. *Dorrigo Environment Watch Inc.*) and develp methods to propagate the vine.

*Community workshops***.** Community workshops can also be included in any local program and by providing support funds. A community workshop on the Southern Pink Underwing Moth was run for Barung Landcare (May 2008) at Maleny (Mary Cairncross Scenic Reserve; cost: ca $2,000. The venue was provided by Council. Community participation was encouraged using the Richmond Birdwing Butterfly Conservation program.

Expert's Contact Details and Plant Nurseries

(i) *Southern Pink Underwing Moth.* Very few if any entomologists with experience in the moth are known to live in the region. NSWPWS Rangers based at Alstonville (e.g. Bob Moffatt) were previously (1990s) experienced in identifying threatened insects and their food plants but interests by current staff are not known. Interest in conservation of the moth has come from Byron Bay NSWPWS but knowledge of insects is limited.

Clearly the surveyor Lindsay Popple has gained a lot of experience and expertise with the moth and beetle, and their specific habitats near Wardell.

Others -

- Dr David Britton, Australian Museum, College St., Sydney. Others may have casual experience in New South Wales.
- For moth in the Bellinger Valley, I recommend Trevor and Carol Deane (address below), have first hand experience with the Southern Pink Underwing Moth and its food plant, mostly on Bellinger Island).
- Botanists (e.g. Alex Floyd, John Rigley) may help with cultivation and distribution of moth food plant, the vine *Carronia multisepalea*.
- Members of Community Group*. Dorrigo Environment Watch Inc.*, PO Box 284, Dorrigo, NSW. 2453. (Trevor and Carol Deane

(ii) *Atlas Ground Beetle*. Reviewer only knows of the first-hand experience with the beetle of Dr Geoff Monteith, Honorary entomologist, Queensland Museum (pr. email geoff.monteith@bigpond.com). Taxonomic and distribution information is available on the website *Atlas of Living Australia*. This is a key point of reference for the moth.

Lighting*.* Lights and their wattage to be minimised; lights mounted as low as possible, and limited where possible to road & signage illumination. Avoid mercury vapour lights; sodium vapour may need evaluation (effects on target species not known).

- Avoid penetration by lights into forest or water courses to avoid disruption of flight behaviour, flight paths, host and mate-finding by the moths.
- No disturbance to southern (and northern ssp.) pink underwing moth behaviour (flight, feeding, avoidance) has been seen (using night vision glasses) at localities in Queensland when lights are 500 m or further from habitat. It is not possible to predict how longer-term exposure to lights will influence moth behaviour without experiments or observations. Sometimes insects will 'condition' themselves to light disturbance.
- Studies on longer-term exposure light requires more research; this may justify use of night vision glasses for a monitoring program.

Other edge effects.

- Dust management in construction and diesel exhausts may have an impact on the larvae of the moth
- Monitoring of dust settlement on foliage may provide an indication of impacts on larvae feeding.
- The recommendation that disturbance should not occur within 500m of breeding sites appears impractical. Therefore an attempt at no disturbance within 100 m of breeding sites appears more feasible.

Methods for Trapping and Monitoring

Southern Pink Underwing Moth

- Monitoring eggs and larvae for numbers and distribution are appropriate methods for determining presence or absence, health of habitat, season and suitability of plant phenotype when stages are present.
- Correct identification of eggs and moth larvae requires experienced personnel. Similar common moth species (e.g. *Eudocima fullonia*) utilise the same food plant as used by *P. imperialis smithersi*.
- Monitoring adults with lights is likely to be of little value for highly mobile moths; they are rarely seen unless feeding. Lights occasionally attract moths but traps have proven (in SE Qld) to be ineffective and may disrupt normal flight behaviour of the target species.
- Lights and light traps (in the forest) may have unwanted impacts on non-target species and disturb the behaviour of other species.
- Fruit baited (e.g. with over-ripe bananas) traps can useful for determining presence/absence of pink underwing moths, especially if mounted in-flight paths.
- Cameras are unlikely to distinguish differences between many species of large night-flying moths (e.g. large silk moths) that occur in the area.
- Night vision glasses are useful research tools for observing host plant selection by female moths, feeding by adults (e.g. on hanging fruit) and flight behaviour. Doubtful value for this – essentially a monitoring project

Atlas Rainforest Ground Beetle

- *Expert with most experience*: Dr Geoff Monteith (retired Hon. Scientist) Queensland Museum. [email geoff.monteith@bigpond.com]
- *Monitoring*: Correctly identifying burrows made by the Atlas Beetle would appear to be the best method.
- *Traps*. Pitfall traps may be useful for determining presence/absence of beetles but the method can also be considered destructive, even when beetles are released, depending on their densities per area of habitat.
- Experienced surveyors are needed to identify burrows and avoid misidentifying burrows of other related beetles in an area.
- Flight? If the beetle is nocturnal or it can fly, night vision glasses may be useful for monitoring beetles when they leave their burrows.
- Off site monitoring of burrows and at control sites need first to establish the identity of this species. Persistence of the beetle after nearby disturbance may be of value in assessing impacts on beetles populations.
- Light interference. Comments on possible effects of lights on the moth's behaviour may apply to beetle behaviour if it can fly.

4. Review of Reports

(1.1) Background and Purpose. The Report provides the objectives and scope of surveys, the names of investigators, the methods used and dates of two Surveys (6-10 February 2012, 13-16 March 2013) and a Supplementary Survey (11-15 February 2013). The objectives are appropriate and the dates for surveys coincided with the times of appearance of the immature stages of the Southern Pink Underwing Moth (to confirm its identity by photographs) and collection of specimens (e.g. to confirm identity of the Atlas Ground Beetle). The Report and Supplement did not indicate if the areas, or parts of areas surveyed, would be classified as 'lowland subtropical rainforests', plant communities protected under the EPBC Act.

(1.2) Site Descriptions. The landscapes and ecosystems targeted for surveys are broadly described, including swamp and mangrove forests, swamp sclerophyll and grasslands, with examples of eucalypts and banksias occurring in woodlands, and basaltic hills with small pockets of rainforest, some with exotic Camphor Laurel. Additional information defining the 'regional ecosystems' being surveyed for moth stages and its food plant and occupied by the beetle are desirable for this report. In addition, the occurrence of these ecosystems and the food plant outside of the study area would provide valuable information for assessing the likelihood of other sites nearby being occupied by the insects.

Two maps were provided, Figure 1-1 provided aerial views of the Study Area and Survey Locations with individual sites numbered and Figure 3-2 provided an enlarged map where the threatened moth and beetle were found, the food plant (*Carronia multisepalea*) for the moth, as well as the very few plants of (*Pararistolochia praevenosa*), food plant for the Richmond Birdwing butterfly,. One map (Figure 3-2) showed the location of insects and plants within, on, or just outside, the Study Area Boundaries and it also illustrated how moth stages were located on only one portion of the area occupied by the food plant (*C. multisepalea*), probably indicating the habitat, food plant phenotype, or shading were not suitable as a breeding site. The reviewer noted that "Fig 3-1" (referred to on pp. 4,7 & 8 of text) may have been an incorrect figure reference for Fig. 1-1.

Excellent images were provided for the threatened species located during the surveys as well as other species of conservation concern and interest. All are relevant by providing indicators for the integrity of the ecosystems and species they are supporting.

Is the area of habitat remaining to be disturbed (after variation in boundaries) 2.4 ha? Can it be described as an area of *Lowland Rainforest of Subtropical Australia* (as under the EPBC Act)?

Survey Reports

Targeted Threatened Invertebrate Study, by Popple, L., Chambers, J and Weber, L (11/04/2012)

Summary. The aims, methods used and seasonal timing of the studies were appropriately designed and implemented, confirming that the field work was effective for locating the two target threatened species at the Study site where the moth was breeding on its known food plants, and the moth and beetle were associated with particular plant communities known to be habitats. The surveys achieved the objectives and have added valuable information to the known distribution and breeding sites of two threatened species, the Southern Pink Underwing Moth (*Phyllodes imperialis smithersi*) and the Atlas Ground Beetle (*Nurus atlas*). From these findings the potential impacts from roadwork disturbance can be extrapolated from the presence of habitats and breeding by the targeted threatened insects, based on location of the food plants and ecosystems occupied. The sightings of an adult Richmond Birdwing Butterfly (*Ornithoptera richmondia*) near Wardell, a species also of conservation concern, and rediscovery of its local rare food plant vine (*Pararistolochia praevenosa*) at the Study Sites, provides renewed evidence for this rare butterfly near the southern edge of its range where it has not been seen since about 1994 (Sands 2008).

