Pacific Highway Upgrade: Woolgoolga to Halfway Creek.

Nest Box Monitoring – Year 1, Winter 2016.

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Cover Photo: Family group of squirrel gliders (Petaurus norfolcensis) in a metal nest box.

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1. Introduction

1.1 Background

The Woolgoolga to Halfway Creek (W2HC) Pacific Highway Upgrade extends from the northern limit of the Sapphire to Woolgoolga Pacific Highway upgrade north 14 kilometres to the southern extent of the Halfway Creek Pacific Highway upgrade. The alignment follows the existing highway in the south with deviations over the Corindi Floodplain and through Dirty Creek Range then re-joins the existing highway at Range Road. It forms section 1 of the 11 staged sections of the Woolgoolga to Ballina (W2B) upgrade. Included in the W2B upgrade Ministerial Conditions of Approval (MCoA) was a requirement to prepare a Nest Box Management Plan (NBMP) to assist in managing displacement of hollow-dependent fauna (MCoA D6). The NBMP for the W2HC section was prepared by Biosis and approved in 2014.

The primary objective of the W2HC NBMP is to outline measures to mitigate the impacts of vegetation clearing on hollow-dependent fauna (HDF). In doing so, it provides "guidance on the provision of nest boxes as a compensatory mechanism for the loss of habitat trees within the clearing area, inclusive of den, roosting and nesting resources" (Biosis, 2014). The NBMP directs that 70% of required nest boxes (i.e. 70% allocation) be installed prior to completion of the clearing phase of the project and that monitoring of these boxes should occur during summer and winter shortly after the installation period. Installation of the 70% allocation was completed in November 2015 and mainline clearing completed in December 2015.

In August 2016 Sandpiper Ecological Surveys (Sandpiper) was contracted by OHL/York joint venture (OHLY) to conduct a winter 2016 inspection of the 70% nest box allocation installed along the W2HC upgrade. The following report presents background information on the installation process, inspection methods and results of the inspection conducted during August 2016. The winter 2016 inspection is the second nest box inspection and follows the summer 2016 inspection (Sandpiper 2016a). The report discusses the implications of results, compares results between summer and winter surveys and proposes a number of management recommendations.

1.2 Nest Box Types

Prior to nest box installation, the NBMP was reviewed to determine the type of boxes required and installation sites. Upon review it was noted that the plan recommended installation of 22 boxes for common planigale (*Planigale maculata*) and 15 boxes for eastern pygmy possum (*Cercartetus nanus*). Common planigale is not an arboreal species and would not benefit from installation of nest boxes. Eastern pygmy possum is unlikely to occur in the study area due to a lack of suitable habitat. Although the Bionet database contains some local records of EPP the species is regarded as very rare in coastal northern NSW (Bowen & Goldingay 2000).

Concern regarding the designated target species was discussed with Roads and Maritime Services (RMS) and it was agreed that boxes designated for common planigale would target feathertail glider (Acrobates spp), *Antechinus* spp and microbats, whilst the eastern pygmy possum boxes would target that species if suitable habitat was present but would otherwise target the aforementioned species. Suitable habitat for eastern pygmy possum was regarded as Dry Eucalypt forest with a heath understorey dominated by

Banksia, *Callistemon* and *Hakea* spp. The final number, type, dimensions and material of the 70% nest box allocation installed are described in Table 1.

Table 1: Number, type and dimensions of the 70% nest box allocation installed adjacent the W2HC upgrade. # = Chamber depth is floor to base of entrance hole. Box material: P = plywood; M = metal; H = hardwood.

Box Type	Inside Measurements	Chamber Depth #	Entrance Diameter	Box Material			Total Boxes
				Plywood	Metal	Hardwood	
Sugar/squirrel glider	150 x 250	300	45	11	6	0	17
Yellow-bellied glider	250 x 350	400	80	6	2	0	8
Brushtail/ringtail possum	250 x 200	300	85	6	6	0	12
Microbat	20 slot	400	30 hole	5	0	0	5
Scansorial small (Antechinus)	150 x 150	200	30	14	4	0	18
Scansorial small (Feathertail glider)	150 x 150	200-300	30	9	3	0	12
Scansorial small (Eastern pygmy possum)	150 x 150	300	30	1	1	0	2
Scansorial large (Brush-tailed phascogale)	150 x 200	300	50	10	8	0	18
Quoll	500 x 500	800	200	4	3	0	7
Cockatoo	300 x 400	1200	200	3	2	0	5
Masked Owl	250 x 300	500	100	2	1	0	3
Powerful Owl	500 x 500	800	200	3	1	0	4
Lorikeet	150 x 150	350	55	0	3	3	6
Treecreeper	150 x 150	350	60	0	2	14	16
Total				74	42	17	133

1.3 Installation Sites

The NBMP divided the alignment into 36 zones and identified a small number of private properties where access agreements had been finalised. Forests NSW provided consent to install boxes within 50m of the upgrade alignment in Wedding Bells and Newfoundland State Forests and the National Parks and Wildlife Service approved the installation of boxes in Yuraygir State Conservation Area. Whilst the abovementioned areas are suitable for nest boxes the number of boxes that could be installed in each area was constrained by the NBMP. There was limited opportunity to identify additional private properties prior to installation despite this being preferred by the installation team. Approval to install boxes on private property within 50m of the alignment was obtained between chainages 5500 and 6000.

In zones where there was no access to private or public land nest boxes were installed in the road reserve, which is not ideal. The road reserve typically lacks a variety of installation sites and boxes tend to be

situated close to the carriageways where they are affected by noise and light. Installing boxes on the western side of the carriageway is constrained by light spill from southbound traffic.

Nest box installation zones were grouped into three Nest Box Installation Areas (NBIA) – south, middle, north (Figure 1a, 1b, 1c). The NBIA graded from floodplain (south) to foothills of Dirty Creek Range (middle) to Dirty Creek Range (north). The extent and number of nest boxes within each NBIA is detailed in Table 2.

Table 2: Location and landscape features of Nest Box Installation Areas (NBIA). ASL = above sea-level.

Nest Box Installation Area (NBIA)	Nest Box Zones	Chainage	No. of boxes	Landscape Type	ASL (m)
South	36-27	0-5000	41	Floodplain	8 - 25
Middle	25-21	5000-8000	39	Foothills	31 - 61
North	18-3	8000-17000	53	Range	69 - 154

