Nest box Monitoring Report - Woolgoolga to Ballina Pacific Highway Upgrade (Sections 3 -11) Year 1 2018

Pacific Complete

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Abbreviations

Abbreviation	Description
BC Act	NSW *Biodiversity and Conservation Act 2016*
ELA	Eco Logical Australia
EPA	Environmental Protection Authority
HBT	Hollow Bearing Tree
HDF	Hollow Dependent Fauna
MCoA	Ministers Condition of Approval
NBMP	Nest Box Management Plan
NBRZ	Nest Box Replacement Zone
NP	National Park
NR	Nature Reserve
PC	Pacific Complete
RMS	Roads and Maritime Services
SCA	State Conservation Area
W2B	Woolgoolga to Ballina

Executive Summary

Eco Logical Australia (ELA) has been engaged by Pacific Complete (PC) to undertake Nest Box Installation and Monitoring for Sections 3-11 of the Woolgoolga to Ballina Pacific Highway Upgrade (W2B). This includes supply, delivery, installation, monitoring and maintenance of approximately 700 nest boxes of 22 different types along the 155 km Pacific Highway corridor between Woolgoolga and Ballina.

The primary objective of nest box installation is to provide some compensation and alternative habitat provisions for hollow dependent fauna that will be impacted by the removal of hollow-bearing trees cleared as part of the W2B project. A range of hollow-dependent threatened and protected fauna species are known to occur across Sections 3 – 11, including forest owls, woodland birds, microbats and arboreal mammals. Nest box installation is one of many mitigation measures being implemented to minimise impacts to native fauna species from the W2B project and forms part of the Ministers Conditions of Approval for the project.

To date, almost 700 nest boxes constructed from a range of materials (hardwood, marine ply and Cyplas) have been installed between Section 3-11 of the W2B project, comprising approximately 70% of the total required to be installed prior to clearing of vegetation. The remaining 30% of nest boxes are to be installed post-clearing once a final tally of functional hollows has been compiled.

Nest boxes are to be monitored in Years 3, 4, 6 and 8 of the project (corresponding to 2018, 2019, 2021 and 2023). Monitoring of boxes is to be undertaken twice per year in Autumn and Spring and this report summarises the results of the first year of monitoring undertaken in 2018. A range of performance measures are addressed to ensure the nest boxes are being used by a wide range of fauna species and that target fauna species are inhabiting and breeding in boxes designed specifically for them. Performance measures are also aimed at ensuring there is minimal uptake of nest boxes by pest species and low rates of repair and maintenance issues. Corrective actions are provided where performance criteria are not being achieved.

Results of 2018 monitoring indicate that three of the performance criteria are being satisfactorily achieved. A range of fauna species are inhabiting the nest boxes with 19 vertebrate species recorded in nest boxes during 2018. Overall rates of use (boxes inhabited and those with evidence of former occupation) were 56% in autumn and 55% in spring, which is comparable to overall rates of use on similar nest box monitoring projects undertaken as part of the Pacific Highway upgrade in NSW (Goldingay 2019, Ecosure 2017, Sandpiper 2013, 2015, 2016a, 2016b, 2016c, 2017a and 2017b). However, only four (mammals) of the nineteen species recorded using nest boxes account for the large majority of records.

There were multiple instances of breeding recorded in both marine ply and Cyplas nest box material types. Species recorded breeding in boxes included *Aegotheles cristatus* (Australian Owlet Nightjar), *Chenonetta jubata* (Australian Woodduck), *Cormobates leucophaea* (White-thraoted Treecreeper), *Petaurus breviceps* (Sugar Glider), *Petaurus norfolcensis* (Squirrel Glider) listed as vulnerable under the BC Act, *Platycercus eximius* (Eastern Rosella), *Pseudocheirus peregrinus* (Common Ringtail Possum) and *Trichosurus vulpecula* (Common Brushtail Possum).

Rates of nest box use by target species are low overall with only 65 boxes (9%) occupied by the target fauna species or group during 2018 and not meeting the performance criteria. Only Glider front and rear entry boxes and three-chambered bat boxes attained occupancy rates of greater than 10% by the target species / group thereby meeting the performance criteria. None of the bird boxes were occupied by the target bird species or species group during 2018 and only five boxes (1%) showed evidence of occupation by the target bird species.

The rates of uptake by pest species are low and below target (<10%), with ants, *Apis mellifera* (European bees), termites, and wasps being the main pest issues. Most pest issues were easily addressed in situ and not evident during the subsequent nest box inspection. The rates of repair and maintenance required are also low and below target with 60 boxes (<10%) requiring maintenance during 2018. Most maintenance issues are addressed in situ during nest box checks but there are 33 boxes which will need to be replaced during 2019 as a result of loss throughclearing, fire, theft, termite damage or persistent pest issues.

Uptake of nest boxes by a range of target threatened fauna has been relatively low with only three of the 24 target threatened species recorded inhabiting boxes during 2018. *Petaurus norfolcensis* (Squirrel Glider) have been recorded in Sections 3, 5, 7, 8, 9, 10 and 11. There have been numerous observations of Squirrel Gliders with young at various ages indicating the boxes are also used for breeding purposes. The two other threatened species recorded include two observations of *Phascogale tapoatafa* (Brush-tailed Phascogale) within Brush-tailed Phascogale boxes in Section 3 during Autumn 2018 and four colonies (3 - 10 bats) of *Nyctophilus bifax* (Eastern Long-eared Bat) in Sections 7, 10 and 11.

Overall rates of use for Cyplas boxes were consistently greater than for timber boxes. There was a trend for Cyplas boxes to be preferentially inhabited over timber boxes. The range of fauna species recorded in Cyplas boxes was lower than for timber boxes with a total of 11 species recorded compared to 16 species recorded in timber boxes. Two of the three target threatened fauna species recorded during 2018 were also recorded using Cyplas boxes designed for their use; Brush-tailed Phascogale and Squirrel Glider. There has been evidence of Australian Owlet Nightjars, Sugar Gliders, Common Ringtail Possums, Squirrel Gliders and Common Brushtail Possums using Cyplas boxes for breeding purposes. The rates of occupancy of Cyplas and timber boxes by the species for which the box was designed are low and do not differ markedly overall or within taxa (birds and mammals). The rates of uptake by pest species in Cyplas boxes are very low (6%) and there were no instances of termites recorded in Cyplas boxes. Rates of pest species uptake of Cyplas boxes are significantly lower than timber boxes, and this is largely a result of significantly fewer ants recorded in Cyplas boxes than in timber boxes. Once boxes lost through clearing, fire and theft were removed from the analysis, repair and maintenance rates of Cyplas boxes were lower than for timber boxes. Only four of monitored Cyplas boxes (1%) and 24 of monitored timber boxes (3%) required active intervention to remain functional, well within the performance indicator target of < 10% in both cases.

Construction works and active vegetation clearing within and adjacent to the Nest Box Replacement Zones (NBRZs) have been a feature of the nest box monitoring period in Sections 3 – 11 of the W2B project between June 2017 and December 2018. The general fauna and threatened species habitation rates, pest species uptake and repair and maintenance levels for nest boxes reported on Sections 3-11 of the W2B project during 2018 fall within the ranges reported for nest boxes installed and monitored on other sections of the Pacific Highway upgrade to the south of the W2B project. The lack of use of

nest boxes by target species or species groups is also a feature common to other RMS nest box projects (Goldingay 2019) and is not unexpected.

1. Introduction

1.1 Background

Eco Logical Australia (ELA) has been engaged by Pacific Complete (PC) to undertake Nest Box Installation and Monitoring for Sections 3-11 of the Woolgoolga to Ballina Pacific Highway Upgrade (W2B) as per the specifications set out in the Nest Box Management Plans (NBMPs) for each Section (GeoLINK 2014a and 2014b, AECOM 2014, Biosis 2014, Melaleuca Group 2014, Australian Museum Consulting 2014). This includes supply, delivery, installation, monitoring and maintenance of approximately 700 nest boxes along the Pacific Highway corridor between Woolgoolga and Ballina.

The W2B project comprises approximately 155 km of upgraded highway achieving a four-lane divided road extending north of Woolgoolga to south of Ballina. The W2B project has been sub-divided into sections from 1 to 11 with Sections 1 and 2 having already been completed. Sections 3 – 11 of the W2B project run from Glenugie to Ballina passing through largely cleared floodplains and crossing the Clarence and Richmond Rivers, passing through or along the edges of forested lands including Glenugie, Mororo, Devil's Pulpit, Tabbimoble and Doubleduke State Forests, Yaegl and Tabbimoble Nature Reserves (NR), Yuraygir, Bundjalung and Broadwater National Parks (NP) and Bundjalung State Conservation Area (SCA).

The primary objective of the NBMP for each Section is to outline measures to mitigate the impacts of vegetation clearing on hollow-dependent fauna. In doing so the NBMPs provide guidance on the provision of nest boxes as a short term compensatory mechanism for fauna that may be displaced by the loss of habitat trees within the clearing area, inclusive of denning, roosting and nesting resources. The list of threatened hollow dependent species referred to as target species in each NBMP is slightly different for each Section because of changes in vegetation and proximity of each Section to existing populations of threatened species. **Table 1** provides a combined list of 24 threatened hollow dependent fauna species known from records within 5km of the W2B alignment that were targeted by the NBMPs and / or listed as threatened under the BC Act or EPBC Act since the NBMPs were prepared.

The NBMP's state that almost 700 nest boxes are required to be installed, with 70% of those installed prior to clearing of vegetation. The remaining 30% of nest boxes are to be installed post-clearing once a final tally of functional hollows has been compiled from data collected during clearing supervision. The final 30% should be installed within three months post completion of clearing once the exact number of hollow-bearing trees removed is known.

The NBMPs provide details on the numbers and types of nest boxes required to be installed based upon the results of ground based surveys of hollow bearing trees (HBTs) within the clearing footprint and in reference sites adjacent to the alignment. Surveys of HBTs estimated the number and size class of hollows contained within each HBT scheduled to be cleared and this list of hollows was used to provide the proportional allocation of nest box types within each section. The Nest Box Replacement Zones (NBRZs) are smaller areas within each W2B section that provide a practical organisational structure and suitable location for the installation of nest boxes. Nest boxes are required to be installed in NBRZs where the density of HBTs in the adjacent landscape is equal to or less than 4 hollow-bearing trees (HBTs) per hectare. There were no surveys of HBTs completed within the NBRZs.

The Ministers Conditions of Approval (MCoA) for the project states that nest boxes are to be monitored in Years 3, 4, 6 and 8 of the project (corresponding to 2018, 2019, 2021 and 2023). Monitoring of boxes is to be undertaken twice per year. The NBMPs indicate that nest boxes are to be monitored in winter and spring when fauna are most active, and most likely to be using nest boxes. Timing of monitoring events was adjusted by PC prior to commencement of monitoring to autumn and spring to align with timing of nest box monitoring in Sections 1 and 2 of the W2B highway upgrade as agreed with the Envrionmental Protection Authority (EPA) and approved by the Environmental Represeantive for W2B.

This report outlines details relating to the installation of nest boxes, the standard inspection methods used, and the results of inspections conducted in autumn and spring 2018. The report also outlines whether the nest boxes are meeting performance indicator targets and provides a range of corrective actions to determine the most appropriate measures to achieve the performance criteria.

Table 1. Combined list of threatened hollow dependent fauna species and the target nest box type included in the NBMPs for Sections 3 – 11 of the W2B project.

Scientific name	Common Name	BC Status	EPBC Status	Target Box Type
Aves				
Calyptorhynchus lathami	Glossy Black-cockatoo	V		Cockatoo / Large Owl
Climacteris picumnus picumnus	Brown Treecreeper	V		Tree Creeper
Glossopsitta pusilla	Little Lorikeet	V		Small Parrot
Ninox connivens	Barking Owl	V		Cockatoo / Large Owl
Ninox strenua	Powerful Owl	V		Cockatoo / Large Owl
Tyto novaehollandiae	Masked Owl	V		Cockatoo / Large Owl
Tyto tenebricosa	Sooty Owl	V		Cockatoo / Large Owl
Mammals				
Dasyurus maculatus	Spotted-tail Quoll	V	E	Spotted-tail Quoll
Petauroides volans	Greater Glider		V	Possum / Large-Glider
Petaurus australis	Yellow-bellied Glider	V		Possum / Large-Glider
Petaurus norfolcensis	Squirrel Glider	V		Glider (front and rear entry)
Phascogale tapoatafa	Brush-tailed Phascogale	V		Phascogale
Microbats				
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	Single, 2, 3 or 4 chambered microbat

Scientific name	Common Name	BC Status	EPBC Status	Target Box Type
Chalinolobus nigrogriseus	Hoary Wattled Bat	V		Single, 2, 3 or 4 chambered microbat
Falsistrellus tasmaniensis	Eastern False Pipistrelle	V		Single, 2, 3 or 4 chambered microbat
Kerivoula papuensis	Golden-tipped Bat	V		Single, 2, 3 or 4 chambered microbat
Miniopterus australis	Little Bent-winged Bat	V		Single, 2, 3 or 4 chambered microbat
Miniopterus schreibersii oceanensis	Eastern Bent-winged Bat	V		Single, 2, 3 or 4 chambered microbat
Mormopterus beccarii	Beccari's Free-tailed Bat	V		Single, 2, 3 or 4 chambered microbat
Mormopterus norfolkensis	Eastern Free-tailed Bat	V		Single, 2, 3 or 4 chambered microbat
Myotis macropus	Southern Myotis	V		Single, 2, 3 or 4 chambered microbat
Nyctophilus bifax	Eastern Long-eared Bat	V		Single, 2, 3 or 4 chambered microbat
Saccolaimus flaviventris	Yellow-bellied Sheath-tailed Bat	V		Single, 2, 3 or 4 chambered microbat
Scoteanax rueppellii	Greater Broad-nosed Bat	V		Single, 2, 3 or 4 chambered microbat

The details of all fauna displaced by clearing activities in Sections 3 – 11 of the W2B project have not yet been compiled. Once those details are available comparisons can be made between the abundance and occurrence of fauna species prior to clearing and that observed to be occupying nest boxes during subsequent monitoring inspections.

1.2 Performance criteria

The monitoring program is intended to allow for evaluation of the nest box strategy and the effectiveness of nest boxes as alternative and replacement habitat for the loss of hollows. It will also allow for repair and replacement of nest boxes over time to ensure that alternative habitat remains viable in the medium term. Evaluation of the nest box strategy is against the following performance indicators over the monitoring period:

1. Use of nest boxes by a wide range of native fauna. If the combined species overall rates of use are equal to or greater than 50% the performance measure is considered to have been achieved. Evidence of a range of fauna species occupying nest boxes throughout the year and using boxes for breeding as well as shelter. If 50% or more of the fauna species displaced by clearing are recorded using (occupying or with evidence of occupation) nest boxes the performance measure is considered to have been achieved. If a box has not been occupied by any fauna after four years, consider moving to an alternative location.
2. Use of nest boxes designed for a target species being used by that species. Measured by reporting on the percentage of boxes inhabited by the target species or species group (nest box type). If the rate of occupation is equal to or greater than 10% the performance measure is considered to have been achieved. Also measured by reporting on the occupancy and usage rates of nest boxes by target threatened fauna species. If uptake is less than 10%, re-evaluate nest box placement and type.
3. Low rates of usage by exotic fauna. Measured by reporting on the percentage of boxes inhabited by pest species. If the percentage is equal to or less than 15%, the performance measure is considered to have been achieved. If exotic fauna usage is higher than 15%, consider applying suitable deterrents and / or re-positioning nest box to deter pest species.
4. Reduced maintenance requirements. Measured by reporting on the percentage of boxes requiring maintenance or repair. If the percentage is less than 10%, the performance measure is considered to have been achieved. At higher rates, notification to RMS is required to allow for an increase in funding for future replacement and repair costs of nest boxes.

1.3 Installation

Nest boxes were installed by a number of contractors over a number of separate periods of installation between 2015 and 2018 with the majority installed in 2016 and 2017. As a result, boxes have been in place for between 6 months and 3.5 years as at December 2018. Dates of installation for each section appear in **Table 2** below (where date of installation was available or provided by contractors). Locations of NBRZs containing nest boxes in Sections 3 -11 of the W2B project are shown in **Figure 1- 9** below.

Nest boxes were constructed from a range of materials including locally sourced hardwood, marine ply and Cyplas (recycled plastic) with the aim of providing data on the nest box preferences of fauna in the region and the performance of different nest box materials (**Figure 10 – 12**). Approximately two thirds of boxes (476 in the 70% pre-vegetation clearance allocation) were to be constructed from timber because this material is known to be occupied by a range fauna species. Approximately one third of boxes (180 in the pre-vegetation clearance 70% allocation) were to be constructed from Cyplas. The reason for the lower proportional allocation of Cyplas boxes was because this material had not been documented to perform at levels similar to timber boxes. Nest boxes were purchased from a range of suppliers including commercial businesses, Grafton Men's Shed and OCI Caringa which provides supported employment to people with disabilities. A total of 20 types of nest boxes were installed within Sections 3 – 11 of the W2B project and the entrance size of each nest box type is listed in **Table 3** below.

Nest boxes on the W2B project are installed at heights ranging from 3 to 18 m in line with the installation guidelines for each species as set out within the NBMPs. All NBRZs were inspected prior to installation of boxes to ensure each receptor site contained suitable habitat for nest box installation and would

remain accessible throughout the construction and operational periods of the W2B project. There is no data currently available on the density of HBTs within each NBRZ.

Table 2. Timing of nest box installations by year on Sections 3 – 11 of the W2B Pacific Highway upgrade.

