A faunal survey of Western Sydney's Cumberland plain woodland and River-flat eucalypt forest remnants at 'Wallaroo' conservation reserve, Mulgoa, NSW.

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(Source: Melissa Tully)

Integrated project prepared as partial fulfilment of the requirements of the Bachelor of Environmental Science.

Copyright statement

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Abstract

Many studies have been conducted to explore the relationship between remnant woodlands and species diversity and abundance. Such studies have found remnant vegetation to possess critical habitat provisions, which younger, less established vegetation is unable to provide. Management of remnant woodlands in many cases has involved revegetation programs, the effectiveness of these programs is uncertain due to the inability to replace the aging dynamics of the remnant. The current study was conducted at a recently purchased property for the purpose of conservation 'wallaroo' over a four-week period. It involved the deployment of multiple wildlife monitoring devices and techniques including wildlife cameras, audio recording, tunnel trapping, Anabat monitoring and spotlighting surveys. The equipment was deployed in 5 habitat types to create an inventory of baseline data regarding fauna present on the site and highlight potential relationships between habitat type and faunal activity. Habitat types surveyed included High quality Cumberland Plain remnants, Low quality Cumberland Plain woodland remnants, River-flat eucalypt remnants, grassland and water body's. The survey found 30 species of fauna to be present on the property including arboreal and ground dwelling mammals, birds, reptiles, amphibians, bats and invertebrates. Introduced species such as fallow deer, foxes and hares were also identified. Data analysis in the form of independent t-tests, tested quantitative data collected by wildlife cameras and found no significant difference between fauna activity between habitat types, potentially due to the small size of the remnants and the influence of the close proximity of one remnant to the next. Due to difficulty in comprehensively surveying, more *detailed surveying, particularly regarding the abundance and diversity of birds, reptiles and arboreal mammals are required. It is however suggested that immediate management efforts include eradication of introduced species of fauna and flora and the continued protection of the remnants from anthropogenic factors.*

Keywords: Cumberland plain woodland, River-flat eucalypt forest, remnant vegetation, introduced species, baseline study.

Contents

Figures & Tables

1. Introduction

1.1. The impacts of agriculture on our remnant woodlands

It is well documented that agriculture has played arguably the largest role in the degradation of the natural landscape, resulting in the largest decline in biodiversity and ecosystem services of all human activities (Jellinek, Rumpff, Driscoll, Parris & Wintle, 2014; Gibbs, Mackey & Currie, 2009).

Agricultural land encompasses 40% of terrestrial land, almost half of the terrestrial land that would otherwise be comprised of natural vegetation such as remnant woodlands and forests. Although the growth in agriculture has slowed over recent years, the 21st century saw a rise in the introduction of new technology and more intensive farming techniques (Rey Benayas & Bullock, 2012). In traditional agriculture, impacts were considerably less and somewhat more direct such as land clearing and over grazing. Such impacts are more measurable and manageable. Traditional methods of farming highly valued making use of nutrient recycling, using breeds suited to the local setting, thus reducing the need to adapt the landscape to suit the breed. Land use was set at a minimum, with an understanding that arable land would need to be retained for future use. The limited knowledge of and access to pesticides and herbicides also meant that traditional farming practices had less impact on other ecosystems such as aquatic ecosystems (Rey Benayas & Bullock, 2012). However in recent times the industry has grown to maximize production, in turn increasing impacts, which are not as easily managed, and hold repercussions, long after the direct impact has been removed (Rey Benayas & Bullock, 2012; Gibbs, Mackey & Currie, 2009).

The implementation of irrigation & flow management structures and riparian clearing often degrade natural water bodies present on the property, which are a valuable ecosystem to both those who inhabit the water body and those who access the water body. The introduction of machinery and the growing number of livestock result in higher rates of erosion and alteration of the drainage system, which in turn increase pollution, agricultural runoff and soil salinity (Hill, Tung & Leishman, 2005; NSW Science committee, 2011; Rey Benayas & Bullock, 2012).

Potentially the most obvious and alarming impact of agriculture is that of the fragmentation of native woodlands. Clearing for agriculture has resulted in heavily fragmented landscapes. Fragmentation results in limited dispersal capacity for native vegetation, increased vulnerability of predation for migrating birds and land animals and poor connectivity, which reduces the availability for genetic variation and transport between remnants. The remnants that are left are often extremely isolated and encompass relatively small patches of land, creating competition between native and non-native species for access to resources (Eberhart, 2011). In many cases the altered landscape favors invasive species, which are fast growing and easily established in the disturbed environment (Abensperg-Traun & Smith, 1999; Jellinek *et.al.,* 2009; Wilkins, Keith & Adam, 2003; NSW Science committee, 2011).

Although the remaining vegetation has a reduced capacity to perform ecological services, it remains vitally important for providing refuge for native fauna, thus requiring protection from further degradation.

1.2. *The role of remnants in maintaining biodiversity and ecosystem services*

Remnant vegetation plays a vital role in maintaining native biodiversity; they are comprised of dynamic and diverse habitat types upon which our native fauna rely (Tozer, Leishman & Auld, 2015; NSW National parks and wildlife service, 2003). Due to remnants being established for such a significant period of time, they have developed the ability to provide a complex habitat, at multiple strata levels, meeting the needs of a diverse range of faunal groups ranging from invertebrates, reptiles and ground dwelling mammals to arboreal mammals and birds (N.S.W National Parks & Wildlife service, 2003).

Generally, remnant plots consist of three broad vegetation strata. At the ground level remnants consist of thick groundcover comprised of native grasses and forbs, providing foraging opportunities and shelter for animals, as well as promoting soil stability and slowing water runoff. The understory level in the remnant is comprised of native shrubs and seedlings, which provides the foundation for future generations of taller species and hosts a number of small ground dwelling mammals, reptiles and bird species. The upper canopy of established, mature trees provides a network across the remnant and plays a vital role in habitat provisions. These provisions are not limited to standing vegetation; increasing in value in fact, once they have begun to deteriorate. At this time they provide hollows, fallen logs and timber, opportunities for fungi invasion and leaf litter. Such provisions are simply not available from younger less established trees, highlighting the importance of the aging dynamic of remnants (Bennett, Kimber & Ryan, 2000).

1.3.Managing the decline in remnant vegetation

Comparative studies of the abundance and diversity of species between cleared agricultural land and remnant vegetation have been conducted to quantify the need for protecting these isolated patches of habitat and have found varying results. Some generalist species have actually indicated a preference of some species to the altered landscape and revegetated patches, while others indicate an increase in introduced species and a decrease in native species. (Munro, Lindenmayer & Fischer, 2007, Wilkins, Keith & Adam, 2003; Munro, Fischer, Barrett, Wood, Leavesley & Lindenmayer, 2011). Many have focused on active restoration programs where revegetation has played a major role in management. Restoration has been described as 'an area where native plants have been actively introduced' (Munro, Lindenmayer & Fischer, 2007). Given the provisions that remnant vegetation provides as it ages, questions have been raised as to exactly how effective revegetation is in restoring remnants in studies based on a number of faunal species including birds, arthropods, small mammals and reptiles (Kimber, Bennett & Ryan, 1999; Munro, Lindenmayer & Fischer, 2007; Soga, Yamaura, Koike & Gaston, 2014). Other more passive approaches focused on protecting the remaining remnants and removing threats, allowing the vegetation to regenerate naturally has also been trialled as a more effective management technique based on cost and response of communities (Rey Banayas & Bullock, 2012; Dorrough, Vesk & Moll, 2008). Some management approaches involving conservation of remnants on agricultural land which is still actively being farmed have also been proposed, although may not be comparable to the management techniques discussed here, given that they depend on the plantings based on the convenience of the farm land rather than the conservation value (Rey Benayas & bullock, 2012). Despite the conflicting results, both revegetation and opportunities for natural regeneration have been accepted as effective management approaches. Their effectiveness however is dependent on a number of variables, both environmental and anthropogenic, such as the need for access to surrounding agricultural land, flow of resources through the ecosystem, economic and social factors, population dynamics within the ecosystem and much more. The variability that is dealt with in managing remnants has highlighted a lack of adequate baseline studies. Baseline studies make management of restoration projects more efficient, ensuring that effort is being applied on achieving objectives that are based on improving the current health of the ecosystem. In order to achieve such outcomes, an adequate understanding of the current health is required and can be attained through baseline studies (Wilkins, Kieth & Adam, 2003; Bull, Gordon, Law, Suttle, & Milner-Gulland, 2013; Fitzsimons & Carr, 2014). In addition to baseline studies, post restoration evaluation is also lacking. Although the importance of rehabilitating remnants has been recognised, both nationally and internationally, resulting in government funded programs to assist in regeneration efforts. The importance of evaluating their biological effectiveness has not. Wilkins, Keith and Adam (2003) point out that strict observation on the effectiveness of programs from a financial and social perspective is generally well evaluated, however such evaluation doesn't adequately describe the biological results of the projects. There is much variety in stated outcomes of biodiversity conservation Australia, with one consistent outcome that many claim to work towards, that being the conservation of biodiversity. Many projects however have claimed to encounter difficulty in fully assessing the contribution they are making due to limited or poor quality benchmark data and inconsistent monitoring approaches. In addition to gaining baseline data, it has become evident that emphasis should be placed on defining the category of a protected area (IUCN, 2014). In order to categorize and there for direct mitigation efforts, a thorough understanding of habitat use of the area in both a historical and current context is essential (Benson & Howell, 2002; Tozer *et al.*, 2014).