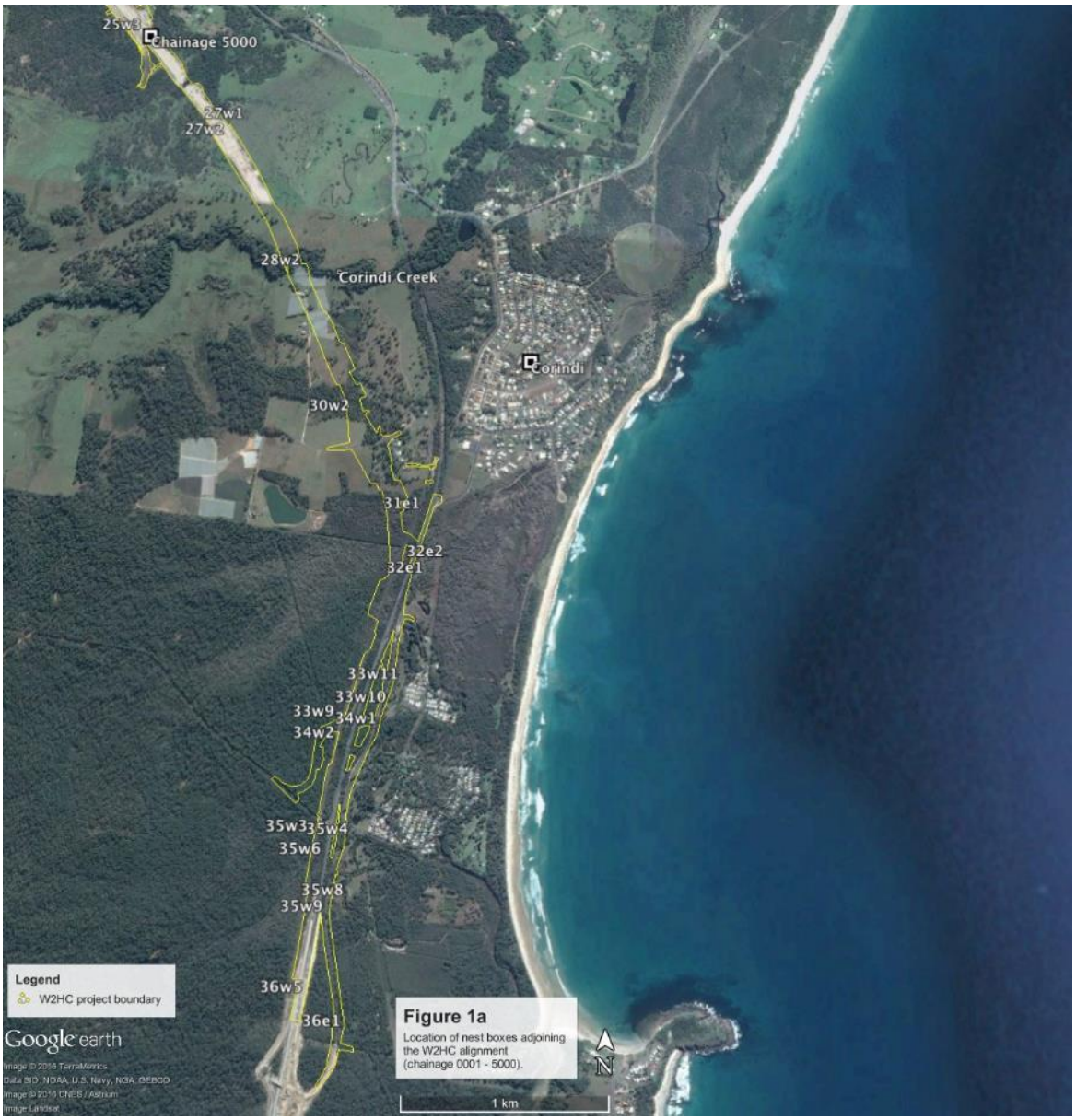

Figure 1a. Location of nest box zones within Nest Box Installation Area south (chainage 0-5000).

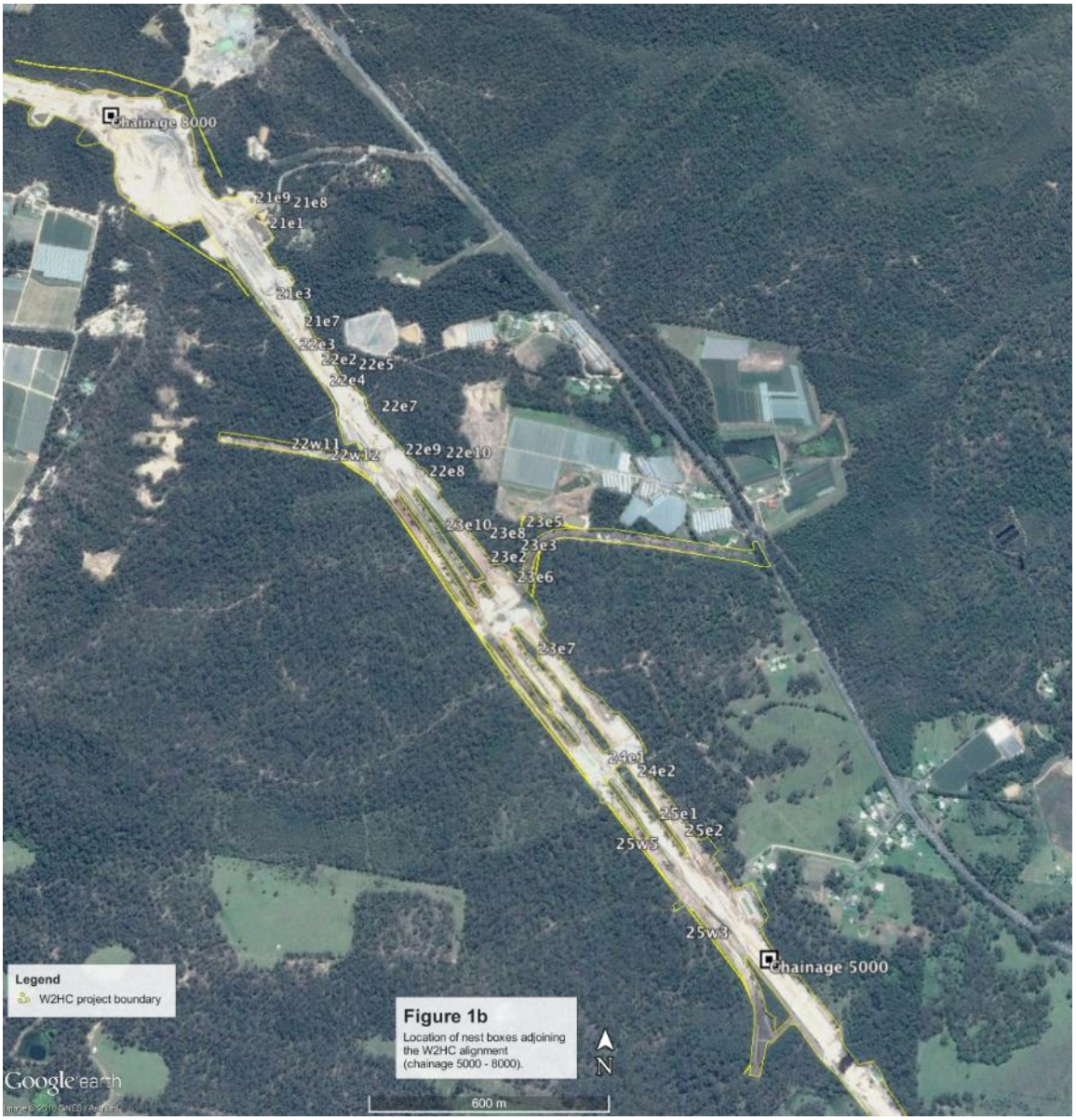

Figure 1b. Location of nest box zones within Nest Box Installation Area middle (chainage 5000-8000).

