Pacific Highway Upgrade: Sapphire to Woolgoolga.

Progress Report: Nest Box Monitoring – Operational Phase, Year 1 (2015).

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Cover Photo: Distinctive nest and latrine of the threatened brush-tailed phascogale in a kookaburra box.

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1. Introduction

The upgrade of the Pacific Highway from Sapphire to Woolgoolga (S2W) involved construction of 25 km of dual carriageway from Campbell Close, Sapphire, to Arrawarra Beach Road, Arrawarra. The upgrade became operational in July 2014.

The Ministerial Conditions of Approval (MCoA) for the S2W upgrade included a requirement to implement appropriate actions to mitigate the impact of removing hollow bearing trees (HBT) on hollow-dependent fauna (HDF). Such actions included preparation of a Nest Box Management Plan (NBMP) in accordance with MCoA 2.9, which states that:

"The proponent shall prepare and implement a nest box plan prior to commencement of clearing of vegetation for construction to provide replacement hollows for displaced fauna in conjunction with SoC F7. The plan shall detail the number and type of nest boxes to be installed, which must be justified based on the number and type of hollows removed, the density of hollows in the area to be cleared and adjacent forest; and the availability of adjacent food resources."

A NBMP was prepared by Benchmark Environmental Management (BEM) in 2009 and approved in 2010. The NBMP guides the installation and monitoring of nest boxes to replace tree hollows removed during the construction phase of the upgrade (BEM 2010). In total, 132 nest boxes were installed within five nest box installation areas (NIA) adjacent to the project during 2010/11. Details of the installation process and results of construction phase inspections conducted in spring 2011 and spring/autumn 2012/2013 have been reported on previously (BEM 2011, 2013a). A further 10 boxes were installed in May 2013 to account for the final number of HBT removed during clearing and construction. The final number and type of nest boxes assigned to each area is described in Table 1.

Table 1: Number and type of nest boxes installed within 5 nest box installation areas (NIA) adjacent the S2W upgrade.

Box Type	Area 2	Area 7	Area 9	Area 10	Area 11/12	Total
Brush-tailed phascogale	-	2	4	1	2	9
Pygmy possum	-	3	5	1	1	10
Sugar/squirrel glider	2	5	9	4	6	26
Yellow-bellied glider	1	3	7	3	3	17
Greater glider	-	-	2	1	2	5
Brushtail/ringtail possum	1	2	10	4	2	19
Microbat	2	2	10	2	4	20
Cockatoo	1	2	3	2	2	10
Corella	-	-	1	1	-	2
Rosella	1	2	1	-	-	4
Lorikeet	2	1	2	-	-	5
Kookaburra	-	1	3	1	-	5
Owlet nightjar	-	2	5	1	2	10
Total	10	25	62	21	24	142

Sandpiper Ecological Surveys (Sandpiper) was contracted by Roads and Maritime Services NSW (RMS) in January 2015 to conduct monitoring of fauna crossings along the S2W alignment and inspect nest boxes. According to the S2W Ecological Monitoring Program (EcMP (Benchmark 2014)), nest box inspections were to occur during summer and late winter of year one (2014/15), year two (2015/16) and year 5 (2018/19) of the operational phase monitoring period. Due to delays in awarding of contracts, commencement of year one monitoring was postponed until early 2015. The following report presents results of year one nest box inspections conducted during late summer and late winter 2015. The report discusses the implications of the results and proposes a number of management recommendations.

2. Methods

2.1 Nest Box Inspections

Year one operational phase nest box inspections were carried out between 24 February and 25 March 2015 (late summer) and 1-3 September 2015 (late winter). One hundred and forty two boxes were inspected during each period. Inspections were conducted by a team of two ecologists. 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. Images from the GoPro camera were wirelessly streamed to an iPad and a photo(s) of the contents was recorded. Some nest boxes featuring concealed contents (e.g. thick leaf nests) were also inspected by means of a ladder to enable closer inspection. 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. Minor repairs and maintenance were undertaken where possible.

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 viewing 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

Based on occupation and evidence of use, 12 vertebrate species were confirmed using nest boxes during the 2015 inspection periods (Table 2; Table A1, Appendix A). An equal number of vertebrate species were confirmed using during summer and winter (i.e. 8 spp.) though they differed in diversity. Common brushtail possum (Trichosurus vulpecula) was the most common species followed by sugar glider (Petaurus breviceps). They were the only species occupying boxes during both inspection periods (Plate 1 & 2).

Common brushtail possums were observed with dependent young on one occasion in both periods and sugar gliders were observed on one occasion with dependent young during winter. The single observation of a common ringtail possum (Pseudocheirus peregrinus) was of an adult with dependent young (Plate 1). Two observations of small Petaurid gliders buried in leaf nests were possible squirrel glider (Pet. norfolcensis) records. Squirrel gliders are listed as vulnerable on the NSW *Threatened Species Conservation Act* (*TSC* Act) 1995. Short-eared brushtail possums (T. caninus) were observed in boxes on three occasions during summer (Plate 1). Microbats were also detected during summer on two occasions. Both observations were of individual Gould's wattled bat (Chalinolobus gouldii) (Plate 2).

Plate 1: Common brushtail possum (left, adult & juvenile) was the most common vertebrate occupying nest boxes during the two inspections. Short-eared brushtail possum (middle) and common ringtail possum (right, adult & juvenile) were observed during the summer inspection.

Plate 2: Sugar gliders (left) were observed in boxes during both inspection periods. Individual Gould's wattled bat (right) were observed on two occasions during the summer inspection.

A roosting owlet nightjar (Aegotheles cristatus) was observed in a kookaburra box on one occasion during summer and a white-throated tree-creeper (Cormobates leucophaeus) was observed incubating eggs in an owlet nightjar box during winter (Plate 3). Reptile observations included lace monitor (Varanus varius) during summer (4 occasions; Plate 3) and an eastern crevice skink (Egernia mcpheei; 1 occasion) during winter. A carpet python (Morelia spilota) was observed inspecting a cockatoo box containing a short-eared brushtail possum (Trichosurus caninus; Plate 3) though snakes were not detected in boxes. Overall, 15% of boxes were occupied by vertebrates in summer and 11% in winter.