At a regional level in Australia, Extensive research has been conducted on the remnants of Western Sydney, regarding flora composition and species identification (Benson, 1992; Benson & Howell, 2002; NSW scientific committee, 2009; NSW scientific committee, 2011; Tozer, 2003). There is a general understanding of biota inhabiting this region however research efforts have not yet included more fauna diverse data, or been conducted at a more localised scale. It is suggested that 60 species of mammalian fauna were recorded prior to extensive clearing; this figure is suggested to have dropped to 37 in the last decade (Tozer, 2014). Research projects acknowledge the role of remnants in habitat availability and resource allocation, and use this as justification for protecting the remnant. Only a minority however have based their findings on progress made in comparison to benchmark surveys. This becomes detrimental when evaluating the success of conservation efforts and highlights the need for benchmark surveys in newly established protected areas such as those protecting the remnants of western Sydney such as the Cumberland plain woodland and the river-flat eucalypt forest (Bull, Gordon, Law, Suttle, & Milner-Gulland, 2013; Fitzsimons & Carr, 2014). The following study provides an opportunity to gain baseline data on the current composition of species within the

Cumberland plain woodland and river-flat eucalypt forest on land recently purchased for conservation of remnants.

1.4. Western Sydney's Wianamatta remnant communities as a case study

Western Sydney basin bioregion is for the most part situated on the Wianamatta shale & alluvial substrate geology and hosts a number of remnants, which are characteristic of this geology. Vegetation in the region is labelled according to the geology it resides on and includes the shale sandstone transitional forest, the Cumberland plain woodland and the Sydney coastal river flat forest (Benson 1992, NSW National Parks & Wildlife service, 2002). Variations in the vegetation are due to the prominence or lack of influence of aspects of geology such as a high or low sandstone influence.

Vegetation in the area has been highly impacted by urbanisation of western Sydney and the remnants that remain are surrounded by heavily cleared agricultural land, which continues to impede on remnants that remain. Historic records of the region indicate a vast decline in remnant size where 26.2% of shale sandstone transitional forest, 9.2% of Cumberland plain woodland & 15.3% of Sydney coastal river flat forest remain since 1750 (NSW National parks & wildlife service, 2002; Benson & Howell, 2002).

Remnants in the region are protected to a degree by a number of nature reserves such as Agnes Banks Nature reserve, Castlereagh Nature reserve, Mulgoa Nature reserve and Windsor downs Nature reserve as well as the establishment of conservation areas on private land. Extensive research has been conducted on remnants of this region including Cumberland plain woodlands and River-Flat Eucalypt forests regarding flora composition and species identification (Benson, 1992; Benson & Howell, 2002; NSW scientific committee, 2009; NSW scientific committee, 2011; Tozer, 2003).

1.5 Vegetation composition & faunal occupancy

Cumberland plain woodland is dominated by Eucalypt species such as *Eucalyptus moluccana* (Grey box), *Eucalyptus tereticornis* (Forest red gum), *Eucalyptus crebra* (Grey ironbark) and *Eucalyptus eugeniodes* (Narrow leaved stringy bark). Such species form most of the top canopy and vegetation becomes progressively smaller, where saplings of the above Eucalypts are generating in addition to Acacia species such as *A. decurrens* (Black wattle), *A. parramattensis* (Parramatta wattle) *A. implexa* (Hickory wattle). *Bursaria spinosa* (blackthorn) which in recent times has multiplied extensively, also contribute to this thick understory. Groundcover of the Cumberland plain is dominated by native grasses such as, *Aristida ramosa* (Purple wiregrass), *Aristida vagans* (three awn spear grass), *Themeda australis* (Kangaroo grass) and *Microlaena stipoides* (weeping grass) (NSW scientific committee, 2011; Benson & Howell, 2002).

The River-flat Eucalypt forest of the western Sydney region is comprised of similar species of Eucalypt to that of the Cumberland plain woodland. It differs in its flood plain location and existence on sandy and clay loams and alluvial flats, characteristic of periodically inundated soil. In addition to the above listed eucalypts it includes *Eucalyptus amplifolia* (Cabbage gum), *Angophora floribunda* (Rough-barked apple), *Angophora subvelutina* (broad-leaved apple) and melaleuca species such as *M.decora* (White feather honeymyrtle) & *M.styphelioides* (prickly leaved tea tree). The river-flat vegetation in this specific region also has a high presence of Casuarina species such as *C.cunninghamiana* (river oak) and *C. glauca* (Swamp oak). Much like the Cumberland plain in this region the river flat vegetation has a high presence of *Bursaria spinosa* and *Acacia* species including *A. floribunda* (white sally). The ground cover is dominated by *Dichondra repens* (Kidney weed) and *Microlaena stipoides* (weeping grass) (NSW scientific committee, 2011).

The Cumberland plain woodlands and the river-flat eucalypt forest provide habitat provisions for an extremely diverse range of species, supporting biodiversity in the otherwise urban ad agricultural landscape.

Based on the Atlas of living Australia there are currently 26 amphibian species, 59 mammalian species and 41 reptile species and 373 bird species that could potentially rely on Cumberland plain woodland and river flat eucalypt forest habitat, many of which are listed as threatened or endangered species such as *Rattus fuscipes* (Bush rat), *Perameles nasuta* (Long-nosed Bandicoot), *Caercartetus nanus* (Eastern Pygmy possum), *Phascolarctos cinereus* (Koala), and *Dasyurus maculatus* (Spotted tail Quoll) (Atlas of living Australia, 2016). This project aims to determine the native species of terrestrial mammal, frog and micro bat that may be present in the Cumberland Plain Woodland of 'Wallaroo' conservation reserve in order to provide a trajectory to work towards, based on the current state of the remnants.

Objectives

- To acquire strong background information relating to the study site and its surrounds
- To acquire as much historical data as possible relating to diversity and abundance of species in region if available
- To conduct surveying of terrestrial wildlife using automated wildlife survey techniques for diversity and abundance data
- To Compile report presenting such findings.

2. Methods

2.1. Study area information

The site selected for surveying is located in Mulgoa, NSW at approximately 33°48'34.5" S & 150°39'18.71" E . The property 'wallaroo' is a small 38ha property, which lies amongst the highly developed agricultural land of the Penrith region in Western Sydney (Figure 1). The property was previously used for agricultural purposes including cattle grazing and attempted horticulture practises, resulting in extensive clearing and associated degradation.

Figure 1. 'Wallaroo's location, dominated by agricultural land (Source: Google Earth, 2015).

The geography of the site encompasses Wianamatta shale sandstone, clay and sandy loams, silts and alluvial substrates (NSW Scientific committee, 2011). There are numerous water bodies present on the site, seven of which were included in this survey, in addition to Mulgoa creek frontage, which stretches along the western boundary of the property through the River-flat Eucalypt remnants that are present. The elevation of the property ranges from 38m asl on the western to south western side of the property to 65m asl on the eastern side of the property where ridge lines run NE toward the boundary.

The property host's two remnant vegetation communities consisting of Cumberland plain woodland and River-Flat Eucalypt forest of varying sizes, which exist on the western and eastern sides of the property respectively. This vegetation is surrounded and supported by large areas of grassland, which infiltrate into the remnants forming the ground cover.

Vegetation type was mapped and described using recent aerial photography, after which the study area was divided into five habitat types (figure 2). These were:

1) Cumberland plain woodland: high quality vegetation;

2) Cumberland plain woodland: low quality vegetation;

3) River-flat eucalypt forest

4) Grasslands

5) Water bodies

The Cumberland plain woodland vegetation was classified as high or low quality vegetation based on the key diagnostic features suggested in the identification and protection guide of the Cumberland plain shale woodlands and shale-gravel transitional forest. This categorizes based on native perennial ground cover present, where areas with >50 % native ground cover were classed as high quality sites and the remaining were classed as lower quality Cumberland plain woodland (Department of the environment, water, heritage & the arts, 2010).

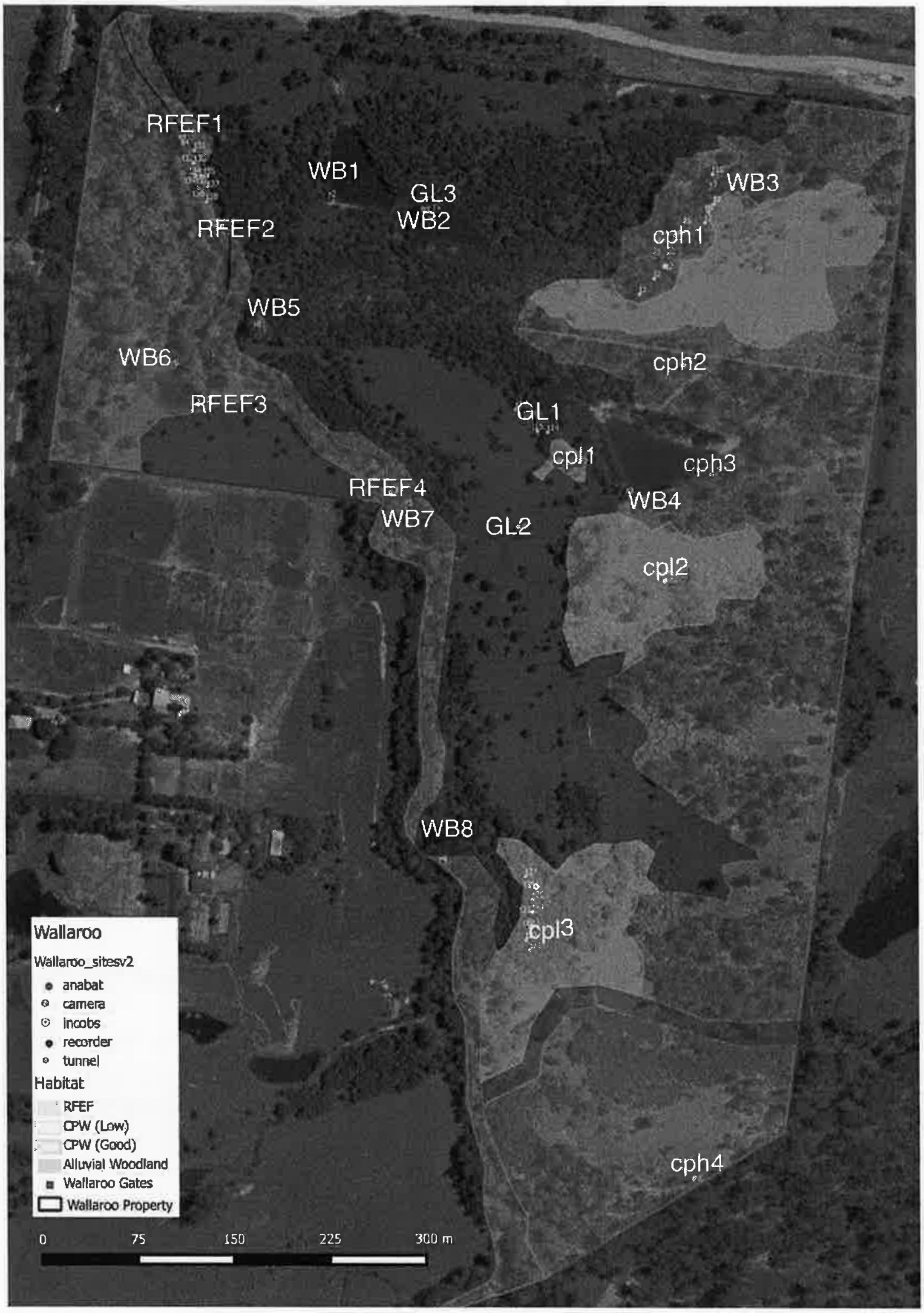

Figure 2. Location of Cumberland plain woodland (CPW low & CPW good), River-flat eucalypt forest (RFEF), Grasslands (GL) and Water body (WB) sites at 'Wallaroo' survey (Map Source: Alison Towerton GSLLS, 2016)

