Nest box Monitoring Report - Woolgoolga to Ballina Pacific Highway Upgrade (Sections 3 - 11) Year 2, 2019

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1300 646 131
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Project Manager	Alicia Scanlon
Prepared by	Liz Brown, Alastair Jones and Alicia Scanlon
Reviewed by	Frank Lemckert
Approved by	Rachel Murray
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Template 2.8.1

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Abbreviations

Abbreviation	Description
BC Act	NSW *Biodiversity 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
SCA	State Conservation Area
TfNSW	Transport for New South Wales
W2B	Woolgoolga to Ballina

Executive Summary

Eco Logical Australia (ELA) has been engaged by Transport for NSW (TfNSW) 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 of the W2B project (the subject site), 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, 662 nest boxes have been installed prior to clearing of vegetation for the W2B project. The remaining nest boxes are to be installed post-clearing, once a final tally of hollow bearing trees has been compiled from data collected during clearing supervision. The final nest boxes should be installed within three months post completion of clearing, once the exact number of hollow-bearing trees (HBTs) removed is known.

Nest boxes are to be monitored twice per year in Autumn and Spring in 2018, 2019, 2021 and 2023. This report summarises the results of the second year of monitoring undertaken in 2019. The Spring monitoring event was split, due to the severe 2019 bushfire events. Subsequently the Spring monitoring was partially completed during September, October and November 2019, with the remainder completed in March 2020. 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. It should be noted that the NBMPs did not provide measureable targets for the performance indicators listed above. The percentage targets being used in this series of monitoring reports are derived from review of the scientific literature on rates of occupancy for nest boxes on similar TfNSW Pacific Highway upgrade projects.

Overall, a lower number of fauna has been recorded using next boxes during the 2019-20 W2B monitoring events, when compared to the 2018 monitoring events, which can largely be attributed to the combination of extensive droughts followed by severe bushfires and surrounding habitat loss. Construction noise and vibration are factors which are also likely to have contributed, given that construction works and active vegetation clearing within and adjacent to the Nest Box Replacement Zones (NBRZs) have continued during 2019-20.

Results of 2019-20 monitoring indicate that two of the four performance criteria are being achieved and comfortably exceeded (P3 and P4) and a third (P1) was also achieved in Autumn 2019 but not in Spring/Summer 2019-20. It is likely that P1 was not achieved in Spring /Summer 2019-20 as a result of

the extreme bushfires that swept across the eastern coast of Australia during this time and directly affected Sections 6, 7 and 10 of the W2B project.

Performance Criteria	Target	2018	2019
1. Box overall usage by native fauna species	50% boxes	55-56%	38-53%
2. Target fauna species occupancy	10% occupancy of nest boxes by species for which the box was designed	6% occupancy, 17% evidence and 23% usage (10% target attained for Glider front and rear entry and 3 chambered bat boxes)	6% occupancy, 17% evidence and 23% useage (10% target attained for Glider rear entry and 2, 3 and 4 chambered bat boxes). 8% occupancy when only mammal boxes are considered.
3. Pest species	< 15%	7-9%	6-9%
4. Repair and maintenance	< 10%	8%	8%

The overall rate of nest box usage (occupancy and evidence combined) was 53% in Autumn and 38% in Spring. Fourteen vertebrate species were recorded in nest boxes during 2019-20 compared with 19 vertebrate species recorded in 2018. This 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 five (mammals) of the 14 vertebrate species recorded using nest boxes account for the majority of records, *Nyctophilus gouldi* (Gould's Long-eared Bat), *Petaurus breviceps* (Sugar Glider) and *Trichosurus vulpecula* (Common Brushtail Possum) and two of these *Nyctophilus bifax* (Eastern Long-eared Bat), *Petaurus norfolcensis* (Squirrel Glider) are target threatened species.

Analysis of nest box types found 6% occupancy and 23% overall usage (by targeted species) in 2019-20 which is below the performance inidicator target of 10% occupancy. This result is unchanged from the 2018 result. A discussion provided in this report provides some justification for the project not attaining this performance indicator target with the suggestion that the target of 10% occupancy is too high for most box types other than arboreal mammals. Even when all bird boxes are removed from the analysis occupancy rates of the remaining arboreal mammal and bat boxes reaches 8%. There is a lack of documented evidence in the scientific literature for occupancy rates of many of the avian nest box types installed and little evidence that nest boxes are used by a range of bird species on a regular basis. These results suggest that the target of 10% occupancy by the species for which a box is designed may be unrealistic and need to be revised.

Uptake of nest boxes by a range of target threatened fauna has also been relatively low, with only three of the 24 target threatened species recorded inhabiting boxes during 2019-20. These three species are Brush-tailed Phascogale, Eastern Long-eared Bat and Squirrel Glider. This is in keeping with other relevant studies (Griffiths et. al. 2018, Rueegger et. al. 2019b, Le Roux et. al. 2015, Lindenmayer et. al. 2009, Lindenmayer et. al. 2015, Lindenmayer et. al. 2018), and indicates that nest boxes do not necessarily provide suitable compensatory habitat for a number of threatened species.

The rates of occupancy by pest species is low and below target (<15%), with ants, termites, bees and wasps being the main pest issues. There were no avian pest species recorded using nest boxes during either the Autumn 2019 or Spring 2019-20 inspections. Most pest issues were easily addressed *in situ* and were not evident during the subsequent nest box inspection. The rates of repair and maintenance required was also low and below target (<10%) during 2019-20. Most maintenance issues are addressed *in situ* during nest box checks, but 55 boxes will need to be replaced during the next monitoring event, largely as a result of fires and termite damage.

There remains a trend for greater rates of use of Cyplas boxes by native fauna than for timber boxes although this is largely centred upon Autumn monitoring results for the 2019-20 monitoring year. In Autumn, timber boxes recorded lower occupancy rates (13%) than Cyplas boxes (21%), lower rates of evidence of use (34% vs 44%) and lower overall rates of use (46%) than Cyplas boxes (64%). The range of fauna species recorded occupying both Cyplas and timber boxes was higher in Autumn than in Spring inspections. Two threatened fauna species were recorded using Cyplas boxes designed for that species; Eastern Long-eared Bat and Squirrel Glider. However, all three of the target threatened fauna species recorded during 2019-20 were found to occupy timber boxes designed for their use; Brush-tailed Phascogale, Eastern Long-eared Bat and Squirrel Glider.

In terms of pest species uptake, Cyplas boxes performed much better than timber boxes, largely due to termites not destroying Cyplas boxes and greatly reduced rates of use by ants, bees and invertebrates. Ants were the most commonly recorded pest in 2019-20. Repair and maintenance requirements (not related to fire damage) for Cyplas boxes were lower than for timber boxes; only 3 (1%) Cyplas boxes required active management or replacement compared to 21 (3%) timber boxes, which is well within the performance indicator target of < 10% in both cases.

There was evidence of breeding recorded in both timber and Cyplas nest boxes. Two species were recorded breeding in timber boxes during 2019-20; Common Brushtail Possum and the threatened Squirrel Glider. There were instances of family groups of Squirrel Gliders and Common Brushtail Possums occupying boxes and evidence that boxes had been used for breeding purposes by each of these species, including records of older juveniles. There was evidence of birds previously nesting within timber boxes, indicated by the presence of egg shells on a number of occassions (potentially Australian Owlet Nightjar, Australian Woodduck and Eastern Rosella).

There were 56 boxes identified that required maintenance or repair / replacement during 2019-20. Of those, 32 need to be reaplced because they were either destroyed by fire (22 boxes including Cyplas and timber), termites (seven boxes), tree fall (two boxes) or persistently occupied by European bees (1 box). Of the remaining 24 that required maintenance but remained functional, seven had to be repositioned on the host tree, four boxes were scorched by fire and were carefully checked for functionality and / or repositioned on the host tree, two had entrance holes chewed by fauna. The remaining 12 boxes had been inhabited by pest species and needed removal of pest species / nests, the lild propped open between monitoring events to encourage pest species to vacate the box or the lid closed again.

When combined with boxes needing replacement from the 2018 monitoring year there are a total of 55 nest boxes needing to be replaced and incorporated into the 100% nest box allocation which are expected to be installed prior to Autumn 2021 monitoring.

1. Introduction

1.1 Background

Eco Logical Australia (ELA) has been engaged by TfNSW 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 (the subject site) runs from Glenugie to Ballina, passing through largely cleared floodplains and crossing the Clarence and Richmond Rivers, and 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 (HDF) species known from records within 5 km of the W2B alignment that were targeted by the NBMPs and / or listed as threatened under the NSW *Biodiversity Conservation Act 2016* (BC Act) or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) since the NBMPs were prepared.

The NBMPs 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 (HBTs) 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 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, four HBTs per hectare. There were no surveys of HBTs for resident fauna completed within the NBRZs.

The Nest Box Management Plans for the project state that nest boxes are to be monitored twice per year in 2018, 2019, 2021 and 2023. 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 (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. This is per the agreement with the Envrionmental Protection Authority (EPA) and was approved by the Environmental Representative for W2B.

This 2019 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.

The Spring monitoring event was split, due to the severe 2019 bushfire events with the Spring monitoring being partially completed during September, October and November 2019, and the remainder completed in March 2020.

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.

When discussing nest box monitoring results the following definitions apply;

- Occupancy: a nest box is inhabited by an animal during the visual inspection
- Evidence of use: a box contains signs that an animnal has visited and used the nest box for shelter or breeding purposes. Signs of visitation by an animal include nests of various forms, scats / guano, feathers, shed skins, bones, eggs, egg shells, scratches on the sides of the nest box, chewing around the entrance hole, a depression in the sawdust provided as bedding material, hair or fur.
- Usage: Occupancy and evidence of use combined

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-tailed Quoll	V	E	Spotted-tailed Quoll

Scientific name	Common Name	BC Status	EPBC Status	Target Box Type
Petauroides volans	Greater Glider		V	Possum/Large-Glider
Petaurus australis	Yellow-bellied Glider	V		Possum/Large-Glider
Petaurus norfolcensis	Squirrel Glider	V		Glider (front-entry, 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
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 are still being compiled. Details of fauna recorded during vegetation clearance in Section 3 are presented in **Table 2** below. A total of 201 occurrences of 32 species, including three species listed as Vulnerable under the BC Act were recorded during clearing surveys of Section 3.

The clearing of HBTs is undertaken as a two stage process over a 48 hr period which allows any fauna inhabiting a HBT to be cleared the opportunity to self relocate prior to second stage clearance and mulching of the the felled HBT. This technique reduces the occurrence of fauna in HBTs to be cleared.

From the clearing data provided, 1243 HBT's cleared in Section 3 identified 201 occurrences of fauna, equating to a fauna occupancy rate of 16%. Over half (55%) of the 201 fauna occurrences recorded were mammals, 32% were reptiles, 9% were invertebrates, 2% were birds and 1% amphibians. There have

been no nest boxes installed that cater to amphibians, reptiles or invertebrates. If occurrences of amphibians and reptiles are removed from the data, occupancy rates are 11%, and if we also remove invertebrates (although nest boxes do provide suitable habitat for Native Stingless Bees and European Honey Bees), occupancy rates are 9%.

Table 2: Species recorded during vegetation clearance in Section 3A Glenugie Link and Section 3, Sept 2016 – June 2018.

Species Name	Common Name	Section 3
Amphibians		
Litoria caerulea	Green Tree Frog	1
	Unidentified Frog	1
Subtotals		2
Birds		
Philemon corniculatus	Noisy Friarbird	1
Podargus strigoides	Tawny Frogmouth	1
Todiramphus macleayii	Forest Kingfisher	1
Trichoglossus moluccanus	Rainbow Lorikeet	1
	Unidentified Lorikeet	1
Subtotals		5
Mammals		
Acrobates pygmaeus	Feathertail Glider	8
Antechinus flavipes	Yellow-footed Antechinus	2
Antechinus spp.	Antechinus	5
Chalinolobus gouldii	Gould's Wattled Bat	1
Chalinolobus morio	Chocolate Wattled Bat	2
Petaurus breviceps	Sugar Glider	30
*Petaurus norfolcensis**	Squirrel Glider	1
*Petaurus volans**	Greater Glider	1
*Phascogale tapoatafa**	Brush-tailed Phascogale	5
Pseudocheirus peregrinus	Common Ringtail Possum	1
Rattus spp.	Unidentified Rat	1
Trichosurus vulpecula	Common Brushtail Possum	41
	Unidentified microbat	12
Subtotals		110
Reptiles		
Boiga irregularis	Brown Tree Snake	1
Cocinnia tenuis	Bar-sided Forest Skink	5
Cryptophis nigrescens	Eastern Small-eyed Snake	1
Cyclodomorphus gerrardii	Pink-tongued Skink	1

Species Name	Common Name	Section 3
Dendrelaphis punctulatus	Green Tree Snake	5
Lampropholis delicata	Delicate Skink	3
Lialis burtonis	Burton's Legless Lizard	1
Morelia spilota	Carpet Python	1
Nebulifera robusta	Robust Velvet Gecko	33
Pogona barbata	Eastern Bearded Dragon	1
Varanus varius	Lace Monitor	6
	Unidentified Leaf-tailed Gecko	1
	Unidentified Skink	4
	Unidentified Gecko	2
Subtotals		65
Invertebrates		
	Native Stingless Bee	18
Apis mellifera	European Honey Bee	1
Subtotals		19
Total species		32
Total occurrences		**201**

Fauna occurrences is the number of times a fauna species was recorded and does not equate to the number of individuals as this information was not provided. * Threatened species listed under the BC Act.

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 over the monitoring period is made by using the following performance indicators:

1. **Use of nest boxes by a wide range of native fauna**. If the combined species overall rates of use of nest boxes are equal to or greater than 50%, the performance measure is considered to have been achieved.
2. **Use of nest boxes designed for a target species being used by that species**. Measured by reporting on the percentage of boxes occupied 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.
3. **Low rates of usage by exotic fauna**. Measured by reporting on the percentage of boxes occupied 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 occupation 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.

It should be noted that the NBMPs did not provide measureable targets for the performance indicators listed above. The percentage targets being used in this series of monitoring reports are derived from review of the scientific literature on rates of occupancy for nest boxes on similar TfNSW Pacific Highway upgrade projects (Ecosure 2017, Goldingay 2019, Lindenmayer et. al. 2017, Sandpiper 2013, 2015, 2016a, 2016b, 2016c, 2017a and 2017b) and on threatened species research programs where nest boxes were installed and monitored (Connecting Country 2016). The reviewed literature is largely focused upon box usage by arboreal mammal species as this fauna group is the most commonly studied in conjunction with nest boxes. **Performance inidicator targets drawn from the reviewed literature on arboreal mammals and applied to other taxa are estimates only and in the absence of other supporting evidence, must be evaluated with caution**.

It is also important to note that many of the 24 target threatened fauna species (**Table 1**) have not been recorded using nest boxes. Thirteen (54%) of the 24 target threatened species are microbats whilst only 86 of the installed boxes (13%) are microbat boxes. At least four of the 13 threatened microbats listed as target threatened species are not known to use nest boxes as roosting habitat and a further three species use nest boxes predominantly when they are installed in subterranean locations (under bridges and in culverts) rather than in trees, as is the case with the NBMP boxes. Similarly, *Dasyurus maculatus* (Spotted-tailed Quoll) has not been recorded using a nest box in the wild. Useage of nest boxes by threatened Large Forest Owls and birds in general is also typically low. The four species of Large Forest Owl listed in **Table 1** comprise 16% of the 24 target threatened fauna whilst only 54 (8%) of the installed nest boxes are suitable for Forest Owls. **The ability of the nest boxes to compensate for target threatened fauna species must be viewed with these limitations in mind**.

1.3 Installation

Nest boxes were installed by a number of contractors over a number of separate periods of installation between 2015 and 2019, with the majority installed in 2016 and 2017. As a result, boxes have been in place for between six months and 4.5 years as at December 2019. Dates of installation for each section appear in **Table 3** below (where date of installation was available or provided by contractors). Locations of NBRZs containing nest boxes in the subject site 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). Using range of materials aims to provide 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 (482 in the 70% pre-vegetation clearance allocation) were to be constructed from timber because boxes made of this material are known to have previously been used by a wide 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 Orara & Clarence Industries, 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 4** 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 3: Timing of nest box installations by year on Sections 3 – 11 of the W2B Pacific Highway upgrade.