Plate 3: A white-throated tree-creeper was observed incubating eggs within an owlet nightjar box during the late winter inspection (left). Lace monitors (middle) were detected on a number of occasions during summer inspections and a carpet python (right) was observed inspecting a cockatoo box containing a short-eared brushtail possum during the same period.

In addition to occupied boxes, a further 36% of boxes contained evidence of use by vertebrates in summer and 47% of boxes in winter (Table 2). The den of a brush-tailed phascogale (Phascogale tapoatafa) was observed in a kookaburra box. Phascogale's are listed as vulnerable on the NSW *TSC* Act 1995 and typically build distinctive shredded bark nests with scat latrines in the corner (Plate 4). Nests of antechinus sp. (probably brown antechinus, *A.stuartii*), another member of the Dasyurid family, also feature scat latrines but tend to be constructed out of leaves (Plate 4). Other identifiable evidence included shredded bark dreys of common ringtail possum, bowl-shaped eucalypt leaf nests of sugar or squirrel glider and ball-shaped eucalypt leaf nests of feathertail glider (Acrobates pygmaeus) (Plate 5). Overall, the proportion of nest boxes that featured fauna activity (i.e. sum of boxes occupied and boxes with evidence of use) increased from 51% in summer to 58% in winter.

Plate 4: Dasyurid's typically create 'latrines' by depositing scats in the corner of a nest box. The combination of scats in the corner and shredded bark in this kookaburra box is indicative of a brush-tailed phascogale den (left) whereas antechinus sp. generally build nests made of leaf material (right).

Plate 5: Some possums and gliders build distinctive dens. Common ringtail possums typically build woven leaf, twig and bark dreys (left). Sugar and/or squirrel gliders generally create bowl-shaped eucalypt leaf nests (middle) while feathertail gliders will build almost ball-shaped eucalypt leaf nests (right).

One active European beehive (Apis sp.) was detected during summer and no active beehives were evident during winter. Three boxes contained abandoned/eaten-out hives in summer and five were evident during the winter inspection (Plate 6). Hives only occurred in medium sized boxes (i.e. yellow-bellied glider, sugar/squirrel glider, owlet nightjar). Ants (probable Polyrachis sp.) were prevalent in 18% of boxes during summer and 20% of boxes during winter. No vertebrates were observed in boxes containing ants and ants were evident across a range of box sizes/types.

Table 2: The number and type of nest boxes occupied and/or showing evidence of use during inspections conducted in summer and winter 2015. SS=SqG/SuG glider; ON=Owlet Nightjar; PP=Pygmy Possum; Pg=Phascogale; Kb=Kookaburra; Ct=Cockatoo; Po=Brushtail/Ringtail Possum; GG=Greater Glider; Mb=Microbat; Yb=Yellow-bellied Glider; Ro=Rosella; Co=Corella; Lo=Lorikeet; ^=juveniles present. Likelihood of use based on evidence were all scored as 'probable'.

Species/Group	No. occupied		No. with evidence of use		Box type used
	Sum	Win	Sum	Win	
Antechinus sp.			4	6	SS=6; ON=1; PP=1; Pg=1; Yb=1
Brush-tailed phascogale				1	Kb=1
Common brushtail possum	9^	8^			Ct=7; Po=7; Kb=2; Ro=1
Short-eared brushtail possum	3				Po=2; Ct=1
Brushtail possum sp.			1	7	Po=5; Kb=2; Ct=1
Common ringtail possum	1^		1	1	Po=3
Feathertail glider				3	PP=2; ON=1
Sugar glider	1	3^		2	ON=2; PP=2; Yb=1; SS=1
Sugar/squirrel glider		2	11	10	SS=14; Yb=3; ON=2; Pg=2; Lo=1; Ro=1
Gould's wattled bat	2				Mb=2
Owlet nightjar	1		1	6	Yb=4; ON=1; Co=1; Pg=1; Po=1
White-throated treecreeper		1			ON=1
Lace monitor	4				Kb=1; Yb=1; Ro=1; Po=1
Eastern crevice skink		1			PP=1
European beehive	1		3	5	Yb=4; SS=4; ON=1
Ants	26	29			SS=18; PP=12; Yb=7; ON=5; Po=4; Pg=4; Lo=2; Ro=2; Mb=1

Plate 6: Boxes that featured European beehives were abandoned and most showed evidence of re-occupation by native vertebrates, such as sugar or squirrel gliders (left). *Polyrachis sp*. ants were evident in 18 and 20% of boxes in summer and winter respectively (right).

Fauna activity (i.e. boxes occupied + evidence of use) across the NIA's showed a general rising trend between the two inspection periods except for area 10 (Table 3). Area 2 was the most active rising from 60 - 80% whereas area 7 continued to demonstrate the least fauna activity registering 40% in summer and 44% in winter. Comparing data from the late winter/early spring 2015 inspection with data from inspections conducted in spring 2011 and spring 2012/autumn 2013, the proportion of nest box fauna activity in areas 2, 7 and 10 shows a general rising trend between 2011 and 2015 with a spike in activity in 2012/13 (Figure 1). This trend is reversed in area 11/12 whereas area 9 demonstrates a relatively even upward trend across the three inspection periods.

Table 3: The number and proportion of vertebrates occupying or showing evidence of nest box use during 2015 inspections according to Nest Box Installation Area (NIA).

NIA	No. installed	No. occupied		No. with evidence of use		Proportion with fauna activity (%)	
		Sum	Win	Sum	Win	Sum	Win
2	10	1	2	5	6	60	80
7	25	3	1	7	10	40	44
9	62	10	9	16	25	42	66
10	21	6	1	11	15	81	76
11/12	24	1	2	10	11	46	54
Total (%)	142	21 (15%)	15 (11%)	49 (36%)	67 (47%)		