The Report was prepared by environmental specialists who hold appropriate qualifications (e.g. two authors hold PhD degrees). Dr Lindsay Popple, who took the lead with field surveys, is known to have extensive ecological and taxonomic experience with several insect groups (e.g. cicadas). Minor recommendations are made by the reviewer in the following sections.

Species Profile. **Southern Pink Underwing Moth (*Phyllodes imperialis smithersi* Sands, Lepidoptera: Erebidae).**

(Management Plan, August 2013, Appendix B, pp. 35-40).

Author([s] of the Profile provided brief summaries for the moth under the headings below, followed by Reviewer's comments. The Report is accompanied by impressive and relevant images, for low growth of the food plant *Carronia multisepalea*, larvae of stages of the Southern Pink Underwing moth and a larva of a similar ("look-alike") moth, *Eudocima fullonia*, for comparison; a species of no conservation significance that has sometimes been confused with the threatened species.

Description. Reviewer: Brief but adequate. Dot point 2 might be improved by emphasising the moth breeds in heavily shaded areas in "old Growth Rainforests" (perhaps give botanical types), where the larvae feed only on soft leaves of the food plant, and on low growth (< 2m) of shoots, or new growth arising from rhizomes.

Adults of the Southern Pink Underwing Moth do not initiate damage to fruit but do feed on juices of over-ripe fruit, or fruit damaged by other means. This is in contrast to the damage caused by large moths in the genus *Eudocima* spp. (e.g. *E. fullonia*) which have a specialised proboscis modified for piercing fruit; these piercing species can be regarded as pests when abundant in the tropics, and less commonly in far northern NSW. It is important that the threatened species, the Southern Pink Underwing Moth is not thought to be a "fruit piercing moth", as sometimes mistakenly inferred by uninformed authors.

Similar Species. Reviewer: Appropriate, but the Author may not know the extent of variation in colour of larvae of the common species, *Eudocima fullonia.* Variation in colour needs to be considered when identifying larvae to species, for example, young larvae of *E. fullonia* can appear to laymen very similar to those of *P. i. smithersi* but its larger larvae never have the spectacular "eye patches" and "teeth" markings, characteristic of the Southern Pink Underwing Moth.

Legislative Status. Reviewer: appropriate reference provided. Worth noting that Queensland has not listed the moth as threatened, with reasons obscure.

Distribution. Reviewer: The map provided is adequate. The southern limit of the moth is known to be Dorrigo and Bellingen and altitudinal limit as about 600 m (NSW/Qld Border Ranges.

Habitat. Rainforest habitat is briefly mentioned but brief floristic definitions of habitat requirements (Regional Ecosystem) would be useful for documenting impacts of roadworks and other ecological studies. Upfront in this section the area (and proportion) of moth breeding habitat proposed for clearing of rainforest vegetation (?2.4 ha) should be compared with the area to be retained.

Threats. Reviewer: Invasive grasses (e.g. green panic, molasses grass) will be serious threats in the shorter term and several weeds including lantana and camphor laurel will invade all disturbed areas as longer-term threats. I recommend dot point 3 expand to name some of these weeds

A major threat could result by defoliation and increased light affecting nearby or adjacent corridors used for adult dispersal, particularly any heavily wooded water courses. Can the tenure and management of these water courses be secured against disturbance and weed invasions? Due to its spectacular appearance the newly-named sub-species (ssp. *smithersi*) has recently become an iconic species, and it may be further threatened by over-collecting of specimens by Australian and International collectors.

Key management Requirements. Reviewer: The management requirements are adequately addressed here and elsewhere in the documents. Translocation of immature stages (dot points) for the site to be disturbed is unlikely to benefit the overall conservation of the species but the method could be seen as a positive by 'uninformed' members of the community who may compare the action with vertebrate translocations. Heavily shaded plants with ample foliage (and correct phonological expression) may support subsequent development but they cannot always be placed at sites free of natural enemies that will use the translocated larvae as prey (a common factor that regulates breeding sites). Trained surveyors might be on the lookout for natural enemies and make a contribution to the knowledge of natural population-regulating factors for the moth (Reviewer would be interested in these data).

Clearing of vegetation containing *Carronia multisepalea* used as food plant and its habitat by the moth is to be avoided. Efforts have been made to re-route the roadworks to avoid damage to the fragile ecosystem used as habitat by the threatened species. Was resumption of farmlands an option to relocate the roadworks to the east and can any nearby fragments of habitat be secured (or purchased) for national parks, or permanently-protected and managed reserves?

Bibliography: Reviewer: Federal listing of the moth resulted from a publication by Clark GM and Spier-Ashcroft F (2003), who outlined the conservation concerns, details of micro-habitats, food plants and other materials of interest, data that resulted from a CSIRO project investigating the moth and the related *E. fullonia*. This reference should be used in this and all future reports. The reference to Herbison-Evans et al. (2004) is inappropriate for reference here and it contains somewhat misleading information.

***Supplementary Survey for the Southern Pink Underwing Moth* (11-15 February 2013), by Lindsay Popple**.

Important new information resulted from this survey and showed that the Southern Pink Underwing Moth and the Atlas Rainforest Beetle both occur in and beyond the proposed developmental footprint of Sections10 and 11. These data included (i) additional habitat for *Phyllodes imperialis smithersi* as confirmed by presence of larvae, (ii) potential habitat for the moth where the host plant was present without moth stages, and (iii) plant communities assessed as potential habitat for the moth (with presence of adult fruit trees) in absence of the larval food plant, and (iv) scores for a *habitat condition assessment* as part of a pre-clearing survey.

Collection of specimens. During the surveys for two species of protected insect species the collection of specimens is necessary to establish without doubt the identity of the species. Nowadays photographs can be taken without difficulties in darkened rainforest and the quality of images is often adequate to establishing the identity of a threatened species, for example the advanced stages (instars 3-5) of larvae of the Pink Underwing moth, provided the images are shown to a specialist (e.g. Dr David Britton, curator at the Australian Museum Sydney). Specimens of most carabid beetles including the Atlas Ground Beetle, cannot be identified with certainty from images. Therefore specimens are needed for referral to an expert. In these surveys specimens of the targeted threatened species were collected under a permit issued by the appropriate State and/or Federal agencies.

*A recommendation to au*thors. it is appropriate to acknowledge taxonomist(s) (+ museum / agency) that identified specimens to species (e.g using images of moth, specimens of beetle) and to acknowledge any agencies that issued ‘permits to collect’.

Results of surveys

The location of 45 larvae (range of instars) and 9 eggs of *Phyllodes imperialis smithersi* on its host vine (*C. multisepalea*) indicates more than one gravid female had oviposited over a period of several weeks in the single block with larvae present (Lot 23), based on estimates for fecundity of moths previously held in captivity. A further record of the Atlas Rainforest Beetle 750 m from the previous record and additional records of the host plants (*Pararistolochia praevenos*a) for the Richmond birdwing butterfly with sightings of an adult butterfly, indicate the overall areas of rainforest surveyed close to Wardell, sustains breeding colonies of several species of insects of conservation significance.