2.2. Survey Methodology

The baseline faunal survey that was conducted was aimed at providing a basic baseline species inventory of species present within 'wallaroo'. A secondary objective was to investigate habitat preference of key faunal species such as native mammals. Ultimately providing an insight into the quality of remnant that fauna are associating with the most.

In order to adequately survey each of the five habitat types, replication was as follows, 4x High quality Cumberland plain woodland, 3x Low quality Cumberland plain woodland, 3x Grassland, 4x River-flat eucalypt forest & 8x Water body's. A variety of monitoring equipment was deployed to ensure that the survey was fully representative of the faunal activity in the remnants, including wildlife cameras and tunnel traps to monitor ground dwelling mammals, audio recorders to monitor frog activity, and ANABAT units to monitor Bat activity (Table 1). Spotlighting was also conducted on two 200m transects within the high quality Cumberland plain woodlands and the River-flat eucalypt forest for a twenty minute period on two nights, a week apart. Faunal activity was monitored across twenty sites overall and monitoring equipment was allocated based on where faunal activity was most likely to occur, through the presence of scats, manipulation of vegetation due to contact with fauna, access to water and areas of shelter. The survey took place over a four-week period where equipment was deployed in the first series of sites for two weeks before data was collected and equipment was moved to the remaining sites.

Table 1. Summary of sites and equipment allocation (cph=Cumberland plain high quality, cpl= Cumberland plain low quality, GL= grass land, WB= Water body, RFEF= River-flat eucalypt forest)

Site	Camera	Anabat	Recorder	Tunnel	Spot lighting	site comments
CPH1	√	√		√	√	Joins low quality cpw, encompasses wb3
CPH2	√					Between low quality cpw and large dam
CPH3	√					Adjacent large dam
CPH4	√					Isolated patch near fence line
CPL1	√					Small patch surrounded by grassland
CPL2	√					On dam wall, very over grown
CPL3	√	√		√		Joins RFEF and alluvial woodland
GL1				√		Near small patch of low quality cpw
GL2	√					Very isolated, high grass
GL3	√	√		√		Right next to smallest of twin dams
RFEF1	√	√		√		Along creek, high numbers of casuarina
RFEF2	√					Adjacent to grassland and non remnant scrub
RFEF3	√					Located on opposite side of creek, close to large dam
RFEF4	√				√	Right on creek, completely surrounded by RFEF
WB1				√		Largest of twin dams
WB2				√		Smallest of twin dams
WB3				√		Small dam high vegetation
WB4				√		Large dam on ridge
WB5				√		Small, surrounded by grassland and non remnant scrub
WB6				√		large dam on opposite side of creek
WB7				√		on creek bed
WB8				√		on creek bed

2.2.1 Tunnel trapping

Tunnel traps are a tested method to identify small ground dwelling mammals, and in some instances are able to identify reptiles and invertebrates. The tunnel traps used have not been used heavily in Australia but were chosen due to the low impact they have on fauna, since no fauna are retained within the traps. The traps were composed of a 30 cm cardboard tube. Within the tube a printing system consisting of an ink soaked pad and track pads. Banana was used as bait and was placed directly on the track pad to encourage fauna to investigate the tubes. (Figure 3). Fauna enter the tunnel in an attempt to access the bait, making contact with the ink soaked pad, resulting in identifiable footprints. Tunnel traps were placed at 10m intervals on a 100m transect in each habitat type.

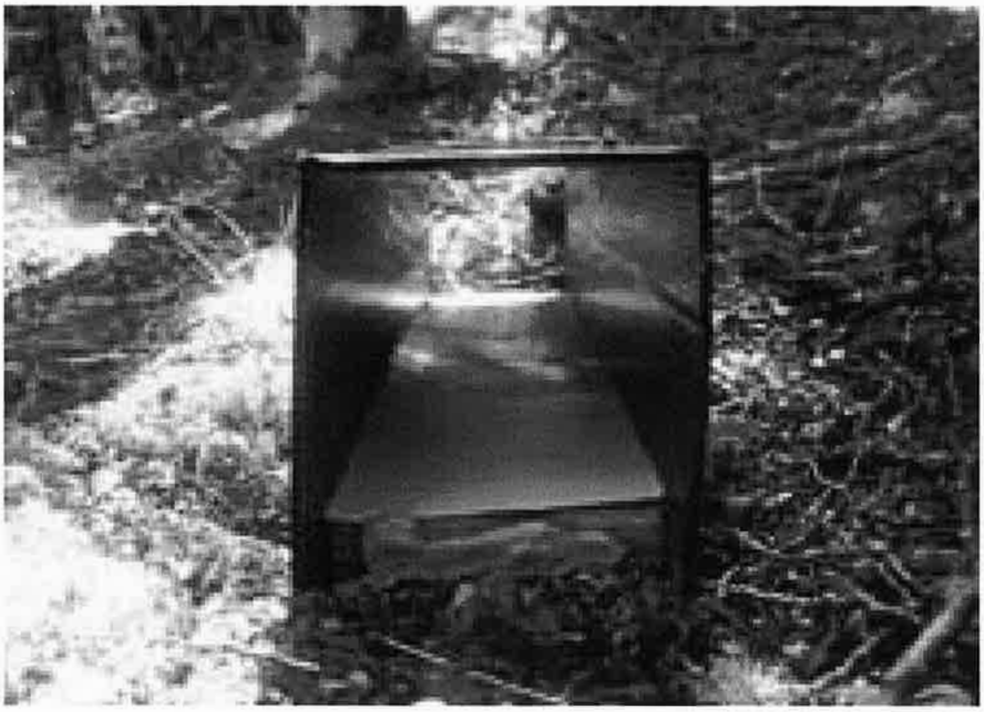

Figure 3. A tracking tunnel trap in New Zealand, set in the same manner as those used in this survey (Source: DOC's, 2016)

2.2.2 Motion activated wildlife cameras

Motion activated wildlife cameras were used to monitor a range of fauna types from ground dwelling to arboreal species of varying sizes. The camera's used infrared monitoring and were triggered by changes in ambient temperature. They were set on tree trunks or posts, directed above the height of underlying grass and away from direct sunlight (figure 4). Images were identified and tagged using EXIFPRO software to allow for comparison between sites. Camera's were deployed for two weeks at eight sites and recorded for 24 hours a day. After two weeks data was collected and cameras were moved to the remaining eight camera sites for surveying. Images from each unit were tagged using EXIFRO photo tagging software, allowing for a species list to be generated per site.

Camera trap results where representative of species presence per hour. If a species was identified in the hour it was given one tag regardless of the number of times it was observed for that hour. (For example: 1 observation/ hour= 1 tag, 9 observations/ hour still=1 tag). Resulting in presence/absence data per hour for each 24-hour period.

Figure 4. Motion activated wildlife camera, set on tree at River-flat eucalypt forest site (Source: Peter Ridgeway. GSLLS, 2016)

2.2.3 Audio monitoring

Audio was recorded at each the seven water body sites to identify frogs present in the area. The set up consisted of a simple smart phone device with specific recording software. The smart phone was placed inside a yoghurt container and milk bottle for weather protection (Figure 5). The audio software was set to record for two hours per night and 20-minute segments were analyzed from each night. The system recorded every night during a two-week period after which activity was compared between sites using RAVENPRO software.

Figure 5. A frog call recording unit, set at a water body site (Source: Melissa Tully, 2016)

2.2.4 *Anabat monitoring*

Anabat units were used as a passive monitoring method to replace traditional harp trapping to lessen the impact on bats. Anabat's are ultrasonic recorders, which use echolocation to detect bat calls. The units are placed in potential flyways, positioned 1 – 2 m from the ground, attached to a tree or post (figure 6). Each unit was programmed to record, from dusk to dawn for a two week period at two sites and were then moved to the remaining two bat recording sites for a further two weeks. At the conclusion of the survey, bat calls were identified using Anabat software.

Figure 6. Anabat unit set on tree trunk, 1-2 m from the ground, in a potential flyway at a Cumberland plain woodland site (source: Melissa Tully).

2.2.5 Spotlighting survey

Two sites in the high quality Cumberland plain woodland and river-flat eucalypt forest habitats were allocated for spotlighting. Each site consisted of a 200m transect which was surveyed for a 20 min period. The survey was conducted one night a week for two consecutive weeks. Species observed were recorded on a data sheet and GPS coordinates were allocated for each observation.