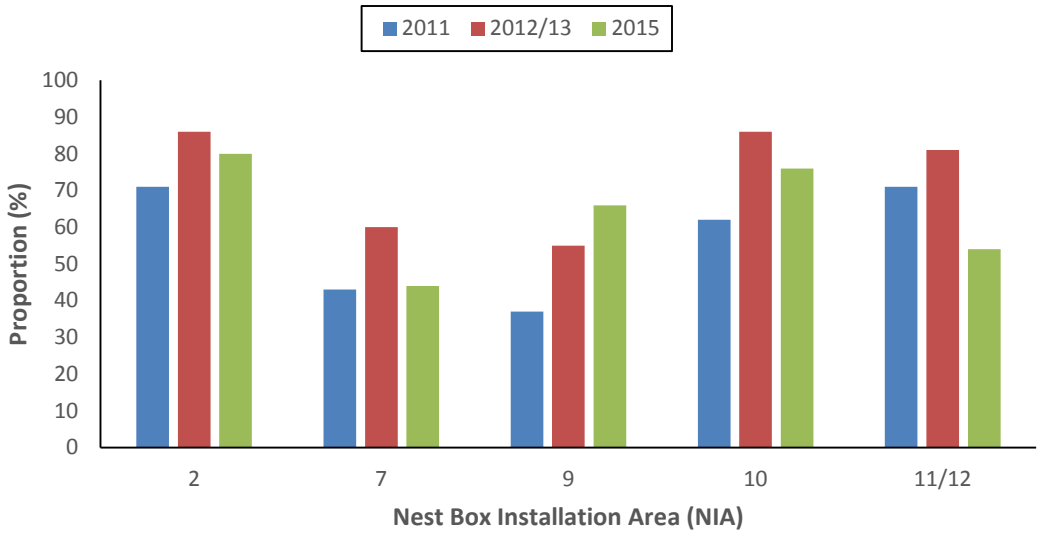

Figure 1. Proportion of nest boxes with fauna activity (i.e. no. boxes occupied + no. showing evidence of use) by Nest Box Installation Area (NIA) across three inspection periods. Spring 2011 and spring 2012/autumn 2013 inspections were conducted during construction phase. Data for 2015 are from the late winter/early spring inspection.

3.2 Fauna Displaced During Clearing and Nest Box Use

Twenty-six vertebrate species were recovered from hollows displaced during the clearing phase and a further three species were identified from evidence of distinct nests within hollows (BEM 2013b). Of the 29 species confirmed to be displaced during clearing, 14 (48%) were recorded using nest boxes across the three inspection periods (Table 4). In total, no frogs, 18% (n = 2) of reptile species, 40% (n = 2) of bird species and 80% (n = 8) of mammal species were recorded in nest boxes. An additional reptile (Eastern crevice skink) and mammal (brush-tailed phascogale) were recorded in nest boxes but not recovered during clearing.

3.3 Nest Box Condition

Most boxes remained in good repair although continued deterioration is evident across the survey periods (Figure 2). The number of boxes in good repair dropped from 133 (94%) to 124 (87%) between summer and winter 2015 and evidence of minor and major deterioration rose from 5% to 9% and from <1% to 4% respectively. Minor deterioration was largely attributed to lid detachment and preliminary termite damage whereas major deterioration featured advanced termite damage (Plate 7). The incidence of deterioration was spread across the sites and box designs.

Table 4: Species of vertebrate retrieved from hollows during the clearing phase of the S2W upgrade (BEM 2013b) and species detected in nest boxes across three inspection periods. O = species occupying nest box; E = species identified from evidence in nest box; Likelihood Rating: D = Definite; Pr = Probable; Po = Possible. * = species detected during nest box inspection only.

Scientific Name	Common Name	No. Ind's	Detected in Nest Boxes		
			2011	2012/13	2015
Litoria caerulea	Green tree frog	2			
Litoria peronii	Peron's tree frog	25			
Litoria tyleri	Tyler's tree frog	8			
Eulamprus tenuis	Greater bar-sided skink	12			
Egernia mcpheei	Eastern crevice skink	7			O
Cyclodomorphus gerrardii	Pink-tongued skink	13			
Oedura robusta	Robust velvet gecko	9			
Saltuarius swaini	Southern leaf-tailed gecko	1			
Physignathus lesueurii	Eastern water dragon	1			
Varanus varius	Lace monitor	4		O	O
Ramphotyphlops nigrescens	Blackish blind snake	8			
Dendrelaphis punctulata	Green tree snake	18			
Boiga irregularis	Brown tree snake	6			
Morelia spilota	Carpet python	5			
Chenonetta jubata	Australian wood duck	E (Pr)			
Trichoglossus chlorolepidotus	Scaly-breasted lorikeet	2		E (D)	
Trichoglossus haematodus	Rainbow lorikeet	9			
Cacatua roseicapilla	Galah	E (Pr)			
Cormobates leucophaeus	White-thr tree-creeper*				O
Aegotheles cristatus	Australian owlet-nightjar	2		E (Pr)	O
Antechinus stuartii	Brown antechinus	10	E (Pr)	O	E (Pr)
Phascogale tapoatafa	Brush-tailed phascogale*				E (D)
Acrobates pygmaeus	Feathertail glider	32	O	E (Pr)	E (D)
Petaurus breviceps	Sugar glider	25	O	O	O
Petaurus norfolcensis	Squirrel glider	10	O	E (Pr)	E (Po)
Trichosurus vulpecula	Common brushtail possum	30	O	O	O
Trichosurus caninus	Short-eared b'tail possum	1			O
Pseudocheirus peregrinus	Common ringtail possum	E (Pr)	E (Pr)	E (D)	O
Chalinolobus gouldii	Gould's wattled bat	4			O
Myotis adversus	Large-footed myotis	50			
Nyctophilus gouldi	Gould’s long-eared bat	1			

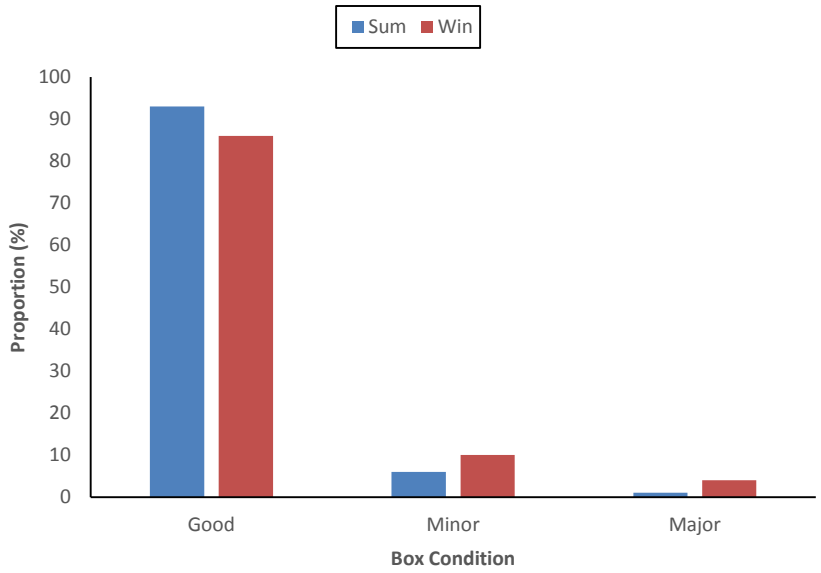

Figure 2. Relative condition of 142 nest boxes inspected during late summer and late winter 2015. Box condition was scored as either good, minor deterioration or major deterioration.