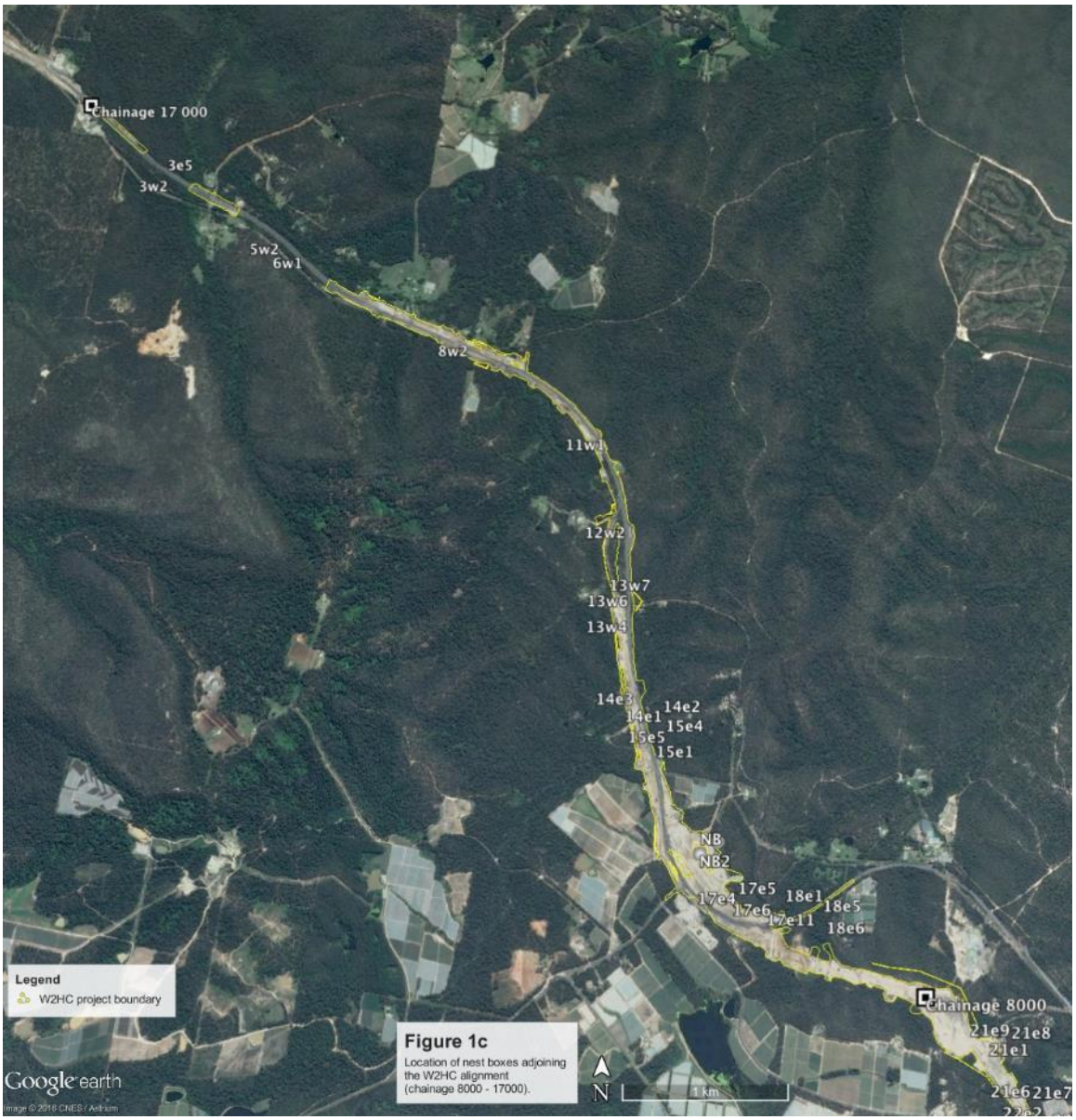

Figure 1c. Location of nest box zones within Nest Box Installation Area north (chainage 8000-17000).

1.4 Box Installation

An ecologist selected nest box trees and the location of the box within each tree (i.e. height and orientation). Each tree was marked with tape and its location logged using a handheld GPS. Critical data such as box type, installation height, orientation and box number was recorded on the tape and onto an iPad. Other data recorded included tree species and installation date. Tree climbers installed all nest boxes. Boxes were installed during three periods, 5-8 May 2015 (prior to clearing), 27 and 28 August 2015 (during clearing) and 10 November 2015 (during clearing).

2. Methods

2.1 Nest Box Inspections

Year one construction phase winter nest box inspections were carried out on 16, 17, 18 and 29 August 2016. One hundred and thirty-three boxes were inspected during the period. A team of two ecologists conducted the inspection. Each box was initially inspected visually from the ground with binoculars to determine its condition followed by inspection of the box contents using a GoPro Hero3 camera mounted to a telescopic extension pole. Tree climbers using the GoPro camera inspected boxes installed above 8m (n = 26). Images from the GoPro camera were wirelessly streamed to an iPad and a photo(s) of the contents recorded. The data recorded for each nest box included: species present, number of individuals, age (juvenile or adult), signs e.g. nesting/denning material, scats, hair and condition of box and supporting wire.

Identification of fauna was based on the ecologist's experience with reference to standard field guides (e.g. Menkhorst & Knight 2004; Churchill 2008; Tyler & Knight 2009) as required. With the exception of some insectivorous bats, most fauna can be confidently identified from photographs/video footage. The identification of fauna signs was based on previous experience of nest characteristics of hollow dependent fauna (HDF) and published information. Where there was sufficient evidence, such as distinct nests/denning material, a probability rating of possible (60-75% certainty), probable (75-90% certainty) or definite (>90% certainty) was assigned to the likely fauna species.

3. Results

3.1 Use of Nest Boxes

Six vertebrate species were observed occupying nest boxes during the 2016 winter inspection and a further two species were probable users based on nesting evidence (Table 3; Table A1, Appendix A). Squirrel glider (Petaurus norfolcensis) was the most abundant species with 19 individuals recorded using four box types, squirrel glider, scansorial, cockatoo and treecreeper boxes (Plate 1). Sugar glider (Petaurus breviceps) was recorded in eight boxes with a total of 12 individuals counted (Plate 2). Five feathertail gliders (Acrobates pygmaeus) were recorded in two boxes. Seven petaurid species' (sugar or squirrel glider) were recorded in four boxes. Both squirrel glider and feathertail glider occupants featured

juveniles, though exact numbers could not be determined. One hylid frog species, Peron's tree frog, was recorded in a masked owl box. No birds, or evidence of birds, were recorded.

Table 3: The number and type of nest boxes occupied and/or showing evidence of use during inspections conducted in winter 2016. Qu = Quoll; Tc = Treecreeper; ScS = Scansorial (i.e. feathertail, eastern pygmy possum, antechinus, Brushtail Phascogale); SS = SqG/SuG glider; MO = Masked Owl; Ct = Cockatoo; Po = Brushtail/Ringtail Possum; YBG = bellied Glider; Lo = Lorikeet.

Species/Group	No. occupied (total individuals)	Evidence of use (No.)	Box type used & No.
Brown Antechinus	1 (6)	8	ScS = 1
Common brushtail possum	2 (2)	3	Po = 3
Feathertail glider spp.	2 (5)	8	ScS = 1; Lo = 1.
Sugar glider	8 (12)		ScS = 3; YBG = 2; PO = 1; LFO = 1; SS = 1
Squirrel glider	5 (19)		SS = 2; ScS = 1; Ct = 1; Tc = 1
Sugar/squirrel glider	4 (7)	28	SS = 10; Tc = 7; ScS = 9, Lo = 4; YBG = 1; Ct = 1
Yellow-bellied glider/ Greater glider	0	2	YBG = 1; MO = 1
Peron's tree frog	1 (1)	0	MO = 1
European bees	0	0	
Ants	2		Tc = 1, ScS = 1
Total vertebrate use	23	52	75
Proportion used by vertebrates (total boxes = 133)	17.3%	39.0%	56.4%

Plate 1: Brown Antechinus were observed in a scansorial box. Note the extensive latrine corner, indicative of antechinus species (L). Squirrel gliders often den in large family groups, including six individuals in a squirrel glider box (R).

Plate 2: An individual sugar glider is seen occupying a small scansorial box, note the tail around the head (left). One of two common brushtail possums recorded during the inspection, this individual is occupying a box designed for masked owls (R).

In addition to occupied boxes, a further 39% of boxes contained evidence of use by vertebrates (Table 3). Nests of *Antechinus* sp. (either brown antechinus, *A. stuartii*, or yellow-footed antechinus, *A. flavipes*) featuring their distinctive scat latrines and leaf material were evident in eight boxes (Plate 3). The distinct eucalypt leaf nests of sugar/squirrel gliders and feathertail gliders were recorded in 28 boxes (Plate 3). Large flattened eucalypt leaf nests, possibly attributable to either greater glider (*Petauroides volans*) or yellow-bellied glider (*Petaurus australis*), were recorded in cockatoo and yellow-bellied glider boxes respectively. Overall, 75 boxes (56.4%) were either occupied or showed evidence of use by vertebrate fauna.

Plate 3: A typical bowl shaped nest of squirrel/sugar gliders (L). Antechinus typically create 'latrines' by depositing scats in the corner of a nest box (R).

European beehives (*Apis* sp.) were not detected in the winter survey and no signs of European bee activity were evident (e.g. abandoned or eaten-out hives). Arboreal ants (probable *Polyrachis* sp.) were observed in two small volume boxes (i.e. scansorial and treecreeper) (Plate 4).

Plate 4: *Polyrachis sp*. ants were evident in two nest boxes, both small volume scansorial boxes.