3. Results

3.1. Camera trap results

The camera trap results indicated a higher level of faunal activity in the high quality Cumberland plain habitat (CPH) than in any other habitat type (figure 7). A total of 118 individuals were tagged in this habitat, demonstrating a higher presence per hour over the two-week period of monitoring for this site. The cleared land, which now forms the Grassland habitat, demonstrated the lowest activity, with a total tag count of 10 individuals (Table 2). The Cumberland plain high quality woodland also produced higher numbers of native macropods, namely the *Macropus robustus* (Wallaroo) and the *wallabia bicolor* (Swamp wallaby) (Figure 8 & 9). Although the low quality Cumberland plain woodland presented a lower presence of macropods than the higher quality habitat it maintained a higher presence of native fauna than the River-flat eucalypt forest remnant (RFEF). The RFEF remnant had a higher presence of faunal activity in general however this was influenced by the higher presence of non-native species such as Fallow deer (Figure 10). Data analysis was performed on results from this monitoring type as it presented the most quantitative data of all the monitoring types (Appendix A).

An independent T-test was performed to test differences between the results in the number of individuals present between the high quality Cumberland plain woodland and the low quality Cumberland plain woodland (n=4, df=6 & P= 0.67) and the number of individuals present between the high quality Cumberland plain and the River-flat eucalypt forest remnant (n=4, *df*=6 & P=0.73). Where the null hypothesis was accepted in both cases, indicating that a significant difference was not found in results based on habitat quality and remnant type. Similarly, an independent T-test was performed to compare the presence of wallaroo and swamp wallaby numbers between the high quality Cumberland plain woodland and the low quality Cumberland plain woodland (wallaroo: n=4, *df*=6 & P=0.30) & (wallaby: n=4, *df*=6 & P=0.85) respectively. The presence of the two macropods was then testes between the high quality Cumberland plain woodland and the River-flat eucalypt forest remnant (wallaroo: n=4, *df*=6 & P= 0.25) & (wallaby: n=4, *df*=6 & P= 0.81). The null hypothesis was accepted in all cases, indicating no significant difference between presences of native macropods based on habitat quality and remnant type at this site. The presence of the most active non-native species at the site was also tested using the independent T-test between the high and low quality Cumberland plain woodland habitat (n=4, *df*=6 & P=0.78) and the high quality Cumberland plain woodland and River-flat eucalypt forest habitat (n=4, *df*=6 & P=0.91) which in both cases accepted the null hypothesis, indicating no significant difference in presence between the habitat types. The number of species present between sites was tested in the same way, between the high quality Cumberland plain woodland and the low quality Cumberland plain woodland (n=4, *df*=6 & P=0.11) and between the high quality Cumberland plain woodland and the River-flat eucalypt forest (n=4, *df*=6 & P=0.81) which rejected the null hypothesis, again supporting no significant difference in the number of species present between the habitat types.

Table 2. Summary of individuals observed through the use of wildlife camera's over a two-week survey period (CPH=Cumberland plain woodland high quality, CPL=Cumberland plain woodland low quality, RFEF=River-flat eucalypt forest, GL=Grassland)

Species	CPH	CPL	RFEF	GL
Wallaroo	19	5	4	0
Swamp wallaby	21	18	17	1
Brushtail possum	0	0	4	0
Fallow deer	69	30	23	1
Fox	3	5	14	2
Hare	4	0	0	0
Magpie	2	0	0	0
Purple swamp hen	0	0	0	6
Total	**118**	**58**	**62**	**10**

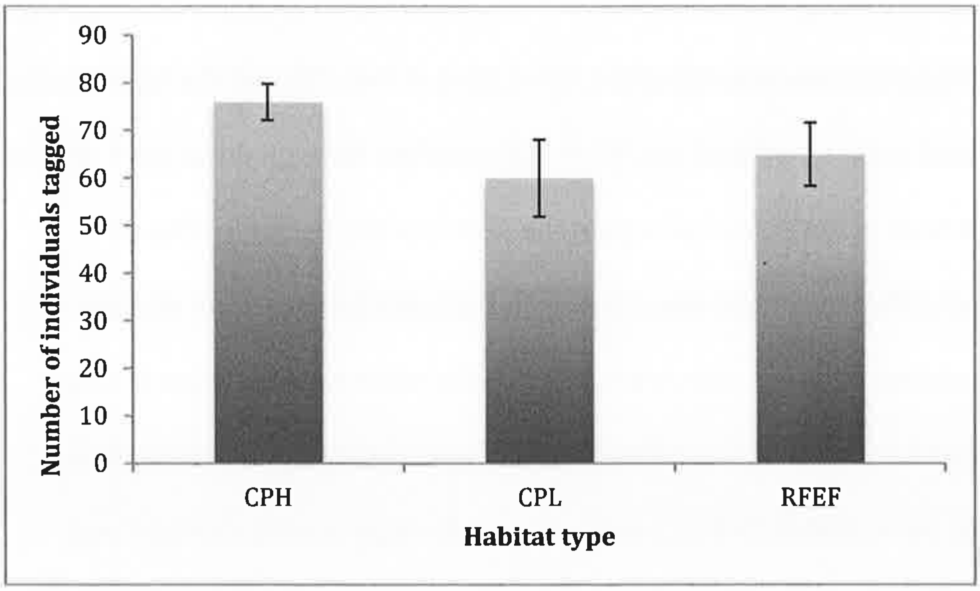

Figure 7. Comparison between numbers of individuals tagged at CPH, CPL & RFEF habitat types. (n=4, error bars= SE, CPH=Cumberland plain woodland high quality, CPL=Cumberland plain woodland low quality, RFEF=River-flat eucalypt forest)

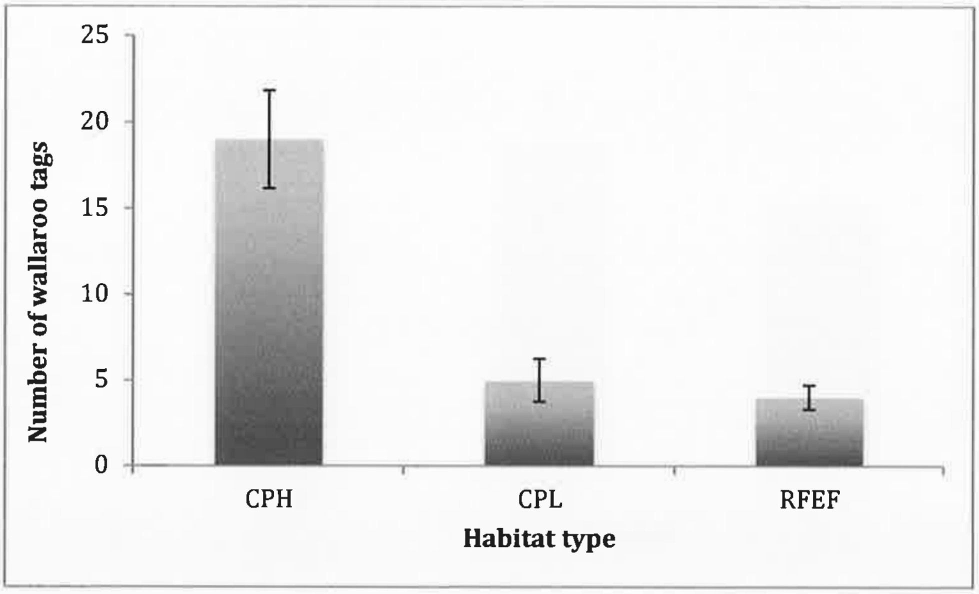

Figure 8. Comparison between numbers of Wallaroo (*Macropus robustus*) tagged at CPH, CPL & RFEF habitat types. (n=4, error bars= SE, CPH=Cumberland plain woodland high quality, CPL=Cumberland plain woodland low quality, RFEF=River–flat eucalypt forest)

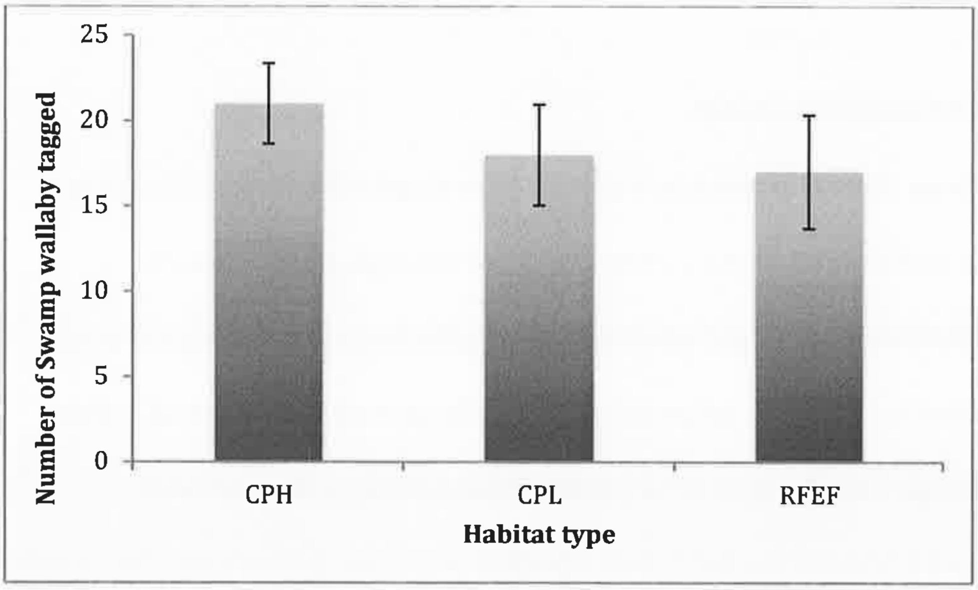

Figure 9. Comparison between numbers of Swamp wallaby (*Wallabia bicolor*) tagged at CPH, CPL & RFEF habitat types. (n=4, error bars= SE, CPH=Cumberland plain woodland high quality, CPL=Cumberland plain woodland low quality, RFEF=River–flat eucalypt forest)