Plate 7: Box damage/deterioration was largely attributed to detached lids and termite attack as evident in a sugar/squirrel glider box (left) and a greater glider box (right).

4. Discussion

4.1 Use of Nest Boxes

Twelve vertebrate species were confirmed using nest boxes along the S2W upgrade during 2015 inspections – antechinus sp. (probable brown antechinus), brush-tailed phascogale, common brushtail possum, short-eared brushtail possum, common ringtail possum, sugar glider, feathertail glider, Gould's wattled bat, owlet nightjar, white-throated tree-creeper, lace monitor and eastern crevice skink. The brush-tailed phascogale record was particularly noteworthy as it was not recorded in previous inspections or during the clearing phase but is known from local records (Bionet 2015). Phascogales are also known to

readily use nest boxes (Beyer and Goldingay 2006). A possible thirteenth species, the squirrel glider, is highly likely as it was recorded during an earlier nest box inspection and retrieved from hollows during clearing (BEM 2011, 2013b).

Both the level of vertebrate species diversity occupying boxes (5-7 spp.) and rate of occupation (11-15%) was higher in the current reporting period compared to 2011 (4 spp. and 12.9%) and 2012/13 (4 spp. and 8.5%) inspections (BEM 2011, 2013a). The occupation rate figures are somewhat less than those reported on highway upgrades at Coopernook (15%), Nabiac (23%) and Branxton (22-29%) (Sandpiper 2009, 2013, 2015). Despite this, the overall rate of fauna activity during the 2015 inspections (51-58%) is similar to that reported for 2011 (51%) and 2012/13 (64%) and is comparable to that reported at Coopernook (50%), Nabiac (72-75%) and Branxton (47-67%) (Sandpiper 2009, 2013, 2015). Importantly, differences in fauna activity values may be an artefact of inspection method. That is, the 2012/13 survey and Nabiac and initial Branxton surveys utilised ladder-based inspections of box contents. Ladder-based inspections enable much closer inspection of box contents, including investigation of thick leaf litter that may conceal fauna. They also enable closer inspection of species that are difficult to distinguish between, such as sugar and squirrel gliders, particularly when they are buried in leaf litter, as was the case in the current winter inspection.

4.2 Displaced Fauna Use of Nest Boxes

The stated purpose of the S2W NBMP "… is to maximize the effectiveness of nest boxes in compensating for tree hollows to be removed during the construction phase …" and to "… provide replacement hollows for displaced fauna …" (MCoA 2.9). As such, the success of the nest box program is largely determined by the degree of uptake by displaced species. Of the 29 species confirmed displaced during clearing, 14 (48%) were recorded using nest boxes across the three inspection periods. The highest uptake by a taxa group was mammals, with 80% of displaced species recorded using nest boxes. This figure is somewhat higher if we include the threatened brush-tailed phascogale, a species not detected during clearing, but detected denning in a kookaburra box in winter 2015. The two mammal species recovered during clearing but not recorded across the three inspection periods were Gould's long-eared bat and large-footed myotis. Both species are known to use timber nest boxes though there are few records of large-footed myotis (Goldingay & Stevens 2009; Sandpiper unpub. data). Further, microbats are infrequently recorded in nest boxes associated with highway upgrades (e.g. Sandpiper 2009, 2013, 2015). Indeed, only two microbats were detected across the three monitoring periods, both individuals were Gould's wattled bat, which was recorded during the summer 2015 survey. Current knowledge suggests that use of bat boxes is affected by a range of factors including canopy cover, abundance of natural hollows, season, box aspect and box design though it is unclear how these factors interact (Goldingay and Stevens 2009).

Forty percent of displaced species of bird were detected using nest boxes across the three monitoring periods. While the overall rate of uptake by displaced birds is relatively low, 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). No bird observations were reported during the 2011 inspection and only two evidence-based observations were made during the 2012/13 inspection. They were attributed to scaly-breasted lorikeets and owlet nightjars (BEM 2011, 2013a). The current 2015 reporting period confirmed use by owlet nightjar and white-throated tree-creeper, a species often targeted in nest box programs but rarely detected. Moreover, this species was not retrieved from hollows during the clearing phase.

Infrequent use of nest boxes by birds may indicate that adequate hollow resources for these species exist in the local landscape. Indeed, 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).

No displaced frog species and 18% of reptile species were recorded in nest boxes across the three monitoring periods. An additional reptile species (Eastern crevice skink) was recorded in a nest box but not recovered during clearing. No nest box designs specifically target either hollow-using frogs or reptiles although they have been recorded in a range of nest box designs (e.g. Sandpiper 2013). With the exception of lace monitors, hollow-using frogs and reptiles appear to be infrequent users of nest boxes (e.g. Sandpiper 2009, 2013, 2015). Further, frogs and reptiles do not readily leave signs of use, such as nesting material and are therefore difficult to detect unless present.

Ants were prevalent in 18-20% of boxes across the two inspection periods. 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. At S2W, vertebrate fauna were not observed in boxes containing ants but 38% of nest boxes featuring ants in summer showed evidence of recent use by native vertebrates in winter, including sugar/squirrel gliders, feathertail gliders and probably owlet nightjars.

European bees regularly establish hives in nest boxes (Beyer and Goldingay 2006; Lindenmayer *et al.* 2009). One active beehive and three abandoned hives were detected during the summer inspection and no active and five abandoned hives were present during the winter inspection. A similar pattern of hive establishment and abandonment was evident at Nabiac and along the Hunter Expressway at Branxton (Sandpiper 2009, 2013). Whilst the reasons for hive failure are unclear, it appears that nest box volume is a limiting factor with abandonment more likely for smaller sized boxes (Goldingay et al. 2007; A. Franks, pers. comm.).