Methods are needed to identify the specific heavily shaded habitats (in lowland subtropical rainforest), to identify and locate the moth's specific food plant requirements (rainforest vine *Carronia multisepalea*), and recognise the phenotypic expression of growth (only young, soft, rapidly-growing and apical foliage) on plants in heavily areas. The shaded soft apical growth on vines is used by moth larvae, and these expressions have proven to be effective when locating various stages of larvae of the moth. The maps (Fig. 3-2) revealed how many moth larvae and all food plant vines were in, or just outside of the study boundaries. Many moth larvae located and the pink underwing moth larvae were distinguished from those of a related and common moth, the fruit piercing moth, *Eudocima fullonia* (images confirm the identities in the Report). In the past, larvae of this and related common moths have been mis-identified as larvae of the pink underwing moth. Whereas larvae of the pink underwing moth are only found in heavily shaded areas, larvae of the common fruit moths will occur in shaded areas as well as more exposed situations. The authors of the Report distinguished the two species which have caused confusion in determinations amongst other experts in the past. They are to be commended for distinguishing the larvae of the threatened species from a common species of no conservation concern.

Pupae and adult moths were not reported during surveys but the sites surveyed and observed supporting the larvae the moth were confirmed suitable for supporting complete development of the immature stages. Eggs of the Pink Underwing Moth are difficult to distinguish from eggs of a common fruit piercing moth (*Eudocima fullonia*) and eggs of both species are found in similar situations attached beneath leaves. Only after emergence and development to 2nd and 3rd instars, can larvae of the two species be readily distinguished, as shown by figures (Photos 5-7) in the Report. Pupae of the moth were not located but the cryptically-selected sites for larvae intending to pupate (folded living leaves, loose cocoons stitched with silk) are very rarely located and would have taken many more hours of searching. Moreover, pupae may not have been present at the same time of the year when young larvae were observed, and the loose cocoons are extremely difficult to locate.

The surveying personnel are to be complemented for their efforts and successes in finding such rare species and previously unknown breeding sites for the moth. As recommended elsewhere in this Review, the area may prove to be extremely important as an intact remnant of the original 'Big Scrub' rainforests and there is a priority need to ensure the tenure and ecosystems on such environmentally-valuable land is secured by State or Commonwealth as a protected, conservation reserve.

Species Profile. **Atlas Rainforest Ground Beetle [*Nurus atlas* (Castelnau), Coleoptera: Carabidae]**

Background. The identity of this beetle has been established for many years (Castelnau 1867) but very little information on the distribution, biology or ecology of this beetle has been available until recently (GB Monteith pers. comm., L. Popple in this Project). The beetle was named at a time when large areas of the 'big scrub', the habitat for the beetle in north-eastern NSW, remained intact. Description, distribution and an illustration of this beetle can be found on the website of "Atlas of Living Australia". The beetle is shown to occur at widely-separated sites in eastern Australia, in central and northern NSW and at one in far northern Queensland. The species is said to be "Endangered" and threats are said to be "Risks of collection (of specimens) and disturbance" (Atlas of Living Australia). The lack of ecological information on the ecology of this beetle makes the tasks of threat abatement and recovery for the species very difficult.

Methods. The Reviewer can add little useful information to recommendations or additional survey methods. The contributions made to date by authors of the surveys indicate the need for supporting future research on the beetle, and development of a *recovery plan for the beetle* – an essential outcome and internationally-recognised step (and in NSW) following from the listing of threatened species.

Methods described for searching for adults and burrows of the beetle have proven to be effective, and the resulting recovery of an adult beetle of the target species, in a locality not previously known, is an indication of effectiveness of implementation of the methods used. The photographs of the beetle are diagnostic and the identity of a specimen was confirmed by an expert based at the Queensland Museum. Location of the burrow and identity of plant with roots used for shelters as well as soil types may be important for defining type of habitat. The photographs of slope and other ecological information could be diagnostic for the beetle's habitat and recovery of a specimen indicates the surveys have been most effective. The dates selected for surveys, the methods of searching and times spent searching added to effective location of this species on the survey site.

Is the beetle nocturnal? The reviewer would be interested to know if the photograph of the living adult was taken during daylight hours or at night; information useful to guide future surveys, whether by day or at night, for this extremely rare beetle. In view of the paucity of biological and ecological information available for the Atlas Ground beetle, those conducting the surveys are to be congratulated for finding adults and burrows, and to making a contribution to the ecological knowledge and the distribution of this endangered species.

5. Threatened Invertebrates Management Plan

The Monitoring Programme (7)

Objectives: To provide reliable information for management of the Southern Pink Underwing Moth and Atlas Ground Beetle at the study sites, by monitoring invertebrate habitats, locations of threatened insect populations and rehabilitation sites adjacent to the alignment, and to document effectiveness of mitigation measures.

Schedule: Program to be conducted for three years post construction subject and to revision if new locations are found after the final survey.

> ***Reviewers comments***: All objectives and the schedule as interpreted above are appropriate. Monitoring might be extended by up to 500m from the edge of disturbance, to assess (and measure) the selection of habitats by the species and tolerance of their populations to edge effects disturbances.

Comments in sections and topics below are provided against dot points.

Southern Pink Underwing Moth (7.2)

Habitat condition assessment (7.2.1).

- The criteria and scores are appropriate and will provide positive indicators of habitat condition
- Recommendations: disturbance should not occur within 500m of breeding sites
- Weed management needs to be maintained indefinitely.

Moth populations (7.2.2).

- Methods to monitor immature moth stages and methods for locating the beetles are appropriate and use of a positive control site will add to information on the effectiveness of rehabilitation efforts

Moth activity at lights (7.2.3)

- Lights attract attention and vandalism by public;

- Lights disrupt flight behaviour of target moth, and activity of the target and non-target nocturnal organisms.
- Any lights are likely to disrupt normal adult moth activity and are not particularly attractive to species of *Phyllodes* moths.
- Cameras are available to monitor nocturnal animals but none would provide certainty of identity for the target moth (at least 15 large non-target moth species occur in the area)
- Fruit baited traps can be designed and used effectively for the Southern Pink Underwing Moth. Trapped moths can be marked, released & recaptured to indicate habitat use and meaningful population estimates.
- Eggs and larvae are always the best means of monitoring local numbers as the stages are not mobile and numbers observed are independent of non-breeding 'visitors'

*Host plant (*Carronia multisepalea*) populations (7.2.4)*

(1) Propagules may be difficult to strike from cuttings – which sex of plant will be used? Good luck with developing effective methods for propagation – they are needed for a future 'recovery plan'.
(2) Methods for monitoring growth seem reasonable but what about watering regimes?
(3) Growth rates and use by herbivores is valuable information for monitoring, 6-month intervals useful but choose season and month
(4) Doubtful result. Flowering (and seed production) on propagules would be unlikely to occur within 5 years unless sites are well-sunlit, and if so, unsuitable for use by moth as food plant. Add to parameters "health/mortality" of propagules
(5) Annual schedules and monitoring frequency. Good parameters proposed.
(6) Is tissue culture for production of vine propagules feasible or has it been considered?

Performance indicators (7.2.5)

- Control sites need to extend >50 m from construction corridor to avoid light interference and false negatives
- Welcome mention of property acquisition – what category will the tenure become, NPs?

Offset and revegetation sites (7.2.6)

- Effectiveness will depend on distance from disturbance (light, air movement etc)
- Large Lepidoptera (Moths, birdwings) are very sensitive to air movements of > 5 km/h and their flight behaviour (from lights and air movement) need to be considered.

Atlas rainforest Ground Beetle (7.3)

Habitat condition assessment. Criteria used for finding habitats for the moth can be applied equally to the beetle. Localised adjustments to searches can be made by focus on the burrowing sites as habitats which differ from plant use by moths.

Monitoring beetle populations (7.3.1)

- Sites monitored can be the same (as per BAAM methods) as for the moth with adjustments for monitoring known "micro-habitats" (including burrows and rock shelters).
- Off-site monitoring may provide an indication for (i) presence of other individuals, (ii) information regarding behaviour and beetle prey, and (iii) how rehabilitation of micro-habitats could be undertaken
- Recommend nocturnal monitoring be included in the monitoring schedules

Performance indicators (7.3.2)

- Beetles along the proposed corridor are unlikely to be observed unless night observations are conducted, due to probable nocturnal foraging behaviour
- Such surveys are unlikely to indicate real impacts of construction activities
- Indicators are needed to predict how many beetle borrows are likely to occur in the area to be disturbed, based on known micro-habitats for the beetle
- Populations changes are difficult to determine for any insects and may not be a useful indicator of insect "health". Presence/absence and burrows being used might be useful monitoring parameters.