Section	2015	2016	2017	2018	2019
3A	-	-	-	January	-
3	-	February, July, September	March, June	-	-
4	June, September	February, June	-	-	-
5	-	February, October	-	-	-
6	-	December	January, July	October	-
7	-	July, November	January	-	-
8	September	July, November	January	-	-
9	-	-	January	-	-
10	-	November	May	-	-
11	October	November	May	-	-

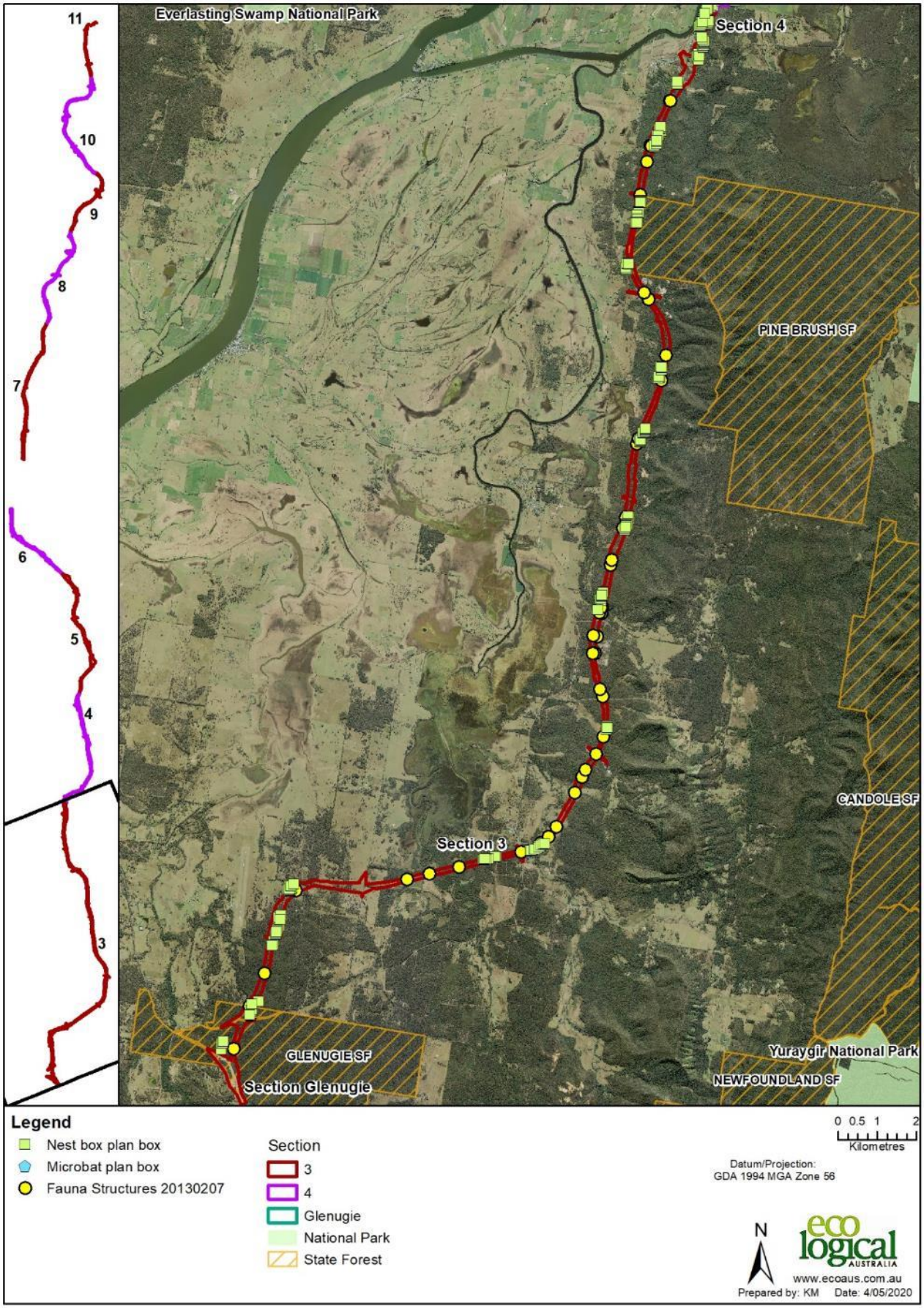

Figure 1: Section 3 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

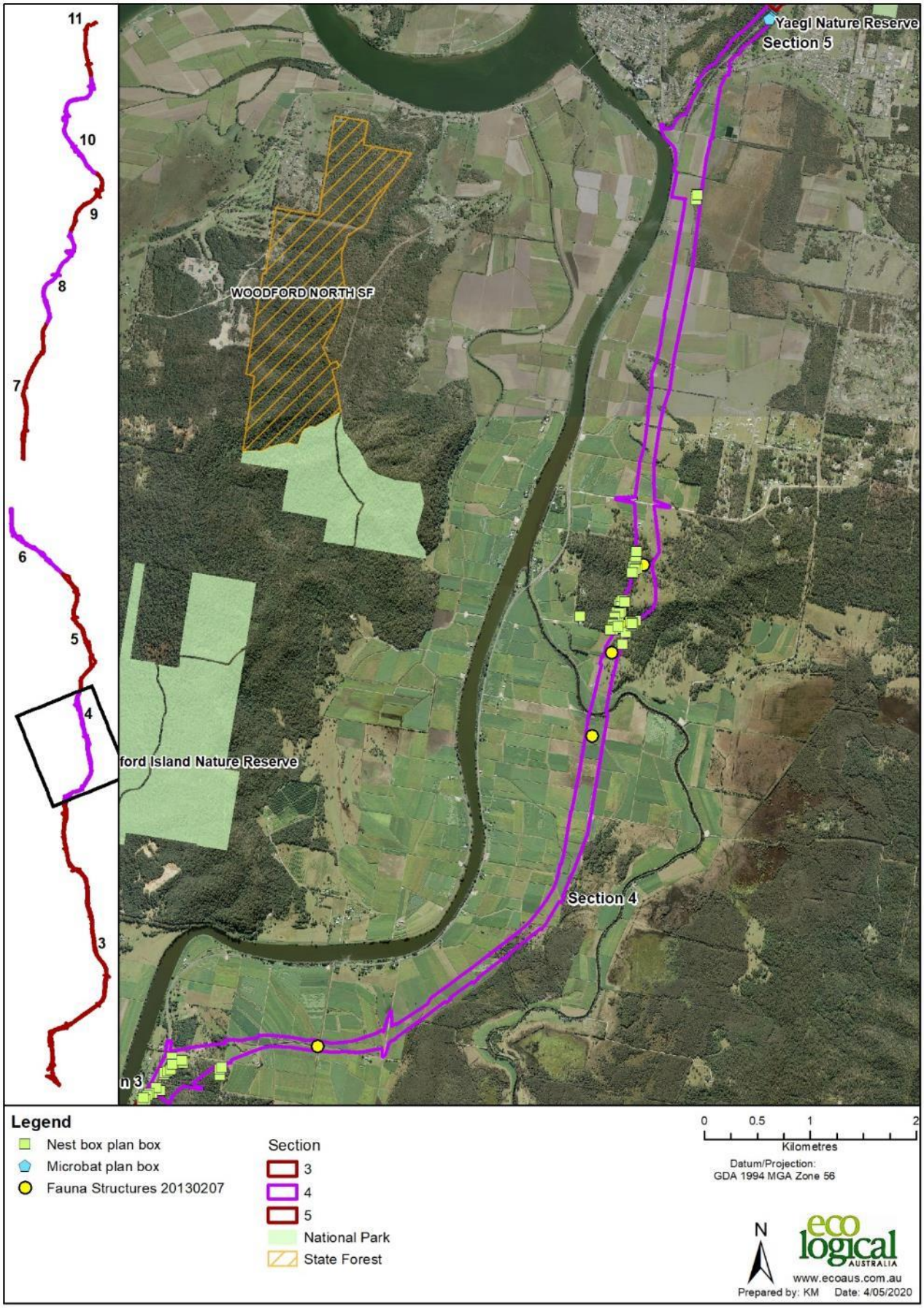

Figure 2: Section 4 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

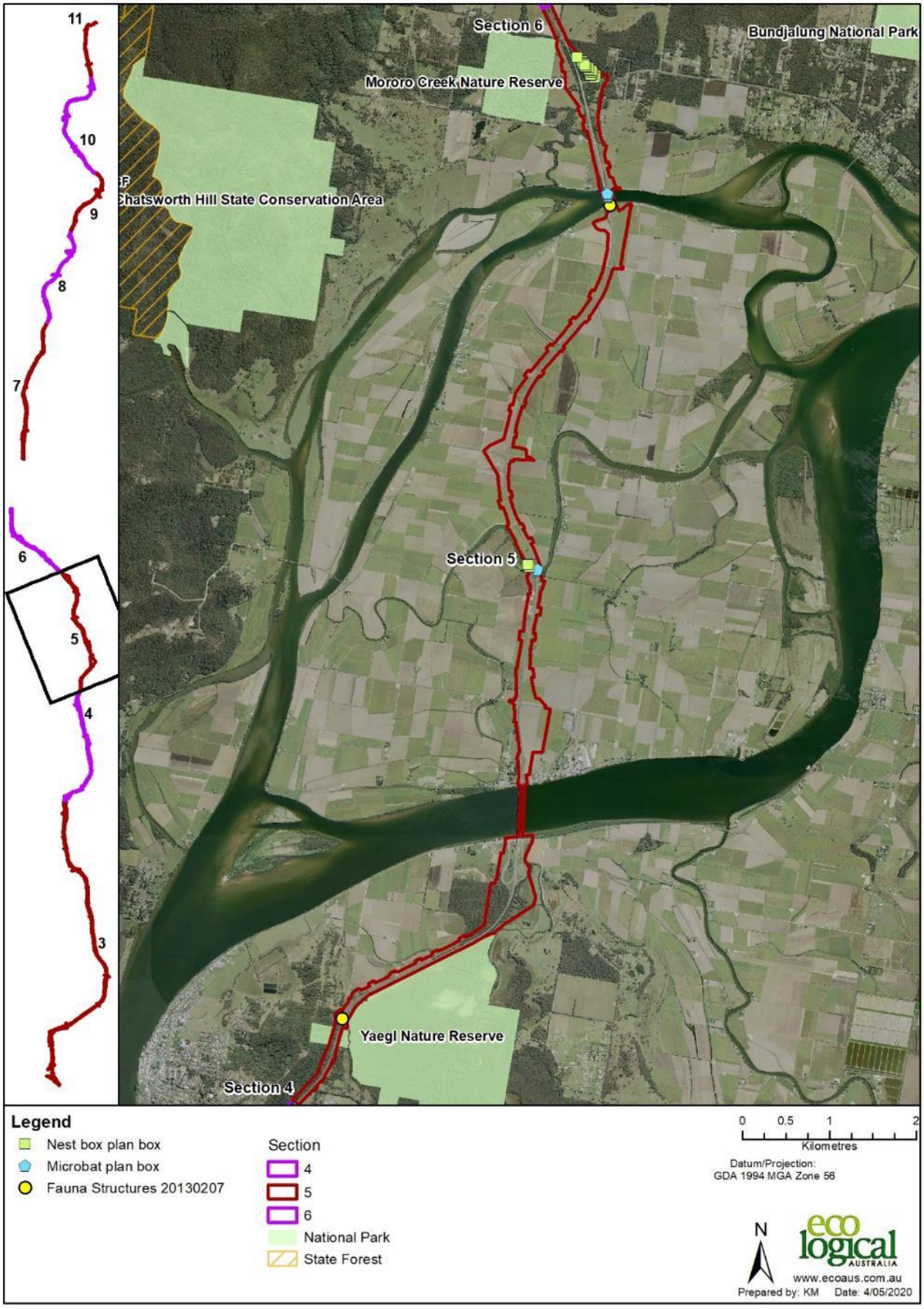

Figure 3: Section 5 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

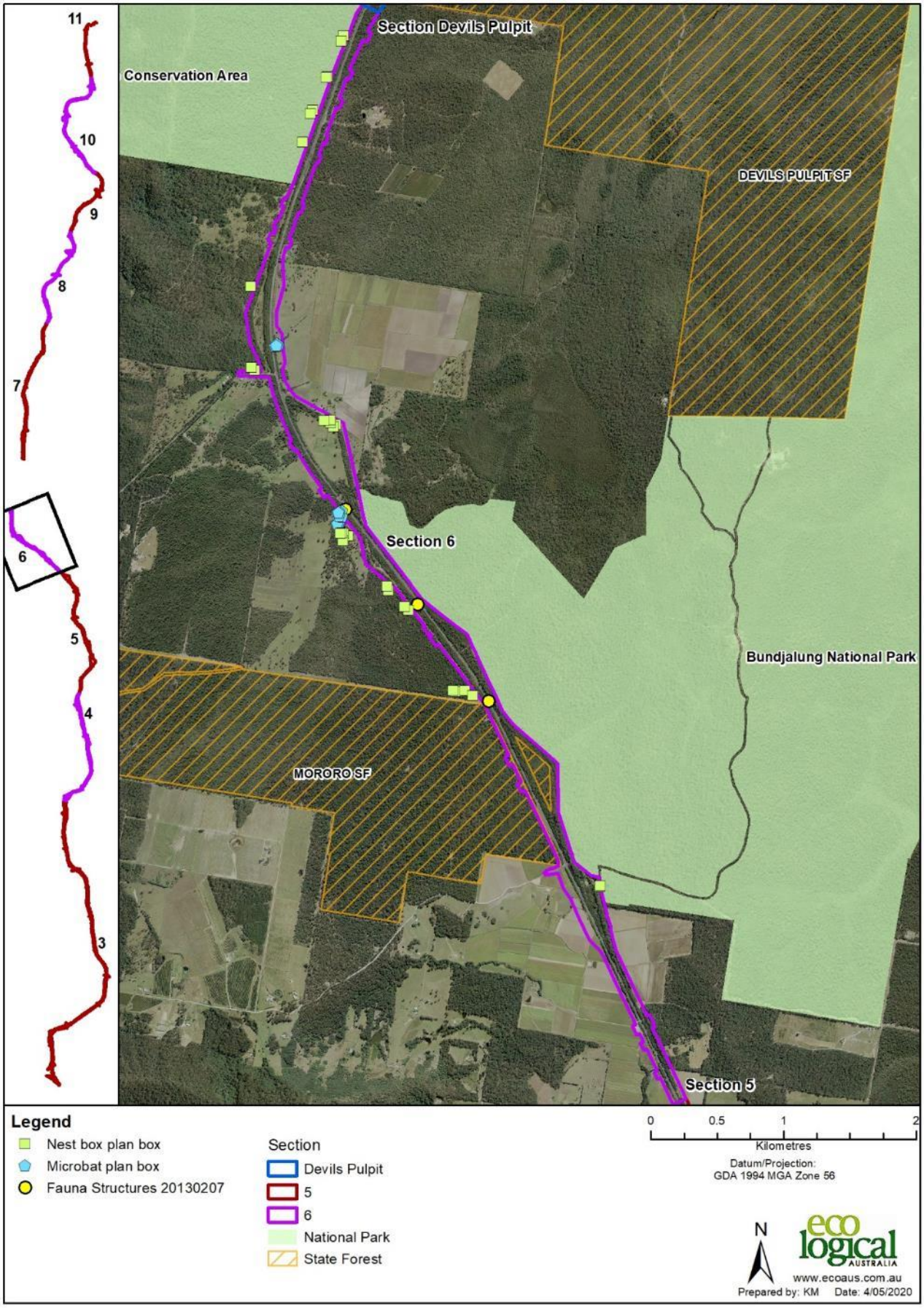

Figure 4: Section 6 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

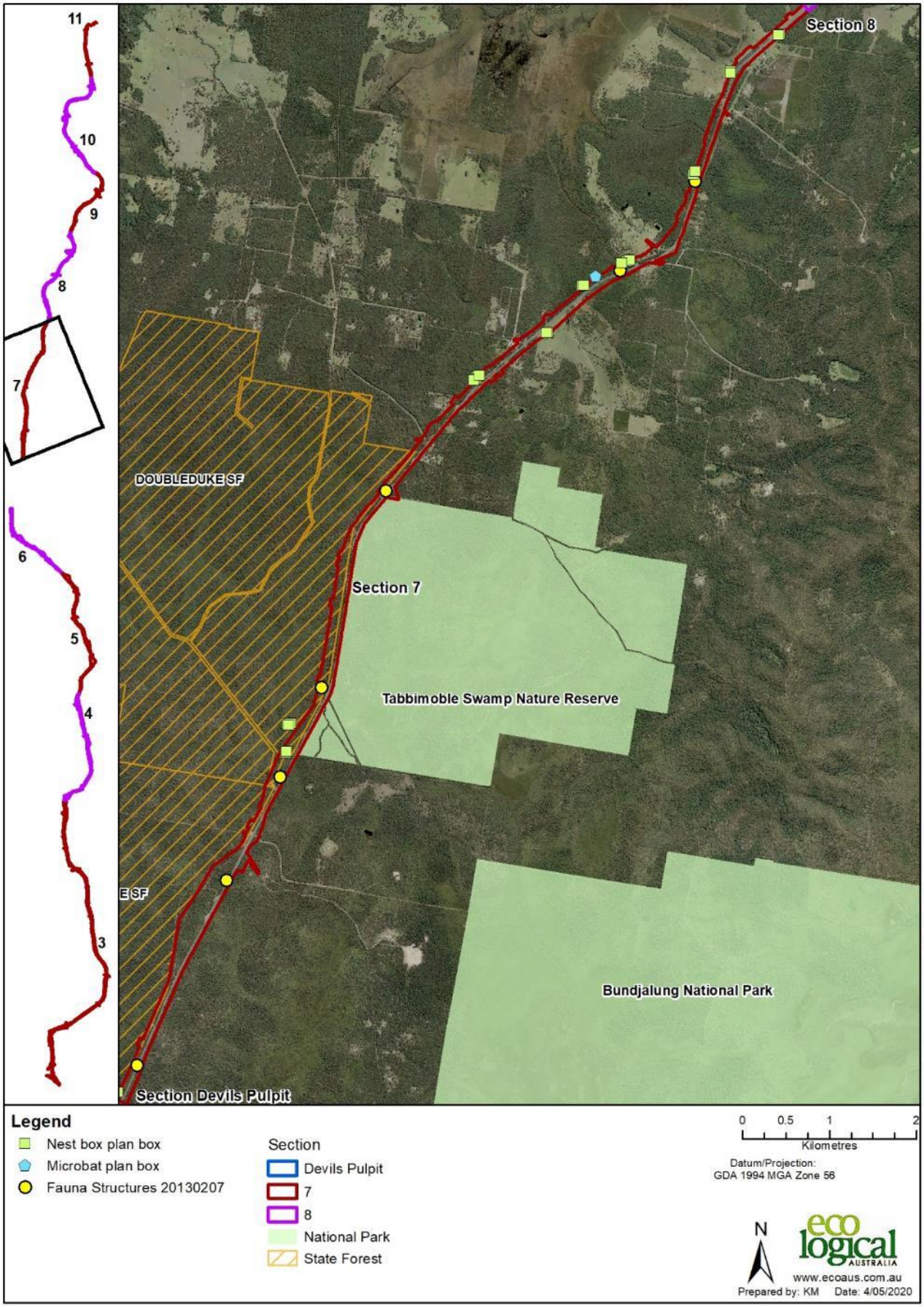

Figure 5: Section 7 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

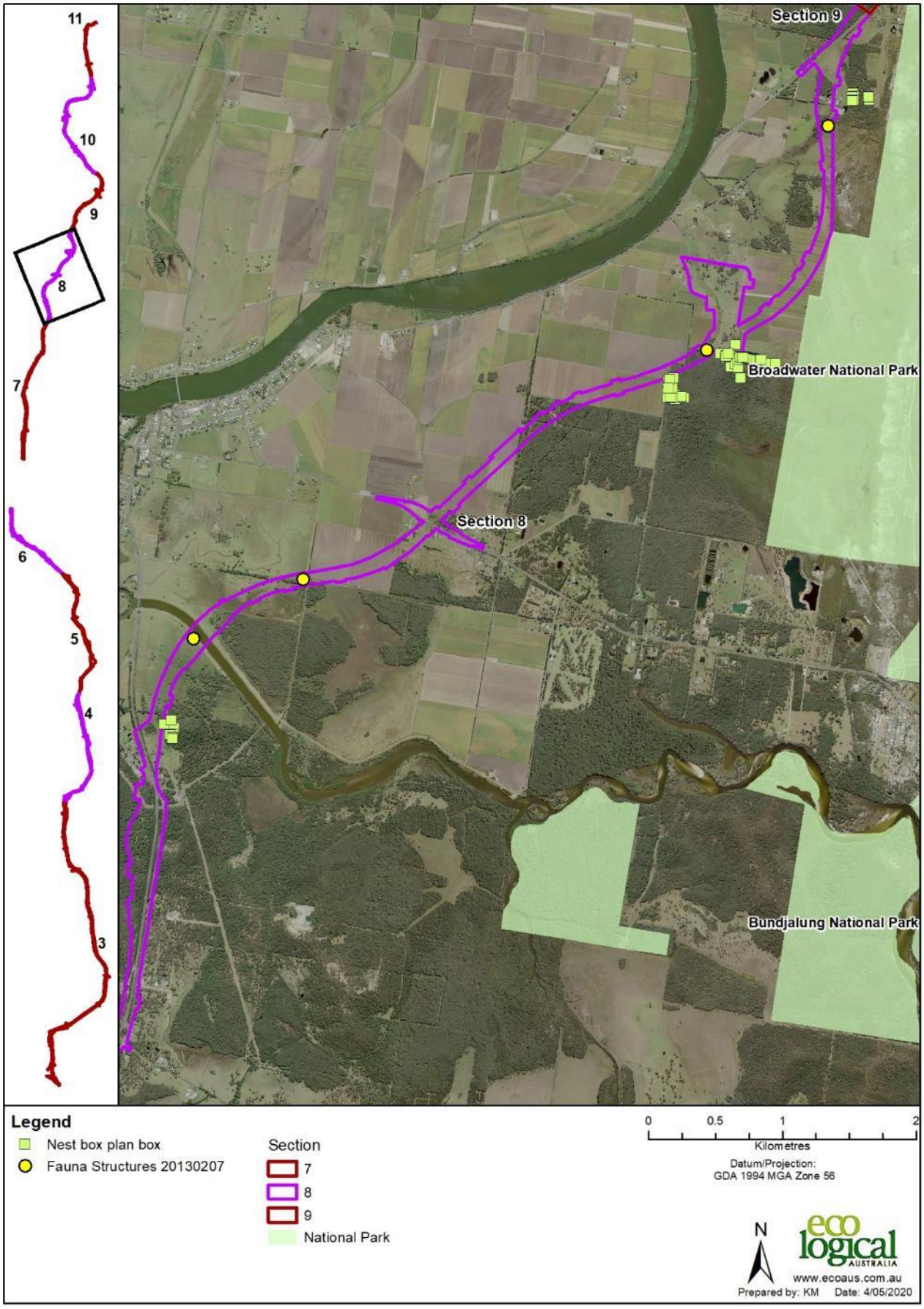

Figure 6: Section 8 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

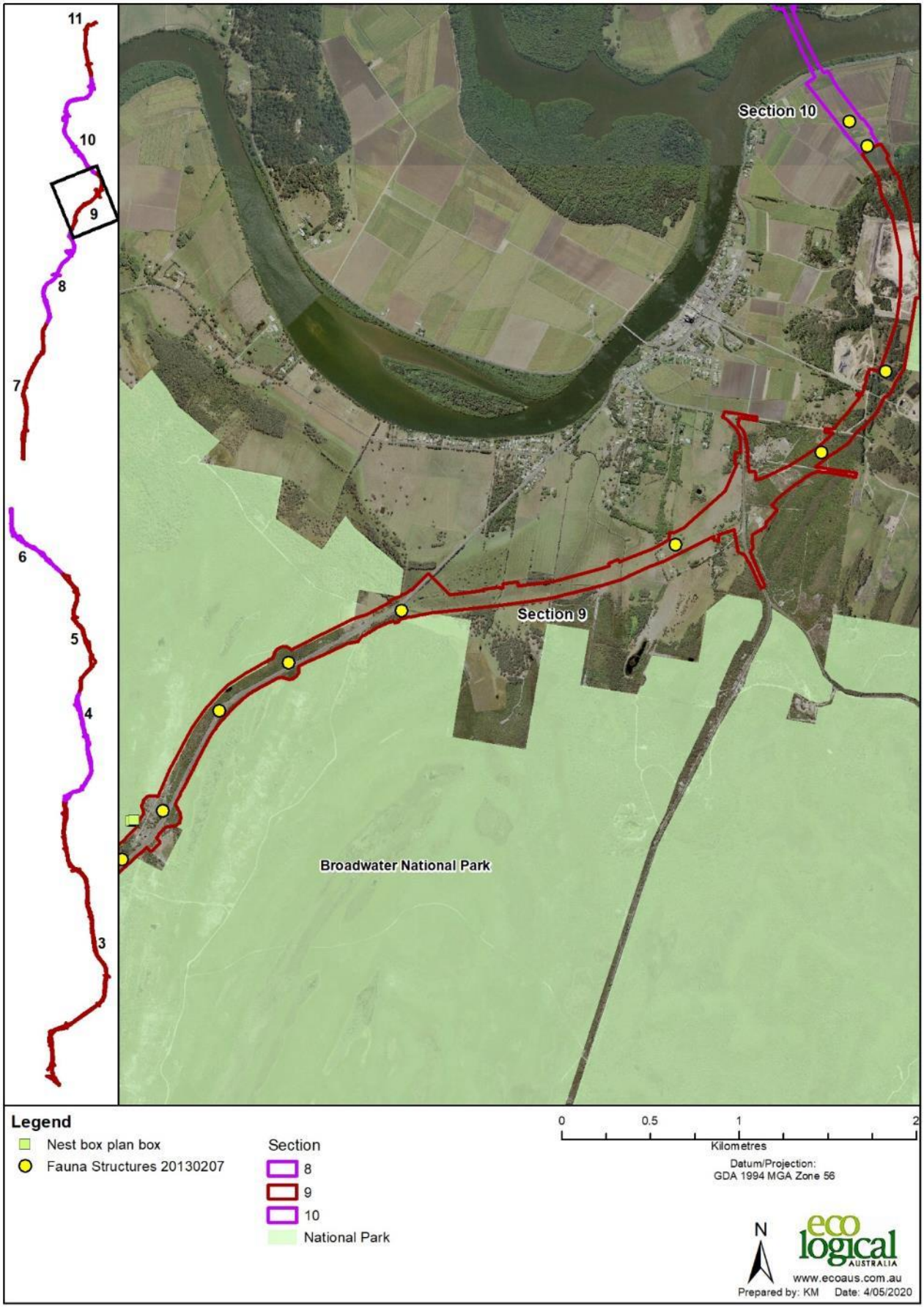

Figure 7: Section 9 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

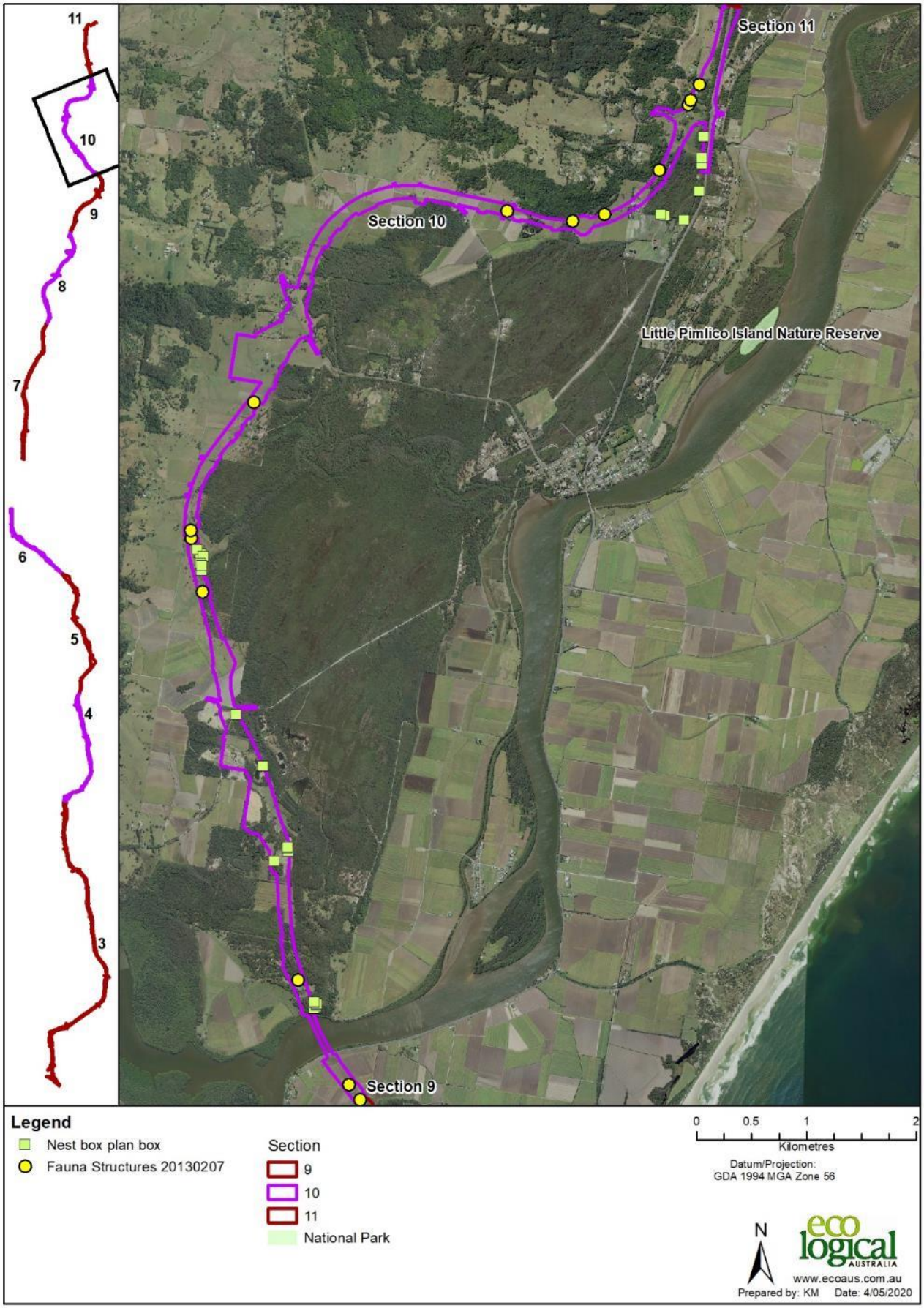

Figure 8: Section 10 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

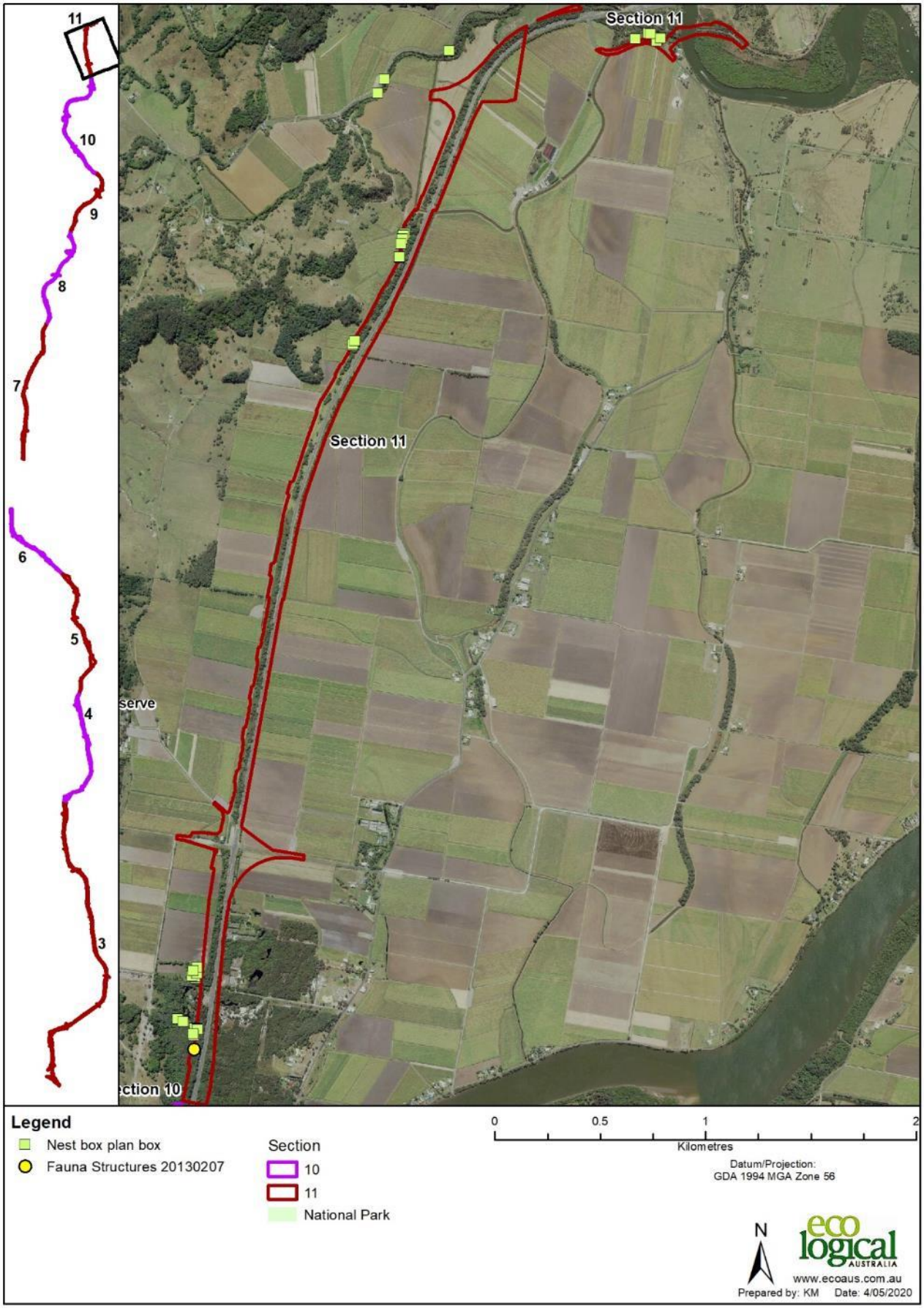

Figure 9: Section 11 of the W2B Pacific Highway upgrade project showing the location of nest boxes.

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 installed in Sections 3 – 11 of the W2B highway upgrade.

