Chapter 1
Owl Diet, Australian Owls, Habitat and Status

1.1 Owl Diet Studies

Owl diet studies in Australia are at a relatively early stage compared with studies from the northern hemisphere where huge sample sizes over decades have produced large robust data sets. The diet of the Barn Owl species complex (*Tyto alba, T. javanica* and others) has probably received the most attention worldwide with many hundreds of papers (Taylor 1994) including diet studies from most parts of the world, detailed comparisons with available prey (e.g. Taylor 2002, Bernard *et al.* 2010) and captive studies of foraging behaviour (e.g. Fux and Eilam 2009a, b). Most species occurring in North America and Europe have been extensively studied, for example in a recent review of the diet of Long-eared Owls *Asio otus*, Birrer (2009) was able to consider 475 publications of which 194 had quantitative diet data with a total of 813,033 prey items. Even the threatened and geographically restricted Northern Spotted Owl *Strix occidentalis caurina* has had details of 24,497 prey items examined from 1118 owl territories (Forsman *et al.* 2004).

In stark contrast to Australia, other parts of the world have owls that will forage in broad daylight, sometimes preferentially (e.g. Blakiston's Fish Owl *Bubo (Ketupa) blakistoni,* Slaght and Surmach 2008) or sometimes because they occupy high latitudes where the sun barely sets during summer (e.g. Snowy Owl *Bubo (Nyctea) scandiaca*). Mainland Australia also lacks specialised fishing owls, although fish and crustaceans have been found to be taken by some Australian non-specialist owls including the Barking Owl (Fleay 1968). Australia has no truly small owls like the Elf Owl *Micrathene whitneyi* or the pygmy owls, which weigh around 40 grams. Instead, Australia has the owl-like Australian Owlet-nightjar *Aegotheles cristatus,* which like some of the small owls is primarily an insectivore (Higgins 1999).

1.1.1 The value of studying owl diets

Bird of prey populations, like most other species, are limited by prey availability or nest site availability (Newton 1979). Potentially, the prey limitation could include an unsuitable foraging environment that afforded high levels of protection for an otherwise abundant prey.

In the Northern Hemisphere, owl breeding success is tied to the "vole cycle". Newton (2002) presents a summary of different species population responses to fluctuations in rodent numbers. Highly mobile species such as the Short-eared Owl *Asio flammeus* simply move on when prey become depleted. In some areas, this forms an altitudinal or latitudinal migration. Species that are more sedentary (such as the Tawny Owl *Strix aluco* or Ural Owl *Strix uralensis*) persist but may show a delayed population response or a decline in breeding success. Even the forest obligate Northern Spotted Owl, which consumes most of its prey biomass from non-fluctuating forest species, coincides its successful breeding years with the fluctuations in abundance of deer mouse, a species that contributes less than one percent to its prey biomass (Rosenberg *et al.* 2003). Hollow breeding species may meet with that limiting factor during periods when the owls are not being limited by prey availability. In parts of Scandinavia, the majority of the hollow-breeding owls rely on artificial nest boxes. For example, in Finland around the year 2000 there were 23200 artificial nest boxes provided for four owl species while only 6000 natural sites were known (Saurola 2002).

In Australia, no large scale predator/prey cycle has been shown within forest dwelling species, although Kavanagh (1988) has presented an example of localised favourite prey depletion by the Powerful Owl, with the subsequent local withdrawal of the owls from that area.

There is some evidence that Eastern Barn Owl *Tyto javanica* and Eastern Grass Owl *Tyto longimembris* dwelling in open environments and dependent on ground dwelling prey may undergo dramatic changes in numbers in response to prey abundance (Olsen and Doran

2002, Hollands 2008). The prey abundance cycles in Australia are unrelated to the effects of the owls themselves, but to climatic events that lead to boom or bust conditions for small mammals and insects (Dickman *et al.* 1999). There is some suggestion that feral mammal predators might make a significant contribution to slowing and finishing booms of arid area rodents (Pavey *et al.* 2008a, Dickman *et al.* 2010) or that house mice can be controled by diurnal raptor with mammalian predators during non-boom conditions (Sinclair *et al.* 1990). However, the timing of a boom and bust is strongly associated with rainfall. Predation, or a lack of it, does not strongly influence booms.

By studying owl diet, we can gain insight into potential limits to the owl population. We can determine the ecological niche, their dietary flexibility and breadth. By studying owl diets, it is also possible to learn about their prey.

1.1.2 Rare species detection

By careful examination of owl pellets and food debris, rare or difficult to detect species may be found. Some small mammals can be cryptic, particularly forest dwelling species. Two such species were revealed in the south-east forests of NSW by collecting and examining Sooty Owl pellets (Kavanagh, 2002). In that case, the Broad-toothed Rat *Mastacomys fuscus and* Southern Brown Bandicoot *Isodon obesulus* were detected. Broad-toothed Rat is normally associated with dense grass and herbage at higher elevations in NSW and is notoriously trap shy. To date no live specimens have been detected at low elevations in the south-east forests. Southern Brown Bandicoots were thought to be in decline in the area and other researchers had been unable to locate any at that time. Remains found at two Sooty Owl territories, confirmed their continued presence. Since that time, live captures in the region have confirmed the finding. The Lesser Sooty Owl *Tyto tenebricosa multipunctata* has proven useful for finding cryptic small mammals of the Wet-tropics region of Queensland. McDonald (2010) proved the worth of Lesser Sooty Owl pellet analysis by revealing 14 mammal species from 152 hours of pellet collection and examination while mammal trapping using more hours only revealed six species.

In some cases, material collected from owl pellets can even help describe new rare species. A recent example is a new rodent species described by Musser and Lunde (2009). Penck and Queale (2002) found undescribed species of spider in Southern Boobook gizzards but these may not have been egested in a pellet (had the owl survived) as they may have passed directly into the lower digestive tract.

One problem with using owl collected materials to determine presence of cryptic fauna is that forest owls typically have large home ranges. Until live specimens are found, there is always going to be doubt about the true source of the species in question. In addition, as specimens are always incomplete, there may be questions about the identity of the species. This is particularly true for Barking Owls. They tend to break their prey into smaller pieces than most other Australian owls.

1.1.3 Historic/prehistoric diet

Sub-fossil prey remains within cave deposits have been compared with fresh deposits to show changes in small mammal populations over recent pre-history (usually Holocene) to the current day in East Gippsland, Victoria (Bilney *et al.* 2006, 2010, Bilney 2009), Tasmania (Mooney 1993), Jenolan Caves west of Sydney (Morris *et al.* 1997), Yarrangobilly caves in the Snowy Mountains (Aplin *et al.* 2010) and the Flinders Ranges, South Australia (Smith 1977).

While there will always be conjecture over the original cave occupant that left the deposits and thus the consistency of hunting styles or foraging habitats that contributed to the prey distribution (Aplin *et al.* 2010), the deposits typically show dramatic change in the small mammal fauna of the regions involved. A number of species present in the sub-fossil remains, particularly conilurine rodents, were absent from the modern cave inhabitants diets and many were presumed extinct, extremely rare or have distributions well outside the areas concerned. Hypothesises for these declines/changes include climate change or other factors inducing vegetation change (Morris *et al.* 1997) and feral predator competition (Bilney *et al.* 2010) and exotic animal grazing (Smith 1977). Vegetation change may change the dominant cave roosting owl predator and/or the available prey, which may affect the animals found in the deposits so the competing predator hypotheses may only be part of the answer.

Caves are an ideal environment for preserving mammal bones, offering constant cool temperatures, humidity and protection from bone scavengers. The Barking Owl is not commonly known to utilise caves for roosting or nesting and does not currently occur near caves within the Pilliga forests so the long-term preservation of their diet record in Pilliga is unlikely. The only possibility for historic recording of diet data might come from bone preserved within large hollow trees used for nesting. It is unlikely that records of great age could be obtained as the acidic environment of tree hollow debris would be detrimental to the preservation of bone. Identification of the cause of death would remain guesswork.

1.2 Barking Owls and Their Place in the Australian Owl Fauna

The study of Australian owls has lagged behind the study of European and North American species, although ahead of many parts of the developing world. It wasn't until the 1980s that extensive survey work and intensive population studies began to reveal the detailed habitat requirements and conservation status of our large forest owls (e.g. Milledge *et al.* 1991, Kavanagh and Peake 1993). The Powerful Owl *Ninox strenua*, Sooty Owl *Tyto tenebricosa* and Masked Owl *Tyto novaehollandiae* all received attention at this time, largely because they were perceived to be rare or vulnerable to forest management practices. In the mid 1990s it became apparent that one species of 'large' forest owl had been overlooked. It was realised that amongst all the owl survey data collected to that point, records of the Barking Owl *Ninox connivens* were uncommon (Anon 1994, Debus 1997, Clemann and Loyn 2001). In 1998, the NSW Scientific Committee added Barking Owl to the vulnerable species schedule (Anon 1998) of the NSW Threatened Species Conservation Act (1995). Similar scheduling had already occurred in Victoria under the Victorian Flora and Fauna Guarantee Act (1988). In 2007, it was upgraded to endangered in Victoria.

Mainland Australia has eight recognised resident owl species in two genera. The genus *Tyto* (family Tytonidae) is represented by four species, two of which may warrant separation into additional species (Christidis and Boles 2008). The Eastern Grass Owl *Tyto longimembris* is the only Australian owl not to nest in tree hollows and is a specialist hunter of prey in tall ground cover. The other three species each occupy vegetation types ranging from wet forests for the Sooty Owl, through to open forest/woodlands and other open habitats for the Eastern Barn Owl *Tyto javanica*. The Masked Owl occupies habitat in between, preferring open forests.

The remaining four species belong to the Hawk Owl genus *Ninox*. Barking Owls are a medium to large sized forest and woodland dwelling species distributed through most of the wooded environments of mainland Australia. They are most abundant in open forests and woodland or places where heavier forest is discontinuous. In southern Australia, rainforest and dense wet forest types are usually avoided, these being populated most commonly by the larger Powerful Owl, similar sized Sooty Owl or Masked Owl and the smaller Southern Boobook Owl *Ninox novaeseelandiae*. In northern Australia, large patches of wet forest typically inhabited by the Lesser Sooty Owl *Tyto tenebricosa multipunctata* or the larger Rufous Owl *Ninox rufa* are also avoided by Barking Owls, however, it is common for Barking Owls to utilise small patches of wet forest as part of a wider more diverse habitat (Hollands 2008, pers. obs.).

At the other extreme, Barking Owls tend to avoid habitats that are treeless or nearly so and these are more usually the domain of the Eastern Grass Owl (where dense grass or herbage occurs), Eastern Barn Owls and occasionally the Southern Boobook, all smaller species (Higgins 1999).

Barking Owls share and compete for the forests, woodlands and fragmented woodlands in between these extremes, with Powerful Owl, Rufous Owl, Masked Owl, Barn Owl and Southern Boobook. In some cases, they appear to coexist with one or more of these species. In the Pilliga forests of New South Wales, Barking Owls coexist with Southern Boobook and Barn Owls. Masked Owls are occasionally reported from the forest and Powerful Owls occur in ranges nearby (Pennay *et al.* 2002, NPWS Wildlife Atlas).

The Barking Owl is not restricted to the Australian mainland, with a population in New Guinea and another in the Moluccas. Within Australia, there are two currently recognised subspecies with *N. c. peninsularis* considered to occur across the northern portion of the distribution and the nominate *N. c. connivens* to occur in the south (Higgins 1999). Only *N. c. connivens* has been found to be declining.

1.3 Barking Owl Diet in Australia

There has been no large-scale study of Barking Owl diet that included multiple pairs across multiple years and all seasons of the year. Material collected for at least two such studies (Chiltern area, Victoria in Taylor *et al.* 2002b, Schedvin 2007 and Northern Territory, in CSIRO 1982, Corbett 1984) has remained unanalysed and unpublished.

Some published information from single territories has made a substantial contribution to date. Barnes *et al.* (2005), published three years of breeding season data from a territory located in Cordoba State Forest, near Bundaberg, south-east Queensland. Hodgon (1996) had previously reported on a small breeding season sample from the same territory and Zillman (1964) had observed Barking Owls in the same area decades earlier. In this habitat, Barking Owls were consuming a wide variety of mammals and birds supplemented with a range of insects. Mammals consumed ranged from one larger item (Little Red Flying-fox *Pteropus scapulatus*) through many mid-sized arboreal marsupials (Squirrel Glider *Petaurus norfolkensis* and Sugar Glider *Petaurus breviceps*) and a couple of small items (Feathertail Glider *Acrobates pygmaeus* and micro-bats). The birds identified ranged in size from Torresian Crow *Corvus oru* at over 500 grams to a Lewin's Honeyeater *Meliphaga lewinii* and a nestling bird. There was a notable absence of small birds in the sample. Insects, which were more than half of the prey items, were mostly beetles (particularly scarabs) or grasshoppers. There was also one cockroach, stick insect, moth and spider.

Of the two successful breeding periods at Cordoba State Forest, more bird prey was found in 2002 and more mammal prey in 2004. Breeding failed in 2003 for unknown reasons. Prey biomass was skewed heavily towards mammals in 2003 as in 2004.

Debus has reported on Barking Owl diet from a territory at Boorolong Creek near Armidale, New South Wales in a series of publications (Kavanagh *et al.* 1995, Debus 1997, Debus *et al.* 1998, Debus *et al.* 1999, Debus 2001). A nearby territory at Dumaresq Dam was reported for the breeding seasons of 2003-4 (Debus *et al.* 2005). Notably, the Boorolong Creek territory data were from both breeding and non-breeding periods.

Boorolong Creek Barking Owls consumed House Mouse *Mus musculus* and Common Ringtail Possum *Pseudocheirus peregrinus* (juv.) as well as Sugar and Squirrel Glider. Birds ranged from larger species such as magpie, currawong and kookaburra, through a wide range of medium sized birds down to small passerines such as Double-barred Finch *Taeniopygia bichenovii* and Silvereye *Zosterops lateralis*. There was a balance of birds and mammals taken with birds more frequent during breeding (or when dependant juveniles present) and mammals more frequent during non-breeding. Insects were 62% of prey items during breeding and 76% of items during non-breeding however they only reached a maximum of 3% of measurable biomass during the non-breeding period. Similar to Cordoba State Forest, the insects were dominated by beetles and grasshoppers.

Kavanagh *et al.* (1995) reported the diets from two territories in the Hawkesbury River catchment of New South Wales. A breeding pair at Glen Alice had taken many rabbits, a few exotic rodents (Black Rat *Rattus rattus*) and birds from a fragmented woodland/farmland habitat. A small sample from a similarly fragmented site near Wilberforce also showed rabbit and insect (beetle) prey items. Additionally there were Sugar Glider and micro-bats represented in the sample but no birds.

In stark contrast to these wooded environments, Barking Owls also occur in areas where the timbered environment is strongly confined. An example is along Cooper Creek in Queensland and South Australia. Debus and Rose (2003) reported on a small non-breeding sample of pellets from a water hole on Cooper Creek. The main prey item (28 items) was the Long-haired Rat *Rattus villosisimus*, which inhabits the Cooper flood plain and can be abundant in good conditions. With the exception of a single cricket, the other six prey items were smaller terrestrial mammals. Possibly terrestrial mammals were the most abundant and available items in the flood plain environment although birds such as parrots and water birds commonly roost in the thin strip of woody vegetation that usually line water holes. As Long-haired Rat numbers tend to fluctuate in response to flooding and plant growth, a longer study of Barking Owls in this environment may reveal a different diet under different conditions.

The diet of Barking Owls in Victoria has received some attention. Calaby (1951) found Barking Owls were taking mostly European Rabbits *Oryctolagus cuniculus* from a site at Gunbower (West of Echuca near the Murray River) where he was studying the interactions of a range of raptors with the large rabbit population before the arrival of myxomatosis. Other items were water beetles, a House Sparrow *Passer domesticus* and a few micro-bats. Calaby recorded that the size of rabbits taken by the owls were "quite large, up to one third grown".

Robinson (1994), included data from a small sample of pellets collected (by Paul Peake) further east in the Chiltern area. The sample contained mostly rabbits with a few birds and bats, a pattern similar to that found by Calaby even though rabbit numbers were undoubtedly lower around Chiltern in the early 1990s compared with pre-myxomatosis 1950.

Taylor *et al.* (2002b) presented a preliminary list of prey items from a larger Chiltern data set. These were remains found around breeding sites. European Rabbit, Common Brushtail Possum *Trichosurus vulpecular* and Sugar Glider were the mammals. Birds included waterfowl and medium to large woodland and farmland birds. Pellets in their collection also contained parts of smaller birds and mammals as well as beetles and cicadas.

In contrast, further down the Murray near Deniliquin in River Red Gum forest, Webster (in Robinson 1994 and Kavanagh *et al.* 1995) reported a diet of birds, particularly rosellas and cockatoos. On the northwest plains, a pair and their fledgling near Moree had eaten a Sugar Glider, a range of birds and a water beetle (Kavanagh *et al.* 1995).

One of the most unusual prey items reported was a Feral Cat *Felis catus* (Shelly 2006). A Barking Owl, hunting from the roof of a building, struggled with the half grown cat before subduing it enough to carry it two kilometres away. Even more unusual was the discovery of a pellet containing fish spines (Fleay 1968).

Kavanagh *et al.* (1995) also reported the results of stomach content analysis from four road-killed Barking Owls from New South Wales. One from the western slopes in spring (November) contained Common Brushtail Possum. The other three, all collected in autumn, had been consuming large numbers of invertebrates. A second Barking Owl recovered from the western slopes had consumed eight moths, a beetle, a grasshopper and a spider. Two female Barking Owls recovered from roads near Coonamble on the northwest plains near the Pilliga forests, had both been feasting on scarab beetles. Between them, they had consumed 157 scarab beetles, 25 mantids, more than 3 moths and a grasshopper. Presumably, some of these were prey items captured near the roads on which the owls encountered vehicles.

The dramatic difference between the stomach contents data and the prey items counted from food debris and regurgitated pellets (all other data reported above) may just be a seasonal observation as few of the other records were from autumn. However, it is notable that the large numbers of insects recovered from the stomachs, is unknown for other kinds of samples (as mentioned above and this study). Also notable is that many regurgitated pellets do contain small numbers of the same kind of invertebrate prey items, but rarely all the hard parts from individual creatures, even when the pellet is entirely composed of invertebrate material. I conclude from these observations, that invertebrate prey items may be under represented in prey debris and regurgitated pellets, at least for part of the year. It seems that the gizzard easily processes much of the invertebrate material and allows it to pass through the lower digestive system. Chapter 3 examines this further.

1.4 Diets of the Other Mainland Hawk Owls

1.4.1 Powerful Owl diet

The Powerful Owl is the largest *Ninox* owl and Australia's largest owl, males possibly exceeding two kilograms in weight (Higgins 1999, Hollands 2008) and at least up to 1.7 kilograms (Kavanagh 2002b). This makes it around double the weight of Barking Owls measured during the Pilliga study (this chapter). Dwelling in wooded environments in Australia's southeast (from Rockhampton to Mt Gambier) Powerful Owls concentrate on arboreal prey, rarely taking any prey from the ground. Prey were typically large arboreal marsupials, flying foxes and larger diurnal birds taken from roosts or nests. Small arboreal and scansorial mammals were included and seasonally, insects were hawked (Higgins 1999, Kavanagh 2002a).

Kavanagh (1997, 2002a) described the diet of Powerful Owls living in two regions of New South Wales with a data set containing 1672 prey items from 47 territories. Powerful Owls living in the forests of southeast were predominantly feeding on Common Ringtail Possum. The population living around the greater Sydney basin were also feeding on large numbers of Common Ringtail Possums, however they were supplementing their diet with more birds, particularly larger species that have done well in the urban environment. In a number of territories, particularly those in the escarpment of the southeast forests where Common Ringtail Possum was rare or absent, Powerful Owls were feeding extensively on Greater Glider *Petauroides volans.* In a single territory at Medowie, Koalas *Phascolarctos cinereus,* were being consumed. Common Brushtail Possums were also taken at that site. One site recorded substantial numbers of Grey-headed Flying Foxes *Pteropus poliocephalus*.

Cooke *et al.* (2006) described the diet of Powerful Owls in a range of territories along an urban to forest gradient near Melbourne. From 2557 pellets, four arboreal marsupial species constituted 99% of all prey. The largest part of the diet was Common Ringtail

Possum and Common Brushtail Possum. All territories consumed Sugar Glider. Greater Glider was only consumed in less disturbed territories where it was most available.

In the Brisbane area (Pavey *et al.* 1994) found that Common Ringtail Possums were also commonly taken, however a larger portion of the diet was flying-foxes (two species). Birds such as lorikeets also made up a considerable portion of the diet. Further north near Rockhampton, the predatory adaptability of Powerful Owls is reported by Schultz (1997). In an area where Common Brushtail Possums were the staple prey item, rock wallabies were also being predated. The rock wallabies are known to ascend tree trunks, which emerge from their rocky habitat.

Soderquist and Gibbons (2007) reported that a population of Powerful Owls living in the box-ironbark woodlands of northern Victoria, had a different diet balance. Over half of their prey was birds. One pair studied, had as little as 13% mammalian prey. Notably the box-ironbark woodlands are one of the last strong holds of Barking Owls in Victoria (Loyn *et al.* 2001, Taylor *et al.* 2002a). Some other Powerful Owls in Victoria also had large proportions of avian prey, for example at Beaufort (Tilley 1982).

The overall picture of the Powerful Owl is of a predator of the largest manageable arboreal prey available. They are flexible enough to adapt to different prey at different locations including birds and they are manoeuvrable enough to capture small invertebrates on the wing. The smaller *Ninox* owls take many of the same prey types. There may be competition between these species, particularly the Barking Owl, where they co-occur. Given their similar build, the main difference is likely to be that Powerful Owls should be able to tackle prey of twice the size, while Barking Owls should be more efficient at tackling smaller, faster prey.

1.4.2 Rufous Owl diet

The closest in size to the Barking Owl is the Rufous Owl, being between 700 g and 1.3 kg (Higgins 1999), up to 30-40% heavier than southern Barking Owls. Rufous Owls occur in wet forests of the tropics, even down to small riparian patches. Their diet is the least reported of Australian Hawk Owls. As the Rufous Owl and Barking Owl roost in similar habitat in many parts of the range of Rufous Owls, there is a strong possibility that there would be dietary competition between these two species. Unfortunately, while the diet of the Powerful Owl (which lives in Australia's largest cities) has been well studied, its northern counterpart's diet has only been documented in a few places.

In Kakadu National Park, Northern Territory, Estbergs and Braithwaite (1985) undertook a small study of the dry season diet of Rufous Owls. The diet was primarily mammal and included a range of terrestrial, scansorial and arboreal mammals in the period that they were supporting fledglings in the early to mid dry season. In the late dry season, the diet shifted to include slightly more arboreal mammals as well as flying foxes and less terrestrial prey. Birds were rare in the diet through the dry season as were insects. While much of the prey was quite small (mouse sized), some of the items were quite large, for example Northern Brushtail Possum *Trichosurus (vulpecular) arnhemensis* and Northern Brown Bandicoot *Isoodon macrourus*. The authors note that almost all common mammals of the surrounding woodlands were included in the diet. Some species restricted to the monsoon forests and wetlands were absent. The authors suggest that the results were strongly tied to relative seasonal abundances of prey. The scansorial dasyurid *Antechinus bellus* was most vulnerable to predation during and immediately after the breeding season (August sample). Rodents breed during the late wet season and were at high abundance during the early dry season, the period when they were most common in the diet sample. They suggest that birds would be more common during the wet season when dense ground vegetation may inhibit hunting terrestrial prey.

Hollands (2008) lists a number of prey items observed by himself and others. In contrast to the Kakadu observations, Hollands listed mostly birds, some of them very large and the only mammals listed were the Sugar Glider and flying fox. Hollands bird list includes megapodes, frogmouth, kookaburra, cockatoo and other parrots, duck and heron, all large prey items. At the other end of the scale, beetles are noted as being taken in flight and stick-insects are snatched from foliage. A photo is included of a Rufous Owl carrying a moth in her bill to the nest.

The Herbert River Ringtail *Pseudochirulus herbertensis* has been noted as a prey item in the wet tropics region (Winter 1993) however, Kanowski (1998) found no distributional relationship to this species or of any arboreal mammals to Rufous Owl distribution in that region. Harrington and Debus (2000) found four species of arboreal mammal in pellet material under a roost in September. Full-grown Common Brushtail Possum, Common Ringtail Possum, Striped Possum *Dactylopsila trivirgata* and Sugar Glider were found.

Further north in the Iron Range, a nesting pair of Rufous Owls was found to predate at least two species of mammals and mostly rainforest birds. Birds ranged from the large Eclectus Parrot *Eclectus roratus*, through, Magnificent Riflebird *Ptiloris magnificus*, Double-eyed Fig-parrot *Cyclopsitta diophthalma*, Rainbow Bee-eater *Merops ornatus* and Metallic Starling *Aplonis metallica*. Mammals were the Spotted Cuscus *Spilocuscus maculatus* and mega-chiropteran bats (Legge *et al.* 2003).

The Rufous Owl is a versatile hunter like the Barking Owl and more so than the Powerful Owl as it is far more likely to take prey from the ground. Like the other two, it targets readily available prey and can have very different diets in different locations. It seems likely that Rufous Owl diet is also seasonal. Also likely is that it partly competes with Barking Owls for prey where they both occur.

1.4.3 Southern Boobook diet

Smallest of the Australian mainland hawk owls is the Southern Boobook *Ninox novaeseelandiae*. While it is a smallish owl, it is sturdily built and has an aggressive temperament to match (for example, McNabb 2002, Olsen and Trost 2007).

Southern Boobooks take many invertebrates and small vertebrates with a range of foraging techniques (Higgins 1999). Occasionally they take larger prey, possibly greater than their own body weight (McNabb 2002).

Recent studies highlight the diverse range of prey items from which Southern Boobooks can gain sustenance. The three studies also highlight how different a result can be obtained by using different techniques to examine the diet (and the way it is reported). Penck and Queale (2002) examined 117 boobook gizzard contents from South Australia. They found 1207 prey items and that 95.9% were invertebrates. These were dominated by beetles and moths. House Mouse was the most important vertebrate prey item.

In contrast, Trost *et al.* (2008) examined 229 regurgitated pellets collected in winter from five owl pairs in the Australian Capital Territory and recovered 496 prey items. Mammals constituted 167 of the items, birds 33, while invertebrates were only 296 items. In this case, invertebrates were 59.7 % of prey items but only 2.8% of the biomass consumed. These results broadly concur with those from Southern Victoria of McNabb (2002) who found prey up to 420 grams (sub-adult Common Ringtail Possum) in the diet. Fitzsimons and Rose (2007) studied a sample of pellets from a Box-Ironbark woodland remnant in Central Victoria and also found mammal in the form of House Mouse to constitute the majority of prey biomass although invertebrates, particularly spiders and beetles were dominant in numbers.

In New Zealand the situation is different again. Southern Boobooks from New Zealand are considerably smaller than those from south-east Australia (Higgins 1999) and they seem to take mainly arthropod prey, at least 99% (Haw and Clout 1999, Haw *et al.* 2001, Denny 2009) even when rodent prey was widely available.

These studies highlight the diversity of foraging environments in which the Southern Boobook can live. Despite the difference in methods, all of the studies may be correct for those particular populations. Clearly, the Southern Boobook is an adaptable predator capable of taking a wide range of prey, in a similar fashion to its larger relatives.

Southern Boobook (and other owl) diet research may benefit from genetic bar-coding technology currently under development that would allow easier faecal material analysis in the same manner that Kim *et al.* (2009) applied to regurgitated pellets.

1.5 Sources of Diet Information for Owls

Australian owls are difficult to study by virtue of their being active at night, they can move through difficult terrain in near silence and typically, they are shy and retiring. Dietary analysis can suffer for these reasons. Fortunately, owls leave some clues to their activity at their roost sites. *Ninox* owls typically roost in the dense foliage of trees or dense shrubs. Once the roosting patterns of an owl have been established, finding roosts is regularly possible and a wealth of data can be accessed.

Four main types of data can be collected at roosts. If the owls are present, there is a chance that they will be holding a prey item from the previous nights hunt. In Australia this behaviour is known from Powerful, Rufous and Barking Owls (Pavey 2008, Schoenjahn *et al.* 2008). Secondly, there may be unconsumed prey scraps scattered under the roost. These are relatively easy to identify but are typically biased towards large prey items such as those held on the roost. Thirdly, there will be faecal material under the roost. This is present under almost all owl roosts, however, the material is not always in discrete scats or pellets and may be difficult to collect or relate to particular meals. Prey identification is also more limited. Fourthly, larger owls regurgitate larger indigestible parts of their food as pellets. Pellets vary depending on what the owl has consumed. Pellets containing fur or feathers tend to hold together, while those lacking long-fibre material, may disintegrate upon striking the ground.

Of these signs, regurgitated pellets have been the most commonly used for analysis of Australian owl diets. Pellets are typically produced at a steady rate of one per day when diet is consistent (Duke *et al.* 1980, Hollands 2008) and usually deposited at or near the daytime roost. Pellet production can vary due to the food quantity, food type, feed timing and availability of the next meal (Smith and Richmond 1972, Duke *et al.* 1976, Duke and Rhoades 1977). Regular pellet production makes calculation of prey numbers per day possible. Pellets are easy to collect and store and easier to identify and count prey items compared with faecal material. The capacity of pellets to accurately reflect the volume of soft-bodied prey items in an owls diet has remained untested but on circumstantial evidence may be quite poor (Rose 1996, Penck and Queale 2002, Forsman *et al.* 2004, Livezey *et al.* 2008). For some raptors that can take relatively large prey and feed selectively from the carcass, that large prey may also be absent from pellets, or difficult to identify (Trost *et al.* 2008).

Faecal material analysis has not been used for large forest owls in Australia before. It is a common method for insectivorous birds, however as most owls consume hard-bodied prey items and produce regurgitated pellets at least some of the time, the pellets have attracted more attention. At least one small insectivorous owl from Asia produces negligible numbers of pellets making faecal analysis the only option (Lee and Severinghaus 2004)

Analysis of prey remains is appropriate for large raptors that target large prey but then only during the breeding season or if the raptor has regular feeding perches. The direct observation of predation events is impractical for nocturnal fauna but would be useful for interpreting the results of regurgitated pellet or scat analysis. Prey held at the roost is biased towards large items and is too uncommon to be of great use for Barking Owls. Direct observations in this study are presented in Chapter 5.

Observation of prey items brought to nests can be captured by autonomous cameras. Lewis *et al.* (2009) demonstrate that video recording goshawks delivering prey to their nests was an effective method for diurnal raptors. Currie *et al.* (2003) were able to identify 26 prey items from 33 hours of video for Seychelles Scops Owl *Otus insularis*, however sampling just 24 pellets revealed over 400 prey items. Delaney *et al.* (1999) were able to record the rate of prey deliveries for Mexican Spotted Owls *Strix occidentalis lucida,* but did not report the items involved. In the near future, it should be possible to revolutionise owl diet analysis as genetic techniques are perfected and become affordable. Kim *et al.* (2009) demonstrated that genetic bar-coding technology could be applied to egested Short-eared Owl pellets. Not only can different species be counted but also individuals may be able to be identified, allowing counting of partial remains. For now, this technology is too expensive for large data sets and appropriate 'bar-codes' are not available for many Australian taxa. Another approach is to use protein or oil composition of pellet components to identify prey items (e.g. Hall *et al.* 2009).