Rehabilitation of areas and host plants (7.4).

Food for adult Moths. Planting indigenous figs and other fruit bearing species will provide food for both sexes of adults. as a long term strategy this will help provide fruit as food for other moths and wildlife. Depending on species of *Ficus*, it is likely that local production of fruit would not be adequate as an adult source in the shorter term (*Ficus coronata* may be the most rapid species to produce fruit. *Ficus watkinsiana* is known to produce fruit attractive to the moth when damaged)

Performance measures and corrective actions (7.5)

Add to Corrective Action 1…, "Evidence of a decline in numbers of *eggs and larvae*…", to reflect changes occurring to the suitability of the breeding site whereas adult sightings or trapped may relate only to individuals "passing through"..

Corrective Action 2. "options to improve habitat condition and connectivity" This objective might better be identified soon so that a cost/benefit prediction against effectiveness can be made. The only positive action is likely to be to – resume land for habitat restoration/enrichment and to ensure it has indefinite protected tenure.

Second, a species can be considered a "rehabilitated species", either from successful recovery actions or from new information that leads to down-listing from the "threatened" categories.

> *Recommend*: a *Corrective Action 3* be included to "be informed the conservation status of the threatened species by agencies every 2 years", to ensure that rehabilitation efforts and on-going management expenses are justified.

Evaluation, project review and reporting (7.6)

> Annual reports are essential. What will be the response if there are recommended activities not forecast during the planning stage?

Responsibility (7.6.1)

> Clear directions for evaluations

Timing (7.6.2)

> Appropriate. If new ecological information becomes available it should be referred to appropriate agencies or their staff (e.g. Museum staff, and as outlined 7.6.3).

Adaptive Management (7.6.3)

Reviewer: The criteria (e.g. 75% survival of tube stocks) would appear unreasonably optimistic taking into account the little information on propagation currently available. Has anyone had recent success in propagation of this vine?

Reviewer's Comments:

- Provision for variation in monitoring & assessments is needed as changes are recognised during implementation, or alternatives proposed if methods prove to be ineffective
- Sites selected need to take into consideration predatory ants
- Methods to propagate need to be developed (for male and female vines)
- Watering regimes are likely to be important (e.g. minimum of once per week in drought periods)
- Young plants grow very slowly in shaded areas
- Edge effects likely to be considerable
- Weeds likely are mostly exotic grasses, camphor laurel and lantana. Need to consider control methods (removal/slash/herbicides/ early on.
- It is unlikely that (i) moths will start using the planted vines within 5 years after planting and (ii) that " decreases in abundance* of threatened invertebrate populations and likely reasons…" can be measured, or the reasons given, unless the moth discontinues using the undisturbed section of the site. Presence/absence of breeding by the moth on particular plants is the key cue for monitoring
- Seasonal & parasitoid-induced fluctuations normally make counts and estimates for most insect numbers very difficult or impossible, especially for mobile species such as the Southern Pink Underwing Moths with meta-population structures.

Summary table and implementation schedule of management plan (Table 8-1).

Reviewer: This appears as a 3-year operational plan, can the planned duration for monitoring and surveys be indicated?

Draft Threatened Invertebrates Management Plan - Agency Comments

(W2B)

Reviewer's comments (relate to Version R01 of the Plan and Response. Comments are by item No. and RO1 numbers). It is noted that the Responses relate to an up-dated plan. Generally the Agency comments appear to be reasonable and only relevant comments are added below:

3. - considers all breeding sites with *Caronia multisepalea* (and *Pararistolochia praevenosa*) would be classifiable as *Lowland Rainforest of Subtropical Australia.*
4. - doubts if translocation of immature stages will contribute towards local conservation of the moth.
5. - would encourage propagation attempts for *C. multisepalea* as part of (suggested) rainforest rehabilitation. Bear in mind that there are male and female vines that both need propagating.
6. See 4 above
7. Propose as additional need to predict the position of moth flight corridors to see if they will be impacted by the roadworks or presence of the carriageway.
8. Light is known to disrupt behaviour of moths (and carabid beetles) over considerable distances. Lights should be minimised near the habitats and potential watercourse corridors. The Southern Pink Underwing Moth is weakly attracted to light but its ovipositional and mating behaviour is likely to be disrupted.
9. A good proposal.
10. How about supporting development of a Recovery Plan for the moth by an incorporated community group

101 - 104. No comment needed

EPA Comments (WB2)

The Reviewer considered the comments, up-dates and responses, with little further to add. Most EPA concerns were considered appropriate but have been alleviated by changes in the boundaries as shown in Responses. Monitoring should take into account the 'meta-population' of the moth where each patch of food plant used as a breeding site may either be utilised, or avoided, year to year, or season to season. As mentioned in the notes, large and sub-migratory Lepidoptera such as the Pink Underwing Moth are prone to this movement between sites to avoid in-breeding depression, well known for the Richmond Birdwing Butterfly.

Reviewer's responses according to Section:

3.3.1 The low probability for impacts due to refinement of design applies here to *Carronia multisepalea*. Does the same apply to the vine *Pararistolochia praevenosa* if it is present? It is a food plant for the locally threatened Richmond Birdwing butterfly. Apart from being diurnal and using a different food plant, the ecological interactions of the two insects – a moth and a butterfly, are similar as are the habitats.

4.2.5 The moths are unlikely to utilise any plants translocated within the time frame for monitoring unless mature plants survive and produce suckering growth or low shoots suitable for attracting oviposition. Propagation, planting and translocating vines and maintaining them, is an exercise for the "long haul" and plans need to be made for long-term watering, management and protection. It is more important to consider the security and tenure of the receiving (planted vines) land and adjoining habitats, to ensure all local habitats for moth and food plant are zoned for indefinitely protection (e.g. Nature Refuges, proper;y managed national parks.

……

6. Reviewers Dossiers.

An overview of ecosystems and insect habitats

(i) Southern Pink Underwing Moth

The region proposed for road works contains remnants of natural ecosystems described and mapped in documents provided for review. The region has a subtropical climate with a moderate to high coastal rainfall that declines progressively towards the west to base of the Main Divide. To the south, lowland subtropical rainforests once fringed the Clarence River and its tributaries, with its rich alluvial soil areas extended northwards and forming flood plains surrounding the Richmond River. The natural ecosystems support a very high diversity of plants, animals and their habitats, with many species dependent on undisturbed plant communities surrounding intact water bodies and edging water courses. This ecosystem, earlier referred to as the 'Big Scrub', once extended over 75,000 hectares, but since the 1840s this rainforest area has been extensively cleared, leaving only remnants. Natural wetlands have been equally disturbed by clearing, draining and grazing, resulting in losses of most native grasslands and sedge lands, and displacement of native vegetation by exotic pasture grasses and weeds. In the 1900s the lowland floodplain topography rendered much of the area amenable to clearing following widespread timber extraction (predominantly for the Australian red cedar, *Toona australis*). By the early 1990s, only 556 hectares (approximately) of rainforest remained (Lott and Duggan 1993), with all of it seriously fragmented. By the end of the nineteenth century, many rainforest plants and communities with associated indigenous animals, vertebrates and invertebrates, had become displaced, extirpated or extinct, the destruction promoted by feral animals and introduced weeds, including camphor laurel and lantana. The remnants of predominantly subtropical lowland rainforest in now said to be protected (Federal EPBC Act).

Since the late 1990s, the integrity of the subtropical rainforests and wetlands has suffered from clearing, drainage and the displacement of native flora by exotic weeds. Earthworks, roadworks, blue metal extraction, clearing for powerlines and deliberately-lit fires (particularly increased frequency, scale, season), added to impacts on invertebrate biodiversity, particularly in the remnant riparian zones and wetlands. Diversified cropping, including subtropical fruit, avocado and macadamia nuts, have recently increased pressures on the health of stream flows, and from chemical and bacterial pollution extending from urbanization.