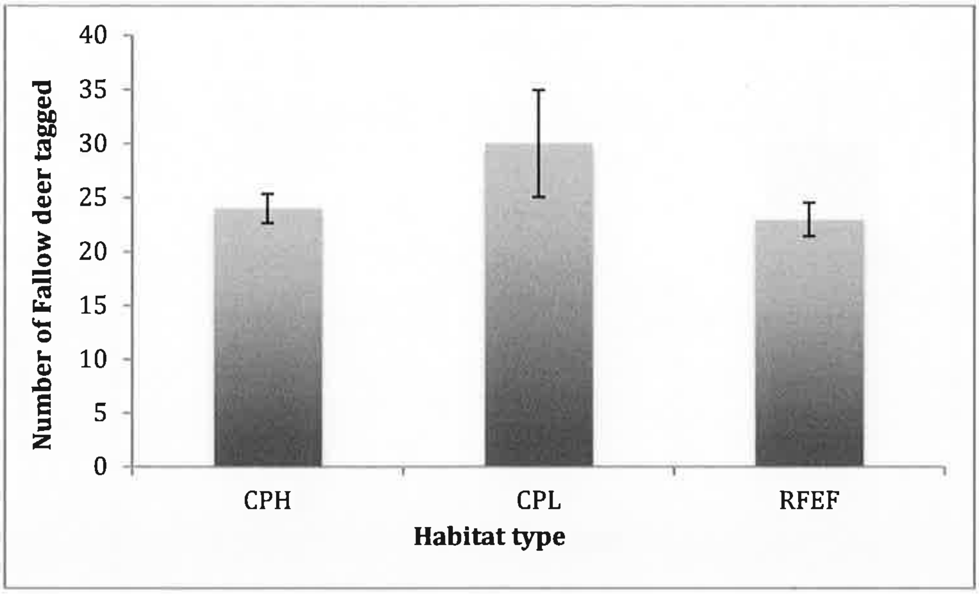

Figure 10. Comparison between numbers of Fallow deer (*Dama dama)* tagged at CPH, CPL & RFEF habitat types. (n=4, error bars= SE, CPH=Cumberland plain woodland high quality, CPL=Cumberland plain woodland low quality, RFEF=River–flat eucalypt forest)

3.2. Audio monitoring results

Results from the audio recorders identified two species of frogs. *Uperoleia laevigata* and *Crinia signifera* were identified through audio however *Limnodynastes peronnii* was observed during deployment, although was not represented in the audio recordings. Frog calls gave an indication of activity level through classification of <10 individuals calling as few and >10 individuals as many. Overall *Crinia signifera* was most active when the results of both nights were combined, with more 'many' listings *Uperoleia laevigata,* The water body within the high quality Cumberland plain site (R7) and the water body within the River-flat eucalypt forest (R4) (Table 3).

Table 3. Summary of activity at water body labelled according to surrounding vegetation. (CPWH=Cumberland plain woodland high quality, CPWL=Cumberland plain woodland low quality, RFEF=River–flat eucalypt forest, GL=Grassland)

Species	R1 GL	R2 GL	R3 CPWL	R4 RFEF	R5 RFEF	R6 RFEF	R7 CPWH	R8 GL & RFEF
Uperoleia laevigata	Many	Nil	Many	Nil	Nil	Few	Nil	Many
Crinia signifera	Many	Few	Few	Nil	Few	Many	Nil	Many

3.3. Tunnel trap results

The tunnel traps demonstrated a strong presence of introduced species in all habitat types (Table 4). The most commonly observed species was the Rat, which was identified as being 'rattus rattus' or Black rat. Following this, the Garden snail and the house mouse were the most observed species. The low quality Cumberland plain had the largest count of individuals accessing the trap (Figure 12). Overall 41 individuals visited the traps, of which only 2 were identified as native to Australia, that being the Skink and the water dragon. The River-flat eucalypt forest site reflected this highest species diversity of the four sites (Figure 11). Beyond this, there was little difference in faunal activity between sites.

Table 4. Summary of species identified in tunnel traps in habitat types (CPWH= Cumberland plain woodland high quality, (CPWL= Cumberland plain woodland low quality, GL= grassland & RFEF= River-flat eucalypt forest).

Species	CPH1	CPL3	GL1	RFEF1	Grand Total
Vulpes vulpes (Fox)				1	1
Helix aspersa (Garden snail)	4		5	1	10
Mus musculus (Mouse)		3	3	4	10
Rattus rattus (Black rat)	5	7	1		13
Skink (unknown species)		2		1	3
unknown	1			2	3
Itellagama lesueurii (Water dragon)			1		1
Grand Total	**10**	**12**	**10**	**9**	**41**

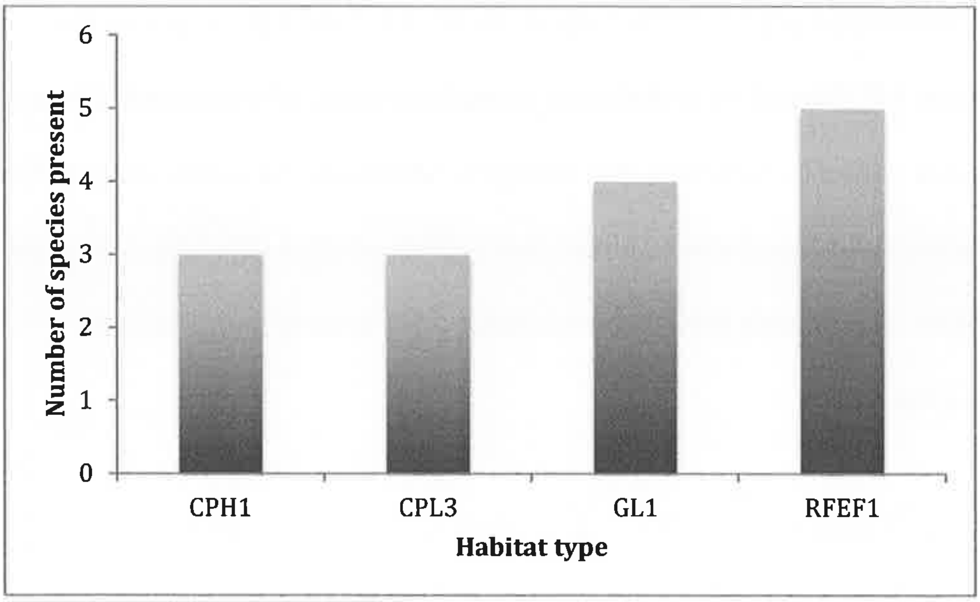

Figure 11. Comparison of the number of species observed in tunnel traps within the CPH, CPL, GL & RFEF sites (n=4, CPH=Cumberland plain woodland high quality, CPL=Cumberland plain woodland low quality, RFEF=River–flat eucalypt forest, GL=Grassland)

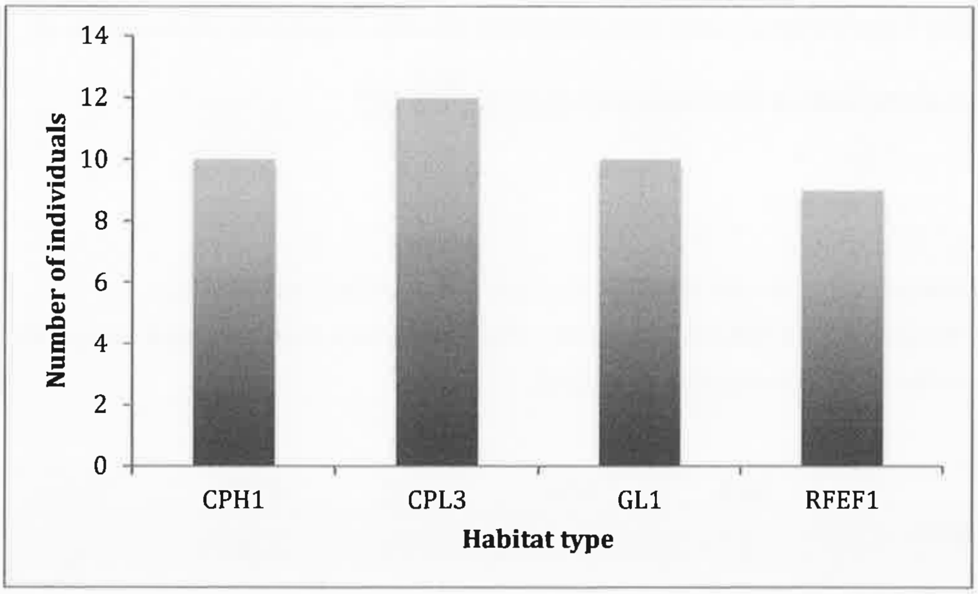

Figure 12. Comparison of the number of individuals observed in tunnel traps within the CPH, CPL, GL & RFEF sites (n=4, CPH=Cumberland plain woodland high quality, CPL=Cumberland plain woodland low quality, RFEF=River-flat eucalypt forest, GL=Grassland)

3.4. Anabat results

Species diversity was highest in the grassland and low quality Cumberland plain remnant; species diversity was lowest at the high quality Cumberland plain site and the River-flat eucalypt forest site (Figure 13). The grassland site also produced the highest activity based on number of calls per night while the high quality Cumberland plain site (CPH) was the least active of all sites (Table 5). Of the 12 bat species identified the most active bat was *Chalinolobus gouldii* followed by *Mormopterus norfolkensis* (Table 5). In the River-flat eucalypt forest (RFEF) and the low quality Cumberland plain woodland (CPL) *Chalinolobus gouldii* was the most active species, making up 96 % of calls in the RFEF figure 14) and 39% of calls at the CPL site (Figure 15). At the grassland site Mormopterus norfolkensis and *Miniopterus schreibersii oceanensis* were most active contributing to 24% and 19% of calls respectively (Figure 16). The high quality Cumberland plain site consisted of only 4 species, where 50% of calls were identified as *Mormopterus sp.2* (Figure 17).