1.6 The Pilliga Barking Owl Project

In 2001, Milledge (2004) and Soderquist (2009) completed a broad scale survey of large forest owls on the public lands of the Pilliga, Warrumbungle and Goonoo forests. Sites were located every two to three kilometres on roads and tracks in these areas. Apart from scattered Barking Owl records in the Goonoo forests, the main finding was that a substantial population of territorial Barking Owls occurred in the western and northern parts of the Pilliga forests. The distribution correlated with the distribution of the Pilliga outwash geology formation and negatively correlated with the occurrence of repeated wildfires that typically affect the Pilliga sandstone geology (Milledge 2004, Soderquist 2009).

In 2003 Dr Rod Kavanagh (of Forest Science Centre, NSW Industry and Investment), Dr. Todd Soderquist (of NSW Department of Environment, Climate Change and Water) and the author commenced a long-term study of the Pilliga Barking Owl population. We aimed to determine the population density, recruitment and vital resources of the Barking Owl with a view to sustainable management of the population. We also sought insight into the plight of the greater south-eastern Barking Owl population.

Initially, efforts were made to find nest and roost sites. In 2004, we started capturing Barking Owls so that we could band individuals, collect genetic samples and attach radio transmitters with methods similar to those described for other Australasian owls in Kavanagh (1997), Stephenson *et al* (1998), Schedvin (2007) and Bilney (2009). The radio transmitters allowed us to easily find the owls without having to disturb them. We learnt about roost choices, nest trees, home range sizes, preferred foraging areas and habitats used (Kavanagh and Stanton 2009 and unpublished data). Our banding study is ongoing and provides data about longevity, site and pair fidelity and helps us track breeding success when combined with nesting observations. To date, 33 Barking Owls have been banded. Information about natal dispersal is being discovered from the genetic samples.

The Handbook of Australian, New Zealand and Antarctic Birds reported the Barking Owl as being 390-440 mm long with a wingspan between 850-1200 mm. Males reportedly weigh from 475 to 740 grams while females range from 380 to 710 grams (Higgins 1999). Museum specimen labels were the source of the data in Higgins (1999) and give the impression of a lightly built medium-sized owl. However, weights from Barking Owls captured in the Pilliga during winter paint a different picture. Table 1.1 shows the mean weight and weight range for male and female Barking Owls based on the maximum weight recorded for each individual. On average, the male weighs ~10% more than the female and pairs have rarely been weighed where the male is lighter than the female.

Table 1.1 Live weights of captured adult Barking Owls in the Pilliga.

	No. Individuals	Minimum	Mean	Maximum
Males	14	640	824	960
Females	17	640	745	846

Wing and tail lengths were on average, slightly longer in the Pilliga Barking Owls than the specimens used for HANZAB. Museum specimens may under represent live weights and measures for a number of reasons, for example, desiccation of the dead bird, starvation or disease may have lead to the death or blood loss when collected. In a number of cases for nocturnal birds, museum specimens were shown to poorly represent the size of live individuals, for example Sooty Owl (Higgins 1999), Southern Boobook (Trost *et al.* 2008) and Tawny Frogmouth (Kaplan 2007). Larger Barking Owl live weights were also supported by Schedvin (2007) who captured a male Barking Owl weighing 900 grams and a female at 830 grams.

1.6.1 Aims of the Pilliga Barking Owl diet study

Determining the diet and important food resources of the Barking Owl has been a major aim during the Pilliga study. This thesis aims to document the prey of Barking Owls in the Pilliga forests by examining the foraging behaviour and prey remains for 19 owl territories in the study. The study methods have allowed close observation of Barking Owl behaviour. In Chapter 3, I quantified the diet by analysing 1542 regurgitated pellets and 315 faecal scats collected from a range of pairs, through every season and multiple years.

A secondary aim was to explore reasons for the restricted distribution of territorial Barking Owls in the Pilliga, particularly in relation to prey availability. Prey availability data have been collected for all major prey groups in areas where territorial Barking Owls have and have not been detected. In Chapter 4, these data were compared with the regurgitated pellet data to reveal the dietary preference of Barking Owls and reasons for their distribution in the Pilliga and at extralimital sites. Barking Owl feeding behaviour and observations of food debris are related in Chapter 5 as supporting evidence for the findings of Chapter 3 and 4. By studying the diet of Barking Owls in this relatively large population it is hoped that the some avenues of investigation for Barking Owl decline in Southern Australia may be revealed.

Chapter 2
The Pilliga Forests

2.1 Landscape and context

The forests and woodlands of the Pilliga Scrub cover over half a million hectares. At the time of writing, 241,600 hectares is managed by NSW Forests and the Department of Industry and Investment for timber production, nature conservation, recreation, stock grazing and mineral extraction. Timber production has a long history in the Pilliga (van Kempen 1998). A further 277,000 hectares is managed by the NSW Department of Environment, Climate Change and Water (DECCW) for nature conservation and mineral extraction. Currently the only mining use is for coal seam gas extraction. The remainder of the wooded area is on private tenure. Some areas are largely unmanaged and heavily vegetated while other areas have been selectively cleared and/or heavily grazed. The largest patches are enclosed by the public land or lie to the north and south of the public land.

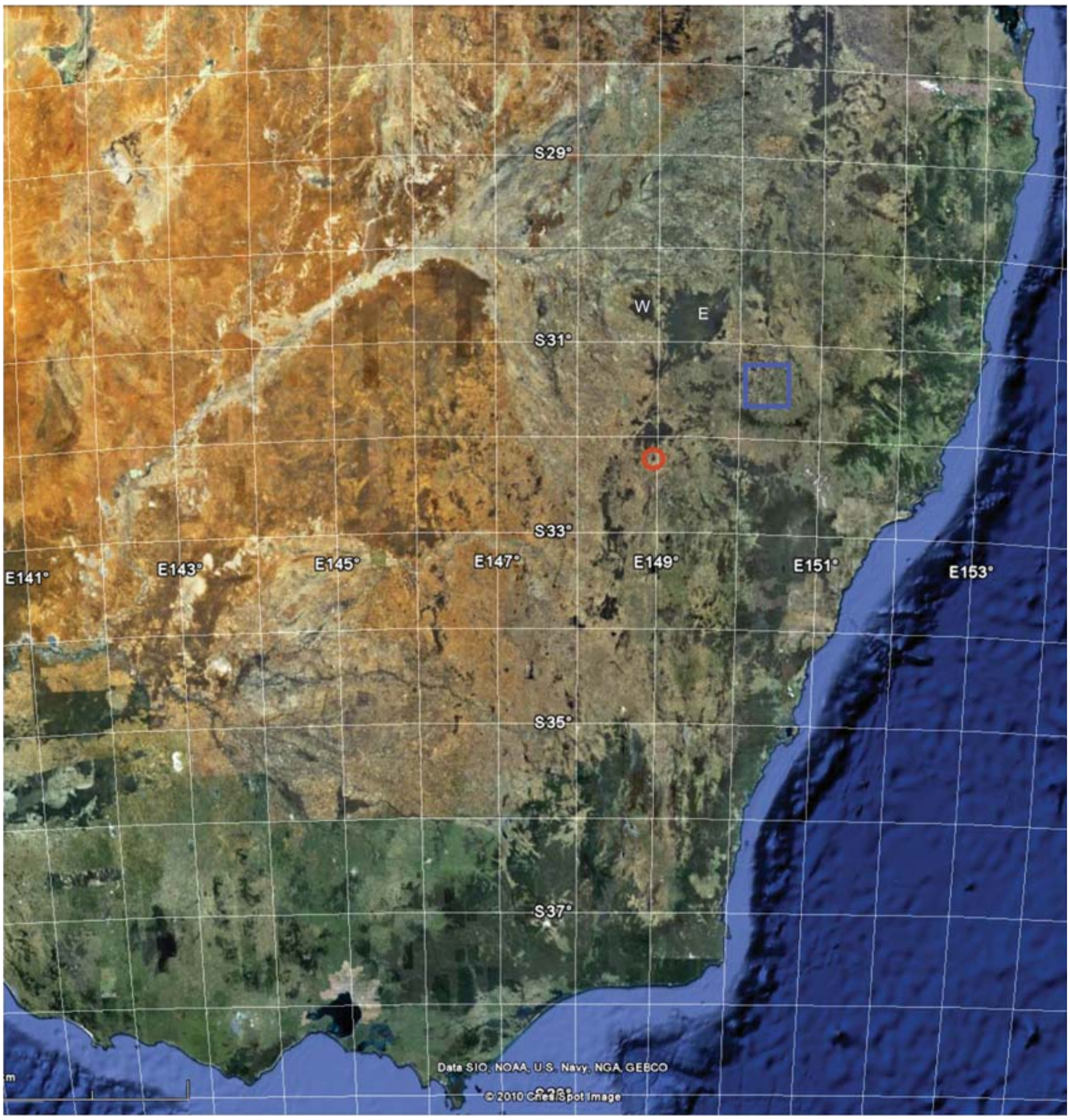
In 1912, Jensen reported that "the area of the Pilliga Scrub proper is about 2,000,000 acres" (~800,000 ha) indicating that the district was considerably more forested at that time. He also noted that "it is hemmed in on all sides by large stations," indicating that the extensive grazing and cropping agriculture surrounding the forest today was already established.

The forest also extends to the Warrumbungle National Park (23,300 ha) to the south-west. The terrain and forest here is significantly different being partly volcanic and mountainous. To the north-east on the other side of the Namoi River valley, lies Mt. Kaputar National Park (50,200 ha), a younger volcanic feature. Mt. Kaputar is so high that it is possible to see 1/16th of NSW from the top and it generates significant orographic rainfall. As a result, Mt. Kaputar and to a lesser extent the Warrumbungles, feature significantly wetter forests, richer, younger geology and biota more typical of the great dividing range to the east. However, the lower elevation areas of both features contain some vegetation resembling that found within parts of the Pilliga forests.

To the east lie the Liverpool Plains. In stark contrast to the Pilliga region, the soils of the plain are amongst the richest for agriculture in Australia. Over 95% of the landscape has been cleared or modified from native grassland and used for agriculture. The remaining forest is mostly on poor sedimentary geology forming small 'islands' surrounded by the 'lake' of the plain. Most of the 'islands' resemble Pilliga Sandstone in geology and vegetation.

To the north and west lie the Darling Riverine Plains. At the time of European settlement the plains were largely wooded with some open areas and extensive wetlands near some of the rivers (Oxley 1819, Mitchell 1839). Today these are also over 95% treeless and used for agriculture. To the south lies more agricultural land, though with more retained woodland and forest. Figure 1 shows the location of the Pilliga forests, the connected Warrumbungle's to the south-west and their isolation in a sea of cleared agricultural land. The nearest forest patches are Mt Kaputar to the north-east and the Goonoo forests to the south.

Figure 2.1 South Eastern Australia as seen by a mosaic of SPOT satellite images compiled in Google Earth. The Pilliga forests can be clearly seen as the dark green patch in the vicinity of 31° South and 149° East. A 'W' marks West Pilliga and an 'E' marks East Pilliga. The pale land surrounding the forest is open country. Yarindury State Forest is marked by an orange circle and the Liverpool Plain is indicated by a blue square.



2.2 Geology

Hesse and Humphreys (2001) give a good summary of the geology and geomorphology of the Pilliga landscape. They divide the area into two distinct landscapes.

The first is the 'Pilliga Sandstone hills'. Pilliga sandstone is predominantly quartz-based sandstones and conglomerates originating in the Jurassic period. The stone varies in structure considerably and often shows signs of deep weathering by the time it becomes exposed. The landform ranges from deep gullies and rugged hills in the more elevated south through to low hills with broader gullies where it merges with the neighbouring Pilliga outwash plain in the north and west. The two largest drainage lines in this area, being Baradine and Bohena Creeks, form substantial valleys and have eroded right through the Pilliga Sandstone and into the underlying Purlawaugh formation. The junction of the two formations is often marked with freshwater springs. Substantial cliffs occur in a number of the southern extremities of the forest, particularly where there has been uplifting associated with the neighbouring volcanic Warrumbungles. Heavy clay soils occur in many areas, having formed in situ from weathered sandstone. Soil fertility is low, regardless of type. Water is shed easily and not well retained.

The second landscape is called the 'Pilliga outwash plain'. This is largely an alluvial outwash plain formed from material eroded from the Pilliga Sandstone hills, via the creeks draining them to the west and north. Some material may have been weathered in situ. The typical geology on the surface has no substantial rock, being typically deep soils of sand and various clays at least in some areas overlying Pilliga Sandstone or re-cemented products of weathering.

Baradine Creek continues out of the Pilliga Sandstone hills and through the plain, however, it is the most westerly continuous creek in the forest with almost all of West Pilliga having no substantial drainage lines.

Instead there are palaeo-channels over filled with sand until they often form the highest features in the generally flat landscape. These ancient channels filled with sand are called 'sand monkeys'. In West Pilliga, the sand monkeys tend to run in a north-west or west-north-west direction away from Baradine Creek which runs north through the plain. Occasionally there are low dunes associated with wind movement of sand from the channels during a period of aridity. Dust from clays in the local landscape may also be associated with these features. The dunes typically run parallel to the sand monkeys. The sand features have the lowest water holding capacity and are the best drained (Humphreys *et al.* 2001). As a result, they dry out more quickly after rainfall events.

Sand monkeys also occur further east where there are still active drainage lines. Typically, these radiate out from the area where the drainage enters the plain. Most sand monkeys formed over 40,000 years ago (Hesse and Humphreys 2001).

Between sandy areas are clay flats. The clays may be mineral clays and organic clays. They are poorly drained and tend to accumulate large areas of shallow water after heavy rain.

Other creek lines to the east of Baradine Creek are also choked with sand, only showing water during times of flood. Water still flows through the sand beds most of the time. The sand in these creeks and to a lesser extent in Baradine Creek is of a more recent origin than that found in the sand monkeys. It is probable that much of this sand is from erosion events associated with the introduction of stock grazing at the time of European settlement and with sand washed in from roads (Hesse and Humphreys 2001).

2.3 Forest types

The earliest published work, which sought to quantitatively describe the forest types of Western NSW, was the Forestry Commission of NSW Technical Paper No. 8, (Lindsay 1967). Known as the 'Lindsay Report', it described 107 vegetation types, a classification still used by forest managers today. The Pilliga Forests were mapped by this classification in work carried out between 1945 and 1953. It is probable that there have been some forest changes since mid-20th century, however that change has been difficult for researchers to detect within the limitations of mapping of the day (Norris *et al.*, 1991, Whipp *et al.* 2009).

Binns and Beckers (2001) classified the vegetation of the Pilliga forests into six broad groups with two of the groups being further broken into sub-types making a total of nine types. The analysis of 482 x 0.1 hectare plots incorporated 753 native species and 100 exotic species. The groupings resulted from considering all plant species, not just the overstorey species typically used for forest typing.

The Binns and Beckers six main types and their dominant overstorey species were:

Box-Herb	*Eucalyptus populnea, Callitris glaucophylla* and *Allocasuarina luehmannii.*
Grassy White Pine - Box	*Callitris glaucophylla* and Assorted Boxes
Grassy White Pine - Ironbark	*Eucalyptus crebra, Callitris glaucophylla* and *Allocasuarina luehmannii*
Riparian Angophora - Red Gum	*Angophora floribunda* and *Eucalyptus blakelyi*
Heathy Bloodwood - Ironbark	*Callitris endlicheri, Corymbia trachyphloia* and *Eucalyptus fibrosa*
Heath	*Melaleuca uncinata* and other shrubs rarely tree high.

In contrast, Humphreys *et al.* (2001), working in the western most portion of East Pilliga State Forest classified forest into 12 types in six main groups. The groups were:

Sand Monkey	Broadly similar to Binns and Beckers 'Riparian Angophora - Red Gum'
Broom	Broadly similar to Binns and Beckers 'Heath'
Mallee	*Eucalyptus viridus*, a species of limited distribution in the Pilliga
Mixed Forest	*Eucalyptus crebra* dominated forest.
Box Forest	*Eucalyptus pilligaensis* dominated forest.
Belah	*Casuarina cristata* dominated forest.

All groups except the Broom and Belah also commonly feature *Callitris glaucophylla.* In particular, *C. glaucophylla* can dominate "Mixed Forest". Humphreys *et al.* (2001) demonstrate that *C. glaucophylla* is probably absent from Belah and Broom types because these areas can remain waterlogged for extended periods.

From my own observations, the woody vegetation on the outwash plain is typically forest, dominated in height by eucalyptus species, 16 to 30 metres high, but dominated in numbers by White Cypress Pine which is 10 to 24 metres high. In most areas, canopy height does not exceed 20 metres.

The lowest places in the landscape are occupied by Belah *Casuarina cristata* or by Pilliga or Poplar Box *E. pilligaensis* and *E. populnea*. The sandiest "ridge" areas are usually covered in red gum woodland. Narrow-leaf Ironbark *E. crebra* and Bulloak *Allocasuarina luehmannii* can occur abundantly in both environments, only absent from the lowest clay flats. Numerous other tree species occur in lower abundance through the out-wash zone. These include other box eucalypts (*E. albens, E. conica, E. melliodora, E. microcarpa*), Silver leaf Ironbark *E. melanophloia*, Rough-barked Apple *Angophora floribunda and* Kurrajong *Brachychiton populnea*.

Prominent tall shrubs sometimes form a mid-storey. In clay-based soils, these are typically Wilga *Geigera parviflora* up to ten metres tall and Emu Bush *Eremophila mitchellii*. In sandy areas, assorted acacias and hop-bush *Dodonea sp.* dominate. Broom and Mallee areas form distinctive communities of tall shrubs generally not more than four metres high.

The forests of the sandstone hills are markedly different. The most typical community is Binns and Beckers "Heathy Bloodwood – Ironbark" featuring Black Cypress Pine *Callitris endlicheri,* Brown Bloodwood *Corymbia trachyphloia* and Broad-leaf Red Ironbark *Eucalyptus fibrosa*. Generally the forests of the sandstone hills produce a dense understorey or midstorey of Casuarinaceae, Ericaceae, Fabaceae, Myrtaceae, Rutaceae, or other shrubs. Sometimes Black Cypress Pine grow densely enough to prevent an understorey forming. The high density of shrubs makes the sandstone-based forests highly vulnerable to wild fire and there have been at least eight large wildfires in this area in the last 60 years. Only two of these wild fires have substantially impacted on the Pilliga outwash zone.

2.4 Exploration and research

The earliest European visitors to the Pilliga were an exploration party led by John Oxley in the winter of 1818. After attempting to navigate the Macquarie River and halted by the Macquarie Marshes, Oxley headed east across the flooded Castlereagh River to the Warrumbungle Range and then north-east through the Pilliga sandstone hills. The going was so difficult that Oxley chose to back track rather than persevere through the thick vegetation and boggy soils he encountered (Oxley 1819). His notes of the flora and fauna were limited and sometimes difficult to interpret. The following quotes are most of what he provided about the southern Pilliga biota.

One of his few positive comments was “adorned with various species of acacia in full bloom, with a vast variety of other flowering shrubs of the most beautiful and delicate description, adding greatly to our botanical collection”.

All other comments were negative. For example, on August 17th “The whole was a mere scrub covered with dwarf iron barks, apple trees and small gums; the soil scarcely any thing but sand, on which grass grew in single detached roots.” In addition, “In our track we saw no signs of natives and the country seemed abandoned of every living thing. Silence and desolation reigned around.”

What wildlife they did encounter proved worthless by their measure. “These woods abound with kangaroo rats and it is singular that, pinched as the dogs were, they would not touch them even when cooked.” Exactly what “kangaroo rats” meant is unclear, however some later authors have interpreted “kangaroo rats” as Rufous Bettongs *Aepyprymnus rufescens*. Normally these are quite palatable and live in areas with plentiful grass (Short 1998). Oxley may have been referring to another animal, possibly a rodent or maybe to the Swamp Wallaby, a species with a strong odour, which is common in scrub areas of the Pilliga.

The Pilliga forests came to prominence in recent decades as the subject of a best selling book, ‘A Million Wild Acres’ by Eric Rolls. Its publication in 1981 outlined the process of settlement not just for the Pilliga region, but also for much of NSW. The story is one of changes brought about through the actions of graziers and their stock, combined with the effects of feral animals and the change in fire regimens. Eric Rolls included his own experience and viewpoint as a local farmer. For example, he mentions his own experience with Barking Owls nesting in a strip of trees on his property adjacent to Merriwindi State Forest just north of Baradine. He also brings a sense of wonder to the region as the last great tract of forest left standing west of the Great Dividing Range.

The underlying message of a Million Wild Acres is that the forest is in some respects, a man made forest. In many ways, this is obviously true given its history. However, Rolls goes further and suggests that the forest has become denser over time. Particularly he refers to regeneration events associated with the initial overgrazing when the area was opened to agriculture, changes in fire regimen, rainfall events, the decline of “Rat-kangaroos” (misquoting Oxley) and the rise of rabbits followed by their decline with the release of Myxomatosis. Van Kempen (1997) refines some of these ideas in her history of the Pilliga cypress pine forests.

A more recent treatment of the subject of White Cypress Pine regeneration has painted a slightly different picture. Norris *et al.* (1991) point out some errors of timing in Rolls arguments and his selective quoting from explorers journals. By comparing the earliest vegetation maps with those of today, they found that the forest had not changed much over a 77-year period during last century. Benson and Redpath (1997) pursue this idea further and conclude that the continued misquoting (intentional and unintentional) of explorers journals has lead to a false impression of the nature of pre-European woodlands, particularly in the Pilliga.

In the last fifty years, the Pilliga (as the last large tract of woodland west of the great dividing range) has been utilised to study woodland fauna. In the 1960s and 70s, Bustard (1968 and numerous other papers), made an intensive study of the geckos and other reptiles within Merriwindi State Forest. His mark and recapture study of thousands of geckos made a longstanding contribution to our understanding of woodland gecko biology and ecology.

Some type specimens of newly described species have come from the Pilliga area, including reptiles, a rodent (Fox and Briscoe 1980) and most recently a newly defined bat species *Nyctophilus corbeni* (Parnaby 2009).

The Koala was the subject of an experimental study, to determine the effects of White Cypress Pine logging in the Pilliga. Koalas were radio-tracked before and after harvesting operations, in the first experimental logging study of its kind (Kavanagh *et al.* 2007a).

Jefferys and Fox (2001), Tokushima *et al.* (2008) and Paull (2009) studied the Pilliga Mouse *Pseudomys pillagensis*. Thought to be endemic to the Pilliga Forests, the Pilliga Mouse, has recently been reclassified by some authors, as a wide-ranging species, *Pseudomys delicatulus* (Breed and Ford 2007, Van Dyke and Strahan 2008).

Two studies published in the first half of last century established a basic bird list for the Pilliga area (Cleland 1919, Chisholm 1936). Chisholm's notes that "*Ninox strenua*. Powerful Owl… seen moving about in the late afternoon" and "*Neophema chrysostoma*. Blue-winged Parrot… Fairly plentiful" without recording the relatively common Barking Owl *N. connivens* or Turquoise Parrot *N. pulchella* suggests that he was making misidentifications and these species may never have occurred there.

More recently, Date *et al.* (2002) explored the effects of forest management on the avifauna of the Pilliga forests. They detected 170 bird species in the forest area compared with 219 species recorded historically. The historical records do not all relate directly to what we now recognise as the Pilliga. Many species on their list would never have occurred in the area remaining under forest today, as they are not forest dwelling species. At least twenty others could only have been detected as vagrants as they are southern mallee dwelling species. Some of the species they did not detect are nomadic and only occur in the Pilliga when conditions are unsuitable elsewhere, such as during the recent drought. For example, Red-backed Kingfisher *Todiramphus pyrrhopygius*, Little Button-quail *Turnix velox* and Diamond Dove *Geopelia cuneata* were all present in the forest in 2008 when the Pilliga had some rain but further west was still in drought.

2.5 Management and exploitation

Exploitation of the Pilliga timber resources have had a marked effect on the forest, in some ways amplifying natural differences between the Pilliga sandstone and Pilliga outwash areas. Two high quality and potentially high value timber species, grow well in the Pilliga outwash and have dominated the timber industry. White Cypress Pine is uniquely termite resistant and as a result has been used widely where termite resistance is useful, particularly the building industry. As the Pilliga has been one of the largest sources of White Cypress Pine, the White Cypress Pine has been the target of much of the forest management for the last hundred years. Almost as desirable is the Narrow-leaved Ironbark *Eucalyptus crebra*. The durable heavy ironbark timber is put to many uses, but most notably has been a preferred material for railway sleepers, fencing and construction.

White Cypress Pine often regenerates in dense stands, which monopolise the water supply. Dense stands can reach a point known as "lock-up" where there are insufficient resources for the trees to continue growing, but nothing that actually kills them to self thin the stand. Lock-up can effectively prevent anything growing. Forestry practice has been to thin such stands to a stem density where the remaining cypress can continue growing (generally between three to six metre spacing). This also allows some other plant species to grow. In the past, other non-commercial tree stems were also felled or ringbarked. Many large hollow ironbarks, red gums and box are still standing today as dead trees that were ringbarked between the 1920s and 1970s. For as long as they can stand, those dead hollow trees remain a resource for hollow dwelling wildlife, many of which are Barking Owl prey. Today they are still threatened by illegal firewood harvesting as well as by natural attrition. In many parts of the forest, their replacements are not yet obvious.

The volumes of timber that have been removed from the Pilliga seem to have been vast. Paull (2001) measured the density of large stumps and large living trees in West Pilliga. Living Narrow-leaved Ironbark occurred at only a quarter of the density of the stumps of similar sized trees. White Cypress Pine occurred at an even lower density. The forest is now dominated by many small stems of the same species.

While timber production has focused on the more productive outwash area, the Pilliga sandstone area has resources of its own. In the last decade, mineral resources of the area have been explored and exploited. Coal seams underlie much of the Pilliga sandstone and at the time of writing the coal seams are being utilised for gas extraction. Apiarists and their honeybees have utilised the diverse array of flowering plants for their nectar and pollen. The broom-bush plains have been cut for *Melaleuca uncinata* to produce brush fencing.

Fire management has resulted in a strong dichotomy in the vegetation of the Pilliga. Because Callitris species are vulnerable to fire, managers have actively managed the forest to reduce the risk of wildfire damaging the White Cypress Pine crop. Commercial cypress areas have a well-developed road network. Roads act as firebreaks as well as allowing reliable access to the forest to suppress fires. Earth dams and tanks are scattered through the forest to ensure water is available for fire suppression. Control burns are conducted around the edges of commercial areas to reduce fuel loadings and provide some chance of defending the White Cypress Pine from a summer wild fire. Such wildfires usually originate in the Pilliga sandstone hills and have done so most recently in 1997, 2006 and 2007.

2.6 Summary

The Pilliga environment has been created by nature and human actions. The less-commercial forests of the sandstone hills probably look similar today to when Oxley saw them in 1818. The effects of fire exclusion and timber management have shaped the forest of the outwash plain towards one of numerous smaller stems and fewer large old trees. Yet, Barking Owls persevere in the Pilliga environment. They are able to utilise the resources of the more fertile portion of the forest to maintain breeding territories while they have been unable to do so in most of the surrounding agricultural land or the least productive portions of the Pilliga forest. In the remaining chapters, the influences of these resources on Barking Owl diet are examined.

Chapter 3
Barking Owl Diet in the Pilliga Forests

The regurgitated pellet samples used in this chapter are jointly owned by Dr. Rod Kavanagh and Matthew Stanton.

3.1 Introduction

Since it was discovered that the Pilliga forests had the most substantial known population of Barking Owls in Southern Australia (Milledge 2004), forest managers and regulators have speculated about the reasons why this population has persisted, while others appear to have declined or failed (Debus 1997, 2001, Taylor *et al.* 2002a, Parker *et al.* 2007, McGregor *in press*).

One hypothesis is that the food resources of other populations are now based around boom-bust species of open agricultural land, while the Pilliga Barking Owls base their feeding on relatively stable populations of forest-dwelling species. As a sedentary, seasonal breeder (Schedvin 2007), Barking Owls would seem unsuited to habitat and prey-base simplification and the resulting boom-bust prey cycles unless those prey cycles were synchronised with the breeding season when maximum prey are required.

Barking Owls in other studied localities in Southern Australia have an affinity for forest and woodland edges (Kavanagh *et al.* 1995, Taylor *et al.* 2002b) while large expanses of non-edge woodland appear to be sparsely used or occupied (Taylor *et al.* 2002b). When examined in detail, Schedvin (PhD thesis Chapter 5, 2007) found that 13 radio-tracked Barking Owls in the Chiltern region of Victoria were not using the structural pasture/woodland edges preferentially for foraging even though their nest sites and territories were associated with edges by virtue of high levels of woodland fragmentation and location near agricultural areas. Some structural edges such as those created by roads intersecting forest were used preferentially as were forest areas closer to the nest tree.

The Pilliga forest provides a special opportunity in this regard, as it has Barking Owl territories that are not associated with edges. The 2001 Milledge (2004) survey reported

Barking Owl records in the centre of West Pilliga State Forest. The Barking Owl radio-tracking study in the Pilliga has confirmed that there are numerous territories not associated with forest edges. While West Pilliga State Forest is a strongly modified environment, it still represents one of the most natural environments available to study Barking Owls without the heavy effects of forest clearing and agriculture.

Kavanagh *et al.* (1995) and Taylor *et al.* (2002a) also found that drainage lines and the low-lying portions of the landscape were more heavily occupied by Barking Owls and speculated that they provide more productive habitat that Barking Owls rely on. Schedvin (2007) could not confirm the low-lying landscape model in the Chiltern area, however all the study owls were in the lower portions of the landscape. The drainage lines model was confounded by the main areas of retained trees being along drainage lines (or along road reserves). In the Pilliga, there are extensive forest areas with and without drainage lines. Both environments have Barking Owl territories. A dietary comparison is made of territories with and without drainage lines in this chapter.

The primary difference between areas with and without active drainage lines is in vegetation structure and floristics. Fourth-order streams and those below them, form broad sandy creek beds fringed with water associating vegetation such as large red gums and callistemon thickets. Water availability to wildlife is not greatly different as drainage lines have little open water and dams are scattered throughout the Pilliga, with most owl territories having access to at least one natural or artificial watering point.

As Barking Owls are seasonal breeders, they have different feeding requirements through the year. The data provided in this chapter allow a seasonal examination of those requirements and how the Barking Owls satisfy them.

This chapter has the following aims:

1. To describe the diet of Barking Owls in the Pilliga forests, seasonally and spatially.

2. To compare the diet of Barking Owls occupying forest edge territories with those occupying forest core territories.

3. To assess the importance of the presence or absence of drainage lines in territories for owl diet.

4. To compare the diet of the Pilliga Barking Owls with the diet of other populations where known.

5. To explore the potential of faecal scat analysis as a method of describing owl diet (a new method for Australian Owls).