3.2 Spatial Use of Nest Boxes

Use of nest boxes varied amongst the three NBIA (Table 4). Overall use was highest in the southern (floodplain) area (37.4%), followed by the northern area (36%) and middle (foothills) area (26.6%) around Dirty Creek Range (Table 4).

Table 4: Nest box occupation and use according to Nest Box Installation Area (NBIA).

Nest Box Installation Area (No. of boxes)	No. Occupied	No. Evidence of Use	No. Overall Use	% Overall Use
South (41)	9	19	28	37.4
Middle (39)	7	13	20	26.6
North (53)	7	20	27	36.0

Nest box use varied somewhat with distance from the Limit of Clearing (LoC) boundary, although the trend was less evident in winter (Figure 2). In summer 2016, evidence of use increased with distance from the LoC up to 100m. In winter 2016, the highest rate of use (68%) was still evident for boxes located 51-100m from the LOC. Boxes located closest to the LOC (0-25m) reported 52.6% overall use and boxes located 26-50m from the LOC had a 50% evidence of use rate. Evidence of use rates for boxes located 101-200m from the LOC reported a jump in use from 0% in summer to 46.6% in winter 2016 (Figure 2).

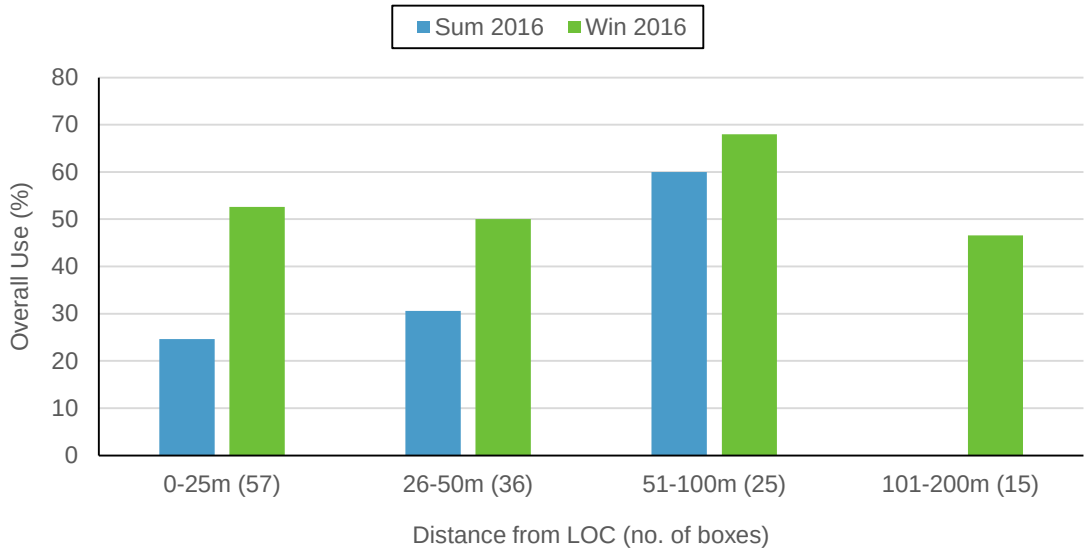

Figure 2: Overall use of nest boxes according to distance from Limit of Clearing (LOC). Summer and Winter 2016 results are exhibited. Number of nest boxes installed in each distance category is shown in parenthesis.

3.3 Fauna Displaced During Clearing and Nest Box Use

Twenty-three vertebrate species were recovered from tree hollows during the clearing phase (Sandpiper Ecological 2016b). Of the species recovered, 27% (six species; all mammals) were recorded using nest boxes (Table 5). No reptile or bird species recovered during clearing were recorded using nest boxes.

Table 5: Species of vertebrate retrieved from hollows during the clearing phase of the W2HC upgrade (Sandpiper unpub. data) and species detected in nest boxes during winter 2016 inspections. O = species occupying nest box; E = species identified from evidence in nest box; Pr = Probable.

Scientific Name	Common Name	No. Individuals detected in hollows	Detected in Nest Boxes
Antechinus spp.	Antechinus species	2	
Antechinus stuartii	Brown antechinus	Not recorded	O
Antechinus flavipes	Yellow-footed antechinus	1	
Trichosurus caninus	Short-eared brushtail possum	1	
Trichosurus vulpecula	Common brushtail possum	7	O
Trichosurus spp.	Brushtail possum sp.		E (pr)
Acrobates pygmaeus	Feathertail glider	30	O; E (pr)
Petaurus norfolcensis V	Squirrel glider	2	O
Petaurus breviceps	Sugar glider	29	O; E (pr)
Petaurus australis/Petauroides volans	Yellow-bellied glider/Greater glider	Not recorded	E (pr)
Chalinolobus gouldii	Gould's wattled bat	1	
Microbat sp.		1	
Litoria caerulea	Common green tree frog	1	
Litoria Dentata	Bleating tree frog	2	
Litoria peronii	Peron's tree frog	4	O
Oedura lesueurii	Lesueur's velvet gecko	14	
Dendrelaphis punctulata	Common green tree snake	13	
Egernia mcpheei	Eastern crevice skink	3	
Morelia spilota	Carpet python	5	
Hemisphaeriodon gerrardii	Pink tongue lizard	5	
Varanus varius	Lace monitor	7	
Ramphotyphlops nigrescens	Blackish blind snake	2	
Hoplocephalus stephensii V	Stephens banded snake	2	
Eulampris tenuis	Bar-sided skink	15	
Trichoglossus chlorolepidotus	Scaly-breasted lorikeet	4	

3.4 Nest Box Condition, Material and Occupation

Of the 133 boxes inspected, four were damaged to the extent repairs were required. Three boxes required lids to be reattached and one box needed to have the lid reattached and reinstalled as the host tree had fallen to the ground. Of these four boxes, three were metal and one ply. A further two metal boxes were damaged by falling branches. These were not repaired, as they were deemed still functional. The lids of a number of metal boxes were difficult to open due to the strong adhesiveness of the Velcro strips used to keep lids closed.

Increased use rates for all material types were recorded in winter 2016. Overall use was highest for hardwood boxes (70.5%) followed by plywood (64.8%) and metal (33.3%) (Figure 3). Occupancy ranged

from 9.5% for the 42 metal nest boxes, 17.6% for the 17 hardwood boxes, and 21.6% of the 74 plywood boxes.

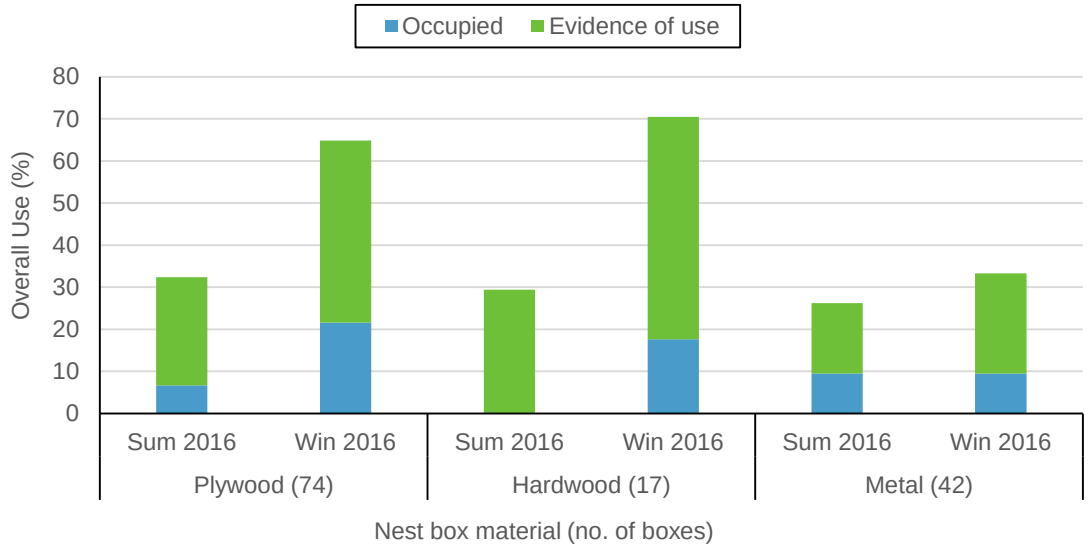

Figure 3: Comparison between nest box material and use of 133 nest boxes installed adjacent the W2HC alignment between summer and winter 2016. Number of each box material type is shown in parenthesis.