Section	2015	2016	2017	2018
3A				Jan
3		Feb, July, Sept	Mar, June	
4	June & Sept	Feb, June		
5		Feb, Oct		
6		Dec	Jan, July	Oct
7		July, Nov	Jan	
8	Sept	July, Nov	Jan	
9			Jan	
10		Nov	May	
11	Oct	Mar	May	

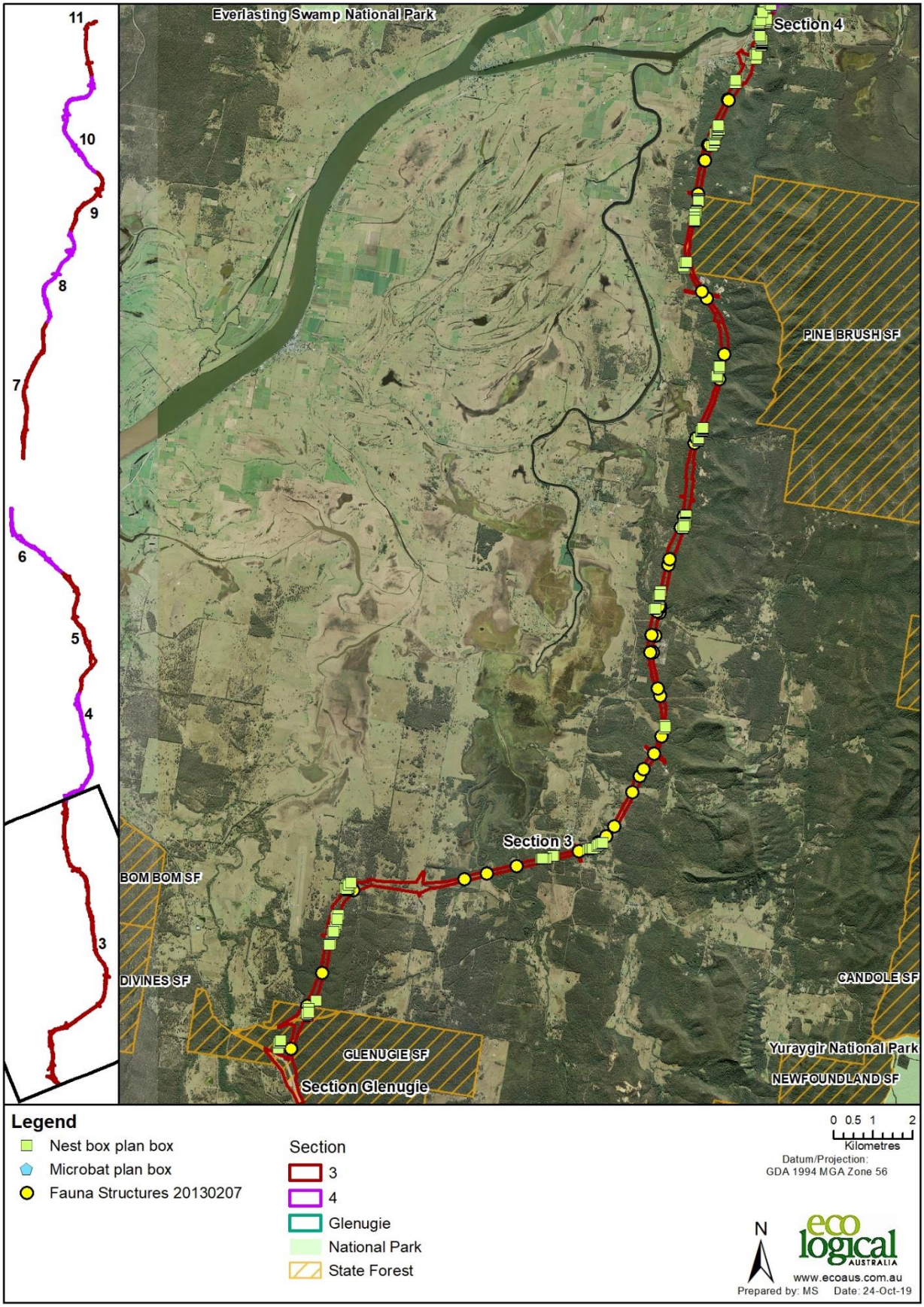

Figure 1. Section 3 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

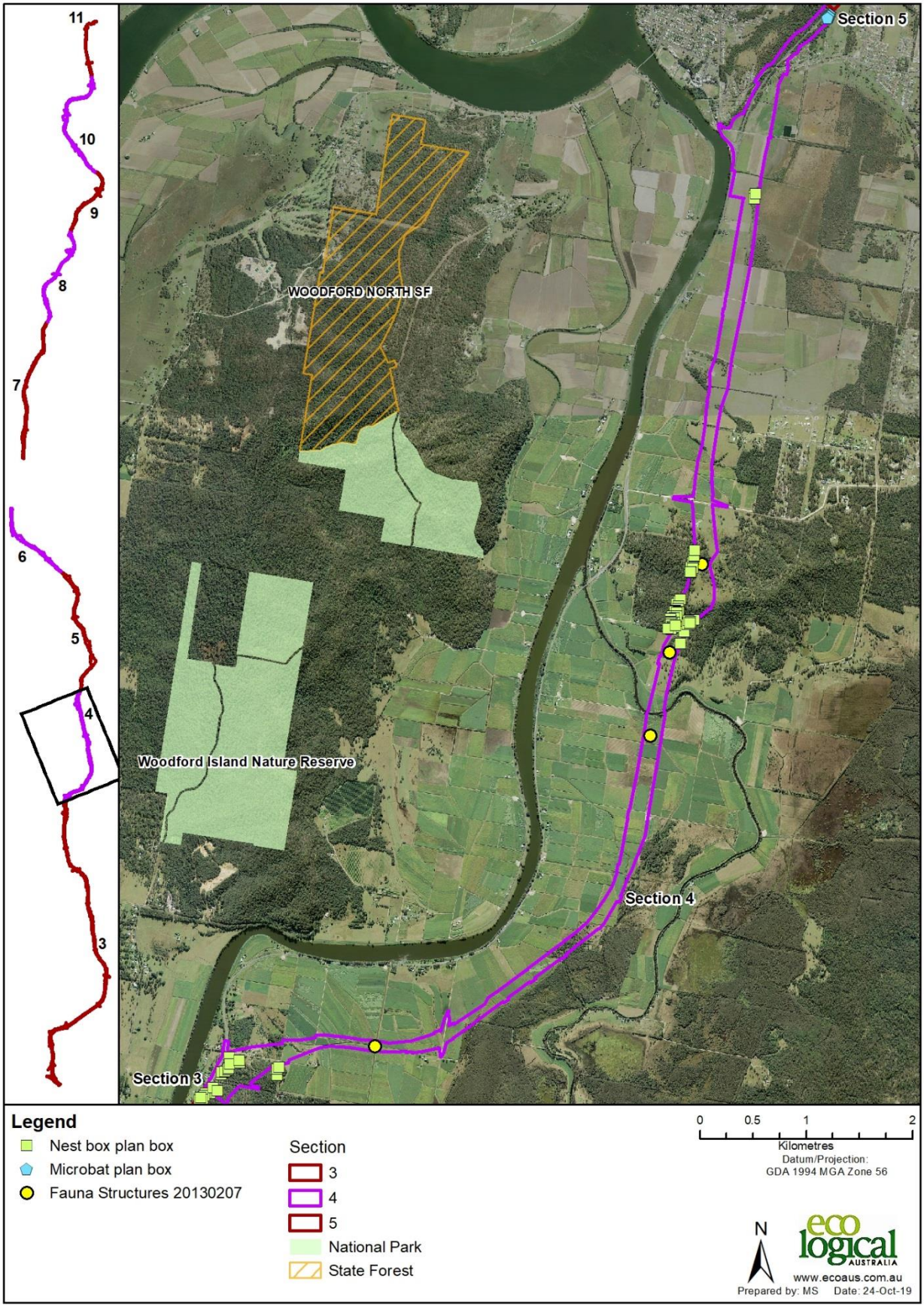

Figure 2. Section 4 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

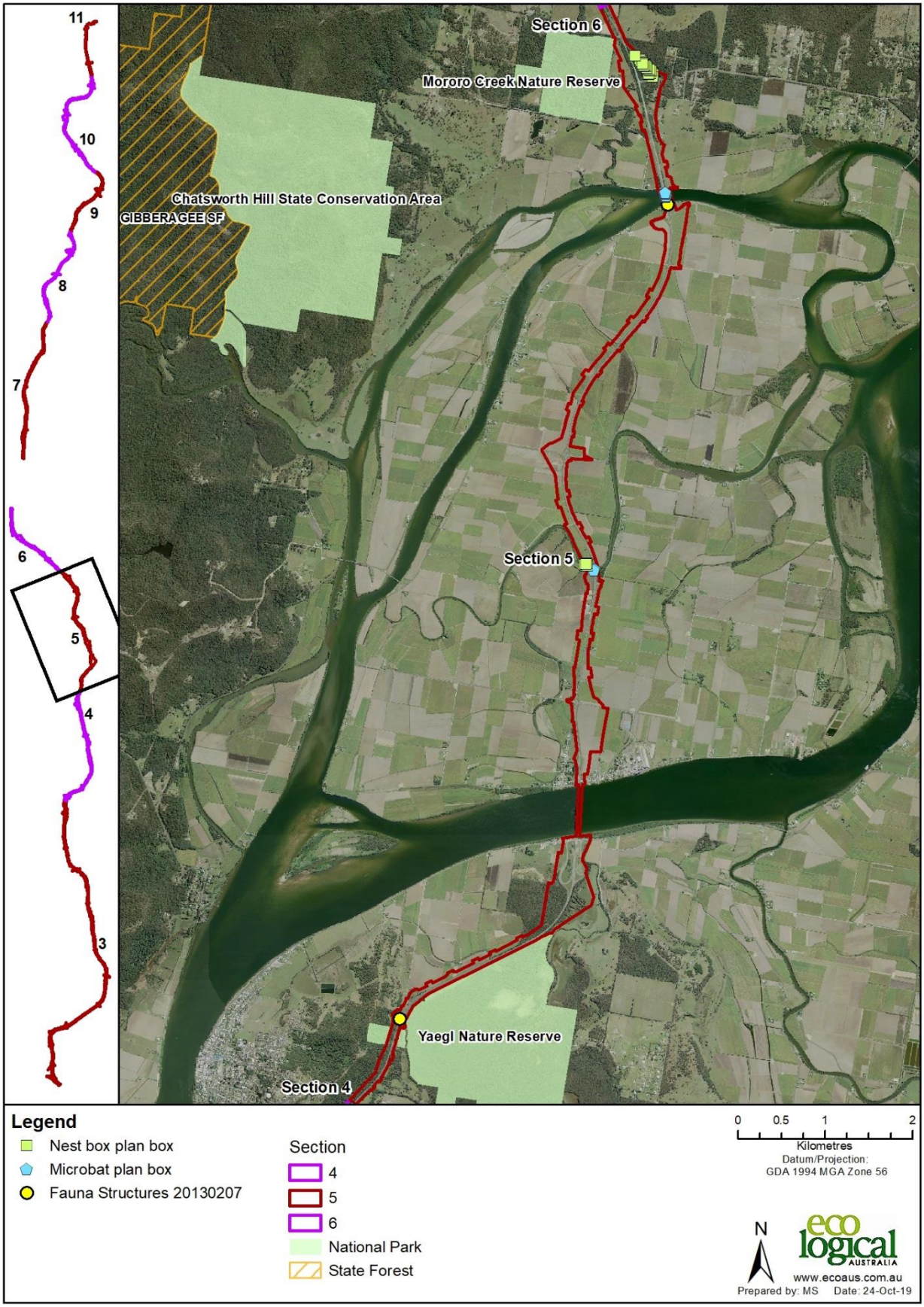

Figure 3. Section 5 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

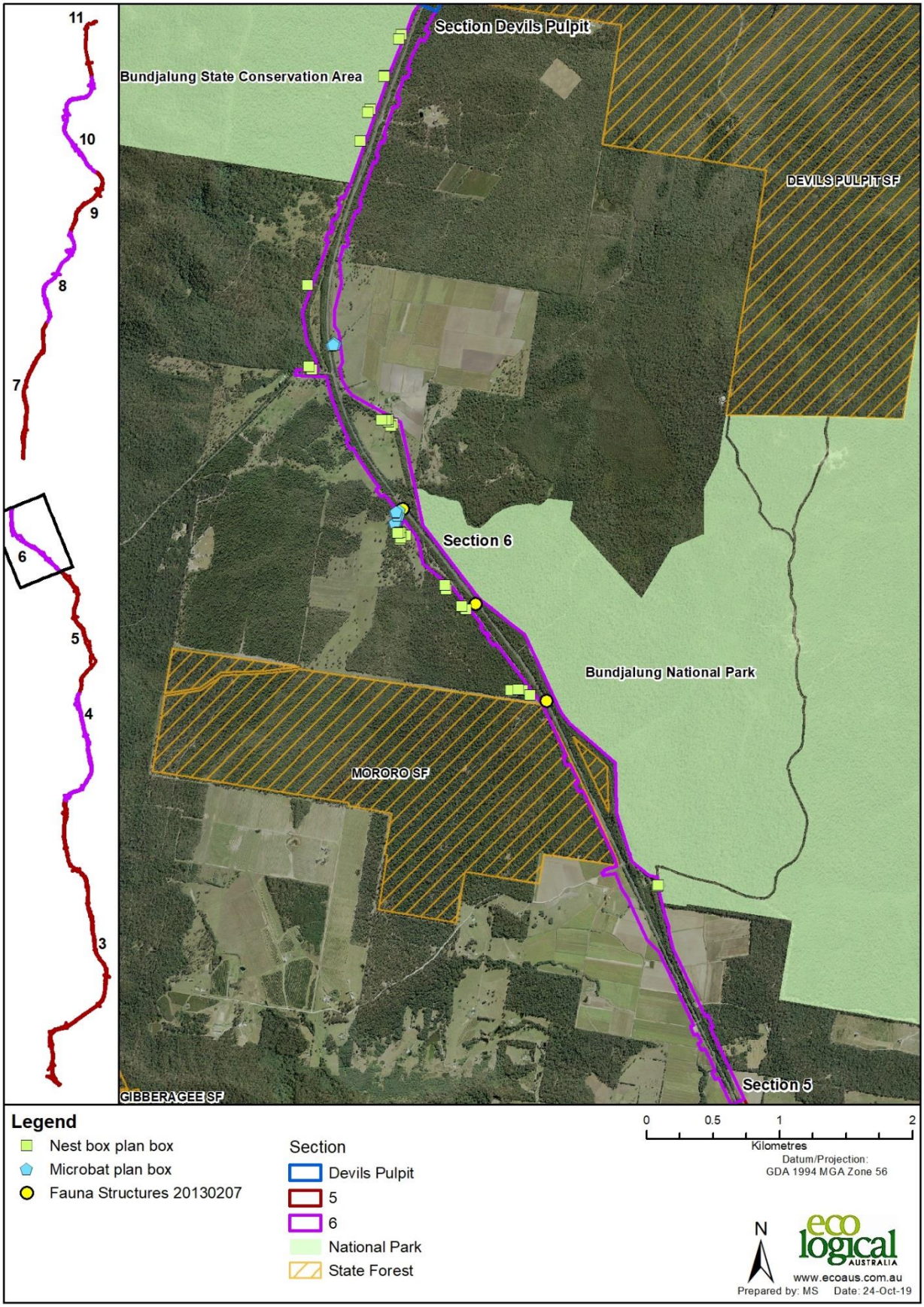

Figure 4. Section 6 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

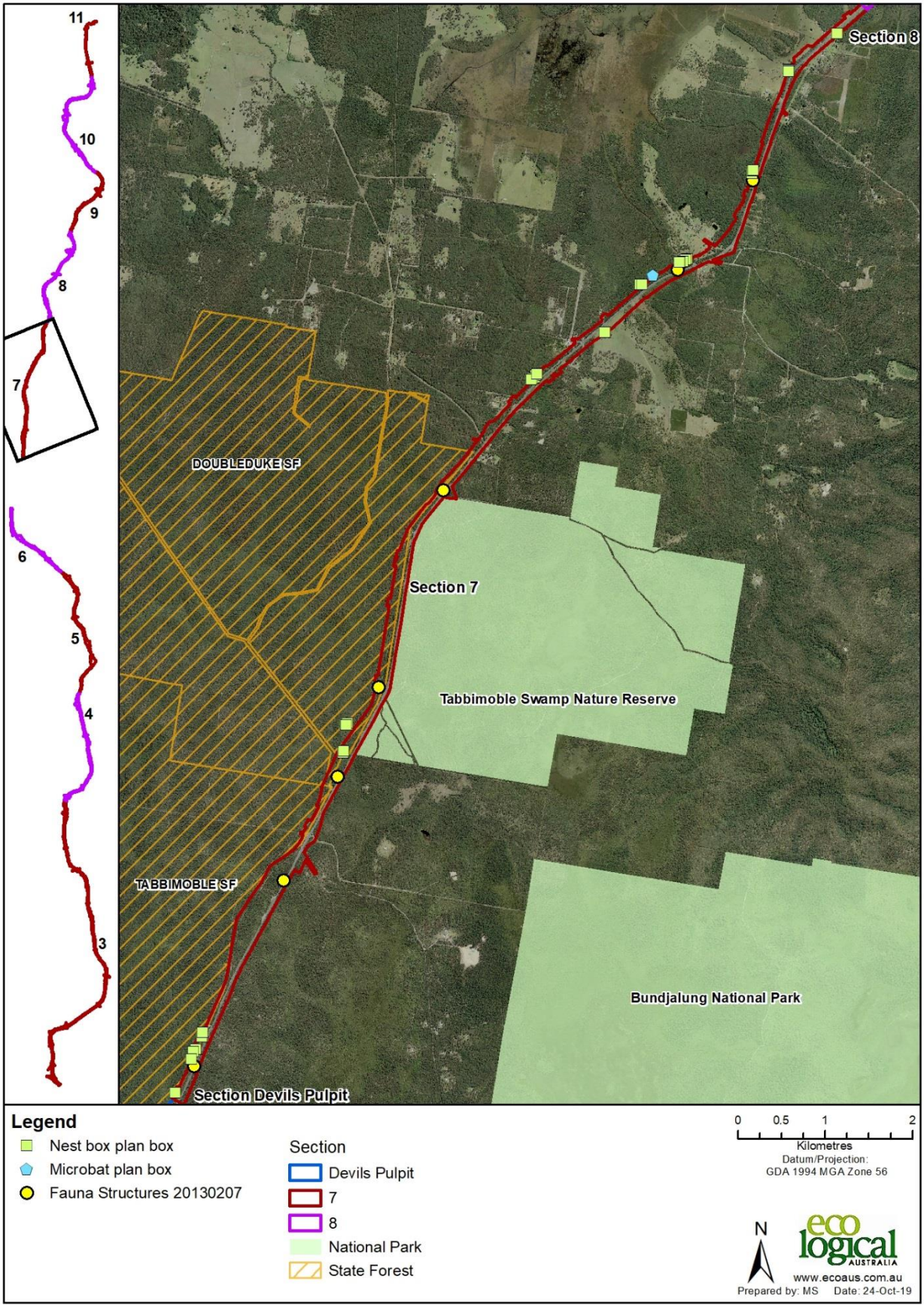

Figure 5. Section 7 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

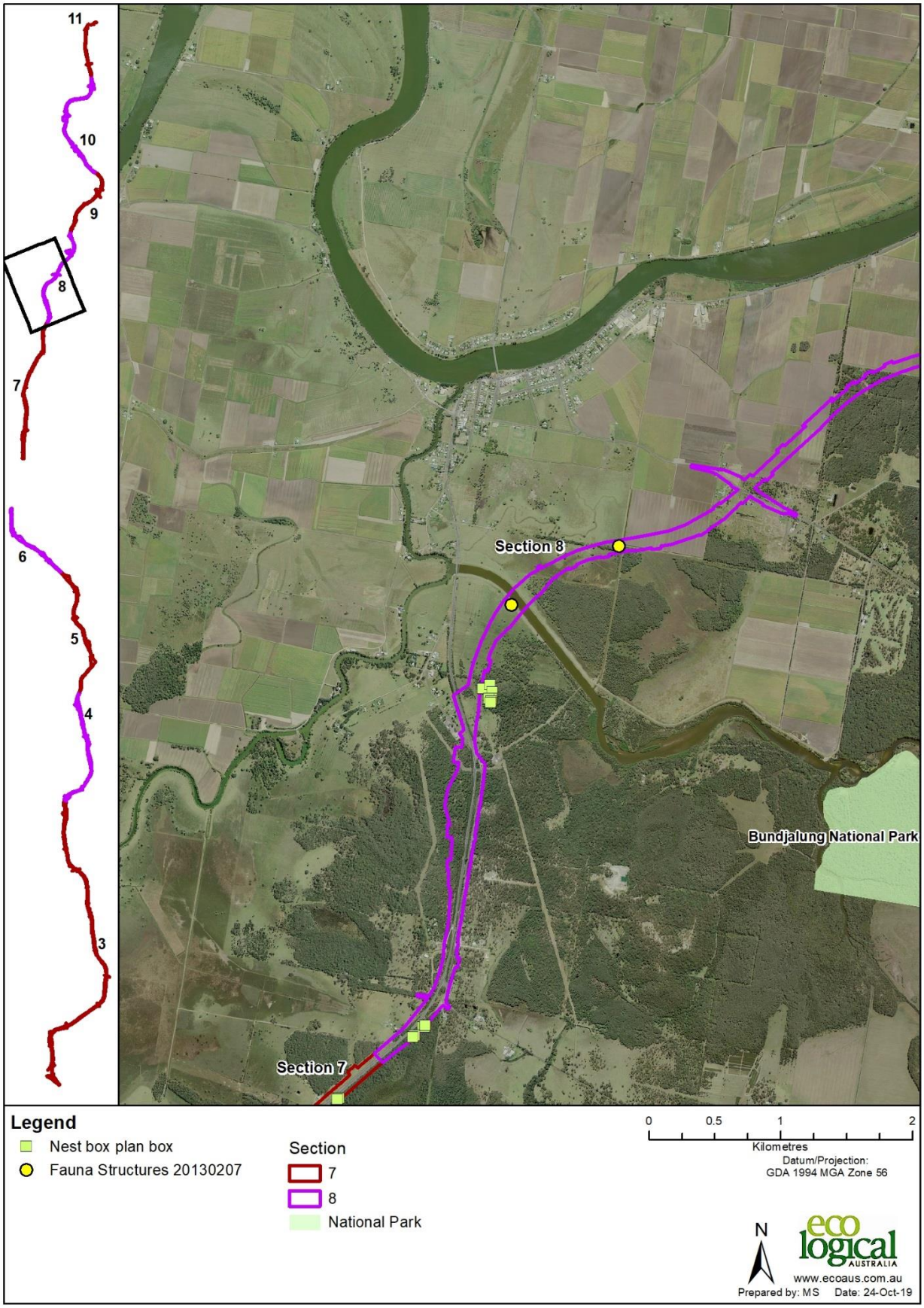

Figure 6. Section 8 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

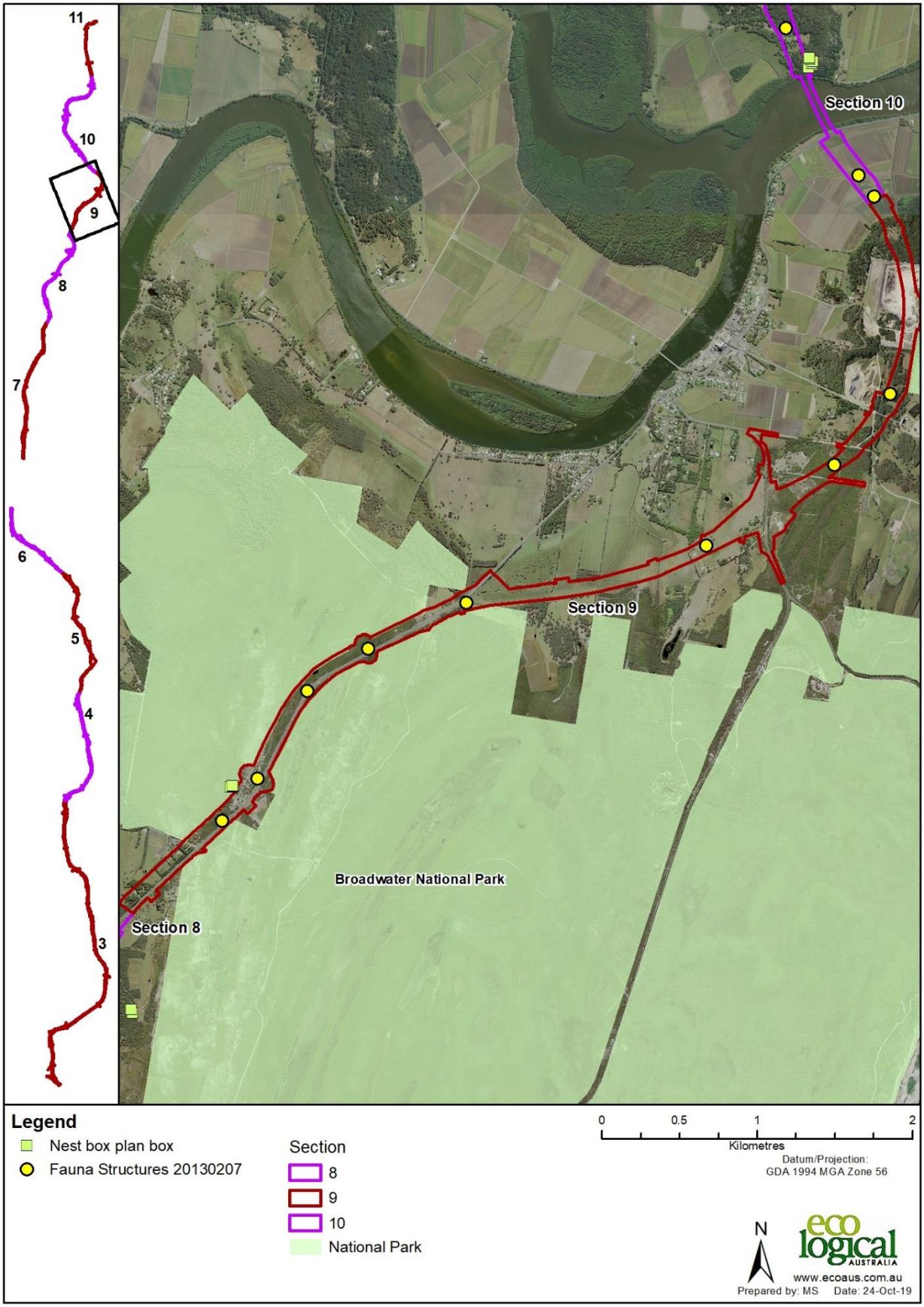

Figure 7. Section 9 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

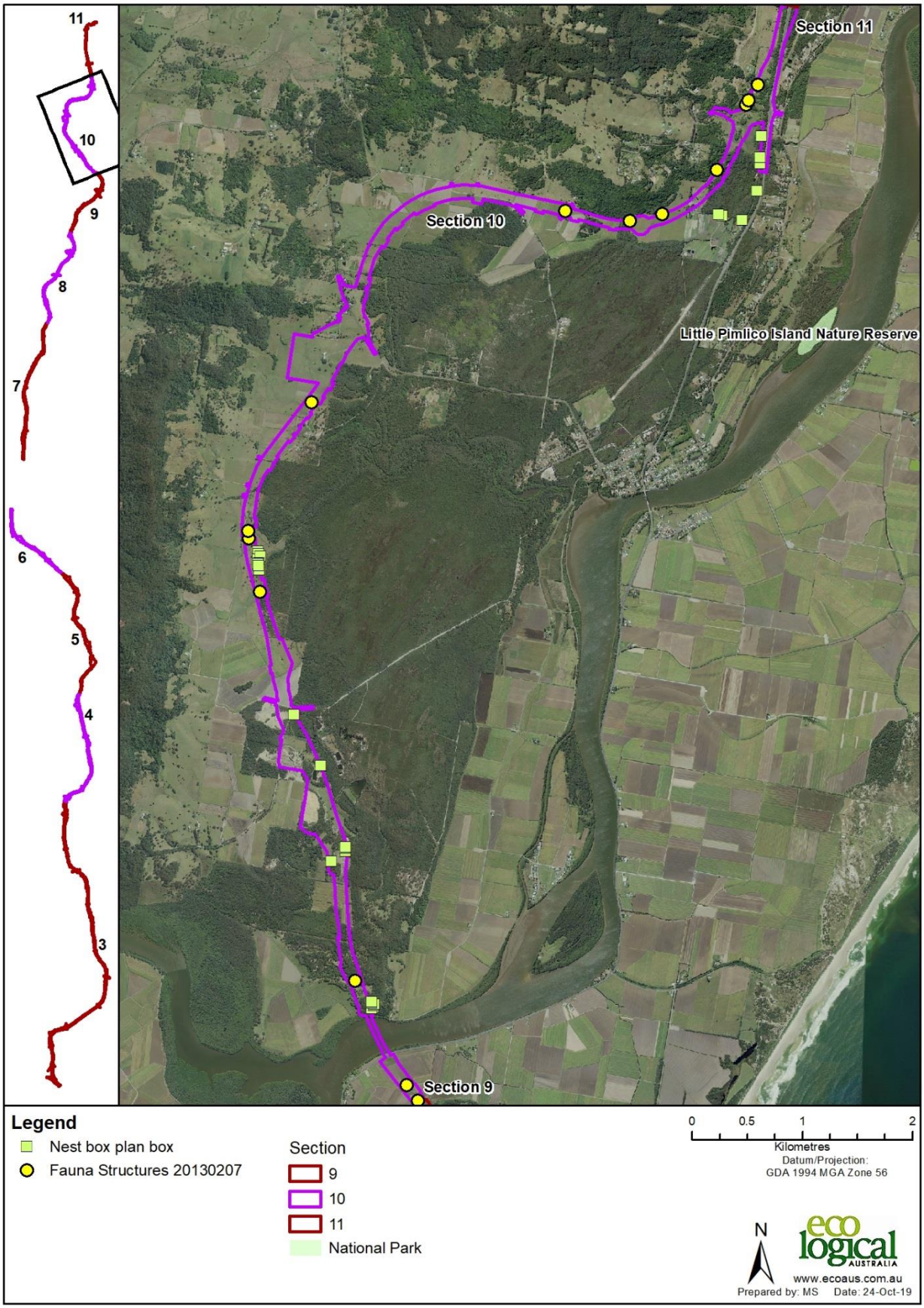

Figure 8. Section 10 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

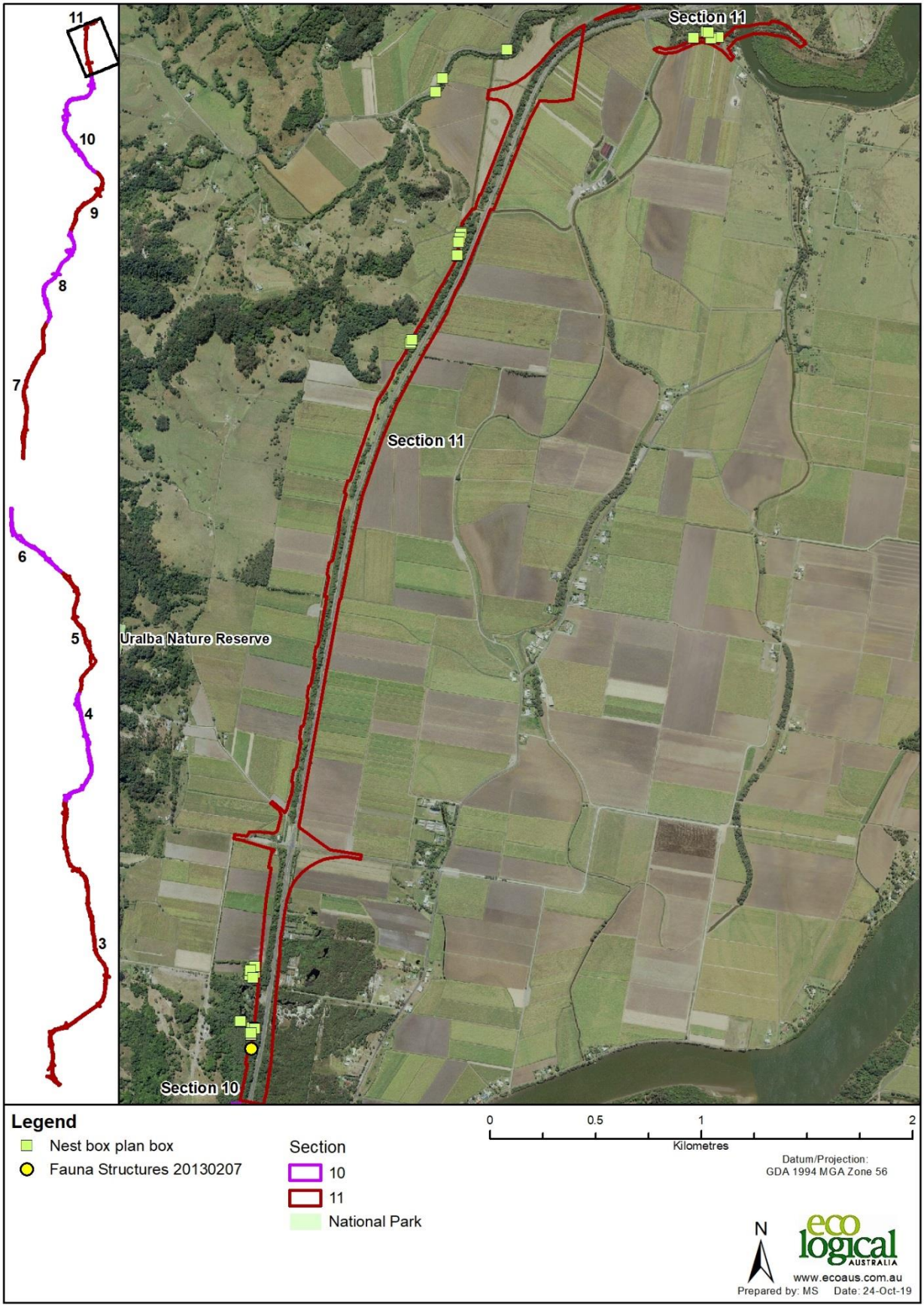

Figure 9. Section 11 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

Figure 10. A front-entry hardwood glider nest box waiting to be installed in Section 3 of the W2B highway upgrade.

Figure 11. Marine ply nest boxes ready for installation on Sections 3 – 11 of the W2B highway upgrade.

Figure 12. Cyplas (recycled plastic) nest boxes ready for installation on Sections 3 – 11 of the W2B highway upgrade

Table 3. Box types and corresponding entrance sizes installed along the W2B alignment.