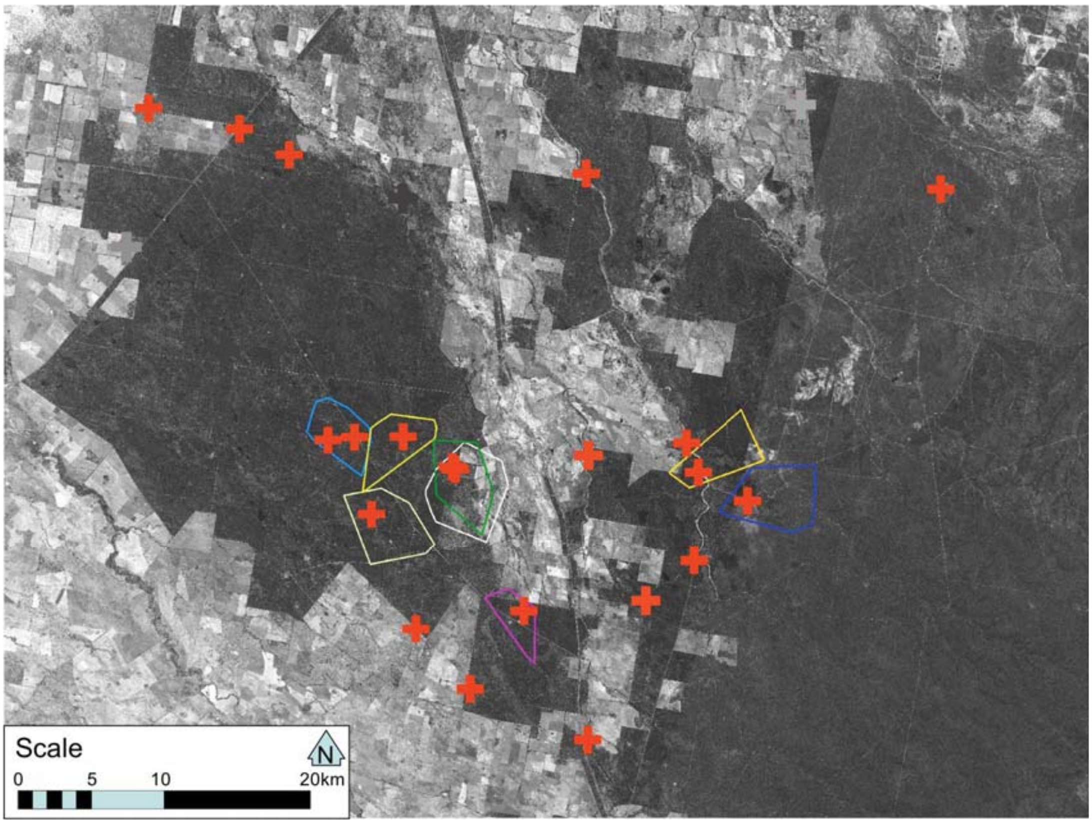
3.2 Methods

3.2.1 Study areas

3.2.1.1 The Pilliga forests

A detailed description of the study area was given in Chapter 2. The analysis presented here was based on data obtained from 19 Barking Owl territories (and one non-territory holding owl) found between 1999 and 2009 within the Pilliga. Apart from data collected from radio-tracked individuals during 2004/2005, most data have been collected from the vicinity of nest sites shown for the Pilliga in Figure 3.1. Roosts near nest sites are used year round by many Barking Owls in the Pilliga. Roost sites away from nest trees were less easily discovered and so will be under represented in some territories within the data set.

Figure 3.1 Barking Owl territories known from radio-tracking (coloured polygons) and known nest areas (brown crosses) from which diet data were obtained during this study. Dark grey indicates wooded areas. SPOT satellite image © CNES 2004/5.



3.2.1.2 Yarindury State Forest

Yarindury State Forest, a small (1200 ha) wood production and conservation forest set in an agricultural landscape (cropping and grazing), lies approximately 150 km due south of West Pilliga State Forest. Forest types in Yarindury were largely similar to the Pilliga forests found on Pilliga Sandstone, areas not frequented by territorial Barking Owls in the Pilliga. These portions of Yarindury feature dense stands of Black Cypress Pine, with emergent ironbarks. A sizable portion of the forest's western edge, supports White Box and White Cypress Pine, species more typical of productive forest. The Barking Owls were most often found on the western side of the forest.

Yarindury and the surrounding private property supported at least two pairs of Barking Owls during 2006/2007. I was able to collect a significant diet sample from one of those pairs. The pair fledged three chicks over those two years. The second pair was often using private property preventing significant roost or nest areas being found. The Yarindury State Forest samples were compared with the Pilliga samples, as the site was more similar to many of the small forest remnants scattered around southern Australia that support Barking Owls.

3.2.2 Method selection

A number of approaches can be taken to studying bird diets. Traditional methods include stomach contents from dead specimens, food regurgitation or stomach flushing of living specimens, ligatures on nestling necks, faecal samples, regurgitated pellets and direct or photographic observation of foraging or food delivered to a nest (Rosenberg and Cooper, 1990) or of uneaten prey remains discarded around a nest. A few studies have observed the number of marked prey items that turn up in regurgitated pellets (for example, Streby *et al.* 2008). Some owls, including Barking Owls, hold larger prey items at diurnal roosts, allowing easy prey identification (Pavey 2008, Schoenjahn *et al.* 2008)

As a threatened species in New South Wales (Threatened Species Conservation Act 1995), any method that endangered individual Barking Owls or posed a significant risk to their breeding success was ruled out. Sacrificing Barking Owls for their stomach contents or any other purpose would be unacceptable and extremely inefficient. Inducing regurgitation may be possible, however with only 44 captures made during this study, the sample size would be small. I feel that it would be unethical to experiment with this method on a rare and vulnerable species given the known mortality rate in some other groups of birds where forced regurgitation and stomach flushing has been tried (Rosenberg and Cooper 1990). Using ligatures on nestling owls would be impractical due to nestling inaccessibility and only useful for a month of each year.

Instead, to understand the diet of Barking Owls I adopted four methods designed to have a minimal impact on the owls and their behaviour. The largest data set comes from naturally regurgitated pellets of undigested prey remains. Most raptors and owls that prey on vertebrates regurgitate compacted pellets of indigestible/less digestible material such as hair, feather, claws, larger bones and exoskeleton (Rosenberg and Cooper 1990). Barking Owls regularly produced such pellets at a rate of one per day regardless of the volume consumed (pers. comm. Lenore Wilbow, wildlife carer), although production varied with the kind of food consumed (pers. comm. Chad Staples, Featherdale Wildlife Sanctuary). This method was biased towards medium-sized prey items with hard indigestible body parts. Soft-bodied prey may leave traces that are ejected along with hard-bodied items, however, if the owl was only eating soft-bodied prey, there may be no pellet produced. This was the case with small species such as some Scops Owls *Otus spp.*, which eat mostly small insects and may rarely produce regurgitated pellets at all (e.g. Lee and Severinghaus, 2004). It has also been suspected as a cause of under estimation of soft-bodied invertebrates for larger species such as the Spotted Owl *Strix occidentalis* (Forsman *et al.* 2004), the Barred Owl *Strix varia* (Livezey *et al.* 2008) and the Southern Boobook *Ninox novaeseelandiae* (Rose 1996, Penck and Queale 2002). Barking Owls, like all *Ninox* owls, are known to eat insects (Hollands 2008). Observations reported in Chapter 5 indicate that Barking Owls may go through periods of not regurgitating pellets associated with high rates of invertebrate consumption.

This leads to the second method; faecal pellet analysis. Barking Owls produce a wide variety of faeces. At times, their excrement was a thick white paste that hardened into a chalky whitewash typical of large owls that eat mostly birds and mammals. Often there was a hint of rough material contained in it or entirely composed of material that might almost have been a regurgitated pellet. Occasionally, Barking Owls were observed to excrete a runny dark liquid. During this study, I was able to collect a small sample of faecal material from every season. The method was difficult to use to identify prey items precisely and impossible to count items consumed. However, it provides an overview of what species groups were being consumed as material from all known prey groups can be found in faecal material. The four broad groups are mammals (with some ability to determine coarse haired from fine haired species), birds, hard-bodied arthropods and moths. Some samples have no visibly recognisable prey remains, being completely digested to a fine paste or consisting of blood-derived waste products such as uric acid, the white material in bird faeces.

The third and fourth methods used in this study were collection of prey debris at nest sites and direct observations of predation and prey holding, both reported in Chapter 5. Prey debris collection was only reliable during nesting when prey items are torn into pieces and exchanged at regular perches around the nest. The benefit of this material was that it was usually easiest to identify, often to species and even to the size and age of the specimen. The method was biased towards larger prey items, particularly birds and was always difficult to quantify due to the haphazard nature of items being dropped. Direct observation of prey capture or consumption provided a small but useful data set. Most observations were made during a year of radio-tracking and/or at dusk, while there was still natural light to aid the observation. Often the prey identity was not confirmed until it showed up in a pellet collected after the following day. Observing hunting technique was most helpful in interpreting the other results. It was also possible to see Barking Owls holding partly eaten prey, while roosting during the day. The direct observations are presented and discussed in Chapter 5.

In their review of diet analysis, Rosenberg and Cooper (1990) strongly recommended using more than one method. Data from the four methods that I used cannot be combined in a quantitative manner. Rather, they stand as checks on each other. It was possible to confirm elements of the results of the main regurgitated pellet data with the other three methods.

3.2.3 Pellet collection

Pellets were consistently collected from October 2003, through most seasons until July 2007 and a few additional samples were taken up until November/December 2009 (Table 3.1). Samples were collected in all months. During September, Barking Owl pairs were usually incubating. I felt it was not warranted to disturb them and risk the nest being abandoned or failing because the parents were putting extra time into defending the nest site from me. However, in early September 2008, I cautiously collected a small sample of pellets from a selection of pairs that were relatively used to my presence.

Pellets were collected during at least two years for each season. Autumn was the most difficult season to collect pellets as owl movements and roost use was least predictable at this time. Additionally, pellets appeared to be scarcest at this time of year for a variety of reasons discussed in Chapter 1.

All localities for pellet collection are referred to as territories rather than attributed to particular individuals. Often I had no way of knowing which bird had created which pellet. To further complicate the situation, some territories showed high turn over of individuals. The replacement individual often used the same roosts and nests and the exact time of change-over was not always noticed. Not all Barking Owls in this study were banded, however, those that were had ten different colour/leg band combinations to allow a probable identity to be established when a roosting bird was seen.

Initial pellet samples came from nest sites and from post fledging roosts, where Barking Owls were relatively easy to find. The following winter (2004), as part of a larger study

Dr. Rod Kavanagh, Dr. Todd Soderquist and I fitted nine owls from eight territories with radio transmitters. This allowed consistent discovery of roosts and thus of pellets throughout the year. The greater knowledge of roosting patterns enabled me to continue to find Barking Owl roosts from these and other individuals after the transmitters had been removed. Even so, it was not always possible to locate every pair of Barking Owls every time I made another collection of pellets and other material. Table 3.1 shows the collection periods and sample size as well as the radio-tracking period for each territory. The 'Underwood' territory had both male and female radio-tagged. 'Al' refers to a single owl which was tagged in the 'Aloes' territory, before moving through a number of other territories and the transmitter failing.

Table 3.1 The distribution of regurgitated pellet samples by date and territory. Territories that included forest edge (E) and/or contained creeks (C) are indicated.
* = at least one radio-tracked Barking Owl found in the territory at that time.
FD = no pellets found but food debris recorded. B = broken portions of pellets.
N = Barking Owls found but no pellets or food debris present at roosts.

Season	Month Year	Westburn	Bee	Belah	Underwood E	Trapyard E	Hunt C E	Rocky C	Al C	Aloes C	Euligal Crossing C E	Taylors E	Cowens Crossing C E	Vale	Leyland C	Rusty Swamp E	Yetta E	Wombo E	Etoo C E	Tara South C E	Karingal C E	Yarindury E	Month Total
Summer	Jan 1999										1												1
Spring	Oct 2003				4			2			10	1											17
Summer	Dec 2003				8	2		4			2	13	7	3	FD								39
Winter	Jun 2004	*1	*2	*2	*4	*B	*5	*	*2	4													20
Winter	Jul 2004	*3	*6	*7	*13	*5	*8	*12		B	9												63
Winter	Aug 2004	*8	*4	*6	*15	17	*6	*5		8	5												74
Spring	Oct 2004	*17	*1	*15	*9	23	*8	*13		12	13		9										120
Spring	Nov 2004	*12	*5	*24	*10	19	*13	*7		6	3		7										106
Summer	Jan 2005	*14	*	*1	*1	N	*5				5												26
Summer	Feb 2005	*4	*2	*6	*1	3	*4				3		FD										23
Autumn	Mar 2005	*6	*	*	*3	B	*FD			12	3		2										26
Autumn	Apr 2005	*7	*8	*2	*2	N	*2																21
Autumn	May 2005	*7	*13	8	*3	7	*1			1	5		1										46
Winter	Aug 2005	1			2	25				23	15												66
Summer	Feb 2006	11	6	1	11	1					3												33
Winter	Jun 2006					17					5					8						50	80
Spring	Nov 2006	15	10	7	4	1	1			B	2					35	17	19	8			88	207
Summer	Feb 2007	3	2	7		2					2					13	17					12	58
Autumn	May 2007	11	1	4		43										23	12					22	116
Winter	Jul 2007	7	28	6		18				4	2					11	13	FD				7	96
Spring	Oct 2007	9	16		20		13									23						41	122
Spring	Sep 2008	8	9							9							7	9		3			45
Winter	Aug 2009	14	19							15						2				1			51
Spring	Nov 2009	4	22							19						22					23		90
	Total	162	154	96	110	183	66	43	2	113	88	14	26	3	FD	137	66	28	8	4	23	220	1546

When few if any regurgitated pellets were found, I started collecting faecal material to attempt to determine the reason for the lack of regurgitated pellets and fill in blanks left by the absence of pellet data. This was done consistently for some owl territories. Towards the end of the sampling period, another effort was made to improve these data during the breeding season and the pre-breeding season. Table 3.2 shows the collection periods and sample size of faecal material for each territory

Table 3.2 The distribution of faecal samples by date and territory.
Territories that included forest edge (E) and/or contained creeks (C) are indicated.

Season	Month Year	Westburn	Bee	Belah	Underwood E	Trapyard E	Hunt C E	Rocky C	Al C	Aloes C	Euligal Crossing C E	Taylors E	Cowens Crossing C E	Vale	Leyland C	Rusty Swamp E	Yetta E	Wombo E	Etoo C E	Tara South C E	Karingal C E	Yarindury E	Month Total
Spring	Oct 2003										1												1
Summer	Dec 2003							1															1
Winter	Aug 2004				1					1													2
Spring	Nov 2004					1																	1
Summer	Jan 2005	2																					2
Summer	Feb 2005		1		5		5				10												21
Autumn	Mar 2005		3		6		9																18
Autumn	Apr 2005				9																		9
Autumn	May 2005				5						4												9
Summer	Feb 2006	1																					1
Summer	Feb 2007	5														5						5	15
Autumn	May 2007																1					4	5
Winter	Jul 2007					1											1						2
Spring	Oct 2007															1						1	2
Spring	Sep 2008	6	5							1	8						16	9		9			54
Winter	Aug 2009	40	11	5						17						33							106
Spring	Dec 2009	11	5							13						28					9		66
	Total	65	25	5	26	2	14	1		32	23					67	18	9		9	9	10	315

3.2.4 Regurgitated pellet examination

After collection, pellets were frozen to minimise biotic activity breaking down some pellet components. Pellets were examined in a number of phases. Initial examination was made without breaking or wetting the pellet. There were four reasons for this.

1. When pellets fall to the ground, they are usually a little moist and can be soft enough to deform and pick up foreign material. It was important to determine that all material collected was indeed part of that pellet. Many places that Barking Owls roost have other bones and insect remains scattered around. Much of the material comes

from old Barking Owl feeding debris, but could also come from other raptors, fox scats or from animal carcasses. These typically end up in a shady spot where a scavenger has been chewing them or where the animal happened to die. It was usually obvious if the pellet had picked up the material by the relative age of the components.

2. Some pellet features are delicate. Small bird and bat skulls crush easily when dissecting pellets, as do some invertebrate parts. On tightly bound pellets, whole delicate parts can only be seen complete before dissection.

3. Some features were only evident when the pellet was dry. Some pellets have to be moistened to extract components or reduce dust. When moist it becomes difficult to observe feather and hair colours. Moth scale curls up and becomes indistinguishable. Generally, these features become obvious again once the material dries, however it was easier to spot them at the start.

4. To check that a Barking Owl had actually produced the pellet. Confusion was possible with other species of owl or diurnal raptor pellet and other predator scats. Fox and Cat scats tend to have a distinctive odour, which usual becomes apparent upon opening the pellet bag. Mammal predator scats are typically long and will often have a pointed tail, which was rarely present on an owl pellet. Fox scats also often contain large quantities of seed and dirt. Barn Owl regurgitated pellets tend to be dark grey due to a mucous coating. Typically, they contain complete skulls. Skeletal material often remains articulated within the pellet. Southern Boobook Owl pellets (were they to occur at Barking Owl roosts) would be difficult to differentiate.

The second phase of pellet examination was to pull apart the pellet to reveal hidden components, separate prey groups and count individuals. Where possible this was completed dry, however on occasion, pellets needed moistening in order to tease items apart and reduce dust. Ethanol (70-80%) was used as it dried more quickly than water and minimised risk of infection from pathogens still residing in the pellet (Bangert *et al.* 1988).

Once pellets were dissected, pellet proportions were estimated to the nearest 10 for the three main prey groups (arthropods, birds and mammals). Prey items were then identified to the highest level possible by comparison with published images of bones, hair, feathers and insects and by direct comparison with reference material from the local collection at New South Wales Forest Science Centre and the Australian Museum. Published material used included Brunner and Coman (1974), Triggs (1996), Brunner and Triggs (2002) and Museum Victoria's online collection and various insect texts. Where possible, unusually sized prey items were noted for a more accurate estimation of biomass.

Mammal identification was performed preferentially by bones (particularly skulls, jaws and teeth) and then by hair. Some hair samples were cross-sectioned by the method used in Brunner and Coman (1974), however this was time consuming and identification was possible for many samples by observing the hair length, maximum diameters along the length, the hair shape by turning it under high magnification of a microscope, hair colour and surface structure. Mixed samples, where multiple species had been consumed, were the most difficult and some samples could not be identified.

Bird identification was mostly based on bones with additional information often available by feather colour or by stomach contents (e.g. grass seeds). The beneficial qualities and issues of each large bone used to identify birds in the context of Barking Owl pellets is highlighted in Table 3.3. Most larger species, parrots and ground birds could be identified to species. Many smaller specimens could not be assigned to a species, however most birds were confidently assigned a nominal mass for biomass calculations based on preferences established from Table 3.3. Multiple bird prey items in the one pellet contributed to lower identification rates for small species.

Table 3.3 Bird skeleton components, their measured relationship to bird mass and benefits/issues of each item. Bone length/body mass correlation was derived from measurements taken from bones of 55 species lodged in the Australian Museum bird skeleton collection compared with their mean body mass taken from HANZAB (Marchant *et al.* (ed.) 1990–2006).

Component	Mass Correlation	Item benefits/issues
Lower Bill	73.2	Shape/Often broken
Upper Bill	68.1	Shape
Skull	NA	Shape/often broken
Synsacrum/Pelvis	NA	Shape/often broken
Sternum	NA	Shape/often broken
Coracoid	87.0	Shape
Carpometacarpus	91.3	Shape and length
Radius	91.4	Length/often broken
Ulna	90.7	Length
Humerus	90.1	Length and shape
Tarsometatarsus	56.2	Shape
Tibiotarsus	85.3	Often broken
Femur	90.6	Length

Insects were identified from whatever hard components remained most intact. For most Coleopterans, this was by elytra, legs and/or pronatum, with heads sometimes used for a tally of individuals. For Orthoptera, Phasmatodea and Blattodea identification was by heads and robust leg sections. Hemiptera were recognised (rarely) by wing bases and mouthparts. Lepidoptera were recognised by wing and body scale and their numbers and size could only be estimated by examining the volume of scale and the size of the scale.

Much of the smaller insect component remained unidentified. Any ants or small insect larvae were ignored as pellet scavengers or prey items of other consumed prey. For the purposes of biomass calculation, the masses given in Table 3.4 were used. These were based on live specimens from the Pilliga weighed during this study. Maximum insect mass was capped at ten grams, even though stick insects and moths were weighed up to 17 and 23 grams respectively.

Table 3.4 Mass (grams) for insect biomass calculations.

Grouping	Small	Medium	Large
Orthoptera (crickets, grasshoppers)	1	2	4
Blattodea (cockroaches)		2	10
Phasmatodea (stick insects)		4	10
Hemiptera (Cicadidae) (cicadas)		2	4
Coleoptera (beetles)	0.3	0.7	4
Lepidoptera (moths)	0.3	4	10
Unidentified Arthropod		1	

Results from pellet examination were compiled into three data sets. The results of a bootstrap simulation based on four of the largest samples, suggested a minimum number of pellet-samples required to reduce chance results to an acceptable level. Thus for season/territory analysis, a minimum of seven pellets was required to be included as a sample.

'Regurgitated pellet volume', a measure of the volume of insect, bird and mammal material regurgitated, was averaged for each territory in each sample period (season). Volume data were suitable for comparisons between species (Dickman *et al.* 1991a, Hart *et al.* 2002) and was included to allow such comparisons with other studies.

'Prey individuals' was a simple tally of individuals eaten by the owls found regurgitated in a pellet. Care was taken not to double count large items spread across multiple pellets. Data were compiled as the average number of items per pellet and split into eight groups being insects, nocturnal birds, woodland dependent birds, non-woodland dependent birds, Sugar Gliders, large mammals (>400 grams), small mammals (<75 grams) and insectivorous bats.

'Prey biomass' was the number of prey individuals multiplied by the estimated prey mass (Table 3.4, 5.1 & 5.2, Appendix 1). Unusually small or large individuals were given their own prey mass. The same eight categories were used for analysis.

3.2.5 Faecal sample examination

After being frozen, faecal samples were examined under a 10*40 power microscope to find evidence of moth scale, other invertebrate matter, feather and hair. Where significant dust was a generated, samples were moistened with 70-80% ethanol to minimise pathogen risks (Bangert *et al.* 1988). Bone fragments were also noted but could not easily be ascribed to bird or mammals. Some feather and hair features were visible enabling species identification, however this was inconsistent and those data are not considered further here. Some samples showed no indication of prey type. These were ignored for analysis purposes. 'Faecal Volume', a measure of the volume of insect, bird and mammal material that passed recognisable through the gut, was averaged for each territory in each sample period (season) and collated as a percentage.

3.2.6 Data analysis

Data were presented graphically using pie charts, stacked column charts and as seasonal plots. Differences between seasons and territory landscapes were investigated using non-metric multidimensional scaling and tested using ANOSIM in the statistical package PRIMER (Clarke and Gorley 2006).

All multi-variate analysis requires independent observations. In this case, the fact that multiple samples were sourced from the same territory may be seen as conflicting with this ideal. I have chosen to ignore this on the following basis. Samples were not collected in a continuous series, only as isolated events. The sample data represents a small fraction of the possible material available. There was not an alternative means to investigate seasonal differences.

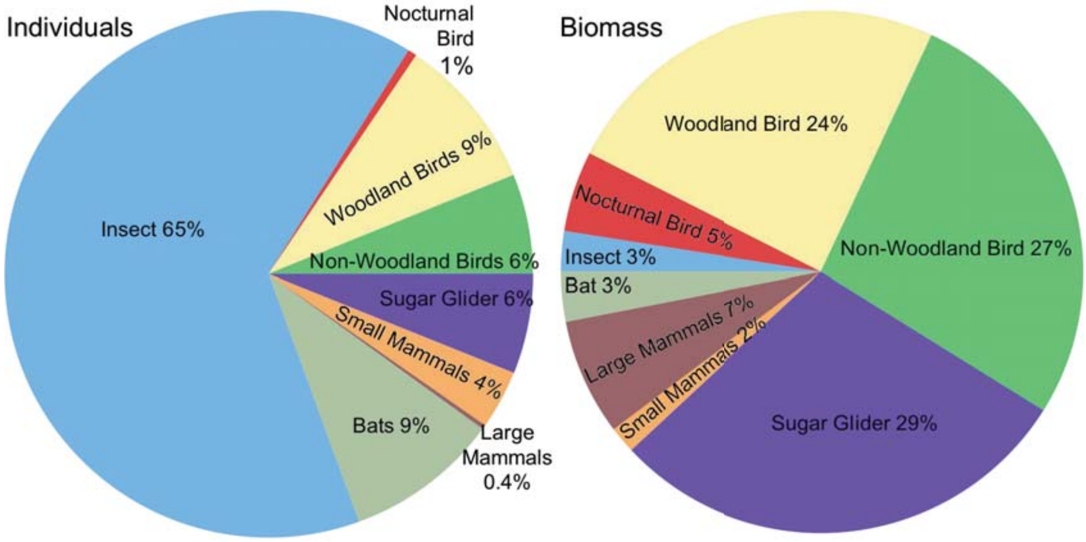
Canonical Correspondence Analysis was used to investigate the relationship of consumed prey groups with environmental variables of four seasons and two simple location variables: Forest edge/core and presence/absence of creeks in territories. The Yarindury extralimital-group was included for some analysis and a Yarindury (non-Pilliga) environmental variable was included for those analyses. All CCA was performed in the CANOCO software package (ter Braak, 1997).

3.3 Results

3.3.1 Overview

A total of 1546 pellets revealed 3665 prey items with an estimated live biomass of 116 kg. Raw averages for species and groups are presented for five groups of territories in Table 3.5a, b & c. The raw proportions of identified prey individuals and their estimated biomass is shown in Figure 3.2 as pie charts. Prey items are grouped into insects, nocturnal birds, woodland dependent birds, non-woodland dependent birds, Sugar Gliders, large mammals (>400 grams), small mammals (<75 grams) and insectivorous bats. The volume of material was skewed towards Spring and Winter when pellets were more easily collected (see Chapter 1). Regurgitated pellets collected in spring from around nest trees totalled 707. Pellets deposited in winter survived longest allowing 450 to be collected. In contrast, only 180 complete pellets were found during summer when pellet survival was often only a matter of hours. Autumn also proved difficult to collect pellets with only 209 collected. This skewing has not been corrected in Table 3.5, nor in Figure 3.2, however it has been accounted for in all analysis that features season as a factor.

Figure 3.2 Proportions of individual prey items and estimated prey biomass found in regurgitated pellets for all samples by eight classes
Total individuals = 3665. Total estimated prey biomass = 116 kg from 1546 regurgitated pellets. Data were not balanced for season or location.



3.3.2 Mammalian prey

Twenty-one species of mammals were identified. Of these, there were eleven micro-chiropteran bats, one mega-chiropteran bat, six marsupials (terrestrial, scansorial and arboreal), two mice and rabbit. The mammal prey items are heavily dominated by the Sugar Glider *Petaurus breviceps,* which was the most commonly identified single species. The forest core with creek sites may be unduly biased towards this species because of a high number of samples in the winter and spring seasons. A single sample contained a partial skull that may represent a young Squirrel Glider *P. norfolcensis* but is included here as a large Sugar Glider. Sugar Gliders are notably scarce in the Yarindury sample, the numbers of pellets containing House Mouse and Feathertail Glider were almost as large.

Unidentified mammals were mostly from small species where there were no diagnostic bones and/or mixed hair and were probably of the same species as those identified. However, there remains the possibility that with a more thorough investigation, particularly the use of genetic techniques, that these samples will reveal additional species.

Five species recognised in New South Wales as being vulnerable (Threatened Species Conservation Act, 1995) were represented in the data set. Three bats; Yellow-bellied Sheathtail Bat *Saccolaimus flaviventris*, South-eastern Longeared Bat *Nyctophilus corbeni* and Little Pied Bat *Chalinolobus picatus* were consumed in moderate numbers. The Yellow-bellied Sheathtail Bat weighs up to 60 grams so was also a notable addition to prey biomass for some owl territories. The Eastern Pygmy Possum *Cercartetus nanus* has been identified from two samples, but requires confirmation. The Delicate Mouse *Pseudomys delicatulus* was identified from one site and may be in other samples. It is scheduled as the Pilliga Mouse *P. pillagaensis*.

Table 3.5a Mammal species recognised in Barking Owl regurgitated pellets from the Pilliga and Yarindury State Forests. The number of pellets each species was detected in is indicated as a percentage. Species binomials and biomass are given in Appendix 1.

Species or group Number of pellets/territories	Forest core no creek 415 / 4	Forest core with creek 158 / 2	Forest edge no creek 538 / 6	Forest edge with creek 215 / 6	Yarindury 220 / 1
Mammals					
Yellow-footed Antechinus			0.2	0.9	
Common Dunnart			0.7		0.5
Sugar Glider	22.4	47.5	11.9	7.0	5.5
Feathertail Glider	1.4	2.5	0.7	0.5	4.1
Eastern Pygmy Possum (prob)		0.6	0.2		
Common Brushtail Possum			0.4		0.9
Little Red Flying Fox (prob)	0.2		0.9		
House Mouse/Delicate Mouse•	0.5		1.9•	0.5	5.0
Rabbit		0.6			1.8
Unidentified Mammal	3.6	0.6	5.8	4.2	9.5
All Mammal (non-microbat)	**28**	**52**	**22**	**13**	**24**
Chocolate Wattled Bat			0.6		
Gould's Wattled Bat	1.0	1.3	1.3	0.9	
Little Pied Bat			0.2	0.5	
Gould's Long-eared Bat	0.5	0.6		0.5	
Lesser Long-eared Bat	0.2	2.5	0.2		
South-eastern Long-eared Bat	0.5	1.3	0.9		
Unidentified Long-eared Bat		0.6	0.2		
Inland Broad-nosed Bat	0.2	0.6		0.5	
Little Broad-nosed Bat	0.5	1.9	0.4		
Little Forest Bat	13.3	8.2	5.4	4.7	1.8
White-striped Freetail Bat		1.3			
Yellow-bellied Sheathtail Bat	3.4	3.8	0.7	2.3	
Unidentified Micro Bat	13.5	10.1	8.9	8.8	3.2
All Micro Bat	**31**	**29**	**19**	**16**	**5**
All Mammals	**57**	**72**	**40**	**28**	**29**

3.3.3 Avian prey

Of birds, 67 species were identified in pellets collected from the Pilliga forests with an additional three species identified in pellets sourced from Yarindury State Forest. Birds were diverse in the pellet samples as seen in Table 3.5b. Many small birds remained unidentified. These were mostly small to medium sized birds where more than one species was represented in the pellet. The small species represented in the data were identified as the 'species most likely'. Small birds were extremely difficult to identify even when alone in the pellet. Identification was partly thanks to chance; a bit of distinctive feather colour, a bill that hadn't been crushed or a good set of long bones to compare measurements from. No great weight should be placed on the small insectivorous species identification but they are included as an indication of the kind of species represented. Waterfowl were not detected in this study but may be present in the unidentified material if the Owls only ate selectively from their carcases.

The only species identified in any quantities were small parrots (particularly Red-rumped Parrot) and the Magpie Lark in certain territories. As a group, the honeyeaters were reasonably common. Other notable species present in the data were Sulphur-crested Cockatoo, being the largest species identified, the White-throated Needletail, a fast flying long distance migrant (Bird 2004) and the Turquoise Parrot, Glossy Black Cockatoo and Grey-crowned Babbler which are scheduled as vulnerable in New South Wales under the Threatened Species Conservation Act (1995).

Table 3.5b Bird species recognised in Barking Owl regurgitated pellets from the Pilliga and Yarindury State Forests. The number of pellets each species was detected in is indicated as a percentage. "*" = species detected in food debris but not pellets. Species binomials and biomass are given in Appendix 1.