4. Discussion

4.1 Use of Nest Boxes

Six vertebrate species were confirmed using nest boxes and a further two, possibly three species were probable users based on nesting evidence. Species confirmed using nest boxes in winter 2016 were brown antechinus, common brushtail possum (*Trichosurus vulpecula*), brushtail possum spp. (*Trichosurus* sp.), squirrel glider, sugar glider, feathertail glider and Peron's Tree Frog. No obvious further use of the possible yellow-bellied/greater glider nest box noted in summer 2016 was recorded in winter. The occurrence of possible yellow-bellied glider/greater glider use in a nest box is noteworthy as there are few records of these species using nest boxes (Sandpiper Ecological 2016a). Both species are known to occur in the study area (Sandpiper unpub. data). Yellow-bellied glider is listed as vulnerable by the NSW *Threatened Species Conservation Act* (*TSC* Act) 1995 and greater glider as vulnerable by the *Environment Protection and Biodiversity (EPBC) Act 1999*. The other recorded species readily use nest boxes in areas where they occur.

The rate of occupation for the winter 2016 survey increased substantially from 6.8% in summer to 17.3% in the winter. The more recent rate of occupation (17.3%) is higher than that reported on highway upgrades at Woolgoolga (8.5-15%), Coopernook (13-16%) but less than at Branxton (22-29%) (Sandpiper 2013, 2015, 2016c). Similarly, the overall rate of use (i.e. sum of boxes occupied and those featuring

evidence of use) for the current inspection (56.4%) is higher than that of the summer 2016 inspection (30.1%). This is more in line with rates at Woolgoolga (51-64%), Coopernook (65-74%) and Branxton (47-67%) (Sandpiper 2013, 2015, 2016c). Admittedly, use rates rise with time since installation as fauna utilise more boxes.

4.2 Spatial Use of Nest Boxes

In summer 2016, use of nest boxes was clearly more prevalent along the southern floodplain (51.2%) compared to either the Dirty Creek range foothills (17.9%) or the range plateau in the northern section of the alignment (22.6%). In comparison, the winter 2016 inspection showed similar occupancy rates for the southern and northern areas but lower occupancy in the central area.

There are a few reasons that may explain the variances between areas. The receiving environment amongst the floodplain (south) and foothills (north) areas feature fewer hollows thereby making nest boxes an attractive resource. Further, the least used area (middle) features a receiving environment with relatively higher abundance of arboreal hollows as well as the highest density of nest boxes (i.e. 39 boxes spaced along ~3000m of alignment). The combination of these two factors would create less competition for hollow resources and less dependence on nest boxes. The 10% increase in evidence of use from summer to winter in the northern area may be explained by seasonal changes in habitat use, or gradual movement of hollow dependent fauna into areas that originally had a low abundance of hollows and hollow dependent fauna. During clearing, fewer fauna were removed from HBTs in the middle and northern areas than in the southern area (Sandpiper 2016b). A lower density of arboreal mammals would explain the delayed uptake of boxes.

The summer 2016 inspection showed a positive relationship between distance from LOC and occupancy rate. This pattern was less obvious in winter 2016 when a slightly higher occupancy rate was recorded in the 0-25m zone than 26-50m zone. Lower rates of occupancy close to the alignment were initially attributed to disturbance associated with construction (Sandpiper Ecological 2016a). Increasing occupancy close to the alignment from summer to winter may suggest that fauna have habituated to the initial disturbance caused by clearing and have begun to reuse areas of habitat close to the alignment.

4.3 Displaced Fauna Use of Nest Boxes

A primary objective of the W2HC NBMP is to provide “guidance on the provision of nest boxes as a compensatory mechanism for the loss of habitat trees within the clearing area, inclusive of den, roosting and nesting resources” (Biosis 2014). As such, the level of uptake by displaced species largely determines the success of the nest box program. Of the 23 vertebrate species recovered from hollows during the clearing phase, six (26%) were recorded using nest boxes. This is up from 22% in summer 2016. The other three mammal species recovered during clearing – short-eared brushtail possum, yellow-footed antechinus and Gould’s wattled bat – are known to use nest boxes but were not recorded during the current inspection period. Albeit, only a single individual of each of the three species was recovered during clearing.

One displaced frog species was recorded during the nest box inspection. No nest box designs specifically target either hollow-using frogs or reptiles although these fauna groups have been recorded in a range of nest box designs (e.g. Sandpiper Ecological 2013). With the exception of lace monitors, hollow-using frogs

and reptiles appear to be infrequent users of nest boxes (e.g. Sandpiper Ecological 2009, 2013, 2015) and we are unaware of any nest box records of the threatened Stephen's banded snake, which was recovered during clearing. Frogs and reptiles do not readily leave signs of use, such as nesting material and are therefore difficult to detect unless present. Further, reptiles may conceal themselves under nesting material making detection difficult. This being noted, one yellow-bellied glider box showed evidence of probable reptile scat.

None of the two species of hollow-dependent birds displaced during clearing were recorded using nest boxes. Infrequent use of nest boxes by birds has been reported in other nest box programs associated with highway upgrades (e.g. Sandpiper 2013, 2015) and in forest landscapes (e.g. Menkhorst 1984). Infrequent use of nest boxes by birds may indicate that adequate hollow resources for these species exist in the local landscape. It may also be the case that high summer temperatures and limited insulation capacity of nest boxes inhibit use by birds. 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 (see Goldingay and Stevens 2009). For example, individuals or family groups of possums and gliders may utilise several nearby boxes and exclude other species (Menkhorst 1984).

4.4 Pests, Condition and Material of Nest Boxes

European bees regularly establish hives in nest boxes (Beyer and Goldingay 2006; Lindenmayer *et al.* 2009). No European beehives (active or abandoned) were recorded during the winter 2016 survey. During the summer 2016 survey one active beehive was recorded in a squirrel glider box. Often once bees have abandoned a box, mammals will occupy the box and consume the remaining honeycomb leaving no evidence of the hive.

Arboreal ants were present in two (1.5%) nest boxes during the winter inspection. This is down from five (3.8%) boxes in summer 2016. These figures are relatively low in comparison to the neighbouring Sapphire to Woolgoolga Pacific Highway upgrade where ant occupation in nest boxes is as high as 31.2% (Sandpiper Ecological 2016c). Ants were only observed in small-volume boxes, which included all three material types. Little is known about the potential competitive interactions between ants and native vertebrates although Dobson (2002 cited in 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 were not observed in boxes containing ants.

Five boxes were in need of repair and of these, four were metal. Three metal boxes needed lids reattached and one needed lid reattachment and reinstallation. One plywood squirrel glider box needed a lid reattachment. A further two metal boxes showed signs of damage (deformation due to branch strike) but were still functional. Damage to metal boxes suggests issues with durability in a native forest landscape. The difficultly in opening the lids of a number of metal boxes and the looseness of some of the metal box lids may also present a future maintenance issue. It is likely that the amount of Velcro stripping used to adhere the lids shut is excessive. Less Velcro and/or use of magnets would have been a preferable alternative. Further, the structural integrity of some metal boxes is questionable and these are likely to deteriorate over time.

Beyer and Goldingay (2006) suggest that most boxes will persist for five years but concede few data exist on how habitat type, designs or materials may affect this. At C2HC the majority (75%) of boxes required replacing eight years after installation (Sandpiper Ecological 2015). Indeed, use of three material types for nest boxes at W2HC presents an opportunity to gauge possible differences in longevity and rates of structural deterioration.

