THE POWERFUL OWL PROJECT

Conserving owls in Sydney's urban landscape

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Acknowledgements

The project would not have been possible without the generous time and commitment gifted to the project from all the volunteers that participated. It would be impossible to name all the volunteers here but they all know who they are. A special mention also, to all those members of the public who sent in owl sightings, a valuable addition to our understanding of the owls and where they are.

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Front cover photos: All photos by Kristen Hardy. Clockwise from top left: Young in hollow; adult female; adult male with ringtail possum; two recent fledglings.

"It is not hard to become entranced by owls. There is an aura about them, which no other birds possess." David Hollands

Contents

Executive Summary

This project is the result of collaboration between a research scientist and an inspired community member, both focused on the conservation of the Powerful Owl. Adoption of the project by BirdLife Australia provided the resources necessary to further develop the idea. The project's focus has been to investigate the breeding ecology of the species in Sydney's urban landscape, engage the broader community in urban conservation and enhance management of the Powerful Owl.

The Powerful Owl Project had two main avenues for participation, volunteers and the general public. Three hundred and thirty three volunteer owl observers were trained in survey techniques and allocated to survey sites. They were typically middle aged with even numbers of males and females. The volunteers were generally interested in birds and bird watching, were engaged already with the natural world and often already supporting conservation initiatives. Participation increased knowledge of urban conservation and all volunteers felt that their contribution was valuable. Over 800 members of the general community were also engaged through submitting less formal observations of opportunistic sightings. These records underwent a vetting process and contributed significantly to narrowing down locations of new breeding territories.

Ecological research was the underpinning of the project, with a broad range of investigations focused on breeding. Sixty breeding territories were mapped within the Sydney urban area, with a fledgling success of 1.22. Dietary changes were observed from previous studies and between the breeding and non-breeding season, primarily reflecting prey abundance. Powerful Owls were observed to nest in proximity to roosting habitat in drainage lines, typically high in the catchment area where hollow-bearing trees were most common. Breeding territories were also focused on sites with high prey abundance and intact foraging habitat. Numerous threats are present within the urban context, with a large proportion of deaths attributed to car-strike. Other threats included urban development and land management practices such as hazard reduction burning.

Education for all sectors of the community was an important component of the project. Avenues of engagement included 29 talks and workshops, various media avenues, web-based resources, an ongoing schools education program, and presentation at scientific conferences. Resources were also developed and disseminated to land managers to improve their ability to manage the species. These included management guidelines covering development and land management, survey and important habitat characteristics.

Overall the project has been hugely successful in engaging the community and fostering an understanding of the value of our urban bushland remnants. Over 1,000,000 people were reached and an increase in understanding of the Powerful Owl has been achieved utilising citizen science, for researchers, land managers and the community.

1. Introduction

This project is the result of collaboration between a research scientist and an inspired community member, both focused on the conservation of the Powerful Owl. Adoption of the project by BirdLife Australia helped to secure funding and provided an avenue to enlist community volunteers to participate. The project's focus has been to investigate the breeding ecology of the species in Sydney, engage the broader community in urban conservation and enhance management of the Powerful Owl.

1.1 Background

1.1.1 The project

Dr Rod Kavanagh has been keeping records on Powerful Owl nests throughout Sydney for over 25 years. This work, both formally and informally, has been undertaken as part of ongoing research and work on owls in Sydney's urban bushland (for example Kavanagh 2003). One of the recommendations within this published research was the need for broad-scale community involvement in voluntary surveys for owls.

In 2009, unknown to Rod, an inspired young music teacher by the name of Kristen Hardy had begun investigating the occurrence of Powerful Owls in the northern beaches of Sydney following a chance meeting with a juvenile Powerful Owl (see story overleaf).

The eventual coming together of Rod and Kristen created 'The Powerful Owl Project'. Through Rod's involvement with BirdLife Southern NSW, the project was adopted by BirdLife Australia through its urban bird conservation program, Birds In Backyards (BIBY).

In 2011, BIBY ran a pilot project to understand the potential of the project. Following advertising, over 50 volunteers were engaged and trained. The pilot project was a huge success and further project funding was sought through the NSW Environment Trust Education (Community) Grants. It was thought that the Powerful Owl provided an icon species to engage the wider community and a suitable vehicle to spread the message of urban conservation.

Funding was secured through a two year grant with the Environment Trust as well as two lots of additional support from BirdLife Southern NSW through their annual 'Twitchathon' fund raising events.

Powerful Owl family. Kristen Hardy

A POWERFUL IMPACT by Kristen Hardy

One Spring morning in 2009, I was awe-struck when I happened to notice two newly fledged Powerful Owls roosting in broad daylight in my Sydney backyard. They were divine, like two fluffy white snowballs, but with beaks, feathers and staring yellow eyes that were fixed upon me and followed my every move from the tree above.

I became entranced that day, and owls have been a huge part of my life ever since.

After becoming captivated by these two fluff-balls, I embarked upon a personal quest of curiosity, to find out everything I could about this species, the largest of all Australia's owls. I wanted to know where they were, how many there were, if they were breeding, what they were eating and much more. This would eventually become The Powerful Owl Project.

In 2010, I had an article published in the local newspapers asking for members of the public to report their sightings of these magnificent birds to me. The response to this was overwhelming and through it I was able to locate a number of individual birds and breeding pairs, keep tabs on owlets and how many were being produced and get a rough estimate of how many territories were in my local area.

My camera went everywhere I did and by photographing and filming these divine birds, I hoped to raise public awareness as to their presence in suburbia and spark public interest in their long-term conservation.

As I had no scientific training (I was working as a music teacher at the time), I presented my findings to Australian owl expert, Dr Rod Kavanagh who developed my idea further. It was then adopted by Birdlife Australia (Australia's leading conservation organisation for birds) and has been successfully running as one of their projects since 2011.

When embarking upon this journey, I did not have any training in any conservation, ecology or scientific related field and the entire experience has taught me that any passionate individual has the power to make a difference.

Kristen with a juvenile owl in the bushes behind

1.1.2 The Powerful Owl

The Powerful Owl (*Ninox strenua*) is the largest owl in Australia, standing at just over 60 cm with a wingspan of 140 cm (Simpson & Day 1996). It is one of a number of threatened forest owls in Australia, being listed as threatened or vulnerable in all States that it occurs in.

The Powerful Owl is found in the forests of eastern Australia from north of Brisbane down the coast through Melbourne and just making it around to South Australia (Simpson & Day 1996; Haywood 2010). Curiously, it survives within many of our cities despite its size and threatened status (Kavanagh 2003; Cooke et al. 2002).

Predominantly feeding on possums and gliders, the Powerful Owl is a specialist hunter of arboreal prey with the bulk of its diet being Common Ringtail Possums (*Pseudocheirus peregrinus*) and Greater Gliders (*Petauroides volans*), along with Common Brushtail Possums (*Trichosurus vulpecula*), Flying-foxes (*Pteropus* spp.) and birds (Kavanagh 2002a). The species is considered to mate for life and breeds during winter, nesting in hollows in large, old trees from May to October (Higgins 1999).

Adult female Powerful Owl. Kristen Hardy

1.1.3 Citizen science

Citizen science is the collection of scientific data by volunteer members of the community. Although citizen science has been in existence for a long time (Havens & Henderson 2013), there is an increasing strategic utilisation in large projects (Tulloch et al. 2013; Cooper et al. 2014).

Citizen science provides several opportunities to undertake large widespread studies and to collect large amounts of data (Tulloch et al. 2013). Inherent in the use of citizen science, however, is the management of volunteers and quality and accuracy of the data collected

(Cooper et al. 2014; Szabo et al. 2012). None of these need be road blocks to the application of citizen science, just appropriate study design to take into account these limitations.

This project is an example of a grass roots citizen science endeavour. A project born from a young member of the community full of initiative, along with a seasoned research scientist advocating the need for community driven surveys.

1.2 Aims and Objectives

This project aims to educate the community and a range of stakeholders about the importance of landscape level habitat management for the protection of biodiversity by using a vulnerable icon species, the Powerful Owl.

The Powerful Owl appears to be widely distributed within the Sydney region, with previous estimates of approximately 20–30 pairs and at least fifteen confirmed breeding locations (Kavanagh 2003). While the species has had a high level of community interest, there was no formal process for coordinating information about the distribution and status of the Powerful Owl in the Greater Sydney region. Little was known about the exact roosting and breeding locations and requirements of Powerful Owls and very little information was available about their fidelity to nesting sites and annual breeding success.

Powerful Owls also have large home ranges (often larger than 1000 ha; Kavanagh 2002b) that are likely to stretch beyond the boundaries of individual Local Government Areas and thus, whilst land managers may know of birds in their area, unless there is communication between different Councils and other land managers, it is impossible to know the actual population size of the birds and the importance of various individual bushland remnants across the landscape.

This project stimulates and harnesses community interest in this iconic Australian bird by engaging the general public in citizen science and in doing so, educates the general public in ways that are likely to significantly enhance efforts to ensure the owls long-term conservation.

In consideration of the above, the objectives of The Powerful Owl Project were:

1. To engage the community to collect data to inform the conservation status of Powerful Owls in the Sydney Basin.

2. To identify site-specific management recommendations for all stakeholders and land managers with breeding pairs of Powerful Owls.

3. To inform, coordinate and support management amongst stakeholders and between land managers for conservation of Powerful Owls and other species.

During the course of the project, it was clear that stakeholders beyond the Sydney region were interested. As a result of this, the project was expanded in a more limited form through the urban areas of the Central Coast and north to Newcastle in 2013 and 2014.

2. Powerful Owl Volunteers & Community Involvement

The Powerful Owl Project had two main avenues for participation. Volunteer 'Owl Observers' who were trained in survey techniques and allocated to survey sites; or members of the general community who submitted less formal observations. Volunteers were surveyed to understand who they were and what they got from participation.

2.1 Volunteer Recruitment and Training

2.1.1 Recruitment

Volunteers were sourced via a number of avenues. These included media releases in local newspapers, radio interviews, Council volunteer newsletters, bird club newsletters and word of mouth.

In total 333 volunteers registered and were engaged in some capacity with the project between 2011 and 2014. Of these, 287 undertook active surveys of sites. The number of volunteers steadily grew each year as the project matured, with 51 volunteers in the pilot project in 2011, 69 in 2012, 124 in 2013 and 127 in 2014. On average the volunteer retention rate was 51% from year to year.

Predominantly volunteers participated for only one year (68%) (Figure 1). As with many volunteer programs, there was a core group of people (12%) that participated in 3 or more years of the project.

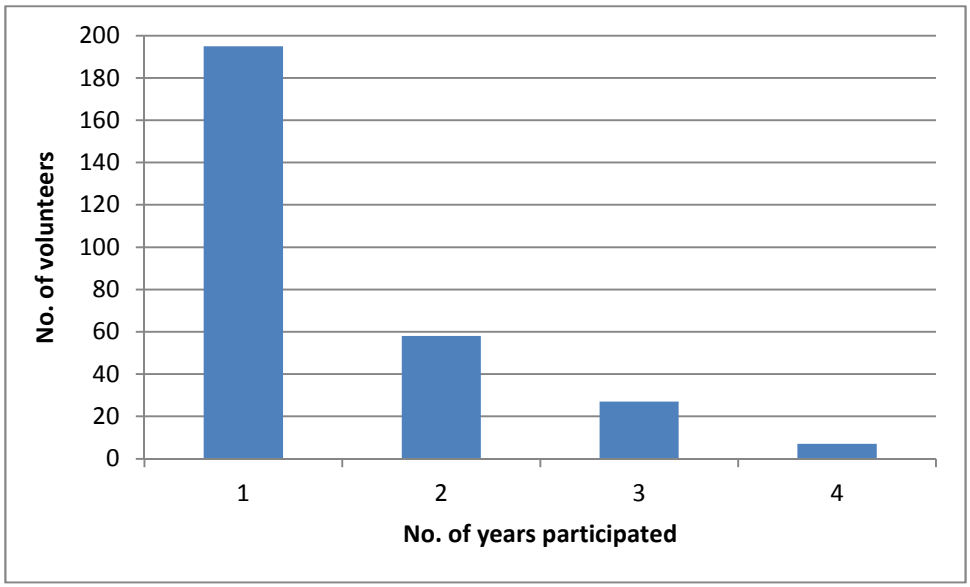

Figure 1: Number of years volunteers participated

2.1.2 Training

All volunteers were encouraged to attend a free 3 hour training workshop. These workshops provided some general project information, survey techniques, ethical responsibilities and safety issues for both volunteers and the owls.

For those volunteers who could not attend workshops, electronic training resources were provided. In addition to these resources, questions and discussions were encouraged between project officers and volunteers.

In general there was more than one volunteer per survey site. These volunteers were introduced and encouraged to discuss results with each other to help develop each other's knowledge along with ensuring there was no doubling up of effort through each stage of the surveys.

2.2 Community Involvement

As part of promotional material, requests were made for members of the public to contact the project with current records of Powerful Owls. To ensure accuracy, records were vetted through three different measures: conversations with observers; photo verification (photos were requested or photos of common nocturnal species were sent to observers); and consideration of the likelihood of the location.

During the course of the project, over 600 observations of Powerful Owls in unique locations were submitted. The numbers of these unique observations were greatest in the first two years of the project, and slowly reduced as owls were repeatedly reported in known locations (see Chapter 3.2.1).

2.3 Understanding the Volunteers

Volunteers were asked to undertake a survey before and after participating in the project. This was undertaken to understand who the volunteers were and what the impact was of participation.

In total, 106 volunteers filled out the initial before questionnaire but only 16 of those filled out the second, after participation questionnaire. We were able to follow these 16 individuals across their experience of participation and also understand the demographics of all these 106 volunteers.

2.3.1 Who were the volunteers?

Volunteers were typically middle aged (Figure 2). Most had completed some form of education post high school (Figure 3) and 42% were male and 58% female. A large proportion of volunteers were members of wildlife or conservation organisations (Figure 4) and unsurprisingly over 80% participated in passive nature or wildlife experiences such as bushwalking, visiting zoos or wildlife sanctuaries or watching nature documentaries (Figure 5).

Only 21% of volunteers were a member of a bird club or organisation (including BirdLife Australia), although 74% considered themselves to be bird watchers (Figure 6). Over half of these people were regular bird watchers, with 32% bird watching every week and 18% bird watching once a month (Figure 6).