Figure 12: Cyplas (recycled plastic) nest boxes installed in Sections 3 – 11 of the W2B highway upgrade.

Table 4: 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
Feathertail 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-tailed Quoll	STQ	
Tree Creeper	TC	50
Wood Duck/Boobook	BOO	110

Data held by ELA indicated that, for the duration of monitoring throughout 2019-20, there were a total of 662 nest boxes that had been installed for between 9 and 30 months in the subject site (**Table 5**). This included nest boxes installed to provide short-term replacement habitat for fauna displaced by vegetation clearance, for a number of ancillary sites in Section 3 (20 boxes) and Section 6 (six boxes). Section 6 also includes eight boxes that had not been included in the NBMPs from Devils Pulpit, installed in October 2018 in response to design changes and additional clearing. No additional nest boxes were installed during 2019-20. Total monitored boxes does not equal total installed boxes for the following reasons and will be outlined in more detail in Section 3;

- Box has been cleared
- Box has been destroyed (termites / tree fall)
- Box has been stolen
- No access to box as a result of construction actvities
- Box not located during monitoring
- Data storage failure

Table 5: Summary of 70% installation details and number of boxes monitored in Autumn 2019 and Spring / Summer 2019 - 20 for nest boxes required in Sections 3 – 11 of the W2B project.