Box Type	Box Type Code	Entrance size (mm)
Antechinus	A	32
Barn Owl	BO	115-125
Cockatoo/Large Owl	Cock_Owl	150
Dollar Bird/Crimson Rosella	Dollar	75-80
Feather Tail Glider	FTG	24
Glider (front entry)	GLF	45-50
Glider (rear entry)	GLR	45-50
King Parrot	KP	90
Kingfisher	Kf	50
Pardalote	Pard	38
Phascogale	BTP	50-55
Possum	Pos	110
Single Chamber Bat	B1	25
2 Chamber Bat	B2	25–60 tapering
3 Chamber Bat	B3	25 and 50-60

Box Type	Box Type Code	Entrance size (mm)
4 Chamber Bat	B4	25–60 tapering
Small Parrot	SmP	65-70
Spotted-tail Quoll	STQ	
Tree Creeper	TC	50
Wood Duck/Boobook	BOO	110

Data held by ELA indicated that, at the time of the first monitoring event in Autumn 2018, there were a total of 632 nest boxes that had been installed for between 9 and 30 months in Sections 3 – 11 of the W2B highway project (**Table 4**). This included boxes installed to provide short term replacement habitat for fauna displaced by vegetation clearance for a number of ancillary sites in Section 3 (20 nest boxes) and Section 6 (six nest boxes), additional clearing resulting from design changes (Section 6, eight boxes) that had not been included in the NBMPs. At the time of monitoring in Spring 2018 there were a total of 656 nest boxes installed in Sections 3 – 11 of the W2B highway project (Table 5). This included a number of nest boxes installed by other contractors as part of the early works packages for the W2B project that were not included in the original data transfer to ELA.

Table 4. Summary of 70% installation details and number of boxes monitored in autumn 2018 for nest boxes required in Sections 3 – 11 of the W2B project.