Interpreting the data on overall nest box use according to material type is somewhat confounded by differences in the proportion of each box type. For example, hardwood boxes only featured two types - lorikeet and treecreeper; plywood boxes did not feature any lorikeet or treecreeper designs; and metal boxes featured few owl designs and no microbat boxes. Despite this, differences in usage rates are worth noting and have become even more apparent between the summer and winter inspections. That is, hardwood boxes showed the highest rate of overall use in winter (70.5%) followed by ply (64.8%) then metal (33.3%). These have all increased from the summer 2016 inspection where hardwood boxes showed 29.4% use rate, ply boxes showed 32.4% and metal 26.2%. Increases in use rates for ply and hardwood suggests a preference for these materials over metal.

Our assessment of the metal boxes is that they provide a highly 'artificial' internal environment; present a very smooth/stiff external surface that may be difficult to gain traction on; and feature extremely hot outer surfaces when exposed to direct sunlight. Indeed, a recent comparison of internal nest box temperatures reported that metal boxes demonstrated the least insulating capacity compared to hardwood or plywood, including recording daytime internal box temperatures in excess of 7^0C above the ambient during late summer (Sandpiper 2016d). Conversely, hardwood boxes performed the best at moderating daytime maximum temperatures. The internal temperature extremes exhibited by metal boxes may inhibit use by some hollow-using fauna and should be further investigated (see Goldingay 2015).

5. Performance Indicators

The W2HC NBMP provides four performance indicators with which to assess the nest box program against (Biosis 2014). The following addresses each of the four indicators:

1. *Use of nest boxes by a wide range of native fauna*

   The W2HC nest box program has provided nesting resources for at least 26% of hollow using vertebrate fauna species, including the threatened squirrel glider, displaced during clearing and construction. Ongoing monitoring is likely to detect additional displaced species, such as microbats, that may occasionally utilise nest boxes.

2. *Use of nest boxes designed for target species by those species*

   Fourteen nest box designs targeting specific fauna were installed along the W2HC alignment (Table 1). Six of the 14 target species were confirmed using the specific boxes – *Antechinus* sp. (brown or yellow-footed antechinus), common brushtail possum, feathertail glider, sugar glider, squirrel glider, yellow-bellied glider (probable). Target species such as masked owl, powerful owl, cockatoo, lorikeet, treecreeper and brush-tailed phascogale are infrequent users of nest boxes. The spotted-tailed quoll has not been reported using a nest box; eastern pygmy possum is probably not present in the study

area; and microbats do not leave extensive roosting signs but are likely to have used the nest boxes since their installation. Subsequent inspections may record use by target species not yet recorded.

3. *Low rates of exotic fauna using nest boxes*

   No exotic fauna was recorded using nest boxes in the winter 2016 survey.

4. *Reduced maintenance requirements*

   Ceasing to install any additional metal nest boxes may contribute significantly to a reduction in maintenance costs in the short and long term. Metal boxes, in particular, require close attention in subsequent inspections due to uncertainty about their structural integrity. Further box maintenance is likely during subsequent inspections, particularly in the later stages of the 8-year monitoring program.

6. Recommendations

1. Repair all damaged boxes.

2. Closely monitor structural integrity and performance of metal nest boxes. Ideally no further metal boxes should be installed.

3. Conduct year 3, 4, 6 and 8 inspections during autumn and spring rather than winter and summer. Autumn inspections are preferable to summer because high temperatures during summer may inhibit use by some species. Spring is preferable to winter as there is greater likelihood of detecting bird nesting activity and possum and glider breeding.

7. References

Beyer, G. L. & Goldingay, R. L. (2006). The value of nest boxes in the research and management of Australian hollow-using arboreal marsupials. *Wildlife Research:* 33, 161-174.

Biosis (2014). Nest Box Management Plan. Woolgoolga to Ballina Pacific Highway Upgrade Section 1 – Woolgoolga to Halfway Creek. Prepared for Roads and Maritime Services.

Bowen, M. and Goldingay, R. (2000). Distribution and status of the eastern pygmy possum (Cercartetus nanus) in NSW. *Australian Mammalogy* 21, 153-64.

Goldingay, R. L. (2015). Temperature variation in nest boxes in eastern Australia. *Australian Mammalogy* online early.

Goldingay, R., Grimson, M. and Smith, G. (2007). Do feathertail gliders show a preference for nest box design? *Wildlife Research:* 34, 484-90.

Goldingay, R. L. and Stevens, J. (2009). Use of artificial tree hollows by Australian birds and bats. *Wildlife Research:* 36, 81-97.

Lindenmayer, D., Welsh, A., Donnelly, C., Crane, M., Michael, D., Macgregor, C., McBurney, L., Montague-Drake, R. and Gibbons, P. (2009). Are nest boxes a viable alternative source of cavities for hollow-dependent animals? Long-term monitoring of nest box occupancy, pest use and attrition. *Biological Conservation:* 142, 33-42.

Menkhorst, P. A. (1984). The application of nest boxes in research and management of possums and gliders. Pages 517-525 in *Possums and Gliders*, Eds A. Smith and I. Hume, Surrey Beatty and Sons, Chipping Norton.

Sandpiper Ecological Surveys (2009). *Bundacree Creek to Possum Brush Pacific Highway Upgrade: Nest Box Monitoring Report no. 3*. Unpublished report prepared for Bilfinger Berger Services Australia.

Sandpiper Ecological Surveys (2009). *Coopernook to Herons Creek Pacific Highway Upgrade: Tree Clearing Report.* Report prepared for the C2HC Alliance.

Sandpiper Ecological Surveys (2010). *Glenugie Pacific Highway Upgrade: Clearing Report and Final Nest Box Assessment.* Report prepared for McMahon Contractors.

Sandpiper Ecological Surveys (2013). *Hunter Expressway Upgrade – Kurri Kurri to Branxton: Nest Box Inspection #4.* Unpublished report prepared for Lend Lease Engineering.

Sandpiper Ecological Surveys (2014). *Pacific Highway Upgrade. Nambucca Heads to Urunga: Clearing Report*. Unpublished report prepared for Lend Lease Engineering.

Sandpiper Ecological Surveys (2015a). *Pacific Highway Upgrade. Oxley Highway to Kundabung: Clearing Report*. Unpublished report prepared for Lend Lease Engineering.

Sandpiper Ecological Surveys (2015b). *Pacific Highway Upgrade - Coopernook to Herons Creek: Nest Box Monitoring Year 3.* Unpublished report prepared for Roads and Maritime Services NSW.

Sandpiper Ecological Surveys (2016a). Pacific Highway *Upgrade – Woolgoolga to Halfway Creek: nest box monitoring summer year 1.* Unpublished report prepared for Pacific Complete.

Sandpiper Ecological Surveys (2016b). Pacific Highway *Upgrade – Woolgoolga to Halfway Creek: Clearing Report.* Unpublished report prepared for OHL/York.

Sandpiper Ecological Surveys (2016c). *Pacific Highway Upgrade – Sapphire to Woolgoolga: Nest Box Monitoring Year 1 Operational Phase.* Unpublished report prepared for Roads and Maritime Services NSW.

Sandpiper Ecological Surveys (2016d). *Nest box temperature study, draft report*. Unpublished report prepared for Pacific Complete.