Section	NBMP 100%	ELA install	Non ELA install	Total installed	Total Monitored (Autumn 2019)	Total Monitored (Spring /Summer 2019-20)
3A	12	12	0	12	11	10
3	311	253*	60*	313*	231	250
4	86	1	70	71	55	58
5	44	25	6	31	7	30
6	23	41*	0	41*	36	31
7	49	27	10	37	28	20
8 and 9	102	12	79	91	88	86
10 and 11	71	52	14	66	60	58
Total	698	423	239	662	516	543

* Includes additional nest boxes not included in NBMPs

2. Methodology

A team of two staff (an ELA ecologist and an arborist) conducted each nest box inspection. Each box was initially visually inspected from the ground using 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 used the GoPro camera to inspect boxes installed above 8 m (**Figure 14**). Images from the GoPro camera were wirelessly streamed to a mobile and photo(s) of the contents were recorded. The data recorded for each nest box included:

- Date
- Weather conditions
- Observer
- Box number and location
- Box type code (see **Table 4**) 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.

Fauna identification of is based on senior ELA ecologist's experience, with reference to standard field guides (e.g. Menkhorst and 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 the ecologist's previous experience of hollow dependent fauna nest characteristics 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 Transport for New South Wales (TfNSW) where possible, damaged boxes and those inhabited by pest species were fixed or replaced *in situ*, otherwise repairs were noted and scheduled for completion during the following round of monitoring. Where pest species persistently occupied nest boxes, a decision was made regarding changing the design or leaving them *in situ* until the following monitoring inspection, based on 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 was required to be changed, the nest box was relocated during *in situ* or during the following monitoring inspection. If a nest box needed to be removed from site for repair and showed 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 is 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.

3. Results

ELA conducted the second Autumn and Spring inspections of the nest box allocation installed throughout the subject site in April, May, September, October, November 2019. The Spring monitoring event was split, due to the severe 2019 bushfire events. Subsequently the Spring monitoring was partially completed during September - November 2019, with the remainder completed in March 2020. These monitoring events correspond to Year 2 of the scheduled nest box monitoring inspections.

The 2019 Autumn nest box inspections in Year 2 were carried out over 18 days; on 30 April to 3 May, 7-10 May, 14-16 May, 21-24 May and 27-30 May. The 2019-20 Spring nest box inspections in Year 2 were carried out over 14 days; on 3-5 September, 17-19 September, 31 October and 7 November 2019, followed by 8-12 March and 26 March 2020.

Weather conditions during monitoring are provided in **Table 6** below. The minimum overnight temperature recorded during Autumn inspections was 3.0°C on 30 May 2019. The maximum daily temperature recorded during Autumn inspections was 17.7°C recorded on 2 May 2019. The minimum overnight temperature recorded during Spring inspections was 8.0°C on 7 November 2019. The maximum daily temperature recorded during Spring inspections was 28.3°C recorded on 31 October 2019.

During the 2019 Autumn monitoring event, 516 boxes (78%) out of the 662 installed across the subject site were monitored. A total of 12 boxes could not be inspected in Autumn due to restricted access (boxes were located in construction or clearing zones). There were 28 boxes that were non functional during the Autumn 2019 monitoring event. There were 106 boxes that were visited and monitored but a data upload failure of the digital recording software led to the loss of monitoring details, leaving 516 monitored boxes (**Table 7**). The digital recording software was audited by ELA to locate the source of the problem and to try and recover the data with no success. The company who licenses the software were contacted for advice but could provide no further assistance in retrieving the lost data. The software was tested before being used during the Spring 2019-20 monitoring event and it appeared to be working as expected.

During the 2019-20 Spring monitoring event, 543 nest boxes (82%) out of the 662 installed were monitored. Three nest boxes could not be inspected in Spring due to restricted access (nest box zones unsafe to enter with changed traffic conditions and high risk trees following recent bushfires). There were 55 boxes that were non functional and not available to be used by fauna of any species during the Spring 2019-20 monitoring event. The same data upload failure caused the loss of monitoring data for 61 boxes that were inspected, leaving 543 monitored boxes (**Table 8**). Following this second data upload failure, the system for data capture in the field is being rebuilt and streamlined prior to the next monitoring event in Autumn 2021 as the large amount of data contained within the data capture platform for this project has been contributing to the data upload issues. The streamlined data capture platform will be tested prior to the next monitoriong event.

Boxes labelled as non functional were not available to be used by fauna for any of the following reasons;

- Cleared
- Destroyed by fire

- Destroyed by termites
- Stolen
- Damaged/ destroyed by tree fall
- Persistently occupied by European Honey Bees or Native Bees

3.1 Summary

The results for Autumn are presented in (**Table 7**) and the results for Spring are presented in (**Table 8**). A total of 80 of 516 nest boxes (16%) were occupied in Autumn 2019 and 54 of 543 boxes (10%) were occupied in Spring 2019-20. Evidence of nest box usage without the presence of fauna was observed in 193 of 516 boxes (37%) in Autumn and in 153 of 543 monitored boxes (28%) in Spring.

Evidence of usage can include 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 useage (i.e. sum of boxes occupied and those featuring evidence of use) in Autumn 2019 was 273 of 516 boxes (53%) and 207 of 543 boxes (38%) in Spring 2019-20. A summary of the overall rate of use for each season is provided in **Figure 16** and **Figure 17**. The Autumn results meet the first performance indicator target of equal to or greater than 50% boxes being used by fauna of any species. The Spring results do not meet this performance indicator target and it is suggested that widespread and severe bushfires over spring and summer 2019-20 contributed significantly to this lower than expected result.

Figure 15: Examples of the type of evidence of nest box occupation recorded from the subject site during 2019. Top left: Spiral leaf nest (Glider). Top right: Common Brushtail Possum scats. Bottom: Leaf and feather nest (possibly made by a Brush-tailed Phascogale) with a possible Glider species inhabiting at the time of photo capture.

Table 6: Weather conditions experienced during nest box monitoring in Autumn and Spring 2019-20*.

Date	Min temp ºC	Max temp ºC	Rainfall (mm)	Wind direction	Max wind speed (km/hr)
30/04/2019	11.8	21.9	0.0	E	20
1/05/2019	16.8	24.5	3.0	ENE	24
2/05/2019	17.7	24.5	0.8	NE	24
3/05/2019	16.8	23.9	0.0	N	15
7/05/2019	8.4	25.4	0.0	N	24
8/05/2019	5.2	27.0	0.0	NNW	24
9/05/2019	7.5	24.3	0.2	ENE	20
10/05/2019	7.6	27.2	0.0	WSW	46
14/05/2019	13.6	23.8	0.8	E	19
15/05/2019	10.1	24.4	0.0	S	33
16/05/2019	15.4	19.8	11.2	SSW	24
21/05/2019	10.6	25.6	0.2	NE	19
22/05/2019	9.2	25.3	0.0	ENE	17
23/05/2019	9	23.4	0.0	NE	26
24/05/2019	10.7	23.8	0.2	ENE	22
27/05/2019	7.3	26.7	0.2	W	44
28/05/2018	5.9	22.0	0.0	WSW	26
29/05/2019	10.4	23.0	0.0	W	31
30/05/2019	3.0	21.9	0.0	ESE	30
3/09/2019	9.5	26.0	0.0	SE	39
4/09/2019	12.1	20.7	0.0	SSE	46
5/09/2019	12.4	19.3	1.4	SSE	30
17/09/2019	8.8	24.2	0.0	ESE	44
18/9/2019	8.7	23.5	19.4	S	33
19/9/2019	10.8	24.3	0.0	ESE	28
31/10/2019	11.6	28.3	0.0	E	35
7/11/2019	8.0	27.0	0.0	N	39
8/3/2020	19.3	24.9	0.0	S	30
9/3/2020	17.8	23.6	0.8	S	26
10/3/2020	17.1	25.2	4.2	S	39
11/3/2020	18.4	25.8	0.2	S	46
12/3/2020	16.1	26.1	0.0	SSE	44
26/3/2020	18.5	24.8	1.4	S	33

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

Table 7: Summary of nest box monitoring results - Autumn 2019.

Section	Total boxes installed	Total boxes monitored	# Inhabited	% Inhabited	Detected threatened species	# Evidence of usage	% Evidence of usage	# Total usage	Overall rate of usage (%)	Comments
3A	12	11	1	9	Nil	1	9	2	18	
3	313	231	39	17	Squirrel Glider, Eastern Long-eared Bat, Brush-tailed Phascogale	86	37	125	54	9 cleared, 4 termites, 2 tree fall, 66 data issue
4	71	55	12	22	Nil	19	35	31	56	5 cleared, 1 European Honey Bees, 11 data issue
5	31	7	1	14	Nil	4	57	5	71	1 termites, 6 Serpentine no access, 18 data issue
6	41	36	3	10	Squirrel Glider	18	50	21	58	5 access issue
7	37	28	5	18	Squirrel Glider	8	29	13	48	1 cleared, 7 data issue, 1 no access
8 and 9	91	88	13	15	Squirrel Glider, Eastern Long-eared Bat	32	36	45	52	1 termites, 2 data issue
10 and 11	66	60	6	10	Eastern Long-eared Bat	25	42	31	55	3 cleared, 1 termites, 2 data issue
Total	662	516	**80**	**16**		**193**	**37**	**273**	**53**	

Table 8: Summary of nest box monitoring results - Spring 2019-20.

Section	Total boxes installed	Total boxes monitored	# Inhabited	% Inhabited	Detected Threatened Species	# Evidence of usage	% Evidence of usage	# Total usage	Overall rate of usage (%)	Comments
3A	12	10	0	0		0	0	0	0	2 data issue
3	313	250	32	13	Squirrel Glider	67	27	99	40	9 cleared, 2 tree fall, 4 termites, 50 data issue
4	71	58	9	16	Squirrel Glider	19	33	28	48	7 cleared, 1 European Honey Bees, 5 data issue
5	31	30	0	0		15	50	15	50	1 termites
6	41	31	3	10	Squirrel Glider	13	42	16	52	7 fire, 3 no access
7	37	20	1	5		9	45	10	50	13 fire, 1 cleared, 1 Native Bees, 3 data issue
8 and 9	91	86	8	9	Squirrel Glider	20	23	28	33	2 termites, 1 Native bees, 3 data issue
10 and 11	66	58	1	2	Squirrel Glider	10	17	11	19	4 fire, 2 termites, 1 stolen, 1 data issue
Total	**662**	**543**	**54**	**10**		**153**	**28**	**207**	**38**	

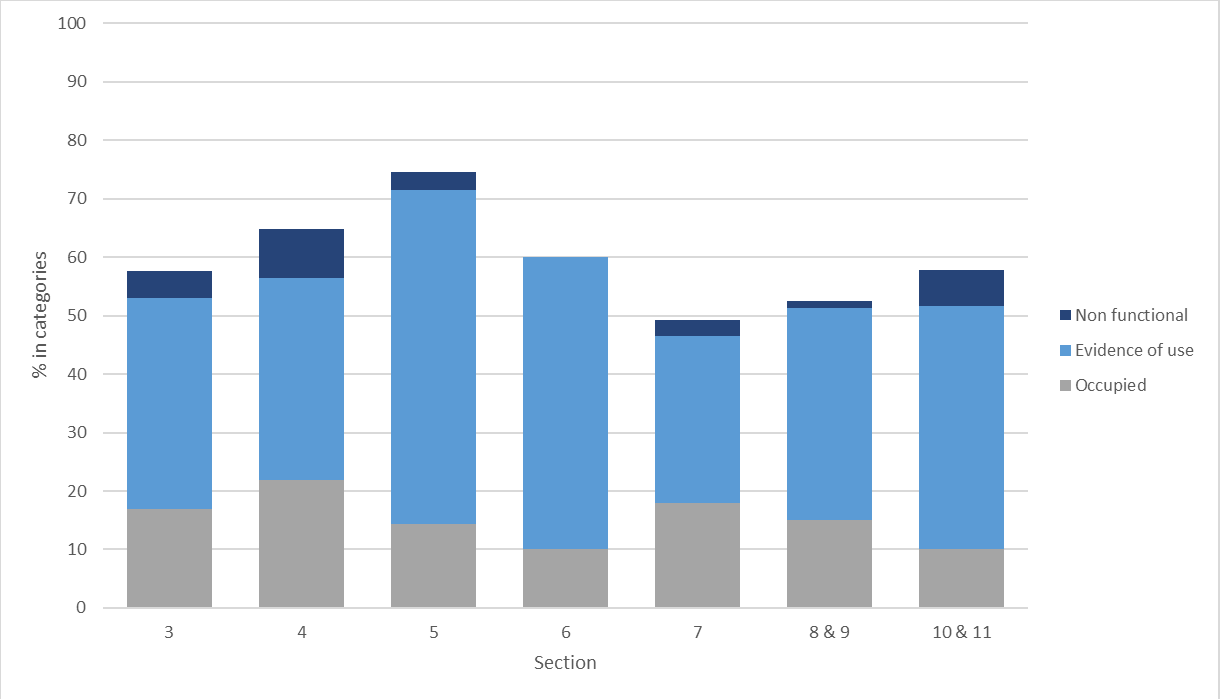

Figure 16: Overall use of nest boxes (%) in Autumn 2019 across Sections 3 to 11 of the W2B alignment.

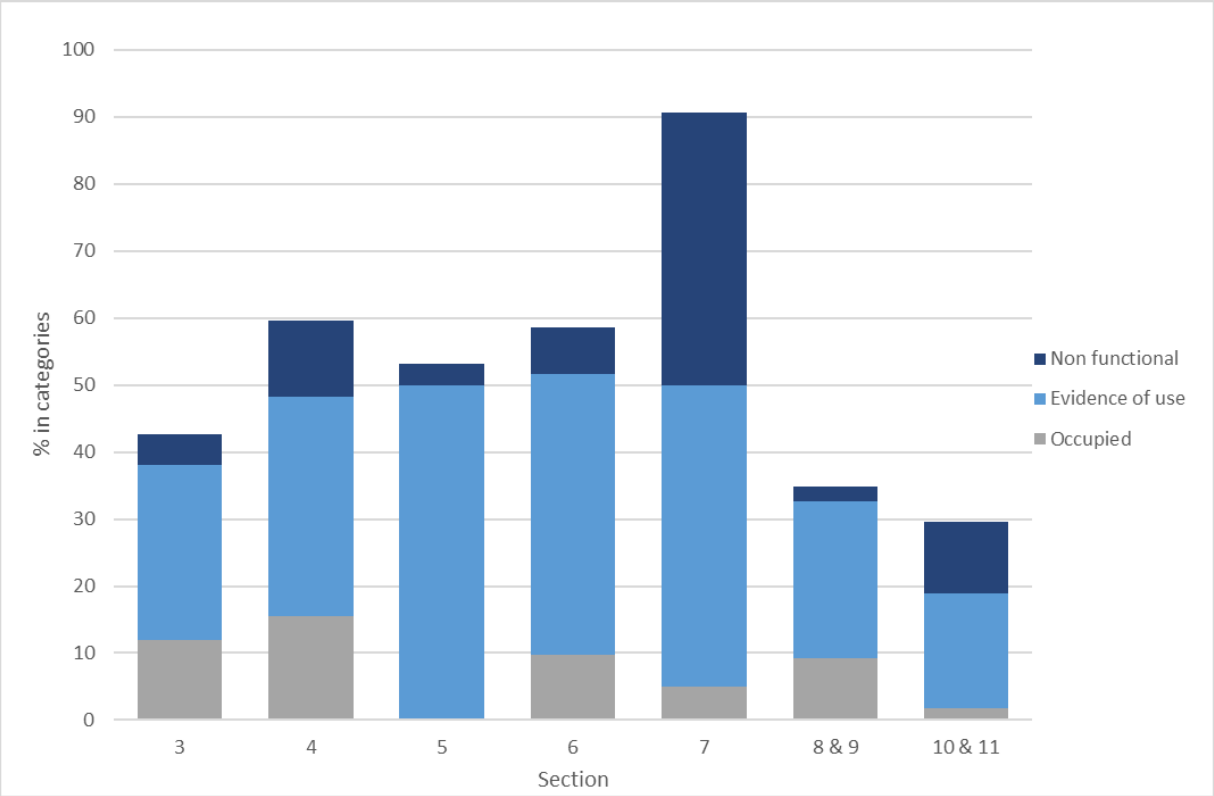

Figure 17: Overall use of nest boxes (%) in Spring 2019 across Sections 3 to 11 of the W2B alignment.

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

Fourteen vertebrate species (two birds, six mammals, three microbats and three reptiles) were observed occupying nest boxes during the 2019-20 inspections (**Figure 18**). One invertebrate group (native bees) was also recorded. There were two species recorded during the 2019-20 monitoring that had not been recorded during the 2018 monitoring period and these were *Morelia spilota* Carpet Pyhton and *Ninox boobook* Southern Boobook Owl. There were four species recorded during 2018 that were not recorded during this monitoring period; *Acrobates sp*. Feathertail Glider, *Chalinolobus gouldii* Gould's Wattled Bat *Cormobates leucophaea* White-throated Treecreeper and *Litoria peronii* Peron's Tree Frog. There have now been a total of 22 native vertebrate fauna species recorded occupying nest boxes since monitoring began in 2017, and this figure includes 1 amphibian, five bird, 9 mammal, 4 bat and 3 reptile species, but does not include native bees.