The main motivation of volunteers in participating in the project was largely an interest in conservation, both specifically for birds and in general. An additional 32% of volunteers had an interest in or an experience with Powerful Owls prompting them to participate (Figure 7).

Encouragingly, over 80% of participants recognised that habitat loss was the key threat impacting on native birds (Figure 8), which broadly is true (Garnett & Crowley 2000).

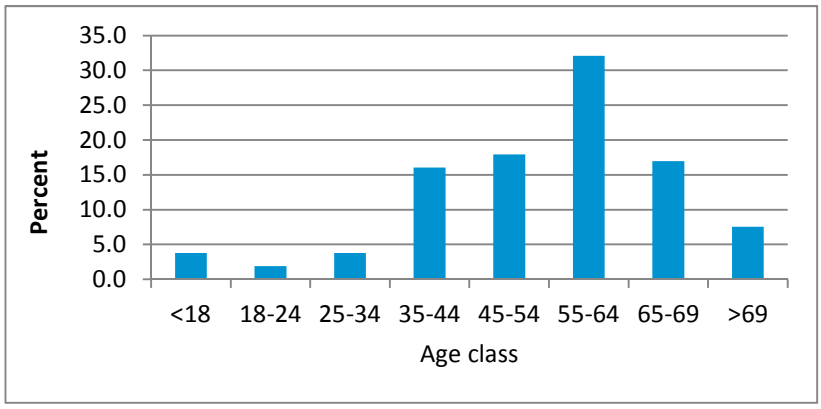

Figure 2: Age of volunteers.

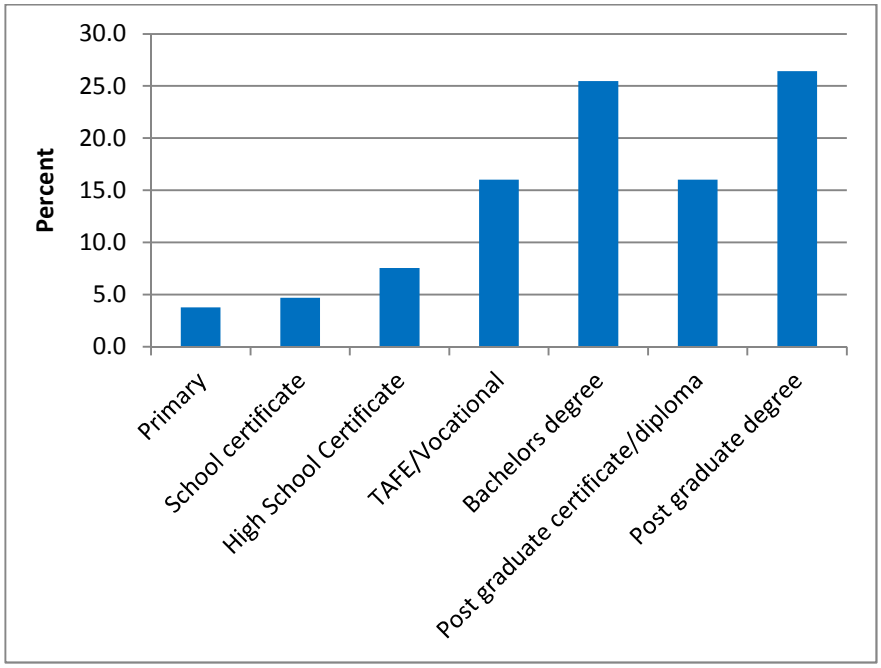

Figure 3: Highest level of education of volunteers.

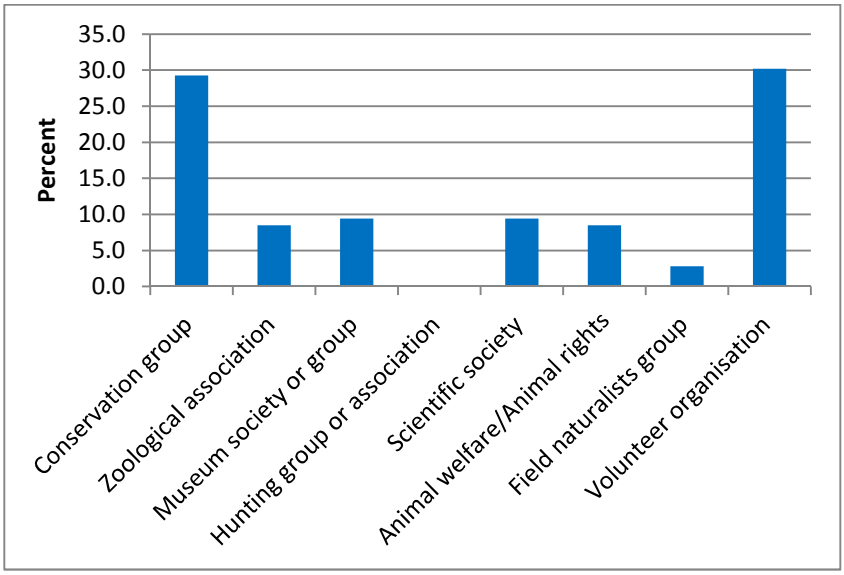

Figure 4: Membership of other wildlife or conservation organisations.

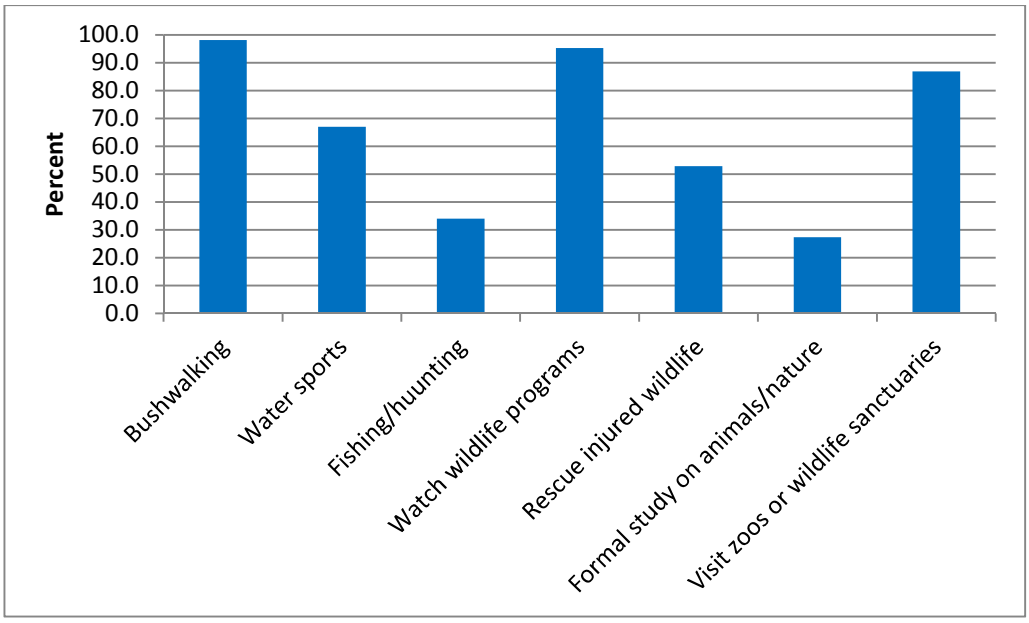

Figure 5: Other activities volunteers take part in.

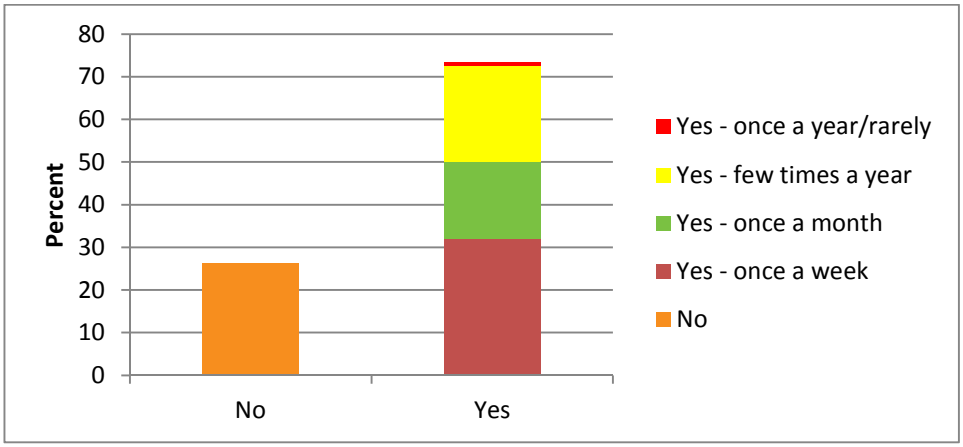

Figure 6: Do the volunteers specifically go bird watching?

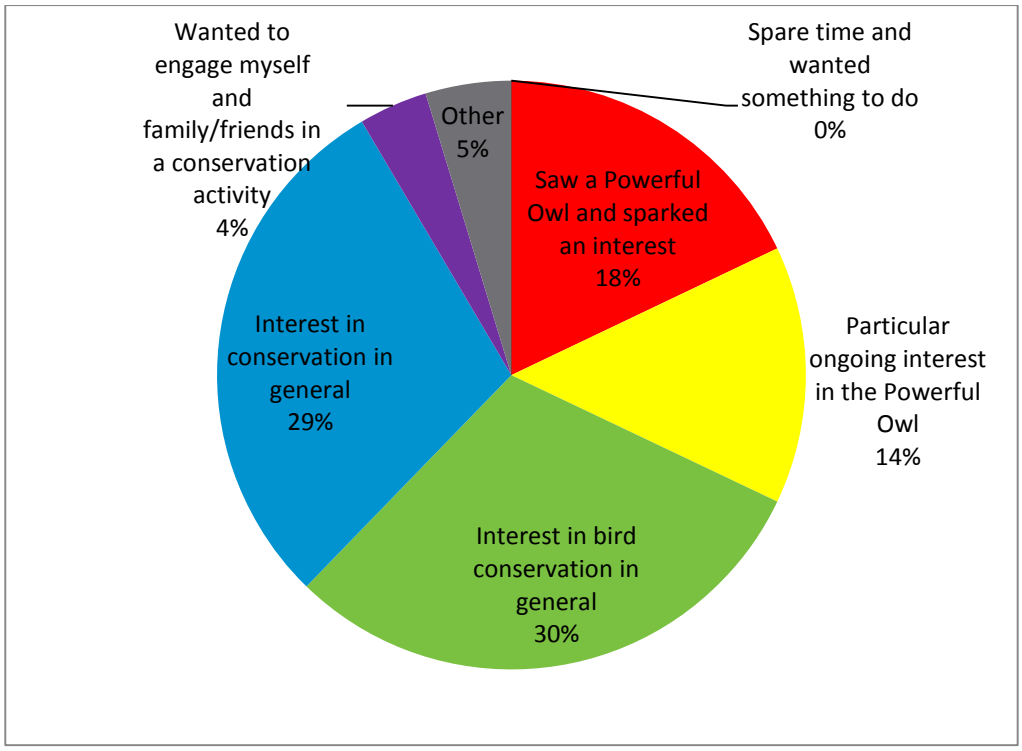

Figure 7: Main motivation of volunteers.

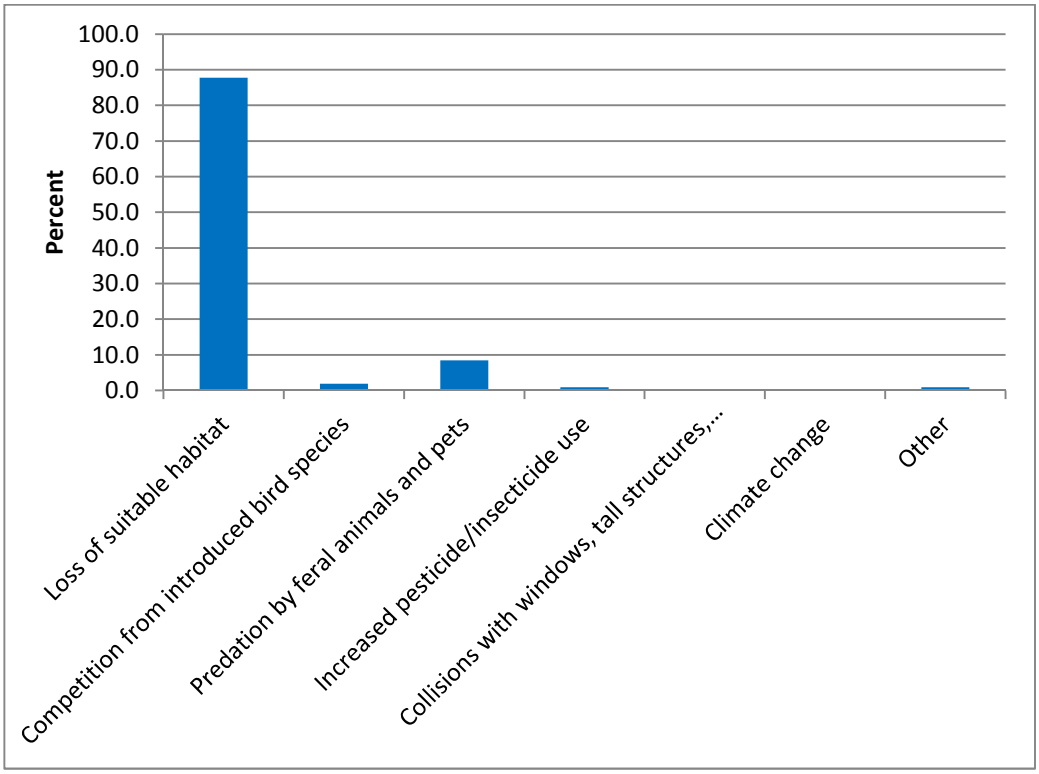

Figure 8: What is the biggest problem affecting native birds?

2.3.2 What did volunteers get from participating?

As well as understanding who the volunteers were, an attempt was made to understand the knowledge volunteers had of the Powerful Owl and whether that changed through participation in the project.

When answers were pooled across the volunteers, the group knowledge on Powerful Owls and their threats increased as a result of participation (Figure 9 & Figure 10).

In relation to Powerful Owls, potentially the most important increase in knowledge was about the roosting and nesting habitat (Figure 9). This knowledge is critical for communities to build an understanding of their local area.