Table 3.5b Species	Forest Core no creek	Forest Core with creek	Forest Edge no creek	Forest Edge with Creek	Yarindury
Nº. pellets/territories	415 / 4	158 / 2	538 / 6	215 / 6	220 / 1
Stubble Quail	*	*	2.0	0.5	1.8
Rock Dove					0.5
Common Bronzewing	0.7		0.7	0.5	0.5
Crested Pigeon			0.6	0.5	0.5
Diamond Dove	0.2				
Peaceful Dove			1.9	0.5	2.3
Bar-shouldered Dove	0.7	0.6	0.6	0.5	
Tawny Frogmouth	1.0	2.5	1.7	0.5	2.7
Spotted Nightjar				0.5	
Australian Owlet-nightjar	0.7		0.4	*	
White-throated Needletail	2.4	1.3	1.9	1.4	0.5
Painted Button-quail			0.4	0.5	0.5
Little Button-quail		0.6			
Glossy Black-Cockatoo		0.6			
Galah	0.5	3.2	1.3	0.9	0.9
Sulphur-crested Cockatoo	0.2	*	0.4	*	1.4
Cockatiel			0.2		
Australian King-Parrot			0.2	0.5	
Crimson Rosella					0.5
Eastern Rosella			1.1	0.5	0.5
Australian Ringneck	0.2		2.8	0.9	0.5
Blue Bonnet	0.2		0.4		0.5
Red-rumped Parrot	0.2	0.6	5.8	7.0	5.0
Budgerigar			0.2		
Turquoise Parrot	0.2	2.5	3.3	2.8	1.4
Laughing Kookaburra	0.2	0.6		0.5	0.5
Sacred Kingfisher			0.2		
Rainbow Bee-eater		0.6			

Table 3.5b Species	Forest Core no creek	Forest Core with creek	Forest Edge no creek	Forest Edge with Creek	Yarindury
Spotted Bowerbird	0.2				
Superb Fairy-wren		0.6	0.2		0.5
Variegated Fairy-wren	0.2				
Weebill	1.0	0.6	0.2	1.4	0.9
Western Gerygone	1.0	0.6	0.6		0.5
Yellow Thornbill	0.7			0.5	
Yellow-rumped Thornbill				0.5	0.5
Inland Thornbill			0.4		
Striated Pardalote		0.6	0.2	0.5	
Yellow-faced Honeyeater	0.2		0.7		
White-eared Honeyeater					0.5
White-plumed Honeyeater		0.6	0.2	0.5	
Noisy Miner	0.2		0.6	0.9	0.5
Spiny-cheeked Honeyeater	0.2	0.6	0.4	1.9	0.5
Brown-headed Honeyeater	1.0		0.6	0.5	
Noisy Friarbird	0.2		0.7	2.3	0.5
Striped Honeyeater	0.2	0.6	1.1	1.4	1.4
Grey-crowned Babbler	1.0		0.2	1.4	
White-browed Babbler	0.2		*		
Black-faced Cuckoo-shrike		0.6	0.6	2.3	0.5
White-winged Triller	0.2		0.2		
Crested Shrike-tit	0.2				
Golden Whistler	0.2				
Rufous Whistler	0.7	0.6	0.4	1.9	0.5
Grey Shrike-thrush	0.5		0.4	0.5	0.9
Masked Woodswallow	0.2				
White-browed Woodswallow	0.2		0.4	0.5	
Grey Butcherbird	1.0	0.6	0.2	0.5	0.9
Pied Butcherbird			0.6		
Australian Magpie		0.6	1.5	2.3	1.4
Pied Currawong	*	0.6	0.4		0.5
Grey Fantail			0.2	0.5	0.9
Willie Wagtail	0.7		0.7	0.9	0.5
Australian Raven			0.2		0.9
Restless Flycatcher	0.2		0.2		0.5
Magpie-lark	0.2		2.0	5.1	1.8
White-winged Chough	1.7		0.9	1.9	2.7
Apostlebird			0.2		
Jacky Winter	0.7	0.6	0.2		0.5
Eastern Yellow Robin	0.7		0.4		0.9
Mistletoebird		0.6			
Double-barred Finch	0.2		1.1	1.4	0.9
Unidentified Birds	15.9	10.1	19.0	19.5	27.7
All Birds	**37**	**32**	**60**	**66**	**67**

3.3.4 Other vertebrates

Two other species were detected in food remains during this study. In November 2007 a Bearded Dragon *Pogona barbata* skull was found directly under a nest hollow. In November 2010 a partial frog skull was found in a pellet (pers. comm. Todd Soderquist). The frog was a large ground dwelling species, most probably *Limnodynastes terrerginae,* or possibly a *Cyclorana albogutata.* As the rest of the pellet contents are unknown it is not included in any further analysis.

3.3.5 Invertebrate prey

Invertebrates appear to be entirely represented by insects, however there is every possibility that the unidentified "insects" in this sample include other arthropod groups such as spiders in low quantities. Insects from six orders were identified. By far the most abundant of the identified orders were Coleoptera with six families recognised and probably many more unidentified. Four families of Orthoptera were identified. Moths were commonly recorded, however, numbers and diversity were difficult to determine. The insect samples are probably underestimated in terms of numbers of individuals and subsequently biomass. Soft-bodied prey items are easily missed in favour of more robust species, notably the Coleoptera and vertebrates. Beetles were present in over half the pellets found. They appear to represent a wide range of species ranging from small passalids estimated to weigh 0.3 of a gram, up to large jewel and scarabs at around 4 grams. The majority of beetles taken probably weigh less than a gram in life. Only the large ground cockroaches (Blaberidae) would have to be taken from the ground and these seem to be rare in the sample. However, they were frequently found in fox scats deposited near Barking Owl roosts.

Notably, some of the insects taken were large enough to turn up in feeding debris found around nest trees. The Goliath Stick Insect *Eurycnema goliath*, Wood Moth *Endoyxla sp.* and Emperor Moth *Opodiphthera sp.* were all found. Each of these species has live weights of over 10 grams, which was more than many of the bats and small birds being consumed (see Table 3.4 and Table 5.3).

Table 3.5c Arthropod species recognised in Barking Owl regurgitated pellets from the Pilliga and Yarindury State Forests. The number of pellets each species was detected in is indicated as a percentage.

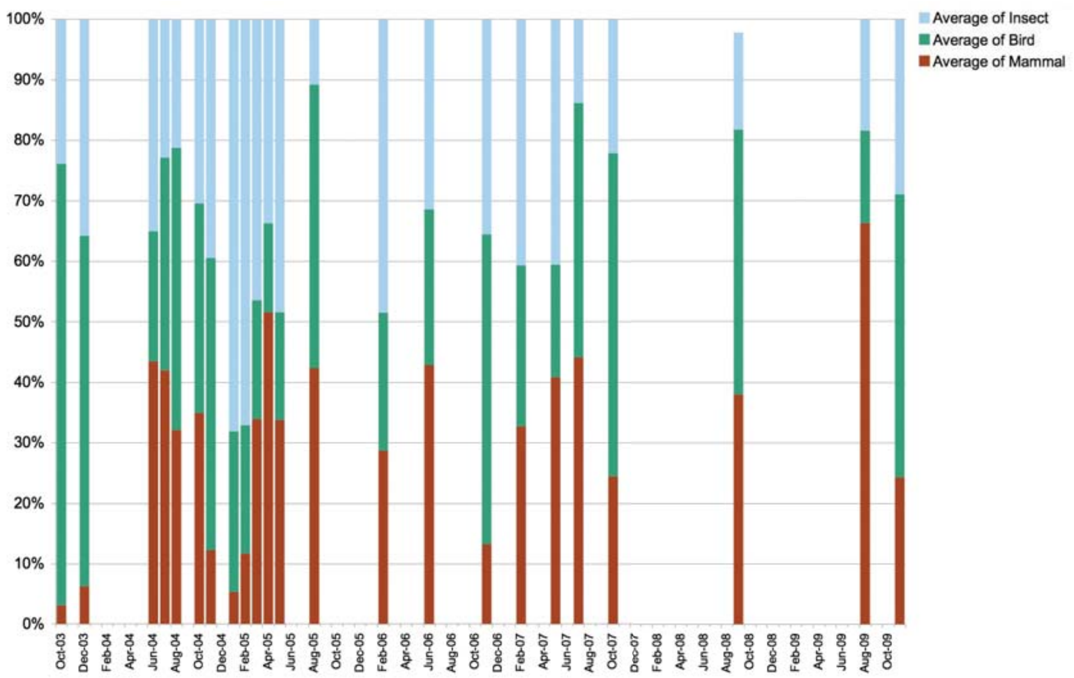
Order/Family	Forest core/ no creek	Forest core/ with creek	Forest edge/ no creek	Forest edge/ with creek	Yarindury
Number of pellets/territories	415/4	158/2	538/6	215/6	220/1
Insects					
Blattodea/Blaberidae & Blattidae		0.6		0.5	
Hemiptera/Cicadidae				0.9	
Coleoptera/Buprestidae	0.5	1.3		1.4	
Coleoptera/Carabidae			0.2		
Coleoptera/Cerambycidae				0.5	
Coleoptera/Elateridae	1.0				
Coleoptera/Geotrupidae	2.7	6.3	1.5	3.7	
Coleoptera/Passalidae			0.2		
Coleoptera/Scarabaeidae	1.7	3.8	0.9	4.2	1.4
Coleoptera/*Unidentified*	53.7	54.4	52.8	53.0	48.2
Lepidoptera/*various families*	12.0	4.4	9.3	11.2	10.9
Orthoptera/Tettigoniidae	0.2	0.6	0.4	0.5	
Orthoptera/Acrididae		0.6	0.4	1.4	0.5
Orthoptera/Gryllacrididae	0.2	0.6		0.5	
Orthoptera/Gryllidae	0.7			0.5	
Phasmatodea/Phasmatidae	0.2			0.5	
Unidentified Arthropoda	8.2	1.9	7.2	8.4	8.2
All Insects	**72**	**71**	**66**	**74**	**61**

3.3.6 Seasonal pattern

The proportions of material being regurgitated that belong to each major category is a measure of the amount of indigestible material being consumed. The data are represented in a range of ways. The spread of data over individual sampling months for all sites and the amount of variability over time is shown in Figure 3.3. It shows that any of the three groups can comprise over 2/3rds of regurgitated material in any individual sample period, e.g. birds in October 2003, insects in January 2005 and mammals in August 2009.

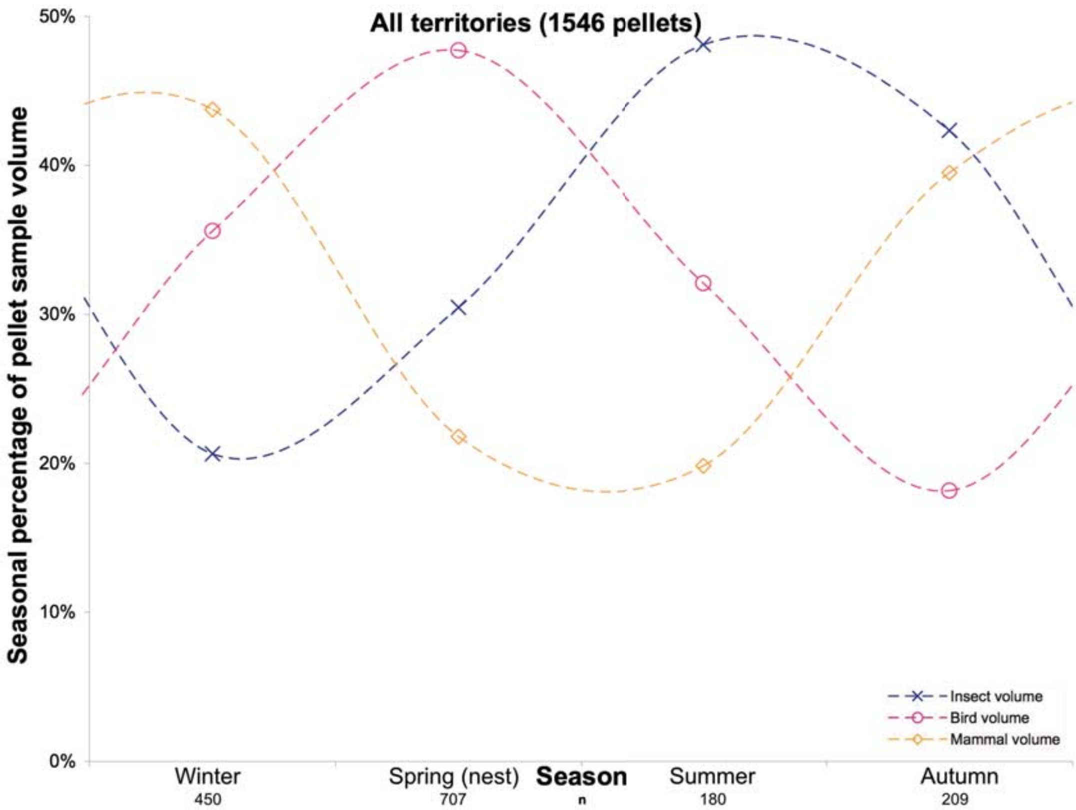
The results of ANOSIM tests on prey composition data are presented in Table 3.6. The difference between summer and autumn/winter was the greatest of the season comparisons. The differences are shown graphically in Figures 3.5a and 3.6a.

Figure 3.3 Three broad prey groups as represented by volume in regurgitated pellets over the period of the study (except a single early sample). Sample sizes are given in Table 3.1.



To display seasonal variation more clearly, the average has been calculated by season for the following plots of the same broad groups. Over all territories, the broad categories appear to be evenly distributed, however, there is a strong seasonal pattern (Figure 3.4). Broken lines aid interpretation. All groups are consumed throughout the year. Mammals are most frequent in winter, birds in spring and insects in summer.

Figure 3.4 The percentage (volume) of mammal, bird and insect material present in regurgitated Barking Owl pellets from all samples, plotted by season. Number of pellets is indicated under each season label.



3.3.7 Location (habitat) pattern

When territories were separated into five main categories based on location, there was a marked trend for different locations to be dominated by different diet components. Figures 3.4 (a-e) present those divisions. Season is retained as a prominent variable.

Mammal material was far more prevalent in the pellets of the forest core Barking Owls whereas the forest edge owls were regurgitating higher volumes of bird material for all seasons except autumn. Insect material peaked in summer for most territories and autumn for the two forest core/creek territories and the Yarindury territory.

The increase in bird material during spring nesting seems to be reasonably consistent across all groups, except that the forest edge groups have similar levels pre-nesting (winter).

Figure 3.5 The percentage (volume) of mammal (◊), bird (o) and insect (x) material present in Barking Owl pellets from all samples, plotted by season and split into five categories based on forest core (a/b) or edge (c/d) and presence (b/d)/absence (a/c) of creeks. Yarindury is presented as the fifth category (e). Numbers below the season labels give sample sizes.

Figure 3.5a

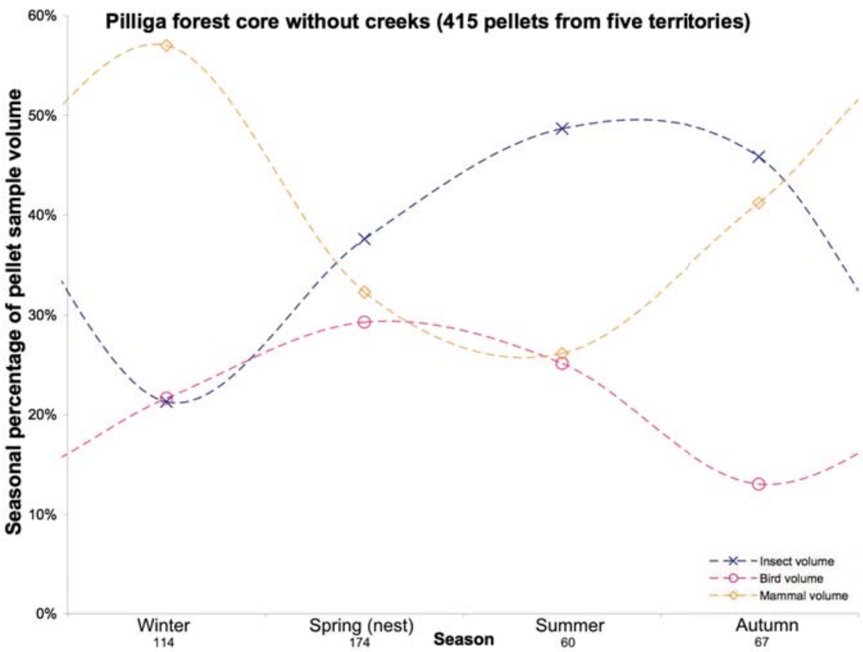


Figure 3.5b

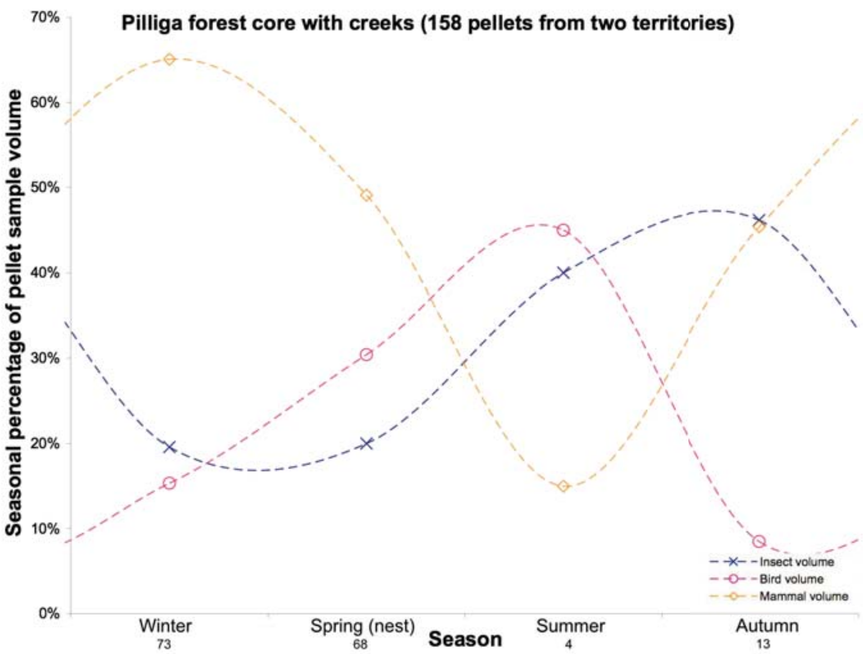


Figure 3.5c

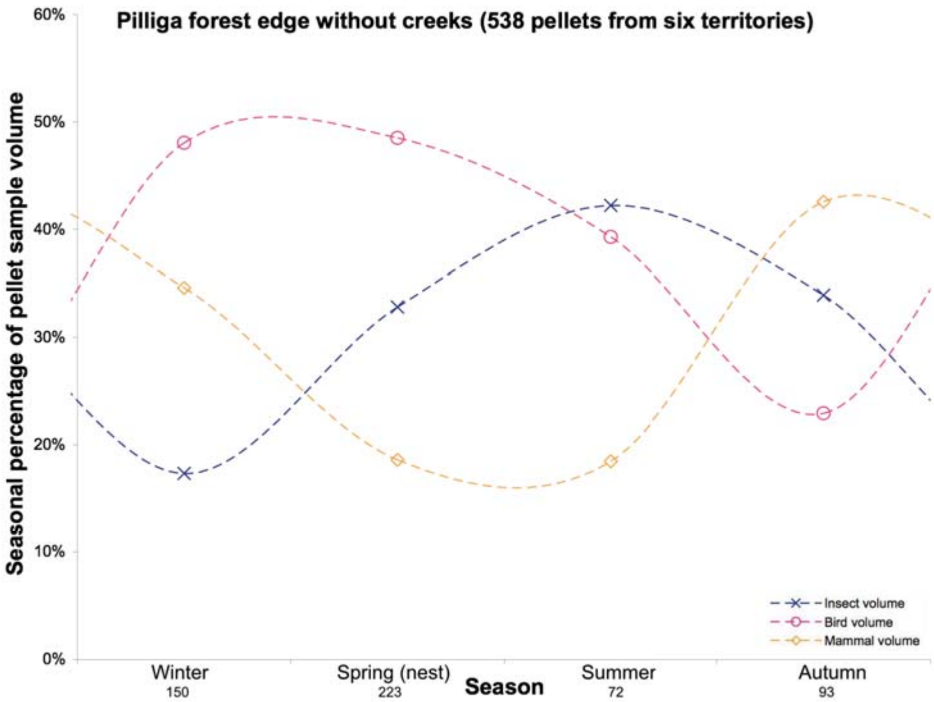


Figure 3.5d

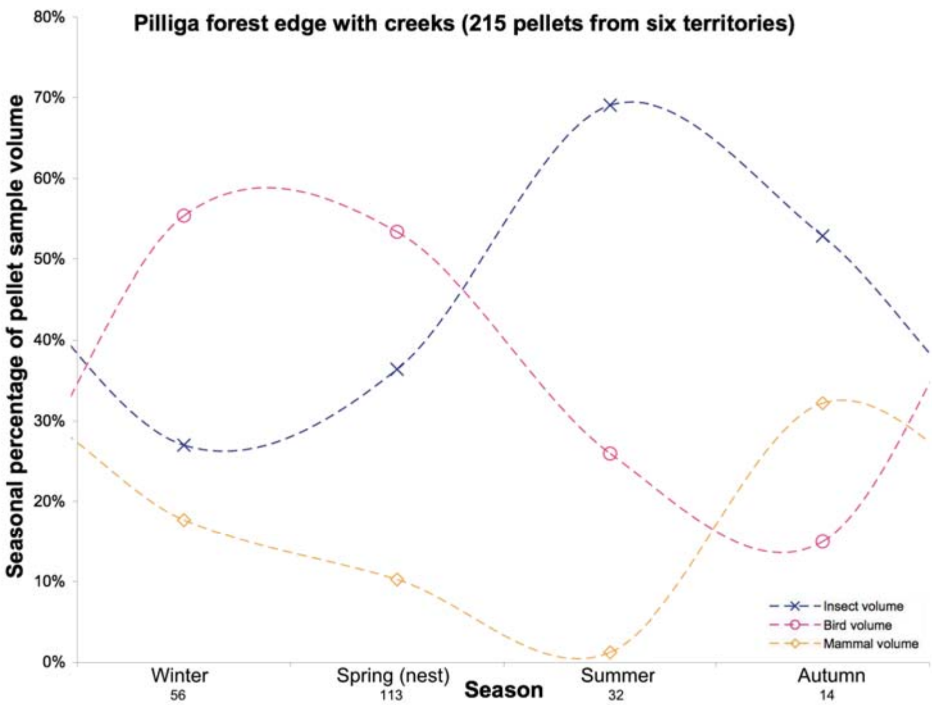
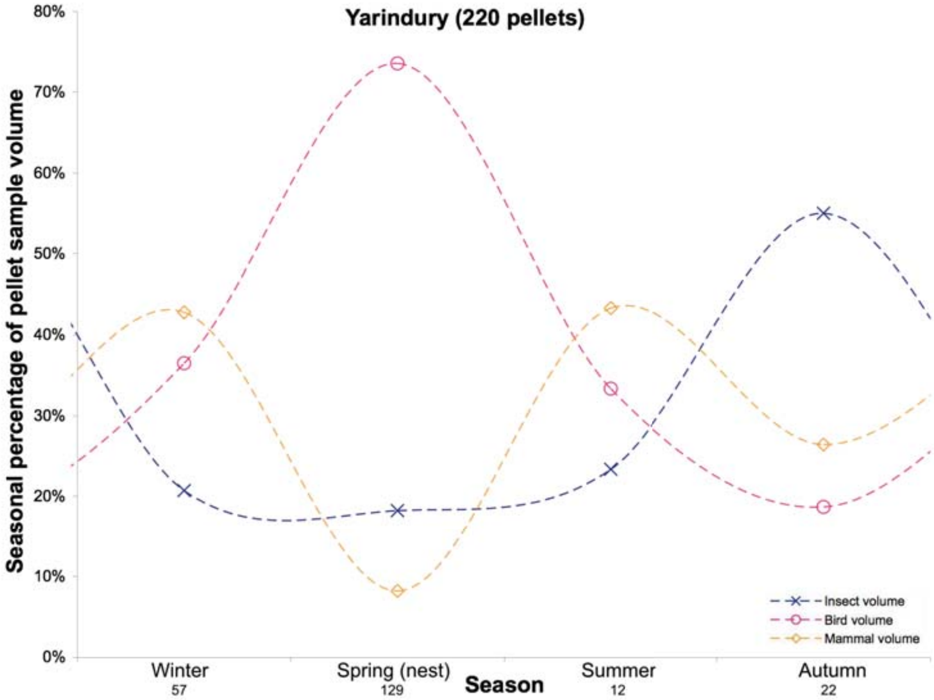


Figure 3.5e

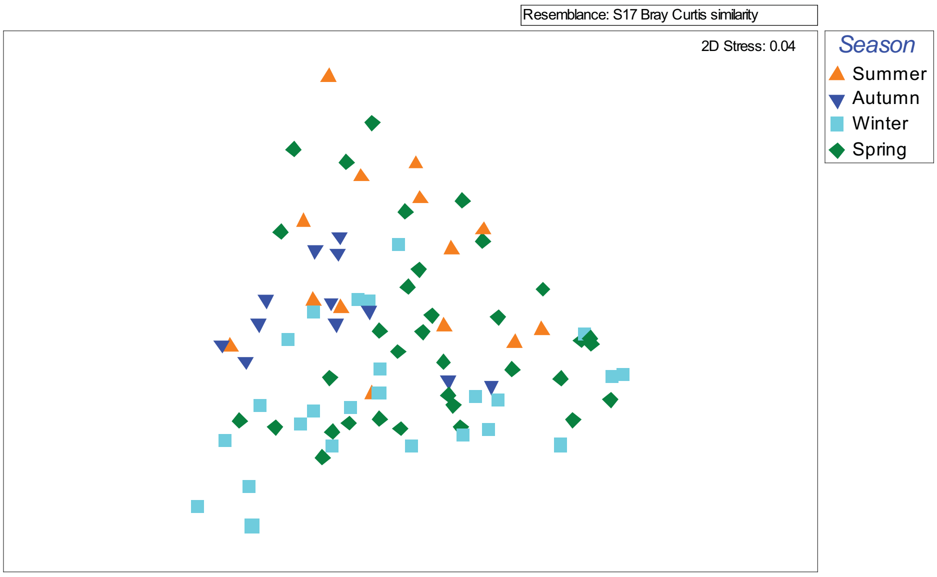


The results of ANOSIM tests on prey composition data are presented in Table 3.6. The most notable result was the difference between the Pilliga forest core territories and the Pilliga forest edge territories. The Pilliga forest core territories were also markedly different from the Yarindury territory. The difference between summer and autumn/winter were the greatest of the season comparisons. The significance of these results is discussed below.

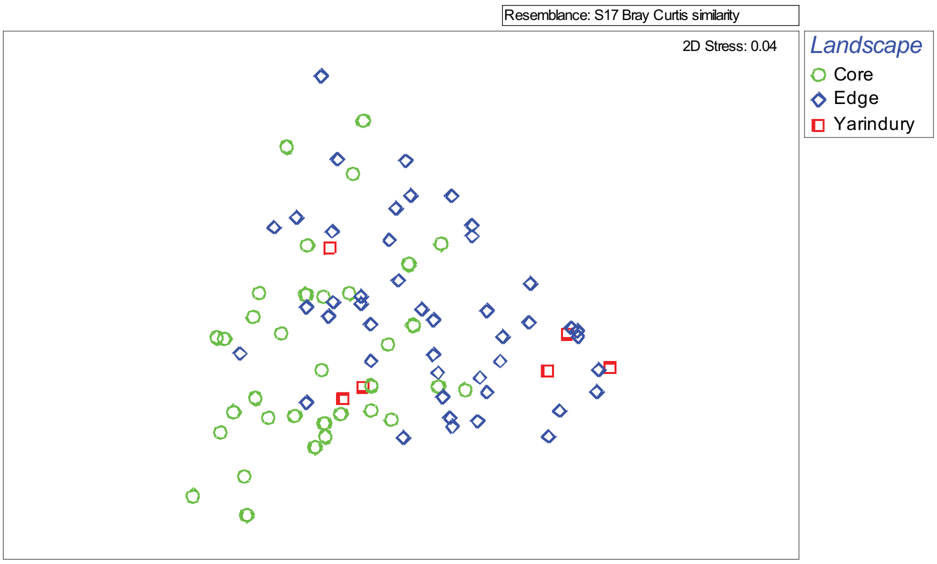
Table 3.6 ANOSIM results for Landscape and Seasonal factors associated with regurgitated pellet sample measurements. Underline indicates a notable result. Global indicates a comparison with all factors at once.

Factors		Data set	R value	P value
Landscape Factors (creeks)				
Creeks	No Creeks	Volume proportions 3 'spp.'	0.092	0.030
Creeks	No Creeks	Count of Individuals 8 'spp.'	-0.010	0.543
Creeks	No Creeks	Calculated biomass 8 'spp.'	-0.033	0.731
Landscape factors (edge/core)				
Landscape	Global	Volume proportions 3 'spp.'	0.208	0.001
Pilliga Core	Pilliga Edge	Volume proportions 3 'spp.'	0.229	0.001
Pilliga Core	Yarindury	Volume proportions 3 'spp.'	0.276	0.024
Pilliga Edge	Yarindury	Volume proportions 3 'spp.'	0.042	0.299
Landscape	Global	Count of Individuals 8 'spp.'	0.161	0.001
Pilliga Core	Pilliga Edge	Count of Individuals 8 'spp.'	0.127	0.001
Pilliga Core	Yarindury	Count of Individuals 8 'spp.'	0.442	0.001
Pilliga Edge	Yarindury	Count of Individuals 8 'spp.'	0.156	0.074
Landscape	Global	Calculated biomass 8 'spp.'	0.226	0.001
Pilliga Core	Pilliga Edge	Calculated biomass 8 'spp.'	0.266	0.001
Pilliga Core	Yarindury	Calculated biomass 8 'spp.'	0.249	0.038
Pilliga Edge	Yarindury	Calculated biomass 8 'spp.'	-0.034	0.543
Seasonal Factors				
Season	Global	Volume proportions 3 'spp.'	0.077	0.010
Summer	Autumn	Volume proportions 3 'spp.'	0.100	0.067
Summer	Winter	Volume proportions 3 'spp.'	0.216	0.004
Summer	Spring	Volume proportions 3 'spp.'	0.045	0.200
Autumn	Winter	Volume proportions 3 'spp.'	0.067	0.130
Autumn	Spring	Volume proportions 3 'spp.'	0.053	0.194
Winter	Spring	Volume proportions 3 'spp.'	0.054	0.057
Season	Global	Count of Individuals 8 'spp.'	0.084	0.080
Summer	Autumn	Count of Individuals 8 'spp.'	0.135	0.026
Summer	Winter	Count of Individuals 8 'spp.'	0.129	0.025
Summer	Spring	Count of Individuals 8 'spp.'	0.050	0.186
Autumn	Winter	Count of Individuals 8 'spp.'	-0.017	0.545
Autumn	Spring	Count of Individuals 8 'spp.'	0.065	0.150
Winter	Spring	Count of Individuals 8 'spp.'	0.111	0.005
Season	Global	Calculated biomass 8 'spp.'	0.063	0.026
Summer	Autumn	Calculated biomass 8 'spp.'	0.211	0.007
Summer	Winter	Calculated biomass 8 'spp.'	0.123	0.029
Summer	Spring	Calculated biomass 8 'spp.'	-0.003	0.458
Autumn	Winter	Calculated biomass 8 'spp.'	0.150	0.020
Autumn	Spring	Calculated biomass 8 'spp.'	0.149	0.021
Winter	Spring	Calculated biomass 8 'spp.'	-0.013	0.618

Figure 3.6 (a) Seasonal and (b) forest landscape differentiation of multi-dimensional scaling of regurgitated pellet volume data (Insect/Bird/Mammal).