There were 13 fauna species recorded in Autumn and eight recorded in Spring, with seven species recorded during both inspections. In Autumn 2019 the three threatened species recorded using boxes were Brush-tailed Phascogale, Eastern Long-eared Bat and Squirrel Glider. In Spring 2019-20, the only threatened species recorded using the boxes was the Squirrel Glider (**Table 7** and **Table 8**). The three species listed as vulnerable under the BC Act are denoted * and highlighted in **bold** in the lists below. The seven species recorded in both Autumn and Spring were:

- *Aegotheles cristatus* Australian Owlet Nightjar
- *Morelia spilota* Carpet Python
- *Petaurus breviceps* Sugar Glider
- ***Petaurus norfolcensis* Squirrel Glider***(vulnerable under the BC Act)
- *Pseudocheirus peregrinus* Common Ringtail Possum
- *Trichosurus vulpecula* Common Brushtail Possum
- *Varanus varius* Lace Monitor.

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

- *Dendrelaphis punctulatus* Green Tree Snake
- *Ninox boobook* Southern Boobook Owl
- ***Nyctophilus bifax* Eastern Long-eared Bat*** (vulnerable under the BC Act)
- *Nyctophilus gouldi* Gould's Long-eared Bat
- *Nyctophilus* sp. Long-eared Bat
- ***Phascogale tapoatafa* Brush-tailed Phascogale*** (vulnerable under the BC Act)
- *Trichosurus cunninghami* Mountian Brushtail Possum
- Native bees.

The five species with the greatest number of individuals recorded within nest boxes across Autumn and Spring 2019-20 combined were:

- Common Brushtail Possum – 47 individuals (40 separate observations ranging from 1-2 individuals per box)

- Eastern Long-eared Bat - 26 individuals (eight separate observations ranging from 1-8 individuals per box)
- Gould's Long-eared Bat – 17 individuals (four separate observations ranging from 3-6 individuals per box)
- **Squirrel Glider*** - 51 individuals (34 separate observations ranging from 1-3 individuals per box)
- Sugar Glider – 32 individuals (16 separate observations ranging from 1-3 individuals per box).

These five species accounted for 116 of the total of 138 individual animals (84%) recorded using nest boxes during the Autumn 2019 inspections. Similar results were obtained during the Spring 2019-20 inspections, with 57 of the total of 67 individual animals (85%) recorded being one of the five species listed above.

The species encountered the greatest number of times occupying nest boxes (regardless of the number of individuals) across Autumn and Spring 2019-20 were:

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

Lace Monitors were recorded in nest boxes in Sections 3, 4, 8 and 9. Six boxes (1%) showed evidence of occupation in Autumn, and one box (<1%) showed evidence in Spring 2019-20.

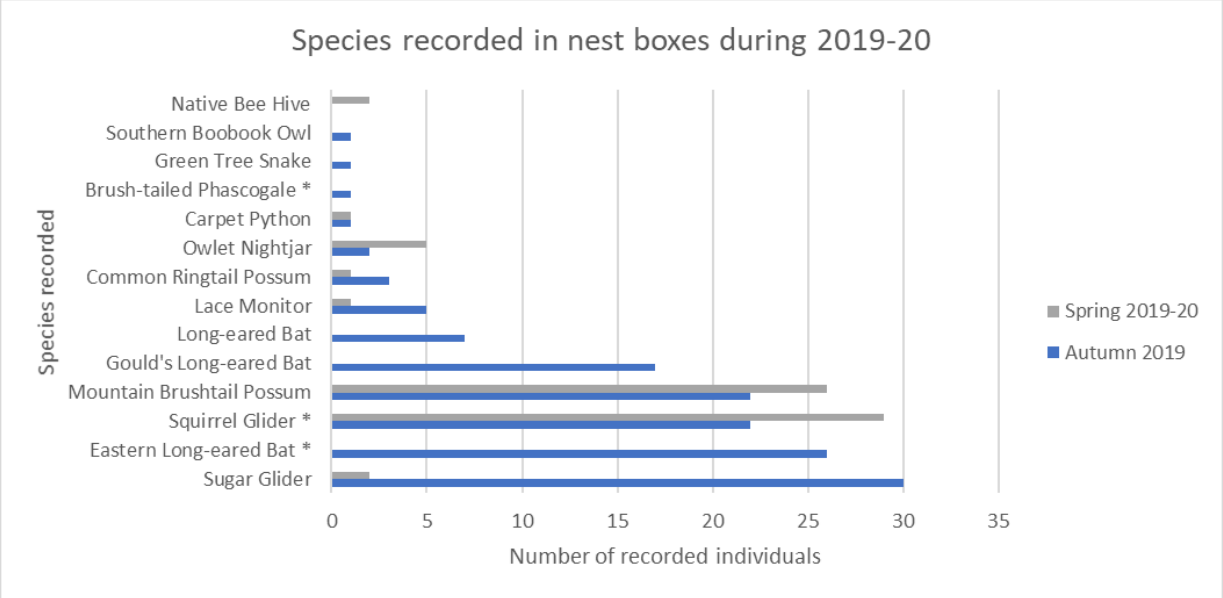

Figure 18: Species observed inhabiting nest boxes in 2019-20 within the W2B Sections 3 to 11. * Threatened species listed under the BC Act.

3.1.1.1 Evidence of breeding in nest boxes

There were several instances of family groups of Squirrel Gliders and Common Brushtail Possums occupying Cockatoo_Owl, Glider (rear entry), King Parrot, Phascogale and Possum timber and Cyplas nest boxes, and evidence that boxes had been used for breeding purposes by each of these species, including records of older juveniles (**Figure 19**). The only boxes used in both Autumn and Spring for breeding were Cyplas boxes. There was evidence of birds nesting within Cockatoo_Owl, Glider (front

entry) and Possum Cyplas and timber nest boxes, indicated by egg shells (potential Australian Owlet Nightjar, *Chenonetta jubata* (Australian Woododuck) and *Platycercus eximus* (Eastern Rosella)) and downy feathers (Australian Woodduck) (**Figure 20**).

Figure 19: Top Left: A Timber box containing a Common Ringtail Possum, Spring 2019. Top Right: A Cyplas box containing one adult and one juvenile Common Brushtail Possum, Spring 2019. Bottom left: A timber box containing a family of Squirrel Gliders, Spring 2019. Bottom right: A Glider species (spiral leaf nest) nesting in a timber box, Spring 2019.

Figure 20: Timber box with a single white egg (possibly an Australian Owlet Nightjar).

3.1.1.2 Comparison of fauna recorded during clearing with fauna using nest boxes

Of the 32 species of fauna recorded during vegetation clearance in Section 3 (**Table 9**), seven species (22%) have been recorded occupying nest boxes in Section 3 since monitoring began in 2018. If we include monitoring results for nest boxes in all sections, 12 (38%) of the 32 species have been recorded using nest boxes since monitoring began.

A total of 15 fauna species have been recorded using nest boxes in Section 3. A total of 24 fauna species (including Native Bees) have been recorded using nest boxes in Sections 3 – 11 of the W2B project since monitoring began (**Table 9**).

Over half (55%) of the fauna recorded in Section 3 during vegetation clearance were mammals (incl bats), with occupancy rates of 9% (110 occurrences in 1243 cleared trees) during the two stage clearing process.

Mammals accounted for over 90% of all fauna recorded occupying nest boxes in Section 3 during the 2019-20 monitoring year. Nest box occupancy rates for arboreal mammals (incl bats) in Section 3 during the 2019 – 20 monitoring period were 14% (35 of 247 monitored boxes) in Autumn and 12% (30 of 256 monitored boxes) in Spring. When combined with the results of the 2018 monitoring year,the occupancy rate for mammals (incl bats) in nest boxes to date is 11% (119 occurences in 1065 box checks).

Almost one third (32%), of all fauna recorded in Section 3 during vegetation clearance were small reptiles, largely comprised of skinks and Gecko's with occupancy rates of 5% (65 occurrences in 1243 cleared trees). It is notable that no small reptiles have been recorded during nest box inspections in any Section for the duration of the monitoring period, however Lace Monitors and snakes have been recorded using nest boxes (**Figure 21**). There were no nest boxes designed specifically for reptiles installed on the W2B Sections 3-11 project.

Birds accounted for only 2% of all fauna recorded in Section 3 during vegetation clearance with occupancy rates of <0.4% (5 occurrences in 1243 cleared trees). Birds accounted for 7% of all fauna recorded occupying nest boxes during the 2019-20 monitoring year. Nest box occupancy rates for birds in Section 3 during the 2019 – 20 monitoring period were 0.8% (2 of 247 monitored boxes) in Autumn and 0.8% (2 of 256 monitored boxes) in Spring. When combined with 2018 data, nest box occupancy rates for birds in Section 3 total 0.8% (9 occurrences in 1065 box checks) double the occupancy rate for birds recorded during fauna clearance. A completely different suite of birds was recorded in nest boxes than were recorded during vegetation clearance (**Table 9**).

Figure 21: A Lace Monitor in a Sugar / Squirrel Glider leaf nest in a timber nest box, Spring 2019.

Table 9: Comparison of fauna recorded during clearing with that recorded from nest box inspections

Species Name	Common Name	Fauna recorded during clearing surveys	Fauna recorded during nest box inspections 2017 - 2020	
		Section 3	Nestboxes S3	Nest boxes all sections
Amphibians				
Litoria caerulea	Green Tree Frog	Y	N	N
Litoria nasuta	Rocket Frog	N	N	N
Litoria peronii	Peron's Tree Frog	N	Y	Y
	Unidentified Frog	Y	N	N
Subtotals		2	1	1
Birds				
Aegotheles cristatus	Australian Owlet Nightjar	N	Y	Y
Chenonetta jubata	Australian Woodduck	N	Y	Y
Cormobates leucophaea	White-throated Treecreeper	N	Y	Y
Ninox boobook	Boobook Owl	N	Y	Y
Philemon corniculatus	Noisy Friarbird	Y	N	N
Platycercus eximus	Eastern Rosella	N	N	Y
Podargus strigoides	Tawny Frogmouth	Y	N	N
Todiramphus macleayii	Forest Kingfisher	Y	N	N
Trichoglossus moluccanus	Rainbow Lorikeet	Y	N	N
	Unidentified Lorikeet	Y	N	N
Subtotals		5	4	5
Mammals				
Acrobates pygmaeus	Feathertail Glider	Y	N	Y
Antechinus flavipes	Yellow-footed Antechinus	Y	N	N
Antechinus spp.	Antechinus	Y	N	Y
Chalinolobus gouldii	Gould's Wattled Bat	Y	Y	Y
Chalinolobus morio	Chocolate Wattled Bat	Y	N	N
*Nyctophilus bifax**	Eastern Long-eared Bat	N	Y	Y
Nyctophilus geoffroyi	Lesser Long-eared Bat	N	Y	Y
Nyctophilus gouldi	Gould's Long-eared Bat	N	Y	Y
Nyctophilus spp.	Unidentified Long-eared Bat	N	Y	Y
Petaurus breviceps	Sugar Glider	Y	Y	Y

Species Name	Common Name	Fauna recorded during clearing surveys	Fauna recorded during nest box inspections 2017 - 2020	
		Section 3	Nestboxes S3	Nest boxes all sections
*Petaurus norfolcensis**	Squirrel Glider	Y	Y	Y
*Petaurus volans**	Greater Glider	Y	N	N
*Phascogale tapoatafa**	Brush-tailed Phascogale	Y	Y	Y
Pseudocheirus peregrinus	Common Ringtail Possum	Y	N	Y
Rattus spp.	Unidentified Rat	Y	N	Y
Trichosurus cunninghami	Mountain Brushtail Possum	N	N	Y
Trichosurus vulpecula	Common Brushtail Possum	Y	Y	Y
	Unidentified microbat	Y	Y	N
Subtotals		11	8	13
Reptiles				
Boiga irregularis	Brown Tree Snake	Y	N	N
Cocinnia tenuis	Bar-sided Forest Skink	Y	N	N
Cryptophis nigrescens	Eastern Small-eyed Snake	Y	N	N
Cyclodomorphus gerrardii	Pink-tongued Skink	Y	N	N
Dendrelaphis punctulatus	Green Tree Snake	Y	Y	Y
Egernia cunninghami	Cunningham's Skink	N	N	N
Eulamprus martini	Martin's Skink	N	N	N
Lampropholis delicata	Delicate Skink	Y	N	N
Lialis burtonis	Burton's Legless Lizard	Y	N	N
Liopholis whitii	White's Skink	N	N	N
Morelia spilota	Carpet Python	Y	N	Y
Nebulifera robusta	Robust Velvet Gecko	Y	N	N
Pogona barbata	Eastern Bearded Dragon	Y	N	N
Varanus varius	Lace Monitor	Y	Y	Y
	Unidentified Leaf-tailed Gecko	Y	N	N
	Unidentified Skink	Y	N	N
	Unidentified Gecko	Y	N	N
Subtotals		12	2	3
Invertebrates				

Species Name	Common Name	Fauna recorded during clearing surveys	Fauna recorded during nest box inspections 2017 - 2020	
		Section 3	Nestboxes S3	Nest boxes all sections
	Native Stingless Bee	Y	N	Y
Apis mellifera	European Honey Bee	Y	N	Y
Subtotals		2	0	2
Total species		**32**	**15**	**24**

3.1.2 Performance Indicator 2: Boxes occupied by target fauna species

There were a total of 62 records (6%) of target fauna species occupying nest boxes designed for that species in 2019. **Evidence of use by target species was found in 179 (17%) boxes with an overall nest box usage rate by target species of 241 boxes (23%)** (**Table 10**). 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. Ten box types recorded occupancy by target species and these were:

- Brush-tailed Phascogale – Brush-tailed Phascogale
- Cockatoo / Large Owl – *Ninox boobook* Southern Boobook Owl
- Glider front and rear entry boxes – Sugar and Squirrel Glider
- Possum / Large Glider boxes – Common Brushtail Possum, *Pseudocheirus peregrinus* Common Ringtail Possum and *Trichosurus cunninghami* Mountain Brushtail Possum)
- Microbat boxes (Single chamber, 2 chamber, 3 chamber and 4 chamber) – Eastern Long-eared Bat, Gould's Long-eared Bat, *Nyctophilus geoffroyi* Lesser Long-eared Bat.
- Small Parrot – Australian Owlet Nightjar.

Four box types achieved the performance indicator target of 10% occupancy by target species and these were Glider rear entry boxes and 2, 3 and 4 chamber bat boxes (**Table 10**). All other box types recorded occupancy rates lower than 10% when Autumn and Spring results were combined. When overall usage rates (occupancy + evidence of use) were considered Antechinus boxes were also considered to be relatively successful with 12 (24%) of the 49 inspections of Antechinus boxes recording leaf nests made by Antechinus. Similarly for Glider front entry boxes when overall usage rates were considered 32 (51%) of the 63 inspections of Glider front entry boxes recorded leaf nests made by Sugar or Squirrel Glider species.

Three of the 24 target threatened fauna species were recorded using nest boxes and all three are listed as vulnerable under the BC Act:

- **Brush-tailed Phascogale***
- **Eastern Long-eared Bat***

- **Squirrel Glider*.**

There was one instance of Brush-tailed Phascogale using a timber nest box designed specifically for Brush-tailed Phascogale, during the Autumn inspections in Section 3 (**Figure 15**). Eastern Long-eared Bats were recorded on multiple occasions in Autumn, using each of the four types of bat boxes in Sections 3, 9 and 11, and occupied both timber and Cyplas boxes. Squirrel Gliders were recorded on multiple occasions in both Autumn and Spring in all Sections, except for Section 5, and used both timber and Cyplas nest boxes (**Figure 23**). Squirrel Gliders were recorded predominantly using Glider front-entry and rear-entry boxes, but also inhabited Brush-tailed Phascogale, Cockatoo and Large Owl, Possum, Single Chamber Bat and Small Parrot boxes.

Nest box type and associated rates of occupancy collected from nest box inspections carried out across the two periods are summarised in **Table 10** and described in **Sections 3.1.2.1, 3.1.2.2** and **3.1.2.3** below. A total of 1,047 nest box inspections were able to be carried out for the 662 nest boxes installed. The majority of boxes were inspected twice (Spring and Autumn), but 55 boxes were non functional during the monitoring preriod and were not available for use by fauna or able to be inspected as a result of being cleared, subject to fire, destroyed by termites or tree fall, occupied by European Bees or having been stolen. ELA notes that nest box type was not recorded for 23 boxes, and these data have not been included in this analysis. Two of these 23 boxes of unknown type contained Squirrel Gliders, 10 boxes were inhabited and 14 boxes showed evidence of use.

3.1.2.1 Birds

Of the bird boxes (Barn Owl, Boobook/Wood Duck, Cockatoo/Owl, Dollarbird/Crimson Rosella, Kingfisher, King Parrot, Pardalote, Small Parrot and Treecreeper) only Cockatoo/Owl and Small Parrot were occupied the target bird species / species group during the Autumn and Spring 2019-20 survey periods (**Table 10**). The Australian Owlet Nightjar (no box design specified for this species) was found in a Small Parrot box, and the Southern Boobook Owl was recorded in a Cockatoo/Large Owl box.

Birds, or evidence of bird occupation, was recorded in 5 (2%) bird boxes in 2019-20. Birds or evidence of their presence was recorded in other box types including records of the Australian Owlet Nightjar in Barn Owl, Cockatoo/Large Owl and Possum timber boxes, as well as Small Parrot Cyplas boxes. There was also evidence of Australian Woododucks, Eastern Rosellas from eggs and their remains observed in Cockatoo/Owl, Glider (front entry) and Possum boxes. A total of four bird species were recorded during the 2019-20 monitoring event.