Wildlife endemicity of the region. The remnant rainforest patches are widely recognized as important for sustaining biodiversity, and they support significant numbers of rare and threatened plants and small animals. The regional ecosystems targeted during the surveys are known to be shared by a range of threatened vertebrate animals and birds (e.g. Coxen's Fig Parrot) and threatened insects (e.g. Pink Underwing Moth), animals that occupy ecosystems currently recognized as Endangered by Federal and State Agencies. These habitats for threatened species, particularly rain forested areas, are often small in area but they continue to be disturbed by invasions by feral animals and subtropical weeds, particularly wild pigs and dogs, lantana, exotic grasses, and edge effects.

The subtropical invertebrates of eastern Australia are unique and as much so as those of the northern Wet Tropics. Losses of patches of subtropical habitats have had a serious impact on the diversity of invertebrates as they have "no-where to go" and do not have the mobility to escape from habitats when they are disturbed. Many locally endemic insects, some referred to in these reports, have declined in abundance and become extremely rare, others are recognised as threatened (with extinction) or have become extinct. Most invertebrates (making up 99% of animals), many species now considered threatened, have co-evolved with particular plant species or other animals and are adapted to one or few ecosystem types. The majority of invertebrates have evolved as part of the Australian ecosystems over much longer periods than vertebrates, especially those with important interactions (e.g. specific pollinators, dung beetles, dragonflies) with other animals and plants.

Threatened species. Australian threatened phytophagous insects are often restricted to feed on particular plants in specific plant communities, where climate is compatible with specific biological processes including mate-finding, reproduction and immature development. In this category are species surveyed including the Southern Pink Underwing Moth (*Phyllodes imperialis smithersi*), the Australian (= "Laced") Fritillary (*Argyreus hyperbius inconstans*), and the Richmond Birdwing butterfly (*Ornithoptera richmondia*). Not uncommonly, specific densities of one species of plant, with a particular phenotypic expression, are essential for survival. Such insects usually occur only where adapted to ecosystems with specific "climatic envelopes" where they are susceptible to extirpations and extinctions from: (i) loss or disturbance of specific habitat, (ii) lack of corridors enabling escape and re-colonisation, (iii) lack of mobility or opportunity when disturbed, (iv) seasonal susceptibility of quiescent stages to disturbance, and (v) isolation of colonies from loss of connectivity leading to in-breeding depression. Food plants may survive disturbance but their phenotypic expression, age structure and exposure to light may change and also make them unsuitable as food plants. The threatened insects surveyed in this study are susceptible to one or more of these threats. In relation to the Australian Fritillary, It is likely that fragmentation of habitats, severance of flight corridors and in-breeding may have been one of the major causes of declines in distribution and extirpations that have led to it being now recognised as a seriously endangered butterfly.

In addition to threatened status of the Southern Pink Underwing Moth (*Phyllodes imperialis smithersi*), the Richmond Birdwing butterfly (*Ornithoptera richmondia*) both are considered by the community and agencies as 'iconic species', with spectacular appearances carrying the message of 'conservation needs' for invertebrates and when selecting threatened species for listing by agencies (Clark GM and Spier-Ashcroft F, 2003).

Biology and population structure

Little is known about population structure of the Southern Pink Underwing Moth, particularly in NSW, but from recent studies on the Blackall Ranges, Queensland, meta-populations of the breeding sites are in place, made up of mosaics of heavily shaded old growth rainforest plant communities containing the food plant for larvae, *Carronia multisepalea*. The moth has been seen (using night vision glasses) to move from one individual plant to another when selecting plants for oviposition, only utilising the suitable shaded foliage on low shoots or from root suckers, and avoiding the older stems and higher (>2m) parts of the host vine that ascend into the canopy. Meta-populations composed of patches of suitable food plants and immature stages of the moth are distributed over large areas and their distribution may be important in sustaining survival in the region. The migratory behaviour between widely-spaced plants selected for egg deposition, is likely to be a strategy used to avoid in-breeding (unpublished), similar to the Richmond Birdwing butterfly where in-breeding depression is well known to occur when populations become fragmented and genetically isolated (Orr 1994). The moths are thought to have cryptic mating cues and specific mating sites but they have not been observed mating in the wild. For movement between habitats and breeding sites moths have been seen (using night glasses) moving through moist rainforest gullies, surrounding flowing streams. This is likely to be the only way movement between breeding sites, covering large areas in search of food plants, can occur without heavy losses to predation. Adults of the southern pink underwing moth are very rarely seen but on occasions they have been observed feeding on damaged or over-ripe fruit of various types in forests and occasionally in orchards. In the wild, adults have been observed feeding on soft, over-ripe fruit of wild figs, lillipillies, and one or two other native fruit. They do not damage fruit, or feed on fallen fruit, but will feed on the juices after some damage has already been done to ripe fruit by other insects or birds.

Adult moths are not readily attracted to light and light traps have not proven to be successful for trapping these moths. Light traps targeting this moth are therefore not reliable for identifying habitats, adult abundance or flight corridors and the effects of light (when using night vision glasses) appear to disrupt flight and moths will often turn away from light sources. Light traps also frequently attract unwanted attention from passers by and have suffered from vandals. For monitoring presence and absence, both sexes of adult moths can be collected from fruit-baited traps. However, fruit-baited traps also attract many non-target species and the method is not encouraged unless the trap contents can be attended to on a daily basis.

In Queensland, very few rainforest sites with the vine *C. multisepalea* have been found to carry populations of larvae of the moth and there is strong evidence for “meta-populations” where different patches of vines are used each season. The nocturnal feeding of adult Southern Pink Underwing Moth (only on damaged/over-ripe fruit) and flight between breeding habitats occurs at similar times to more abundant species (e.g. *Eudocima fullonia,* a fruit piercing and at times, a pest species) but the Southern Pink Underwing Moth probably uses deep forested gullies for dispersal adults and mate searching, whereas *E. fullonia* will use a range of open as well as forested habitats. With adequate food a female moth (in captivity) lives for up to 30 days and deposit up to 300 eggs, depositing up to 30 (usually 12-15) eggs at each site over several evenings before moving on in search of other suitable sites. The results of surveys indicated food plant vines were present at times when moth stages were absent. The numbers of larvae observed on each sampling occasion, and number of similar instars, suggest that they were likely progeny from one or two females. This would be expected as very few vines in an otherwise suitable ecosystem carry immature stages, due to absence of low soft growth of the vine needed as food by larvae, inadequate shade effects or presence of insect predators that would attack the eggs and larvae (e.g. ants). These factors contribute to the patchy and scarce distribution of the moth even when the food plant appears adequate in densities and with needed phenotypic expression of the needed foliage.

Dependence of moth on food plants and ecosystems.

When assessing the conservation status for insects, recognized threats and threat abatement strategies for insects and their particular ecosystems. Species of insects investigated in this study are endemic, and found only in subtropical eastern Australia. Those classified as "Endangered" or other threat categories have lost large areas of habitats from human disturbance and survive as species only in fragments of suitable habitats. Losses of small remnants or disturbance, added to 'edge effects', could easily lead to total extinctions. In this category the wetland-adapted species investigated, the wetland "laced" Fritillary, the rainforest-adapted Atlas Rainforest Beetle, *Nurus atlas* and Southern Pink Underwing moth, *Philodes imperialis smithersi*, are threatened by loss of habitats and any disturbance of the habitats in northern New South Wales. The large beetle is extremely rare and is only known from a few fragmented localities in Northern New South Wales that have survived since the clearing of 'Big Scrub' rainforests. This predatory Atlas Rainforest Ground Beetle (*Nurus atlas*), is not known to occur in south-eastern Queensland and is thought to be restricted to the very small 'climatic envelopes' of north-eastern NSW with one habitat pocket in far northern Queensland. It belongs to a group of beneficial group of well-known invertebrates and many important as predators of pests (e.g. armyworms) in cropping systems.