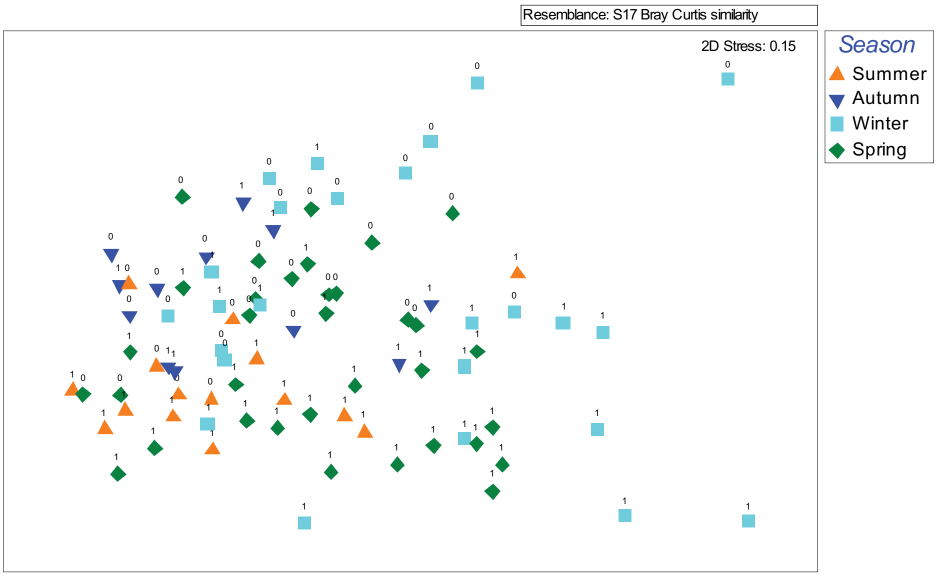


a)

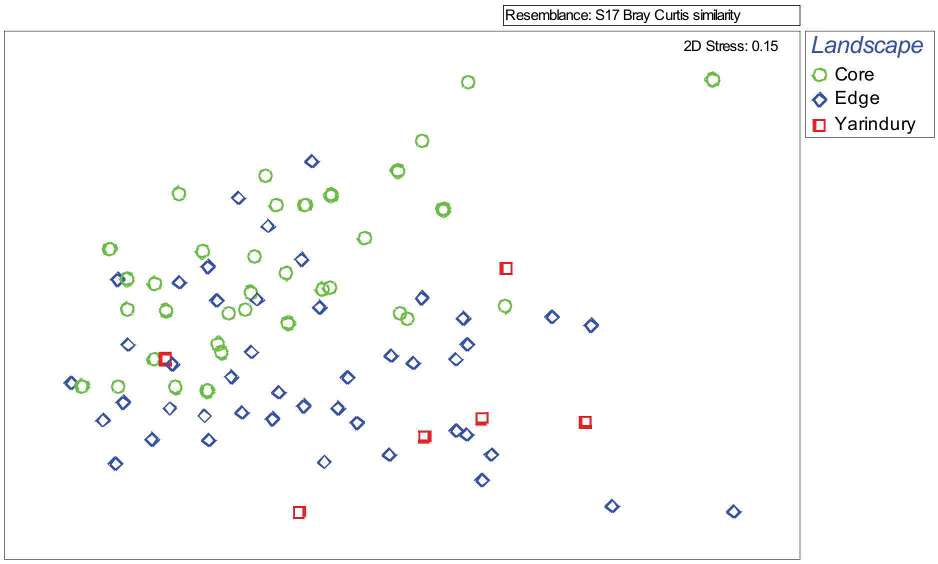


b)

Figure 3.7 (a) Seasonal and (b) forest edge territories differentiation of multi-dimensional scaling of territory/season/year regurgitated pellet prey item count data.



a)



b)

As creek proved to be a weak variable in ANOSIM, it has not been differentiated in the multi-dimensional scaling. In all three data sets, forest core and forest edge were mostly lying on opposite sides of the plot. The Yarindury samples were mostly within the spread of the edge samples but do not ever seem to fall together as a coherent group. Notably the three dimensional nature of the ordination in Figure 3.6 induces little stress with samples falling into a neat triangle. The right hand point samples were dominated by bird, the left hand point samples were dominated by mammal and the upper point samples were dominated by insect. The insect component probably helped drive the only strong seasonal split being that of summer and winter (Figure 3.6a). The eight dimensional nature of the ordination in Figure 3.7 induced greater stress. The equivalent ordination for the biomass data had an unacceptable level of unexplained noise (20%), possibly induced by the increase in importance of the few samples containing large mammals.

Figure 3.8 Canonical Correspondence Analysis (bi-plot) of regurgitated pellet volume proportions with environmental variables (territory on forest edge, territory with broad creek lines) and seasons. Longest axes are the most powerful variables. The 'species' are most closely related to the variable axis they are close to, including the inverse axis.

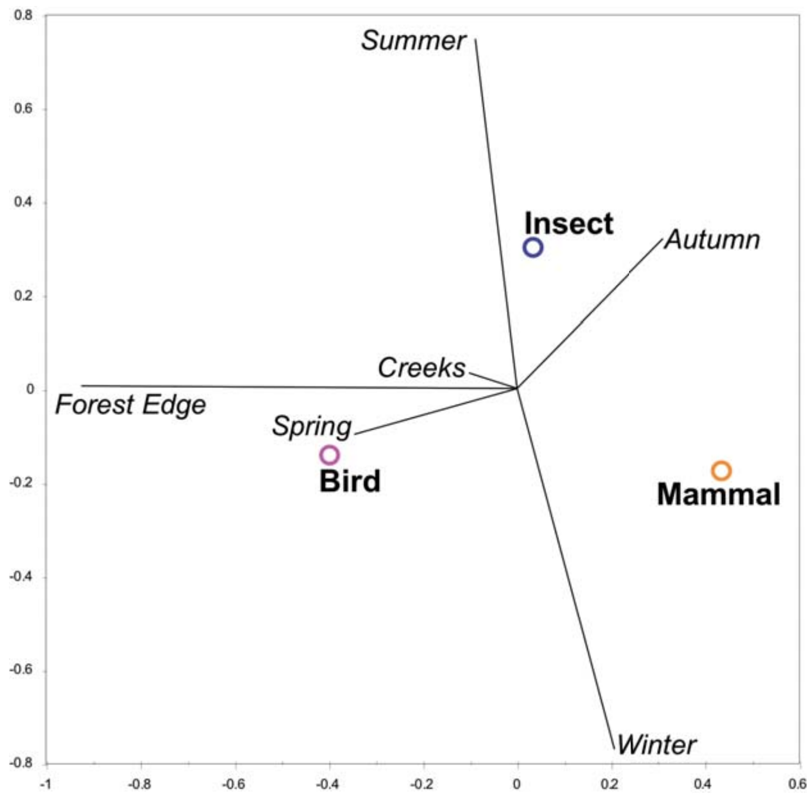
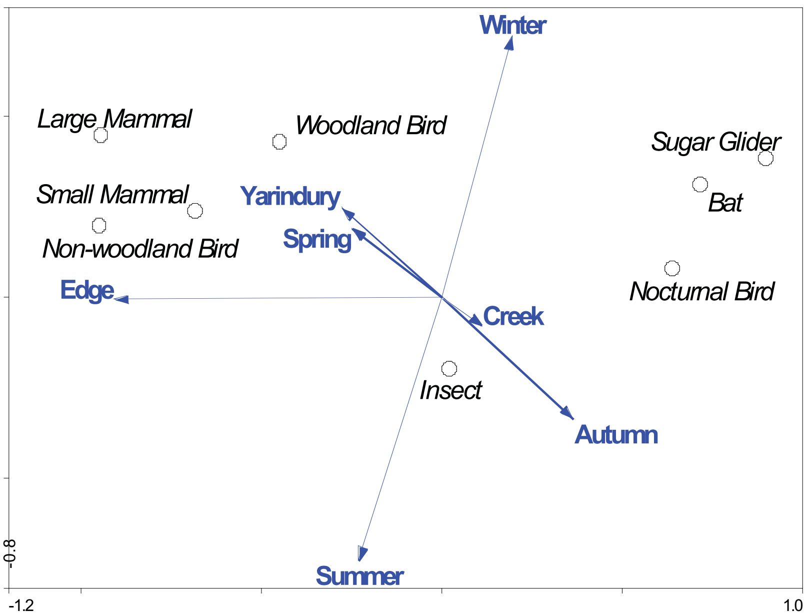
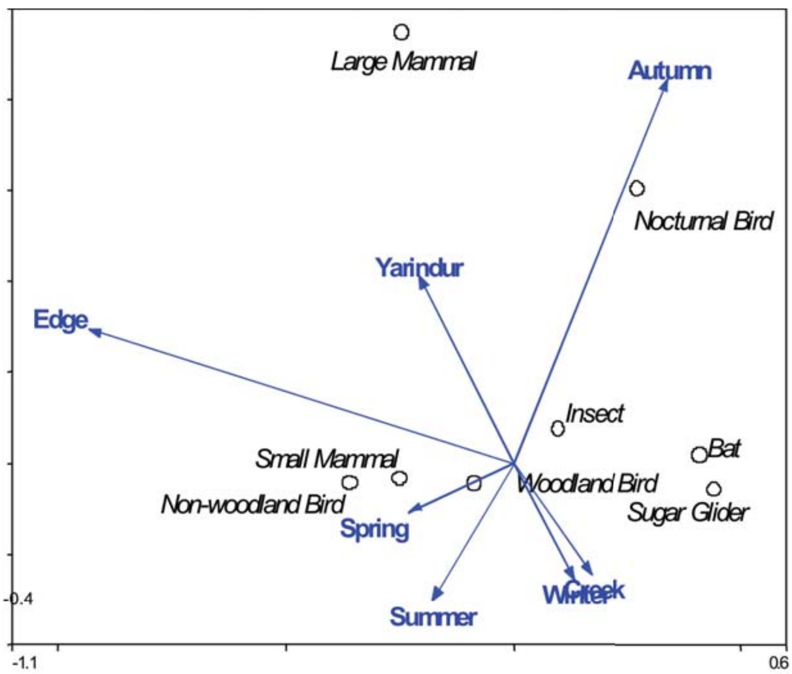


Figure 3.9 Canonical Correspondence Analysis (bi-plot) of regurgitated pellet prey item numbers (a) and biomass (b) (in eight classes) with environmental variables (territory on forest **edge**, territory with **creek** drainage lines and seasons). Data were from the Pilliga and Yarindury sites



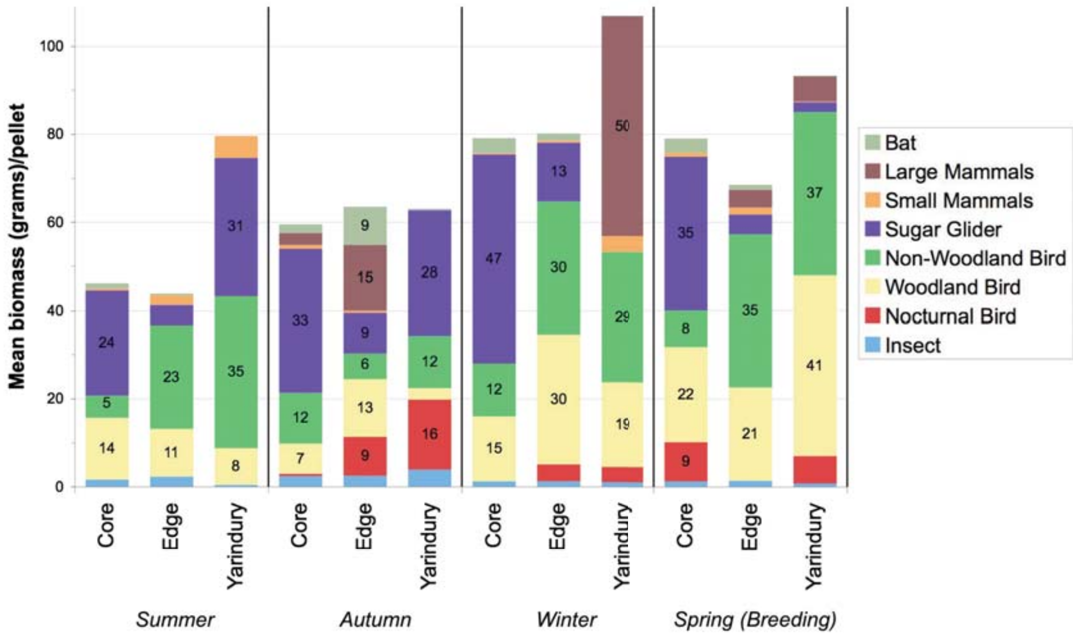
a)



b)

All three data sets show that the forest edge/core variable was considerably stronger than the creek variable. This agrees with the ANOSIM analysis, which only found one weakly significant result for creeks. The forest edge territories were strongly aligned with diurnal bird prey, particularly non-woodland birds as might be expected. Sugar Glider and bat prey were always aligned most strongly away from the forest edge. They also lie in between the autumn and winter axes. The seasonal variables change strength considerably depending on the data set.

Figure 3.10 Mean Prey Biomass for regurgitated pellets with samples divided by season and three territory location categories. Eight classes were used for prey items.

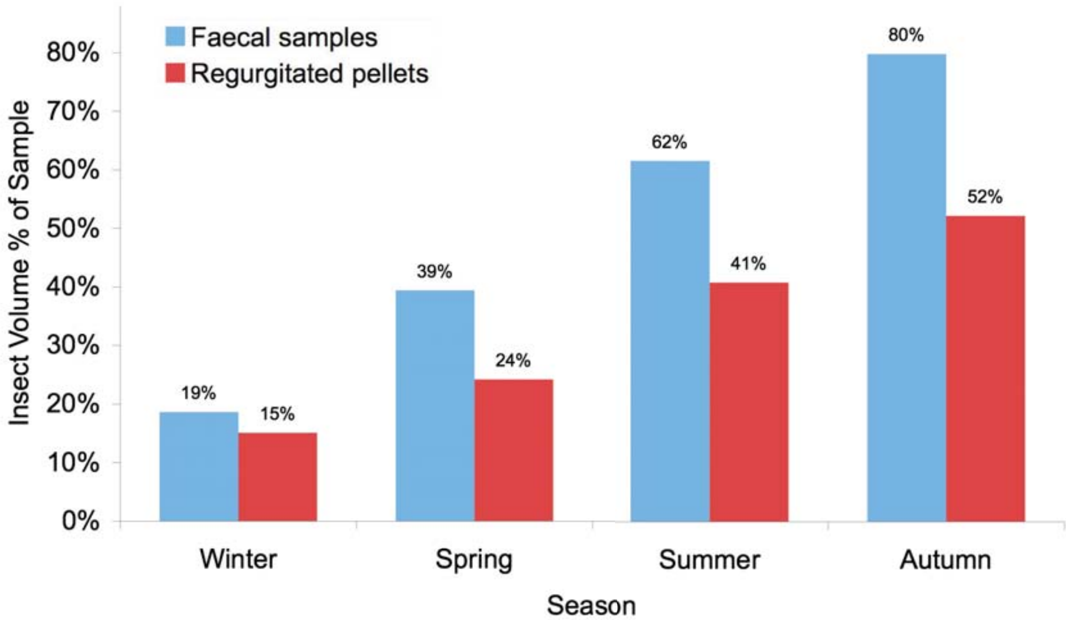


Due to the discounting of the landscape variable 'creek', it was possible to distil the major variations in consumed biomass to the 12 stacked columns shown in Figure 3.10. There were clear seasonal variations in total biomass per pellet and Yarindury samples were always equal or greater than those from the Pilliga (Core and Edge columns).

3.3.8 Faecal samples

As was seen in Table 3.1, regurgitated pellets from some territories were scarce during summer and autumn sample periods. Faecal samples were collected during some of those periods. A comparison of total volume of insect material in faecal samples and regurgitated pellets is presented in Figure 3.11. Data for regurgitated pellets has been excluded from sample periods and territories where there were no faecal samples to compare with. There was no guarantee that there was an equal amount of data (by territory) in the comparisons, thus it stands only as a guide to interpreting the data. Total sample numbers in the comparison are shown with Figure 3.11. Both bird and mammal results showed the inverse trend to insects. The insect proportion was always higher in faecal samples but the seasons showed a similar trend to the pellet data. The difference indicates that regurgitated pellets and faecal material are not sufficiently similar in composition to use in direct substitution. However, the differences have a seasonal consistency, allowing us to consider the two sample types side-by-side allowing for the biases of each.

Figure 3.11 Comparison of insect volume in faecal samples and in regurgitated pellets. Volume is expressed as a percentage of the total volume. Sample sizes are tabulated below.

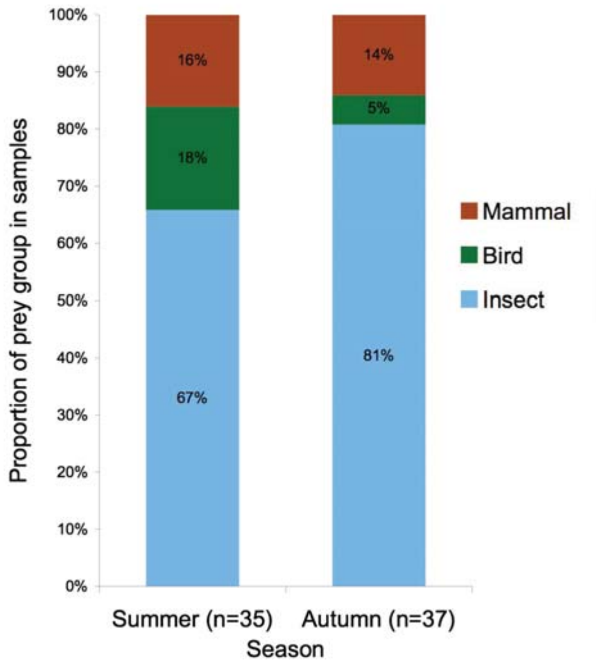


Sample Sizes	Winter	Spring	Summer	Autumn
Faecal Samples	110	124	40	41
Regurgitated Pellets	104	228	67	47

The important role of the faecal sample data is what it can reveal about territories that had poor collections of regurgitated pellets during summer and autumn (Table 3.1 compared with Table 3.2). Figure 3.12 shows the proportions of the three main prey groups for summer and autumn, with all territories combined. The majority of the samples were from territories on the forest edge, with a few from the core of West Pilliga State Forest.

Consistent with regurgitated pellet volume, faecal sample volume shows low bird consumption during autumn. Mammal consumption appears to have stayed consistent between summer and autumn whereas the Pilliga territories all showed a dramatic increase in mammal consumption between these periods when judged by the regurgitated pellet volume.

Figure 3.12 Faecal sample prey proportions in three broad groups for Barking Owl territories/periods with low numbers of regurgitated pellets.



3.4 Discussion

3.4.1 The Pilliga Barking Owl diet compared to other regions

As reported in Chapter 1, Barking Owls are non-specialist predators, readily tackling prey ranging from their own size (or even larger) down to tiny prey items that would seem almost inconsequential. This study confirms and extends this breadth of diet with at least 91 vertebrate species taken and countless invertebrate species. Yet, those small items, both insects and vertebrates, clearly occupy a substantial amount of foraging effort on the part of the Barking Owls. Each beetle caught by an owl has required pursuit of some kind. Likewise, bats are taken on the wing but may only yield a small proportion of a nights food requirement (Chapter 5). However, both these prey groups are readily presenting themselves by actively, noisily and naively moving about the Barking Owl domain. Roosting birds may be more difficult to find but potentially give a larger reward when captured.

The range of species detected in Barking Owl pellets from this study was broadly similar to the range from a study in South-eastern Queensland (Barnes *et al.* 2005) but with more small and medium sized birds than that study. There was also reasonable correspondence with the diet from the Armidale area (Kavanagh *et al.* 1995, Debus 1997, Debus *et al.* 1998, Debus *et al.* 1999, Debus 2001, Debus 2005) including the seasonality of birds/mammals and the approximate proportion of insect prey. This study has similar components to other studies from Southern Australia (Summary given in Chapter 1) however the rodent and rabbit component was relatively sparse and no waterfowl were detected in this study.

The dominance of native fauna was notably different from the diet reported by Calaby (1951), Robinson (1994), Kavanagh *et al.* (1995) and Taylor *et al.* (2002b). Rabbits made up a minor portion of the diet in the Pilliga with only three records in total. No *Rattus* species were confirmed for this study.

As this study was larger than other published data sets, it was difficult to make a solid comparison, however it was clear that the environment had a marked effect on the prey species utilised. Studies from fragmented landscapes with productive farmland, typically feature more rabbits. Owl diets near large water bodies feature waterfowl, while the forest dwellers of the Pilliga feature arboreal mammals and hollow dwelling bats, tree roosting birds and a wide diversity of insects that include wood borers and litter consumers.

3.4.2 Patterns in the prey data

The diet shows seasonality. The ANOSIM analysis indicates that a reasonable proportion of the variation between samples was contributed by season, however there was sufficient noise from other sources that causes the R-values to remain low. Some of that noise was from the strong forest core/forest edge effect. Variation also came from year to year changes. One contributor to this was that the long running drought in western New South Wales (2001 – 2007, BOM), was effectively broken towards the end of the study. House Mouse were observed to increase markedly in abundance in the surrounding croplands, which were utilised by some Barking Owls living in the forest edge territories. Year to year variation in insects may also have provided some of the variation. Summer/autumn of 2005 had a large population of mid-sized cicadas, which were largely absent in the other summer/autumn samples. The influence of large uncommon prey items may also have contributed to some of the annual variation as has the breadth of the diet.

The proportion of prey types taken was partially dependent on location within the forest. This study was limited to two landscape variables; creeks as presence/absence and forest edge, also as presence/absence. Forest types, structure and other topographic variables could not be used as not all the subjects had been radio-tracked to gain an accurate measure of the use of these habitats. In any case, the topography of the Pilliga Barking Owl territories comes down to being flat or low relief hills and in most cases was tied to the creeks variable, i.e. areas without creeks were flat. Most of the common forest types were represented within any particular owl territory of ~2000 ha. Forest structure was dependent on time to last disturbance. Disturbance events (logging, stand thinning and fire) were ongoing through the study period and thus difficult to categorise for each territory.

Creeks were a weak predictor of dietary composition where as the difference between forest edge and forest core has a stronger influence. ANOSIM, MDS and CCA all present a strong picture of this pattern. The edge/core trade off seems to be between birds and mammals with insects being a seasonal constant, even in Yarindury State Forest. The mean mass of non-woodland dependent birds was considerably greater than the mean mass of woodland dependent birds giving the biomass results a considerable boost for forest edge territories.

3.4.3 Volume of prey

The overall amount of food required to sustain Barking Owls can be estimated in broad terms from captive Barking Owls and other studies of similar sized owls. In rehabilitation where Barking Owls were given unlimited food in the form of day old chickens (weight of ~35 grams each) Barking Owls will take 2 to 4 chicks per day (pers. comm. Lenore Wilbow). This gives a minimum prey mass of ~70 grams per day to a maximum of 140 grams per day. Regardless of the quantity consumed, the owls always produced just the one pellet per day. Featherdale Wildlife Park feeds Barking Owls with whatever meat they have available, often feral mammals. They feed approximately 150-gram chunks of whatever they were using, often without bones. This was often completely consumed and if it was principally flesh, a pellet may not be produced. Featherdale also have one food free day and one half portion day per week (pers. comm. Chad Staples) so they were averaging ~120 grams per day.

The Spotted Owl *Strix occidentalis* of western North America is a forest dwelling species of a similar size to Barking Owls. They have been assumed to consume between 72.3 grams per day (Forsman *et al.* 2004) and 56 grams per day (Weathers *et al.* 2001). These estimates were a little below those of captive Barking Owls but reasonably close to the actual means for the Pilliga Barking Owls derived from the pellet data.

If we make the reasonable assumption that one pellet was being produced per owl per day, we can see that pellets from wild Barking Owls were on average representing a smaller amount of prey than captive Barking Owls were capable of consuming.

During summer, the Pilliga Barking Owls seem to lose condition. Newton *et al.* (1983) found similar patterns in spring-nesting sparrowhawks and the pattern may be common in a wide range of birds (Norberg 1981). This study shows that the pattern seems to correlate with lower food consumption. Summer should be a period when prey is just as available as at any time of the year, however hunting time would be shorter so potentially they were constrained by foraging time. If that were the case, the Pilliga habitat would seem to be somewhat marginal. Alternatively, the Norberg (1981) theory that weight loss during summer is a strategy that saves energy may apply.

Yarindury Barking Owls had a higher biomass of prey per pellet than did the Pilliga Barking Owls. This was almost certainly due to a greater mean mass per prey item. Larger prey items were more likely to be shared between partners and offspring and there was likely to be more waste.

3.4.4 Filling in the blanks with faecal samples

During periods when regurgitated pellets were not found for particular territories, faecal samples were collected in the hope that they may be able to substitute for the missing data. The results comparing the insect content of pellets and faeces show that faecal samples have higher proportions of insect material and lower proportions of vertebrates than regurgitated pellets sourced from the same period and territories. This may be due to a lower proportion of insect material being retained in the gizzard for egestion, while very little bone passes the gizzard. Both materials are biased and the amount of bias will not be determined until feeding studies of captive Barking Owls are completed. The biggest hurdle with such a study will be sourcing adequate quantities of natural foods for testing.

The faecal samples revealed that owls not producing large numbers of pellets are consuming large quantities of insects but were still feeding on some birds and mammals. Possibly the non-pellet producing owls were eating fewer mammals than other owls during autumn. The pattern of low bird intake during autumn seemed consistent with the rest of the owl territories as assessed by pellets.

3.4.5 Effect on other endangered wildlife

An irony of the Pilliga Barking Owl diet was that a number of species that they were preying upon, were themselves considered vulnerable to extinction (Threatened Species Conservation Act 1995). There were five species of mammal, and three species of birds in this category. Some of the threatened species occurred only rarely in the diet, perhaps indicative of their very low abundance in the Pilliga or their cryptic nature (Eastern Pygmy Possum, Little Pied Bat, Delicate/Pilliga Mouse, Glossy Black Cockatoo). However, several other threatened species appeared to form an unexpectedly high proportion of the diet of Barking Owls in the Pilliga forests. These species, including the Yellow-bellied Sheathtail Bat, South-eastern Long-eared Bat, Turquoise Parrot and Grey-crowned Babbler, may warrant special conservation efforts, particularly a regular monitoring program.

This study provides information (Chapters 3 and 4 and appendix 1) that could be important for performing Population Viability Analysis for these threatened species. The rate of predation of adults and juveniles is required for a PVA and the Barking Owl may be the major predator of the majority of the threatened species. Other predators potentially taking substantial numbers of these species are Lace Monitor, Feral Cat, Fox, Southern Boobook and Barn Owl.

3.4.6 Ideal diet for Barking Owls

The breadth of the Barking Owl diet undoubtedly makes them more adaptable to live in forest through to semi-arid environments. Almost all the Barking Owl pairs within this study were able to nest and raise young at least to fledging age. The question remains, do Barking Owls require a wide range of prey or can they survive on a diet with only a narrow range? Relying on a single abundant prey species might make Barking Owls vulnerable to a population crash.

Past studies of raptors have found that some specialist hunters that have short digestive tracts (Barton and Houston 1994) required particular foods or they lost condition. For example, a short digestive tract pursuit forager, the Peregrine Falcon *Falco peregrinus* fed with rabbit lost weight but when fed a diet of pigeon gained condition (Barton and Houston 1993). In the same study, a generalists feeder (Common Buzzard *Buteo buteo*) that did not use rapid pursuit of fast prey was able to gain weight on both diets. Recent studies have shown that a range of owls can utilise a wider range of foods without compromising growth. Tawny Owl chicks showed no difference in growth rate when feed on day old chicks or mice probably because their longer gut (than a specialist pursuit hunter) supports more caecal bacteria which can synthesise additional essential amino acids and improve digestive efficiency (van den Burg 2009). Such a hypothesis may also apply to the Barking Owl, which from the results of this study, appears to make no effort to exclude particular prey types.

To determine if Barking Owls do show a preference for particular food types or if their diet is a function of the way they hunt and the prey they have available, we need to compare the diet described in this chapter with measures of the available prey and the observations on foraging behaviour presented in Chapter 5. That comparison is presented in Chapter 4. In the Pilliga, the diet balance of birds versus mammals swings both ways depending on location and time of year. This may not always reflect the relative abundance of the prey groups in the landscape. It may be the behaviour of prey, which makes some species more vulnerable to predation. The range of prey types taken by the Pilliga Barking Owls makes their prey selection difficult to assess, however, within-group preferences can be cautiously assessed. Chapter 4 also provides that assessment.

Chapter 4
Barking Owl Prey Availability in the Pilliga Forests

Some data incorporated in this chapter are owned by Dr. Bradley Law, Mark Chidel and Dr. Patrick Tap as indicated. Some data are jointly owned by Dr. Rod Kavanagh and/or Graham Turner with Matthew Stanton as indicated.

4.1 Introduction

The selection of prey by owls has been well studied for some cosmopolitan and northern hemisphere species. In particular, the Barn Owl *Tyto alba* has been well studied in a number of environments (e.g. Fast and Ambrose 1976, Taylor 1994, 2002, Bernard *et al.* 2010). Predator/Prey cycles (the vole cycle) have been well documented in Northern Europe (e.g. Korpimaki 1986, 1994). Larger Owls have been assessed for their competition with human hunters (Valkama *et al.* 2004) and their vulnerability to prey declines (Penteriani *et al.* 2002) however often these assessments are from a single prey or prey group perspective. Additionally some studies are able to extrapolate from comparison of consumed prey and prey availability data to predict breeding success, for example for Spotted Owls (Rosenberg *et al.* 2003).

A comparison of Barking Owl prey items with available prey has not been published before. Such studies are rare in Australia, however, the Powerful Owl has been assessed for its prey selection in at least two studies (Cooke *et al.* 2006, Kavanagh 1997). Kavanagh also compared prey availability for the Sooty and Masked Owls living in the same region. The Southern Boobook has been assessed for prey selection through multiple seasons on a New Zealand island by Denny (2009). Pavey *et al.* (2008b) compared the availability of two small mammals with the proportions taken by the Barn Owl and the Letter-winged Kite. In that case, Barn Owls were selective of the larger species while the kites predated rodents in a similar proportion to their detection rate by trapping. Dickman *et al.* (1991b) compared Eastern Barn Owl foraging patterns and diet with distribution of different age classes of House Mouse and performed an experimental modification of House Mouse demographics. McDonald (2010) compared the diet of Lesser Sooty Owls with mammals trapped, with the intension of identifying the most efficient small mammal survey technique.

The Powerful Owl is a relatively easy study subject as in many areas their main prey items all fall within a single category and can all be measured by a single technique, i.e. spotlighting for arboreal mammals (Kavanagh 2007, Cooke *et al.* 2006). Similarly, Barn Owl prey can usually be studied by a single method; small mammal trapping. Sooty Owls are more problematic as at least two methods are required to assess their prey availability (spotlighting and small mammal trapping). Masked Owls (and Powerful Owls) are known to take a larger quantity of birds in some environments (Kavanagh 2002, Soderquist and Gibbons 2007), potentially necessitating a measure of diurnal bird abundance/biomass. Barking Owls are more complicated again. From Chapter 3 it is apparent that at least in terms of prey numbers, insects and bats are important prey along with the other groups mentioned above. Thus, at least five methods are required to assess prey availability for Barking Owls in the Pilliga.