Table 5. Summary of bat species identified through Anabat units in survey area. (CPH=Cumberland plain woodland high quality, CPL=Cumberland plain woodland low quality, RFEF=River–flat eucalypt forest, GL= Grassland)

Species	GL3	CPH1	CPL3	RFEF1	TOTAL
Chalinolobus dwyeri	1			2	3
Chalinolobus gouldii	5	1	11	47	64
Chalinolobus morio		1			1
Miniopterus australis			2		2
Miniopterus schreibersii oceanensis	12		2		14
Mormopterus norfolkensis	15	1	7		23
Mormopterus sp.2	9	3	4		16
Myotis macropus	9				9
Nyctophilus spp.	3				3
Rhinolophus megaphyllus			1		1
Tadarida australis	8		1		9
Total	62	6	28	49	145

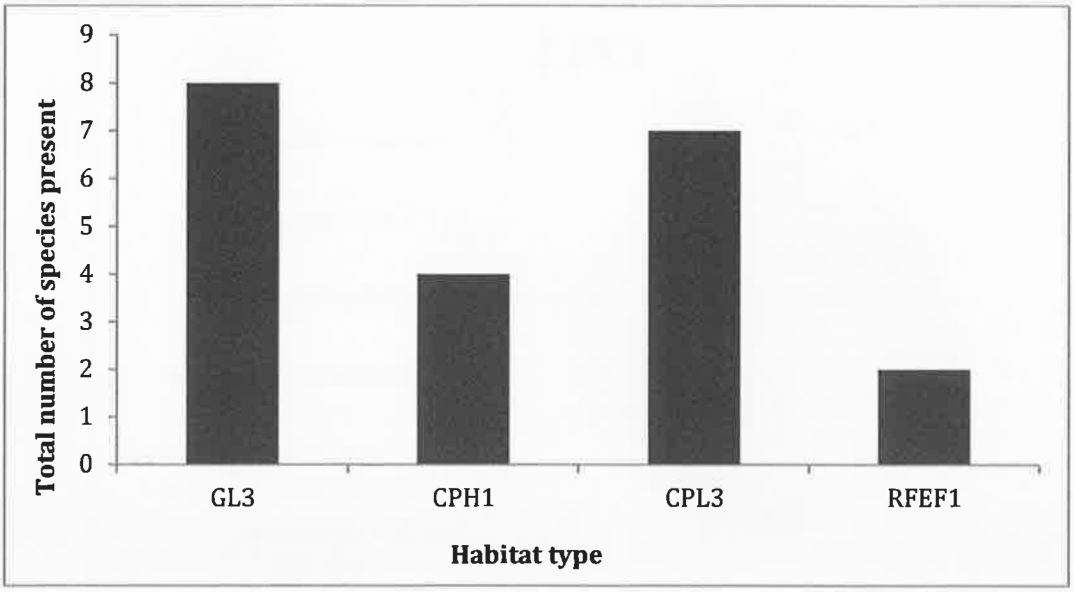

Figure 13. Species diversity of bats identified using Anabat monitoring units in grassland (GL), high quality Cumberland plain (CPH), low quality Cumberland plain (CPL) and River-flat eucalypt forest (RFEF) habitats.

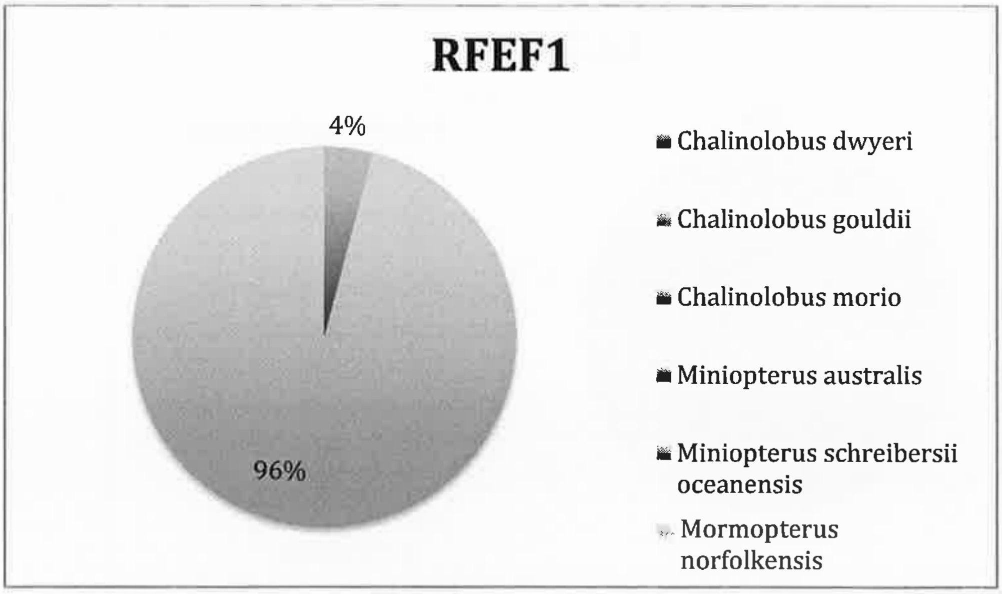

Figure 14. Bat species identified through nightly call recording by Anabat monitoring in the River-flat eucalypt forest (RFEF) remnant over a period of 13 nights.

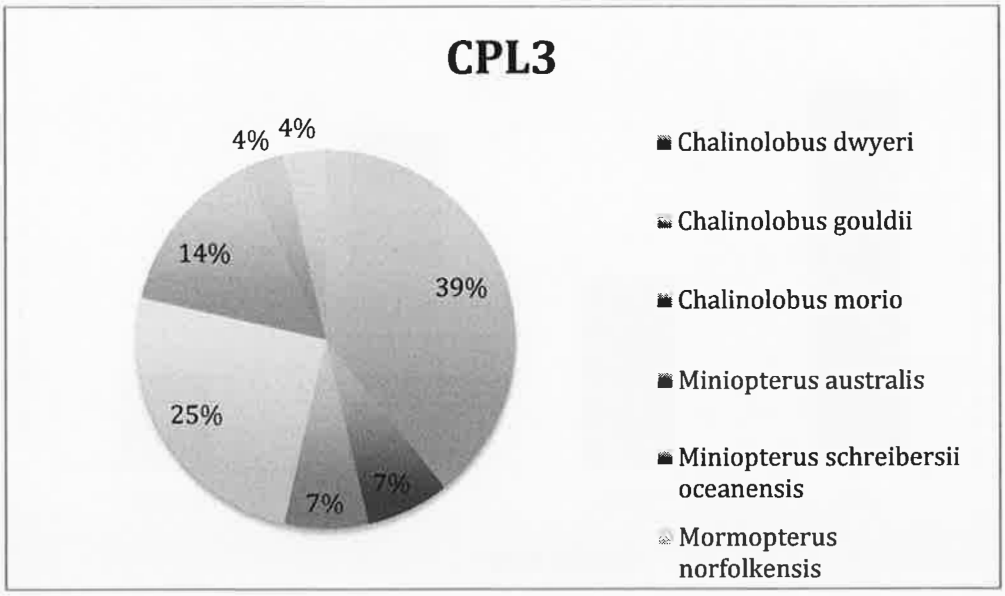

Figure 15. Bat species identified through nightly call recording by Anabat monitoring in the Low quality Cumberland plain (CPL) remnant over a period of 13 nights.

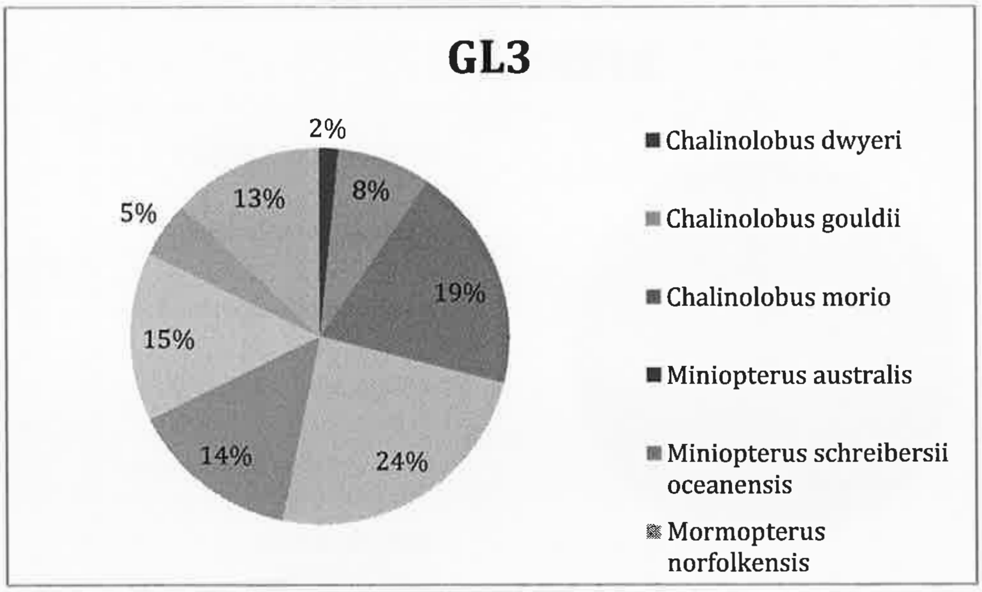

Figure 16. Bat species identified through nightly call recording by Anabat monitoring in the Grassland (GL) site over a period of 13 nights.

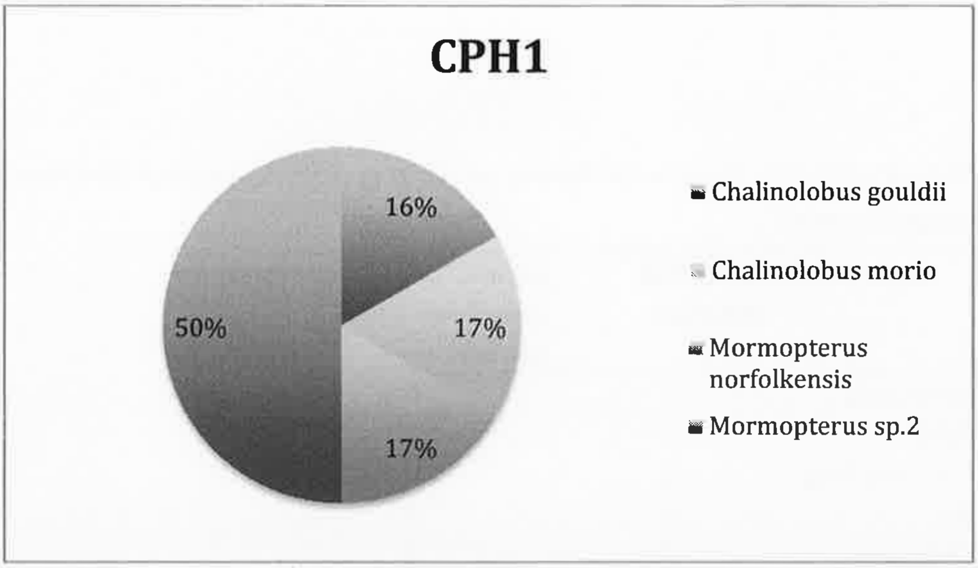

Figure 17. Bat species identified through nightly call recording by Anabat monitoring in the high quality Cumberland plain (CPH) remnant over a period of 13 nights.