Section	NBMP total boxes	ELA 70% install	Non ELA install	Total installed	Total monitored
3A	12	12	0	12	0
3	311	247*	0	247*	230
3	Wave 1/3#	0	51#	51#	27
4	86	0	64	64	27
5	44	25	6	31	30
6	23	33*	0	33*	33
7	49	27	10	37	25
8 and 9	102	12	80	92	86
10 and 11	71	51	14#	65#	61
Total	698	407	225	632	519

*Additional nest boxes not included in NBMPs (20 boxes in Section 3 and 6 boxes in Section 6 for ancillary site clearing, remaining 30% in Section 6).

Not included in NBMPS, part of early works nest box installation.

Table 5. Summary of 70% installation details and number of boxes monitored in spring 2018 for nest boxes required in Sections 3 – 11 of the W2B project.

Section	NBMP total boxes	ELA 70 % install	Non ELA install	Total installed	Total monitored
3A	12	12	0	12	12
3	311	247*	0	247*	231
3	Wave 1/3#	0	66#	66#	54
4	86	0	65	65	63
5	44	25	6	31	29
6	23	41*	0	41*	26
7	49	27	10	37	31
8 and 9	102	12	80	92	83
10 and 11	71	51	14#	65#	62
Total	698	415	241	656	591

*Additional nest boxes not included in NBMPs (20 boxes in Section 3 and 6 boxes in Section 6 for ancillary site clearing, remaining 30% in Section 6, 8 boxes for additional clearing for Devil's Pulpit tie in with Section 6).

Not included in NBMPS, part of early works nest box installation.

2. Methodology

A team of two staff (ecologist and arborist) conduct each nest box inspection. Each box is initially inspected visually from the ground with binoculars to determine its condition followed by inspection of the box contents using a GoPro Hero5 camera mounted to a telescopic extension pole (**Figure 13**). Arborists using the GoPro camera inspect boxes installed above 8 m (**Figure 14**). Images from the GoPro camera are wirelessly streamed to a mobile and a photo(s) of the contents recorded. The data recorded for each nest box includes:

- Date
- Weather conditions
- Observer
- Box number and location
- Box type code (see **Table 3**) and specifications
- Species using box or inferred from secondary evidence
- Number of individuals
- Age of individuals
- Sex of individuals (if possible)
- Evidence of breeding
- Signs of box use (scats, feathers, bone, hair, guano, skin, nests, shells, eggs, pellets, carcass, chewing, seeds, fruits, other)
- Pest species use (ants, bees, wasps, termites, rats, other)
- General condition of nest box and signs of damage/deterioration
- Required maintenance.

Identification of fauna is based on the ecologist's experience with reference to standard field guides (e.g. Menkhorst & Knight 2004; Churchill 2008) as required. Except for some insectivorous bats, most fauna can be confidently identified from photographs/video footage. The identification of fauna signs is based on previous experience of nest characteristics of hollow dependent fauna (HDF) and published information.

Host tree condition, surrounding landscape changes and required maintenance works since last monitoring event were also noted if significantly different from that recorded at the time of installation.

In consultation with PC and Roads and Maritime Services (RMS), where possible, damaged boxes and those inhabited by pest species are fixed or replaced in situ, otherwise repairs are noted and scheduled for completion during the following round of monitoring. Where pest species persistently occupy nest boxes, a decision will be made regarding changing the design or leaving them in place until the following monitoring inspection as there is now evidence that some species (e.g. bees) only occupy boxes for a short period of time (Goldingay 2019). If the design of the box or its placement on the tree is required to be changed, the nest box will be relocated during the current or following monitoring inspection. If a nest box needs to be removed from site for repair and shows signs of use, an alternative box of the same or similar type will be installed in the same location upon removal of the damaged box in

consultation with PC. A record of all repairs and changes to nest boxes will be maintained. Maintenance works included:

- Repair of nest boxes
- Re-attachment of fallen undamaged nest boxes
- Removal of pest species (including possible retro-fitting of nest boxes to exclude pest species)
- Removal of excessive denning material (i.e. leaf litter)
- Replacement of fallen, degraded or damaged nest boxes
- Repositioning or relocation of dysfunctional nest boxes.

Figure 13. Nest box inspection in Section 3 of W2B upgrade using a GoPro camera attached to an extendable pole.

Figure 14. Nest box inspections for boxes installed above 8 m high require tree climbers in Sections 3 - 11 of the W2B upgrade.

3. Results

ELA conducted the first Autumn and Spring inspections of the 70% nest box allocation installed along Sections 3 to 11 of W2B in April, May, September, October and November 2018. These monitoring events correspond to Year 1 of the scheduled nest box monitoring inspections. ELA also undertook an additional non scheduled monitoring inspection in May 2017 of 14 nest boxes installed in October 2015 in Sections 10 and 11 as part of the early works package and these results do not form part of this report (ELA 2017).

Year 1 Autumn nest box inspections were carried out over 16 days on 23, 25, 26, 27, 30 April and 1, 2, 7, 8, 9, 10, 11, 13, 14, 16 and 17 May 2018. Year 1 Spring nest box inspections were carried out over 20 days on the 17, 18, 19, 23, 24, 25, 26 September and 2, 3 and 4 October, 6, 7, 8, 9, 12, 13, 14, 20, 21 and 22 November 2018. The increase in time taken to complete Spring inspections is due to the discovery of additional nest boxes that were not included in the spatial data layers held by ELA prior to Spring 2018. Weather conditions during monitoring are provided in **Table 6** below. The minimum overnight temperature recorded during autumn inspections was 3°C on 30 May 2018, with an average minimum of 11.4°C across the 16 survey dates. The maximum daily temperature recorded during autumn inspections was 27.2°C recorded on 10 May 2018, with an average maximum of 24°C. The minimum overnight temperature recorded during spring inspections was 7.2°C on 2 October 2018, with an average minimum of 12°C across the 20 survey dates. The maximum daily temperature recorded during spring inspections was 37.2°C recorded on 7 October 2018, with an average of 25.5°C.

During the Autumn monitoring event 519 boxes (82%) out of the 632 installed across Section 3 - 11 were inspected. A total of 113 boxes could not be inspected in Autumn due to restricted access (e.g. boxes were located in construction or clearing zones), theft, fire or unknown GPS coordinates (**Table 7**). During the Spring monitoring event 591 nest boxes (90%) out of the 656 installed were inspected. A total of 65 nest boxes could not be inspected in Spring due to restricted access, theft, fire or inability to locate boxes at identified locations (**Table 8**).

3.1 Summary

A total of 67 (13%) of 519 nest boxes were inhabited in Autumn 2018 and 62 (10%) of 591 boxes were occupied during Spring 2018. Evidence of nest box usage without the presence of fauna was observed in 226 (44%) of 519 boxes in Autumn 2018 and in 262 (44%) of 591 monitored boxes in Spring 2018. Evidence of usage included nesting material, scratching on the outside of nest boxes, chewed entrances, the presence of depressions in the bark chips inside the box, animal skeletal remains, scats, feathers, owl pellets and egg shells (**Figure 15**). The overall rate of use (i.e. sum of boxes occupied and those featuring evidence of use) in Autumn 2018 was 293 boxes (56%) of 519 monitored boxes and 324 (55%) of 591 monitored boxes in Spring 2018. A summary of the overall rate of use for each season is provided in **Figure 16** and **Figure 17**.

Figure 15. Examples of the type of evidence of nest box occupation recorded from sections 3 – 11 of the W2B project during 2018. Top Left Possum skeleton, Top Right Leaf and feather nest (possible Brush-tailed Phascogale) with bird guano on a wasp nest, Middle Left Owl Pellet recovered from an Owl box, Middle Right Glider leaf nest (likely Feathertail Glider), Bottom Brushtail Possum scats.

Table 6. Weather conditions experienced during nest box monitoring in autumn and spring 2018*.

Date	Min temp ºC	Max temp ºC	Rainfall (mm)	Wind direction	Max wind speed (km/hr)
11/04/2019	15	23.8	0	SE	33
12/04/2019	13.7	23	5.6	SE	31
1/05/2019	16.8	24.5	3	NE	24
2/05/2019	17.7	24.8	0.8	ENE	24
3/05/2019	16.8	23.9	0	N	15
8/05/2019	5.2	27	0	NNW	24
9/05/2019	7.5	24.3	0.2	ENE	20
10/05/2019	7.6	27.2	0	WSW	46
15/05/2019	10.1	24.4	0	S	33
16/05/2019	15.4	19.8	11.2	SSW	24
17/05/2019	14.3	24.1	8.2	SSE	24
22/05/2019	9.2	25.3	0	ENE	17
23/05/2019	9	23.4	0	NE	26
24/05/2019	10.7	23.8	0.2	ENE	22
29/05/2019	10.4	23	0	W	31
30/05/2019	3	21.9	0	ESE	30
17/09/2018	8.1	20.5	0	SE	35
18/09/2019	8.1	24	0	N	37
19/09/2018	7.3	28.4	0	NNE	37
23/09/2018	9.5	26	0	SE	39
24/09/2018	12.1	20.7	0	SSE	46
25/09/2018	12.4	19.3	1.4	SSE	30
26/09/2018	9.8		0.2		
2/10/2018	7.2	24	0	E	30
3/10/2018	7.4	26.1	0	NNE	31
4/10/2018	10.3	27.2	0	SSE	33
6/11/2018	18.3	35.2	0	WSW	39
7/11/2018	21.4	37.2	0.2	S	63
8/11/2018	18.1	23	4.4	SSE	41
9/11/2018	11.4	23.3	0.6	S	31
12/11/2018	12.6	25.9	0	SE	37
13/11/2018	12.8	26.6	0	NE	33
14/11/2018	12.7	27.7	0	NNE	26
20/11/2018	14.6	28.9	0	N	35
21/11/2018	18.2	33.9	0	N	35

Date	Min temp ºC	Max temp ºC	Rainfall (mm)	Wind direction	Max wind speed (km/hr)
22/11/2018	20.4	31.8	5.4	NW	46

*Taken from the Bureau of Meterology website as recorded at Grafton airport station 058161.

Table 7. Summary of nest box monitoring results - Autumn 2018

Section	Total nest boxes installed	Total nest boxes Monitored	# Inhabited	% Inhabited	Detected Threatened species	# Evidence of usage	% Evidence of usage	# Total usage	Overall rate of usage (%)	Comments
3A	12	0	0	0	N/A	0	0		0	No access due to clearing
3	247*	230	23	10	Brush-tailed Phascogale Squirrel Glider	119	52	142	62	9 missing boxes, 8 boxes no access due to clearing
3	51	27	2	7	Nil	9	33	11	41	Unknown location of 24 boxes
4	64	27	4	15	Nil	13	48	17	63	Unknown location of 37 boxes
5	31	30	5	17	Nil	11	37	16	53	1 missing box
6	33*	33	7	21	Nil	15	45	22	67	
7	37	25	4	16	Eastern Long-eared Bat Squirrel Glider	9	36	13	52	2 missing boxes, 10 boxes installed by GeoLINK not monitored
8 and 9	92	86	11	13	Squirrel Glider	22	26	33	38	1 missing box, unknown location of 5 boxes
10 and 11	65#	61	11	18	Eastern Long-eared Bat	28	46	39	64	3 missing boxes, 1 box not monitored – not located
Total	632	519	**67**	**13**		**226**	**44**	**293**	**56**	

* 20 Additional boxes installed in Section 3 for Ancillary site clearing, 10 additional boxes installed in Section 6 for ancillary site clearing and remaining 30% installed with increased nest box tally. # 14 early works boxes incorporated into monitoring.

Table 8. Summary of nest box monitoring results - Spring 2018

Section	Total nest boxes installed	Total nest boxes monitored	# Inhabited	% Inhabited	Detected Threatened species	# Evidence of usage	% Evidence of usage	# Total usage	Overall rate of usage (%)	Comments
3A	12	12	0	0	Nil	1	8	1	8	
3	247	231	29	13	Nil	102	44	131	57	9 boxes lost through clearing, 6 boxes not monitored - not located, 1 box destroyed by termites
3	66	54	4	7	Squirrel Glider	29	54	33	61	3 boxes lost through clearing, 9 boxes not monitored - not located
4	65	63	5	8	Nil	40	63	45	71	2 boxes lost through clearing (Tyndale)
5	31	29	1	3	Squirrel Glider	13	43	14	48	1 box lost through clearing (Serpentine), 1 box not monitored - not located (Illuka)
6	41*	26	1	4	Nil	9	35	10	38	No access to 15 boxes due to construction works
7	37	31	2	6	Squirrel Glider	11	35	13	42	1 box installed by GeoLINK not monitored, 5 boxes no access
8 and 9	92	83	13	16	Squirrel Glider	23	28	36	43	2 boxes lost through clearing, 2 not monitored - not located
10 and 11	65#	62	7	11	Eastern Long-eared Bat Squirrel Glider	34	55	41	66	3 boxes lost through clearing or theft
Total	656	591	**62**	**10**		**262**	**44**	**324**	**55**	

*Additional nest boxes not included in NBMPs (20 boxes in Section 3 and 6 boxes in Section 6 for ancillary site clearing, remaining 30% in Section 6, 8 boxes for additional clearing for Devil's Pulpit tie in with Section 6). # Not included in NBMPS, part of early works nest box installation.

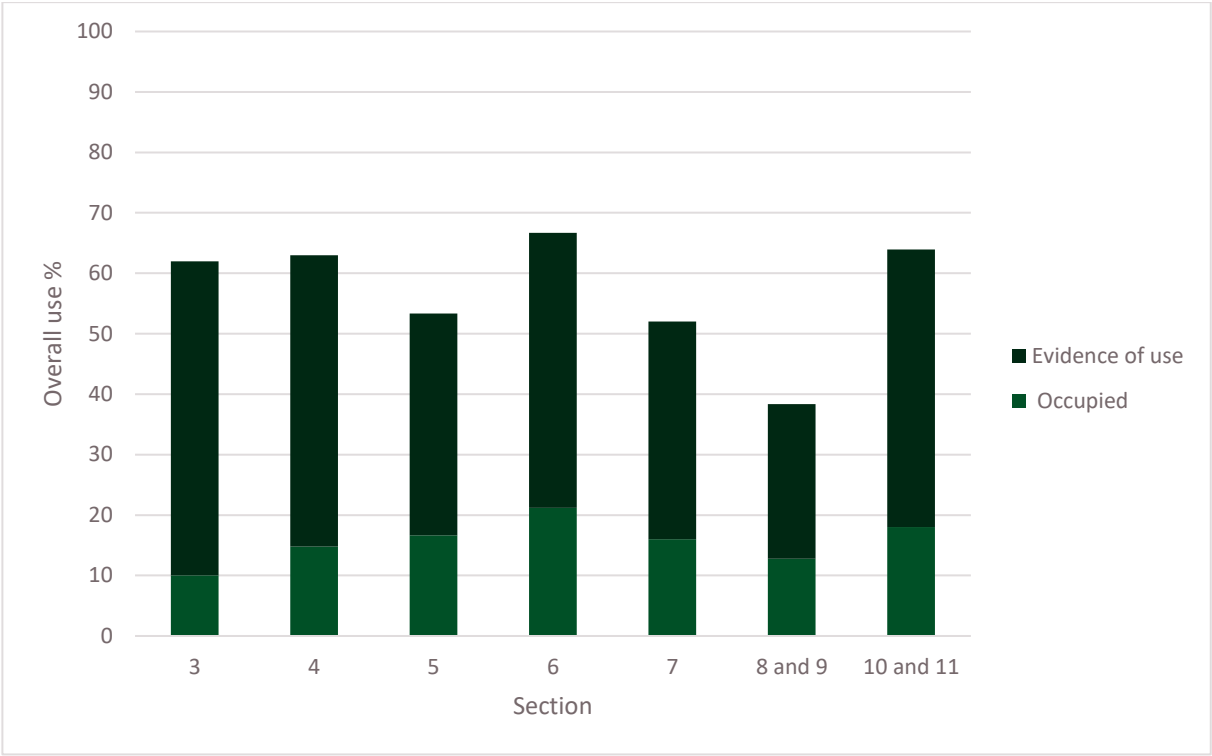

Figure 16. Overall use of nest boxes in Autumn 2018 across Sections 3 to 11 of the W2B alignment

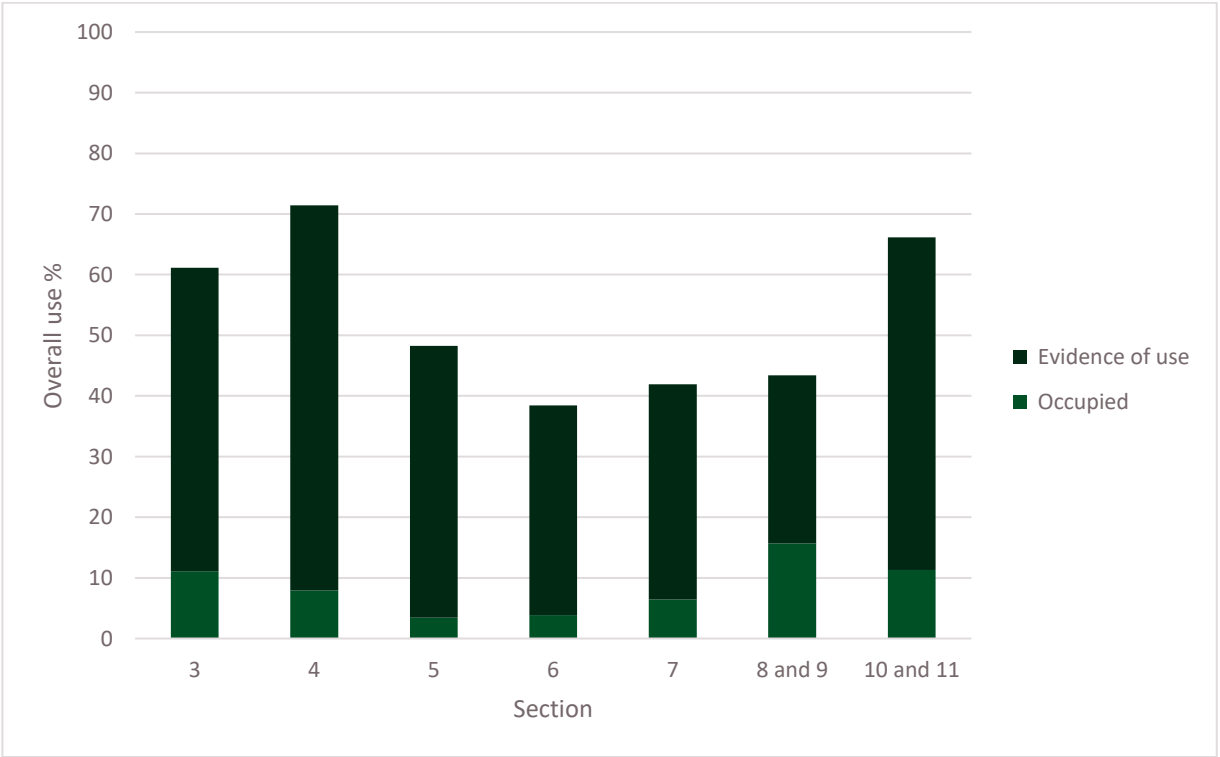

Figure 17. Overall use of nest boxes in Spring 2018 across Sections 3 to 11 of the W2B alignment

3.1.1 Performance Indicator 1: Boxes used by a wide variety of fauna species

Nineteen vertebrate species (one amphibian, four birds, nine mammals, three microbats and two reptiles) were observed occupying nest boxes during the 2018 inspections (**Figure 18**). There were 13 fauna species recorded in autumn and 13 in spring with seven species recorded during both inspections, including two species listed as vulnerable under the NSW *Biodiversity Conservation Act 2016* (BC Act) denoted by an * and highlighted in bold type in the lists below. The seven species recorded in both autumn and spring were;

- *Aegotheles cristatus* Australian Owlet Nightjar
- ***Nyctophilus bifax* Eastern Long-eared Bat*** (listed as vulnerable under the BC Act)
- *Nyctophilus gouldii* Gould's Long-eared Bat
- *Petaurus breviceps* Sugar Glider
- ***Petaurus norfolcensis* Squirrel Glider***(listed as vulnerable under the BC Act)
- *Pseudocheirus peregrinus* Common Ringtail Possum
- *Trichosurus vulpecula* Common Brushtail Possum.