When looking at threats to Powerful Owls, the biggest increases in knowledge was that fire regimes were important in Powerful Owl survival and conservation, loss of nesting and breeding resources (habitat and hollow-bearing trees) and car-strike (Figure 10 and discussed further in Chapter 3). Also of note was the decrease in numbers of people who considered secondary poisoning to be a significant threat. This is likely due to an increased understanding by volunteers of the dominance of arboreal prey that the Powerful Owl consumes, rather than ground dwelling fauna which is more likely to be the focus of poison control measures. An interesting artefact in the data was the increase in numbers of people considering collision with windows and tall structures a threat. It is likely that this comes from a photo commonly shown in talks where a Powerful Owl had hit a lounge room window and was lying on a verandah.

When individuals (16) were followed across time, rather than the group as a whole, only four (24%) people improved on their overall knowledge of owls. This was based on the overall number of questions answered right or wrong (Figure 11). One (6%) of these individuals got more questions wrong after participation than before.

All volunteers felt as though they contributed to the project, although 12% felt that their expectations of participation were not met due to not finding a nest. Encouragingly, several volunteers mentioned that the experience led them to talk to family and friends about the Powerful Owl and had opened their eyes to their local area.

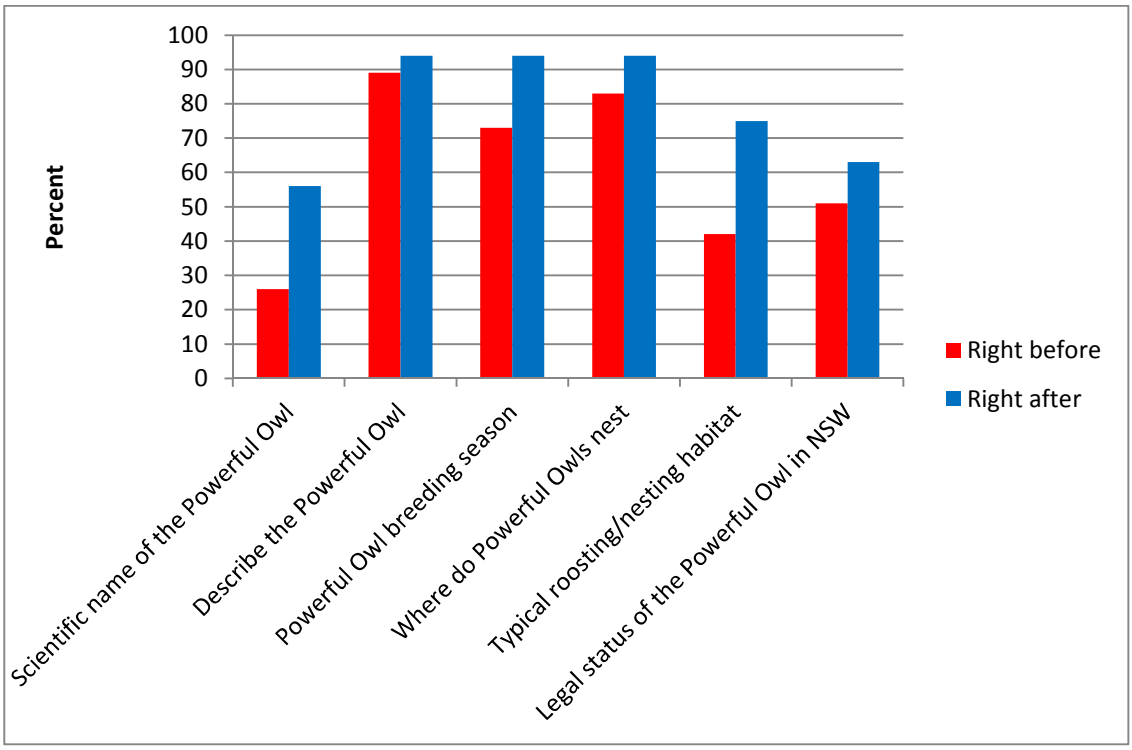

Figure 9: Volunteer knowledge of the Powerful Owl taken as a group before and after participation.

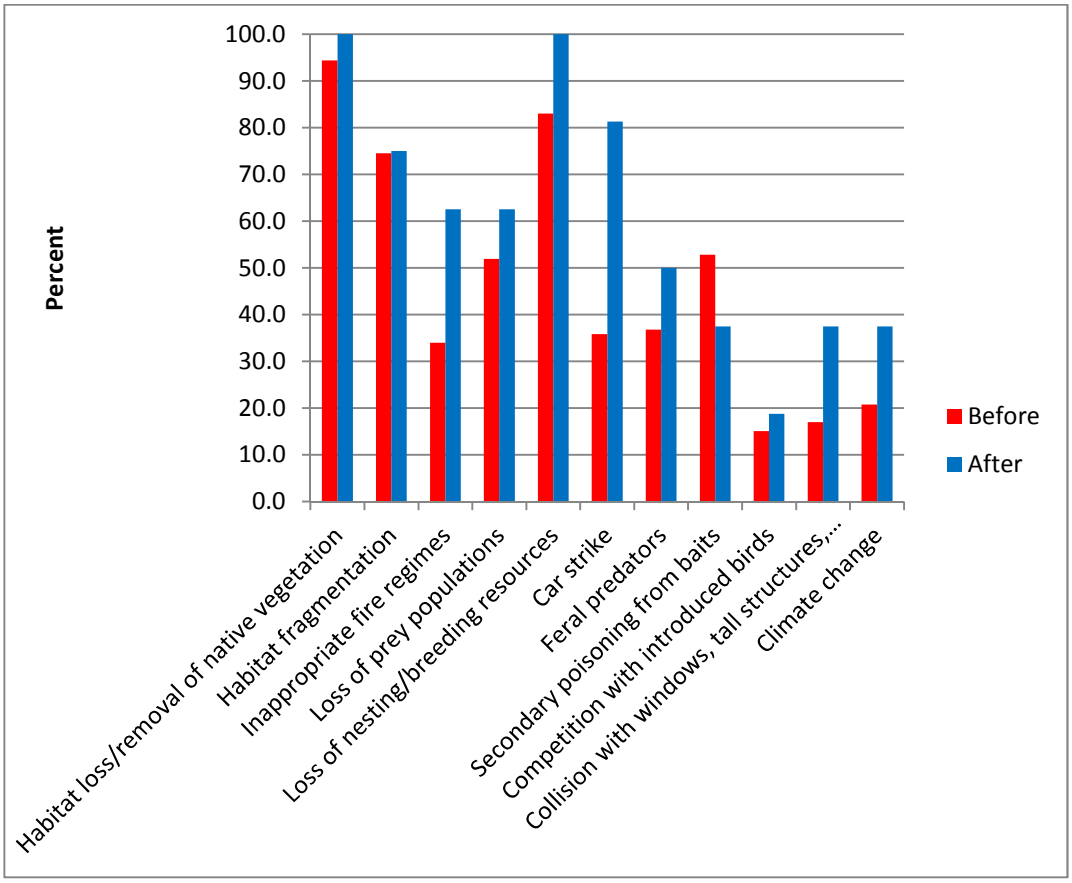

Figure 10: What are the current threats to Powerful Owls taken as a group before and after participation.

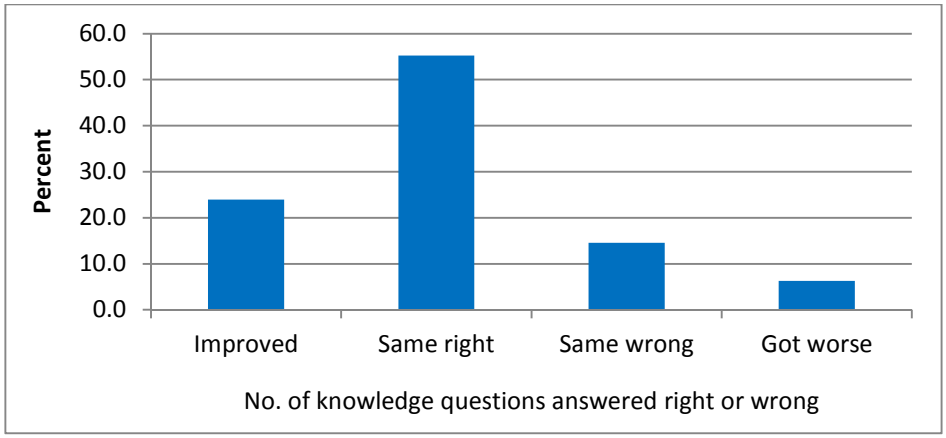

Figure 11: Volunteer knowledge of the Powerful Owls. Individuals followed over the first year of involvement presented as a comparison of the number of questions answered right or wrong using the same questions before and after participation.

3. Ecological Research

Ecological research undertaken as part of the project involved the community and volunteers as much as possible. Investigations included; breeding sites and success; dietary changes; environmental, landscape and habitat characteristics; and threats in the urban context.

Data are only provided and analysed for the territories located in Sydney, unless specifically identified otherwise.

3.1 Methods

3.1.1 Identifying breeding sites

To find and map breeding sites of the Powerful Owl, a number of techniques were combined. There were a number of breeding sites and nest trees already known within the Sydney area from previous work undertaken by Kavanagh (2003) and those nests identified by Kristen in the formative years of the project. Additional nests were considered likely and these were identified using the following techniques.

Records of Powerful Owls from the NSW BioNET Wildlife Atlas and sightings from the general public which were sent into the project were mapped across the study area.

Areas of likely habitat were identified in proximity to these records, particularly records from within the breeding season, using aerial photography. Habitat was considered likely where it was in proximity to drainage lines and contained suitable forest vegetation as determined from aerial photo interpretation.

Volunteer 'Owl Observers' were engaged to search these areas of likely habitat for evidence of owls, owls and breeding sites. The process of these investigations was based on volunteer availability and was concentrated within the breeding season and followed the general pattern of:

1. Listening for owls early in the breeding season (April-May). This was undertaken in the early evening from vantage points in an attempt to identify the general location of breeding site roosts as at this time of the year the owls typically called from a location in proximity to the nesting site. This was repeated over 4 to 5 nights of suitable listening conditions.

2. Searches for evidence of the owls were then undertaken during the day in the general locations where owls were heard calling from. These searches were focused along the drainage lines where preferred roosting habitat of mesic vegetation with denser dark canopies occurred (Kavanagh 2003). Owl evidence that was searched for included large areas of whitewash, pellets, suitable hollow-bearing trees adjacent to the roosting habitat, and always roosting birds.

3. Once evidence of owls was identified, further listening surveys were undertaken in the vicinity. These surveys were again undertaken in the early evening, throughout the breeding season. Calling birds located using these techniques were often found to be in close proximity to the nest tree and continued observations of the behaviour of the owls in the early evening along with an understanding of the location of hollow-bearing trees in the area would often result in the identification of the nest tree.

4. If a nest tree was identified, approximately weekly monitoring was undertaken to follow the success of the nesting attempt. Alternatively, if nest trees were not identified, surveys of common roosting sites were continued to observe the behaviour of the owls. When adult females were observed regularly outside of the hollow, listening surveys for chicks were undertaken in the evenings. Often, chicks were heard within the hollow prior to fledging. Where the nesting tree was not identified, continued evening surveys commonly recorded chicks following fledging due to their characteristic call.

Protocols were developed to help and safeguard volunteers, and of course, to ensure minimal disturbance to the birds at this critical time of the year. These included:

- do not intentionally get closer than 30 m to birds or their nests,
- undertake surveys in pairs or only small groups of less than 4 or 5 people,
- do not advertise the location of the nest tree,
- reduce flash photography,
- do not shine torches on animals for longer than about 10 seconds at a time.

In the evolution of the project, additional territories were recorded around the periphery of the urban area of Sydney. These territories are not displayed or analysed as part of this work as the focus was on the urban context.

Data were also collected on territories between the Central Coast and Newcastle in 2013 and 2014. Due to a reduced volunteer capacity throughout this region, comprehensive data were not obtained from all breeding sites. These data have been mapped but they do not form part of any detailed analyses.

Data on breeding success were recorded following the successful fledging of young. Categories of data were:

- 1 chick – one chick successfully fledged.
- 2 chicks – two chicks successfully fledged.
- Owls about – adult owls were observed in the territory during the breeding season but either the confirmation of a nesting attempt was never established, or the outcome of nesting was never established. Generally this was due to volunteer availability or expertise.
- Failed – confirmed nesting behaviour was observed such as owls entering the hollow throughout the breeding season with prey or chicks were observed in the hollow, but subsequently young failed to fledge.

The fate of fledged chicks was not followed closely, with the foremost aim to record fledging success.

3.1.2 Owl timelines

Volunteers were asked to send in by email all interesting observations. Often additional information was requested or discussed, and from this critical data were extracted. Information collected included timing of significant events such as; owls seen for the first time in the territory; pair bonding behaviour; mating; owls entering the hollow; chicks seen or heard inside the hollow; female out of the hollow; and chicks fledged.

3.1.3 Diet composition

During the course of all surveys in 2012 and 2013, volunteers were asked to collect pellets from known roosting sites. These pellets were then examined for prey items by identifying the bones and hair present and also other remains such as feathers and beetle carapaces.

The bones were identified by comparison to museum specimens and reference to Lavazanian (1996). Hair was identified using the HairID tool (Triggs & Brunner 2002).

Pellets were investigated through a number of avenues. As part of work by project officers, within a workshop setting provided for interested volunteers, by Julia Murphy for a major third year project as part of a Conservation Biology course at the University of New South Wales and by Stuart Foggo, a volunteer intern at BirdLife Australia's Discovery Centre in Sydney.

The proportions of various dietary items were compared to previous results collected 18 to 24 years previously in the same areas by Kavanagh (2002a, 2003) and between breeding and non-breeding seasons. Due to a large number of pellets coming from one location (Moore Reserve), only a sub-sample from this site was included in the analysis.

Comparisons of the proportions of prey species comprising the diet were investigated using Chi-square analyses.

3.1.4 Environmental variables

This work was undertaken by Grant Lubyckij as part of his Bachelor of Natural Science at the University of Western Sydney in conjunction with the Powerful Owl Project. Edited extracts from his report are provided here, with additional statistical analyses undertaken.

This study utilised several methods to identify different characteristics of the Powerful Owl's preferred habitat. Five environmental variables were investigated: vegetation structure; mesic width; hollow-bearing tree abundance; dominant canopy tree species; and prey density. The study was undertaken throughout the Sydney urban area.