The Pilliga Barking Owls take a wide range of prey and shift their diet dramatically with season (Chapter 3). Owls living in forest edge and forest core environments took different proportions of birds or mammals demonstrating versatility in their foraging strategies and diet. While the diet was variable, all territories were feeding part of the time on each of the main prey groups.

With such versatility to utilise a wide prey base, why were Barking Owls restricted to approximately 40% of the Pilliga forest area? Two hypotheses related to prey availability are:

a) Key elements essential to their diet were absent.

b) The total quantities of prey available were not sufficient to maintain breeding territories.

Considering hypotheses (a) and (b), it should be possible to survey the potential prey in both areas and determine groups that show a significant difference or in the case of possibility (b), to gain insight into the total quantities of prey available.

In this chapter, I examine the differences in Barking Owl prey availability within the major prey groups across areas that have a high density of owls compared with areas that have a low density of owls (as determined by territorial responses to call playback).

The prey preferences of the Pilliga and Yarindury Barking Owls are also examined within prey groups.

4.2 Methods

4.2.1 Prey surveys

Prey availability was established through a variety of surveys, on common sites. NSW Forest Science Centre staff including the author surveyed three sets of sites. The first two sets were established for other purposes, however their distribution and stratification lent them to the purpose of quantifying prey in known Barking Owl habitat and in presumed poor habitat where Barking Owls have not been detected (this study, Forests NSW BIODATA database, NPWS Wildlife Atlas and Milledge 2004).

The first stratification was on sites located to determine the biological width of streams. Streams in the Pilliga forests may have a different species assemblage for some groups: Insects (Dangerfield *et al.* 2001) and birds (Date *et al.* 2002). A set of sites originally used to sample insects was used to sample diurnal birds, bats, small ground mammals, arboreal mammals and nocturnal birds in 2004 and 2007. Some data were also available from the original insect sampling in January 2001. There were six groups of sites with each group having one site on each of three classes of streams or stream surrogates. The stream classes (by 'Strahler' order) were first or second order, third or fourth order and fifth or sixth order. An additional group was in West Pilliga where deep soils on a flat plain have left few watercourses. Here, three roads/tracks of different sizes became stream surrogates. The six site groups were located in East Pilliga SF, Timmallallie SF, Wittenbra SF, Cumbil SF, Orr SF and West Pilliga SF. The sites are hereafter referred to as the 'stream sites'.

The second site stratification was on a spatial basis. A ten-kilometre grid of random origin was used to locate sites across a variety of habitats. Each site had up to nine sub-sites allocated on a 500 metre sub-grid, depending on the sampling method being used. The data collected at these sites was as a pilot study for long term monitoring. The sites are hereafter referred to as the monitoring sites.

Figure 4.1 Location of prey sampling sites across the Pilliga forests. Red circles show stream study sites. Orange squares show monitoring grid sites. Yellow arrows indicate targeted sites. Blue crosses are Barking Owl records from Milledge (2004). Blue ticks are Barking Owl records from this study. Spot 5 satellite images © CNES 2004/5.

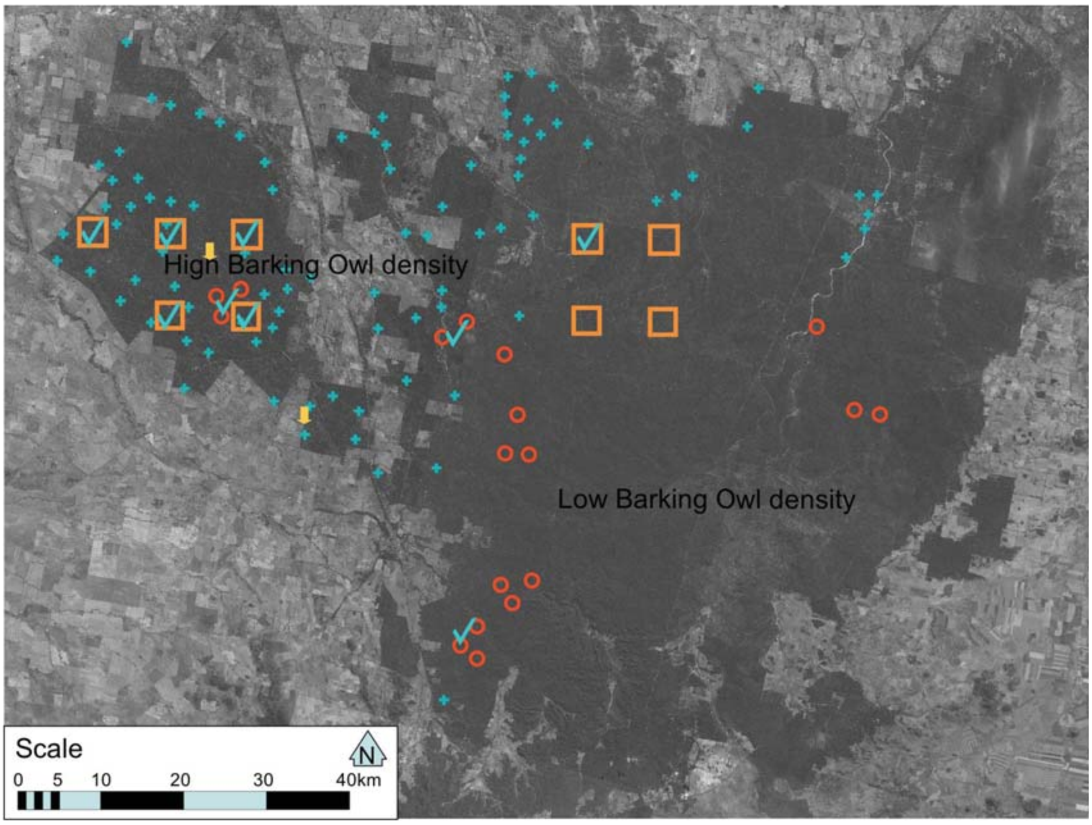


Table 4.1 Sampling periods for prey availability sites in relation to Barking Owl detections. M = Milledge 2004, S = this study, D = Dangerfield *et al.* 2001.

Site	Stratification	Barking Owls detected	Diurnal birds	Nocturnal birds and mammals	Micro bats	Terrestrial mammals	Flying insects
1L	Stream order	M/S	Spring 2004 & 2007		Spring 2004	Spring 2004	D
1M	Stream order	M/S	Spring 2004 & 2007		Spring 2004	Spring 2004	D
1S	Stream order	M/S	Spring 2004 & 2007		Spring 2004	Spring 2004	D
4L	Road size	M/S	Spring 2004 & 2007		Spring 2004	Spring 2004	D
4M	Road size	M/S	Spring 2004 & 2007		Spring 2004	Spring 2004	D
4S	Road size	M/S	Spring 2004 & 2007		Spring 2004	Spring 2004	D
3L	Stream order	S	Spring 2004 & 2007		Spring 2004	Spring 2004	D
3M	Stream order	S	Spring 2004 & 2007		Spring 2004	Spring 2004	D
3S	Stream order	S	Spring 2004 & 2007		Spring 2004	Spring 2004	D
2L	Stream order	Not detected	Spring 2004 & 2007			Spring 2004	D
2M	Stream order	Not detected	Spring 2004 & 2007			Spring 2004	D
2S	Stream order	Not detected	Spring 2004 & 2007			Spring 2004	D
5L	Stream order	Not detected	Spring 2004 & 2007		Spring 2004	Spring 2004	
5M	Stream order	Not detected	Spring 2004 & 2007		Spring 2004	Spring 2004	
5S	Stream order	Not detected	Spring 2004 & 2007		Spring 2004	Spring 2004	
6L	Stream order	Not detected	Spring 2004 & 2007		Spring 2004	Spring 2004	
6M	Stream order	Not detected	Spring 2004 & 2007		Spring 2004	Spring 2004	
6S	Stream order	Not detected	Spring 2004 & 2007		Spring 2004	Spring 2004	
9231	10km grid	M/S	Spring 2008	Aug & Dec 2009	Spring 2008		Aug & Dec 2009
9233	10km grid	M/S	Spring 2008	Aug & Dec 2009	Spring 2008		Aug & Dec 2009
9235	10km grid	M/S	Spring 2008	Aug & Dec 2009	Spring 2008		Aug & Dec 2009
9695	10km grid	M/S	Spring 2008	Aug & Dec 2009	Spring 2008		Aug & Dec 2009
9697	10km grid	M/S	Spring 2008	Aug & Dec 2009	Spring 2008		Aug & Dec 2009
9243	10km grid	S	Spring 2008	Aug & Dec 2009			Aug & Dec 2009
8782	10km grid	Not detected			Spring 2008		
9705	10km grid	Not detected	Spring 2008	Aug & Dec 2009	Spring 2008		Aug & Dec 2009
9707	10km grid	Not detected	Spring 2008	Aug & Dec 2009			Aug & Dec 2009
9245	10km grid	Not detected	Spring 2008	Aug & Dec 2009			Aug & Dec 2009
C091	Targeted	M/S		Aug & Dec 2009			
C131	Targeted	S		Aug & Dec 2009			Aug & Dec 2009
Yarindury SF		S	2006/2007	2006/2007			
Liverpool Plain		Not detected	2006/2007	Autumn 2009	2006/2007		

For comparison with the Pilliga sites, I selected two extralimital areas. The first was Yarindury State Forest, fifty kilometres east of Dubbo. Yarindury was a small forest (1200 ha) that contained at least one breeding pair of Barking Owls during the study. Eight survey sites spread through Yarindury provided data for diurnal birds and nocturnal birds and mammals.

The second extralimital area was the small forest fragments of the Liverpool Plain. No Barking Owls have been detected in any of the forest patches used (NPWS Atlas of NSW Wildlife) which included five State Forests, one travelling stock reserve and five forest patches on private tenure. The eleven sites were surveyed for nocturnal birds and mammals, diurnal birds and micro-bats.

Nocturnal birds and mammals were surveyed at two additional sites within known Barking Owl territories in the Pilliga. As these sites were not selected randomly or after a consistent stratification, the results are not combined with the main surveys. Instead, the results are presented as extremes not detected in the stratified surveys. Figure 1 shows the location of all sample clusters.

4.2.2 Diurnal bird observation

Diurnal birds were sampled on the creek and monitoring study as well as at both extralimital areas. Bird counts commenced for the two additional Pilliga forest sites, however the results were not substantially different, so the surveys were not completed and are not considered further here.

A ten-minute point count method, similar to that described by Kavanagh *et al.* (2007b) tallied all birds within distance categories out to 50 metres (0.78 ha). This data enabled the calculation of bird densities per hectare.

For the stream study, two sampling points were used for each site (six per group). The points were located 50 metres from the watercourse and 150 metres from the watercourse. Two observers sampled each point twice across four different mornings in November 2004 and again in October 2007 making a total 288 ten-minute counts (Kavanagh and Stanton, unpublished data).

In the monitoring study, the same nine monitoring sites that were sampled by spotlighting were sampled for diurnal birds. Nine sub-sample points were located on a 500-metre sub-grid around each site. Sampling was once by each of two observers in September 2008 making 162 ten-minute counts (Kavanagh and Stanton, unpublished data).

The extralimital surveys were by a similar method to the stream study, with two sample points per site. Liverpool Plains sampling consisted of a single visit by each of two observers on four occasions during 2006/2007. There were 176 ten-minute counts across eleven sites (Kavanagh *et al.* 2010). Yarindury sampling consisted of two visits in November 2006/2007. There were 32 ten-minute counts across eight sites for Yarindury (Stanton and Turner, unpublished data).

4.2.3 Spotlighting for arboreal mammals and nocturnal/roosting diurnal birds

Spotlighting has been used to establish prey density for Australian owls before (e.g. Kavanagh 1997, Cooke *et al.* 2006). All sets of sites were spot lit, however there were consistency issues with the stream site data so it is not considered further here (unpublished data, Dr. Patrick Tap).

Spotlighting on nine monitoring sites was conducted as a one kilometre transect running due north-south from 500 metres north of the central point to 500 metres south of the central point. A single observer, always the author, conducted the surveys. The traverse, at approximately ten metres per minute, gave a total survey time of 100 minutes. Animals were detected by their calls, their non-vocal cues or by spotting. The distance from the transect line was noted for constructing detection profiles and calculating prey density.

Two additional spotlight survey transects were included at sites where Barking Owls were known to forage, but which were not sampled by the random origin grid. The first was along the western edge of Merriwindi SF (Compartment 131). The second was in a patch of dense regeneration resulting from a contained wildfire in 1997. The location was in the centre of West Pilliga SF (Compartment 91). These two sites were sampled along established tracks in order to be able to access the targeted habitat. No regard was made of tracks while sampling the grid-based sites. All sites were sampled during August 2009 and again during December 2009. This was not a drought period. Total sampling time came to 2200 minutes.

The two extralimital areas were also sampled by spotlighting. Sampling was by the same method but along 200 metre transects. Yarindury was sampled in November 2006 and July 2007 for a total of 320 minutes. The eleven Liverpool Plain sites were sampled numerous times between September 2006 and May 2009 for a total of 820 minutes (Kavanagh *et al.* 2010).

4.2.3 Bat detection

Bat surveys were conducted using ANABAT ultrasonic detectors for both the stream study (2004/2007) and the monitoring study 2008/2009 (Dr. Brad Law *et al.* papers in prep.). The Liverpool Plains were sampled during 2006/2007 (Kavanagh *et al.* 2010). ANABAT detectors enable counts of echo-locating bats past a single point during a series of nights. The recorded calls allow the identification of many bat species. Species unable to be identified potentially weighed from 8 to 15 grams. The data provided a good relative measure of the availability of bats as prey for Barking Owls.

4.2.4 Trapping for ground mammals

Ground mammal trapping was only carried out in the stream study. Data return is too costly for this method to be used repeatedly in monitoring even in areas with dense populations of small terrestrial mammals (McDonald 2010), which the Pilliga is not (Pennay *et al.* 2002). Trapping was carried out between 8 November 2004 and 4 December 2004. This was a period of drought, although some rain occurred during sampling.

Four nights of trapping using aluminium box traps baited with a mixture of rolled oats and peanut butter were completed at each site. Traps were set at 10 metre intervals in two lines 100 metres apart and 240 metres long, starting at the streambed and working outwards. 3744 trap nights were completed. Staff from Baradine and Dubbo forestry offices conducted the survey (Unpublished data, Dr. Patrick Tap).

4.2.5 Invertebrate trapping

Dangerfield *et al.* (2001) reported some of their data for the biological width of streams study. Pitfall traps were the method used to capture crawling insects. However, the invertebrate groups they chose to report were predominantly unlikely prey of Barking Owls. Beetle samples collected during the study remained unanalysed.

As Barking Owls took many insects from the air or flushed them from foliage (Chapter 3), an attempt was made to collect flying insects with a car-mounted scoop net. Figure 4.2.2 shows photos of the scoop net in use. The mouth of the net measured 1.85 square metres. The net fabric was fibreglass mosquito mesh. The tail of the net was over two metres long and tapered to an opening for recovering the catch.

In August 2009 and again in December 2009, I drove 5km netting routes along roads near each of the monitoring sites as well as along a forest edge in Merriwindi State Forest. Fifty to-sixty km/h proved to be the best speed for collection of specimens without significant damage. I sampled each of the ten sites four times in each sampling month with samples collected on at least two different nights and at different times of night. Insects were counted by type and large specimens were weighed. Most were released alive.

Figure 4.2 The flying insect scoop net, mounted on top of a utility vehicle ready to start sampling at dusk. The rear (cod end) of the net reaches to the vehicles tailgate.

4.2.6 Analysis

Where possible prey abundance has been converted to biomass/hectare (birds and arboreal mammals), biomass/detector/night (micro bats) or biomass/100 trap nights. Insects have been presented as counts/km. Only prey species known to be taken by Barking Owls or within the scope of those prey were included for biomass calculations. Mammals which may exceed the normal prey size, such as the Common Brushtail Possum, were included at a biomass of 1000 grams. Large birds (Sulphur-crested Cockatoo, Glossy Black Cockatoo and Australian Raven) were assessed at 400 grams on the grounds that these prey items seem to be rarely taken in proportion to their abundance. This may be because they are high-risk prey. Prey masses used are listed in Appendix 1.

Differences between biomass or counts for each prey group between areas with Barking Owl territories and areas without territorial Barking Owls were tested using the Wilcoxons rank sum test within the R statistical package (2010). Box and whiskers charts display the medians and data range for each group.

While it was not possible to directly compare between prey groups, broad comparisons of prey abundance between each group were made where variation between survey methods could be accounted for. Within group comparisons were made with the consumed prey data from regurgitated pellets (Chapter 3).

4.3 Results

4.3.1 Available biomass in areas with and without Barking Owls

Bird counts in the Pilliga revealed 94 species of potential prey birds within 50 metres of the count points. An additional ten species were present nearby but outside the plots (thus unable to be used for density estimates. Sites had a wide range of bird biomass across the Pilliga, ranging from only 201 grams/hectare for a recently burnt site in East Pilliga State Forest to 2697 grams/hectare for an outlier site with large numbers of cockatoos and other large birds. There proved to be a significant difference between the sites with and without Barking Owl territories (Table 4.2, Figure 4.3a). Bird density showed a similar trend with a p-value of 0.006 (Figure 4.4a). The diurnal birds proved to be the only vertebrate group to show a significant difference. That difference was not mirrored in the extralimital study areas (which added another eleven species). Yarindury (with Barking Owls) had a mean bird biomass of 1375 grams/hectare while the Liverpool Plains study (few Barking Owls) had a mean bird biomass of 1988 grams/hectare. There was no discernable trend when comparing bird density with mean bird mass, both factors showing a broad range.

The two stratification methods did not contribute a significant difference to diurnal bird biomass. Grid sites had slightly lower biomass at a median 515 grams/hectare while stream stratified sites had 615 grams/hectare.

Spotlighting the eleven Pilliga forest sites found 84 nocturnal prey animals in winter and 89 in summer. Two nocturnal bird and three arboreal mammal species were detected. There was no significant difference between sites with and without Barking Owls (Table 4.2) and the same trend was evident for individual species tested (Sugar Glider and Australian Owlet-nightjar). No Feathertail Gliders were detected on sites without Barking Owls. Figure 4.5 shows biomass breakdown for the five species across the stratified and the targeted Pilliga sites and at the two extralimital study areas. Biomass of the main mammalian prey item in the Pilliga (Sugar Glider) never exceeded 100 grams/ha and was generally less than half that. Likewise, in the extralimital sites, the biomass of gliders remained low. The areas that had Common Brushtail Possum were strongly advantaged by their great size. Even though a biomass of only 1000 grams was used, any site that had a normal population density of Common Brushtail Possums, had vastly more calculated biomass than sites that only had smaller animals, as was the case for all but one site in the Pilliga.

Bats were detected at similar rates across the Pilliga. The number of grams of bat flying past bat detectors was consistently high, indicating few areas with a shortage of bat prey (Figure 4.3). There was no significant difference between areas with and without territorial Barking Owls (Table 4.2). The extralimital study area (few Barking Owls) of the Liverpool Plains also had high levels of bat activity within remnant vegetation (Figure 4.3) but notably low volumes on tree plantings and open country from that study.

Small mammal trapping produced sparse returns with only 41 mammals captured over 3744 trap nights (1.1% return). Low trap return rates are common in many studies in semi-arid Australia (e.g. the Western Regional Assessment for this region (Pennay *et al.* 2002) had a trap return rate of only 0.839%). There was no significant difference between sites with or without Barking Owls (Table 4.2), although the only site with moderately high returns was on a Barking Owl site (Figure 4.3). The higher value on that site was due to a large population of House Mouse.

Insect netting produced a large data set of sub-prey sized insects but only six prey sized insects. The larger insect individual weights are presented in Table 4.3. As prey sized insects were insufficient to analyse, an analysis was performed on the total counts of insects. The slight difference between areas with and without Barking Owls was found to be significant (Table 4.2). Conditions were relatively cool and dry during the sampling periods, possibly contributing to the low catch rate of prey-sized insects. Large numbers of prey sized moths and beetles were not noted on the spotlighting transects conducted in the same periods.

While the Wilcoxens results were mostly not significant, in every case the median and mean biomass was greater in areas with Barking Owls than those without. In the three cases where comparison data were available from Yarindury (with Barking Owls) or the Liverpool Plains (without Barking Owls), the mean and median prey biomass from those study sites were greater than the mean and median found in the Pilliga.

Table 4.2 Prey group biomass/density differences between areas with and without Barking Owls. Wilcoxon rank sum test results for the five available prey groups.

	Barking Owls detected	Barking Owls not detected	Wilcoxon rank sum test	
Prey Group	(median)	(median)	*W*	*P-value*
Diurnal bird biomass (g/ha)	684	530	382	**0.003**
Diurnal bird density (birds/ha)	22.10	15.28	372.5	**0.006**
Nocturnal bird & arboreal mammal biomass (g/ha)	62	57	16	0.49
Bat biomass (grams/detector/night)	2196	1649	63	0.66
Terrestrial small mammal biomass (g/100 trap nights)	36	24	40	0.96
Insects (count/km)	5.2	4.5	999	**0.03**

Figure 4.3 Prey biomass measures of four prey groups of Barking Owls in the Pilliga. Data is split between known territories and sites where Barking Owls have not been detected.
Grey boxes indicate 50% of the group data around the median (heavy line). Whiskers indicate the extent of the remainder of the data except for outliers indicated by grey circles. The mean biomass value is indicated with an orange circle for Yarindury and a blue circle for the Liverpool Plains.

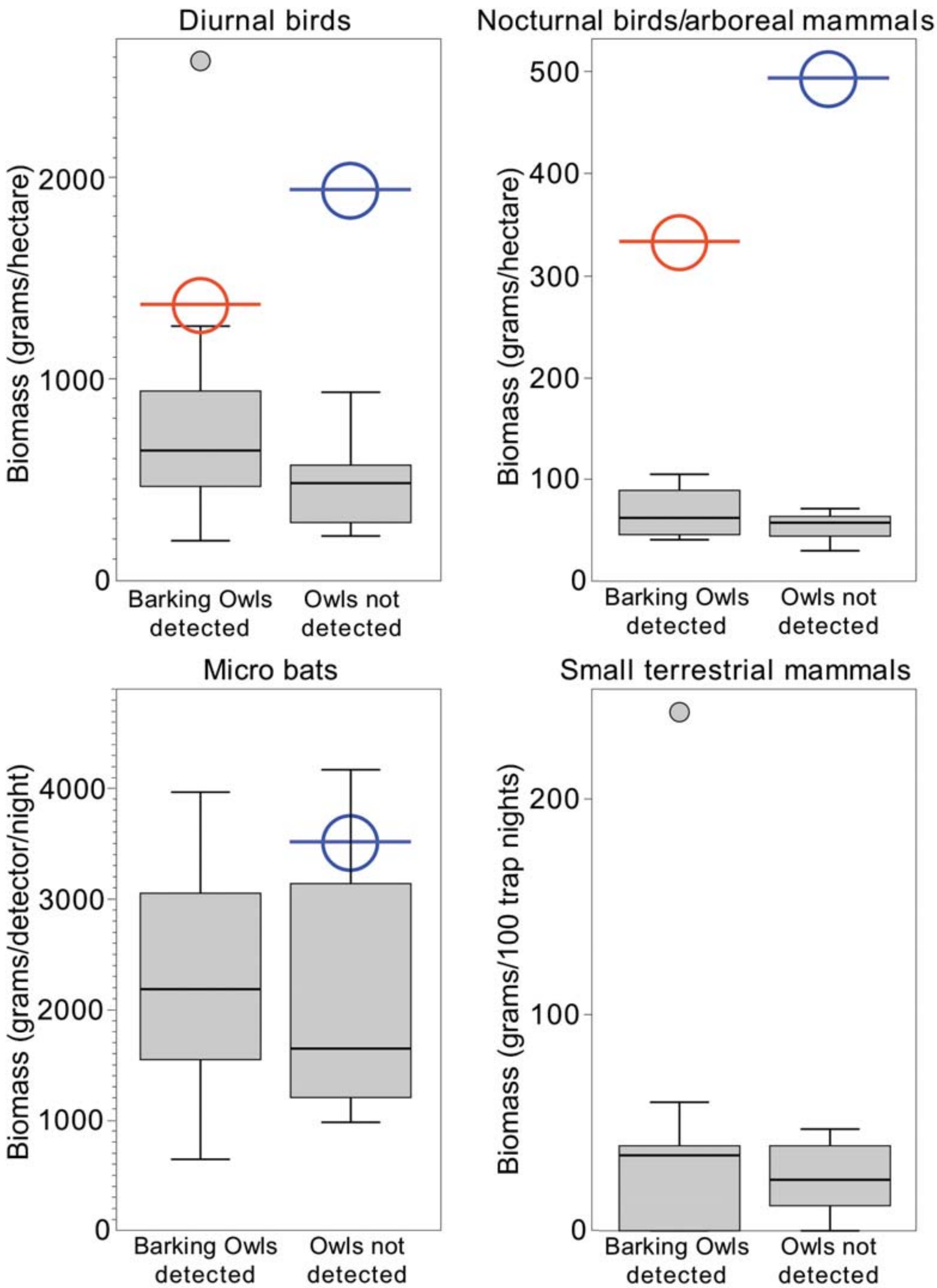


Figure 4.4 Number of birds/hectare and number of flying insects captured with a vehicle mounted scoop net/kilometre in known owl territories and out of known territories in the Pilliga.

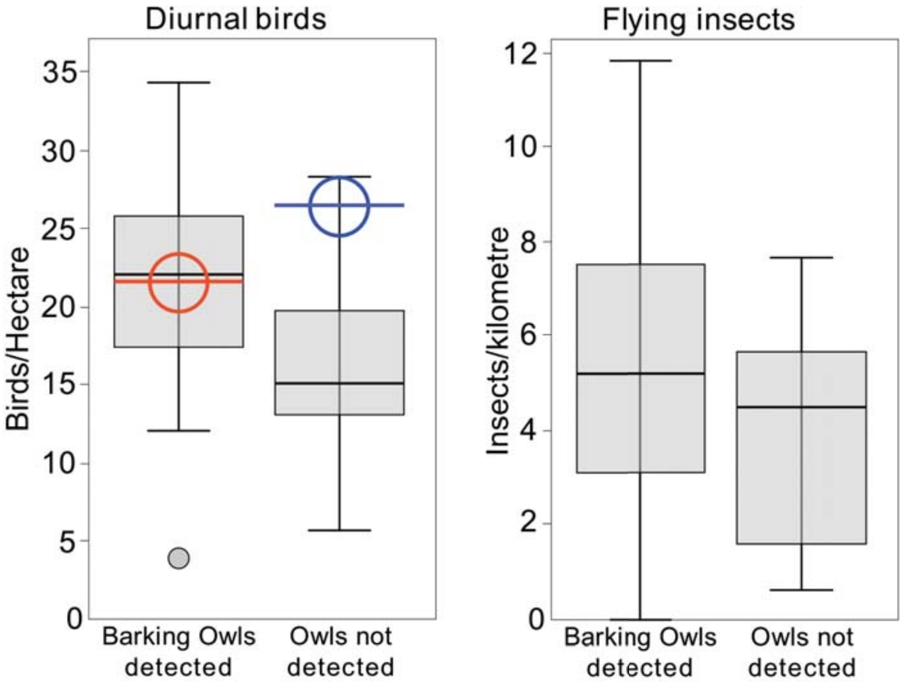
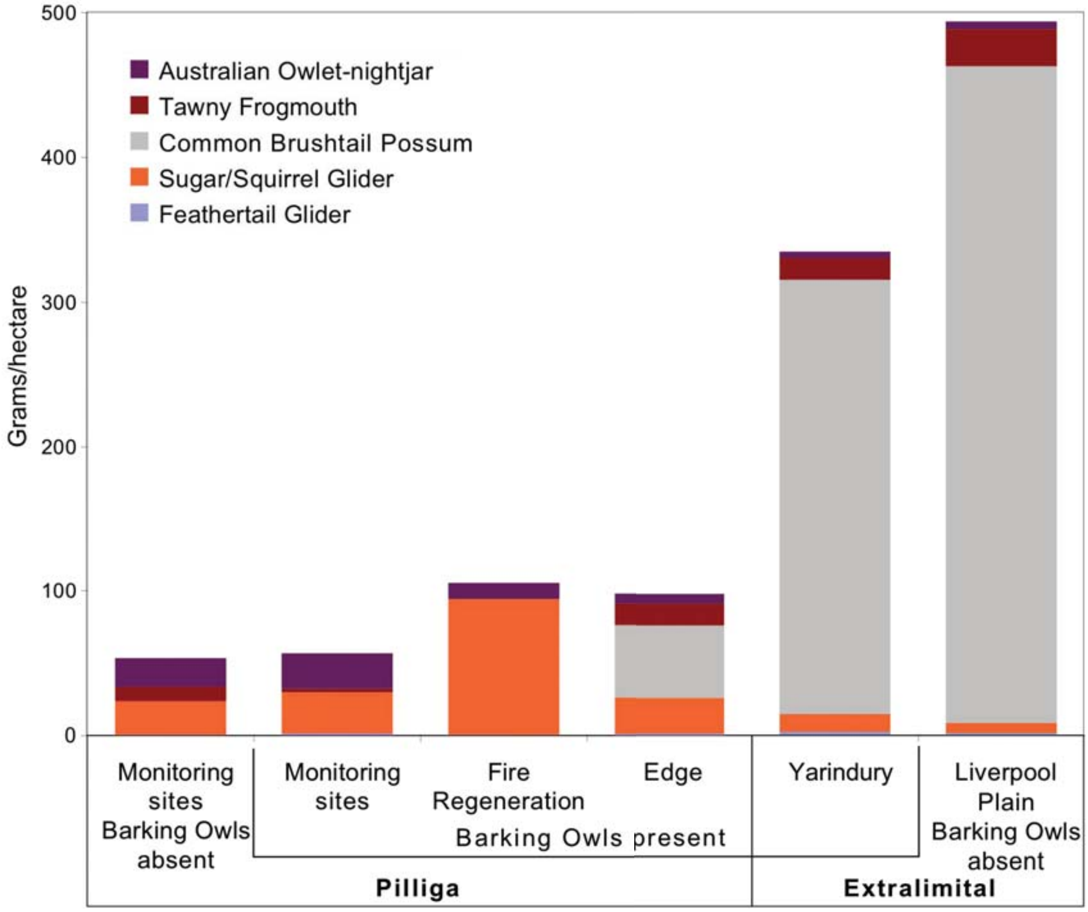


Table 4.3 'Prey sized' and 'sub-prey sized' (italics) insects captured by scoop netting with individual and general prey masses.

Data	August 2009 Barking Owls detected (effort 140 km)	August 2009 Barking Owls not detected (effort 60 km)	December 2009 Barking Owls detected (effort 140 km)	December 2009 Barking Owls not detected (effort 60 km)
Beetles			1 (1.9g)	1 (0.7g)
Moths	1 (0.3g)			2 (1g, 2.2g)
Katydid			1 (0.8g)	
Small beetles 0.1g	*0*	*2*	*0*	*0*
Small moths				
0.007g	*590*	*204*	*866*	*225*
Ants 0.01g	*0*	*0*	*52*	*17*
Lacewings 0.05g			*10*	*5*

Figure 4.5 Nocturnal bird and arboreal mammal biomass breakdown for a range of sites with Barking Owls (middle four columns) and without Barking Owls (outer two columns).