The remaining 12 species were recorded during one season only and include one species listed as vulnerable under the BC Act:

- *Acrobates sp.* Feathertail Glider
- *Antechinus sp.*
- *Chalinolobus gouldii* Gould's Wattled Bat
- *Chenonetta jubata* Australian Wood Duck
- *Cormobates leucophaea* White-throated Treecreeper
- *Dendrelaphis punctulatus* Green Tree Snake
- *Litoria peronii* Peron's Tree Frog
- ***Phascogale tapoatafa* Brush-tailed Phascogale*** (listed as vulnerable under the BC Act)
- *Platycercus eximus* Eastern Rosella
- *Rattus sp.(likely Rattus rattus* Black Rat*)*
- *Trichosurus cunninghami* Mountain Brushtail Possum
- *Varanus varius* Lace Monitor.

The species with the greatest number of individuals recorded within nest boxes across Autumn and Spring 2018 combined were;

- **Squirrel Glider* -** 59 individuals (26 separate observations ranging from 1 to 4 individuals per box)
- Common Brushtail Possum – 52 individuals (35 separate observations ranging from 1 to 3 individuals per box)
- Gould's Long-eared Bat – 43 individuals (9 separate observations ranging from 1 to 10 individuals per box)
- Sugar Glider – 32 individuals (20 separate observations ranging from 1 to 3 individuals per box).

These four species accounted for 98 (70%) of the total of 141 individual animals recorded using nest boxes during the autumn 2018 inspections. Similar results were obtained during spring 2018 inspections with 88 (77%) of the total of 115 individual animals recorded being one of the four species listed above.

The species encountered the greatest number of times occupying nest boxes (regardless of the number of individuals) across Autumn and Spring 2018 were:

- Common Brushtail Possum
- **Squirrel Glider***
- Sugar Glider.

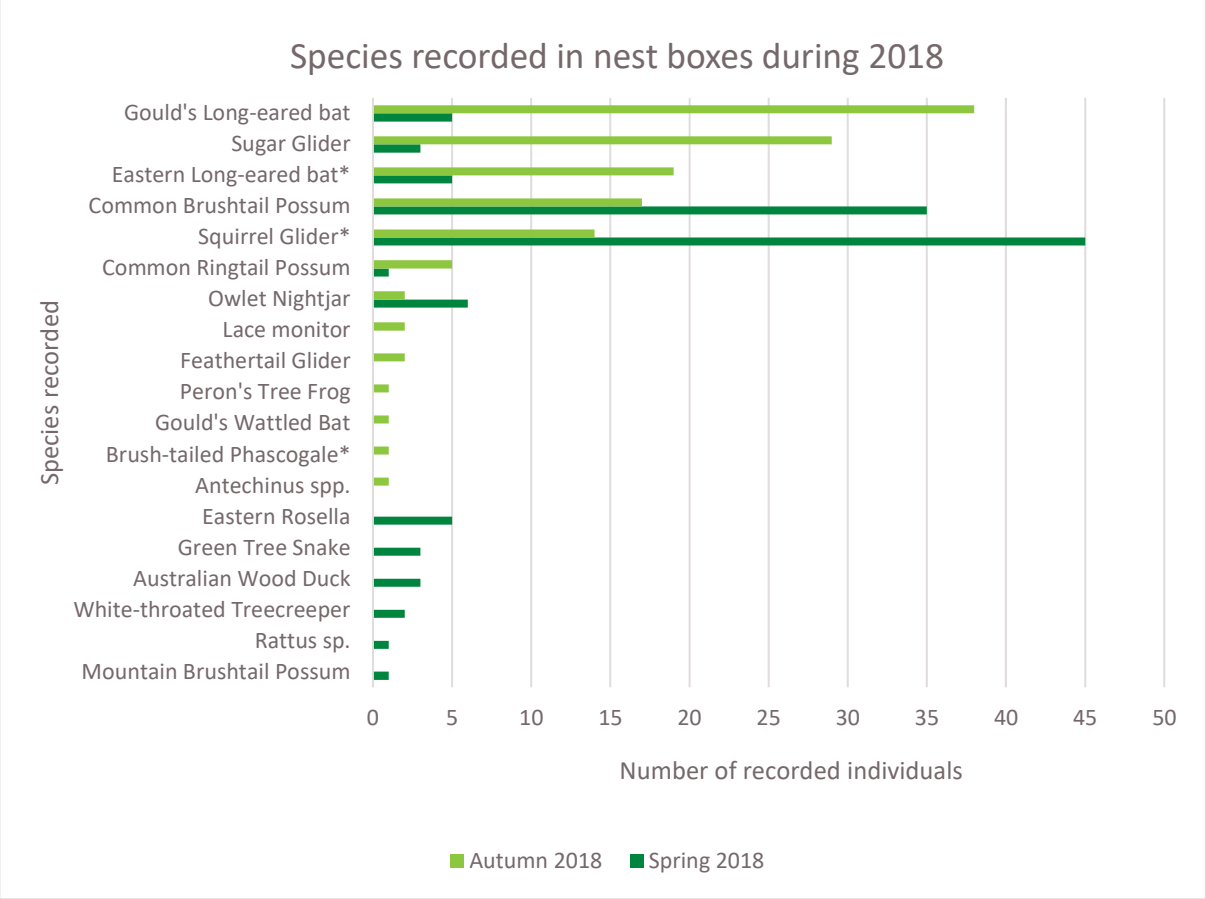

Figure 18. Species observed inhabiting nest boxes in W2B Sections 3 to 11. Those highlighted with an asterix are threatened species listed under the BC Act.

There were 422 (66%) of the 635 nest boxes installed and functional throughout 2018 that showed signs of use during the 2018 monitoring period. The 21 boxes lost through vegetation clearing or destroyed by fire were subtracted from the total installed figure of 656 because these boxes were not available for use by fauna.

3.1.2 Evidence of breeding in nest boxes

There were several instances of family groups of Brush-tailed Possums, Sugar and Squirrel Gliders and Common Ringtail Possums occupying boxes, and evidence that boxes had been used for breeding purposes by each species with a number of records of unfurred young as well as older juveniles (**Figure**

19). There were also several records of birds nesting within nest boxes as evidenced by eggs, egg shells, downy feathers, clutches of juvenile birds (Eastern Rosella, White-throated Treecreeper) and records of Australian Owlet Nightjar sitting on nests with eggs. The characteristic downy feathered nests of Australian Wood Duck were also identified in several boxes (**Figure 20**).

Figure 19. Top Left: A Cyplas glider rear entry nest box containing a female Squirrel Glider with 1 unfurred young as well as a juvenile in Section 3, spring 2018. Top Right, Bottom Left: A timber glider front entry nest box containing a female and 2 juvenile Common Ringtail Possums in Section 4, winter 2018. Bottom right: A timber box containing a family of Sugar Gliders

Figure 20. Top Left: timber nest boxes with a single white egg (likey Australian Owlet Nightjar), Top Right: egg and egg shell (likely Australian Woodduck); Bottom Left: clutch of nestling Eastern Rosellas. Bottom Right: Australian Owlet Nightjar and egg in Cyplas box.

3.1.3 Performance Indicator 2: Boxes occupied by target fauna species

Three of the 24 target threatened fauna species were recorded using nest boxes;

- **Brush-tailed Phascogale***
- **Eastern Long-eared Bat***
- **Squirrel Glider*.**

There were two instances of the Brush-tailed Phascogale using Brush-tailed Phascogale timber and Cyplas nest boxes during the autumn inspections in Section 3 (**Figure 21**). Eastern Long-eared Bats were recorded using bat boxes in Sections 7, 10 and 11 (**Figure 21**). Eastern Long-eared Bats occupied both timber and Cyplas boxes. Squirrel Gliders were recorded on multiple occasions using both timber and

Cyplas nest boxes in all Sections except for Section 6 (**Figure 21**). Squirrel Gliders were recorded predominantly in Glider front and rear entry boxes but also inhabited Brush-tailed Phascogale and Treecreeper boxes.

Nest box type and associated rates of occupancy are summarised in **Table 9** and described in Sections 3.1.3.1 to 3.1.3.3 below. There were a total of 69 records (6%) of target fauna species occupying nest boxes designed for that species in 2018. Evidence of use by target species was found in 199 (17%) boxes with an overall nest box usage rate by target species of 273 boxes (23%). Evidence of use was not always possible to attribute to target fauna species because of the difficulty in accurately assigning incomplete or old leaf nests to Antechinus, Feathertail Glider, Sugar and Squirrel Glider species. In the majority of cases where nest box occupancy was recorded, nest boxes were occupied by non- target fauna species. Eight box types recorded occupancy by target species and these were:

- Brush-tailed Phascogale boxes
- Glider front and rear entry boxes
- Possum / Large Glider boxes
- Microbat boxes (Single chamber, 2 chamber, 3 chamber and 4 chamber).

In the case of Glider front and rear entry boxes and 3 chamber bat boxes occupancy rates of 10% or greater were recorded when results of both autumn and spring inspections were combined (**Table 8**). All other box types recorded occupancy rates lower than 10% when autumn and spring results were combined.

3.1.3.1 Birds

Bird boxes (Barn Owl, Boobook / Wood Duck, Cockatoo / Owl, Dollarbird / Crimson Rosella, Kingfisher, King Parrot, Pardalote, Small Parrot and Treecreeper) were not occupied by any of the target bird species during the Autumn and Spring 2018 survey periods. Birds or evidence of bird occupation was recorded in 19 (5%) bird boxes in 2018 although not in the target boxes for those species; Australian Owlet Nightjar (no box design specified for this species), Australian Wood Duck, Eastern Rosella and White-throated Treecreeper as well as evidence of owl occupation in the form of owl pellets. The Australian Owlet Nightjar was recorded in Barn Owl, Cockatoo / Large Owl and Possum boxes of timber construction as well as Barn Owl, Possum and Small Parrot Cyplas boxes. The Australian Woodduck was recorded in Barn Owl and Cockatoo / Large Owl boxes constructed of timber and Cyplas as well as Possum boxes of timber construction. The White-throated Treecreeper was recorded in a Small Parrot box of timber construction. A clutch of Eastern Rosellas was recorded in an unknown type of nest box (not installed by ELA) of timber construction.

Twelve (3%) of the bird boxes monitored in 2018 were occupied by the Common Brushtail Possum and 11 (3%) were occupied by Sugar or Squirrel Gliders. There was evidence of usage in 42% of boxes in Autumn, however, much of the usage was attributed to possum and glider leaf nests and not target bird species. Similar results were found in Spring 2018 with 51% of boxes showing signs of usage from possums and/or gliders rather than birds. Other non-target species recorded in bird boxes included Green Tree Snakes, microbats, native bees, an introduced rat and a Lace Monitor.

3.1.3.2 Bats

Fourteen (12%) of the monitored bat boxes (single chamber, 2, 3 and 4 chamber) were occupied during the 2018 survey period. Gould's Long-eared Bat occurred in nine bat boxes and ranged in abundance from one to ten individuals per box. A single Gould's Wattled Bat was also recorded in a single chamber bat box. The BC Act listed vulnerable Eastern Long-eared Bat occupied three timber boxes with abundance ranging from three to ten individuals. There were several instances of microbats occupying other box types such as King Parrot, Pardalote and Small Parrot boxes and in some cases it was not possible to identify the species of microbat from camera images. The Lace Monitor was the only non target species recorded using bat boxes.

These results are relatively consistent with recent studies of bat box efficacy which indicate that common and widespread urban adapted bat species tend to occupy boxes, with other bat species making little to no use of boxes, the Eastern Long-eared Bat being the obvious exception in this case (Griffiths et al. 2017, 2018; Rueegger et al. 2019).

3.1.3.3 Arboreal mammals

There were no Antechinus occupying Antechinus boxes during inspections in 2018, however there were several instances of Antechinus nests and latrines recorded. Many Antechinus boxes showed evidence of former use by Antechinus in the form of loose leaf nesting material (52%) but there were also a number of leaf and bark nests that could have been attributed to Brush-tailed Phascogale, Feathertail Glider, Sugar or Squirrel Gliders.

Feathertail Glider boxes were not occupied by Feathertail Gliders during autumn or spring nest box inspections in 2018. Three (15%) boxes showed evidence of use by Feathertail Gliders in the form of leaf nests and there were no non-target species recorded in Feathertail Glider boxes.

Glider boxes (Glider front and rear entry) showed the highest rates of occupancy amongst all target species. A total of 13% of Glider front entry and 10% of Glider rear entry box types were occupied by Sugar Glider and/or Squirrel Gliders in 2018 (**Table** 8 **9**). Evidence of usage in 2018 was 46% for Glider front entry and 47% for Glider rear entry boxes respectively, largely comprising leaf nesting material. As mentioned above there is some difficulty in accurately assigning incomplete or old leaf nests to Antechinus, Feathertail Glider, Sugar and Squirrel Glider species so the figures for evidence of use are to be read with caution. Non target species reported in Glider boxes included Antechinus, unidentified birds, Common Brushtail Possum, Common Ringtail Possum, Green Tree Snake and Native bees.

Brush-tailed Phascogale boxes recorded occupancy rates of 2% during 2018 but were mainly found to contain leaf nests (77%) which were often attributed to Glider usage. Non target species inhabiting Brush-tailed Phascogale boxes were Sugar and Squirrel Gliders and the Green Tree Snake.

Approximately 5% of Possum boxes were occupied in 2018, predominately by the Common Brushtail Possum but also by Common Ringtail Possum and Mountain Brushtail Possum. Evidence of use by possums was 14% and mainly consisted of loose leaves pulled into the box, depressions in the sawdust, hair left behind on the entrance hole, scats and chewing around the box entrance. A range of non target species was recorded in Possum boxes including the Australian Owlet Nightjar, Australian Wood Duck, Feathertail Glider, Peron's Tree Frog, Sugar and Squirrel Glider.

There was no evidence of use in the single Spotted-tailed Quoll box in either autumn or spring 2018.

Figure 21. A cluster of *Nyctophilus bifax* (Eastern Long-eared Bats) roosting in a 3 chambered Cyplas box in Section 11 during spring 2018. A Brush-tailed Phascogale in a timber Brush-tailed Phascogale box in Section 3 during autumn 2018 inspections. A Squirrel Glider and young in a Cyplas Glider rear entry box in Section 9 during autumn 2018 inspections.

Table 9. Nest box type and rates of occupancy per target species following nest box inspections undertaken in autumn and spring 2018 on Sections 3 – 11 of the W2B project.

Box Type	Box Type Code	No. boxes monitored in 2018	No. occurrences of target species inhabiting boxes	% Inhabited by target species in 2018	Evidence of use by target species	% Evidence of use by target species	Overall use by target species	% Overall use by target species	Non-target species detected
Antechinus	A	56	0	0	29	52	29	52	Glider spp., Brush-tailed Phascogale, Feathertail Glider
Barn Owl	BO	26	0	0	0	0	0	0	Common Brushtail Possum, Woodduck, Owlet Nightjar, Lace Monitor, Glider spp.
Boobook / Wood duck	BOO	5	0	0	0	0	0	0	Common Brushtail Possum
Cockatoo/Large Owl	Cock_Owl	104	0	0	5	5	5	5	Sugar Glider, Common Brushtail Possum, Woodduck, Owlet Nightjar, Green Tree Snake
Dollar Bird/Crimson Rosella	Dollar	10	0	0	0	0	0	0	Possum spp. Glider spp.
Feather Tail Glider	FTG	20	0	0	3	15	3	15	Nil
Glider (front entry)	GLF	78	11	14	36	46	47	60	Antechinuns, Bird, Common Brushtail Possum, Common Ringtail Possum, Green Tree Snake, microbats
Glider (rear entry)	GLR	126	17	13	60	48	77	61	Common Brushtail Possum, Native bees
Kingfisher	Kf	16	0	0	0	0	0	0	Sugar Glider, Squirrel Glider
King Parrot	KP	8	0	0	0	0	0	0	Long-eared Bat, Glider spp.
Pardalote	Pard	14	0	0	0	0	0	0	Glider spp., Gould's Long-eared Bat
Phascogale	BTP	70	2	3	23	33	25	36	Sugar Glider, Squirrel Glider, Green Tree Snake

Box Type	Box Type Code	No. boxes monitored in 2018	No. occurrences of target species inhabiting boxes	% Inhabited by target species in 2018	Evidence of use by target species	% Evidence of use by target species	Overall use by target species	% Overall use by target species	Non-target species detected
Possum	Pos	342	21	6	48	14	69	20	Owlet Nightjar, Sugar Glider, Squirrel Glider, Australian Wood Duck, Peron's Tree Frog, Feathertail Glider
Single Chamber Bat	B1	34	3	9	0	0	7	21	Nil
2 Chamber Bat	B2	64	6	9	0	0	6	9	Lace Monitor
3 Chamber Bat	B3	30	3	10	0	0	3	10	Nil
4 Chamber Bat	B4	35	2	6	0	0	2	6	Nil
Small Parrot	SmP	144	0	0	0	0	0	0	Owlet Nightjar, White Throated Treecreeper, Sugar Glider, Gould's Long-eared Bat, Native bees
Spotted-tail Quoll	STQ	2	0	0	0	0	0	0	Nil
Tree Creeper	TC	18	0	0	0	0	0	0	Sugar Glider, Squirrel Glider
Totals		1202*	65	5.41	204	16.97	273	22.71	

*21 nest boxes did not have the nest box type recorded and are not included in this analysis

3.1.4 Performance Indicator 3: Pest species

There was a total of 49 (9%) nest boxes occupied by pest species during the autumn 2018 monitoring inspections and 40 (7%) occupied by pest species during the spring 2018 inspections (**Table 10** and **Table 11**). The seven pest species groups recorded in boxes were:

- ants
- *Apis mellifera* (European bees)
- invertebrates
- native bees
- *Rattus sp*. (Introduced rats)
- termites
- wasps.