Sixteen sites were established along drainage lines containing remnant vegetation. Drainage lines were chosen as they are known habitat for Powerful Owls and represent the best retained habitat in Sydney (Soderquist & Gibbons 2007; Kavanagh 2003). Eight sites were in locations where Powerful Owls were known to roost and nest, labelled 'present', and eight sites were in locations without records of Powerful Owl nesting, labelled 'absent'. Each of these sites was divided in half based on study site elevation into sub-sites; the 'upper', or upstream portion of the location; and 'lower', or downstream portion of the location. The sampling of sites in the upstream and downstream portion of the creek-lines was undertaken as Powerful Owls often nest in the upper portions of drainage lines in Sydney (Kavanagh

2003 and D. Bain pers obs). Transects of 100m were established along the drainage line within each site and sub-site.

Mesic width

At each study site the 'mesic vegetation' width was measured. Mesic vegetation is taken to be the more densely canopied riparian vegetation, which Powerful Owls are known to favour for roosting (Kavanagh 2003). The edge of the mesic area is quite pronounced in the sclerophyll forests of the Sydney area. Measurements were taken perpendicular to the drainage line at 10 evenly spaced locations along a 100m transect.

This mesic area formed the base area for the vegetation structure assessment, functioning as the boundary for all percentage foliage cover measurements and dominant tree species recordings.

Mesic width was analysed using a two-factor analysis of variance to investigate differences between locations with owls present and those where owls were absent and between the upper portions of sites compared with lower portions of sites.

Vegetation structure

Percentage foliage-cover (PFC) of vegetation within the mesic area of the drainage line was measured utilising the methods originally formulated by Walker & Hopkins (1990) and replicated and augmented by McDonald et al. (1998). The PFC was recorded for three vegetation strata layers: canopy, sub-canopy and understorey at all study sites. The PFC was recorded at 10 points along a 100m transect using a quadrat 10m wide by the width of the mesic area.

Vegetation structure was analysed using an analysis of similarity and a multi-dimensional scaling (MDS) plot (Clarke and Gorley 2006) to investigate differences in PFC across all vegetation strata between locations with owls present and those where owls were absent, and between the upper portions of sites compared with lower portions of sites.

Hollow-bearing tree abundance

The 'diameter at breast height' (DBH) technique was utilised as a surrogate measure for trees containing hollows (Smyth et al. 2002) to provide efficiency in data collection. A DBH of >70 cm was applied; if trees met this criterion they were considered to be of a size capable of producing hollows for Powerful Owl occupation (Kavanagh 2003 & personal observation). A count of all trees >70 cm DBH was undertaken within 50 m of the drainage line along a 100 m transect.

Hollow-bearing tree abundance was analysed using a two-factor analysis of variance to investigate differences between locations with owls present and those where owls were absent, and between the upper portions of sites compared with lower portions of sites.

Dominant canopy tree species

Dominant canopy species were investigated by identifying those species that dominated and therefore had structural importance within the vegetation assemblage at the site (Tozer 2003). The same quadrats utilised to determine percentage foliage-cover were also used to collect this information. The two most dominant species in each quadrat were recorded and identified to species level.

Prey abundance

Spotlighting techniques were employed to identify prey species at all sites. The Powerful Owls diet is known to be chiefly and almost exclusively comprised of nocturnal arboreal marsupial prey (Cooke et al. 2006; Kavanagh 2002a). Spotlighting was performed with a 100W light with minimum exposure of animals to torchlight to allow identification (Catling et al. 1997). Observations used the 'distance sampling' method, where the spotter walked a pre-determined distance through the habitat at a constant and set walking-pace (Ruette et al. 2003). This study utilised a set walking pace of 2 km/h for a duration of 30 minutes, equalling approximately 1 km of spotlighting. A 'meandering transect' was used to allow safe traversing of study locations, on worn tracks and level ground (Catling et al. 1997). A list of fauna species found at each site and their relative abundance was recorded.

Spotlighting was only performed for one night in each of the sixteen study locations due to time commitments within the project. This necessarily limits the strength of the data but provided valuable experience for an upcoming researcher.

Prey abundance was analysed using a t-test to investigate differences between locations with owls present and those where owls were not recorded (absent).

3.1.5 Landscape analysis

A landscape assessment was undertaken using some of this environmental information in conjunction with existing datasets. The aim of the landscape assessment was to calculate the amount of habitat within territories.

The extent of roosting habitat throughout Sydney was mapped to provide an indication of important core areas for Powerful Owls. The broadness of the mapping limits the fine scale application although it provides a valuable coarse layer for land management.

The extent of foraging habitat within a territory was investigated in relation to its total area and the number of patches making up this area. Fledgling success was included within this analysis to understand any influence of habitat intactness.

Territory size for the Powerful Owls was assumed to be 1256 ha calculated using a 2 km radius circle centred on the nesting site. Territory sizes have been recorded between 300 ha and 1589 ha and up to 4774 ha (Bilney 2013; Soderquist & Gibbons 2007; Kavanagh 2002b; Higgins 1999). It is acknowledged that Powerful Owl territories are not circular and in reality will be a reflection of the distribution of habitat and location of other pairs. However, for the purposes of this analysis, it was considered that this approximation provides a valuable model for the species.

Roosting habitat (breeding season)

A 15 m buffer on either side of all water bodies and water courses (all stream orders) and restricted to dry sclerophyll forests, wet sclerophyll forests, forested wetlands and rainforests using Keith (2004) vegetation formations was used to define roosting habitat (OEH 2013). A 15 m buffer was chosen based on the widths of mesic areas recorded (Chapter 3.1.4). This vegetation was merged with all areas of wet sclerophyll and rainforest vegetation that formed part of remnants greater than 1 ha in size.

Foraging habitat

Mapping of native and non-native vegetation across Sydney (OEH 2013) was used to investigate foraging habitat. Vegetation considered to be used for foraging was represented by dry sclerophyll forest, wet sclerophyll forest, rainforest, heathland, grassy woodland, forested wetlands and planted exotics/urban vegetation. This vegetation was considered to be that which important prey species, predominantly the Common Ringtail Possum, would utilise within Sydney. Foraging habitat was considered to be represented by any patches greater than 1 ha (i.e. similar to the home range of a Common Ringtail Possum (Van Dyck & Strahan 2008), where a patch was any contiguous area of foraging vegetation separated by less than 50 m.

A number of assumptions have been made in relation to the habitat classification used in the landscape analysis. These classifications necessarily do not capture all of the utilised habitat by Powerful Owls in Sydney, and potentially overestimate the suitability of other areas of vegetation. However, they do provide a valuable approximation during the breeding season, with 81% of known breeding season roosting and nesting sites occurring within 50 m of the mapped roosting habitat.

3.1.6 Car-strike and other incidents

Data were regularly obtained from animal care organisations on the location of Powerful Owl incidents. Organisations included WIRES, Sydney Wildlife, Taronga Zoo and many local vet clinics. In addition, data were often provided by volunteers and members of the public.

The data collated, focused on accurate locations, the cause of the incident and fate of the animal. In an attempt to understand any impact, all incidents resulting in death or permanent captivity that occurred in the lead-up to and during each nesting season were mapped against breeding success. Incidents after the fledging period were not included as adults are known to be able to raise chicks alone following the death of a partner (McNabb et al. 2007; D. Bain pers.obs.).

3.1.7 DNA

Volunteers were asked to collect feathers whenever possible. These were then stored in a freezer and later sent to Fiona Hogan at Federation University. DNA analysis is still ongoing based on previous work undertaken (Hogan & Cooke 2010; Hogan et al. 2008).

3.2 Results

3.2.1 Identifying breeding sites

The number of sightings increased as the reach of the project spread in the first two years (Table 1). Subsequently the number of unique sightings decreased, not due to decreasing records of Powerful Owls, but because only sightings of owls in new localities were recorded. The results therefore indicate that, throughout the project, the distribution of observations from the general public continued to expand.

The total number of breeding sites increased over the first three years of the project (Table 1). Most likely this is considered to have been driven by increased survey effort rather than a

true increase in breeding numbers of Powerful Owls. This is reflected in the similar number of overall breeding sites in 2013 and 2014 (where volunteer numbers were similar).

Based on the amount of foraging habitat available (see Section 3.2.4), the density of breeding sites within the analysis area was one territory per 569 ha of foraging habitat.

The average annual fledging rate in Sydney from 2011 to 2014 was 1.22 chicks. This was similar to the annual fledging success of 1.28 chicks (51 fledglings from 40 breeding attempts) reported by Kavanagh (2003). Figure 12 provides a map of the distribution of breeding sites and nesting success in Sydney.

Breeding site data were collected to a lesser degree between the Central Coast and Newcastle. Figure 13 provides a map of the distribution of breeding sites and nesting success in this area. The average annual fledging rate in the Central Coast and Newcastle from 2012 to 2014 was 1.37.

Table 1: Project statistics for Sydney showing the number of sightings in unique locations submitted by the general public, a breakdown of breeding site success, number of chicks fledged and the number of nest trees mapped. Unknown outcome for a breeding site means adults were observed during the breeding season but no result was recorded due to various reasons. Note that nest trees mapped is a cumulative total across years and not all nest trees were used each year.

	2011 (Pilot)	2012	2013	2014
Unique location sightings	<200	317	231	63
Breeding sites	29	46	59	60
successful	15	21	31	36
unknown outcome	11	20	24	17
failed	2	5	4	7
Fledged chicks	22	28	43	52
Nest trees mapped	?	15	32	41

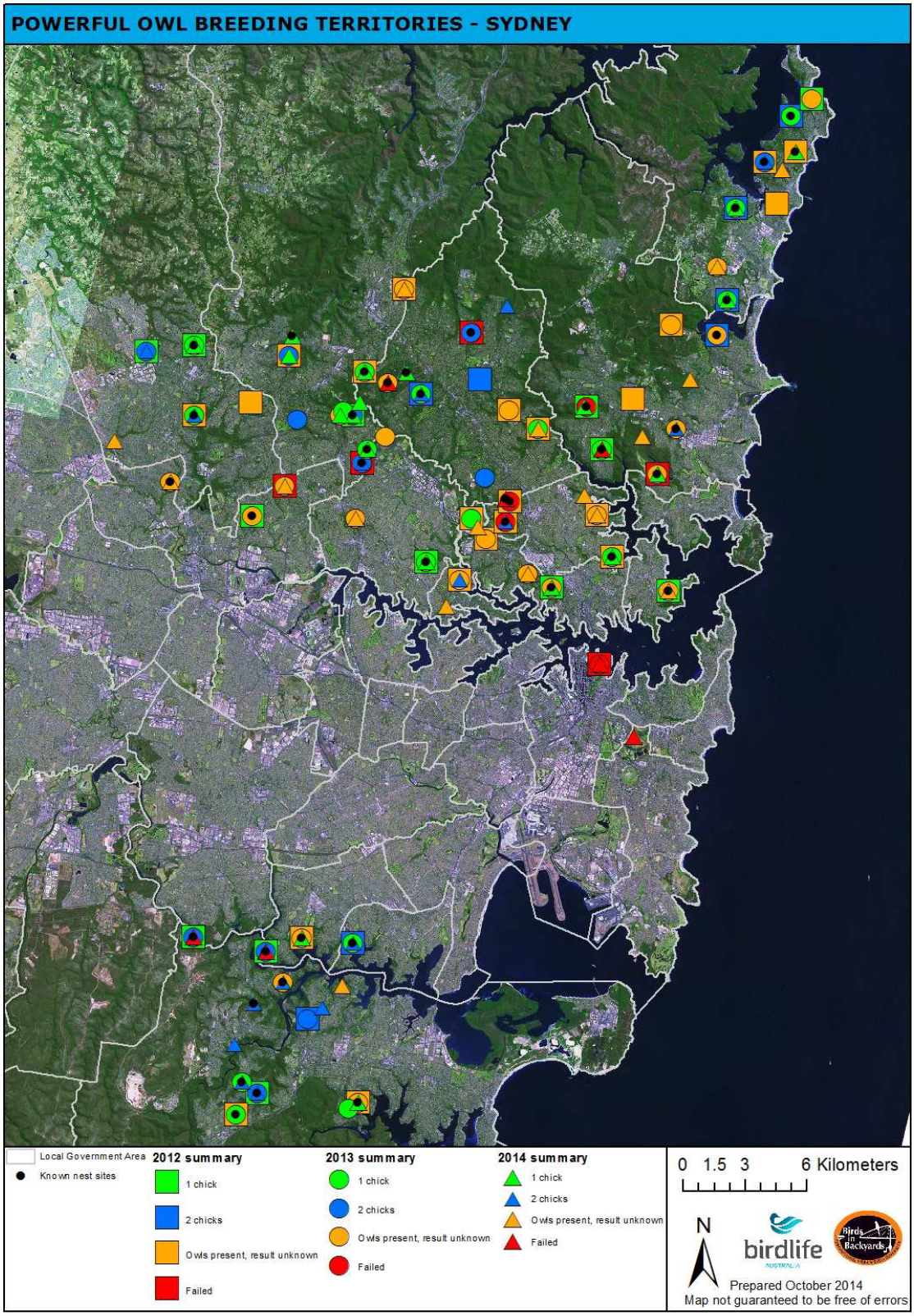

Figure 12: Map of breeding sites (Sydney), breeding success and nest tree location. Note that the size of the legend item does not reflect the size of the territory.