The Southern Pink Underwing moth, *Philodes imperialis smithersi* is likewise threatened by loss and disturbance of its rainforest habitats, and although it occurs in south-eastern Queensland, the moths only rarely breed in suitable "old growth" forests in heavily shaded areas where the larvae feed only on the very soft, low-growing foliage of the rare vine, *Carronia multisepalea*. Presence of soft leaves (measurable by leaf toughness devices) is critical for survival of young larvae of the moth. The moth usually breeds in steep gorges or where the canopy is closed to avoid desiccation from wind and exposure to bright sunlight. The moth is not known to breed within ca 50 m of open areas or near exposed road reserves (e.g. near Maleny, in SE Queensland), even when the food plant vine appears suitable for larvae. The moth is seasonal in the times of appearance of its larvae and adults and all stages, particularly the young larvae are very susceptible to periods of prolonged drought which also affects the quality of leaves of the food plant vine, *C. multisepalea*.

Direct disturbance, particularly weed invasions and nearby disturbances such as reduction in light entering canopies, and changed wind currents affecting host recognition, can influence the ability of the threatened moth and most populations in Queensland occur in national parks. When well-managed for weeds and without disturbance, National Parks are considered as areas set aside to protect the whole ecosystems for the moths, and to provide undisturbed refuges and habitats for other indigenous fauna and flora.

Food plant – insect interactions.

One species of rainforest vine (*Carronia multisepalea*, Menispermaceae) is known to be a food plant for larvae of the Southern Pink Underwing Moth. Unlike the northern subspecies (ssp. *meyricki* Olliff) where larvae feed on more than one species of vine, larvae of Southern subspecies (ssp. *smithersi)* feed on one vine species when growing in heavily shaded areas. The vine occurs only in south-eastern subtropical and sub-coastal rainforest ecosystems from Kin Kin Creek and the Mary River near Gympie, Queensland (Qld), south to the Bellinger River in New South Wales (NSW). The endemic vine is not considered to be of conservation concern in either State but it is regarded by botanists as rare in Queensland and few localities are known for the vine in NSW. Often overlooked, this species of vine bears male and female flowers on separate plants. Its pollinators have not been identified but may possibly be a rainforest species of ant that has been seen visiting the flowers. The reproduction and recruitment of this species of vine is therefore dependent on presence of both sexes of vine occurring within the range of the pollinators, a possible conservation issue for the abundance and recruitment of the vine if any of its habitats are disturbed. Such impacts on the specific food plant would have flow-on effects on the survival and abundance of the moth.

Both sexes of adult Southern Pink Underwing Moths feed on the juices from overripe and damaged (by other agents) fruit from range of species of plants. They have been seen mainly on over-ripe fruit of figs (e.g. *Ficus watkinsiana*, *F. macrophylla*, *Syzygium* spp.) where they imbibe juices containing sugars needed to sustain their longevity. Moths fed in captivity on over-ripe bananas have lived for 30 days and the females require regular food to develop their reproductive systems (Sands unpublished and in press). Many other fruit (damaged or over-ripe) will in time be found attractive to adult moths. Much more information is available from studies on the northern subspecies, *Phyllodes imperialis meyricci*, from near Cairns and in Papua New Guinea, where its feeding behaviour is similar to that of the southern subspecies.

Vine forms selected by the moth. The vine (*C. multisepalea*) is only utilised as a food plant for the Southern Pink Underwing Moth when it is growing in deep shade and when soft, low emergent growth is emerging either from the vine stems or from ground level from the rhizomes. Moths prefer to oviposit on heavily shaded growth up to 1 m from ground level, or rarely soft horizontal shoots to about 1.5 m. This soft growth occurs usually following periods of rain and female moths will not oviposit on the leaves unless the soft growth is present. Immature stages of the moth have never been observed on vines growing in unshaded areas, near fence lines where larvae are disturbed by airflows from frequent traffic or on the vines when ascending into the canopy. The larvae are believed to be very susceptible to ultra violet light and on one occasion, larvae exposed briefly to sunlight died after attempting to find shade.

The Southern Pink Underwing Moth is believed to be very susceptible to disturbance of vegetation and weeds invasions, in and surrounding breeding habitats, due to its selection of shaded vegetation with low vine growth to maximise larval camouflage and survival from predators.

(ii) Ecological profile of the moth's food plant *Carronia multisepalea*.

Identity. The identity, distribution and distinguishing characteristics of this dioecious vine were recently summarised in Harden et al. (2007). *Carronia multisepalea* is one of 7-8 species in the family Menispermaceae occurring in northeastern NSW. In Queensland, the vine is considered uncommon (Leiper et al., 2008) or rare (P. Grimshaw pers. comm.) and where *Carronia multisepalea* often shares its habitat (see RE's below) with two other rainforest vines, *Melodorum leichhardtii* and *Pararistolochia praevenosa*, the latter the principal food plant for another insect of conservation concern, the Richmond Birdwing Butterfly (*Ornithoptera richmondia*). Both moth (*P. i. smithersi)* and butterfly (*O. richmondia*) share similar habitats and are endemic to subtropical, eastern Australia.

Distribution. Carronia multisepalea is restricted to patches of lowland subtropical rainforests (to 600m), sub-coastally from Kin Kin, Queensland (Qld) to the Bellinger River, NSW, and inland from Conondale ranges, Qld to Dorrigo. Other species of *Carronia* occur in northern Queensland and New Guinea but *C. multisepalea* does not occur north of Gympie, Queensland. The vine usually grows on rich, well-drained basaltic soils, less commonly on other volcanic soils and nutrient-rich alluvial soils, where it favours slopes or steep creek embankments with high water tables. The vines produces long, tapering stems with the young, growing tip often without leaves. The roots form rhizomes from which stems often arise meters from the parent rot stocks. The vine is essentially a component of "old growth" rainforests where it ascends to 10m or more into canopies and where most flowers and seeds are produced.

Vine ecology & insect interactions. Little is published on the ecology of the vine. Male and female flowers are produced on separate vines but seeds are not often formed and uncommonly rarely seen. Most low growth (< 2m, as required by larvae of *P. imperialis smithersi*) is produced from underground rhizomes or shoots (often erect to1m from parent stems). Pollinators are not known but ants are active on flowers and some native bees are suspected to be the pollinating agents. As is common with other Menispermaceae (e.g. Blanchfield et al. 1993, Hungerford et al. 1998), the vine may contain biologically active compounds that are consumed and concentrated by moth larvae when feeding on leaves, and when compound are accumulated in the tissues, used to repel predators. Larvae of most moths recorded feeding on *C. multisepalea* belong to the family Erebidae (Calpinae: tribe Phyllodini) (formerly Noctuidae: Catocalinae) and they have developed defensive strategies including camouflage (e.g. as *P. i. smithersi,* image in Zborowski and Edwards, 2007; *Calyptra* spp.,), warning colours (*P. i. smithersi, Eudocima* spp.) or toxicity.

Architecture of vines. Mature vines of *Caronia multisepalea* are usually spindly and tall when growing in shade (usual growth form seen) but the vine may form spreading canopies over other plants when exposed to sunlight (especially following tree falls) or on exposed slopes of basaltic boulders. The high growth and spreading vines in canopies are not used by larvae of the Southern Pink Underwing Moth but are used by other large moth larvae, producubg similar feeding scars. Flowers of *C. multisepalea* are rarely seen unless low forms are present. In sub-coastal south-eastern Queensland most flowering has been observed from mid late September. The seedlings grow slowly in shade but growth is rapid after rain in open areas not used by the moth larvae. The vines used for breeding by the moth are therefore scattered and occur in localised shaded patches.