4.3 Condition of Nest Boxes

Despite most nest boxes appearing in good repair, continued deterioration is apparent. At the time of the winter inspection, 87% of boxes were in good repair, 9% showed minor deterioration and 4% featured major deterioration or collapse. Minor deterioration was largely attributed to lid detachment and preliminary termite damage whereas major deterioration featured advanced termite damage. Few studies report on nest box maintenance and attrition. Lindenmayer *et al.* (2009) reported 51% nest box attrition, mostly caused by tree fall or self-detachment, over the course of a 10 year nest box study in Victoria; albeit their screw-attachment method likely made boxes more prone to detachment. Beyer and Goldingay (2006) suggest that most boxes will persist for ~5 years but concede few data exist on how habitat type, designs or materials may affect this. At S2W, 93% of nest boxes were installed during 2010/11 with the remainder in early 2013. As such, most boxes are 4-5 years old and would be expected to show varying signs of deterioration. A recent inspection of eight year old nest boxes along the highway

upgrade at Coopernook recorded 69% of boxes requiring either full replacement or lid replacement (Sandpiper unpub. data). Moist coastal forests of northern NSW present challenging conditions for the persistence of timber ply boxes. The recent development of a Cyplas (recycled plastic) nest box reputed to last up to 30 years is a promising development and worthy of trials (see www.hollowloghomes.com).

5. Conclusion and Recommendations

The S2W nest box program has been utilized by at least 48% of hollow-using vertebrate fauna species displaced during clearing and construction. A further two species, brush-tailed phascogale and white-throated tree-creeper, that were not recorded as displaced fauna, were detected using nest boxes. Importantly, the brush-tailed phascogale is a threatened species on the NSW *TSC* Act. It is also the second confirmed threatened species along with the squirrel glider which was confirmed during the 2011 monitoring period.

In addition to confirmed users, it is likely that more species have utilized the nest boxes but were not detected. This may particularly be the case for some frogs, reptiles, and microbats. It has also been acknowledged that a limitation of pole and camera-based inspections is difficulty in detecting cryptic or concealed fauna. While rates of occupation are less than at other Pacific Highway upgrade sites, the overall level of fauna activity or use of boxes is comparable. The level of pest activity is very low and self-managing with only a few instances of temporary feral bee incursion.

Box maintenance and repair/replacement is an emerging issue and requires a management response. The monitoring program is required to extend until year 5 of the operational phase (2019). With the current rate of box deterioration, many boxes will feature major deterioration by this time. The S2W NBMP (BEM 2010) states that maintenance of damaged nest boxes should be undertaken on site at the time of inspection. We interpret maintenance to include replacement of screws, replacement of hinges and replacement of wire (i.e. those requiring replacement). The plan also states that in the event a nest box requires replacement (presumably beyond maintenance repair), then an alternative nest box should be installed. We recommend that this should occur at the time of year 2 and year 5 inspections. That is, basic maintenance should be conducted during inspections and replacement of boxes or lids should occur shortly after completion of inspections once an inventory of box condition including those requiring replacement is known. This should follow discussion with RMS staff.

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Appendix A – Nest Box Inspection Data

Table A1: Data for late summer (24/2/2015 - 25/3/2015) and late winter (1-3/9/2015) nest box inspections along the S2W Pacific Hwy Upgrade. CBP = common brushtail possum; SeBP = short-eared brushtail possum; BP = brushtail possum sp.; CRP = common ringtail possum; SuG = sugar glider; Sug/SqG = sugar or squirrel glider; FtG = feathertail glider; ONj = owlet nightjar. Pr = probable; Po = Possible

Nest Box Area & No.	Tree sp.	Box Type	2015 Summer			2015 Winter		
			Condition	Fauna/Evidence of use	Comments/Photo ID	Condition	Fauna/Evidence of use	Comments/Photo ID
02GBC01		Cockatoo	Good	CBP		good	Flattened old leaves (B-tailed possum(Pr))	Ph 3-887
02SG03		SuG/SqG glider	Good	old leaf nest (SuG/SqG (Pr)); abandoned bee hive	G75	Good	SuG (2ad, 1juv)	Ph5/6-890
02MB02	*E. pilularis*	Microbat	Good	nil		Good	Nil	Checked with torch/binos
02MB01	*E. pilularis*	Microbat	Good	nil		Good	Nil	Checked with torch/binos
02RO01	*A. costata*	Rosella	Good	old green leaf nest (SuG/SqG (Pr))	Ph 18-G10020	Good	Entry chewing, v old leaf nest	Ph 7-891
02SG01	*C. intermedia*	SuG/SqG glider	Good	Old leaf nest/scats (Antechinus sp.)	Ph 19-G76 ladder	Good	Old leaf nest, latrine in corner (Antechinus sp.)	Ph8-892
02YG01	*E. pilularis*	Possum	Good	depressed material (BP sp.(Pr))	Ph 24-G66	Good	CBP(f)	Ph 9-894
02YG02+		Yellow-bellied glider	Good	nil		Good	Fresh euc leaves (SuG/SqG(Pr))	Ph 1-885
02L01	*E. pilularis*	Lorikeet	Good	V old leaf material no shape. Chew marks on entrance		Minor; lid missing; replace Lid	v old leaf material	Ph 2-886
02L02+		Lorikeet	Good	nil		Minor; hinge loose	Fresh euc leaves (SuG/SqG(Pr))	Ph 4-888
07PP03	*E. siderophloia*	Pygmy-possum	Good	ants; V old leaf material		Good	ants; V old leaf material	Ph 94-997
07GBC01	*E. acmenoides*	Cockatoo	Good	nil		Good	CBP on wood shavings	Ph 95-998
07SG02	*E. siderophloia*	SuG/SqG glider	Good	ants; V old leaf material		Good	ants; V old leaf material	Ph 96-999