4.3.2 Within group prey selection

Because of the diversity of birds, they are considered here as "woodland dependent" and "non-woodland dependent" groups after Kavanagh *et al.* (2007b). Woodland dependent birds were taken at similar volumes by Barking Owls from forest core (16 grams/pellet) and forest edge territories (19 grams/pellet). However, non-woodland dependent species were consumed at three times the rate by the edge dwelling Barking Owls. The ratio of bird biomass consumed compared to bird biomass available is presented in Table 4.4. As forest edge was under-represented in bird sampling, it is not possible to say if there was a difference in bird availability near the forest edge. All the Pilliga availability results have been combined for the comparison. A similar comparison is included in the table for Yarindury.

Table 4.4 Relative importance of woodland and non-woodland dependent birds contribution to available prey biomass for Barking Owls. The ratio is a relative measure of how much more likely a species will be predated by Barking Owls than detected during a survey. Ratio values higher than "1" may indicate a preferred prey species. Alternatively, it may indicate that survey methods underestimate the species availability.

Bird Species Group	Consumed Biomass (grams/pellet)	Available biomass detected (grams/ha)	Ratio of consumed to available
Forest core territories		*Pilliga*	
Woodland Dependent	16	517	1.0
Non-Woodland Dependent	9	316	0.9
Forest edge territories		*Pilliga*	
Woodland Dependent	19	Core used	0.6
Non-Woodland Dependent	30	Core used	1.6
Yarindury territory		*Yarindury*	
Woodland Dependent	30	753	0.8
Non-Woodland Dependent	34	621	1.2

It is clear that Barking Owls of the forest core were taking broadly equitable amounts of woodland dependent and non-woodland dependent birds. Woodland birds were typically smaller than non-woodland dependent species. Therefore, by default, it seems that Barking Owls were not making a strong distinction about bird size when selecting prey. The forest edge dwelling Barking Owls showed a preference for non-woodland dependent birds, however that was probably due to a deficiency of the availability data which counted birds during the day, while the owls were hunting at night when birds that foraged outside the forest during the day, return to the forest to roost. In addition, most bird sensus sites were away from forest edges.

A better example was found with Yarindury, where the small forest patch size meant that most of the bird sample points were near an edge. In this case, the Yarindury birds were still showing a slight preference for non-woodland dependent birds, indicating that they were still being under-sampled by survey relative to Barking Owl predation.

Mammal and nocturnal bird selection is presented in Table 4.5. The two nocturnal bird prey species showed a strong pattern of selection. Australian Owlet-nightjars were by far the more commonly encountered during spotlight surveys, yet they were detected in pellets from the Pilliga only five times. Tawny frogmouths were 27.8 times more likely to be taken by a Barking Owl than the mean for nocturnal birds. Possibly part of this is under-detection during the spotlight survey, however it couldn't account for all the variation as owlet-nightjars have their own detection issues. More likely is that Tawny Frogmouths were easily detected by Barking Owls and easy targets for a meal that lasts more than one night (see Chapter 5).

Barking Owls showed no great selection between arboreal mammals. Sugar Gliders comprised the main prey item and were the most frequently recorded during spotlight surveys. The low score for Common Brushtail Possum was based on a single record of a rare species in the Pilliga forests during this study. The low score for Feathertail Glider may indicate that Barking Owls have more trouble locating these small non-vocalising possums than an observer with a spotlight does.

Table 4.5 Predation, human detection and their relationship for three groups of mammal species and nocturnal birds in the Pilliga. The ratio is a relative measure of how much more likely a species will be predated by Barking Owls than detected during a survey. Ratio values higher than "1" may indicate a preferred prey species. Alternatively it may indicate that survey methods underestimate the species availability.

Species	Consumed individuals in pellets	Available individuals detected in Pilliga	Ratio of Consumed to detected
Nocturnal birds		*Spotlighting*	
Australian Owlet-nightjar	5	75	0.3
Tawny Frogmouth	13	2	27.8
Arboreal mammals		*Spotlighting*	
Sugar Glider	201	46	1.1
Feathertail Glider	13	9	0.4
Common Brushtail Possum	2	1	0.6
Eastern Pygmy Possum	2	0	high
Terrestrial mammals		*Trapping*	
Mice	13	35	0.8
Common Dunnart	4	1	8.2
Yellow-footed Antechinus	3	5	1.2
Micro bats		*Mean ANABAT Passes/Night*	
Long-eared Bats (3 species)	21	9.3	1.6
Yellow-bellied Sheathtail Bat	29	8.5	2.4
White-striped Freetail Bat	2	2.4	0.6
Little Forest Bat	108	64.3	1.2
Other mid-sized bats	171	152.2	0.8

The comparison between species detected by trapping shows one exceptional value for the Common Dunnart. Common Dunnarts are notoriously trap shy at some locations (Read 1985) and are undoubtedly under-represented in the trapping survey.

There appears to be some discrimination in the bats selected by Barking Owls. Table 4.5 presents data for five groups/species of bat, being those that were most accurately diagnosed due to their skull/jaw size or hair type. The *Nyctophilus spp.* could not be separated by ANABAT analysis.

The White-striped Freetail Bat is a fast and high-flying species that may avoid crossing paths with Barking Owls. The Yellow-bellied Sheathtail Bat is also often a high flyer and the second largest micro bat in Australia (Churchill 2008), however it has a 2.4 times higher chance of falling prey to a Barking Owl than the average bat. Long-eared bats *Nyctophilus spp.* also seem to have a higher than average chance of falling prey although this could be related to reduced detectability by ANABAT. Their echolocation calls are soft and at high frequency. The long-eared bats include one scheduled vulnerable species, *N. corbeni* (formerly *N. timorensis*). The most abundant bat in the Pilliga, the Little Forest Bat appears to have a close to even chance of being predated.

4.4 Discussion

4.4.1 What prey groups are driving Barking Owl distribution in the Pilliga?

In Chapter 3, birds were shown to constitute approximately 50% of the consumed biomass. Sugar Glider was the other main contributor to biomass, particularly for Barking Owls dwelling in the forest core. By prey numbers, insects were the most common item at 65%. Even if the biomass contribution of insects seems insubstantial, they still occupy large proportions of foraging time and effort and deserve consideration of availability.

The most striking result from the prey availability surveys was the diurnal bird biomass. The biomass was much greater in Barking Owl territories than in areas without territorial Barking Owls. Not only was this the only group with a significant result for vertebrate prey, but also the observed biomass per hectare is reasonably high, certainly higher than suggested for the nocturnal bird and arboreal mammal data.

Before comparing between groups surveyed by different methods, it needs to be considered that nocturnal fauna are more difficult to detect than diurnal birds. Birds are not only visible in the day light but also advertise their presence with diagnostic calls. There has been some effort to quantify under-detection of mammals during spotlight surveys. Smith and Phillips (1984) detected Sugar Gliders by spotlighting at a rate of 0.5/hectare where the known occupancy was 0.9/hectare. Goldingay and Sharpe (2004) found that a spotlight survey was detecting approximately 25% of Squirrel Gliders present in a study area. Squirrel Gliders are difficult to detect by spotlighting because they do not vocalise as often as other *Petaurus* gliders but still have the habit of looking away from the light, thus masking any eye-shine that may give them away (pers. obs.). Squirrel Gliders occur in the Pilliga forests but the population size has not been determined because of their cryptic behaviour and confusion with the similar but smaller Sugar Glider. Sugar Gliders are easier to detect because they frequently vocalise, however some probably remain undetected. Given the results of the two studies above, it seems reasonable to assume that approximately half the Sugar Gliders were detected during this study. Thus, Sugar Glider density per hectare may be over 0.4 and biomass per hectare may average around 50 grams. It also seems reasonable that the lack of Squirrel Glider records is at least partly due to a lack of Squirrel Gliders and that they are genuinely rare in the study area.

Bird surveys generally underestimate bird numbers also (e.g. Bart 1985, Johnson 2008. If we accept the unlikely case that the bird biomass estimates are not also an underestimate, then the available prey (per hectare) comparison between these two dominant prey groups sits at ~50 grams for Sugar Gliders versus 684 grams for birds, a 13 times difference. Yet, the consumed prey data, presented in Chapter 3 shows that Sugar Glider provides around half the biomass supplied by birds. Clearly, Sugar Gliders and nocturnally active prey are preferred prey items, even when they are in low abundance.

The most likely reason is that active nocturnal animals will be making more noise and visible movement than a diurnally active animal that stays motionless at roost during the night. Sugar Gliders are moderately vocal, further increasing their detectability.

Other nocturnal mammals such as the Feathertail Glider and Eastern Pygmy Possum are cryptic and detection by spotlight can be difficult. Both species are mouse sized and make a relatively small contribution to the consumed and potential prey biomass. Detection rates are highly influenced by environment and true densities cannot be estimated for the Pilliga forests.

Common Brushtail Possums were only recorded once during the spotlight surveys of the Pilliga forests. They are currently rare in the area, however anecdotally they were common in the past (Rolls, 1981). There remains a population in the town of Baradine. If Common Brushtail Possums were to increase once again in the Pilliga forests, it could result in a dramatic increase in available prey, although such a large possum must always be a difficult proposition for an owl of under a kilogram. The presence of a substantial population of Brushtail Possums in the remnant vegetation of the Liverpool Plains has not guaranteed a substantial Barking Owl population in that area.

Insect abundance cannot be ruled out as an important factor in Barking Owl distribution. While the surrogate insects used here could not contribute a substantial food source for Barking Owls, they would be prey items for many of their vertebrate prey such as micro bats, small mammals and small birds. They are used here in the hope that they represent the potential productivity of the forest for insects. Dangerfield *et al.* (2001) reported that there was little broad variation in insect abundance across the sites they selected around watercourses. However, as they were targeting the same consistent habitat component at each site, this is not a surprising result.

While only two of the groups reported here had a significantly different result (birds and insects, Table 4.2, Figure 4.3, 4.4), the other groups all showed the same trend. The areas occupied by Barking Owls are clearly more productive of all the major prey groups they depend on and given the relatively low levels of most of those groups compared with the extralimital sites, it can be concluded that the Pilliga sits on a dividing line. On one side, the Pilliga outwash province supports sufficient biomass that Barking Owls holding large territories can find sufficient food to support themselves and raise young. On the other side lie the hills of the Pilliga Sandstone province, repeatedly burnt by wildfire and producing fewer prey items suitable for Barking Owls. It may be that these hills support some Barking Owls at a density where they are not able to maintain territories or breed successfully. Therefore, the total productivity hypothesis seems to be the most likely to be correct.

The hypothesis that key elements essential to their diet were absent seems unlikely to be true. All three of the largest consumed biomass groups (woodland dependent birds, non-woodland dependant birds and Sugar Gliders) were present in both environments. The wide range of prey taken and the general trend of all prey groups to be slightly less abundant in areas without territorial Barking Owls lends much greater support to the second hypothesis being true, i.e total quantities of prey available were not sufficient to maintain breeding territories.

4.4.2 Prey selection within groups

4.4.2.1 Diurnal Birds

There was no clear selection for the two groups of birds examined, woodland dependent and non-woodland dependent, despite non-woodland dependent birds being on average larger. However, there were a few clear examples of birds being predated at a rate far beyond their density recorded in the forest. These fall into two groups. The first are non-woodland birds that spend the day foraging in non-forest environments, but return to the forest to roost. Many parrot species fall into this group, particularly the Red-rumped Parrot, but also the Cockatiel, Budgerigar and Blue Bonnet. Others include the Crested Pigeon, Peaceful Dove, Australian Magpie and Magpie Lark. These species are probably being taken at a normal rate, however the available biomass measure falls down because of the temporal anomaly. The second group, are species that leave themselves open to predation through behaviour, either fly late to roost, roosting in predictable and exposed locations or calling from their roosts. Examples are White-winged Chough, Laughing Kookaburra and the White-throated Needletail. The needletail tends to come to roost well after the sun has set, at about the time Barking Owls are typically commencing foraging. The fast moving birds typically make a low pass through the canopy, aiming directly for the vertical stem they intend to roost upon. An observant owl has merely to follow the needletail until it alights on its roost and then grabs the prey from below, thus avoiding making its own silhouette against the pale sky.

4.4.2.2 Nocturnal Birds

Nocturnal birds were represented in the diet study by three species; Tawny Frogmouth, Australian Owlet-nightjar and Spotted Nightjar. Spotted Nightjars were uncommon in the area (Pennay *et al.* 2002). Only Tawny Frogmouth and Australian Owlet-nightjar were detected during the spotlight surveys and in inverse proportion to their occurrence in regurgitated pellets (Table 4.5).

It seems that Tawny Frogmouth is a preferred prey item. Their nocturnal foraging activity and breeding season calling presumably give them away. The reason that owlet-nightjars are relatively under-predated is uncertain but could be related to their use of hollows, even at night (Brigham *et al.* 1998).

4.4.2.3 Arboreal Mammals

The Pilliga appears to have a simplified arboreal mammal fauna with only two species commonly encountered. One of these, the Koala, is not a normal component of Barking Owl diet, being from 4.0 to 9.2 kilograms in this area (Kavanagh *et al.* 2007a). Sugar Gliders were the most commonly detected species with 57 records. The Feathertail Glider, with nine records, may be common but is difficult to assess. Brushtail Possum had one record from this study and zero records from Milledge (2004). The Western Regional Assessment detected some Common Brushtail Possums, mostly through the practice of spotlighting large areas from vehicles (Pennay *et al.* 2002). The other species known to inhabit the area (Eastern Pygmy Possum, Squirrel Glider and Common Ringtail Possum) remained undetected in this survey, although all three were detected (sparsely) during the Western Regional Assessment (Pennay *et al.* 2002). However, records for the ringtail and pygmy possum were restricted to areas that Barking Owls have not been recorded.

If the Common Brushtail and Common Ringtail Possums were to become more widespread and abundant in the Pilliga, it may advantage Barking Owls in the short term, however these prey items are the dietary domain of the Powerful Owl (Kavanagh 2002a, Cooke *et al.* 2006, Soderquist and Gibbons 2007) and may invite occupation and competition by that species. Common Brushtail Possums will always be a high-risk prey item for an owl of less than one kilogram and the interactions of these two species remains unknown.

4.4.2.4 Small Terrestrial Mammals

The scarcity of these species in the Pilliga seems to indicate that they are unlikely to be key prey species in this environment. However, mouse plagues can occur in the forest (pers. obs. 1998) and at such times, they may become a significant dietary element.

4.4.2.5 Insects

The insect data from this study only offers the insight that insect abundance is a haphazard occurrence in this environment. However, the consumed prey data showed that insects were consumed year round. That data also showed a high number of beetles consumed. Unfortunately because of the unmeasurable biases related to assessing insect consumption (Chapter 3) no definitive conclusions can be reached here. Insects that attract attention through noisy flight or abundance are the most commonly consumed.

4.4.3 Barking Owl Food at Extralimital Sites

The extralimital sites included in this analysis had higher prey biomass for all groups measured; yet only the Yarindury site supported pairs of territorial Barking Owls. Why should the woodland remnants of the Liverpool Plains not be able to support territorial Barking Owls as well?

Possibly the explanation is one not directly related to biomass as it seems to be for the Pilliga. Four other hypotheses may provide an explanation.

Vegetation structure may be unsuitable for their hunting methods. The vegetation structure in remnants of the Liverpool Plain is just as diverse as that of the Pilliga, although fire has been even more excluded than for West Pilliga.

Another vital resource may be absent such as tree hollows or roosting environments. Tree hollows would seem to be in similar numbers to the Pilliga, however the greater numbers of Sulphur-crested Cockatoos, supported by the rich cropping agriculture of the plain, may have induced more competition for those hollows. Thus, the fragmented nature of the forest remnants meant that there were fewer available hollows overall. Adult Common Brushtail Possums may have competed for hollows. These conditions applied to Yarindury also, thus it seems unlikely to apply on the Liverpool Plain.

Predation risks in the unoccupied forest are higher than in occupied areas. Predation risk from Lace Monitors *Varanus varius* could be high in the remaining forest fragments of the plains. Lace Monitors were a proven cause of Barking Owl nest failure in the Pilliga (Kavanagh and Stanton 2009) and are suspected of causing failures in other areas (Schedvin 2007). The possibility that high numbers of hollow nesting cockatoos and parrots support a high density of nest hollow predators (Lace Monitors) that adversely affect Barking Owl nest success is worthy of investigation. However, this effect could equally act in Yarindury State Forest as could nest predation from Common Brushtail Possums.

Toxic elements in the unoccupied forest are higher than in occupied areas. As the surrounding land use is almost entirely intensive cropping and the cropping industry has a long history of pesticide use (Popov 2005), pesticide levels in the potential prey of Barking Owls would be worth investigating. Pesticide residues have been reported to cause health issues for Australian raptors before (Olsen and Olsen 1979, Young and De Lai 1997) and rodenticides continue to be problematic for owls in North America and Europe (Walker *et al.* 2008, Albert *et al.* 2010). Factors supporting this hypothesis are that the Pilliga and Yarindury landscapes support much lower intensities of cropping and therefore, potentially lower rates of pesticide use. Factors against the hypothesis are that other raptors are commonly living and breeding in the area (Kavanagh *et al.* 2010). Diurnal raptors are somewhat more mobile and less tied to territories than Barking Owls (Schedvin 2007). Nankeen Kestrels that breed successfully on the plains may not have spent their entire lives there and been as heavily exposed to pesticides.

Of these hypotheses for the absence of Barking Owls on the Liverpool Plain, the toxic environment seems most worthy of investigation in combination with a thorough owl survey of all remnant vegetation to find any remnant Barking Owl pairs.

Chapter 5
Barking Owl Foraging and Feeding Behaviour

Some radio-tracking data and other observations incorporated in this chapter are jointly owned by Dr. Rod Kavanagh, Dr Todd Soderquist and Matthew Stanton.

5.1 Observations of Barking Owl Foraging

5.1.1 Introduction

Detailed Barking Owl foraging techniques have rarely been reported in the literature. Hodgon (1996) made observations of Barking Owl behaviour, including 21 foraging observations during the breeding season in Cordoba State Forest, south-east Queensland. Almost half of the observations (10) were of short-stay perch hunting. Six observations were of hawking with owls making short flights of up to 15 seconds. A further four records were made of long-stay (>5 minutes) perch hunting, where the owl was clearly remaining "vigilant" for prey. There was one record of the male owl diving into a tree crown, presumably seeking to catch or flush prey.

Shelly (2006) observed Barking Owls in the Macquarie Marshes taking large and small mammal prey from the ground. The owls perched on trees or buildings to observe prey before sallying and pouncing. Fleay (1968) reported an observation by McInnes of a duck (species not reported) being swooped upon immediately after alighting on a dam. The Barking Owl was able to carry the duck to a nearby fence. Fleay also reported cases of captive Barking Owls attacking animals that were erroneously housed with them (Tawny Frogmouth *Podargus strigoides*) or found their own way into the cage (Black Rat, Common Ringtail Possum). Most reports from annotated lists lack detail, for example Hobbs (1961) states "appears to catch a good proportion of its food by hawking insects above the tree-tops in the late summer evenings". Occasionally their behaviour is influenced by people causing prey to become more obvious; for example, they take advantage of prey attracted to street lights (Beruldsen and Uhlenhut 1995). In an Australian context, Barking Owls are remarkable for their daylight activity. Some of this is just opportunistic foraging, unwary animals being pounced upon from the roost while the sun is still above the horizon (summarised in Higgins 1999). Territorial calling also takes place on dull overcast days.

I made direct observations of Barking Owl foraging behaviour while radio-tracking the Pilliga owls and at other times. While the Pilliga Barking Owls are typically shy and cautious during daylight, once night falls, they tend to ignore people as long as the observer does not use lights, keeps a sensible distance and does not make owl calls. Radio-tracking was particularly useful for records when there was no natural light. A passive, analogue night-scope was used for some observations in marginal light. Observations of Barking Owl foraging behaviour are presented in categories below.

5.1.2 Capturing active flying prey (sally/strike or hawking)

This form of foraging is most often observed at dusk or when there is moonlight. The Barking Owl waits on a perch with good amounts of space around for sighting oncoming prey. The following observation was similar to many that I made during the study and supports the conclusions in the literature that hawking is a common foraging method for Barking Owls.

During this observation in December 2003, I was always within 15-50 metres of Rocky, a female Barking Owl that we later tracked with a radio transmitter. At dusk ~20:30, Rocky moved directly from her roost about 15 metres away, into one of the channels of a braided watercourse, which were approximately five metres wide. She assumed an exposed perch over the sandy channel and watched for movement. The evening was warm and there were many beetles and a few moths active from dusk. The beetles were mostly scarabs 25 – 30 mm long and ~1 gram and had noisy direct flight. They were flying through the gap in the forest, created by the channel, mostly between the canopy and half way to the ground (9 – 18 m off the ground). Rocky appeared to hear and watch a beetle approach, waiting until it had flown approximately 8-10 metres past her.

Then she would fly after the beetle, usually taking it in level flight or from slightly below, before it had flown another 10 metres. In pursuit, her first two wing beats were clearly audible but then became near silent. Once securing the beetle with her foot, she would proceed on to the nearest exposed perch, where the beetle would be torn into at least three pieces and consumed. The beetle was held against the branch, not raised to the bill with the foot. Each beetle took up to three minutes to consume. This was repeated seven times before taking the eighth prey item, a micro-bat. The bat was taken and eaten by the same method, however the bat took even longer to consume and after 25 minutes, when the owl was still picking at it, there was insufficient light for further observation. Eight attacks had resulted in eight prey items.

Four other observations like this were similarly at dusk in summer and autumn. One observation in April 2005 was shortly before dawn and only involved a bat as prey. Three other observations were in bright moonlight in April 2005, November 2006 and October 2007. All observations were in locations without a dense midstorey or in forest gaps, however observations were biased towards such habitat due to accessibility.

An owl with a territory encompassing an elongated natural waterhole used a variation on this that was effective on moonless nights. The male owl would occasionally sit close to the water. On one occasion, the owl was located by radio triangulation to be sitting approximately two metres above one end of the waterhole on the canes of *Callistemon rigidus*, a tall shrub that surrounded the waterhole. The owl was there for at least ten minutes when the light splashing sound of a bat drinking came from about 15 metres up the waterhole. The owl immediately and noisily powered from its perch. Nothing more was seen or heard for a few minutes, until the owl was relocated by triangulation. He was perched high in a red gum about 40 metres from the original perch. In silhouette, it could be seen dismembering the bat. It is unknown if the owl was using visual cues to aid hunting or if it was relying on sound and the constricted flight-path along the waterhole to aid its ambush.

5.1.3 Capturing White-throated Needletails *Hirundapus caudacutus* at roost

During December 2003 I observed a Barking Owl capturing a White-throated Needletail. Needletails appear to roost singly or in loose aggregations in the Pilliga on a regular basis over summer in a similar fashion reported by Tarburton (1993). On this occasion a male Barking Owl living in a West Pilliga forest edge territory (Taylors Road), had been roosting in a remnant vegetation strip, just outside the state forest. At dusk, he called and proceeded to make short flights (~20 metres) back towards the forest. As he reached the forest edge, a needletail made a low pass past the Barking Owl and swooped up into an outer branch of a large Narrow-leafed Ironbark *Eucalyptus crebra.* Immediately the Barking Owl flew from midstorey height, about 30 metres to the vertical branch in the overstorey on which the needletail had alighted. The needletail did not attempt to fly. The Barking Owl captured it and alighted with its prey on the nearest horizontal branch, a couple of metres below. The owl remained for over 40 minutes on the same perch eating its prey. The following morning there was a series of tail feathers and the outermost portion of one wing on the ground under the perch.

On two other occasions in West Pilliga, I observed similar behaviour; both involving males flying directly from their daytime roost to take needletails that had come to roost near the top of mid-sized White Cypress Pines *Callitris glaucophylla.* In each case, the owl struck the needletail from below, less than 30 seconds after it had come to roost.

Undoubtedly the method of hunting described above is used for other diurnal birds going to their roost and the habit of some birds such as robins and fantails to call from their roost could attract the attention of Barking Owls.

5.1.4 Flushing prey (flush/strike)

During radio-tracking, Barking Owls were found to spend extended periods making short movements between perches, with short stays, within a small area of forest (one to ten hectares). Often this was done in areas of dense tree regrowth or shrubbery. Usually each flight was shorter than 20 metres and the stay at each perch was less than a minute.

When the observer was close enough, the owls could be heard landing and departing from the branches. Of our nocturnal radio-tracking records away from nests and roosts, 31% included observations of this behaviour. Because it was associated with denser vegetation and usually on dark nights, direct observations were difficult to make. However, sometimes the radio signals and audible cues gave a satisfactory picture of what was happening. In one instance, I observed a male owl that had been in open box woodland during twilight. He had no obvious success hunting in the woodland. After twilight had finished, he flew directly to a patch of younger trees with ironbark, cypress, acacia and Wilga. The short hop, short stay movement pattern followed for 20 minutes in an area smaller than two hectares. Frequently I heard the owl land or break small branches. The last short hop was shorter than 50 metres from me and resulted in a noisy explosion of Galahs from a communal roost site in the tree the owl had landed in. The owl then sat, possibly on the ground, in another spot around 70 metres away for about four minutes before proceeding to make short flights of between 100 and 150 metres in a direct line back to its roost/nest area. I positioned myself in its path and the radio receiver indicated that it flew directly over me, but it was so dark I failed to see it. The following morning the roost area was littered with Galah flight feathers, confirming the kill.

This method of flush/strike was also used during times of insect abundance. The same male owl and a partner used it to capture cicadas (HEMIPTERA:Cicadidae) from an enormous *Angophora floribunda* (24 metres high, crown 40 metres diameter). On this occasion, there was sufficient light to observe the technique. The owls would fly onto an outer branch, landing with sufficient force to shake the foliage. Usually this would result in one or more cicadas taking flight. The owl would take a single cicada on the wing and return to the tree to feed. Some parts, particularly the wings, were dropped during consumption. The pair of owls roosted in the same tree the following day and were feeding there again at least for the early portion of the following night. No pellets could be found from these birds at this time.

This foraging method is most similar to the "short stay perch hunting" combined with the "dive" described by Hodgon (1996).

5.1.5 Prey detection by call

The Sugar Glider *Petaurus brevicepes* was a common prey item of some of the Pilliga Barking Owls in some seasons. One instance of Sugar Glider predation was recorded. Soon after twilight during a moonless winter evening, a female owl with an elongated home range flew to one end of it. Arriving by car to the area triangulated as her destination, I exited the car and found a strong radio signal. After a minute, I had confirmed that she had stopped her rapid movement and I firmly closed the car door. A Sugar Glider started yapping, probably an alarm call precipitated by the noise of the car and car door (Van Dyke and Strahan 2008). After about five yaps, there was the noise of breaking twigs near the glider and the yapping ceased. The radio signal from the owl now came from the direction of the glider and there it stayed for at least the next half an hour. During this time, two other Sugar Gliders started yapping and moved in towards the owl, probably to within one tree. The patch of forest was too thick to make out any silhouettes, even though the owl signal was triangulated to be closer than twenty metres into the forest. There was insufficient light for the night-scope to be effective. Pellets collected from below this owl later in the week proved to have Sugar Glider remains. This was an example of a Barking Owl using audible cues to target its attack. The role that sight played in the final stage of the attack is unclear, but it was dark enough that vision would have been limited, even for owls. Barking Owls frequently show that they are prepared to take risks by flying through dense vegetation in the dark. The crashing of light branches is commonly heard when radio-tracking Barking Owls at night.

5.1.6 Ambush/pounce on ground animals

I did not witness terrestrial animal predation in the Pilliga. However, some mainly terrestrial prey items (quail, mice, dunnart, cockroaches, some beetles) were taken and large periods of nocturnal radio-tracking observations when the owl was stationary may have been associated with terrestrial foraging combined with aerial prey observation. Three owls were found to sit on low perches in open areas during May, July and August. Three observations were of one owl in an area of low sparse heath with scattered cypress and two observations of the other two owls were in recently logged areas that had a similar structure. In each case, the Barking Owl perched at a height of 1.5 metres on a low dead branch of a cypress. The owl sat close to the trunk. From this height, the owl would have had a good view of the air space at canopy height, allowing detection of bats, insects or nocturnal birds against the stars. It would also have allowed accurate location by sound of any terrestrial prey item in close proximity to the perch. Alternatively, the owls just chose to sit in low open positions while resting.

5.2 Diurnal Prey Holding Behaviour

Schoenjahn *et al.* (2008) gave an account of Barking Owls holding prey at diurnal roosts. Published and new records are presented in Table 5.1. Holding prey items during the day is behaviour only known for the three large *Ninox* owls (Pavey 2008). Other owl species, large and particularly small, are known to cache prey, hiding it in tree hollows or vegetation, hanging it in tree forks or storing it at the nest (e.g. Korpimaki 1987, Taylor 1994, Marti 2009). Of the three *Ninox* to exhibit diurnal prey holding behaviour, Barking Owls are probably the least reported (Higgins 1999, Hollands 2008, Schoenjahn *et al.* 2008). Of the Pilliga radio-tracked owl records at their roost, only 1.3% of owls were holding prey, so it appears to be a rare behaviour for Barking Owls. Pavey (2008) observed that 13.3% of roost records for Powerful Owl *Ninox strenua* involved prey holding, however, the majority of his records were during nesting. Pavey associated the behaviour with another unique feature of the three largest *Ninox* owls; their normal (or non-reversed) sexual dimorphism. As the Powerful Owl most commonly holds prey during nesting in winter, the male is usually holding the prey while waiting to feed the female at dusk. In the case of the Barking Owl, prey items are also most commonly held during the day in winter but for barking owls, this is the pre-breeding season and the prey has most often been held by the female (Table 5.1). During the pre-breeding season, paired Barking Owls usually roost near their future nest hollow and the majority of their interactions are in that area. Males bring food items to share, possibly as a demonstration of their provisioning ability (see 5.1.3) and this seems a likely reason that the female is left holding the prey remains. Improving the condition of both partners before breeding may be essential to successful egg production and chick raising as reported for Barn, Tawny and Little Owls by van den Burg (2009).

In most instances of prey holding, the owls have visibly bulging gizzards, indicating that the prey is being held because they are unable to eat any more. This is particularly obvious in the photograph by Kavanagh (Schoenjahn *et al.* 2008) and reproduced in Figure 5.2a.

In the Pilliga, the sex of the owls has been established by sighting leg bands or backpack transmitters, which enabled identification of the individual or of the owl's partner. Banded individuals were sexed genetically and behaviourally (Stanton, Kavanagh and Hogan, unpublished data).

During the Pilliga study, males have not been seen holding prey during nesting, although it seems that this does happen in some areas (e.g. Barnard 1911, Barnes *et al.* 2005, Schoenjahn *et al.* 2008) with three records in September, which were likely to be males attending to females in the nest hollow. Those records all involve small to medium sized birds as prey (20 – 130 grams).

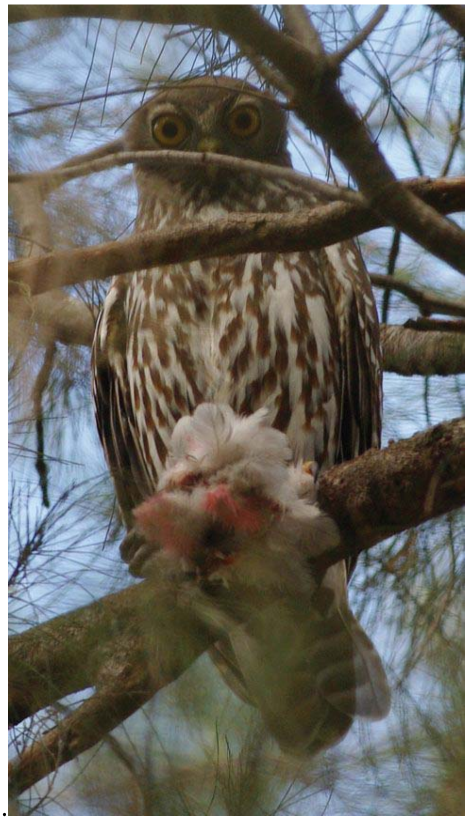
Some of the records clearly involve daytime predation events. The winter record of Heathcote (1933) was one occasion when the owl was observed subduing and then slowly consuming a starling (~80 grams) for over three hours leading into dusk. Some other observers also had the impression that the prey was freshly caught or being consumed, but gave no details.