Bird boxes monitored in 2019-20 were also occupied by or showed evidence of occupation by Antechinus, Common Brushtail Possums, Common Ringtail Possums, Lace Monitors, Squirrel Gliders*, Sugar Gliders, unidentified Long-eared Bats and native bees (**Table 10**).

3.1.2.2 Bats

Three of the four types of bat boxes (Single-chamber, 3-chamber and 4-chamber) all recorded occupancy by one of the target threatened bat species, Eastern Long-eared Bats* (**Table 10**). Gould's Long-eared Bats occurred in 2-chamber, 3-chamber and 4-chamber boxes, Lesser Long-eared Bat occurred in 2-chamber and 4-chamber boxes and there were multiple records of unidientifed *Nyctophilus* sp. (Long-eared Bats) in 2-chamber and 3-chamber boxes (**Figure 22**). Three species of bat were recorded during the 2019-20 monitoring surveys.

During the 2019-20 survey period. Gould's Long-eared Bat was recorded in four bat boxes (Cyplas and timber) and ranged in abundance from three to six individuals per box. The threatened Eastern Long-eared Bat (vulnerable under the BC Act) occupied eight boxes (Cyplas and timber), with abundance ranging from one to eight individuals. In some cases it was not possible to identify the species of microbat from camera images. Squirrel Gliders* were the only non target species recorded using (single chamber) timber 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 (as exemplified by Gould's Long-eared Bat), with other bat species making little to no use of boxes. The Eastern Long-eared Bat is the obvious exception in this case (Griffiths et al. 2017 and 2018; Rueegger et al. 2019a) but is in the same genus as two other common Nyctophilus species known to use bat boxes and shares similar roosting ecology with these species. It is particularly notable that this threatened speices continues to use nest boxes of both timber and Cyplas construction. It is well known that uptake of bat boxes can take several years to occur. **Occupancy levels have risen since the 2018 monitoring events to a level where all but the single chamber bat boxes have attained the performance indicator target of greater than 10% occupancy.**

3.1.2.3 Arboreal mammals

There were no Antechinus occupying Antechinus boxes during inspections in 2019-20 (**Table 10**). Many Antechinus boxes showed evidence of former use by Antechinus, in the form of loose leaf nesting material. There were also a number of leaf and bark nests that could have been attributed to a range of other species including Brush-tailed Phascogale, Feathertail Glider, Sugar Gliders or Squirrel Gliders, although the entrance size of the Antechinus box is generally too small for anything but Feathertail Gliders or juveniles of the other species mentioned to enter.

Feathertail Glider boxes were not occupied by Feathertail Gliders during Autumn or Spring nest box inspections in 2019-20 (**Table 10**). There were no fauna species recorded in Feathertail Glider boxes.

Glider boxes (front and rear entry) showed the highest rates of occupancy by arboreal mammals amongst all arboreal mammal box types. A total of 8% of Glider front entry and 18% of Glider rear entry box types were occupied by Sugar Glider and/or Squirrel Gliders in 2019-20 (**Table 10**). Evidence of usage in 2018 was 43% for Glider front entry and 45% 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 Common Brushtail Possum, Green Tree Snake and Native bees.

Brush-tailed Phascogale boxes recorded occupancy rates of 1% during 2019 but were mainly found to contain leaf nests which were often attributed to Glider usage (**Table 10**). Non target species inhabiting Brush-tailed Phascogale boxes were Sugar and Squirrel Gliders and a Lace Monitor.

Approximately 6% of Possum boxes were occupied in 2019, predominately by the Common Brushtail Possum but also by Common Ringtail Possum and Mountain Brushtail Possum (**Table 10**). Evidence of use by possums was 27% 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, Eastern Rosella, Lace Monitor, *Morelia spilota* (Carpet Python) and Squirrel Glider.

There was no evidence of use in the single Spotted-tailed Quoll box in either Autumn or Spring 2019-20. There has not been any documented records of Spotted-tailed Quolls inhabiting nest boxes reported in the literature.

Figure 22: A colony of *Nyctophilus* sp. Long-eared Bats in a 2-chambered bat box recorded in Autumn 2019.

Figure 23: Top left: A Common Brushtail Possum using a Cyplas box, Spring 2019. Top right: A Glider species (spiral leaf nest) nesting in a Cyplas box, Spring 2019. Bottom centre: A Squirrel Glider and young in a Cyplas box, Spring 2019.

Table 10: Nest box type and rates of occupancy per target species following nest box inspections undertaken in Autumn and Spring 2019-20 on Sections 3 – 11 of the W2B project.

Box Type	# boxes installed	# non functional boxes	# functional boxes	# times boxes checked in 2019	# occurrences of target species occupying boxes	% occupancy by target species	evidence of use by target species	% evidence of use by target species	Overall usage by target species	% Overall usage by target species	All species detected (occupancy and evidence of use)
Antechinus	30	0	30	49	0	0	12	24	12	24	Antechinus (nest/guano), Lace Monitor
Barn Owl	15	4	11	21	0	0	0	0	0	0	Common Ringtail Possum, Owlet Nightjar, Lace Monitor, Sugar/ Squirrel Glider (nest)
Boobook / Wood duck	3	0	3	5	0	0	0	0	0	0	Common Brushtail Possum
Cockatoo/Large Owl	54	7	47	94	1	1	2	2	3	3	Southern Boobook Owl, Owlet Nightjar, Squirrel Glider, Lace Monitor, Common Brushtail Possum
Dollar Bird/Crimson Rosella	5	0	5	8	0	0	0	0	0	0	Sugar / Squirrel Glider (nest)
Feather Tail Glider	10	0	10	17	0	0	5	29	5	29	Feathertail / Sugar / Squirrel Glider (nest)
Glider (front entry)	41	3	38	63	5	8	27	43	32	51	Squirrel Glider, Sugar Glider, Green Tree Snake, Common Brushtail Possum
Glider (rear entry)	68	7	61	112	20	18	50	45	70	63	Squirrel Glider, Sugar Glider, Brush-tailed Phascogale, Carpet Python, Common Brushtail Possum, Native Bees
Kingfisher	8	1	7	16	0	0	0	0	0	0	Sugar / Squirrel Glider (nest)
King Parrot	4	0	4	7	0	0	0	0	0	0	A Long-eared Bat, Sugar Glider, Common Brushtail Possum
Pardalote	8	1	7	16	0	0	0	0	0	0	Sugar / Squirrel Glider (nest), Antechinus (nest / guano)
Phascogale	37	3	34	57	1	2	0	0	1	2	Brush-tailed Phascogale, Squirrel Glider, Sugar Glider, Lace Monitor

Box Type	# boxes installed	# non functional boxes	# functional boxes	# times boxes checked in 2019	# occurrences of target species occupying boxes	% occupancy by target species	evidence of use by target species	% evidence of use by target species	Overall usage by target species	% Overall usage by target species	All species detected (occupancy and evidence of use)
Possum	182	12	170	307	19	6	82	27	101	33	Mountain Brushtail Possum, Common Brushtail Possum, Common Ringtail Possum, Australian Woodduck, Eastern Rosella, Carpet Python, Lace Monitor, Owlet Nightjar, Squirrel Glider
Single Chamber Bat	17	1	16	26	1	4	1	4	2	8	Eastern Long-eared Bat, Squirrel Glider
2 Chamber Bat	35	2	33	64	7	11	0	0	7	11	Gould's Long-eared Bat, Lesser Long-eared Bat, A Long-eared Bat
3 Chamber Bat	16	2	14	25	3	12	0	0	3	12	Eastern Long-eared Bat, Gould's Long-eared Bat, A Long-eared Bat
4 Chamber Bat	18	2	16	27	3	11	0	0	3	11	Eastern Long-eared Bat, Gould's Long-eared Bat, Lesser Long-eared Bat
Small Parrot	73	2	71	120	2	2	0	0	2	2	Native bees, Owlet nightjar, Squirrel Glider, Sugar Glider
Spotted-tail Quoll	1	1	0	2	0	0	0	0	0	0	Nil
Tree Creeper	9	2	7	11	0	0	0	0	0	0	Sugar / Squirrel Glider (nest)
Totals	**634**	**50**	**584**	**1047**	**62**	**6**	**179**	**17**	**241**	**23**	
Unknown	28	5	23	43	0	0	0	0	0	0	Squirrel Glider

* 23 boxes did not have nest box type recorded and are not included in this analysis.

3.1.3 Performance Indicator 3: Pest species

There was a total of 33 (6%) nest boxes occupied by pest species during the Autumn 2019 monitoring inspections, and 31 (6%) occupied by pest species during the Spring 2019-20 inspections (**Table 11** and **Table 12**). These figures meet the performance indicator target of <15% pest species uptake. Where possible pest species were dealt with in situ by leaving the box lid open between monitoring inspections (discouragement for ants / wasps) and clearing old nests / hives out. The six species categorised as pests which were recorded in nest boxes were:

- ants
- *Apis mellifera* (European bees)
- invertebrates (i.e. spiders)
- *Rattus* sp.(rodents)
- termites
- wasps.

Pest species were recorded in all Sections (except Section 5 in Autumn). Rates of pest species uptake varied between 0 – 27% of boxes per section across the subject site. Sections 3A and 7 recorded rates of pest species uptake in Autumn that exceeded performance targets of (<15%), with Section 7 also exceeding performance indicator targets in Spring. Section 7 was one of the most fire affected along the alignment and this may have something to do with the greater incidence of ants in boxes in this Section at this time.

Ants were the most commonly recorded pest species to occur in all Sections except Section 5, with 21 (4%) of nest boxes occupied in Autumn and 15 (3%) occupied in Spring 2019-20 (**Figure 24**). Ants occurred in a broad range of box types including 4-chamber Bat, Antechinus, Brush-tailed Phascogale, Feathertail Glider, Glider (front and rear entry), Pardalote, Possum and Small Parrot. In all but four instances, ants were recorded in timber boxes (both hardwood and marine ply). There was <1% of boxes occupied by ants in Autumn that were still occupied by ants in Spring. Only 1% of boxes in Autumn and Spring had an ant nest or an infestation that required active maintenance (**Figure 24**).

Termites were the second greatest pest issue and only occurred in timber boxes, with seven boxes (1%) completely destroyed during the 2019-20 monitoring period and requiring replacement.

European bees were uncommonly recorded in nest boxes in Sections 3, 4, 10 and 11 with two boxes (<1%) occupied during the Autumn inspections and two boxes (<1%) occupied during the Spring inspections. European Bees were recorded using a Cockatoo/Owl, Glider front entry and Possum 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. One 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 three boxes (<1%) occupied in Autumn and two boxes (<1%) occupied in Spring. Native bees were recorded in Glider rear entry boxes constructed from timber. Two 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 Section 3 with two boxes (<1%) showing evidence of wasp occupation in Autumn and two boxes (<1%) showing evidence of wasp occupation in Spring 2018. Wasps occurred in Kingfisher and Possum boxes (**Figure 24**). Wasps occupied both Cyplas and timber boxes. There was one box occupied by wasps in Autumn that was still occupied by wasps in Spring.

Invertebrates (i.e. spiders) were recorded in nest boxes in Sections 3, 4, 8 and 9. Spiders were recorded in boxes twice (<1%) in Autumn and four times in Spring (<1%) occupying a range of box types (Glider front entry, Possum and Small Parrot) of both Cyplas and timber construction (**Figure 24**). In one case were spiders or their webs recorded in the same box more than once during the 2019-20 monitoring period.

Rodents (likely *Rattus rattus* Black Rat) were recorded in nest boxes in Sections 7, 10 and 11. Two boxes (<1%) showed evidence of occupation, one in Autumn and one in Spring, one a Cyplas box and one a timber box.

There were no avian pest species recorded using nest boxes during either the Autumn 2019 or Spring 2019-20 inspections.

There were numerous instances recorded during 2019-20 monitoring inspections of fauna using a nest box after pest species had left the box, which shows that the current maintenance practices of leaving bee hives alone and clearing boxes of pest ant and wasp infestations where safe and practical to do so during monitoring are effective ongoing practises.

3.1.4 Performance Indicator 4: Repair and Maintenance

A total of 56 nest boxes (8%) were found to require repair or maintenance during the 2019-20 monitoring period and this figure is within performance targets of less than 10% (**Table 13**). Of those 32 (5%) need to be replaced, 15 boxes (2%) required maintenance (repositioning on the host tree or lid propping / closing) and 9 (1%) had some damage (from termites, fire or fauna chewing around the entrance) but remained functional. Where possible and where it was safe to do so, maintenance was completed *in situ*.

The majority, 22 (3%) of boxes needing to be replaced resulted from loss due to severe bushfires, followed by 7 (1%) boxes that were lost due to termites and 3 (<1%) that were lost as a result of tree fall or persistent oiccupation by European Bees.

These results do not include the boxes in need of replacement from 2018 that have not yet been replaced. The combined total of boxes needing to be replaced from commencement of the project to end of the 2019-20 monitoring event is 55 (8%) boxes (**Table 14**). Nest box types and construction material of those 55 boxes is provided in **Table 15**.

It was agreed by TfNSW that no replacement boxes would be installed unitl the final tally (100% nest box allocation) of nest boxes required to be installed for the W2B Sections 3-11 project had been calculated based upon clearing data obtained for each Section. At the time of writing clearing data for Section 7, 8 and 9 is still outstanding but expected to be available before the end of 2020. It is expected that all replacement boxes and the final 30% of the nest box allocation will be installed prior to commencement of the next monitoring event in Autumn 2021.

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

Section	Ants	Bees	Inverts	Rodents	Termites	Wasps	Total	# Monitored	% Uptake
3A	3	0	0	0	0	0	3	11	27
3	7	1	2	0	3	2	15	231	6
4	1	1	0	0	0	0	2	54	4
5	0	0	0	0	0	0	0	7	0
6	1	0	0	0	0	0	1	36	3
7	4	0	0	1	0	0	5	28	18
8 and 9	3	0	0	0	1	0	4	88	5
10 and 11	2	0	0	0	1	0	3	60	5
Total	**21**	**2**	**2**	**1**	**5**	**2**	**33**	**515**	**6**

Table 12: Pest species uptake of nest boxes in Sections 3 – 11 of the W2B project as recorded during Spring inspections.

Section	Ants	Bees	Inverts	Rodents	Termites	Wasps	Total	# Monitored	% Uptake
3A	1	0	0	0	0	0	1	10	10
3	2	0	1	0	3	2	8	250	3
4	4	1	0	0	0	0	5	58	9
5	0	0	0	0	0	0	0	30	0
6	1	0	0	0	1	0	2	31	6
7	4	0	0	0	0	0	4	20	20
8 and 9	2	0	3	0	3	0	8	86	9
10 and 11	1	1	0	1	0	0	3	58	5
Total	**15**	**2**	**4**	**1**	**7**	**2**	**31**	**543**	**6**

Figure 24: Top left: Timber box infested with ants, Spring 2019. Top Right: Timber box containing a mud wasp nests, Spring 2019. Bottom Left: Huntsman Spider in a Cyplas box, Spring 2019. Bottom Right: Timber box filled with cobwebs, Spring 2019

Table 13: Maintenance, repair and replacement required following 2019-20 nest box inspections on Sections 3 – 11 of the W2B project.

Section	Damaged / Non functional - replace				Maintenance / Box condition				
	Fire	Termite	Tree fall	Bees	Repositioned	Termites present box functional	Scorched by fire box functional	Lid opened / closed	Chewing box functional
3A	0	0	0	0	0	0	0	0	0
3	0	3	2	0	3	2	0	2	2
4	0	0	0	1	2	0	0	1	0
5	0	0	0	0	0	0	0	0	0
6	7	0	0	0	0	0	4	1	0
7	13	0	0	0	0	0	0	3	0
8	0	2	0	0	1	0	0	0	0
9	0	0	0	0	0	1	0	0	0
10	2	2	0	0	0	0	0	0	0
11	0	0	0	0	1	0	0	1	0
Sub-total	22	7	2	1	7	3	4	8	2
Total			**32**				**24**		

Table 14: Nest box replacement summary, W2B Sections 3-11 from commencement of project to June 2020.

Section	Fire	Termites	Tree fall	Bees	Stolen	Cleared	Total to be replaced
3A	0	0	0	0	0	0	0
3	0	4	2	0	0	9	15
4	0	0	0	1	0	7	8
5	0	1	0	0	0	0	1
6	7	0	0	0	0	0	7
7	13	0	0	1	0	1	15
8 and 9	0	2	0	0	0	0	2
10 and 11	3	2	0	0	1	1	7
Total	**23**	**9**	**2**	**2**	**1**	**18**	**55**

Table 15: Nest box types and construction material for the 55 nest boxes that need to be replaced on W2B, Section 3-11.