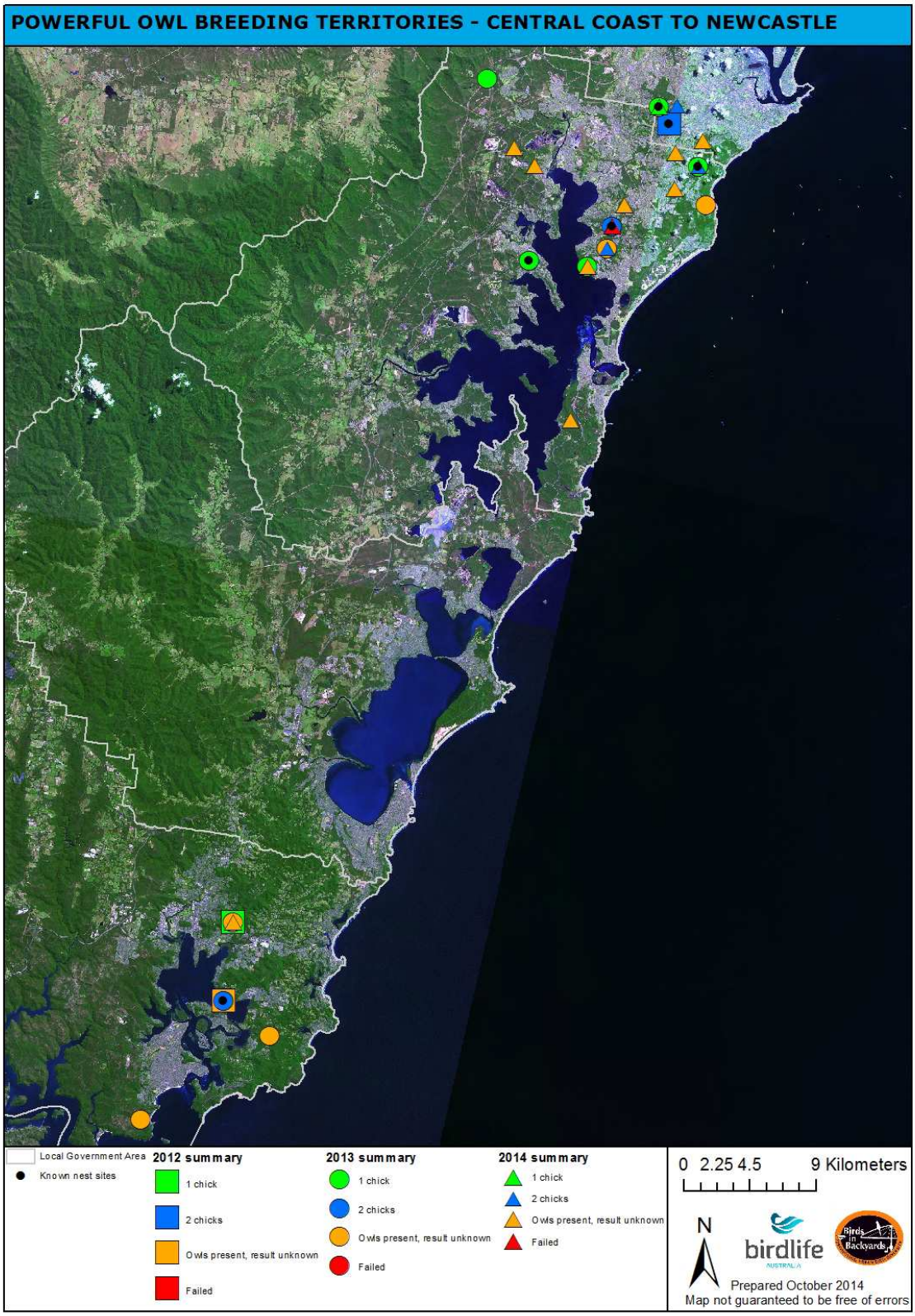

Figure 13: Map of breeding sites (Central Coast and Newcastle), breeding success and nest tree location. Note that the size of the legend item does not reflect the size of the territory.

3.2.1 Owl timelines

The following data reports the timing of significant events during the breeding season (Table 2). The data represent a cumulative total of observations for all years. The number of observations for each class of event is low and varies significantly due to the nature of the monitoring by volunteers and their varying capacities, skill and motivation.

Powerful Owls were sighted in their breeding territories between early May and late October (Table 2). Owls were first seen in their territories between early May and late July, considered to be late and likely reflecting observer competence and availability. Pair bonding and courting was seen between early May and mid-July, and mating occurred between mid-May and mid-June, though there were not many records of mating (n = 3). Owls (gender undetermined) were observed going into hollows between early May and mid-August, with 91% of records between early June and mid-August. Chicks were seen or heard inside their hollow between mid-June and late September, with 65% of records between early August and mid-September. Females were sighted outside of their hollows between early July and mid-October, with 60% of records in early-to-mid August. Chicks were found to fledge between mid-July to mid-October, with 70% of records between mid-August and late September.

Due to the variability in observer experience and availability, the most reliable data presented here is considered to be that of the fledging date.

Table 2: Timeline of significant events in breeding season. Shading represents the number of confirmed observations that included specified dates = 1 - 2, = 3 - 5, = 6 – 10 & >10.

	May 1st - 15th	May 16th - 31st	June 1st - 15th	June 16th - 30th	July 1st - 15th	July 16th - 31st	Aug 1st - 15th	Aug 16th - 31st	Sept 1st - 15th	Sept 16th - 30th	Oct 1st - 15th	Oct 16th - 31st
Owls seen (first time)												
Pair bonding												
Mating												
Owls seen going to hollow												
Chicks seen/heard inside hollow												
Female out of hollow												
Chicks fledged (out of hollow)												

3.2.2 Diet composition

The composition of prey items identified in pellets collected during 2012 and 2013 in this study was significantly different to that published by Kavanagh (2002a) on pellets collected in the same region (χ^2=322.04, df=5, n=200, p<0.01). The main driver of this difference was the higher proportion of Common Brushtail Possums in the current study (Figure 14).

The proportions of prey items identified in pellets varied significantly between the breeding season and non-breeding season (χ^2=203.89, df=5, n=195, p<0.01). This difference was driven by a decrease in Common Brushtail Possums and an increase in insects and birds in the non-breeding season (Figure 15).

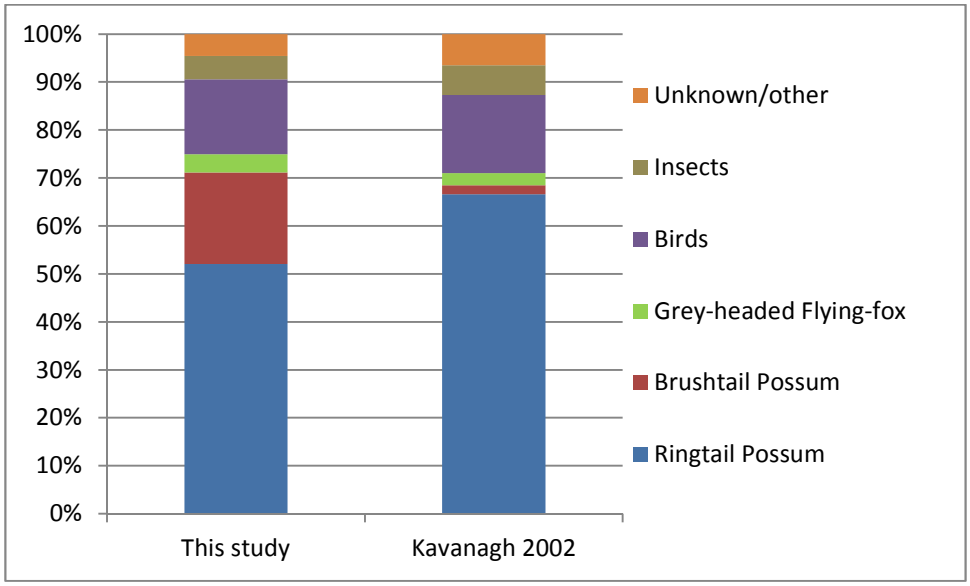

Figure 14: Proportion of prey items in pellets collected in urban locations by count.

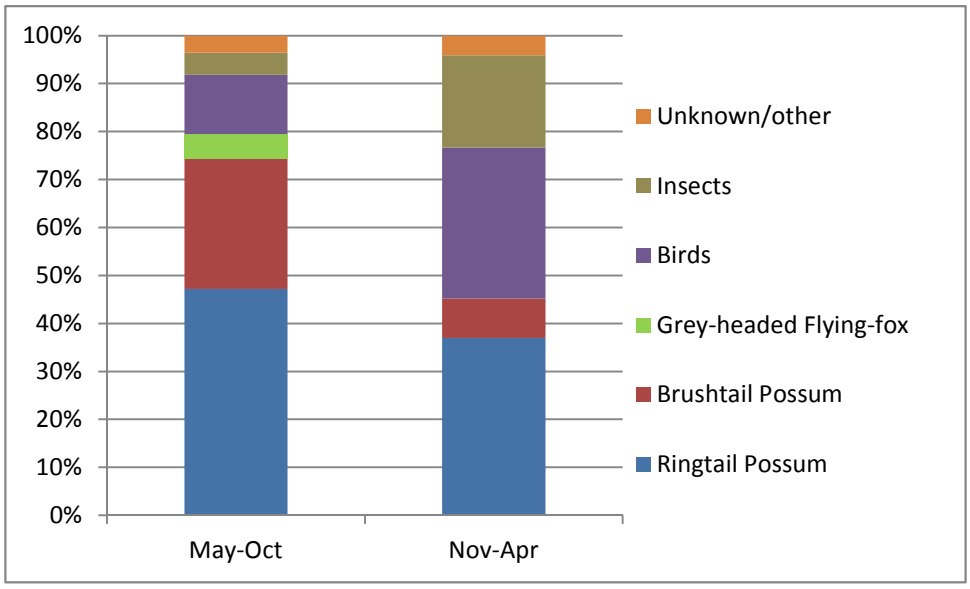

Figure 15: Proportion of prey items by count in urban pellets between the breeding season (May-Oct) an non-breeding season (Nov-Apr).

3.2.3 Environmental variables

Mesic width

Mesic width averaged between 22 m and 30 m across the study area. Although it appeared that the mesic width was wider in areas where owls were present as compared with the areas where owls were not recorded or absent (Figure 16), this was not statistically significant ($F_{1,14}$=3.52, p=0.06).

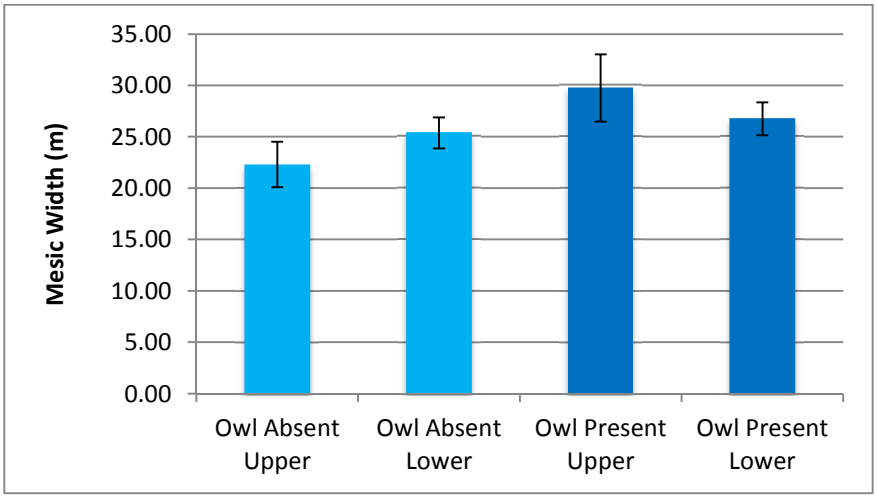

Figure 16: Average width of mesic vegetation between sites. Error bars show standard deviation

Vegetation structure

Figure 17 shows the vegetation structure across the study area. The PFC of the canopy and sub-canopy was between 32% and 41% across all sites. The PFC of the understorey seemed to be on average 12% to 17% greater in sites where owls were present, although this was not significant (t_{30}=2.04, p=0.07).

The analysis of similarities revealed that there was little difference in structure between all the sites or within vegetation strata (p=0.75, Global R=-0.04). The MDS plot (Figure 18) illustrated the similarity between all sites in terms of vegetation structure. There is some suggestion that the sites where owls were present fall more to the right-hand side of the plot, possibly driven by the higher PFC particularly in the understory an canopy in upper portions of the sites (Figure 17).

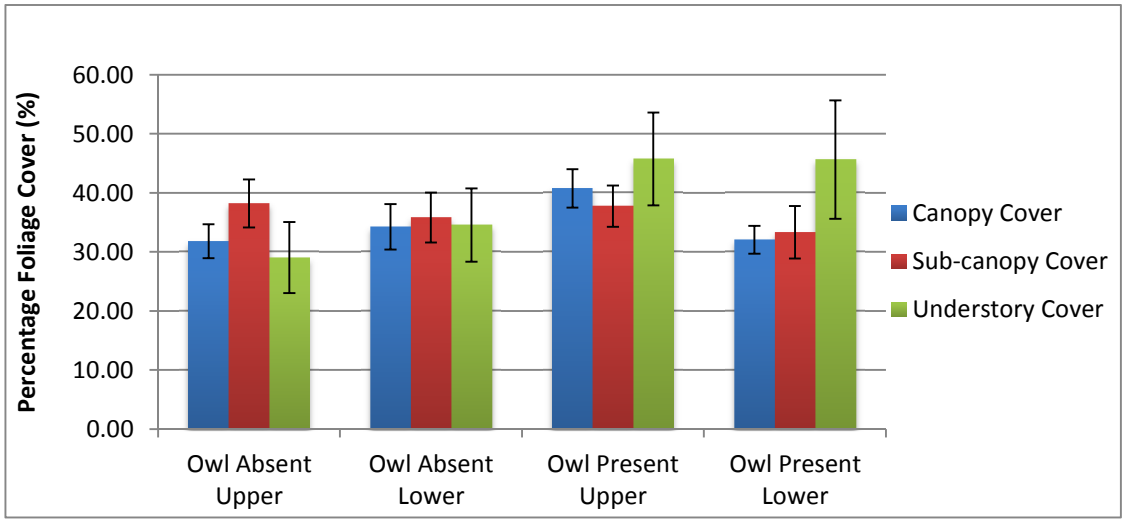

Figure 17: Average percentage foliage cover of different vegetation strata. Error bars show standard deviation.

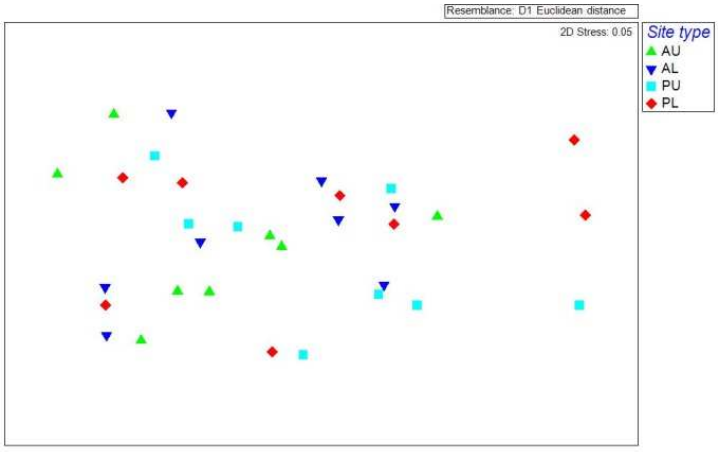

Figure 18: MDS plot comparing vegetation structure between sites, where AU = absent upper, AL = absent lower, PU = present upper & PL = present lower.