07YG02	*E. siderophloia*	Yellow-bellied glider	Good	Active Euro bee hive	Selective logging < 2yrs; recovering from fire.	Good	abandoned Euro bee hive	Ph 97-1000
07ON01	*C.variegata*	Owlet nightjar	Good	V old leaf material		Good	Nil; composting leaves	Ph 99-1002
07 GBC02	*E. microcorys*	Cockatoo	Good	Nil		Good	Nil	Ph 100-1004
07SG04	*E. siderophloia*	SuG/SqG glider	Good	ants		Good	Nil. Ants	Ph 98-1001
07Br 01	*E. microcorys*	Possum	Minor; lid missing; replace Lid	nil		Minor; lid missing; replace Lid	Nil	Ph 101-1005
07L01	*E. microcorys*	Lorikeet	Good	V old leaf material		Minor: termite damage	v old leaf material	Ph 102-1006
07PP02		Pygmy-possum	Good	ants; V old leaf material		Good	mod old leaf material	Ph 104-1008
07SG03	*E. microcorys*	SuG/SqG glider	Good	nil		Good	Ants	Ph 103-1007
07K01	*E. propinqua*	Kookaburra	Good	Lace monitor	G304	Good	Nil	Ph 86-988
07R01	*E. propinqua*	Rosella	Good	ants		Good	Entry chewing	Ph 87-990
07MB01	*E. propinqua*	Microbat	Good	Lace monitor		Good	Ants	(marked as 07mb01b?); Ph 88 rosella box?
07MB02	*E. propinqua*	Microbat	Good	Nil		Good	Nil	Checked with torch/binos
07PP01		Pygmy-possum	Good	Nil		Good	Ants	Ph 89-992
07RP01	*C. intermedia*	Possum	Good	SeBP(m)	G306	Good	Nil	Ph 90-993
07YG01	*E. microcorys*	Yellow-bellied glider	Good	V old leaf material		Good	old leaf material	Ph 91-994
07R02	*E. siderophloia*	Rosella	Good	ants		Good	entry chewed; old leaf material	Ph 92-995
07SG01	*C.variegata*	SuG/SqG glider	Good	V old leaf material		Good	Nil. Ants.	Ph 93-996
07YG03	*E. microcorys*	Yellow-bellied glider	Good	Nil		Good	scattered/flouncy leaves (Onj (Pr))	Ph 109-1013
07SG05	*S. glomulifera*	SuG/SqG glider	Good	Nil		Good	Nil. Ants	Ph 108-1012
07BP01	*E. acmenoides*	Phascogale	Good	Nil		Good	Nil. Ants	Ph 107-1011
07BP02	*E. acmenoides*	Phascogale	Minor; lid missing; replace Lid	nil		Minor; lid missing; replace Lid	Nil	Ph 106-1010
07ON02	*E. grandis*	Owlet nightjar	Good	Nil		Good	Ants. old leaves	Ph 105-1009
09L01	*E. propinqua*	Lorikeet	Good	Nil		Good	Ants	Ph 113-1078

09MB06	*E. microcorys*	Microbat	Good	Nil		Good	Nil	Checked with torch/binos
09MB07	*E. microcorys*	Microbat	Good	Nil		Good	Nil	Checked with torch/binos
09MB09	*L. confertus*	Microbat	Good	Nil		Good	Nil	Checked with torch/binos
09YG05	*E. siderophloia*	Yellow-bellied glider	Good	SuG x2	Ph 74-G248	Good.	mod old euc leaf nest (SuG (Pr);	Ph 124-1089
09Br04	*E. siderophloia*	Possum	Good	nil		Good	Nil	Ph 125-1090
09ON04	*E. globoidea*	Owlet nightjar	Good	V old leaf material		Good	SuG x3	Ph 126-1092
09PP04	*E. microcorys*	Pygmy-possum	Good	Old leaf nest brown material	Checked with ladder	Good	entry chewed; mod old euc leaf nest (SuG (Pr))	Ph 127-1093
09K03	*E. siderophloia*	Kookaburra	Good	Nil		Good	CBP on euc leaves	Ph 128-1095
09MB08	*E. acmenoides*	Microbat	Good	Nil		Good	Nil	Checked with torch/binos
09Br05	*E. acmenoides*	Possum	Good	Nil		Good	spread leaves (Br-tail possum(Pr))	Ph 130-1097
09SG06	*E. acmenoides*	SuG/SqG glider	Good	ants		Good	Nil, ants	Ph 131-1098
09SG08	*E. siderophloia*	SuG/SqG glider	Good	ants		Good	Nil. Ants	Ph 110-1015
09BR06	*E. microcorys*	Possum	Good	ants		Good	Old decaying material	Ph 116-1080
09ON03	*C.variegata*	Owlet nightjar	Good	ants		Good	Ants; recent euc leaf nest (FtG(Pr))	Ph 119-1083
09YG06	*E. siderophloia*	Yellow-bellied glider	Good	ants		Good	Nil, ants	Ph 122-1087
09SG07	*E. microcorys*	SuG/SqG glider	Good	Old SuG/SqG leaf nest	Confirmed with ladder	Good	mod old euc leaf nest (SqG/Sug (Pr))	Ph 123-1088
09MB01	*C.variegata*	Microbat	Good	Gould's wattled bat	Ph 61-G253	Major: termite damage/collapse	Nil	No photo
09MB02	*C. intermedia*	Microbat	Minor termite damage	nil		Good	Nil, full of web	Checked with binos/torch
09GBC01		Cockatoo	Good	CBP	Ph 28-G68	Good	CBP on scattered green/old leaves	Ph 56-954
09MB03	*E. microcorys*	Microbat	Good	nil	Ph 29-G71	Good	Nil	Checked with torch/binos
09RP01	*E. microcorys*	Possum	Good	CRP x2	Ph 30-G72	Major: termite damage, lid off; replace box	Old decaying leaf	Ph 57-955
09MB04	*E. microcorys*	Microbat	Good	Nil		Good	Nil	Checked with torch/binos