Box Type	Number of boxes to be replaced	Total Timber	Total Cyplas
Barn Owl	4	3	1
Cockatoo/Large Owl	7	6	1
Glider (front entry)	3	3	0
Glider (rear entry)	7	5	2
Kingfisher	1	1	0
Pardalote	1	1	0
Phascogale	3	2	1
Possum	12	5	7
Single Chamber Bat	1	1	0
2 Chamber Bat	2	2	0
3 Chamber Bat	2	1	1
4 Chamber Bat	2	2	0
Small Parrot	2	2	0
Spotted-tail Quoll	1	1	0
Tree Creeper	2	2	0
Unknown	5	5	0
Total	**55**	**42**	**13**

3.2 Comparison of the performance of timber and Cyplas nest boxes

Figures presented for comparison of the performance of Cyplas and timber boxes do not include boxes that were unavailable for use by fauna in each monitoring event during 2019-20. Of the 662 nest boxes installed, 180 were made from Cyplas (27%) and 482 (73%) were made from timber . The performance of timber and Cyplas boxes differed between seasons and material types (**Figure 25**). In Autumn timber boxes recorded lower occupancy rates, lower rates of evidence of use and lower overall rates of use than Cyplas boxes. A total of 48 timber boxes (13%) of 384 timber boxes were inhabited in Autumn compared to 28 Cyplas boxes (21%) of 135 Cyplas boxes. Whereas in Spring the results were very similar between timber and Cyplas boxes with 40 (10%) of 405 timber boxes inhabited, compared to 14 (9%) of 157 Cyplas boxes inhabited. The overall rate of use for timber boxes in Autumn was 177 of 384 timber boxes (46%), compared to the overall rate of use for Cyplas boxes of 64% (87 of 135 Cyplas boxes). In Spring, the overall rate of use for timber boxes was 36% (145 of 405 boxes) compared to 39% (61 of 157 boxes). There was a marked difference in the number of Cyplas and timber boxes that were occupied (and those showing evidence of use) between the Autumn and Spring monitoring events, and a marked decline in the evidence of use in both timber and Cyplas boxes from Autumn to Spring 2019-20 (**Figure 25**).

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 trend for Cyplas boxes to be preferentially inhabited over timber boxes which is strongest in Autumn. Further statistical analysis of this trend can be undertaken, once more data is gathered in subsequent monitoring inspections.

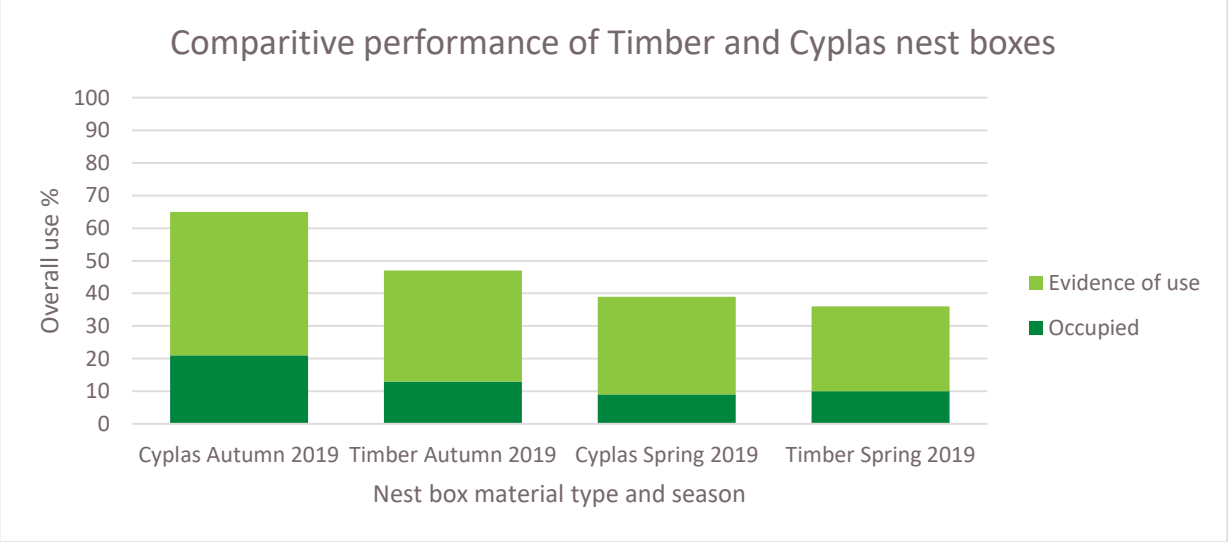

Figure 25: Comparison of overall rates of use for timber and Cyplas nest boxes as recorded during Autumn and Spring 2019-20 in Sections 3 – 11 of the W2B project.

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

The range of fauna species recorded occupying both Cyplas and timber boxes was higher in Autumn than in Spring inspections. A total of ten fauna species were recorded using Cyplas boxes (one bird, five mammals, two microbats and two reptiles) during Autumn, compared to only three fauna species recorded during Spring (**Table 16**). A total of 11 fauna species were recorded using timber boxes in

Autumn (two birds, five mammals, two microbats and two reptiles), and eight species during Spring. The following four species were only recorded occupying timber boxes:

- **Brush-tailed Phascogale* (listed as vulnerable under the BC Act)**
- Southern Boobook Owl
- Green Tree Snake
- Native bees.

Only one species, the Mountain Brushtail Possum, was recorded occupying a Cyplas box and not recorded at all in a timber box during the 2019-20 inspections (**Figure 27**). It is likely that a greater number of species used both timber and Cyplas boxes than reported, 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, due to 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 versus Cyplas boxes.

A total of eight nest boxes, three Cyplas and five timber recorded breeding by arboreal mammal species during 2019-20. There is evidence of three arboreal mammal species using Cyplas boxes for breeding purposes in 2019-20; Common Brushtail Possum, Squirrel Glider* and Sugar Glider, with Squirrel Gliders breeding in the same Cyplas box in both Autumn and Spring. Two arboreal mammal species have been recorded breeding in timber boxes; Common Brushtail Possum and Squirrel Glider*.

In addition to these results there is evidence for two species of birds (Australian Woodduck and Eastern Rosella) breeding in both Cyplas and timber boxes nest boxes, although the majority of records for breeding birds were from timber boxes.

Table 16: List of species occupying timber and Cyplas boxes during Autumn and Spring nest box inspections.

	Autumn		Spring	
Common name	*Cyplas*	*Timber*	*Cyplas*	*Timber*
Brush-tailed Phascogale*		Y		
Carpet Python	Y			Y
Common Brushtail Possum	Y	Y	Y	Y
Common Ringtail Possum	Y	Y		Y
Eastern Long-eared Bat*	Y	Y		
Gould's Long-eared Bat	Y	Y		
Green Tree Snake		Y		
Lace Monitor	Y	Y		Y
Mountain Brushtail Possum	Y			
Nyctophilus sp.		Y		
Australian Owlet Nightjar	Y	Y	Y	Y
Southern Boobook Owl		Y		
Squirrel Glider*	Y	Y	Y	Y

	Autumn		Spring	
Sugar Glider	Y	Y		Y
Native bee hives				Y

* Listed as vulnerable under the BC Act

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

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 25 of 41 records (61%) of target fauna species occupying timber nest boxes and 16 of 41 records (39%) of target fauna species occupying Cyplas nest boxes in 2019-20 (**Table 17**). The percentage occupancy of Cyplas boxes by target species (39%) is higher than the percentage of Cyplas boxes installed (27%) suggesting preferential occupancy of Cyplas boxes by target fauna species.

Evidence of use by all species (**Table 18**) was found in 326 boxes, of which 220 were made of timber (67%) and 106 were made of Cyplas (33%). Once again, the percentages for evidence of use also suggest a preference for Cyplas boxes with higher percentage evidence of use for Cyplas boxes (33%) than would be expected given the lower rates they would be encountered on this project by target fauna (27% of the sample size).

Two of the three target threatened fauna species recorded during 2019-20 were recorded using Cyplas boxes designed for their use; Eastern Long-eared Bat and Squirrel Glider. All three target threatened fauna species recorded in 2019-20 were found to occupy timber boxes designed for their use; Brush-tailed Phascogale, Eastern Long-eared Bat and Squirrel Glider.

During the 2019-20 monitoring events, 23 boxes did not have the nest box type recorded and are not included in this analysis (**Table 18**). Ten fauna species inhabited these 23 boxes, 14 boxes showed evidence of use and two boxes contained Squirrel Gliders (Vulnerable under the BC Act).

It should be noted that duplicate nest box counts occurred during the 2019-20 monitoring inspections, as most boxes were visited and checked twice (in Spring and then again in Autumn).

Table 17: Occupancy by target species within timber and Cyplas boxes across the subject site during Autumn and Spring inspections 2019-20.

Box Type	Box Type Code	Number of occurrences of target species inhabiting timber boxes	Number of occurrences of target species inhabiting Cyplas boxes	% inhabited by target species within timber boxes	% inhabited by target species within Cyplas boxes
Antechinus	A	0			
Barn Owl	BO	0			
Boobook/Wood Duck	BOO	0			
Cockatoo/Large Owl	Cock_Owl	1		100	0
Dollar Bird/Crimson Rosella	Dollar	0			
Feathertail Glider	FTG	0			
Glider (front-entry)	GLF	2	1	67	33
Glider (rear-entry)	GLR	8	5	62	38
Kingfisher	Kf				
King Parrot	KP		1	0	100
Pardalote	Pard				
Phascogale	BTP	6	3	67	33
Possum	Pos	1	3	25	75
Single-chamber bat	B1	2		100	0
2-chamber bat	B2	2	1	67	33
3-chamber bat	B3		1	0	100
4-chamber bat	B4	2		100	0
Small Parrot	SmP	1	1	50	50
Spotted-tailed Quoll	STQ				
Tree Creeper	TC				
Total		**25**	**16**	**61**	**39**

Table 18: Overall use (inhabited and evidence of use) by all species within timber and Cyplas boxes across the subject site during Autumn and Spring inspections 2019-20.

Box Type	# No. occourences all species (timber)	# No. occourences all species (Cyplas)	Evidence of use all species	Evidence of use all species (timber)	Evidence of use all species (Cyplas)	% evidence of use (timber)	% evidence of use (Cyplas)	Overall use all species	Overall use all species (timber)	Overall use all species (Cyplas)	% overall use (timber)	% overall use (Cyplas)	% overall use all species	% overall use all species (timber)	% overall use all species (Cyplas)
Antechinus			13	13		100	0	13	13	0	100	0	27	27	0
Barn Owl	2		5	4	1	80	20	7	6	1	86	14	32	24	4
Boobook/Wood Duck		1	1		1	0	100	2	0	2	0	100	40	0	40
Cockatoo/Large Owl	14	1	33	22	11	67	33	48	36	12	75	25	55	38	13
Dollar Bird/Crimson Rosella			3	3		100	0	3	3	0	100	0	38	38	0
Feathertail Glider			4	4		100	0	4	4	0	100	0	24	24	0
Glider (front-entry)	5	1	28	28		100	0	34	33	1	97	3	53	52	2
Glider (rear9entry)	14	8	55	41	14	75	25	77	55	22	71	29	69	47	19
Kingfisher			3	1	2	33	67	3	1	2	33	67	20	6	13
King Parrot		2	5	1	4	20	80	7	1	6	14	86	100	14	86
Pardalote			7	7		100	0	7	7	0	100	0	47	44	0
Phascogale	6	4	23	16	7	70	30	33	22	11	67	33	65	39	19
Possum	13	14	92	41	51	45	55	119	54	65	45	55	39	17	21
Single-chamber bat	2		2	2		100	0	4	4	0	100	0	15	15	0
2-chamber bat	4	3	0					7	4	3	57	43	11	6	5
3-chamber bat	2	1	0					3	2	1	67	33	7	7	4
4-chamber bat	3		0					3	3	0	100	0	11	10	0

Box Type	# No. occourences all species (timber)	# No. occourences all species (Cyplas)	Evidence of use all species	Evidence of use all species (timber)	Evidence of use all species (Cyplas)	% evidence of use (timber)	% evidence of use (Cyplas)	Overall use all species	Overall use all species (timber)	Overall use all species (Cyplas)	% overall use (timber)	% overall use (Cyplas)	% overall use all species	% overall use all species (timber)	% overall use all species (Cyplas)
Small Parrot	5	4	46	32	14	70	30	55	37	18	67	33	47	31	15
Spotted-tailed Quoll			0					0	0	0			0	0	0
Tree Creeper			6	5	1	83	17	6	5	1	83	17	60	42	8
Total	**70**	**39**	**326**	**220**	**106**	**67**	**33**	**435**	**290**	**145**	**67**	**33**	**42**	**27**	**13**

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

Did not include non-targeted species (see **Figure 18** for a list of non-target species)

^ Most boxes visited twice (Spring and Autumn)

3.2.3 Performance Indicator 3: Timber versus Cyplas pest species

The rates of uptake by pest species in Cyplas boxes was low and falls within performance targets, with 12 occurances in 292 box inspections (4%) (Autumn and Spring combined) recording pest species (**Table 19**). There were five pest species groups recorded in Cyplas boxes (ants, bees, invertebrates, rodents and wasps), with ants the most commonly recorded pest.

Rates of pest species uptake in timber boxes were also low and fell within performance targets, with 60 occurences in 789 (8%) box inspections (Autumn and Spring combined) containing pest species (**Table 19**). Timber boxes recorded all six pest species groups (including termites) with ants still the most commonly recorded pest.

In terms of pest species uptake, Cyplas boxes performed much better than timber boxes, largely due to a complete lack of termites using Cyplas boxes and greatly reduced rates of ants, bees and invertebrates (**Table 19** and **Figure 26**). Overall the rates of pest species uptake in both timber and Cyplas boxes were variable in 2019, when comparing Autumn pest levels to Spring, which may be linked to the prolonged drought conditions and the 2019-20 bushfires (**Figure 26**).

Table 19: Rates of pest species uptake in timber and Cyplas boxes following nest box inspections in Autumn and Spring 2019-20 on Sections 3 – 11 of the W2B project.

Box type	Ants	Bees	Invertebrates	Rodents	Termites	Wasps	Total	# Monitored	% Uptake
Timber	31	7	6	3	12	1	60	789	8
Cyplas	6	1	1	1	0	3	12	292	4

3.2.1 Performance Indicator 4: Timber versus Cyplas repair and maintenance

Repair and maintenance requirements for Cyplas boxes were lower than for timber boxes. Throughout 2019-20 monitoring, only 16 (7%) Cyplas boxes required active management or replacement compared to 40 (10%) timber boxes.

Fire destroyed 22 boxes (Cyplas and timber) and scorched four boxes which required maintenance. Eight timber boxes required replacing due to being destroyed by termites. The remainder of issues comprised tree fall damage, repositioning or lid propping due to infestation by pest species.

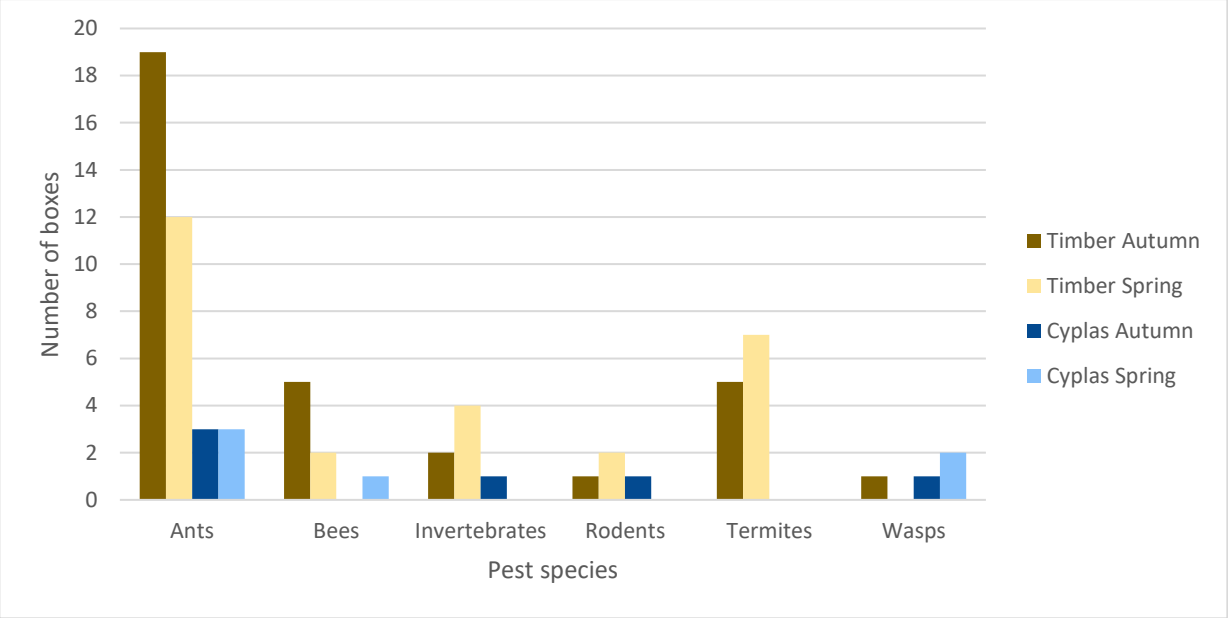

Figure 26: Number of timber and Cyplas boxes containing pest species following nest box inspections in Autumn and Spring 2019-20 on Sections 3 – 11 of the W2B project.

Figure 27: A Mountain Brushtail Possum (melanistic form) in a Cyplas nest box in Section 10, Autumn 2019.

4. Discussion

4.1 2019-20 disturbance events

4.1.1 Bushfire

The NSW bushfire season normally begins in October and continues through until the end of March. The fire season started early in 2019-20, with persistent drought affecting 95% of NSW. During September 2019 to March 2020, the northern parts of NSW experienced extreme fire impacts. In early February 2020, heavy rain through most of coastal NSW extinguished a significant number of fires. All fires in NSW, which peaked during December-January, were completely extinguished by March 2020.

It has been conservatively estimated that over 800 million animals were killed in NSW by the 2019-20 bushfires. This estimate included mammals (but excluded bats), birds and reptiles. Other national estimates (which included bats, amphibians and invertebrates) raised the losses across Australia to over one billion.