Cultivation of Carronia multisepalea*.* The vine has been grown from cuttings and seeds but the success of germination and root growth from cuttings has been slow, and the propagation methods are not easily defined when compared to the propagation of the rainforest vine, *Pararistolochia praevenosa*, used in other rainforest insect conservation projects (Sands and Grimshaw (2013). Sands in 1992 propagated severl vines from cuttings using a root hormone but the "take" (production of roots) was very low and the plants did not thrive after they had reached about 30 cms (at Chapel Hill, Qld). Attempts to propagate numbers of *C. multisepalea* by Barung Nursery at Maleny, Qld as part of a community recovery effort for *P. i. smithersi* met with delays in production of sufficient vines for distribution. However, *Dorrigo Environment Watch Inc.* Dorrigo, NSW, have grown a few plants of *C. multisepalea* from cuttings. At least 2 vines have continued to grow and one is currently thriving (Trevor & Carol Deane pers. comm.). The vine is unlikely to be amenable to translocation of rootstocks due to its extensive and branching sub-surface nature. Care needs to be taken when handling cutting materials due to the possible presence of biologically active compounds known to be present in other species of Menispermaceae (Blanchfield 1994). The Reviewer notes that translocation of the vine is no longer proposed (Response to Agency Comments W2B).

Rehabilitation of breeding sites for *Phyllodes imperialis smithersi*.

Unlike the relative ease for propagating and planting out the lowland birdwing butterfly vines (*Pararistolochia praevenosa*), to attract butterflies to breed, the moth's narrow environmental (plants, climate, landforms) envelope will make the rehabilitation of breeding habitats difficult and prolonged. It would appear that planting the vine *Carronia multisepalea* in places suitable for oviposition, would require: (i) heavy shading, (ii) nearby (? distance) watercourses for searching adults, (iii) permanent moisture, (iv) nearby plants suitable for the vine substrates, and (v) selection of sites where plants associated with the vine (e.g. almost same as for *P. praevenosa*) are already present.

(iii) *Atlas Ground Beetle.*

The identity and distribution of this beetle has been summarised on the website Atlas of Living Australia. The distribution of the beetle is wider that that of the Southern Pink Underwing Moth with records from Atherton tablelands and central NSW. Little is known about the ecology of this beetle but new information has come from the surveys by BAAM. These surveys would indicate that burrows need some overhang, protection (e.g. overhanging log) or embankment, and the Reviewer considers soil type (e.g. basaltic soils) may be important, based on information available for other large ground beetles. The type of rainforest ecosystems and particular plants may also be important. It may be possible to develop micro-habitats in areas rehabilitated. Use of night vision glasses in surveys could contribute to information about nocturnal activity away from burrows, prey, ground shelters and any particular plants used for making burrows (other than While Cedar).

6. Feasibility for developing a Management / Recovery Plan for the Southern Pink Underwing Moth (*Phyllodes imperialis smithersi)*

Preamble. In New South Wales, listing an animal as 'threatened' is recognized by agencies as a catalyst for development of a Recovery Plan. In some other States a Management Plan is though to be adequate to address threatening processes. However, in several states recovery and management plans have not been developed for the majority of listed species. . 'Listing' is not seen as an adequate step to protect a species unless actions to recover the species are identified. The objectives for any Recovery Plan is to address threats, to prevent declines in numbers and in numbers of populations, and to ultimately aim at down-listing the species (or subspecies), provided management for the species includes on-going management of threats (see Sands 1999, Sands and New 2002).

Threats. Very little is know about the ecology of the Southern Pink Underwing Moth (*P. imperialis smithersi*) but its habitats are known to be lowland subtropical rainforest of Australia (NS and Qld) where it is dependent on one species of vine, *Carronia multisepalea*. Some threats (e.g. habitat loss, loss of food plant, weed invasion) are easily identified to for the basis of a recovery plan but how to address these threats requires planning and expert guidance. Most ecosystems that support the Pink Underwing Moth have been threatened by human disturbance and by weeds (camphor laurel, lantana) displacing the plant communities and several grasses (green panic, molasses grass) after invading the understory, threaten habitats by increases in flammability. A serious threat, the insecurity of tenure of habitats (including national parks) may threaten remnants of all indigenous biodiversity in Australia.

A Proposed feasibility study. At a workshop hosted by CSIRO Ecosystem Sciences (Canberra, 6-7 July 2013) several insects of conservation concern were discussed. The Southern Pink Underwing Moth was seen as one species to benefit from habitat management and likely to gain the interest of community groups in northern NSW as a 'Flagship species'. With these species, agencies and the community can contribute to recovery, similar to the contributions to the *Richmond Birdwing Butterfly Conservation Project* (e.g www.richmondbirdwing.org.au), a species that occupies similar habitats. As it is known the southern limit for the moth is Dorrigo-Bellinger River, members of the *Dorrigo Environment Watch Inc*., attending the Canberra Workshop expressed interest in commencing a feasibility study for recovering the moth. Since then in conjunction with their plant nursery, they have been seeking ways to support the first activity - how to cultivate the moth's food plant, *Carronia multisepalea*. Members have already had success in striking cuttings and have one or two vines producing growth after they have been planting out.

Members of *Dorrigo Environment Watch* (DEW) have invited three people as an Advisory Team to assist with developing a 'feasibility study' on the moth: Drs David Britton (Australian Museum, Sydney), Michael Braby (Northern Territory Govt.) and Don Sands (CSIRO Ecosystem Sciences, Brisbane). Objectives of the DEW 'feasibility study' are to: (i) develop methods to propagate *C. multisepalea*, (ii) expand community awareness for the plight of the moth in the region (with workshop / talks), (iii) commence mapping of moth habitats and *C. multisepalea* (north from Bellinger River, NSW), and (iv) integrate information on the moth from further north in its range (including Queensland) to guide production of a recovery plan.

Opportunities to support the DEW *'feasibility study'*

For threatened insect species "offsets" have sometimes been put in place to stabilise declining species populations and gain the recognition and support by members of the community. In their feasibility study, *DEW* will require funds to develop and evaluate their propagation facility and materials (e.g. root hormones, shade cloth, potting mixes, stakes), to run community workshops, to cover travel costs for preliminary mapping etc. I warmly recommend that the Main Roads Authority consider support that could enable *Dorrigo Environment Watch* to begin these activities and I am happy to help facilitate contacts between the two groups.

Publicity. In the local media several years ago, media publicity was given when habitats of the endangered Bathurst Copper Butterfly (*Paralucia spinifera*) were threatened by roadworks near Bathurst, NSW. This related to efforts by the Authority to avoid and then re-locate food plants from the path road widening. The work was recognised by the community as unusually considerate and it has been followed by several local conservation activities sponsored by the Bathurst Council (including publicity by the Lord Mayor, Bathurst).

There is an opportunity for the NSW Main Roads to publicise their efforts to consider impacts on threatened insects and the successes by the contracted surveyors (BAAM) towards locating threatened insect species. Local communities need to be made aware of the importance of protecting threatened species and their habitats (not only koalas!), and how generic threat abatement and off-set strategies can be sought to address potential threats from the range of human environmental disturbances.

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Curriculum Vitae: Dr Donald Sands

Don Sands is an insect taxonomist and ecologist, having specialised in the identities and interactions of predators and parasitoids with their hosts, and how to ensure safety of biological control agents when introduced from overseas in biological control programs. Don's studies sought to distinguish and select those species likely to be efficient for controlling their hosts (plants and insects) from those with benign impacts. His research on insect interactions led more recently to focus on insect conservation issues, particularly beneficial insects in farming systems, as well as 'flagship species' - those charismatic species that can be used as icons for the community, and to involve members in the conservation and rehabilitation of threatened species.

Don joined CSIRO Division of Entomology in Sydney in 1967 to study the biological control of fruit flies and scale insects and in 1972 he transferred to Papua New Guinea to work on agricultural pests, re-joining CSIRO in Port Moresby in 1973 to work on ecology and control of the Old World Screw Worm Fly. In 1978 he returned to Brisbane to work on biological control of the weeds and subtropical pests of horticulture (including fruit-piercing moth *Eudocima* spp.). He applied taxonomic principals to correctly identify and biological control agents in the insect orders Lepidoptera, Coleoptera and Hymenoptera. He developed collaboration with several overseas projects and was involved in the successful biological control of 5 major international weed species and of 6 insect pests. He published more than 120 scientific papers and five books. As a Post-retirement Fellow he wrote two major works, *Biological Control of Arthropods in Australia* (with Dr DF Waterhouse, ACIAR) and *The Action Plan for Australian Butterflies* (with Prof. TR New), the latter to review the conservation status of all Australian butterflies.