The reduction in pest species uptake of nest boxes from autumn to spring is likely a result of active intervention to dissuade pest species from occupying boxes undertaken in autumn 2018. Intervention involved removing ant and wasp nests where safe to do so, clearing out old honeycomb and leaving the lid of the boxes open for the period between one inspection and the next. Pest species were recorded in all Sections except Section 9 which only contains 4 boxes. Rates of pest species uptake varied between 0 – 16% of boxes across Sections 3 – 11. Sections 4, 7 and 8 recorded rates of pest species uptake in autumn that exceeded performance targets of (<10%). Sections 6 and 7 recorded rates of pest species uptake in spring that exceeded performance targets of (<10%).

Although there were only 2 (<1%) of boxes with termites in autumn and 6 (1%) in spring, they caused the most damage with boxes partially or completely destroyed and needing to be replaced in all cases, all boxes being of timber construction.

Ants were the most commonly recorded pest species group occurring in all Sections with 23 (4%) of nest boxes occupied in autumn and 18 (3%) in spring 2018. Ants occurred in a range of box types including, 2 chamber bat, Antechinus, Brush-tailed Phascogale, Glider rear entry, Kingfisher, Possum, Small Parrot and Treecreeper. In all but 3 instances ants were recorded in timber boxes (both hardwood and marine ply). There were only 3 (<1%) boxes occupied by ants in autumn that were still occupied by ants in spring and these boxes did not receive active intervention in autumn. In only 6 (1%) of cases in autumn and 5 (1%) of cases in spring 2018 was there an ant nest or an infestation that required active maintenance (**Figure 22**).

There were numerous instances of fauna recorded using a nest box after pest species had left the box. An Australian Woodduck, Brush-tailed Possum and Sugar Glider were all observed in boxes that had been occupied by pest species (Termites, Ants and Wasps respectively) during 2018 monitoring inspections. There were also 27 instances of fresh leaf nesting material observed within nest boxes that had been previously occupied by pest species during 2018 monitoring inspections. There were 5 (10%) of the nest boxes occupied by pests, also occupied by or showing evidence of occupation by fauna during autumn 2018. There were 22 (55%) of the nest boxes occupied by pests, also occupied by or showing evidence of occupation by fauna during spring 2018.

Table 10. Pest species uptake of nest boxes in Sections 3 – 11 of the W2B project as recorded during autumn inspections.

Section	Ants	Bees	Invertebrate	Native Bees	Rats	Termites	Wasps	Total	Number Monitored	% Uptake
3A	0	0	0	0	0	0	0	0	0	0
3	7	2	0	0	0	0	16	25	257	10
4	2	1	0	0	0	0	0	3	27	11
5	1	0	0	0	0	0	0	1	30	3
6	1	0	0	0	0	0	0	1	33	3
7	2	0	0	1	0	0	1	4	25	16
8	7	2	0	0	0	0	0	9	86	10
9	0	0	0	0	0	0	0	0		
10	1	0	0	0	0	2	1	4	61	10
11	2	0	0	0	0	0	0	2		
Total	23	5	0	1	0	2	18	49	519	10

Table 11. Pest species uptake of nest boxes in Sections 3 – 11 of the W2B project as recorded during spring inspections.

Section	Ants	Bees	Invertebrate	Native Bees	Rats	Termites	Wasps	Total	Number Monitored	% Uptake
3A	1	0	0	0	0	0	0	1	12	8
3	5	1	1	0	0	5	6	18	285	6
4	3	1	0	0	1	0	0	5	63	8
5	0	1	0	0	0	0	0	1	29	3
6	3	0	0	0	0	0	0	3	26	12
7	3	0	0	2	0	0	0	5	31	16
8	2	1	0	1	0	0	1	5	83	6
9	0	0	0	0	0	0	0	0		
10	1	0	0	0	0	1	0	2	62	3
11	0	0	0	0	0	0	0	0		
Total	18	4	1	3	1	6	7	40	591	7

Figure 22. Top left: Timber nest box infested with ants, autumn 2018. Top Right: Cyplas nest box containing a mud wasp nest. Bottom Left: Black Rat in a timber nest box. Bottom Right: timber nest box infested with nest of an unidentified invertebrate species.

European bees were uncommonly recorded in nest boxes in Sections 3, 4, 5 and 8 with five boxes (1%) occupied during the autumn inspections and four boxes (<1%) occupied during the spring inspections. European bees were recorded using a 3 chamber bat box, Brush-tailed Phascogale, Glider rear entry and Small Parrot box types . European bees occupied timber boxes in two thirds of cases and Cyplas boxes in one third of cases, reflecting the proportional allocation of timber and Cyplas boxes. None of the boxes occupied by European bees in autumn continued to be occupied by bees in spring.

Native bees (likely *Tetragonula* sp.) were also uncommonly recorded in nest boxes in Sections 7 and 8 with one boxes (<1%) occupied in autumn and three boxes (<1%) occupied in spring. Native bees were recorded in Glider rear entry and Small Parrot boxes constructed from timber. One of the boxes occupied by native bees during autumn continued to be occupied during spring because no action was taken to remove the native bee hive.

Wasps and wasp nests (largely mud wasps) were recorded in nest boxes in Sections 3, 5, 7 and 10 with 18 boxes (3%) showing evidence of wasp occupation in autumn and seven boxes (1%) showing evidence of wasp occupation in spring 2018. Wasps occurred in 2, 3 and 4 chambered bat boxes, Antechinus, Boobook Owl / Wood Duck, Brush-tailed Phascogale, Cockatoo / Owl, Glider front and rear entry, Kingfisher, King Parrot and Possum boxes (**Figure 22**). Wasps occupied 4% of both Cyplas and timber boxes.

There was one instance of a species of invertebrate creating a communal nest within a nest box (**Figure 22**). A single *Rattus* sp. (likely *Rattus rattus* Black Rat) was also recorded in a Glider rear entry box in Section 4 during spring 2018 inspections (**Figure 22**). There were no avian pest species recorded using nest boxes during either of the autumn or spring 2018 inspections.

3.1.5 Performance Indicator 4: Repair and Maintenance

A total of 43 (8%) of nest boxes required maintenance, repair or replacement in autumn and an additional 17 (3%) of nest boxes required maintenance, repair or replacement in spring 2018, both results well within performance targets (**Table 12** and **Table 13**). Where possible, maintenance was completed in situ. Wasp nests and ants were removed when safe to do so, and boxes heavily infested by ants, bees or wasps were left with lids open between 6 monthly nest box inspections. Weed and vine removal was conducted on a number of boxes to better facilitate observation and ensure the box remained functional. Several boxes were re-positioned on the tree or moved to adjacent trees where tree-fall or storm damage required new nest box placements.

Damage that did not impair functionality for the target species (chewing around the entrance, water damage) was recorded in seven boxes (1%) in autumn with no additional damage recorded in spring 2018. There were 33 boxes that were damaged to a level that impairs functionality and could not be repaired in situ in 2018. These boxes are scheduled for replacement during the next monitoring period. This includes one box destroyed by fire, four boxes with persistent ant or bee uptake, eight boxes destroyed by termites and 20 boxes that were destroyed or lost through vegetation clearance as part of the W2B project. Boxes lost through vegetation clearance do not represent an ongoing threat to nest box security and once those boxes have been removed from the analysis a total of 24 (5%) nest boxes required maintenance, repair or replacement in autumn and nine (1.5%) required maintenance, repair or replacement in spring 2018.

Table 12. Maintenance, repair and replacement required following autumn 2018 nest box inspections on Sections 3 – 11 of the W2B project.

Section	Remove weeds	Remove pests	Reposition	Renumber	Replace	Totals	# Monitored	% Maintenance	Nest box types for replacement
3A	0	0	0	0	0	0	0	0	
3	1	3	0	0	12	16	257	6	B2, B3, BO x 2, Cock_Owl x 2, GLF,GLR x 3, Pos x 2
4	0	0	0	0	2	2	27	7	Unknown
5	0	1	0	0	1	2	30	7	Pos
6	0	1	0	0	0	1	33	3	
7	0	2	0	0	2	4	25	16	GLR x 2
8	1	0	1	0	3	5	86	6	GLR x 2, SmP
9	0	0	0	0	0	0			
10	0	1	1	0	5	7	61	21	B2, Pard, Pos x 2, SmP
11	3	1	2	0	0	6			
Total	5	9	4	0	25	43	519	8	

Table 13. Maintenance, repair and replacement required following spring 2018 nest box inspections on Sections 3 – 11 of the W2B project.

Section	Weeds	Remove pests	Reposition	Renumber	Replace	Totals	# Monitored	% Maintenance	Box Types to replace
3A	0	0	0	0	0	0	12	0	
3	0	3	1	0	5	9	285	3	B3, B4, BO, Cock x 2
4	0	1	1	0	0	2	63	3	
5	0	1	0	0	0	1	29	3	
6	0	1	0	0	0	1	26	3	
7	0	0	0	0	2	2	31	6	GLR x 2
8	0	0	1	0	0	1	83	1	
9	0	0	0	0	0	0			
10	0	0	0	0	1	1	62	1	Pard
11	0	0	0	0	0	0			
Total	0	6	3	0	8	17	591		

3.2 Comparison of the performance of timber and Cyplas nest boxes

The performance of timber and Cyplas boxes differed between seasons and material types (**Figure 23**). In both seasons timber boxes recorded lower occupancy rates, lower rates of evidence of use and lower overall rates of use than Cyplas boxes. A total of 46 (10%) timber boxes were inhabited in autumn and 40 (9%) inhabited in spring compared to a total of 21 (12%) Cyplas boxes inhabited in autumn and 22 (12%) inhabited in spring. The difference was most pronounced during spring 2018 where the overall rate of use for timber boxes was 140 (31%) of 448 timber boxes monitored compared to the overall rate of use of 98 (55%) of 177 monitored Cyplas boxes. There was little change in the number of Cyplas boxes that were occupied and those showing evidence of use between the autumn and spring monitoring events but a marked decline in the evidence of use in timber boxes from autumn to spring (**Figure 23**).

Cyplas boxes would be encountered less often by fauna because of the proportional allocation of boxes (a ratio of one Cyplas : two timber). When the availability of each box type is considered, there is a clear trend for Cyplas boxes to be preferentially inhabited over timber boxes. Further statistical analysis of this trend will be undertaken once more data is gathered in subsequent monitoring inspections.

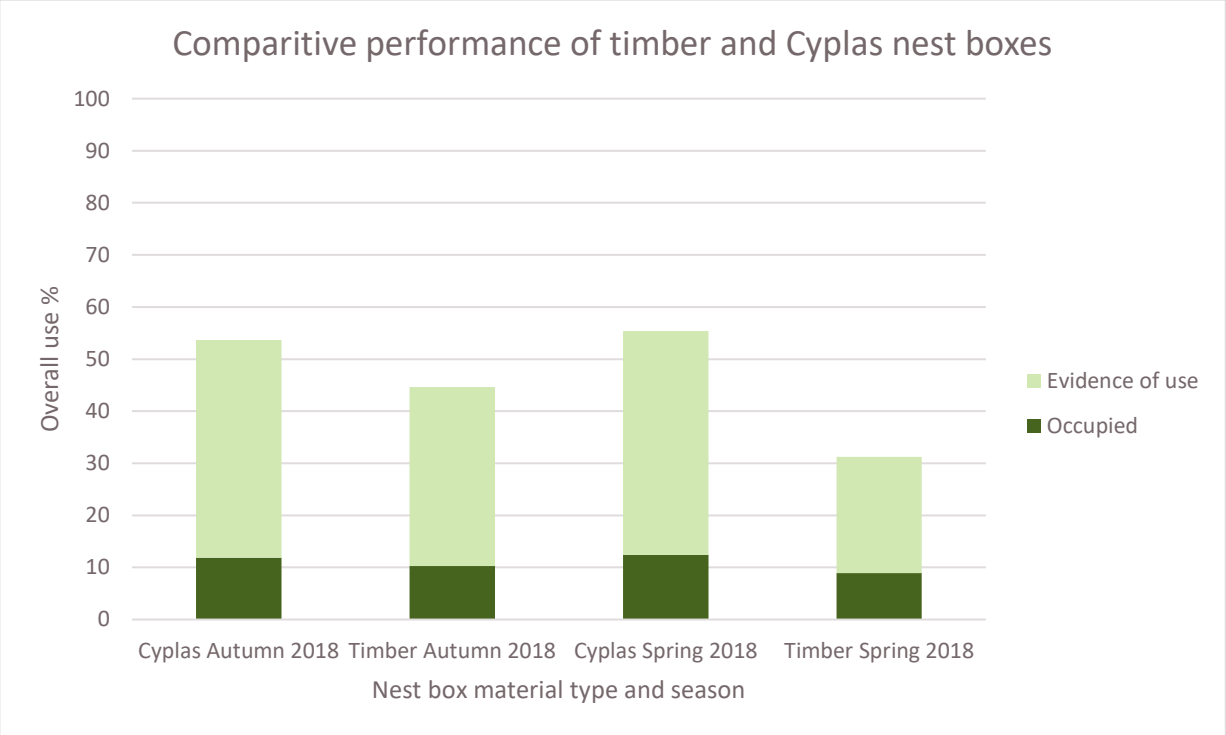

Figure 23. Comparison of overall rates of use for timber and Cyplas nest boxes as recorded during autumn and spring 2018 in Sections 3 – 11 of the W2B project.

3.2.1 Performance Indicator 1 : Timber v Cyplas boxes used by a variety of fauna

The range of fauna species recorded occupying Cyplas boxes at the time of inspections was lower than for timber boxes with a total of 11 fauna species recorded (1 bird, 8 mammals,1 microbat and 1 reptile) and only six fauna species recorded during spring inspections (**Table 14**). In comparison timber boxes recorded a total of 16 fauna species (one amphibian, four bird, seven mammal, three microbat, two reptile) with 11 species recorded in both autumn and spring inspections. The following seven species were only recorded occupying timber boxes:

- **Eastern Long-eared Bat (listed as vulnerable under the BC Act)***
- Eastern Rosella
- Gould's Wattled Bat
- Introduced Rat
- Lace Monitor
- Peron's Tree Frog
- White-throated Treecreeper.

Antechinus sp. and Mountain Brushtail Possum were the only two species observed in Cyplas boxes and not in timber boxes during the 2018 inspections. It is likely that a greater number of species used both timber and Cyplas boxes than reported above because animals will not always leave behind evidence of their presence. It is important to note that these figures represent direct observations of animals during autumn and spring inspections and do not include evidence of use because of the difficulty in accurately estimating this for different fauna species. Further monitoring may assist in determining whether these results are an accurate reflection of a greater diversity of species using timber boxes than Cyplas boxes.

Fewer species bred or raised young in Cyplas boxes than in timber boxes. There has been evidence of five species; Australian Owlet Nightjars, Common Brushtail Possum, Common Ringtail Possum, Squirrel Glider and Sugar Glider using Cyplas boxes for breeding purposes. Seven species have been recorded breeding in timber boxes; Australian Wood Duck, Common Brushtail Possum, Common Ringtail Possum, Eastern Rosella, Squirrel Glider, Sugar Glider and White-throated Treecreeper.

Table 14. List of species occupying timber and Cyplas boxes during autumn and spring nest box inspections.

Scientific Name	Common Name	Autumn		Spring	
		Cyplas	Timber	Cyplas	Timber
Acrobates sp.	Feathertail Glider	Y			Y
Aegotheles cristatus	Australian Owlet Nightjar	Y	Y	Y	
Antechinus sp	Antechinus	Y			
Chalinolobus gouldii	Gould's Wattled Bat		Y		
Chenonetta jubata	Australian Wood Duck				Y
Cormobates leucophaea	White-throated Treecreeper				Y
Dendrelaphis punctulatus	Green Tree Snake			Y	Y
Litoria peronii	Peron's Tree Frog		Y		
Nyctophilus bifax*	**Eastern Long-eared Bat**		Y		Y
Nyctophilus gouldi	Gould' Long-eared Bat	Y	Y		Y
Petaurus breviceps	Sugar Glider	Y	Y		Y
Petaurus norfolcensis*	**Squirrel Glider**	Y	Y	Y	Y
Phascogale tapoatafa*	**Brush-tailed Phascogale**	Y	Y		
Platycercus eximius	Eastern Rosella				Y
Pseudocheirus peregrinus	Ringtail Possum	Y	Y	Y	
Rattus sp.					Y

Scientific Name	Common Name	Autumn		Spring	
		Cyplas	Timber	Cyplas	Timber
Trichosurus cunninghami	Mountain Brushtail Possum			Y	
Trichosurus vulpecula	Common Brushtail Possum	Y	Y	Y	Y
Varanas varius	Lace Monitor		Y		

* Listed as vulnerable under the BC Act

3.2.2 Performance Indicator 2: Timber v Cyplas boxes occupied by target fauna species

Two of the three target threatened fauna species recorded during 2018 were recorded using Cyplas boxes designed for their use; Brush-tailed Phascogale and Squirrel Glider. All three threatened fauna species recorded in 2018; Brush-tailed Phascogale, Eastern Long-eared Bat and Squirrel Glider were found to occupy timber boxes.