09ON01		Owlet nightjar	Good	Nil		Good	SuG/SqG x2; buried in leaf nest	Ph 53/54-949/51
09SG01		SuG/SqG glider	Good	Nil		Good	Old euc leaf nest (SqG/Sug (Pr))	Ph 55-952
09ON02	*C.variegata*	Owlet nightjar	Good	V old leaf nest shallow		Good	W-thr t'creeper on 2 spotted eggs; cup-shaped bark nest	Ph 62/63/64-964
09BP01	*E. siderophloia*	Phascogale	Good	V old leaf nest shallow		Good	v old euc leaf nest;	Ph 65-965
09GG01	*E. acmenoides*	Greater Glider	Good	few leaves		Good	Nil	Ph 66-966
09R01	*C.variegata*	Rosella	Good	nil		Good, hinge stiff	CBP	Ph 61-961
09PP03		Pygmy-possum	Good	ants; V old leaf nest shallow		Good	old leaf nest (FtG (pr))	Ph60-959
09K02	*E. propinqua*	Kookaburra	Good	CBP(m)	Ph 40-G81	Good	depressed fresh leaf material (Br-tail possum(Pr))	Ph 59-958
09YG04	*E. siderophloia*	Yellow-bellied glider	Good	V old leaf Nest		Good	Decayed material, entrance chew. Ants	Ph 58-956
09SG04	*C. intermedia*	SuG/SqG glider	Good	ants; Old euc leaf nest (SqG/SuG (Pr)) ;	G77	Good	Ants; v old euc leaf nest;	Ph 67-967
09YG02	*E. siderophloia*	Yellow-bellied glider	Good	nil		Good, hinge stiff	decaying material; abandoned Europ bee hive	Ph 68-970
09BP03	*E. siderophloia*	Phascogale	Good	V old leaf nest		Minor termite damage	Entry chewing, old decayed material	Ph 69-971
09Br03	*E. siderophloia*	Possum	Good	CBP	G115	Good	CBP on euc leaves	Ph 70-972
09GBC02	*E. siderophloia*	Cockatoo	Good	CBP	Ph45-G117	Good	Nil	Ph 71-973
09BP02	*E. microcorys*	Phascogale	Good	V old leaf Nest		Good. hinge stiff	mod old euc leaf nest (SqG/Sug (Pr))	Ph 72-974
09YG01	*E. siderophloia*	Yellow-bellied glider	Good	ants		Good	Ants	Ph 73
09SG02		SuG/SqG glider	Good	ants	Ph46	Good. Lid loose	recent euc leaf nest (SqG/Sug (Pr)); abandoned Europ bee hive	Ph 74-976
09CO01	*E. siderophloia*	Corella	Good	Nil		Good	Nil	Ph 75-977
09MB05	*E. microcorys*	Microbat	Good	Nil		Good	Nil.	Checked with torch/binos
09SG03	*E. siderophloia*	SuG/SqG glider	Good	V old leaf nest		Good	Old leaf nest; latrine in corner (Antechinus sp.)	Ph 76-978
09Br01	*E. microcorys*	Possum	Good	V old leaf material		Good	CBP	Ph 77-979

09K01	*E. propinqua*	Kookaburra	Good	nil		Good	depressed/spread material (Br-tail possum(Pr))	Ph 78-980
09SG05	*E. microcorys*	SuG/SqG glider	Good	Ants	Ph 47	Good	decayed material. Ants	Ph 79-981
09PP02		Pygmy-possum	Major: termite damage; Replace Box	Ants	Ph48	Major: termite damage ; replace box	Ants	Ph 80-982
09Br02	*E. siderophloia*	Possum	Good	Ants	Ph49	Good	Ants	Ph 83-986
09GG02	*E. siderophloia*	Greater Glider	Minor; termite damage	Nil		Minor: termite damage	Nil	Ph 84-987
09PP01	*E. microcorys*	Pygmy-possum	Good	Ants	Ph51	Good	Ants	Ph 81-983
09YG03	*C. intermedia*	Yellow-bellied glider	Good	Ants		Good. Stiff hinge.	euc leaf bed nest (Onj(Pr)) Ants.	Ph 82-984
10K01	*E. pilularis*	Kookaburra	Good	owlet nightjar; leaf material		Good	Shredded bark, scats at edge (B-tail phascogale)	Ph 49-944
10YG03	*E. pilularis*	Yellow-bellied glider	Good	Lace monitor	G263	Good	euc leaf bed nest (Onj(Pr))	Ph 50-945
10ON01	*E. pilularis*	Owlet nightjar	Good	ants; old leaf nest (SqG/Sug(Pr))		Good	v Old leaf material. Ants	Ph 51-946
10GG01	*E. microcorys*	Greater Glider	Good	V old leaf material		Good	Old decaying leaf material.	Ph 52-947
10SG03	*E. resinifera*	SuG/SqG glider	Good	V old leaf nest (Antechinus(Pr))		Good	Old leaf nest, latrine in corner (A'chinus(Pr)).	Ph 35-928
10RP02	*E. resinifera*	Possum	Minor; lid missing; replace Lid	leaf & needles drey (CRP(Pr))	Replace lid	Minor: lid missing; replace lid.	leaf & needles drey (CRP(Pr))	Ph 34-927
10GBC02	*E. resinifera*	Cockatoo	Good	CBP	Injured eye-G20124	Good	Nil	Ph 36-929
10MB01	*C. intermedia*	Microbat	Good	nil		Good	Nil	Checked with torch/binos
10RP01	*C. intermedia*	Possum	Good	nil		Good	depressed & spread material (Br-tail possum(Pr))	Ph 42-936
10YG01	*C. intermedia*	Yellow-bellied glider	Good	Old euc leaf nest (SqG/SuG (Pr) ;		Good	v Old leaf material. Entry chewing	Ph 43-937
10SG01	*E. pilularis*	SuG/SqG glider	Good	Old leaf nest & latrine in corner (Antechinus sp.)	G154	Good	Old leaf nest & latrine in corner (Antechinus sp.)	Ph 44-938
10SG02	*E. resinifera*	SuG/SqG glider	Minor; termite damage	old leaf nest (SqG/Sug(Pr))	Box still sound	Minor: termite damage	Decaying leaf,	Ph 45-939
10Br02	*E. siderophloia*	Possum	Good	CBP(m)	Ph 92-G301	Good	CBPx2 (1ad, 1juv)	Ph 46-940