3.5. Spotlighting results

The spotlighting survey identified a number of species that were not yet observed during this survey including two bird, one frog and two arboreal mammal species. The Cumberland plain remnant surveyed, which was of high quality, was more active in total than the river-flat eucalypt forest. The most common species encountered during the survey included the *Crinia signifera,* followed by the tawny frogmouth and individuals of the macropod family, which were not readily identifiable. Outside of spotlighting time segments fallow deer, Common Brushtail possum and tawny frogmouth owls were sighted within the High quality Cumberland plain remnant indicating a further increase in activity however due to the timing of the sightings these were not included in the spotlighting data sheets.

Table 6. Summary of species found in spotlighting survey on two remnant types present based on two spotlighting events.

Species	River-flat eucalypt forest	Cumberland plain woodland (High quality)
Grey butcherbird	1	0
Sugar glider	1	1
Verreaux's Tree Frog	1	0
Black rat	1	1
Ring tail possum	1	0
Crinia signifera	0	>20
Uperoleia laevigata	0	<20
Tawny frog mouth	0	2
Wallaroo	0	1
Macropods (Too distant to identify)	0	2
Total species count	5	7

3.6. Species diversity across the habitat types

The species list generated consists of 3 arboreal mammals, 7 ground dwelling mammals, 4 birds, 2 reptile, 2 amphibian, 1 invertebrate and 11 bat species (Appendix B).

Species counts from each monitoring technique were combined to give an indication of total species diversity across habitat types. In this case the River-flat eucalypt forest produced the highest number of species, followed by the grassland habitat. The Cumberland Plain woodland of high and low quality produced the same number of species despite the varying habitat quality. This remnant had the lowest species diversity of the terrestrial habitats (Figure 18). The water body habitats presented only two species of frogs through frog call identification however a third species was observed at the time of deployment which was not picked up by the recording devices as presented in the spotlighting data.

The Cumberland plain woodland (CPW) habitats produced six species of ground dwelling mammals, which proved to be higher than any other habitat type including the River-flat eucalypt forest remnant (RFEF) despite its high species diversity. Bats proved to be the most species diverse fauna group in the RFEF remnant. This remnant also produced the highest diversity of arboreal mammals. Arboreal mammals, invertebrates and birds were not observed in the low quality CPW habitat however it did produce a more bat species diversity than the high quality CPW site (Figure 19).

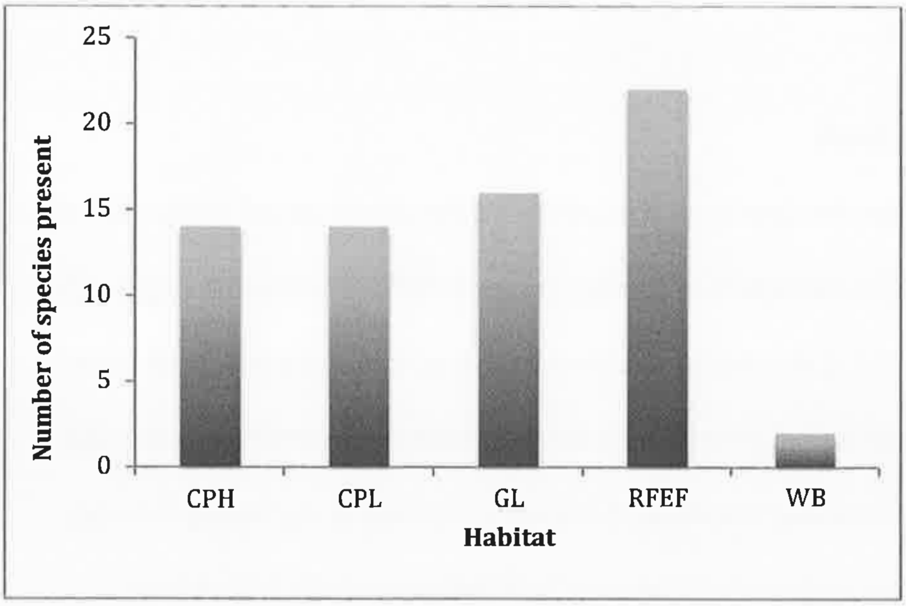

Figure 18. Total species diversity observed across habitat types during a two-week survey period (CPH=Cumberland plain woodland high quality n=4, CPL=Cumberland plain woodland low quality n=4, RFEF=River–flat eucalypt forest n=4, GL=Grassland n=3, WB= Water body n=8)

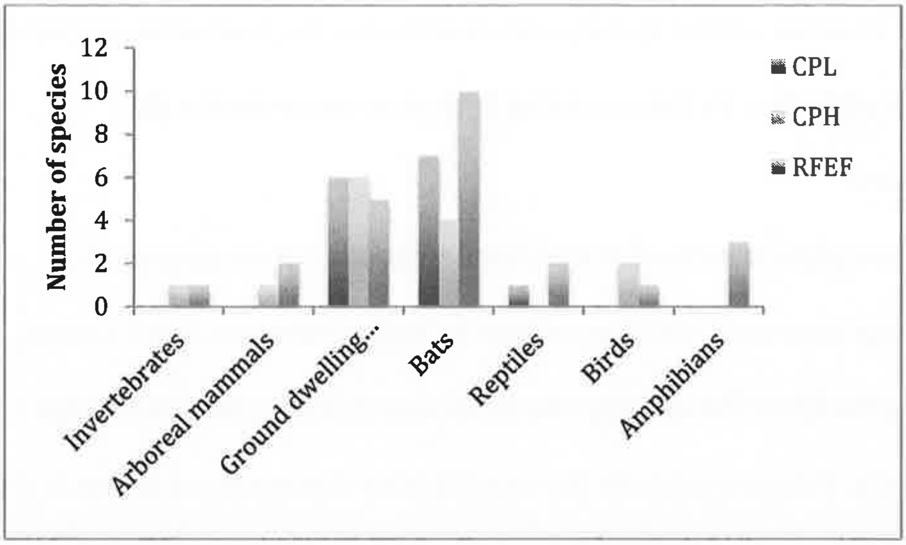

Figure 19. Species diversity across faunal groups in remnant vegetation sites over a two-week survey period (n=4, CPH=Cumberland plain woodland high quality, CPL=Cumberland plain woodland low quality, RFEF=River–flat eucalypt forest)

4. Discussion

4.1. Survey methods

This survey was the first to be conducted on the site; it aimed to gain baseline data, building an inventory of species present. Although the survey provided this information, it was not as comprehensive as it had the potential to be in surveying some faunal groups such as the arboreal mammals, reptiles and small ground dwelling mammals. Lack of replication in surveying through tunnel trapping and spotlighting may have influenced the low activity suggested in these groups. Only two of the four terrestrial habitats were surveyed through spotlighting, and only two sites in each of these habitats were selected. There for if arboreal mammals were present in the low quality Cumberland plain site or were present in higher numbers in other sites within the habitats surveyed, they were not counted and hypotheses about their habitat preference could not adequately be tested. Similarly, in the tunnel trap survey only one transect in each habitat was surveyed, limiting the ability to define relationships between the results at a particular site and their proximity to other habitat types. An example of this is where the tunnel traps were located close to a water body in the River-flat eucalypt forest remnant and the high quality Cumberland plain remnant. Had they been replicated in sites further from the water body and close to the edge of the remnant, there is the potential for differing results. Reptiles and birds were represented in the results only in instances where they could be identified using the equipment that was deployed, this equipment however has a limited ability to pick up the presence of these groups. This survey does not provide a true representation of the activity of these faunal groups in the available habitat types, active ground searches and bird survey transects will still be required in order for these groups to be represented adequately in the species list.

4.2. *Species diversity and habitat preference*

Despite achieving the main objective of this study, that being to build an inventory of base line data regarding fauna present on the property, we experienced difficulty in defining the preferred habitat of fauna. 'Wallaroo' is a relatively small conservation reserve at 38ha, and the encompassed vegetation is heavily isolated from surrounding remnants due to its location in the agricultural and urbanised matrix that now exists. Previous studies on the persistence of other faunal groups on agricultural and fragmented land have applied the island biogeography theory to their results such as Abensperg-Truan, M & Smith (1999). Referring to the suggestion made by MacArthur and Wilson (1967) that small remnant patches have similar ecological dynamics as isolated small islands, restricting the potential of population growth. The size of the largest patch of remnant, that being a river-flat eucalypt remnant patch is only 6.92ha, indicating that generally speaking the patch sizes of vegetation within the property are quite small. Little difference was noted between the species present in the River-flat eucalypt forest remnant and the Cumberland plain woodland remnant despite their potential for hosting more diverse fauna and specialist species under more elaborate circumstances. The limited opportunity available for movement across the landscape has resulted in low species diversity with few ground dwelling mammals present, The Swamp wallaby and the Wallaroo exist due to the availability of shelter in remnants and from slopes which both the swamp wallaby the wallaroo rely on (Taylor, 1984). This is evident in the increased activity observed in the high quality Cumberland plain woodland which includes resource provisions such as habitat complexity that open areas or younger vegetation patched do not offer. Very few differences were observed between the high quality Cumberland plain woodland, low quality Cumberland plain woodland, and the River-flat eucalypt forest. Any differences that were evident in initial data analysis were minimal and were non-existent when statistical analysis (independent t-test) was performed. A potential explanation for the lack of difference could be that the low quality patches were encased in higher quality Cumberland plain, and were not independent enough to demonstrate any preference by the generalists that it hosts, similarly the River-flat eucalypt remnant was joined to the Cumberland plain woodland and hosted the main water source for the property, increasing the likelihood of immigration from the remnants on the eastern side of the property. Although the differences were not found to be significant in this case, a longer more comprehensive study may highlight the evidence that does suggest preference for the complex remnant habitats. Despite the lack of complexity in the grassland site, species diversity was comparable to that of the remnant communities. This may too be attributed to its proximity to remnant vegetation and the water body's it encompasses. The presence of water body's increases the provision of resources available and host's water birds such as the swamp hen that would otherwise not exist on the property. The lack of vegetation on a larger scale across the fragmented landscape forces local populations to take advantage of all available resources, using remnants as a network particularly when they are situated around the boundary of the property and provide the only protected route to and from surrounding properties.