Rates of occupation by target species did not differ markedly between timber and Cyplas nest box types and remained under 10% in each case. There were a total of 44 records (5%) of target fauna species occupying timber nest boxes and 21 records (6%) of target fauna species occupying Cyplas nest boxes in 2018 (**Table 15** and **Table 16**). Evidence of use by target species was found in 151 (18%) timber boxes with an overall nest box usage rate by target species in timber boxes of 194 boxes (23%). Evidence of use by target species was found in 53 (15%) Cyplas boxes with an overall nest box usage rate by target species in Cyplas boxes of 74 boxes (21%).

A greater number of timber box types recorded target species use (eight box types) than did Cyplas boxes (five box types). Eight timber box types recorded occupancy by target species and these were:

- Brush-tailed Phascogale boxes
- Glider front and rear entry boxes
- Possum / Large Glider boxes
- Microbat boxes (Single chamber, two chamber, three chamber and four chamber).

The five Cyplas box types occupied by target species included all of the above with exception of single, three and four chamber microbat boxes. There were differences in rates of occupancy of different box types in timber and Cyplas boxes. Glider front and rear entry, Cockatoo / Owl, Brush-tailed Phascogale, Possum and two chamber bat boxes constructed from Cyplas recorded greater overall rates of occupancy than did the same box types constructed from timber (**Table 15** and **Table 16**). Feathertail Glider, three and four chambered bat box types constructed from timber recorded greater overall rates of occupancy than did the same box types constructed from Cyplas. There were a greater number and diversity of non target species recorded in timber boxes than in Cyplas boxes (**Table 15** and **Table 16**).

Table 15. Rates of occupancy and evidence of use in timber nest boxes from Sections 3 – 11 of the W2B project following nest box inspections in autumn and spring 2018.

Box Type	Box Type Code	No. boxes monitored in 2018	No. occurrences of target species inhabiting boxes	% Inhabited by target species in 2018	Evidence of use by target species	% Evidence of use by target species	Overall use by target species	% Overall use by target species	Non-target species detected
Antechinus	A	56	0	0	29	52	29	52	Glider spp., Brush-tailed Phascogale, Feathertail Glider
Barn Owl	BO	20	0	0	0	0	0	0	Common Brushtail Possum, Woodduck, Owlet Nightjar, Lace Monitor, Glider spp.
Boobook / Wood duck	BOO	1	0	0	0	0	0	0	Nil
Cockatoo/Large Owl	Cock_Owl	78	0	0	1	1	1	1	Common Brushtail Possum, Woodduck, Owlet Nightjar, Green Tree Snake
Dollar Bird/Crimson Rosella	Dollar	8	0	0	0	0	0	0	Possum spp. Glider spp.
Feather Tail Glider	FTG	9	0	0	3	33	3	33	Nil
Glider (front entry)	GLF	76	10	13	35	46	45	59	Antechinus, Bird, Common Brushtail Possum, Common Ringtail Possum, Green Tree Snake, microbats
Glider (rear entry)	GLR	92	9	10	43	47	51	55	Native Bees, Common Brushtail Possum
Kingfisher	Kf	10	0	0	0	0	0	0	Squirrel Glider
King Parrot	KP	2	0	0	0	0	0	0	Glider spp.
Pardalote	Pard	10	0	0	0	0	0	0	Glider spp., Gould's Long-eared Bat
Phascogale	BTP	44	1	2	12	27	13	30	Sugar Glider, Squirrel Glider, Green Tree Snake

Box Type	Box Type Code	No. boxes monitored in 2018	No. occurrences of target species inhabiting boxes	% Inhabited by target species in 2018	Evidence of use by target species	% Evidence of use by target species	Overall use by target species	% Overall use by target species	Non-target species detected
Possum	Pos	205	11	5	28	14	39	19	Owlet Nightjar, Squirrel Glider, Sugar Glider, Australian Wood Duck, Peron's Tree Frog, Feathertail Glider
Single Chamber Bat	B1	34	3	9	0	0	3	9	Nil
2 Chamber Bat	B2	56	5	9	0	0	5	9	Lace Monitor
3 Chamber Bat	B3	24	3	13	0	0	3	13	Nil
4 Chamber Bat	B4	21	2	10	0	0	2	10	Nil
Small Parrot	SmP	80	0	0	0	0	0	0	White Throated Treecreeper, Sugar Glider, Gould's Long-eared Bat, Native bees
Spotted-tail Quoll	STQ	2	0	0	0	0	0	0	Nil
Tree Creeper	TC	14	0	0	0	0	0	0	Sugar Glider, Squirrel Glider
Totals		842*	44	5.23	151	17.93	194	23.04	

*21 nest boxes did not have the nest box type recorded and are not included in this analysis

Table 16. Rates of occupancy and evidence of use in Cyplas nest boxes from Sections 3 – 11 of the W2B project following nest box inspections in autumn and spring 2018.

Box Type	Box Type Code	No. boxes monitored in 2018	No. occurrences of target species inhabiting boxes	% Inhabited by target species in 2018	Evidence of use by target species	% Evidence of use by target species	Overall use by target species	% Overall use by target species	Non-target species detected
Antechinus	A	0	0	0	0	0	0	0	Glider spp.
Barn Owl	BO	6	0	0	0	0	0	0	Common Brushtail Possum, Woodduck, Owlet Nightjar, Lace Monitor, Glider spp.
Boobook / Wood duck	BOO	4	0	0	0	0	0	0	Common Brushtail Possum
Cockatoo/Large Owl	Cock_Owl	26	0	0	4	15	4	15	Sugar Glider, Common Brushtail Possum, Woodduck
Dollar Bird/Crimson Rosella	Dollar	2	0	0	0	0	0	0	Possum spp. Glider spp.
Feather Tail Glider	FTG	1	0	0	0	0	0	0	Nil
Glider (front entry)	GLF	2	1	50	1	50	2	100	Nil
Glider (rear entry)	GLR	34	8	24	17	50	25	74	Antechinus
Kingfisher	Kf	4	0	0	0	0	0	0	Sugar Glider
King Parrot	KP	6	0	0	0	0	0	0	Long-eared Bat, Glider spp.
Pardalote	Pard	4	0	0	0	0	0	0	Glider spp.
Phascogale	BTP	26	1	4	11	42	12	46	Sugar Glider, Squirrel Glider, Green Tree Snake

Box Type	Box Type Code	No. boxes monitored in 2018	No. occurrences of target species inhabiting boxes	% Inhabited by target species in 2018	Evidence of use by target species	% Evidence of use by target species	Overall use by target species	% Overall use by target species	Non-target species detected
Possum	Pos	137	10	7	20	15	30	22	Owlet Nightjar, Sugar Glider, Squirrel Glider, Feathertail Glider
Single Chamber Bat	B1	0	0	0	0	0	0	0	Nil
2 Chamber Bat	B2	8	1	13	0	0	1	13	Nil
3 Chamber Bat	B3	6	0	0	0	0	0	0	Nil
4 Chamber Bat	B4	14	0	0	0	0	0	0	Nil
Small Parrot	SmP	64	0	0	0	0	0	0	Owlet Nightjar, Glider spp., Gould's Long-eared Bat
Spotted-tail Quoll	STQ	0	0	0	0	0	0	0	Nil
Tree Creeper	TC	4	0	0	0	0	0	0	Nil
Totals		348*	21	6.03	53	15.23	74	21.26	

*21 nest boxes did not have the nest box type recorded and are not included in this analysis

3.2.3 Performance Indicator 3: Timber v Cyplas pest species

The rates of uptake by pest species in Cyplas boxes was low and within performance targets, with 12 (3%) of 355 monitored boxes (autumn and spring combined) containing pest species (**Table 17**). There were three pest species groups recorded in Cyplas boxes; ants, European bees and wasps. Wasps were the most commonly recorded pest species group in Cyplas boxes.

Rates of pest species uptake in timber boxes were also low and within performance targets, with 77 (9%) of 885 monitored boxes (autumn and spring combined) containing pest species (**Table 17**). Timber boxes recorded all seven pest species groups including ants, European bees, invertebrates, native bees, rats, termites and wasps. The most commonly recorded pest species group in timber boxes was ants.

Cyplas boxes performed better than timber boxes in terms of pest species uptake and this is largely due to a lack of termites and greatly reduced rates of ants in Cyplas boxes (**Table 17** and **Figure 24**). In both timber and Cyplas boxes rates of pest species uptake were greater in autumn than in the following spring inspections but this effect was more marked in Cyplas boxes (**Figure 24**).

Table 17. Rates of pest species uptake in timber and Cyplas boxes following nest box inspections in autumn and spring 2018 on Sections 3 – 11 of the W2B project.

Box type	Ants	Bees	Invertebrate	Native Bees	Rats	Termites	Wasps	Total	# Monitored	% Uptake
Timber	38	8	1	4	1	8	17	77	885	9
Cyplas	3	1	0	0	0	0	8	12	355	3

3.2.1 Performance Indicator 4: Timber v Cyplas repair and maintenance

Repair and maintenance requirements for Cyplas boxes were lower than for timber boxes. Only 8 (2%) of the monitored Cyplas boxes required active management or replacement compared to 50 (6%) of the monitored timber boxes throughout 2018. These figures include boxes with minor damage that does not impair functionality (chewing around entrance, box number faded or unreadable) and boxes lost through clearing for the W2B project which is not considered to be an ongoing threat to nest box longevity. Once those figures are removed from the analysis, only four of monitored Cyplas boxes (1%) and 24 of monitored timber boxes (3%) required active intervention to remain functional, well within the performance indicator target of < 10%. The main reasons for repair or maintenance were due to pest species uptake (timber and Cyplas boxes), water damage (timber), treefall (timber), repositioning (timber), lid unable to be opened (timber).

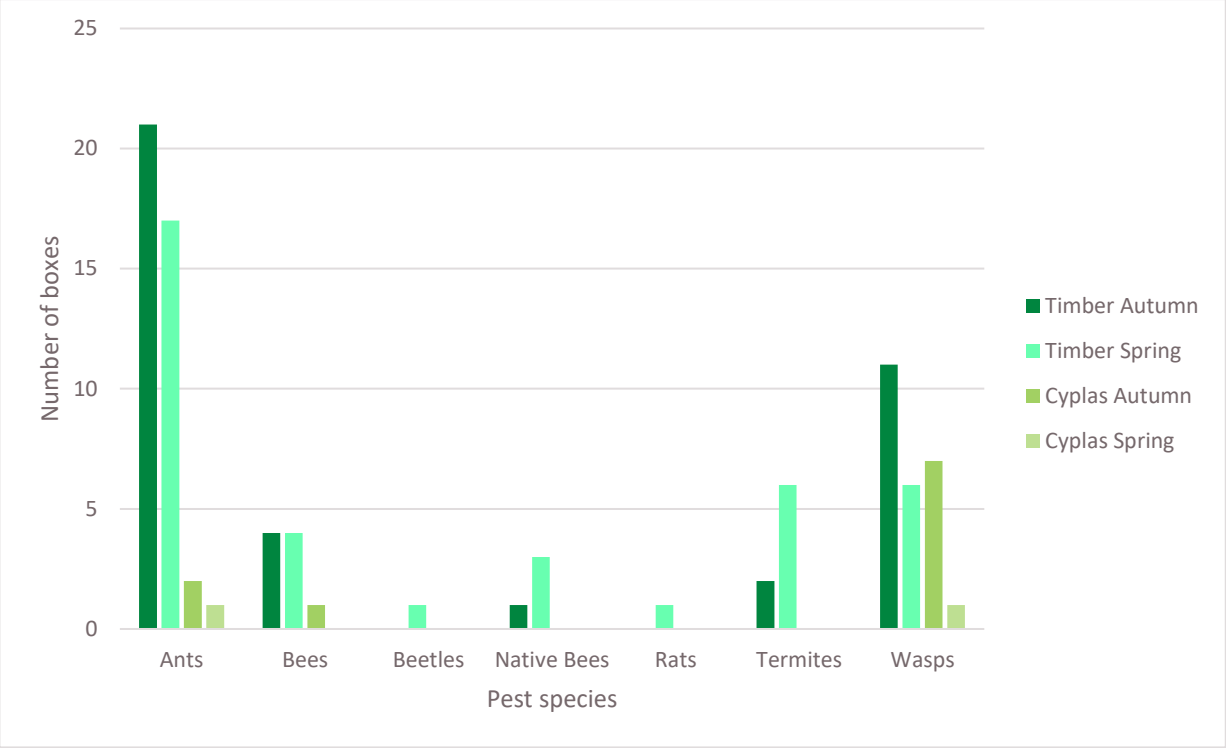

Figure 24. Number of timber and Cyplas boxes containing pest species following nest box inspections in autumn and spring 2018 on Sections 3 – 11 of the W2B project

3.3 Section 3

During the Autumn 2018 monitoring period seven vertebrate species were observed occupying 25 (11%) of 230 nest boxes monitored in Section 3. Common Brushtail Possum was the most abundant species with 13 individuals recorded using 11 boxes. Sugar Glider was recorded in seven box types – Small Parrot, Brush-tailed Phascogale, Glider front and rear entry – with a total of 11 individuals counted. Unidentified microbats, Gould's Wattled Bat and Gould's Long-eared bat were recorded in three boxes with a total of six individuals observed (**Figure 25**). Two individual Brush – tailed Phascogales, listed as Vulnerable under the BC Act 2016 was recorded in a timber and a Cyplas BTP nest box (**Figure 25**). A single *Litoria peronii* (Peron's Tree Frog) was present within a timber Possum box (**Figure 25**).

In Spring 2018, six vertebrate species were detected utilising 31 (13%) of 231 monitored nest boxes. The BC Act listed vulnerable Squirrel Glider was the most abundant species with 26 individuals using 11 nest boxes. Common Brushtail Possum was also abundant with 24 individuals inhabiting 16 nest boxes. Sugar Glider, Owlet Nightjar and White throated Treecreeper were also observed with three, two and two individuals observed. An individual Australian Wood Duck and Green Tree Snake were also present.

Figure 25. Top Left: Brush-tailed phascogale outside a Brush-tailed Phascogale box. Top Right: Four Gould's long-eared bats occupying a bat box. Bottom Left: Peron's Tree Frog recorded from a timber nest box. Bottom Right: Gould's Wattled Bat.

3.4 Section 4

During the Autumn 2018 inspection four vertebrate species were observed occupying four (15%) of 26 nest boxes in Section 4. Gould's Long-eared bat was the most abundant species with eight individuals

recorded using a single box. Three Common Ringtail Possum were identified in a single nest box. An individual Sugar Glider and Lace Monitor were observed using a Glider and Barn owl box respectively.

In Spring, three native species and one exotic species (Black Rat) were recorded utilising five of 63 monitored nest boxes (8%). Five individual Eastern Rosella were present in one nest box. Four Common Brushtail Possum occupied two nest boxes and two individuals of an unidentified *Nyctophilus* sp. were also detected.

3.5 Section 5

During the Autumn monitoring period two vertebrate species were detected inhabiting five of 31 nest boxes (16%). Gould's long-eared bat occupied two boxes with a total of four individuals. Sugar Glider occupied three boxes with a single individual in each box.

Only one family group of four Squirrel Gliders (including juveniles) was observed occupying one of 30 monitored nest boxes in Spring 2018.

3.6 Section 6

Four vertebrate species were detected occupying seven (21%) of 33 nest boxes in Autumn 2018. Sugar Glider was the most abundant with four individuals recorded occupying three boxes. Two Feathertail Gliders were observed in two Possum nest boxes (**Figure 27**). Two Common Ringtail Possums (including a juvenile) and one *Antechinus* sp. were also identified in separate boxes.

Only one individual Owlet Nightjar was observed occupying one of 26 monitored nest boxes in Spring 2018.

Figure 26. Left Feathertail Glider in a leaft nest in a Cyplas Possum box, Right Green Tree Snake on a leaf nest within a Cyplas nest box.

3.7 Section 7

During the Autumn monitoring period three species were recorded inhabiting four (16%) of 25 monitored nest boxes. The BC Act listed vulnerable Squirrel Glider was the most abundant species with five individuals recorded in two box types – Possum and Tree Creeper. Four individuals of an unknown

Nyctophilus sp. were recorded in one bat box. Three Sugar Gliders were also detected occupying one Tree Creeper box.

In Spring, two of the 31 monitored boxes (6%) were occupied. An adult and juvenile Squirrel Glider were recorded in one box, and a Common Ringtail Possum was recorded in another box.

3.8 Section 8 and 9

Autumn monitoring results indicated that five fauna species occupied 11 of 86 monitored nest boxes. (13%). A small colony of ten BC Act listed vulnerable Eastern Long-eared Bats were detected in a single chamber bat box. Squirrel Gliders were also common in Sections 8 and 9 with nine individuals detected in four nest boxes (Glider front and rear entry). Ten Gould's Long-eared Bats occupied two boxes (two chamber bat and Pardalote). An individual Owlet nightjar was also present in one box.

In Spring, five species were recorded inhabiting 14 (17%) of 83 monitored nest boxes. The most commonly observed species was Squirrel Glider with eight individuals observed in five nest boxes. Common Brushtail Possum (two occurrences), Australian Owlet Nightjar (three occurrences), Australian Woodduck (one occurrence) and Green Tree Snake (two occurrences, **Figure 26**) also utilised Possum, Glider front entry and Cockatoo / Owl nest boxes.

3.9 Section 10 and 11

The Autumn monitoring event detected five species inhabiting 11 of 61 monitored nest boxes (18%). Gould's Long-eared bat was the most common species recorded with 13 individuals present in two bat boxes. Nine Eastern Long-eared Bats were also recorded in two bat boxes. Sugar Glider were also regular occupants of nest boxes, with eight individuals occurring in four nest boxes. Three Common Brushtail Possums and one Lace monitor (**Figure 27**) were detected in three boxes.