Hollow-bearing tree abundance

Hollow-bearing tree abundance varied between 3 trees per 100 m to almost 7 trees per 100 m. There were significantly more hollow-bearing trees recorded in the upper portions of study areas as compared to the lower portions (Figure 19) ($F_{1,14}$=5.36, p=0.04). Although there seemed to be more hollow-bearing trees in the upper portions of sites where owls were present compared to where they were absent, this was not significant (t_{14}=1.76, p=0.06).

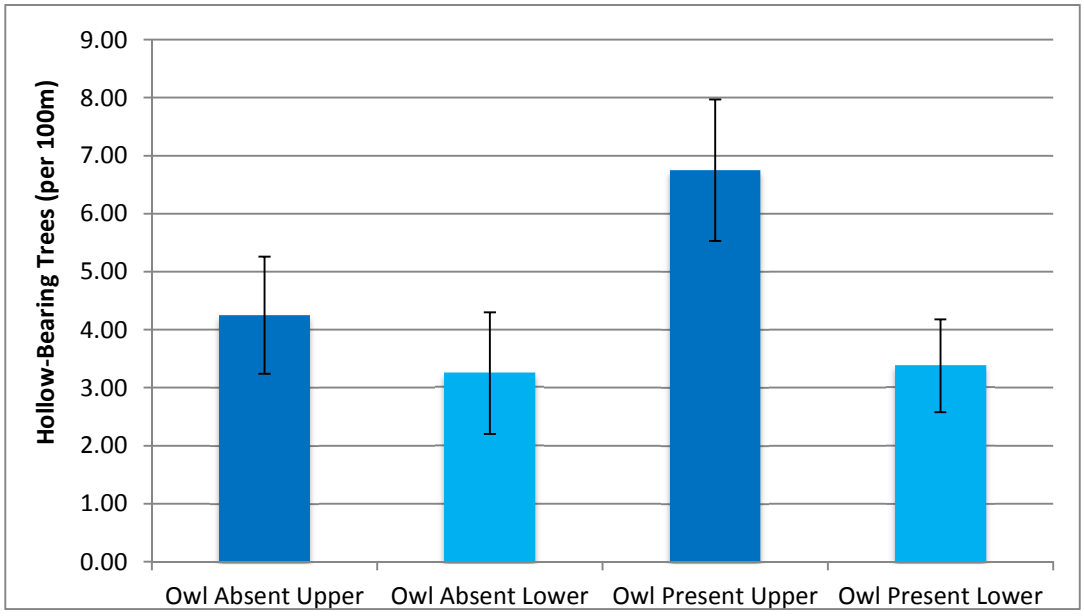

Figure 19: Average number of hollow-bearing trees per site. Error bars show standard deviation

Dominant canopy tree species

Due to there being significantly more hollow-bearing trees in the upper portions of sites than the lower, the dominant tree species were compared between these areas (Figure 20). As expected, the results show a greater number of typical hollow-producing tree species higher in the drainage lines and a more varied canopy composed of species more typical of more protected, high moisture vegetation communities lower down in elevation.

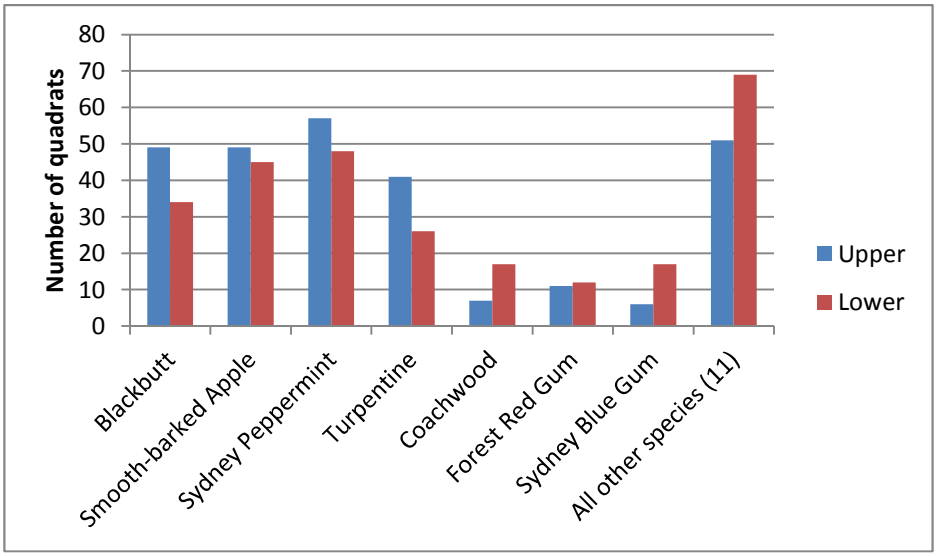

Figure 20: Dominant canopy species in the upper and lower sub-sites. Total number of quadrats across all study sites.

Prey abundance

Unsurprisingly, more prey items were observed in areas with owls present than in areas where owls were not recorded or absent (Figure 21) (t_{12}=2.18, p=0.02). However, as sites were only surveyed on a single occasion the inferential power of these results is limited.

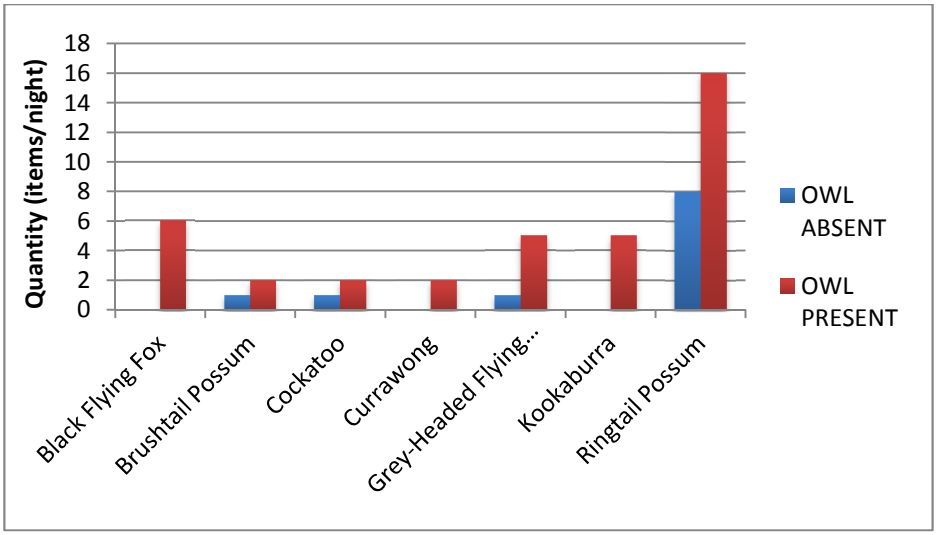

Figure 21: Prey abundance. No error bars are presented as only one night of survey was undertaken

3.2.4 Landscape analysis

The roosting habitat analysis is considered to have over-estimated the true distribution of roosting habitat. This is particularly so regarding the forested wetland vegetation and some of the wet sclerophyll vegetation in the northern suburbs (Figure 23).

There was a negative relationship between foraging habitat area and the number of patches ($r=-0.7373$, $n=75$, $p<0.01$) (Figure 22), with the number of patches decreasing as foraging habitat area increased.

In total there was 34,150 ha of foraging habitat modelled (Figure 23) in 656 patches ranging from 10,643 ha to 1 ha. The median area of foraging habitat for all territories was 488 ha and the median number of habitat patches was three (Figure 22). Only 20% of territories (12) had less than 286 ha of habitat in greater than 9 patches, with two of these being in locations that were known not to breed.

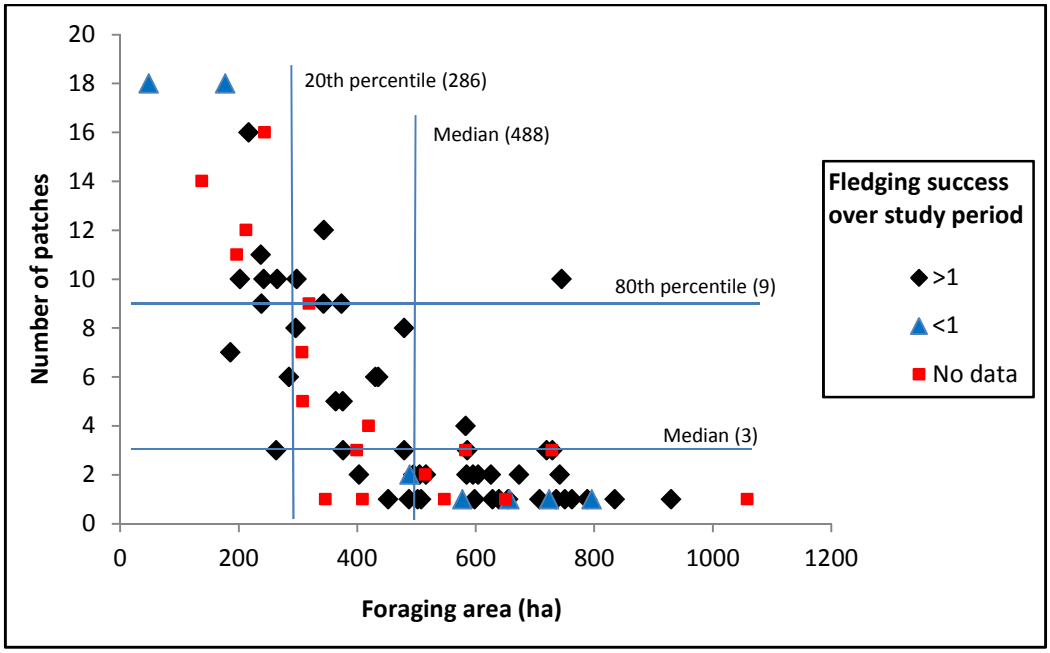

Figure 22: Patchiness of foraging habitat for all territories with fledging success. Regarding fledging success; 'no data' represents those territories where owls were regularly seen in breeding season but no confirmation of a breeding attempt was recorded; and '<1' includes sites where no nesting attempts were ever successful, despite mating being observed.

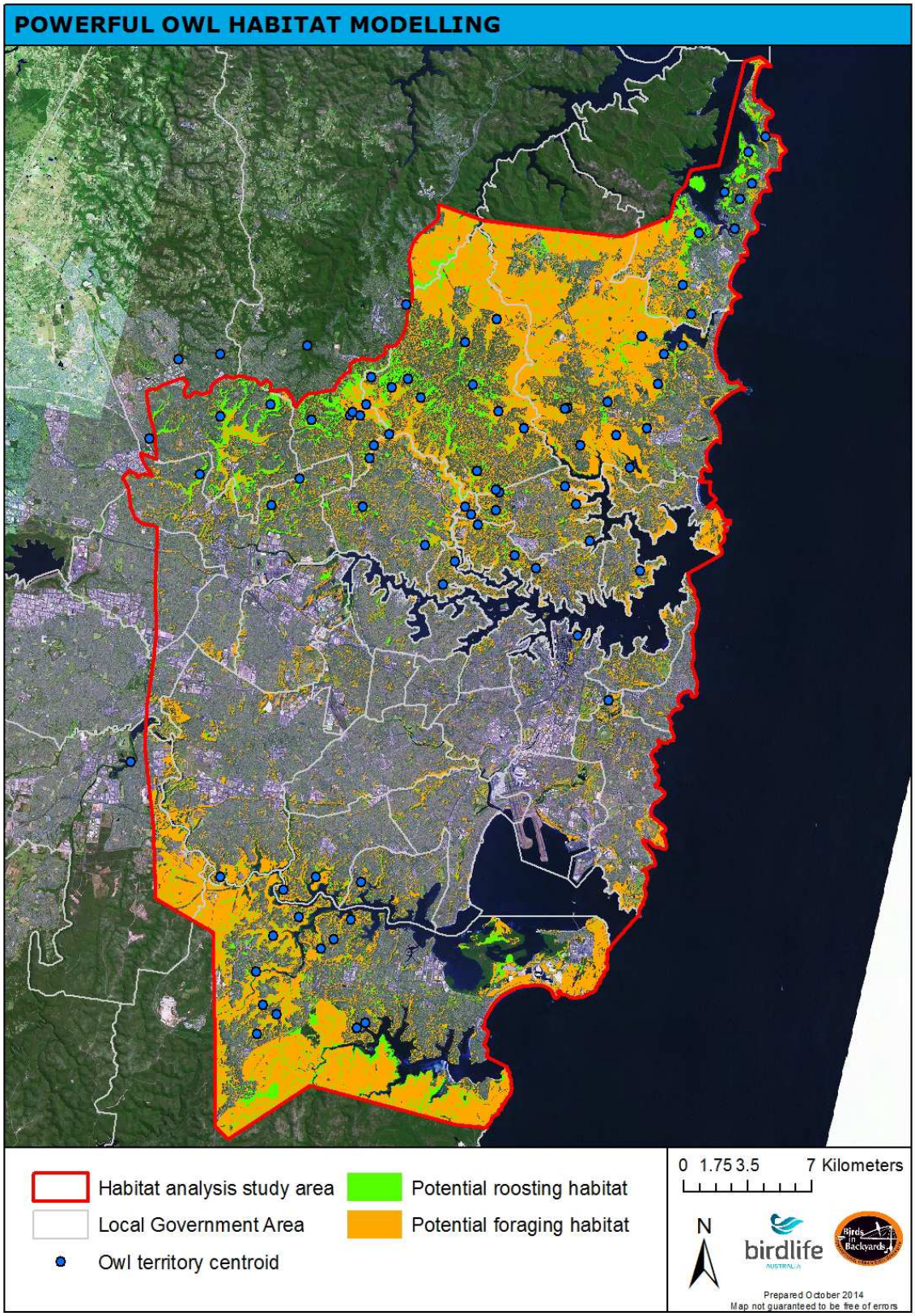

Figure 23: Modelled foraging and roosting habitat of Powerful Owls in Sydney

3.2.5 Car-strike and other incidents

Car strikes were the cause of more than half of all recorded mortalities for Powerful Owls near Sydney. Table 3 shows the total incidents and car-strikes reported to the project from wildlife care organisations between Sydney and Newcastle. Other incidents (with totals for the project) included in the total besides car-strike between 2011 and Oct 2014 included: predation by feral animals (2); disease (1); electrocution (2); weather/environmental (1); injury (4); misadventure (2); and unknown (26).