Whilst bushfires are common in Australia, they are usually of a lower scale and intensity, and affect smaller areas of the overall distribution of various fauna species. Besides immediate fire mortalities, further post-fire deaths occurred due to additional indirect impacts (e.g. starvation, reduced shelter and increased feral predator attacks).

The September fires destroyed next boxes in three sections of the subject site and disrupted the spring 2019 monitoring event, the majority of which was completed in March 2020 following a resumption of saf working conditions through the project area. The areas worst affected by fire within the W2B subject site were the central and northerly sections (Sections 6, 7 and 10). The entire W2B project area was very dry following the extended drought conditions which occurred prior to the 2019-20 fire events. The 2019-20 bushfires destroyed 22 nestboxes (**Table 13**), with the highest number of boxes (13) lost in Section 7 of the W2B project.

The New Italy area (Section 7) of the subject site was burnt on both sides of the Pacific Highway. In this area some nest boxes and mature trees were destroyed, including those positioned highest of any box type at above 12 m (**Figure 28** and **Figure 29**), while some boxes were scorched but remained functional. Large swathes of surrounding habitat were lost.

Figure 28: Entrance piece from an owl nest box (placement >12 m high) burnt and lost from Section 7, March 2020.

Figure 29: Burnt base of a tree (central hollow pipe) from Section 7, March 2020.

In Autumn 2019 three of the target threatened fauna species were recorded using boxes; Squirrel Glider, Eastern Long-eared Bat and Brush-tailed Phascogale. In Spring 2019-20, the only target threatened species recorded using the boxes was the Squirrel Glider, which is most likely to be attributed to the combination of extensive droughts followed by severe bushfires.

4.1.2 Construction

A lower number of fauna has been recorded using next boxes during the 2019-20 W2B monitoring events, when compared to the 2018 monitoring events. Construction noise and vibration is a factor which is likely to have contributed to this (Peter Knock pers. comm. ELA 2019), combined with other factors including drought, fire and surrounding habitat loss.

4.2 Use of nest boxes

Fourteen native vertebrate species were confirmed using nest boxes during 2019-20 and 22 have been recorded in total since monitoring began in 2017, which represents a greater species diversity than reported for similar TfNSW nest box programs on the Pacific Highway upgrade. Similar programs include those immediately to the south at Sapphire to Woolgoolga (S2W), Woolgoolga to Halfway Creek (W2HC) and Halfway Creek to Glenugie (HC2G) (Sandpiper 2016a and 2016b and Ecosure 2017). This result could be partially 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 TfNSW nest box programs except for W2B Sections 1 and 2 which has approximately 400 nest boxes installed. The greater area and diversity of habitats encountered than on any adjacent nest box projects is also likely to be a contributing factor. Cumulative species diversity will continue to be tracked over time in subsequent nest box monitoring reports.

A total of 85% of records in Autumn and in Spring were attributed to just five dominant mammal species (Common Brushtail Possum, Sugar Glider, Squirrel Glider, Eastern Long-eared bat* 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 and 2016b and Ecosure 2017). It also aligns with the findings of a review of TfNSW 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).

The overall rates of next box usage by all species (for functional boxes only) was 53% in Autumn and 38% in Spring, which are largely within the range reported on similar nest box monitoring projects (such as S2W), where overall usage was reported at 51-58% (Sandpiper 2016a), W2HC where overall usage was reported at 30-56% (Sandpiper 2016b), and Coopernook where overall usage was reported at 65-74% (Sandpiper 2015), the adjacent HC2G where overall usage was reported at 14-26% (Ecosure 2017) and Branxton 47-67% (Sandpiper 2015).

Estimated rates of occupancy for naturally occurring hollows are lacking in the literature. However Goldingay reports evidence to suggest that occupancy of Squirrel Gliders in hollow bearing trees is between 3 and 10%, with other threatened arboreal mammals with larger home ranges even lower than that. Lindenmayer et al (2017) reported occupancy rates of the threatened *Lathamus discolor* Swift Parrot in hollows as lower still at 5%.

Some evidence for rates of nest box occupancy by fauna are summarised in Goldingay (2019) and include the threatened Brush-tailed Phascogale (9%) and Squirrel Glider (5-44%). Goldingay (2019) also summarises studies looking at occupancy of nest boxes designed for certain bird species and reports rates of occupancy of between 4 and 100% for common species such as Eastern Rosella and *Platycercus elegans* Crimson Rosellas, and around 18-21% for threatened bird species such as Swift Parrots and Carnaby's black Cockatoo's. However Goldingay (2019) has suggested that differences in occupancy rates across the distribution of a species will exist and are related to the quality of habitat available to the species in question. The same will be true for occupancy rates of fauna in nest boxes. **Goldingay (2019) has suggested that a benchmark for occupancy of nest boxes by mammals (excluding bats) should be in the order of 10% and with less certainty for birds, the benchmark should be in the order of 5%**. When only arboreal mammal boxes are included in the analysis (Antechinus, Feathertail Glider, Glider front and rear entry, Phascogale and Possum), our 2019-20 results return an occupancy rate of 45 (7%) of 605 box checks, still below the 10% performance indicator target. As stated in Section 3.1.2 above, only Glider rear entry boxes and 2-chamber, 3-chamber and 4-chamber bat boxes attained the 10% performance indicator target for occupancy during 2019-20.

If nest box projects are not able to install boxes for a particular species in groups of 3 and there is a lack of naturally available hollows, a single nest box is unlikely to serve the year round needs of any given animal. A single nest box is likely be used less often than a cluster of the same type of boxes (Goldingay 2019). This may be one of the reasons for the lower occupancy rate of Brush-tailed Phascogale boxes in this study (2% as compared with that reported in Goldingay 2019 of 9%), as most of the installations occurred as single boxes of that type. There is an opportunity to improve occupancy rates of Brush-tailed Phascogale nest boxes (and potentially other arboreal mammal boxes) with nest boxes / artificial hollows remaining to be installed to fulfil the 100% required for the project. Prior to installation of the remaining boxes consideration will be given to box type, box construction material and installation configurations that have been the most successful on this project or proven to be successful in the recent literature review conducted by Godlingay (2019).

The results of 2019-20 monitoring recorded nest box occupancy rates of 16% in Autumn and 10% in Spring for all fauna combined. The Autumn nest box monitoring result is the same as occupancy rates of 16% recorded from fauna occupying trees in Section 3 during vegetation clearance. It is important to note that reptiles accounted for a significant percentage (32%) of the fauna recorded during vegetation clearance and there have been no boxes installed that are targeted towards reptiles. When occurrences of only mammals and birds are included from the vegetation clearance records, the occupancy rate is 9%. This figure has been exceeded by the occupancy rates for mammal and bird nest boxes on Sections 3-11 of the W2B project in both Autumn and Spring 2019-20. The lower occupancy rate recorded in Spring has likely been brought down by extreme bushfires occurring within parts of the project footprint.

These results are encouraging given that the reduction in habitat from vegetation clearance associated with the highway upgrade, along with the ongoing disturbance from heavy plant and machinery and increased human and vehicular presence and disturbance during construction is expected to deter fauna from inhabiting or visting remaining habitat in the study area . If this is true and fauna are still present in an area, and the nest boxes are providing suitable habitat, we would expect occupancy rates to increase once construction has finished and the project moves into the operational phase. If no increases in occupancy are recorded, or only recorded in some box types, we must question the ability

of certain nest box types to provide suitable alternative habitat for fauna displaced from hollows along the W2B alignment.

Overall rates of use of 53% (Autumn) and 38% (Spring) (occupancy and evidence of use combined) falls within the range reported on the adjacent S2W of 51-64% (Sandpiper 2016c) W2HC of 30-53% (Sandpiper 2016a, 2016b, 2017a and 2017b) and HC2G of 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.). This will be a commonality across most nest box monitoring projects

4.3 Target 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.

Only three of the 24 hollow dependent threatened vertebrate species previously recorded within 5 km of the subject site (Squirrel Glider, Eastern Long-eared Bat and Brush-tailed Phascogale) were observed to inhabit nest boxes in the Autumn and Spring 2019-20 monitoring period. Squirrel Glider (Vulnerable under the BC Act) was the most abundant, and were recorded across a broad range of box types. Eastern Long-eared Bats occupied three of the four bat box types with abundance ranging from one to eight 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 (including Cyplas boxes) by this species in this study is encouraging.

An individual Brush-tailed Phascogale was detected utilising a Brush-tailed Phascogale box in Autumn 2019. Rates of occupancy and overall use by Squirrel Gliders and Brush-tailed Phascogales are at 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.

Whilst rates of nest box uptake by the species for which the box was designed were 6% and below target (>10%), when results for all nest box types were combined, there were some nest box types that were successfully inhabited by the target species or species group. **Ten (50%) of the 20 nest box types (including mammal and bird boxes) recorded uptake by target species.** Some (40%) of the nest box types installed for this project targeted common species or groups of birds (Barn Owl, Boobook / Woodduck, Dollar Bird / Crimson Rosella, Kingfisher, King Parrot, Pardalote, Small Parrot, Tree Creeper) for which there is very little documented evidence of widespread use in those species. Glider rear-entry, 2-chamber, 3-chamber and 4-chamber bat box types all recorded occupancy rates by target species above the target of 10%. The successful uptake of Glider rear entry boxes and a number of bat box types by target threatened fauna species is encouraging. However the broader results indicate that nest boxes installed for the W2B project;

- are predominantly used by commonly occurring and adaptable species,
- are used by a lower number of, and different suite of species than was recorded during vegetation clearance activities, and
- that current nest box designs (particularly for birds and some mammals) are not attracting the target species or target threatened bird / mammal species or species group to a level which makes investment in the purchase, installation, monitoring and maintenance of these box types questionable.

There may be multiple reasons for the lower than expected uptake of target species in boxes designed for those species, including the loss of habitat that accompanied the W2B project, the high level of disturbance from heavy plant, humans and vehicular traffic in the immediate vicinity of remaining habitat in which the boxes were installed, poor / untested box design, and, in the case of birds and some larger mammals, home ranges or territories that greatly exceeded the size of nest box replacement zones so that displaced fauna was not reliant upon nest boxes for alternative habitat.

In light of these results and the scant literature on occupancy rates of naturally occurring hollows and results of scientific studies of nest box programs focusing on single species reviewed in Section 4.2 of this report, the performance indicator target of > 10% uptake by target species may be considered overly optimistic, particularly when applied across the board. It is suggested that the 10% benchmark be removed as a performance indicator until such time as the scientific literature provides clearer insight into acceptable levels of occupancy for programs such as this. A review and agreement on a suitable benchmark is recommended before inclusion in future TfNSW nest box programs.

Several mammal species 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 low records of birds occupying bird boxes, and none of the six species of threatened hollow-dependent birds predicted or known to occur in the subject site were recorded using nest boxes during 2019-20. The four species of birds recorded using nest boxes during 2019-20 are commonly occurring species (Australian Owlet Nightjar, Australian Woododuck, Eastern Rosella and Southern Boobook Owl). However, evidence of birds breeding in nest boxes was recorded during 2019-20, indicating the boxes are at least occassionaly fulfilling key lifecycle requirements for some common bird species (Australian Woodduck and Eastern Rosella).

Infrequent use of nest boxes by birds has been reported in other nest box programs associated with Pacific Highway upgrades (Goldingay 2019, Sandpiper 2013 and 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 and Lace Monitors, Green Tree Snakes and Carpet Pythons, all known predators of birds and their eggs were recorded in nest boxes. 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 and 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 species preferences 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 et 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. 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. Only in 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. Switching 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 compare the rates of uptake of nest boxes when presented in clusters of three or more, with those presented individually or in pairs.

4.4 Pests and nest box condition

There were low rates of pest species uptake of nest boxes recorded across the subject site in 2019-20. The results support recent research, which 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 were abandoned and subsequently used by native species.

Ants were the main pest species encountered during 2019-20, 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 and 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 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 2019-20.

The nest boxes monitored in 2019-20 included 32 (5%) which were damaged and required replacing, predominately due to fire (22 boxes) but also timber boxes being destroyed by termites (7 boxes), and damage from falling trees or branches during storms. Combined with boxes that required replacement from the 2018 monitoring event, there are a total of 55 nest boxes which are currently destroyed or non-functional and need replacing or repair (**Table 15**).

4.5 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 (Section 1). 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 (2018 and 2019-20) and Spring (2018). 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 in timber boxes of the same type, when directly exposed to the sun (ELA pers. comm. 2018, Sandpiper 2016d). Goldingay (2015) conducted trials testing the temperature profiles and associated rates of uptake of paired nest boxes, and recommended nest boxes for non-flying mammals should be installed to minimise extreme temperatures. For this reason, usage of Cyplas boxes in Spring was expected to be lower, because of the likelihood of exposure to higher temperatures and associated detrimental effects 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 could be undertaken.

Cyplas boxes performed better than timber boxes, in relation to lower pest species uptake and levels of maintenance and repair. However, the diversity of fauna species using Cyplas boxes was lower than for timber boxes. Fifteen (65%) of the 23 vertebrate fauna species so far recorded in nest boxes since monitoring began in 2017 have been recorded in Cyplas boxes during monitoring, in comparison to 21 (91%) of the 23 species recorded in 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. 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

This section provides recommendations for the nest box monitoring program and is summarised in **Table 20**.

Specific, measureable, achievable, realistic, time bound (SMART) benchmarks with the inclusion of all performance indicators would add value to future nest box monitoring programs.

The benchmark level of > 10% uptake of nest boxes by the species for which the box was designed (Performance indicator 2) is considered overly optimistic, particularly when applied to all species. The benchmark should be reviewed for it's applicability to species other than arboreal mammals (as per Goldingay 2019). The benchmark should be adjusted to account for the unique scenario that a highway upgrade nest box program presents in terms of tracking nest box occupancy over time throughout the construction and early operational periods of a major infrastructure build. A more appropriate and achievable figure would be > 5% occupancy until such time as the scientific literature provides clearer insight into acceptable levels of occupancy by target species for highway upgrade nest box programs.

Manipulation of the box type, material, installation configurations and locations for the 100% nest box allocation utilising the successful results from this project and the recent Goldingay review (2019) to increase performance against targets. Specifically consider installing only arboreal mammal and bat boxes, install in clusters of 3 or more of the same box type and install at heights of between 3 and 6 m. It is also recommended to install a majority in selected nest box zones that are known to be inhabited by target species, are easily accessible for monitoring and installation and that will not become over supplied with nest boxes. The 100% allocation will comprise a mix of timber (only those remaining in stock), Cyplas boxes and potentially artificial hollows.

Investigating the rates of uptake of nest boxes (particularly by arboreal mammals) when they are presented in clusters of three or more, compared with those presented individually or in pairs (as per the findings of the 2019 Goldingay review). An opportunity exists with the 100% nest box allocation to install remaining boxes in line with the 'clusters of 3 of the same box type' scenario and to look at usage rates of the same box types before and after clusters were introduced.

Table 21 provides an evaluation of nest boxes against the performance criteria discussed in Section 1.

Table 20: Recommendations

Recommendation	TfNSW Response
Provide Specific, Measurable, Achievable, Realistic and Time bound (SMART) benchmarks against which performance indicator targets can be evaluated in future monitoring plans	Agree
Reduce performance indicator 2 benchmark of > 10% occupancy to > 5% occupancy by species for which the box was designed. This accounts for the wide range of species being targeted and the lack of documented evidence for nest box usage rates for many of those species.	Agree
Implement the 100% nest box allocation so that the demonstrated most successful nest box types are installed at prioritised locations and boxes of the same type occur in clusters of 3.	Agree to be adopted
Investigate the rates of usage of arboreal mammal nest boxes installed in clusters compared with those presented individually or in pairs.	Agree to be adopted

Table 21: Performance indicator evaluation, W2B Sections 3 – 11, Autumn to Spring / summer 2019-20.

Performance indicator	Target	Status	Corrective Action	Proposed Action
1.Use of nest boxes by a range of fauna species	Boxes inhabited by any fauna species within four years. Overall rates of use >50%.	1.1 **Achieved** in Autumn (53%). **Not achieved** in Spring 2019-20 (38%). 14 fauna species inhabiting boxes during 2019-20. 23 fauna species inhabiting boxes since monitoring began in 2017.	Nil. Extreme bushfires in Spring / Summer 2019-20 likely responsible for <50% usage rates during Spring monitoring.	Continue to monitor usage in 2021 and 2023.
2. Use of boxes by target species	>10% occupancy of nest boxes by species for which the box was designed. Limited literature on occupancy of naturally occurring hollows indicates rates of occupancy for target species of 10% are achievable *under optimal conditions*. Studies based largely on arboreal mammals.	**Not achieved**. 6% boxes inhabited by species for which the box was designed during 2019-20. Evidence for occupancy of nest boxes by target species in similar studies suggests rates can fluctuate between 5 and 10%.	Benchmark measure amended to > 5%. Recommend installing remaining (as part of 100%) boxes so that clusters of same box type are available in key target species habitat.	Modified benchmark of >5%. Strategy for 100% nest box allocation adjusted to use the demonstrated most successful box types and installed in clusters.
3. Low rates of pest species usage	<15%	**Achieved 6**% in Autumn and Spring	Nil	Nil
4. Reduced maintenance and repair requirements	<10% boxes requiring repair or maintenance	**Achieved** 8% boxes required maintenance or repair	Replace 55 nest boxes (**Table 11**) during next monitoring event or as part of 100% nest box allocation install.	TfNSW approve replacement of termite damaged boxes with Cyplas boxes or artificially created hollows (chainsaw hollows).

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Appendix A - Monitoring data

Supplied as a separate digital file.

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