The Spring monitoring event recorded six vertebrate species occupying seven of 62 monitored nest boxes (11%). The most common species recorded were Gould's Long-eared Bats and Eastern Long-eared Bats with five individuals of each species occurring in two separate nest boxes. Five Squirrel Gliders were also detected in two nest boxes. Australian Wood Duck, Common Brushtail Possum and Mountain Brushtail Possum (**Figure 27**) were also identified inhabiting three nest boxes.

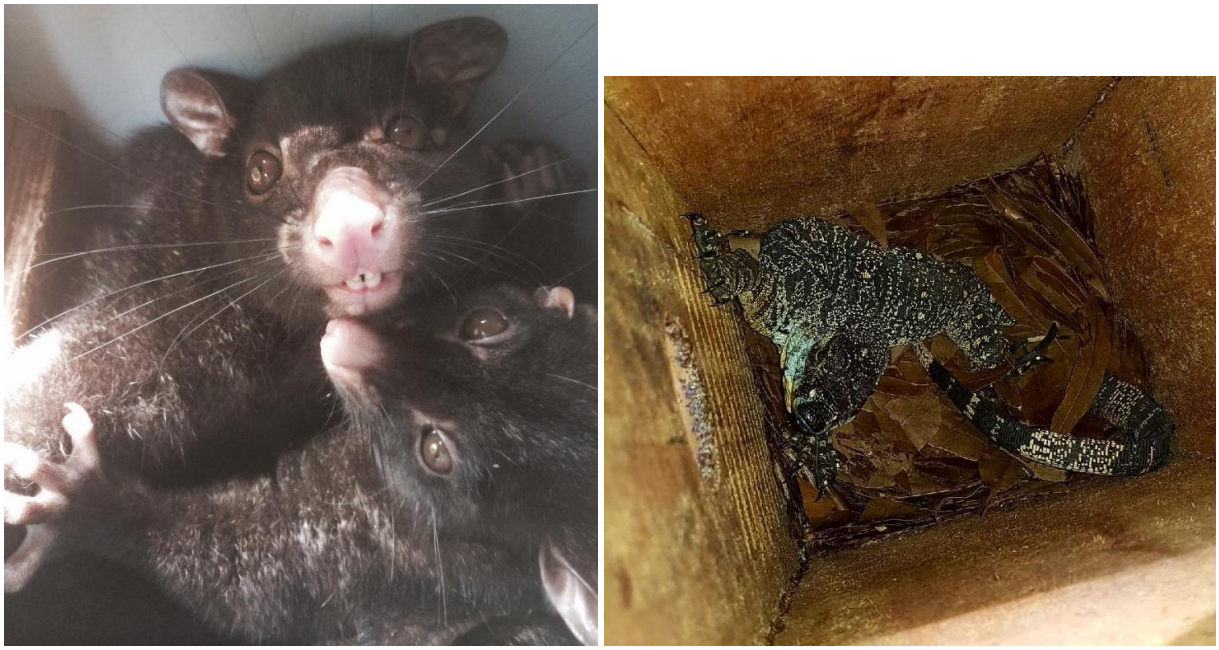

Figure 27. Left: Two Mountain Brushtail Possums in a Cyplas nest box. Right: Lace Monitor in a timber nest box.

4. Discussion

4.1 Use of nest boxes

Nineteen vertebrate species were confirmed using nest boxes which represents a greater species diversity than reported for similar RMS nest box programs on the Pacific Highway upgrade including those immediately to the south at Sapphire to Woolgoolga (S2W), Woolgoolga to Halfway Creek (W2HC) and Halfway Creek to Glenugie (HC2G) (Sandpiper 2016a, Sandpiper 2016b and Ecosure 2017). This result could be due to the larger sample size with more than three times the number of nest boxes involved on the W2B project than any of the adjacent RMS nest box programs and / or the greater area and diversity of habitats encountered than on any of the adjacent nest box projects. Cumulative species diversity will be tracked over time in subsequent nest box monitoring reports. Documented species lists for fauna displaced by vegetation clearance for the W2B project are not yet available for comparison with species occurring in nest boxes.

A total of 70% and 77% of records in autumn and spring respectively were attributed to just four mammal species (Common Brushtail Possum, Sugar Glider, Squirrel Glider and Gould's Long-eared Bat). This result is similar to those reported on other nest box projects with arboreal mammals being the most commonly encountered species using a range of nest box types (Sandpiper 2016a, Sandpiper 2016b and Ecosure 2017). It also aligns with the findings of a recent review of RMS nest box projects which similarly found that arboreal mammals (particularly Squirrel Gliders, Sugar Gliders, Common Brushtail Possums and Brush-tailed Phascogales) were the most successful species groups in terms of nest box uptake (Goldingay 2019).

Occupancy rates of 13% in autumn and 10% in spring 2018 are also within the range reported on similar nest box monitoring projects such as S2W where occupancy was reported at 11 – 15% (Sandpiper 2016a), W2HC where occupancy was reported at 7% (Sandpiper 2016b), and Coopernook where occupancy was reported at 13 – 16% (Sandpiper 2009). Occupancy rates are higher than those reported from the adjacent HC2G where occupancy was reported at 1 – 6% (Ecosure 2017) and lower than those reported for Branxton 22 – 29% (Sandpiper 2015). Estimated rates of occupancy for naturally occurring hollows are lacking in the literature and not yet available for this study. Some evidence for rates of occupancy in the order of 10% exist for certain species in certain landscapes (Goldingay 2019, Lindenmayer et al 2017). Without knowledge of the occupancy rates obtained during pre-clearing surveys it is difficult to determine whether nest boxes are providing suitable alternative habitat along the W2B alignment but from the literature it appears that nest box occupancy levels are satisfactory. Once the data on occupancy rates recorded during pre-clearing surveys is available analysis will be performed on the data to examine whether nest boxes are providing suitable alternative habitat for the species affected by clearing.

Similarly, overall rates of use of 55 – 56% (occupancy and evidence of use combined) fall within the range reported on the adjacent S2W 51 - 64% (Sandpiper 2016c) W2HC 30 - 53% (Sandpiper 2016a, 2016b, 2017a and 2017b) and HC2G 14 – 26% (Ecosure 2017) as well as those reported in the wider nest box literature (Goldingay 2019, Lindenmayer et al 2017). It is also likely that overall nest box use is underestimated because of the inability to detect species that do not leave any evidence of their presence and / or remain cryptic and hidden amongst leaf nests even when present during inspections

(e.g. Feathertail Glider and Antechinus spp.) but this will be a commonlaity across most nest box monitoring projects

4.2 Targeted species use of nest boxes

A primary objective of the NBMPs is to provide guidance on the provision of nest boxes as a short term compensatory mechanism for the loss of habitat trees within the clearing area, inclusive of den, roosting and nesting sources. As such, the level of uptake by displaced species, particularly detected threatened species, largely determines the success of the nest box program.

Of the 24 hollow dependent threatened vertebrate species previously recorded within 5km of the Section 3 - 11 alignment, only three - Squirrel Glider, Eastern Long-eared Bat and Brush-tailed Phascogale – were observed inhabiting nest boxes in the Autumn and Spring 2018 monitoring period. Squirrel Glider, listed as vulnerable under the BC Act, was the most abundant with 14 and 29 individuals recorded in Autumn and Spring respectively. Squirrel Gliders were recorded across a range of box types including Possum, Treecreeper, Glider front and rear entry. Eastern Long-eared Bats occupied three bat boxes with abundance ranging from three to ten individuals. There have been a limited number of reported incidences of Eastern Long-eared Bats using nest boxes and the reported uptake of nest boxes by this species in this study is encouraging.

Two individual Brush-tailed Phascogales were detected utilising Brush-tailed Phascogale boxes in Autumn 2018. Rates of occupancy and overall use by Squirrel Gliders and Brush-tailed Phascogales are on the lower end of those reported on other projects targeting these species (Rhind and Bradley 2002, Goldingay et al 2015, Goldingay et al 2018). Relatively lower rates of nest box use by Gliders and Brush-tailed Phascogales in this study may be related to the availability of natural hollows within the surrounding landscape and the local occurrence of each species. Comment on this can only be made once clearing reports have been provided for comparison.

Whilst rates of nest box uptake by target species were low (5%) when results for all nest box types were combined, there were a few nest box types that were successfully inhabited by the target species or species group. Eight nest box types (all mammal) recorded uptake by target species. Glider front and rear entry boxes and three chamber bat boxes all recorded occupancy rates above 10%. As a group, mammal boxes showed the greatest uptake with 8% of nest boxes designed for mammal species occupied by the target mammal species and overall usage rates of 31%.

Of the 19 species recorded using nest boxes in 2018, seven were recorded in both autumn and spring and aside from the Australian Owlet Nightjar, all were mammals. Several species of mammal were recorded breeding in nest boxes, including the Squirrel Glider indicating that nest boxes are being used for key lifecycle functions and contributing to the reproductive success of these mammal species.

In contrast there were no records of birds occupying bird boxes and only a few bird boxes showed evidence of use by birds (5%). None of the six species of threatened hollow-dependent birds predicted or known to occur in Sections 3 to 11 were recorded using nest boxes during 2018. All four species of birds recorded in nest boxes have been recorded using nest boxes in previous studies and are commonly occurring species. However, all four bird species also recorded evidence of breeding in nest boxes during 2018 indicating the boxes are fulfilling key lifecycle requirements for these avian species.

Infrequent use of nest boxes by birds has been reported in other nest box programs associated with Pacific Highway upgrades (Goldingay 2019, Sandpiper 2013, 2015) and even in forest landscapes (e.g. Lindenmayer et al. 2009). Infrequent use of nest boxes by birds may indicate that adequate hollow resources for these species exist in the local landscape and reflect the fact that these species are a lot more mobile and able to locate resources away from construction / operational activities. It may also be the case that high summer temperatures and limited insulation capacity of nest boxes inhibit use by birds during the breeding season. Lower uptake of nest boxes by birds may be related to predator avoidance strategies. Nest boxes are generally more conspicuous in the landscape than natural hollows which may make them less attractive as places to build nests and lay eggs. Moreover, some species may prefer natural hollows to nest boxes and only use nest boxes as temporary roosting sites (Lindenmayer et al. 2009). Temporary use of nest boxes by roosting birds is difficult to detect as signs may not be readily apparent (e.g. guano/faeces) or may be covered by mammal leaf nests. Low use may also be indicative of competitive interactions from other species, which may negatively affect bird usage (Goldingay & Stevens 2009). For example, individuals or family groups of Possums and Gliders may utilise several nearby boxes and exclude other species (Goldingay & Stevens 2009).

Although amphibian and reptile species were recorded infrequently occupying nest boxes, there were no boxes installed that were designed for use by amphibians or reptiles.

It is important to note that there are few documented studies which have tested the preference of a range of target species for different nest box designs (Goldingay 2019). There is relatively little evidence to indicate that the nest box designs used in this study for bird species in particular actually replicate the preferences of the species for which they have been designed.

Research has also shown that nest boxes are more likely to be inhabited when they are placed in areas of contiguous habitat rather than separated by cleared areas (Lindenmayer el al 2016). Squirrel Gliders have been found to occur in higher abundances in interior forest sites compared to those close to roads and residential edges (Brearley et al 2010). In most cases NBRZs were selected because they were part of larger areas of contiguous habitat, but it was not always possible to locate large areas of contiguous forest within the relatively narrow W2B project boundary and in the majority of cases NBRZs were located immediately adjacent to the existing or new highway alignment.

Nest boxes were largely installed in clusters of between two and 30 boxes dependent upon the availability of suitable trees within selected receptor sites. In only the larger NBRZs were several boxes of the one type installed. Goldingay 2019 has highlighted the need for several boxes of each type to be installed at a receptor site in order to allow for periodic nest box switching to occur which assists in parasite control and predator avoidance. A lack of similar box types within a NBRZ may contribute to poor uptake by certain species and lead to dominant species excluding other less dominant species. It may be worthwhile to investigate the rates of uptake of nest boxes when they are presented in clusters of 3 or more compared with when they are presented individually or in pairs.

4.3 Pests and nest box condition

There were low rates of pest species uptake of nest boxes recorded across Sections 3 – 11 of the W2B project in 2018. The results support recent research that indicates that European bees do not pose a significant problem for nest box programs. As suggested by recent research (Goldingay 2019) most nest

boxes occupied by European bees during autumn 2018 were abandoned and subsequently used by native species.

Ants were the main pest species encountered during 2018 at rates much lower than reported by Sandpiper (2016c) on S2W (31.2%) and similar to that reported on W2HC (Sandpiper 2016a, 2016b, 2017a and 2017b). Little is known about the potential competitive interactions between ants and native vertebrates although (Beyer & Goldingay 2006) reported that Squirrel Gliders were not deterred by the presence of ants and Feathertail Gliders have been observed in bat boxes containing ants. During the current inspection, vertebrate fauna was not observed in boxes containing ants but there were instances of leaf nests recorded in boxes with previous ant infestation.

Termite damage was a problem in a small number of timber boxes however the use of Cyplas boxes completely removed the incidence of this pest species. Cyplas boxes performed better than timber boxes for all pest species in 2018.

Of the nest boxes monitored in 2018, 33 (6%) required repair predominately due to loss through clearing, but also as a result of damage from fire, theft, termites or infestation by exotic species (bees, wasps or ants).

4.4 Comparison of timber and Cyplas nest box materials

The use of Cyplas boxes on this project aims to document how they compare to timber boxes in relation to the four indicators of performance. After one year of monitoring there was a trend for Cyplas boxes to be preferentially used over timber boxes, with higher occupancy rates and overall usage rates in autumn and spring. This was an unexpected result given the differing temperature profiles of Cyplas and timber boxes and the unnatural feel of the construction material. Anecdotal and unpublished evidence suggests that higher temperatures can be expected in Cyplas boxes than timber boxes of the same type when directly exposed to the sun (ELA pers comm, Sandpiper 2016d). Goldingay (2015) conducted trials testing the temperature profiles and associated rates of uptake of paried nest boxes and recommended nest box installation for non flyuing mammals should place nest boxes to minimise extreme temperature. For this reason, usage of Cyplas boxes in spring was expected to be lower because of the likelihood of exposure to higher temperatures and the detrimental effect high temperatures can have on fauna. Condensation was observed on the interior of occupied Cyplas boxes. Humidity levels may also play a role in the uptake of nest boxes and this is another area where further research is recommended.

Cyplas boxes performed better than timber boxes in relation pest species uptake and levels of maintenance and repair. However, the diversity of species using Cyplas boxes was lower than for timber boxes. The lower species diversity may be a result of the novel look and unnatural feel of the box material, with uptake of Cyplas boxes favouring the more gregarious and commonly occurring species. Our results only partially support this with several common and gregarious species only being recorded in timber boxes (Australilan Woodduck, Eastern Rosella, Gould's Wattled Bat and Lace Monitor). And if this is the case, a greater diversity of species would be expected to use Cyplas boxes over time as animals continue to encounter the Cyplas boxes, become familiar with them in the landscape and are willing to use them as habitat.

5. Recommendations

Table 18 provides an evaluation of nest boxes against the performance criteria discussed in Section 1. Evaluation of performance indicators is described in detail in Sections 3.1.1 to 3.1.4. **Table 19** provides a list of the 33 nest boxes and the corresponding nest box types requiring replacement as a result of extensive pest species damage, loss through clearing, fire or theft. Other recommendations include;

- tracking cumulative species diversity in each box type and for all nest boxes over time based upon the results of successive monitoring inspections
- comparing of the rates of occupancy for species displaced by vegetation clearance with species occurring in nest boxes
- potentially investigating the rates of uptake of nest boxes (particularly by arboreal mammals) when they are presented in clusters of 3 or more compared with when they are presented individually or in pairs (in line with the findings of the Goldingay 2019 review).

Table 18. Performance measures

Performance measure	Target	Status	Corrective Action	Proposed Action
Use of nest boxes by a range of fauna species	Boxes inhabited by any fauna species within 4 years. Overall rates of use >50%. Used by at least 50% of the species displaced through clearing	Pending. 55 - 56% of boxes recorded usage(occupancy combined with evidence of use) in Autumn and Spring. No information available on species displaced by clearing to date.	Nil	Continue to monitor occupancy in 2019, 2021 and 2023.
Use of boxes by target species	>10% uptake by target species. Limited literature on use of naturally occurring hollows indicates rates of occupancy for target species of 10% are achievable.	**Not achieved**. 5% boxes inhabited by target species during 2018. 19 hollow dependent fauna species observed inhabiting boxes. 14% of Glider boxes occupied by target species during 2018. 10% of 3 chambered bat boxes inhabited by target species in 2018.	Evaluate evidence for usage of nest boxes by target species in similar studies, re-position boxes in more suitable habitat, examine nest box types, survey to determine if target species are present.	Discuss with PC / RMS, re-assess after next monitoring event in Autumn 2019.
Low rates of pest species usage	<15%	Achieved: 9% nest boxes inhabited by pest species in Autumn 2018. 7% nest boxes inhabited by pest species in Spring 2018.	Nil	Nil
Reduced maintenance and repair requirements	<10% boxes requiring repair or maintenance	Achieved: 8% of all nest boxes required maintenance in autumn and 3% in spring. 5% of boxes required replacement in autumn and 1.5% in spring.	Replace 33 nest boxes (See **Table 19**) during next monitoring event (dependent upon 30% install figures). Renumber 7 boxes that were never numbered or the number has faded	Discuss with PC / RMS and consider replacing termite damaged boxes with Cyplas boxes or artificially created hollows (chainsaw hollows). Discuss potential to consider supplementing bird boxes with arboreal mammal boxes. Discuss potential to tag trees with nest box number with PC / RMS.

Table 19. Details of box types requiring replacement in each of Sections 3 – 11 of the W2B project.

Section	Number of boxes	Nest box types
3A	0	N/A
3	17	B2, B3 x 2, B4, BO x 3, Cock/Owl x 4, GLF, GLR x 3, Pos x 2
4	2	Unknown
5	1	Pos
6	0	N/A
7	4	GLR x 4
8	3	GLR x 2, SmP
9	0	N/A
10	6	B2, Pard x 2, Pos x 2, SmP
11	0	N/A
Total	33	B2 x 2, B3 x 2, B4, BO x 3, Cock/Owl x 4, GLF, GLR x 9, Pard x 2, Pos x 5, SmP x 2

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Appendix A - Monitoring data

Supplied as a separate digital file.

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