An estimated calculation of the impact of car-strike in Sydney was 8% loss of the population per year. This has been calculated as follows: the total population of adult Powerful Owls of 120 individuals (see Section 3.3) and an average of 9 fatal car-strikes per year (average of 2011 – 2013 where complete years of data are known).

This is likely to be an underestimate due to unreported incidents and approximations about the size of the Powerful Owl population.

Table 3: Reported incidents of Powerful Owls from wildlife organisations from 2011 to Oct 2014. Dead owls and owls remaining in captivity are grouped together as they are both lost from the population.

Fate	Dead or in captivity		Released		Unknown		Total	
	All reports	Sydney	All reports	Sydney	All reports	Sydney	All reports	Sydney
Car-strike	32	28	4	2	1	1	37	31
Total*	55	45	15	13	5	3	75	61

* Other incidents besides car-strike included in the total are: predation by feral animals; disease; electrocution; entanglement; and injury, although the totals for each are small.

The impact of these incidents on the Powerful Owl population and breeding is hard to quantify. Figure 24 presents all incidents resulting in death or permanent captivity that occurred in the lead-up to and during each nesting season.

In total over the three years, 11 fatal incidents occurred in close proximity to breeding sites which either failed or the outcome was unknown. However, 9 fatal incidents also occurred in close proximity to breeding sites that were successful (Figure 24).

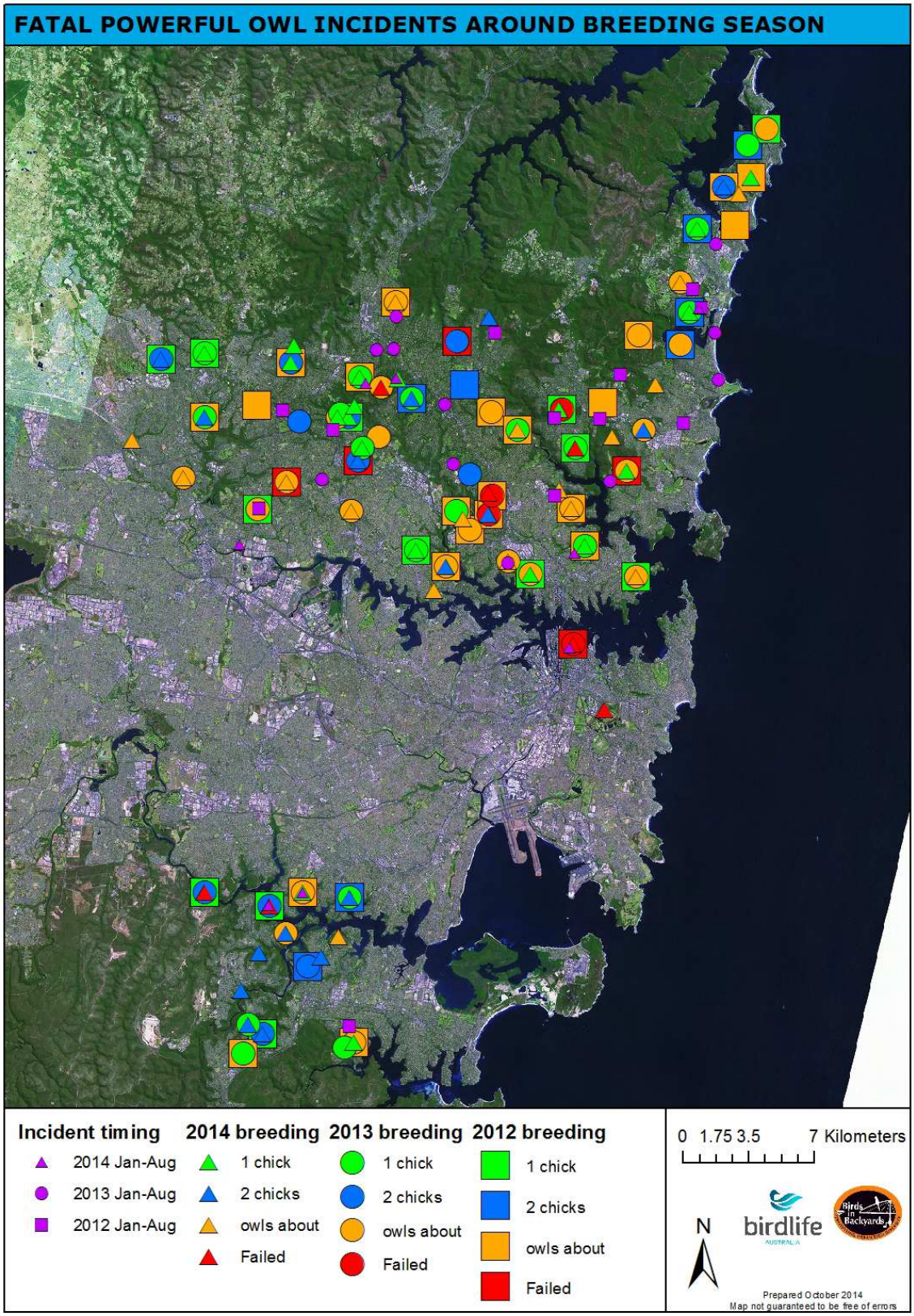

Figure 24: Incidents resulting in death or permanent captivity in the lead up to or during nesting season (until fledging).

3.2.6 DNA

The DNA analysis work is still underway with Fiona Hogan at Federation University.

3.3 Discussion

Breeding sites in Sydney are concentrated in two main areas, the Hills District/northern suburbs/northern beaches and the Sutherland/Hurstville area. The density of breeding sites in these areas is high at 1/569 ha of modelled foraging habitat, with over 50% known to be successful and a further 30% to 40% with an unknown outcome. These figures are considered to be greater than in other urban areas such as Melbourne, where Powerful Owls breed in only limited areas and seem to be intolerant of human disturbance to a larger degree (Webster et al. 1999; Cooke et al. 2002). Nests sites in Sydney were commonly located close to bushland walking tracks, and two nests that were successful each year were even located in backyards albeit that backed onto significant bushland reserves.

Other curious examples of both disturbance and close human habitation were recorded. A pair in Newcastle vacated a nesting site following significant disturbance from bird watching activity during one season, only to subsequently nest in a tree within a heavily used picnic area (closed at night) the following year. This pair successfully raised two chicks, although they did not subsequently return to that site but returned to the original breeding location. In Carlingford, a breeding pair (observed mating) received very high visitation from photographers each year and vacated the area prior to laying. However, it is suspected that this pair actually utilised a hollow in a neighbouring reserve, unbeknownst to the photographers. Finally, a new pair in 2014 established a regular roosting site above a busy café in Centennial Park in the middle of Sydney City. They were observed almost daily during the breeding season and also seen mating, despite the high day time human activity. Breeding was not ultimately recorded, although this is likely due to a lack of suitable hollows rather than disturbance.

Both despite the human disturbance, and as result of the close proximity to humans allowing ease of survey, valuable data has been collected on urban populations of Powerful Owls. The total population of adult Powerful Owls within the Sydney urban landscape has been estimated at 120. This has been calculated as follows:

- the breeding population of Powerful Owls in Sydney rounded to be 110 individuals (average of 55 breeding sites in the last 3 years),
- plus an estimated additional 10% of non-breeding floaters (10)

The estimated number of non-breeding floaters is based on observations of 're-pairing' where breeding individuals have been killed, along with an examination of incident data. The survivorship of juveniles and accurate estimation of floaters in the population is a key area of future research.

The population estimate above suggests that there is in the order of 285 ha of foraging habitat available per individual, although likely there is significant overlap in foraging ranges. With estimated territory sizes in the order of 1256 ha, it would seem that the Sydney population of Powerful Owls is at capacity and recruitment of juveniles into the breeding population will only occur when established pairs break up. This breaking of a pair will likely be due to death of one individual, although possibly also through rarely reported mate competition as observed by one volunteer. Two males, one established male from the previous year and an 'intruder' male were observed together in a breeding territory in May,

the start of the breeding season. Aggressive behaviour was observed between the two males at about mid-morning, culminating in the previous year's male flying away. By the afternoon all had quietened down with the intruder roosting in proximity to the established female and the previous year's male nowhere to be seen.

There were 16 confirmed nesting failures from 2011 to 2014. At least two of these were directly attributed to Sulphur-crested Cockatoos (*Cacatua galerita*) taking over the nesting hollow prior to chicks fledging. Another two were highly suspected to be the result of cockatoos also. Sulphur-crested Cockatoos were also known to 'move into' hollows almost on the day of fledging in a number of other nests. Interestingly, one volunteer witnessed a male Powerful Owl chasing cockatoos away from the nest hollow in the early evening just prior to the chick fledging. It seems as though hollow-bearing trees are significant real estate in Sydney and competition for them, particularly with increasing numbers of Sulphur-crested Cockatoos, may be an ongoing concern for Powerful Owls.

Fledgling success has apparently remained stable over the last 10 years. Kavanagh (2003) reported fledgling success of 1.28 in Sydney, and was recorded at 1.22 in this study. One factor not taken into consideration with this calculation, however, is the number of breeding sites with an unknown outcome. This unknown outcome is by in large due to the skill and availability of volunteers to undertake comprehensive surveys.

Some aspects of breeding behaviour such as: mating; owls entering hollows; and chicks being observed in hollows, seemed late compared with other published studies (Higgins 1999). However, chicks fledged from mid-July to mid-October in line with other observations (Higgins 1999). The discrepancy in timing of early breeding season events is likely a factor of volunteer observer competence rather than a true temporal shift in behaviour.

The variation in diet observed between Kavanagh (2002a) and this study along with the change between seasons reflects the hunting strategy of the Powerful Owl. Both Kavanagh (1988) and Cooke et al. (2006) postulated that the Powerful Owl is both a specialist hunter of arboreal prey and also a generalist, by preying on the most available prey item within this group. As was seen in this study, the change in proportions of dietary items likely reflects a change in prey abundance in Sydney but may also be, as a result of high density, due to owl territories increasingly being located within a variety of urban localities where the suitability for prey species varies.

In a similar way, as the seasons change, so does the Powerful Owl diet. In regard to the increases observed in winter with Common Brushtail Possums as prey, juveniles are often still on their mother's backs at this time or just recently weaned (Van Dyck & Strahan 2008), making them ideal targets for Powerful Owls. Insects are prevalent at the time chicks are maturing and several instances of chicks eating Christmas Beetles (*Anoplognathus* spp.) were observed, an easy and nutritious prey to practice hunting. In the same way, birds are more conspicuous in the environment in the warmer months and are an easy sleeping target for an arboreal hunting owl at night. In addition, it is noted that birds form a larger part of the diet of Powerful Owls closer to cleared areas (Bilney 2013), with obviously large cleared areas throughout Sydney.

The assessment of environmental variables showed no surprises, although it did confirm several assumptions used as part of the landscape assessment. Mesic widths in drainage lines in the Powerful Owl distribution within Sydney were of the order of 30 m wide. Hollow-bearing trees were more prevalent in the upper elevations of these drainage lines (Figure 19), corresponding to typical hollow-producing canopy species from dry sclerophyll and wet

sclerophyll forests in Sydney (Figure 20) and known nesting trees documented in Kavanagh (2003).

The PFC of the understorey seemed to be greater in sites where owls were present, which may represent a preference of some structural elements of vegetation by the owls. Within Sydney the denser understory is often associated with a less dense sub-canopy, providing a 'cathedral' like structure anecdotally considered suitable for roosting. Increases in sub-canopy density in the riparian mesic vegetation within Sydney can often be a result of invasive species such as Privet (*Ligustrum* sp.) which may reduce the suitability of the area for roosting. However, these assertions require further investigation to understand.

As previously discussed, the analysis of roosting habitat during the breeding season has over-estimated the extent. However, it does provide a valuable coarse layer to focus attention on important areas for Powerful Owls. To more accurately predict roosting habitat during the breeding season, areas of known older age vegetation including large hollow-bearing trees within the mapped roosting habitat distribution provide a valuable prediction for the species.

The landscape analysis indicates that foraging habitat for the Powerful Owl is widespread in the 'leafer' suburbs of Sydney. In these areas backyard gardens and bushland reserves are prevalent and prey availability is unlikely to be a limiting factor due to the high prevalence of species such as Common Ringtail Possums in these areas. However, the availability of nesting habitat with large hollow-bearing trees is likely a limiting factor. Areas lacking these resources may create an ecological trap for some individuals that are attracted to the available prey but do not contribute to the breeding population (Isaac, Cooke, et al. 2014). The number of territories with large areas of foraging habitat but where little or no breeding has been recorded provides collaborating evidence for this.

Car strike was estimated to impact 8% of the Sydney population per year and all reported fatal incidents combined equated to 9% per year. Interestingly, when fatal incidents during the breeding season were plotted against breeding success at adjacent sites (Figure 24), there was an almost equal rate of successful breeding and not. As non-breeding floaters are known in Powerful Owl populations in Sydney (McNabb et al. 2007), it is likely that a proportion of these fatalities are non-breeding individuals, possibly sub-adults or non-breeding adults. Alternatively, or in conjunction, McNabb et al. (2007) observed a recently widowed Powerful Owl pair with a younger owl, suggesting any fatalities within a breeding pair in the lead up to the breeding season may be replaced by nearby non-breeding individuals.

In any case, the loss of at least 9% of the population to largely human created threats suggests the need for management of these threats in urban planning and land management (Isaac, et al. 2014).

Although Powerful Owls are surviving in Sydney's urban areas, increasing urbanisation is continuing to impact on their long-term persistence (Isaac et al. 2013). Current urbanisation typically results in smaller lot sizes, reduction in the size of backyards, increased traffic, encroachment into bushland and the 'cleaning up' of natural areas with the removal of 'dangerous' trees containing hollow branches. These factors slowly reduce the suitability for Powerful Owls which, despite the ecological imperative to conserve, are at present an important and engaging part of the environment for local communities.