Appendix A – Nest Box Inspection Field Data

Table A1: Data for winter inspection of W2HC nest boxes conducted 16-18 and 29 August 2016. CBP = common brushtail possum; SeBP = short-eared brushtail possum; BP = brushtail possum sp.; CRP = common ringtail possum; YbG = yellow-bellied glider; GG = greater glider; SqG = squirrel glider; SuG = sugar glider; Sug/SqG = sugar or squirrel glider; FtG = feathertail glider; ONj = owlet nightjar. Pr = probable; Po = Possible

Zone/SoC/Box No.	Box no.	Box type	Material	Inspection date	Pic no.	Fauna	Signs	Box condition	Notes
36e1	1	Cockatoo	Ply	16/8/16	1448	Nil	Nil	Good	
36e2	2	Possum T10	Ply	16/8/16	1434	Nil	Few scattered leaves, CBTP (prb)	Good	
36e3	3	Squirrel Glider T08	Ply	16/8/16	1438	Petaurid sp x 3	Petaurid nest (def)	Good	
36e4	4	Scan (ant) T07	Ply	16/8/16	1443	Nil	Few scats, antechinus (prb)	Good	
36w5	5	YB glider T09	Ply	16/8/16	1525	Nil	Nil	Good	
35w1	17	Microbat	Ply	16/8/16	1621	Nil	Nil	Good	
35w2	18	Squirrel glider T08	Ply	16/8/16	1619	Nil	Old scrappy leaf nest, antechinus (prb)	Good	
35w3	19	Scan (ant) T07	Ply	16/8/16	1623	Nil	Antechinus nest, latrine Cnr (def)	Good	
35w4	20	Scan (ftg) T07	Ply	16/8/16	1624	Nil	Few scattered leaves, pet (poss)	Good	
35w5	21	Powerful owl	Metal	29/8/16	1001	Nil	Nil	Good	Too high -climber; Foam debris in box; inspected by climber
35w6	22	Possum T10	Ply	16/8/16	1629	Nil	Nil	Good	
35w7	23	Scan (ant) (T07)	Metal	16/8/16	1627	Nil	Nil	Good	Difficult to open lid

35w8	24	Quoll	Ply	18/8/16	Nil	Nil	Few scats, ante (poss)	Good	
35w9	25	Lorikeet (hh)	Hwood	18/8/16	1600	Petaurid sp x 2	Leaf nest, pet (def)	Good	Difficult to open lid
34w1	26	Quoll	Ply	16/8/16	1537	Nil	Nil	Good	
34w2	27	SG	Ply	16/8/16	1604	Nil	Fresh pet nest, extensive chewing. (def)	Good	Lid reattached
33e1	6	Squirrel glider	Ply	16/8/16	1642	Squirrel glider x 6	Leaf nest (def)	Good	
33e2	7	Scan (btp)	Ply	16/8/16	1643	Nil	Pet nest (prb)	Good	
33e3	8	Treecreeper	HWood	16/8/16	1645	Nil	Nil	Good	Difficult to open lid
33e4	9	Scan (btp)	Ply	16/8/16	1647	Nil	Messy leaf nest, chew at entrance pet (prb)	Good	
33e5	10	Treecreeper	HWood	16/8/16	1652	CBTP x 1	Chewing at entrance (def)	Good	Difficult to open lid
33e6	11	Scan (ftg)	Ply	16/8/16	1648	Nil	Messy leaf nest, ante (prob).	Good	
33w7	12	Cockatoo	Ply	29/8/16	0935	Nil	Extensive messy leaf nest, some chew. Pet nest (prb)	Good	Inspected by climber
33w8	13	Scan (ant)	Ply	16/8/16	1543	Brown Ante x 6	Leaf nest, latrine Cnr, chewing at entrance. (def)	Good	
33w9	14	Squirrel glider	Ply	16/8/16	1540	Nil	Fresh pet nest (def)	Good	
33w10	15	Possum	Ply	16/8/16	1545	Nil	Chewing at entrance, Few scattered leaves, CBTP (prb)	Good	
33w11	16	Squirrel glider	Ply	16/8/16	1556	Squirrel Glider x 2	Leaf nest (def)	Good	
32e1	134	Treecreeper	HWood	17/8/16	0725	Nil	Nil	Good	

32e2	82	Scan	Ply	17/8/16	0729	Nil	Nil	Good	
31e1	28	Scan (ant)	Ply	17/8/16	0757	Nil	Nil	Good	
31e2	29	Scan (not Mb box)	Ply	17/8/16	0745	Nil	Chewing at entrance, nil inside. Bird (poss)	Good	
31e3	30/104	Treecreeper	HWood	17/8/16	0752	Nil	Unorganised leaf arrangement but clean, pet (prb)	Good	
30w1	31	Scan (ant)	Ply	17/8/16	0810	Nil?	Fresh messy, flouncy nest, Ftg (prb)	Good	
30w2	32	Scan (ant)	Metal	17/8/16	0814	Nil?	Packed with leaf, Ftg (prb)	Good	
30w3	33	Scan (btp)	Metal	17/8/16	0813	Squirrel Glider x 4	Old leaf nest. Animals all on top. (def)	Good	
28w1	68	Scan (btp)	Ply	17/8/16	0835	Squirrel Glider x 1	Pet leaf nest (def)	Good	
28w2	69	Scan (ftg)	Ply	17/8/16	0833	Nil	Few scattered leaves, Ftg (poss)	Good	
28w3	70	Scan (not Mb box)	Ply	17/8/16	0838	Ftg x 4 (at least)	Globular leaf nest (def)	Good	
28w4	71	Quoll	Metal	17/8/16	0829	Nil	Nil	Good	
27w1	66	Squirrel glider	Ply	17/8/16	0855	Nil	Messy leaf nest, pet (prb)	Good	
27w2	67	Scan (ftg)	Ply	17/8/16	0853	Nil	Leaf nest, ftg (prb)	Good	
25e1	129	Scan (phas)	Ply	17/8/16	0933	Nil?	Fresh bowled pet leaf nest (def)	Good	
25e2	130	Lorikeets	Metal	17/8/16	0930	Ftg (prob) x 1 at least	Extensive leaf nest (def)	Good, branch fall has crushed lid but still	

								functional	
25w3	131	Sq glider	Ply	17/8/16	0911	Nil	Old scrappy leaf nest, pet (poss)	Good, minor deterioration	
25w4	132	Scan (phas)	Ply	17/8/16	1039	Nil	Nil	Good	
25w5	133	Treecreeper	HWood	17/8/16	1044	Nil	Few leaves, Ftg (poss)	Good	
24e1	126	Sq glider	Metal	17/8/16	0952	Nil	Nil	Good	Difficult to open lid
24e2	127	Cockatoo	Metal	17/8/16	0949	Nil	Sticks and debris	Good	
24e3	128	Possum	Metal	17/8/16	0937	Nil	Nil	Good, mud wasp	Difficult to open lid
23e1	115	Quoll	Metal	Box found on ground					Reinstalled 29/8/26
23e2	116	YBG	Ply	29/8/16	1204	Nil	Partial leaf nest, pet (poss)	Good	Inspected by climber
23e3	117	Scan (ant)	Ply	17/8/16	1108	Nil	Nil		
23e4	118	Squirrel	Ply	17/8/16	1106	Nil	Extensive bowled pet nest (def)		
23e5	119	Scan (microbat)	Ply	17/8/16	Nil	Nil	Nil	Good	Lid jammed
23e6	120	Lorikeets	HWood	17/8/16	1101	Nil	Nil	Good	
23e7	121	Scan (phas)	Metal	17/8/16	1055	Nil	Nil	Good	
23e8	122	LFO	Ply	29/8/16	1250	Sugar Glider x 2 (at least)	Lots of leaf, whole floor covered	Good	Sugar glider sitting at entrance. Inspected by climber
23e9	123	Possum	Metal	17/8/16	1137	Nil	Nil	Good	
23e10	124	Sq glider	Metal	17/8/16	1117	Nil	Chewed polystyrene	Good	