4.3. Micro bat species diversity

The micro bats were one faunal group that were well represented in the species list generated. The results of this group were representative of the habitat types present on the property and the resource requirements of the species. Many species were found to be protected or vulnerable species and habitat type reflected species that were common of that habitat type. The grassland site yielded the highest bat activity. The high number of

Mormopterus norfolkensis (East-coast free tailed bat) and *miniopterus schreibersii oceanensis* (Eastern bent-winged bat), which are both listed as vulnerable, supports studies that suggests that although these species require tree hollows and caves for roosting, they still require open areas for foraging and fly ways, meaning being a small colony species they respond manage quite well to the agricultural landscape providing the necessary roosting requirements are met (McConville & Law, 2013, Threlfall, Law & Banks, 2012). This may explain why they were also represented in more complex sites such as in the Cumberland plain remnant. The most active species of bat was *Chalinolobus gouldii* (Gould's wattled bat) which had a very high presence in the River-flat eucalypt forest sites and was also present in the Cumberland plain woodlands however was barely existent in the grassland site, indicating a preference for more complex habitats for both foraging and roosting. This species has been found to be quite particular in its roosting and therefore requires access to old but living trees with hollows, such as those in the River-flat forest (Lumsden, Bennett & Silins, 2002).

Perhaps the most noteworthy finding regarding bats was the slight presence of Sydney's only fishing bat, *Myotis macropus*, which surprisingly was absent from the River-flat eucalypt forest, which encompasses the creek. It was identified only in the grassland site. Although the species is a specialist species in terms of its roosting requirements, it was obviously only identified during periods of activity. Its reliance on open water body's for foraging suggests that although it may roost in nearby remnants the closed water body's in the grassland allow for more energy efficient foraging that the creek within the river-flat eucalypt remnant (Campbell, 2009).

4.4. Introduced species

This study highlighted a strong presence of introduced species in the area, species such as the fox (*Vulpes vulpes*), hare (*Lepus europaeus*), and fallow deer (*Dama dama*). Also likely in the urban and agricultural landscape on which the survey took place although not observed are the feral cat (*Felis catus*) and the common dog (*Canis lupus familiaris*). These species tend to thrive in fragmented environments where prey in the form of native mammals, birds and reptiles are forced into smaller patches and are therefore more easily accessible (Misfud & Woolley, 2012). The presence of hares in particular can encourage introduced predators such as the fox into altered landscapes as they are a favored prey, in turn this can result in opportunistic predation on native fauna present in the area. Similarly, feral cats, which are quite predominant in Western Sydney, feed heavily on birds and small arboreal mammals, which may contribute to the persistence of populations at this site (May & Norton, 1996). Although fallow deer do not have the same direct impact on native fauna as more predatory species such as the fox and cat, they do directly impact on the composition of remnants. This species was represented in every habitat type surveyed, indicating a strong persistence even in the altered landscape. Here they browse on vegetation, stripping bark and rubbing against the trunks of larger trees and shrubs. This provides opportunity for infection, invasion of exotic species and degrades soil, effecting the complexity and composition of the ecosystem at multiple levels particularly in open woodlands (Moore, Hart & Langton, 1999). The preference for open woodlands by deer may explain the high numbers of deer represented in the low quality Cumberland plain habitat in this survey, further decreasing the quality of the remnant.

5. Conclusion

Although a baseline species list for 'Wallaroo' has been generated, more comprehensive wildlife surveys are necessary for some faunal groups such as arboreal mammals and birds. Active grounds surveys, bird surveys and further spotlighting would greatly assist in building an inventory for the property and better guide future management decisions. Based solely on the results of this survey, management should begin with restoring and protecting the remnants that do remain and eradication of invasive species before revegetation is considered. The reason being that resident fauna are seemingly more reliant on the older more established vegetation and revegetation may not benefit current residents in the short term. The continued protection from stock and removal of invasive weeds will greatly support the natural regeneration of remnants on the property, as will continued monitoring of habitat use.

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Appendix A) Independent t-test results

Number of individuals in high quality Cumberland plain woodland compared to low quality Cumberland plain woodland

Data Summary			
	A	B	Total
n	4	4	8
ΣX	60	76	136
ΣX^2	1682	1618	3300
SS	782	174	988
mean	15	19	17

Results

$Mean_a - Mean_b$	t	df			
-4	-0.45	6	P	one-tailed	0.334256
				two-tailed	0.668512

Number of individuals in high quality Cumberland plain woodland compared to River-flat eucalypt forest remnant.

Data Summary			
	A	B	Total
n	4	4	8
ΣX	76	65	141
ΣX^2	1618	1589	3207
SS	174	532.75	721.875
mean	19	16.25	17.625

Results

$Mean_a - Mean_b$	t	df			
2.75	+0.36	6	P	one-tailed	0.36559
				two-tailed	0.731180

Number of Wallaroo in Low quality Cumberland plain woodland compared to high quality Cumberland plain woodland.

Data Summary			
	A	B	Total
n	4	4	8
$\sum X$	19	5	24
$\sum X^2$	187	25	212
SS	96.75	18.75	140
mean	4.75	1.25	3

Results

$Mean_a - Mean_b$	t	df	P		
3.5	+1.13	6		one-tailed	0.150808
				two-tailed	0.301616

Number of Wallaroo in High quality Cumberland plain woodland compared to River-flat eucalypt forest.

Data Summary			
	A	B	Total
n	4	4	8
$\sum X$	19	4	23
$\sum X^2$	187	10	197
SS	96.75	6	130.875
mean	4.75	1	2.875

Results

$Mean_a - Mean_b$	t	df	P		
3.75	+1.28	6		one-tailed	0.1239025
				two-tailed	0.247805

Number of Swamp wallaby in high quality Cumberland plain woodland compared to low quality Cumberland plain woodland

Data Summary			
	A	B	Total
n	4	4	8
ΣX	21	18	39
ΣX^2	177	186	363
SS	66.75	105	172.875
mean	5.25	4.5	4.875

Results

$Mean_a - Mean_b$	t	df		P	
0.75	+0.2	6	P	one-tailed	0.4240435
				two-tailed	0.848087

Number of Swamp wallaby in high quality Cumberland plain woodland compared to River-flat eucalypt forest remnant.

Data Summary			
	A	B	Total
n	4	4	8
ΣX	21	17	38
ΣX^2	177	205	382
SS	66.75	132.75	201.5
mean	5.25	4.25	4.75

Results

$Mean_a - Mean_b$	t	df		P	
1	+0.25	6	P	one-tailed	0.4054635
				two-tailed	0.810927

Number of Fallow deer in High quality Cumberland plain woodland compared to low quality Cumberland plain woodland.

Data Summary

	A	B	Total
n	4	4	8
$\sum X$	24	30	54
$\sum X^2$	166	518	684
SS	22	293	319.5
mean	6	7.5	6.75

Results

$Mean_a - Mean_b$	t	df			
-1.5	-0.29	6	P	one-tailed	0.390789
				two-tailed	0.781578

Number of Fallow deer in High quality Cumberland plain woodland compared to River-flat eucalypt forest remnant.

Data Summary

	A	B	Total
n	4	4	8
$\sum X$	24	23	47
$\sum X^2$	166	161	327
SS	22	28.75	50.875
mean	6	5.75	5.875

Results

$Mean_a - Mean_b$	t	df			
0.25	+0.12	6	P	one-tailed	0.4542005
				two-tailed	0.908401

Number or species present in high quality Cumberland plain woodland compared to low quality Cumberland plain woodland.

Data Summary

	A	B	Total
n	4	4	8
ΣX	18	9	27
ΣX^2	90	29	119
SS	9	8.75	27.875
mean	4.5	2.25	3.375

Results

$Mean_a - Mean_b$	t	df	P		
2.25	+1.85	6		one-tailed	0.056895
				two-tailed	0.113790

Number or species present in high quality Cumberland plain woodland compared to low quality Cumberland plain woodland.

Data Summary

	A	B	Total
n	4	4	8
ΣX	18	17	35
ΣX^2	90	75	165
SS	9	2.75	11.875
mean	4.5	4.25	4.375

Results

$Mean_a - Mean_b$	t	df	P		
0.25	+0.25	6		one-tailed	0.4054635
				two-tailed	0.810927

Appendix B) Species list for 'Wallaroo' conservation reserve

Arboreal mammal	Ground dwelling mammal	Birds	Reptiles & Amphibian	Invertebrate	Bats
Brushtail possum	Fallow deer	Tawny frogmouth	Water dragon	Garden snail	*Chalinolobus dwyeri*
Sugar glider	Fox	Purple swamphen	Skink		*Chalinolobus gouldii*
Ring tailed possum	Hare	Magpie	*Crinia signifera*		*Chalinolobus morio*
	Black rat	Grey butcher bird	*Uperoleia laeigata*		*Miniopterus australis*
	Mouse				*Miniopterus schreibersii oceanensis*
	Wallaroo				*Mormopterus norfolkensis*
	Swamp wallaby				*Mormopterus sp.2*
					Myotis macropus
					Nyctophilus spp.
					Rhinolophus megaphyllus
					Tadarida australis