4. Education and Outreach

Education for all sectors of the community was a core component of the project. Avenues to engage different sectors of the community involved talks, media, web-based resources, school education, and participation in scientific conferences. Resources were also developed and disseminated to land managers to improve their ability to manage the species.

4.1 Education

Community involvement and education has been a large focus of the project. The opportunity to utilise this iconic species to engage the community in urban conservation is far reaching.

Education was undertaken through a number of avenues and with a number of different audiences. Education focused on various subject matters such as the Powerful Owls themselves, the project and urban conservation. Educational opportunities took the form of: community talks; media articles and radio interviews; children's television; community workshops; newsletters; a schools program; conference talks; and web-based resources.

From 2012 to 2014, educational resources reached 2400 people face to face and an estimated audience of >1,000,000 people through media avenues.

Community talks

Twenty two talks were given over the course of the project to bird clubs, community groups and at local government environmental days.

Media articles and radio interviews

Seven articles were published in local and regional newspapers; articles were published in Australian Geographic and BirdLife magazines; and three radio interviews were conducted with ABC local radio.

Children's television

The Powerful Owl Project was featured in series 2, episode 23 of the successful ABC3 television program 'Bushwacked'. This involved filming owls, their habitat and a staged survey for the species, including evidence for the presence of the owls.

Community workshops

Seven survey workshops were undertaken which focused on training volunteers but were also open to other members of the community. Two workshops were also held that were open to anyone in the community on the topic of dietary analysis of regurgitated pellets.

Pellet analysis workshop. David Bain

Newsletters

Annual newsletters were distributed at the end of each breeding season to volunteers, land managers and interested parties. These provided an update and overview of the season's results and what had been happening in the project.

Schools program

Gibberagong Environmental Education Centre lead a partnership with The Powerful Owl Project, Taronga Zoo and Habitat Stepping Stones to deliver a schools program focused on the Powerful Owl. Each year the program involved four primary schools, one high school and approximately 350-400 students.

Primary school students were mentored through the program by high school students. The program consisted of a number of stages including: Powerful Owl expert days; a night at Taronga Zoo meeting their owls and other animals; habitat days at the school; and a final expo to showcase student projects on Powerful Owl conservation in their local area to the public. The habitat days involved walks through known Powerful Owl habitat, assessing and adding value to habitat at the school and a pellet analysis workshop.

Conference talks

The project was presented at three scientific conferences: the 2013 Australian Raptor Association Conference; the 2013 Australasian Ornithological Conference; and the 2014 Australian Bird Study Association Conference.

Web-based resources

Two web-based resources were developed during the project. These included: a short nine minute documentary on Powerful Owls, their ecology and conservation; and edited nest

camera footage showing a full breeding season at one nest site. These resources were hosted on the BIBY website, in conjunction with more general information on the Powerful Owl.

A Facebook page has also been running (https://www.facebook.com/ThePowerfulOwlProject), created and lead by Kristen Hardy. To date the page is 'liked' by over 600 people and has reached over 135,000 people.

Powerful Owl schools program. David Bain

4.2 Land manager resources

The project has worked with 33 land managers including 22 local councils, nine National Parks, the Royal Botanic Gardens and the Centennial Park Trust. These bodies have been consulted regarding many topics ranging from access to specific management issues for the Powerful Owl.

Following every breeding season, land managers have been provided with a summary of nesting success and locations in their jurisdiction and a discussion of the breeding season in general.

All records of Powerful Owls have been submitted to the NSW Wildlife Atlas.

The project was involved in a number of workshops relating to land management and Powerful Owl conservation. A number of sites in Powerful Owl territories in Sydney were the subject of urban services works such as water and sewerage services upgrades and powerline easement management. Discussions relating to the timing of works to avoid disturbance to breeding owls, including proposals to conduct fuel reduction burning nearby, were successfully undertaken.

A workshop held by Lake Macquarie City Council on management guidelines for all the threatened owls found in the local government area was attended. This workshop brought together a number of owl experts from across NSW and resulted in the production of the Interim Lake Macquarie Large Forest Owl Planning and Management Guidelines (LMCC 2014).

Successful consultation with land managers in relation to a hazard reduction burning in a breeding site was undertaken. The result was an altered burn plan focusing on avoiding the nesting season and providing security and escape routes for the owls. Owls were also located prior to, and monitored during the burn. Unexpectedly, the fledglings continued to be fed by a parent during the operation right on the edge of the burn area about 20 m from a fire tanker with flashing lights and pumps going. Post-fire the whole family left the area, likely in search of better hunting grounds. Surprisingly, seven months later the adults returned to the same nest tree and successfully bred. However, the next year following, the adults failed to breed.

Post-fire response by Powerful Owls has been investigated in Victoria and in NSW. Results have suggested that post-fire recovery can be variable depending on circumstances. Generally recovery takes more than three years as a result of one or a combination of impacts including death, displacement, loss of hollow-bearing trees and slow arboreal prey recovery (Willig & Atkins 2013). In south-eastern NSW, a significant increase was recorded in the distribution and abundance of the Powerful Owl approximately 15 years after major disturbance caused by intensive logging and wildfire. Site-occupancy by this owl continued to increase until approximately 25 years after disturbance and then to decrease substantially, coinciding with marked changes in the distribution and abundance of its principal prey species in the region, the Common Ringtail Possum. The rapid increase in numbers of this possum within a decade of major disturbance, and its subsequent steady decline thereafter, suggested the existence of a classic predator-prey response by the owls (Kavanagh and Stanton 2013).

Guidelines have been produced for land managers. These are aimed at guiding them on issues relating to Powerful Owl ecology as well as survey, land management and development issues (Chapter 5.3 and Appendix A).

5. Outcomes & Recommendations

The project has been successful in participating with and engaging the community and exposing them to the values of our urban bushland remnants. Increased understanding of the Powerful Owl has been achieved utilising citizen science, benefitting both researchers and the community. This has driven the development of management recommendations for the continued survival of Powerful Owls in Sydney and other urban areas.

5.1 Volunteers and citizen science

The numbers of volunteers steadily increased over the course of the project, with a number of key volunteers participating for multiple years. There are benefits for both projects and volunteers through the participation in citizen science projects. Projects gain through having a large labour base to collect information, over large geographical ranges. Volunteers benefit through a feeling of contribution to science and knowledge and engaging in activities that they have an interest in. There are important considerations for any citizen science project in relation to the use of volunteers from the wider community:

- projects should sufficiently consider timescales of projects, to ensure the required effort from volunteers matches realistic recruitment timeframes,
- volunteers should be regularly engaged, through project updates and correspondence to maintain their engagement with the project, motivation to continue and acknowledgement of efforts,
- the tasks or data that is the responsibility of volunteers to collect should reflect the experience and availability of volunteers to collect.

There are large numbers of bird watchers in the community that are not involved in bird organisations, and, for BirdLife Australia, this provides a great audience to approach. Understanding how to engage these people with the organisation will serve to benefit both the community, through increased awareness and exposure to issues relating to birds, and for BirdLife in tapping into a large knowledge base and potential membership which ultimately provides a more comprehensive voice on bird conservation. One obvious opportunity may be to offer a discounted or bonus membership to volunteers who participate in projects.

5.2 Community

Community interest in the project steadily grew from year to year with a significant increase in engagement in the last two years. Engagement occurred through various avenues from word of mouth from volunteering opportunities and free educational talks and workshops to collaboration with other community groups, newspaper and magazine articles, radio interviews and television coverage. This wide and varied engagement repertoire ensured a broad audience for the project. Another important aspect was the identification of key engaged individuals who have the motivation and capacity to spread the message of the project.

Key lessons were the need for sustained communication within the community about the project. Events, news articles and social media all play a role in keeping the community engaged. In addition, providing the community with the information and capacity so they can

implement actions at home or in their local area provides ownership and attachment to place that is critical to ensuring long-term local conservation outcomes.

The long-term goals of any community project need to be aligned with capacity building and long-term outlook for a community.

5.3 Urban Powerful Owl management

The project has delivered important results, providing a rigorous understanding of how many Powerful Owls are within the Sydney urban area and what areas they are utilising. This vital information provides key focal data for land managers to better ensure their conservation. Some of the key data that has been gathered within the project includes:

- maps of nest sites, breeding success and habitat utilisation,
- understanding of threats present in the urban area, such as car-strike, hazard reduction burning, hollow-bearing tree competition and maintenance of prey populations.

From this information and discussions with land managers, key management recommendations have been formulated and are provided in Appendix A. These recommendations cover:

- location, area and type of habitat present,
- areas of habitat critical to maintain for the maintenance of Powerful Owl,
- guidelines for land management including development, hazard reduction burning and services works,
- key survey protocols to ensure adequate and focused effort.

The conservation of owls in urban areas requires the protection of extensive bushland areas from urban and rural development. In particular the major forested gully systems which provide essential nesting and roosting habitat for the Powerful Owl. Some important questions remain unanswered such as; juvenile survivorship and number of non-breeding individuals in the population; and, the role of fire frequency and weed control, both directly on Powerful Owls but also indirectly with regard to impacts on important prey species.

6. Conclusions

The Powerful Owl Project has been successful in achieving its outcomes. The three year project has achieved significant results on minimal funding.

The project has engaged widely with the community, with over 300 volunteers in systematic surveys of the species throughout the study area, direct communication with 2500 people through community talks, educational programs and events and indirect communication with more than 1,000,000 people through various media channels.

The location of key owl breeding sites, measuring breeding success and modelling habitat at those sites has provided valuable baseline data for management. Information has been widely disseminated to land managers in a clear and direct manner to enable integration with existing management actions.

Based on the level of success, the project has a continuing role to play in the conservation of Powerful Owls and the promotion of urban conservation. The future of the project will require continued funding, although the motivation of a number of volunteers will ensure ongoing monitoring of several sites regardless of the status of the project.

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Appendix A: Land Manager Guidelines

See following two pages

LAND MANAGER GUIDELINES FOR POWERFUL OWL CONSERVATION IN URBAN SYDNEY

Habitat Types	
Nesting	Forest containing suitable nest trees in proximity (100 m) to roosting habitat. Nesting trees are typically large live trees (generally >70 cm DBH) with large hollows in the main trunk.
Roosting	Mesic vegetation along ephemeral and perennial drainage lines and gullies where tree species provide a dense canopy (including individual trees) and often a more open sub-canopy. Includes all areas of rainforest and wet sclerophyll forest.
Foraging	Forest, woodland and complex urban vegetation suitable for arboreal prey species. Habitat patches greater than 1 ha where patch is any contiguous area of foraging vegetation separated by gaps less than about 50 m. Includes: all treed vegetation with >10 habitat trees (any hollow size) per hectare or >3 trees over 70 cm DBH per hectare; complex urban vegetation (including planted vegetation) with dense vegetation of mid-storey and/or canopy, including parks and residential backyards suitable for movement of urban adapted arboreal fauna (eg Common Ringtail Possum).
Location and Distribution	
Territory & nest site	Records of owls (roosting or calling), particularly in the early evening or early morning, from March to September in combination with roosting and nesting habitat should be assumed as having a nesting site in the area. Use surveys to confirm. A surrogate territory can be defined as a 2 km radius circle around the nest site, common roost site or records as above.
Local population	A breeding territory and adjacent territories within 5 km, where the core of the territory is defined as the nest site, common roost site or records as above.
Retention of Habitat	
Area of habitat	Nesting and roosting habitat: All habitat is to be retained within a known territory. Foraging habitat: Retain a minimum 450 ha in a maximum of 4 patches within the territory (2 km radius around the nest site, roosting site or records as above).
Buffer zones	100 m around nest sites. 50 m around roost sites.
Prey	Consideration must be given to the viability of prey populations in known Powerful Owl areas, including breeding, foraging and movement of these species.
Connectivity	Corridors are important, particularly riparian corridors and foraging habitat. Maintenance of at least 100 m wide corridors between large remnants and a reduced length where corridors are narrower.

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Land Management	
Development	Proposals to remove >1 ha of foraging habitat within 2 km of a nest site (including staged proposals), where the remaining habitat in this area is below the minimum 450 ha vegetation retention threshold, need to be carefully considered and justified with regard to significance assessment (Section 5A, *Environmental Planning and Assessment Act 1979*). Nest boxes and fauna over/underpasses are to be used to mitigate impacts to prey species where clearing is permitted. Nest boxes cannot be used as offsets for the loss of Powerful Owl nesting hollows. Other impacts such as lighting installations should include impact modelling and adhere to the buffer zones described above.
Hazard reduction burning	Rural Fire Service Threatened Species Hazard Reduction List: No burning around known nesting sites at any time. No slashing, trittering or tree removal of or around known nesting sites. Records of owls from March to September in combination with mesic vegetation and adjacent forest should be assumed as a nesting site in the vicinity. Use surveys to confirm OR exclude the area from the burn. Where fire is necessary and a nest site is known or assumed, create an exclusion zone (50 m) around nesting site and the adjacent roosting habitat and burn outside of the breeding season (May to end-September).
Services work	Where there will be minimal impact on vegetation (mowing, track maintenance works etc), avoid loud machinery and equipment or night time lighting during the breeding season (May to end-September) within the buffers outlined above. Where large impacts on vegetation are proposed, refer to Development guidelines above.
Survey	
Effort	Minimum 8 nights survey (with at least 4 consecutive nights and all in suitable conditions)
Technique	Early evening listening surveys in the lead up to and during breeding season (March to end-September) provide the most valuable and accurate information on breeding sites. Playback should not be used in known or suspected breeding sites from May to end-September due to disturbance to breeding. Playback can be used at other times of the year.

Photos Top right: Adult by Kristen Hardy | Top left: Chick in hollow by Jenny Stiles | Bottom: Juveniles by Kristen Hardy

For more information, please contact BirdLife Australia (powerfulowl@birdlife.org.au) or the NSW Office of Environment and Heritage.

These guidelines have been prepared based on work conducted within the Powerful Owl Project, in conjunction with the large forest owl management workshop held by Lake Macquarie City Council in 2014 and the LMCC Draft Interim Large Forest Owl Planning and Management Guidelines 2014 developed as a result.

Land Manager Guidelines for Powerful Owl Conservation in Urban Sydney

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