10PP01	*E. siderophloia*	Pygmy-possum	Good	Old leaf nest (Antechinus (Pr)); ants		Good	Fresh leaf material, ants. Entry chew (Sug(Pr))	Ph 47-941
10BP01	*E. resinifera*	Phascogale	Good	V old leaf material no shape		Minor: lid off; reattach.	Old leaf nest & latrine in corner (Antechinus sp.)	Ph 48-942
10GBC01	*E. resinifera*	Cockatoo	Good	CBP		Good	Nil	Ph 41-935
10SG04	*E. resinifera*	SuG/SqG glider	Good	Old leaf material		Good	Fresh leaf nest. (Sug/SqG (Pr))	Ph 40-933
10CO01	*E. tereticornis*	Corella	Good	old leaf nest	Confirmed with ladder	Good	Old scattered leaves (Onj (Pr)	Ph 39-932
10Br01	*C. intermedia*	Possum	Good	CBPx2 (ad&juv)	G258	Minor: lid off; reattached.	Nil	Ph 38-931
10YG02	*C. intermedia*	Yellow-bellied glider	Good	Nil		Good	Entry chewing; ant debris	Ph 37-930
10MB02	*L. suaveolens*	Microbat	Good	Nil		Good	Nil	Checked with torch/binos
12PP01	*C. intermedia*	Pygmy-possum	Good	Ants		Good	Old euc leaf nest (FtG (Pr)); Estn crevice skink;	Ph 15/16-899;Checked with ladder after seeing movement under leaves
12BR01	*Cas. glauca*	Possum	Good	Ants		Good	old leaf	Ph 14
12BP01	*E. resinifera*	Phascogale	Good	ants; V old leaf material		Good	old shallow leaf nest (Onj (Pr))	Ph 13-897
12YG01	*C. intermedia*	Yellow-bellied glider	Good	Old euc leaf bed nest (Onj (Pr)) ;		Good	v old euc leaf nest	Ph 12-896
12ON01	*C. intermedia*	Owlet nightjar	Good	V Old leaf nest brown		Good	v Old leaf	Ph 11-895
12MB01	*C. intermedia*	Microbat	Minor; lid off; reattached	Old leaf nest brown		Major: termite damage/collaps	Nil	Replace box; No photo
12SG01	*M. quinquenervia*	SuG/SqG glider	Good	old euc leaves (SqG/Sug (Pr)); Ants		Good	Ants; v old lvs	Ph 22-914
12GBC01		Cockatoo	Minor; termite damage	nil	Box still sound	Major: termite damage; Replace box	Nil	Ph32-925
12SG04	*C. intermedia*	SuG/SqG glider	Good	Old euc leaf nest (SqG/SuG (Pr)) ;		Good	Old decayed material, ants	Ph31-924
12SG05	*E. resinifera*	SuG/SqG glider	Good	Old euc leaf nest (SqG/SuG (Pr)) ;		Minor: termite damage	Old decaying material	Ph 29-922
12YG02	*E. resinifera*	Yellow-bellied glider	Good	nil		Good	Old decayed material; abandoned bee hive	Ph 28-921

12RP01	*E. robusta*	Possum	Good	Lace monitor	Ph 89-G298	Good	Nil	Ph 27-920
12SG06	*C. intermedia*	SuG/SqG glider	Good	old abandoned bee hive	Ph 91-G300	Good	old euc leaves (SqG/Sug (Pr))	Ph 19-907
12YG03	*C. intermedia*	Yellow-bellied glider	Good	Nil		Good	Nil	2 boxes?; Ph 20/21-910/11
12MB04	*C. intermedia*	Microbat	Good	Nil		Good	Nil	Checked with torch/binos
12MB03	*L. suaveolens*	Microbat	Good	Nil		Good	Nil	Checked with torch/binos
12BP02	*C. intermedia*	Phascogale	Good	V old leaf nest		Good	SuG/SqG	Ph 24/25/26-916/18
12ON02	*E. resinifera*	Owlet nightjar	Good	Abandoned bee hive		Good	Old decayed material	Ph 23-915
12MB02	*L. suaveolens*	Microbat	Good	Nil		Good	Nil	Checked with torch/binos
12SG02	*M. quinquenervia*	SuG/SqG glider	Good	Nil		Good.	Old material; ants	Ph 17-904
12SG03	*M. quinquenervia*	SuG/SqG glider	Good	old leaves scattered		Good	V Old scattered leaves; abandoned Europ bee hive	Ph 18-905
12MB01b	*C. intermedia*	Greater Glider	Good	V old leaf material		Minor: detached lid.	Nil	replace lid; No photo
12GG01	*E. resinifera*	Greater Glider	Good	Nil		Good	Nil	Ph 33-926
12GBC01b	*C. intermedia*	Cockatoo	Good	Nil	Location: 517781-6675521	Minor: termite damage	Nil	Ph 30-923
35GBC01	*C. intermedia*	Cockatoo	Good	S-eBP	G156-238; Carpet python inspecting box	Good	depressed & spread material (Br-tail possum(Pr))	Ph 111-1016
35ON01	*E. acmenoides*	Owlet nightjar	Minor; termite damage; spout ungluing	V old leaf nest		Minor; termite damage; spout ungluing	SuG (exited box)	No photo
35YG01	*E. siderophloia*	Yellow-bellied glider	Good	V old leaf material		Good	Old leaf nest & latrine in corner (Antechinus (Pr))	Ph 112-1017
35BP01	*E. siderophloia*	Phascogale	Good	nil		Good	Nil. Ants	No photo
35MB01	*C.variegata*	Microbat	Good	Gould's wattled bat	Ph 75-G240	Good	Nil	Checked with torch/binos
35L01	*E. propinqua*	Lorikeet	Good	nil		Good	Nil. Ants	Ph 118-1082
35BR03	*C. intermedia*	Possum	Good	S-eBP	G242	Good	Nil	Ph 117-1081
35SG01	*E. microcorys*	SuG/SqG glider	Good	fresh euc leaf nest (SqG/Sug(Pr))	Confirmed with ladder	Good	Fresh euc leaves (SqG/Sug (Pr))	Ph 120-1085

35BR02	*E. microcorys*	Possum	Good	nil		Good	old spread leaves/material (Br-tail possum(Pr))	Ph 121-1086
35BR01	*E. microcorys*	Possum	Good	nil		Good	Old euc leaf bed (Onj(Pr))	Ph 115-1079
35PP01	*E. globoidea*	Pygmy-possum	Good	ants		Good	Nil. Ants	Ph 114-1078