23e11	125	Tree creeper	HWood	17/8/16	1118	Nil	Pet bowled nest (def)	Good	No lip; Climber attached arm;
22e1	43	Lorikeet	Metal	18/8/16	1440	Nil	Pet nest(def)	Good	
22e2	44	Scan (btp)	Ply	18/8/16	1443	Sugar Glider x 1	Extensive leaf nest, (def)	Good	
22e3	45	Scan (ant)	Metal	18/8/16	1437	Nil	Nil	Good	
22e4	46	YB glider	Ply	18/8/16	1451	Nil	Reptile scat/tracks (prb)	Good	
22e5	47	Scan (ftg)	Ply	18/8/16	1453	Nil	Chewing at entrance, pet (poss)	Good	
22e6	48	Treecreeper	HWood	17/8/16	1232	Nil	CRTP drey, (prb)	Good	No lip; Climber attached arm;
22e7	49	Squirrel glider	Metal	17/8/16	1229	Nil	Extensive pet nest (prb)	Good	
22e8	50	Quoll	Metal	17/8/16	1213	Nil	Nil	Good	
22e9	51	Powerful owl	Ply	29/8/16	Nil	Nil	Nil	Good	Inspected by climber
22e10	52	Possum	Metal	17/8/16	1212	Nil	Nil	Good	
22w12	54	Scan btp	Metal	17/8/16	124?	Nil	Nil	Good	
22w11	53	YBG	Metal	17/8/16	1252	Sugar Glider x 2	Extensive pet nest (def)	Good	
21e1	34	Scan (btp)	Ply	18/8/16	1352	Nil	Pet nest (prb)	Good	
21e2	35	Scan (epp)	Ply	18/8/16	1349	Nil	Nil	Good	
21e3	36	YB glider	Ply	18/8/16	1419	Sugar Glider x 1	Pet leaf nest (def)	Good	
21e4	37	Scan (ftg)	Metal	18/8/16	1414	Nil	Nil	Good	
21e6	39	Scan (ftg)	Ply	18/8/16	1428	Sugar Glider x 1	Leaf nest and chewing at entrance, sug (def)	Good	
21e7	40	Treecreeper	Metal	18/8/16	1432	Nil	Nil	Good	

21e8	41	Masked owl (T02)	Ply	29/8/16	1354	CBTP X 1	Nil	Good	Inspected by climber
21e9	42	Possum	Ply	18/6/16	1355	Nil	Nil	Good	Lid was open – inspected by climber
18e1	72	Scan (ant)	Ply	18/8/16	0934	Nil	Nil	Good	
18e2	73	Treecreeper	HWood	18/8/16	0930	Nil	Fresh pet leaf nest (prb)	Good	No lip; Climber attached arm;
18e3	62	Scan (ftg)	Metal	18/8/16	0932	Nil	Latrine Cnr, no leaf. Ante (prb)	Good	
18e4	75	Microbat	Ply	18/8/16	1006	Nil	Nil	Good	
18e5	76	Treecreeper	HWood	18/8/16	1004	Nil	Nil	Good	Ants
18e6	77	Scan (btp)	Metal	18/8/16	1000	Nil	Nil	Good	Ants
17e1	55	Lorikeet	Metal	18/8/16	0837	Nil	Pet nest (prb)	Good	
17e2	56	Scan (btp)	Metal	18/8/16	0835	Nil	Nil	Good	
17e3	57	YB Glider	Ply	18/8/16	0834	Nil	Nil	Good	
17e4	58	Scan (btp)	Ply	18/8/16	0841	Nil	Extensive pet nest (prb)	Good	
17e5	59	Microbat	Ply	18/8/16	0843	Nil	Nil	Good	
17e6	60	Scan (ftg)	Ply	18/8/16	0850	Nil	Few scats, ante (poss)	Good	
17e7	61	Squirrel glider	Metal	18/8/16	0848	Nil	Extensive pet nest (def)	Good	
17e8	74	Scan (ant)	Metal	18/8/16	0908	Nil	Nil	Good	
17e9	63	Quoll	Ply	18/8/16	0921	Nil	Nil	Good	
17e10	64	Squirrel glider	Ply	18/8/16	0913	Petaurid sp x 1	Extensive leaf nest, pet (def)	Good	Burrowed down into leaf
17e11	65	Treecreeper	HWood	18/8/16	0918	Nil	Nil	Good	Extended pole, Inspected by climber
16e1	98	Lorikeet	HWood	18/8/16	0810	Nil	Old pet nest (prb)	Good	Difficult to open lid
16e2	99	Microbat	Ply	18/8/16	0801	Nil	Nil	Good	
16e3	100	Scan (btp)	Ply	18/8/16	0804	Petaurid x	Leaf nest, pet (def)	Good	Burrowed down into

						1 (m)			leaf
16e4	101	Scan (ftg)	Metal	18/8/16	0812	Nil	Messy but clean leaf nest, Ftg (prb)	Good	Small wasp nest on outside
16e5	102	Scan (ant)	Ply	18/8/16	0818	Nil	Nil		
16e6	103	Scan (btp)	Metal	18/8/16	0817	Nil	Few scattered leaves, pet (prb)	Good	
15e1	105	Squirrel glider	Metal	17/8/16	1437	Sugar Glider x 3(2j)	Leaf nest, Sug (def)	Good	
15e2	106	Scan (ant)	Ply	17/8/16	1434	Nil	Some chewing on outside, parrot (prb)	Good	
15e3	107	Treecreeper	Metal	17/8/16	1431	Nil	Nil	Good	
15e4	108	Squirrel glider	Ply	17/8/16	1418	Nil	Loose leaf nest, pet (prb)	Good	
15e5	109	Scan (btp)	Metal	17/8/16	Nil	Nil	Nil	Good	
15e6	110	Treecreeper	HWood	17/8/16	1413	Nil	Loose leaf nest, pet (prb)	Good	
14e1	111	Masked owl	Ply	29/8/16	1604	Lit. peronii X 1	Leaf nest, very deep. GG or YBG (poss)	Good	Inspected by climber
14e2	112	Possum	Metal	17/8/16	1405	Nil	Nil	Good	
14e3	113	YB glider	Ply	17/8/16	1503	Nil	Old scrappy leaf, YBG (poss)	Good	
13w1	88	Powerful owl	Ply	29/8/16	1454	Sugar Glider X 1	Extensive leaf nest, Sug (def)	Good	Inspected by climber
13w2	89	Possum	Metal	17/8/16	1530	Nil	Nil	Good	
13w3	90	YB glider	Metal	17/8/16	1533	Nil	Nil	Wobbly	Hard to open lid
13w4	91	Scan (btp)	Ply	17/8/16	1534	Nil	Nil	Good	
13w5	92	Treecreeper	HWood	17/8/16	1522	Nil	Old scrappy leaf nest, pet (poss)	Good	
13w6	93	Squirrel glider	Metal	17/8/16	1521	Nil	Nil	Good	
13w7	94	Scan (btp)	Metal	17/8/16	1524	Nil	Nil	Good	

12w1	86	Cockatoo	Metal	29/8/16	Nil	Nil	Some leaf material	Lid reattached 29/8/26	Inspected by climber
12w2	87	Possum	Ply	17/8/16	1547	Nil	Old scrappy leaf nest, CBTP (poss)	Good	
11w1	95	Masked owl	Metal	29/8/16	Nil	Nil	Nil	Good	Inspected by climber
11w2	96	Possum	Ply	17/8/16	1600	Nil	Nil	Good	
8w2	97	Microbat	Ply	188/16	Nil	Nil	Nil	Good	Difficult to check with pole as lid does not open far enough
6w1	83	Microbat	Ply	18/8/16	1129	Nil	Little bit of leaf, Ftg (prb)	Good	
5w1	84	Cockatoo	Ply	29/8/16	1615	Squirrel Glider x 4	Extensive leaf nest, SqG (def)	Good	Inspected by climber
5w2	85	Possum	Metal	18/8/16	1134	Nil	Nil	Lid damaged, still functional	
5w3	114	Tree creeper	HWood	18/8/16	138	Nil	Old pet nest (prb)	Good	No lip; Climber attached arm;
3w1	78	Scan (epp)	Metal	17/8/16	1639	Nil	Leaf nest, latrine Cnr, ante (poss)	Good	
3w2	79	Squirrel glider	Ply	17/8/16	1636	Nil	Old flattened leaf nest, pet (prb)	Good	
3w3	80	Treecreeper	HWood	17/8/16	1634	Squirrel glider x 3 (1juv) at least	Leaf nest, SqG, (def)	Good	
3e4	81	Quoll	Ply	18/8/16	1107	Nil	Nil	Good	
3e5	82	Scan (ftg)	Ply	18/8/16	1109	Nil	Few scattered leaves	Good	