Don's conservation research and concerns began in the 1990s (e.g. Richmond birdwing butterfly, *Ornithoptera richmondia*) ands was followed by a research project on the Queen Alexandra's Birdwing Butterfy (*Ornithoptera alexandrae*), a large and spectacular threatened species of international concern. His studies with CSIRO on fruit piercing moths led to the discovery in 1987 of spectacular, non-destructive related Southern Pink Underwing Moth, subsequently recognised as endangered species (Federal, NSW). Most recently Don published the description of this moth and provided a name for this new and unnamed sub-species. This moth, the Southern Pink Underwing Moth (*Phyllodes imperialis smithersi*), is becoming an icon for insect conservation, and is threatened by its dependence on only one endemic vine as a food plant, occurring in threatened fragments of the subtropical rainforests of eastern Australia.

Academic qualifications:

MSc (1976), PhD (1982); *Associate Australian Institute of Medical Science* (1965).

Employment & postings:

1967-1972	CSIRO Division of Entomology, Sydney, NSW
1972-1973	Department of Agriculture, Stock and Fisheries, Lae, Papua New Guinea
1973-1978	CSIRO, Division of Entomology, Port Moresby. Papua New Guinea
1978-1997	CSIRO Division of Entomology, Brisbane:
	Experimental Officer 1978-1983,
	Senior Research Scientist 1983-1985,
	Principal Research Scientist 1985-1994,
	Senior Principal Research Scientist 1994-1997; Officer-in-Charge Brisbane 1992 – 1995, Deputy Program Leader 1995 - 1997
1998 -	Post-retired Fellow, Honorary Research Fellow; CSIRO Ecosystem Sciences

Awards

1985. *UNESCO Science Prize* (with CSIRO colleagues). The specific contribution by Sands was identified as "… discovery by Sands of a weevil previously unknown to science;..."

1988. *AIDAB Award for Excellence in Overseas Development Assistance* (shared with colleagues).

1990. *EUREKA POL Prize* (with colleagues). For Environmental Research, hosted by the Australian Museum, Sydney, for "Scientific excellence in research leading to the resolution of an environmental problem".

1990. *ROLEX AWARD FOR ENTERPRISE*, Honourable Mention (with colleagues)

1991. *CSIRO National Incentive Scheme*, for work done in National Interest. Awarded for contributions towards biological control of scale insects.

2001. *Medal of the Order of Australia*. For service to the horticultural industry in Australia and the Pacific region through the development of biological pest control solutions, and to entomology particularly through conservation projects.

2010 *Australian Natural History Medallion*. Nomination by the Australian Entomological Society.

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Appendix 1. Plant communities associated with *Caronia multisepalea* (in SE Queensland)

(RE: Regional ecosystems classification of plant communities in Queensland)

RE 12.2.1 Notophyll / evergreen vine forest (rarely) . Moist or wet valley floors of parabolic high sand dunes.

RE 12.2.2. Mixed microphyll / notophyll vine forest (rarely). Coastal dunes and behind beach ridges.

RE 12.3.1 Complex to simple notophyll vine forest and gallery rainforest edging stream channels (usually). Quaternary alluvial soils and plains, edging stream channels and embankments in high rainfall areas.

RE 12.3.2 Tall, wet sclerophyll forest, with rainforest understory (usually). Soils of alluvial plains, fringing streams and narrow gullies in high rainfall areas.

RE 12.5.13. Microphyll and notophyll vine forest (rarely). Soils on lateritised basalt .

RE 12.8.3 Complex and wet notophyll vine forest (rarely). Soils on igneous rocks, especially basalt.

RE 12.8.4 Complex Araucarian notophyll vine forest (rarely). Soils on igneous rocks including basalt and lateritised basalt.

RE 12.8.13 Microphyll / notophyll rainforest (usually). Soils on igneous rocks, especially basalt.

RE 12.11.1 Simple notophyll vine forest (rarely). Sils of gully floors on old, deformed metamorphic sediments and volcanic rocks.

RE 12.11.2 Tall moist-adapted eucalypt forest with rainforest understory (rarely). Soils on strongly metamorphosed sedimentary and inter-bedded metamorphic rocks.

RE 12.11.10 Evergreen notophyll vine forest ()usually). Soils on metamorphosed sedimentary and sometimes inter-bedded metamorphic rocks.

Appendix 2. Plant nurseries with cultivation experience on *Carronia multisepalea*

1. *Dorrigo Environment Watch Inc.*, PO Box 284, Dorrigo, NSW. 2453. Has grown *C. multisepalea* from cuttings. At least 2 vines have continued to grow and one is currently thriving (Trevor Deane pers. comm.). Likely to provide information on cultivation of the vine.

2. Barung Nursery. Shop 3, Riverside Centre, Maleny, Qld 4552. No longer growing *C. multisepalea* but cultivators may have useful information on propagation.

Appendix C – Southern Pink Underwing Moth species profile

Southern Pink Underwing Moth
(*Phyllodes imperialis smithersi*)

Photo source: Dr Don Sands

Adult Southern Pink Underwing Moth

***Carronia multisepalea*, host plant for Southern Pink Underwing Moth (and also Common Fruit-piercing Moth; see below)**

Mature larva of Southern Pink Underwing Moth on its host plant, in alarmed position

Mature larva of Southern Pink Underwing Moth on its host plant, in resting position

Eggs (left) and young larva (right) of Southern Pink Underwing Moth on the underside of a leaf of its host plant

Larva of Common Fruit-piercing Moth (a non-threatened species) on the same species of host plant used by Southern Pink Underwing Moth

DESCRIPTION

- A large moth with leaf-like wings that camouflages well against foliage; hind wings (normally hidden when stationary) have distinctive pink and black colouration.
- Larvae feed on the foliage of *Carronia multisepalea*, a plant that grows in the form of a shrub or a vine on rich volcanic soils in association with mature rainforest and regrowth vegetation.
- Immature larvae are cryptic (twig-like) and often occur on the underside of leave and sometimes on stems
- More mature larvae have a characteristic threat display as pictured

SIMILAR SPECIES

- Common Fruit-piercing Moth *Eudocima fullonia*
  - Adult moth a similar size and shape; hind wings *orange* and black (rather than pink and black).
  - Larvae also occur on the same vine, but are more uniformly brown and have two “eye spots” on each side.

CURRENT LEGISLATIVE STATUS

EPBC Act: Endangered; TSC Act: Endangered.

AUSTRALIAN DISTRIBUTION

From near Gympie in south-eastern Queensland south to near Urunga in north-eastern New South Wales.

Source: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=86084

HABITAT

- Rainforest on rich volcanic soils and fertile alluvium where the host vine, *Carronia multisepalea,* is present.
- The adult feeds on the soft fruits of native rainforest plants, including *Ficus* and *Syzigium* and possibly also on fruits of cultivated plants in the vicinity of rainforest.

THREATS

- Habitat loss and fragmentation due to clearing for various purposes.
- Degradation of habitat through disturbance and weed invasion.
- Adult moths may be displaced through attraction to artificial light sources.

KEY MANAGEMENT REQUIREMENTS

- The project boundary (i.e. area intended for vegetation clearing) is to be pegged out prior to site inspection.
- A site inspection by an ecologist would be required on each day prior to the clearing of mapped potential habitat for Southern Pink Underwing Moth.
- The ecologist would check the area thoroughly for the presence of the host plant (*Carronia multisepalea*).
- On each occasion where a host plant is located within the project boundary, the plant would be checked thoroughly for eggs or larvae.
- The identification of any larvae would be checked carefully to confirm if it matches Southern Pink Underwing Moth (c.f. Common Fruit-piercing Moth)
- Any eggs located on the host plant would be assumed to belong to Southern Pink Underwing Moth
- Any larvae or eggs would be relocated to another host plant >10 m outside of the project boundary; preference would be given to a plant that has ample foliage and at least some evidence of host use by the moth (e.g. recent feeding activity; or 1–2 larvae already present).
- The development of any relocated immature stages would be monitored for three weeks following translocation.

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