The majority of other records were from winter and involved large prey items particularly large birds. The Tawny Frogmouth was the most commonly encountered species. In the instances that I have observed Tawny Frogmouths being held, the head had been removed and at least one wing was still intact and left hanging, fully extended. The magpie had also had the head and upper body removed. The Galah had a part of the lower body and at least one leg remaining. On all five of these instances, the male was roosting within sight of the female. All three large bird species are commonly predated by Barking Owls in the Pilliga and other places (Chapter 3). The odd bird out was the Australian Owlet-nightjar, being much smaller and almost whole. On this occasion, the female was almost two kilometres from her normal roost and her mate was not with her.

Large prey items are probably most commonly observed because the owls cannot eat the whole item in one night. I predict that other large birds and mammals, greater than 300 grams will be observed being held at diurnal roosts.

Figure 5.2 Barking Owls holding prey at diurnal roosts. (a) Rabbit, photo by R.P. Kavanagh. (b) Galah. (c) Australian Magpie, photos by the author.

a.


b.


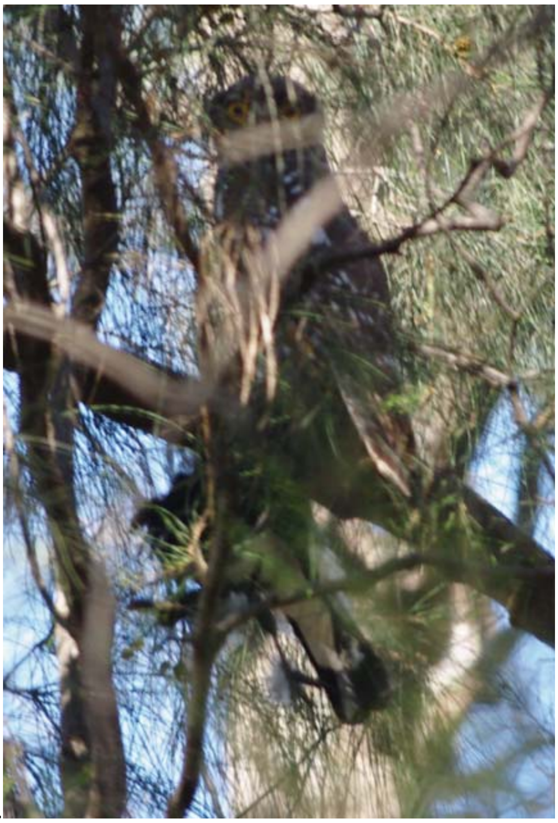
c.


Table 5.1 Prey items held at roost by Barking Owls. Published and new records by date.

Location/ State	Date Month Year	Prey Item	~Live weight (grams)	Owl sex	Observer	Publication
Brisbane Qld.	Aug 1903	Laughing Kookaburra *Daecelo gigas*	330	Unkn.	Anon	Emu 1903
Cape York Qld.	Sep 1910	Superb Fruit-dove *Ptilinopus superbus*	130	Prob. Male	Barnard, C.A.	Barnard 1911
Unknown Qld.	<1912	Tawny Frogmouth *Podargus strigoides*	350	Unkn.	Barnard, C.A. Barnard, H.G.	in North 1912 in Innes 1931
Bundaberg Qld.	May 1930	Tawny Frogmouth *Podargus strigoides*	350	Unkn.	Innes	Innes 1931
Glenroy Vic.	May 1933	Common Starling *Sturnus vulgaris*	80	Unkn.	Heathcote	Heathcote 1933
Violet Town Vic.	<1934	Australian Magpie *Cracticus tibicen*	300	Unkn.	Fleay	Fleay 1933
Urana NSW	~1967	Magpie Lark *Grallina cyanoleuca*	85	Unkn.	Debus	Kavanagh *et al.* 1995
Chiltern Park Vic.	Unkn.	Grebe Podicipedidae	>100	Unkn.	McNabb	Schoenjahn *et al.* 2008
Bundaberg Qld.	Sep 2003	Nestling bird	>20	Prob. Male	Barnes	Barnes *et al.* 2005
Pilliga NSW	Jun 2004	Australian Owlet-nightjar *Aegotheles cristatus*	44	Fem.	Stanton	Schoenjahn *et al.* 2008
Pilliga NSW	Jul 2004	Tawny Frogmouth *Podargus strigoides*	350	Fem.	Kavanagh, Stanton	Schoenjahn *et al.* 2008
Pilliga NSW	Jul 2004	Tawny Frogmouth *Podargus strigoides*	350	Fem.	Kavanagh, Stanton	Schoenjahn *et al.* 2008
Pilliga NSW	May 2005	Tawny Frogmouth *Podargus strigoides*	350	Fem.	Stanton	Schoenjahn *et al.* 2008
Townsville Qld.	Aug 2004	Common Myna *Sturnus tristis*	130	Unkn.	Roberts	Roberts 2005
Kimberley WA	Sep 2006	Pied Butcherbird *Cracticus nigrogularis*	120	Prob. Male	Schoenjahn, Weber	Schoenjahn *et al.* 2008
Yarindury SF NSW	Feb 2007	Prob. Brushtail Possum *Trichosurus vulpecula*	>1000	Unkn.	Stanton	Schoenjahn *et al.* 2008
Pilliga NSW	Jul 2007	Rabbit *Oryctolagus cuniculus*	800	Prob. Fem.	Kavanagh	Schoenjahn *et al.* 2008
Pilliga NSW	Aug 2009	Galah *Eolophus roseicapillus*	310	Fem.	Stanton	This study
Pilliga NSW	Jun 2010	Australian Magpie *Cracticus tibicen*	300	Fem.	Stanton	This study

5.3 Food Debris Around Nest Trees

Food debris is often used as a measure of prey items for large raptors taking large prey. For example, studies of the diet of Wedge-tailed Eagles often use food debris around nests as the eagles have long nesting periods when samples can be collected (e.g. Debus *et al.* 2007). Prey debris can also be combined with pellet and other data to determine the minimum prey item count (e.g. Kavanagh 2002a, Olsen *et al.* 2006). In this study, the different data types have been kept separate because there were strong biases evident in the food debris data. Food debris can only be reliably collected when prey items are being shared at a regular meeting point. With Barking Owls that point is the nest during nesting or a larger area around the nest in the winter pre-breeding period. Table 5.2 presents the food debris items found during the first few breeding seasons of this study. After 2005, food debris was noted but not consistently quantified and no new species were added.

The most obvious feature of the species list is that the majority of prey items are birds, particularly larger birds. This was partially matched by the data collected from regurgitated pellets and faecal samples. It may also be indicative of inedible biomass. The majority of bird prey debris items found were of greater individual mass than all the commonly consumed mammals and invertebrates. However there were also many small bird feathers found, indicating that Barking Owls reject flight feathers from all sizes of bird. Some feathers like the stiff and sharp flight feathers of the White-throated Needletail would be difficult to swallow. The majority of hard bird parts found were bones or bills longer than 60 mm. Some difficult to hold parts such as the owlet-nightjar skull may have been dropped by accident.

Most prey species detected by food debris were also found in the regurgitated pellets, although not always for the same territory or sample period. Food debris helped when identifying some prey items in the pellets. The pellets presented a much more consistent and quantitative dataset than food debris. Those data are presented in Chapter 3.

Table 5.2 Food debris collected from nest and roost areas of Barking Owls in the Pilliga. N is the number of samples found before December 2005.

Common Name	Species	Material found	N	~Mass
Stubble Quail	*Coturnix pectoralis*	Feathers	3	100
Common Bronzewing	*Phaps chalcoptera*	Feathers	2	330
Crested Pigeon	*Ocyphaps lophotes*	Feathers	2	200
Peaceful Dove	*Geopelia striata*	Feathers	1	50
Bar-shouldered Dove	*Geopelia humeralis*	Feathers	1	130
Tawny Frogmouth	*Podargus strigoides*	Feathers, bill, bones	11	350
Spotted Nightjar	*Eurostopodus argus*	Feathers	1	100
Australian Owlet-nightjar	*Aegotheles cristatus*	Feathers, skull	2	44
White-throated Needletail	*Hirundapus caudacutus*	Feathers	9	115
Galah	*Eolophus roseicapillus*	Feathers, bones	4	310
Sulphur-crested Cockatoo	*Cacatua galerita*	Feathers, wing	2	(400) 800
Australian King-Parrot	*Alisterus scapularis*	Feathers, bill	1	230
Eastern Rosella	*Platycercus eximius*	Feathers	2	105
Australian Ringneck	*Barnardius zonarius*	Feathers	1	140
Red-rumped Parrot	*Psephotus haematonotus*	Feathers	5	61
Laughing Kookaburra	*Dacelo novaeguineae*	Feathers, bill	1	330
Western Gerygone	*Gerygone fusca*	Feathers	1	6
Noisy Miner	*Manorina melanocephala*	Feathers	1	60
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*	Feathers	1	45
Noisy Friarbird	*Philemon corniculatus*	Leg and foot	1	100
Grey-crowned Babbler	*Pomatostomus temporalis*	Feathers	1	65
Rufous Whistler	*Pachycephala rufiventris*	Feathers	1	25
Grey Shrike-thrush	*Colluricincla harmonica*	Feathers	1	64
White-browed Woodswallow	*Artamus superciliosus*	Feathers	1	35
Pied Butcherbird	*Cracticus nigrogularis*	Feathers	1	120
Australian Magpie	*Cracticus tibicen*	Feathers, bones	3	300
Pied Currawong	*Strepera graculina*	Feathers, bones, skull, bill	3	300
Willie Wagtail	*Rhipidura leucophrys*	Feathers	2	20
Australian Raven	*Corvus coronoides*	Feathers	1	(400) 650
Magpie-lark	*Grallina cyanoleuca*	Feathers	5	85
Apostlebird	*Struthidea cinerea*	Tail	1	135
White-winged Chough	*Corcorax melanorhamphos*	Feathers, long bones	3	360
Eastern Yellow Robin	*Eopsaltria australis*	Feathers	3	20
Bat (unknown)	Microchiroptera	Hair	1	
Common Dunnart	*Sminthopsis murina*	Hair	1	
Wood Moth	Cossidae *Endoyxla sp.*	Wings	3	15
Emperor Moth	Saturniidae	Wings	1	8
Swift Moth	Hepialidae	Wings	1	10
Goliath Stick Insect	*Eurycnema goliath*	Leg sections	2	15

Chapter 6
Conclusions and Management Implications

6.1 The Prey of the Pilliga Barking Owls

6.1.1 Consumed prey

Prey of the Pilliga Barking Owls were diverse with at least 21 species of mammal and 67 species of bird found in the diet during this study. It seems probable that all mammals under ~1 kg and birds smaller than a Sulphur-crested Cockatoo were vulnerable to Barking Owl predation if they were active at night or roosting in accessible positions. A wide range of insects over 0.3 grams were taken by Barking Owls. The importance of insects in the diet is difficult to quantify given the difference in volume estimates by different methods. There is no doubt that insects were of seasonal importance and occupy a large proportion of foraging effort. Insect consumption was greater than indicated by prey measures of regurgitated pellets. Insects may be less important than indicated by faecal samples.

Diet varied by season, with birds taken most often during spring breeding, Sugar Gliders being important in the winter pre-breeding season and bats being an important component in autumn. Insects were particularly important in summer and autumn.

The major spatial variation in Barking Owl diet was between forest edge and forest core territories. Sugar Gliders were most important for owls living in forest core territories while birds dominated the diet of owls living in forest edge territories. Insects were taken as a regular feature in the diet of all Barking Owls.

6.1.2 Prey compared with other studies

The balance of prey groups eaten in the Pilliga is subtly different from other studies. This study revealed a higher proportion of small birds than others and a greater number and variety of micro-bats. The two studies most similar to this one are the Barking Owls from Cordoba State Forest Queensland (Barnes *et al.* 2005) and the Armidale region of

NSW (Kavanagh *et al.* 1995, Debus 1997, Debus *et al.* 1998, Debus 2001, Debus *et al.* 1999, 2005). Coincidentally these areas had the largest sample sizes of the other studies. Notably different from some other studies was the importance of terrestrial mammals, particularly the exotic European Rabbit *Oryctolagus cuniculus* (Calaby 1951, Robinson 1994, Kavanagh *et al.* 1995, Taylor *et al.* 2002b), *Rattus* species (Kavanagh *et al.* 1995) and the House Mouse *Mus musculus*, which played a minor role in the Pilliga. Rabbits and House Mice were consumed more commonly in Yarindury State Forest (this study) with the trade-off of fewer micro-bats.

One new prey group was revealed in the Barking Owl diet in this study: Frogs. The extent of use of frogs during wet periods when they are available is yet to be seen.

6.1.3 Available prey

Prey were selected by the Pilliga Barking Owls based on manageability and detectability. Nocturnally active prey, with the possible exception of the Australian Owlet-nightjar, was taken in preference to diurnally active prey. Observations of Barking Owl hunting methods support this, with owls continuing to hunt the most obvious prey and resorting to active searching and flushing if this failed. Some prey items were taken in greater quantities than their measured abundance would suggest; notably a large micro-bat, the Yellow-bellied Sheathtailed Bat *Saccolaimus flaviventris* and the Tawny Frogmouth *Podargus strigoidies*.

The Koala *Phascolarctos cinereus* was unrecorded in the diet despite being common in the Pilliga Forests (Kavanagh *et al.* 2007a). Presumably, independent Koalas were too large to prey upon. There was a lower size limit on insects taken, with beetles down to approximately 11 mm being the smallest prey confirmed.

6.2 Pilliga – The Best of the Rest

Land in Southern Australia has typically been allocated to highest value uses first and perceived lowest value uses (such as conservation) last. As a result, land of value for cities, mineral exploitation and agriculture has largely been excluded from conservation uses and as a result, particular landforms and vegetation types that occupied those lands are now under represented in conservation reserves (Margules and Pressey 2000). In particular, the most productive land has been used for agriculture, which has resulted in the destruction of many of the richest wooded habitats. The story of the Pilliga forests follows the same pattern. The partial occupation of the Pilliga (and other forests) by Barking Owls is because the forest grows on the edge of acceptably productive land. The further one pushes into the Pilliga Sandstone hills and away from the outwash plain of alluvium, the lower the productivity becomes. The lower the productivity, the lower the landscapes capacity to support a higher order carnivore. The fact that the Pilliga forests still grow on a poorer section of the alluvium is a quirk of history, the result of the area being valued more for its trees than its grass growing potential at a time when protection of forests became available (van Kempen 1997). Watson (2011) argues that over clearing on fertile soils and overgrazing of the remaining native vegetation has lowered soil productivity. As a direct result, woodland birds have declined. Ford (2011) agrees that there is evidence for a decline in the food of woodland birds compounding the clearing, degradation and fragmentation of the remaining woodlands. Long-term drought appears to have been a factor in some species recent declines (MacNally *et al.* 2009). Barking Owls appeared to have adapted to the first wave of change to the landscape brought by European settlement, remaining widespread (e.g. Calaby 1951, Fleay 1968). However, the landscape remained in flux after those changes and recent evidence indicated that Barking Owls are in retreat (Debus 1997, 2001, Taylor *et al.* 2002a, Parker *et al.* 2007, McGregor *in press*). Land converted for agriculture has not remained consistently productive for Barking Owls. Without the stabilising influence of trees, a moderating/diversifying factor, there has been little protection against drought, flood and disease.

The Pilliga home of the Barking Owl is a forest set between two edges. On one edge is the lower productivity, fire scarred environment of the Pilliga Sandstone hills. Low productivity sandstone regions are typical of much of the conservation estate in Australia (and the rest of the world). The adversity of these environments breeds diversity but not abundance (e.g. Ch 3 of Flannery 1994). On the other edge is the barrier of land converted to cropping and grazing. Other Barking Owl populations occur in similar localities (Kavanagh *et al.* 1995, Debus 1997, 2001, Taylor *et al.* 2002a, b), usually a few pairs clinging to the edge of a forest patch. Those Barking Owl habitats lack the scale of the Pilliga forests. Size gives the Pilliga owls a buffer. Areas can easily be recolonised after disturbance or disasters that affect their prey, because those events are unlikely to affect the whole population. In lieu of high quality habitat that would allow Barking Owls to occur at higher densities, the Pilliga is currently the best they have available.

6.3 Management

6.3.1 Increasing the density and distribution of Barking Owls

As the largest known population of Barking Owls in Southern Australia, the Pilliga forests may have an important role to play in conserving and recovering the species. Schedvin (2007) has reported Barking Owl home range sizes in the Chiltern forests that are smaller than those measured in the Pilliga (Kavanagh, Stanton and Soderquist unpublished data), indicating that higher densities should be possible. From the data presented in this study, it appears that prey volumes are restricting Barking Owl distribution. Means of increasing the density of prey items, particularly nocturnal species should be investigated. The Sugar Glider was an important prey item, constituting around one quarter of prey biomass during this study. One site was found that supported higher densities of Sugar Gliders. That site had been burnt by wildfire resulting in dense 12-year-old regrowth of acacia, other shrubs and small trees. The productivity of such disturbed sites needs to be examined further, combined with the suitability of the vegetation structure for Barking Owl foraging methods. Logging operations also occasionally lead to similar vegetation structure and the productivity of those sites needs to be assessed.

Feral herbivores are currently abundant in much of the Pilliga forests. These include goats, horses and pigs, all species that contribute nothing toward Barking Owl prey. Control of those herbivores may permit the vegetation productivity to be utilised by herbivores in the Barking Owl prey size range. Most such vertebrate species are locally extinct (Short 1998, Paull and Date 1999) and would be threatened by fox predation if they were re-introduced.

Hollows are critical for Barking Owls and many of their prey species. The preservation and recruitment of hollow trees is critical for the sustainment of Barking Owl populations.

Pilliga Barking Owls may be an isolated population (Soderquist 2009). Revegetation of the surrounding agricultural land would help make new Barking Owl habitat and help break the isolation. This would be reliant on conservation or forest agencies prioritising acquisition of productive land and being committed to revegetation. Studies of Barking Owl dispersal capacity are required.

6.3.2 Managing Barking Owl predation of threatened species

Pilliga is also an important habitat for other threatened species. Only one of those was found to be predated to a significantly higher level than normal for its prey group. That was the Yellow-bellied Sheathtail Bat, a widespread species. Further research on this species to establish its population size and importance in Pilliga is recommended. Most other threatened species in the Barking Owl diet are hollow utilising and would benefit from the recommendation to maximise hollow retention and recruitment.

The alternative approach to Barking Owl conservation is to improve outcomes at critical points in their life cycle. An obvious point to apply management is to protect nests from predation by Lace Monitors *Varanus varius*. This would be possible by placing climbing barriers around known nest trees to prevent Lace Monitors from accessing nest hollows. Fledging success could be increased by this method. Additional Barking Owls without additional food resources could be disastrous for both owls and prey, including those species already threatened. Any intervention that will only benefit barking owls will require careful monitoring and should be used only as a last resort.

Targeted Barking Owl territory pellet analysis would be a relatively efficient method of monitoring Eastern Pygmy Possum and the scheduled bat species; in a similar way that McDonald (2010) showed in the wet tropics of Queensland.

6.3.3 Transferring the Pilliga example to declining populations.

This study informs managers of the baseline diet requirements to sustain a Barking Owl population. If a population was not able to access the same volume, and quality of food as the most productive parts of the Pilliga provided during this study, then that would be a likely reason for the population to decline. However, if the amount of available food is similar or greater than the Pilliga provided, then the reason for the population decline must lie elsewhere. Other sources of decline could be nest predation, poisoning from agricultural chemicals or other toxic pollutants, high adult mortality from hunting, accidental collisions, predation and genetic problems related to inbreeding and loss of genetic fitness. Alternatively, the population may have been pushed to local extinction by the same factors affecting all woodland birds through Southern Australia: Loss and degradation of habitat, combined with a final blow such as prolonged drought.

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Appendix 1
Species detected during prey surveys or pellet analysis

Bird species are sorted by taxonomic order (after Christidis and Boles 2008). Mass is the approximate live weight of an average individual of the species from the Pilliga region derived from HANZAB (Marchant *et al.* 1990–2006). Group is the bird groups used for analysis in this study: Woodland dependent, non-woodland dependent or nocturnal (after Kavanagh *et al.* 2007). Birds per hectare gives a value for four groups of bird survey sites used in Chapter 4 of this study: Pilliga sites with Barking Owls detected (n=15), Pilliga sites without Barking Owls detected (n=12), Remnants from the Liverpool Plain without Barking Owls (n=11), Yarindury State Forest with Barking Owls (n=8). The number in pellets is the tally of individual birds for all pellets from the Pilliga (n=1326) and for all pellets from Yarindury State Forest (n=220).

				Birds per hectare				No. in pellets	
Common Name	**Scientific Name**	Mass grams	Group	With owls	No owls	Liv. Plain	Yarin dury	Pilliga	Yarin dury
Stubble Quail	*Coturnix pectoralis*	100	Non-WL			0		14	3
Rock Dove*	*Columba livia*	300	Non-WL					1	1
Common Bronzewing	*Phaps chalcoptera*	330	Woodland	0.06	0.04	0.07	0.24	9	1
Crested Pigeon	*Ocyphaps lophotes*	200	Non-WL	0.01	0.02	0.47	0.24	5	1
Diamond Dove	*Geopelia cuneata*	35	Non-WL	0	0			1	
Peaceful Dove	*Geopelia striata*	50	Woodland	0.08	0.01	0.06		16	5
Bar-shouldered Dove	*Geopelia humeralis*	130	Woodland	0.04	0.00	0.09		8	
Tawny Frogmouth	*Podargus strigoides*	350	Nocturnal			0.01		17	4
Spotted Nightjar	*Eurostopodus argus*	100	Nocturnal					1	
Australian Owlet-nightjar	*Aegotheles cristatus*	44	Nocturnal	0.05	0	0.01	0	5	
White-throated Needletail	*Hirundapus caudacutus*	115	Non-WL	0.06	0		0	25	1
Painted Button-quail	*Turnix varius*	92	Woodland					3	1
Little Button-quail	*Turnix velox*	45	Non-WL	0	0.01			1	
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	450	Woodland	0	0.02			1	
Galah	*Eolophus roseicapillus*	310	Non-WL	0.39	0.00	1.06	0.72	15	1
Sulphur-crested Cockatoo	*Cacatua galerita*	800	Non-WL	0.11	0	0.58		6	3
Cockatiel	*Nymphicus hollandicus*	87	Non-WL	0.01	0	0.02		1	
Musk Lorikeet	*Glossopsitta concinna*	75	Woodland			0.48			
Little Lorikeet	*Glossopsitta pusilla*	39	Woodland	0.06	0.14	0.14			
Australian King-Parrot	*Alisterus scapularis*	230	Woodland	0.04	0.10	0.19		2	
Red-winged Parrot	*Aprosmictus erythropterus*	160	Woodland	0	0.01	0.06			
Crimson Rosella	*Platycercus elegans*	140	Woodland	0.04	0.01			1	1

Common Name	Scientific Name	Mass grams	Group	Birds per hectare				No. in pellets	
				With owls	No owls	Liv. Plain	Yarin dury	Pilliga	Yarin dury
Eastern Rosella	*Platycercus eximius*	105	Non-WL	0.05	0.04	1.36	0.56	8	1
Australian Ringneck	*Barnardius zonarius*	140	Non-WL	0.22	0.02		0.08	18	1
Blue Bonnet	*Northiella haematogaster*	80	Non-WL					4	1
Red-rumped Parrot	*Psephotus haematonotus*	61	Non-WL			0.09	0	57	10
Budgerigar	*Melopsittacus undulatus*	26	Non-WL					1	
Turquoise Parrot	*Neophema pulchella*	41	Woodland	0.01	0.07			28	2
Horsfield's Bronze-Cuckoo	*Chalcites basalis*	23	Woodland	0.09	0.03	0.07			
Shining Bronze-Cuckoo	*Chalcites lucidus*	24	Woodland	0.10	0.04	0.03			
Pallid Cuckoo	*Cacomantis pallidus*	88	Non-WL	0.01	0.04				
Fan-tailed Cuckoo	*Cacomantis flabelliformis*	50	Woodland			0.05			
Laughing Kookaburra	*Dacelo novaeguineae*	330	Woodland	0.02	0.01	0.10	0	4	1
Red-backed Kingfisher	*Todiramphus pyrrhopygius*	52	Non-WL	0	0.02				
Sacred Kingfisher	*Todiramphus sanctus*	40	Woodland	0.13	0.05	0.01	0.08	1	
Rainbow Bee-eater	*Merops ornatus*	28	Non-WL	0.11	0.02		0.08	1	
Dollarbird	*Eurystomus orientalis*	130	Woodland	0	0.01	0.04	0		
White-throated Treecreeper	*Cormobates leucophaea*	23	Woodland	1.00	0.63	0.37	0.64		
Brown Treecreeper	*Climacteris picumnus*	32	Woodland	0.11	0.04	0.09	0.24		
Spotted Bowerbird	*Ptilonorhynchus maculatus*	140	Woodland	0	0			1	
Superb Fairy-wren	*Malurus cyaneus*	10	Non-WL	0.23	0.13	0.63	0.16	3	1
Variegated Fairy-wren	*Malurus lamberti*	8	Woodland	0.00	0.09			1	
Chestnut-rumped Heathwren	*Hylacola pyrrhopygia*	17	Non-WL	0.00	0.02				
Speckled Warbler	*Chthonicola sagittata*	14	Woodland	0.16	0.21	0.10	0.24		
Weebill	*Smicrornis brevirostris*	6	Woodland	2.05	2.41	3.53	1.91	11	2
Western Gerygone	*Gerygone fusca*	6	Woodland	0.23	0.06	0.20	0.16	9	1
White-throated Gerygone	*Gerygone albogularis*	7	Woodland	0.10	0.09	0.19			
Striated Thornbill	*Acanthiza lineata*	7	Woodland	0.08	0.05	0.12	0.48		
Yellow Thornbill	*Acanthiza nana*	6	Woodland	2.09	0.92	1.91	2.39	4	
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	9	Non-WL	0.07	0.03	0.26	0.08	2	1
Chestnut-rumped Thornbill	*Acanthiza uropygialis*	6	Woodland	0.05	0.02				
Buff-rumped Thornbill	*Acanthiza reguloides*	8	Woodland	0.21	0.46	0.02	0.48		
Inland Thornbill	*Acanthiza apicalis*	7	Woodland	0.29	0.17	0.29	0.32	2	
Spotted Pardalote	*Pardalotus punctatus*	9	Woodland	0.54	0.33	0.46	0.32		
Striated Pardalote	*Pardalotus striatus*	12	Woodland	0.23	0.20	2.18	0.96	3	
Eastern Spinebill	*Acanthorhynchus tenuirostris*	11	Woodland	0.03	0.12	0.01	0		
Yellow-faced Honeyeater	*Lichenostomus chrysops*	17	Woodland	0.35	0.76	0.09	0.40	5	
Singing Honeyeater	*Lichenostomus virescens*	26	Non-WL			0.01			
White-eared Honeyeater	*Lichenostomus leucotis*	23	Woodland	0.36	0.33	0.01	0.08	1	1
Yellow-tufted Honeyeater	*Lichenostomus melanops*	24	Woodland		0				
White-plumed Honeyeater	*Lichenostomus penicillatus*	19	Woodland	0.65	0.12	0.64	0.56	3	
Noisy Miner	*Manorina melanocephala*	60	Woodland	0.06	0.11	2.39	0.96	7	1
Yellow-throated Miner	*Manorina flavigula*	60	Woodland	0					
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*	45	Woodland	0.67	0.27	0.12	0.24	9	1
Red Wattlebird	*Anthochaera carunculata*	110	Woodland			0.01	0.24		

Common Name	Scientific Name	Mass grams	Group	Birds per hectare: With owls	No owls	Liv. Plain	Yarindury	No. in pellets: Pilliga	Yarindury
Crimson Chat	*Epthianura tricolor*	11	Non-WL	0	0.20				
Scarlet Honeyeater	*Myzomela sanguinolenta*	8	Woodland			0.01			
Brown Honeyeater	*Lichmera indistincta*	12	Non-WL	0.01	0	0.03			
Brown-headed Honeyeater	*Melithreptus brevirostris*	14	Woodland	0.59	0.36	0.10	0.88	8	
White-naped Honeyeater	*Melithreptus lunatus*	14	Woodland			0			
Blue-faced Honeyeater	*Entomyzon cyanotis*	100	Woodland	0.03	0				
Noisy Friarbird	*Philemon corniculatus*	100	Woodland	0.37	0.37	0.19	0.32	11	1
Little Friarbird	*Philemon citreogularis*	66	Woodland	0.02	0				
Striped Honeyeater	*Plectorhyncha lanceolata*	38	Woodland	0.29	0.22	0.22	0.96	14	3
Grey-crowned Babbler	*Pomatostomus temporalis*	65	Woodland	0.14	0.08	0.14	0	8	
White-browed Babbler	*Pomatostomus superciliosus*	40	Woodland	0.28	0.02		0		
Spotted Quail-thrush	*Cinclosoma punctatum*	114	Woodland	0.02	0				
Varied Sittella	*Daphoenositta chrysoptera*	13	Woodland	0.30	0.10	0.01	0		
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	115	Non-WL	0.08	0.06	0.13	0.08	10	1
White-bellied Cuckoo-shrike	*Coracina papuensis*	67	Woodland	0.05	0.01	0.01	0		
Cicadabird	*Coracina tenuirostris*	70	Woodland	0.09	0.11		0		
White-winged Triller	*Lalage sueurii*	26	Woodland	0.08	0.15	0.04	0	2	
Crested Shrike-tit	*Falcunculus frontatus*	27	Woodland	0.01	0.02		0.08	1	
Golden Whistler	*Pachycephala pectoralis*	25	Woodland	0.01	0	0.05		1	
Rufous Whistler	*Pachycephala rufiventris*	25	Woodland	2.12	1.54	1.03	1.43	11	1
Grey Shrike-thrush	*Colluricincla harmonica*	64	Woodland	0.81	0.48	0.13	0.32	7	2
Crested Bellbird	*Oreoica gutturalis*	65	Woodland	0.08	0.01				
Olive-backed Oriole	*Oriolus sagittatus*	95	Woodland	0.10	0.04	0.01			
White-breasted Woodswallow	*Artamus leucorynchus*	14	Non-WL	0.03	0				
Masked Woodswallow	*Artamus personatus*	36	Non-WL	0.25	0.52		0	1	
White-browed Woodswallow	*Artamus superciliosus*	35	Non-WL	0.84	1.52			4	
Dusky Woodswallow	*Artamus cyanopterus*	35	Woodland	0.26	0.07	0.04	0		
Grey Butcherbird	*Cracticus torquatus*	90	Woodland	0.20	0.27	0.75	0.40	9	2
Pied Butcherbird	*Cracticus nigrogularis*	120	Non-WL			0.14	0.24	3	
Australian Magpie	*Cracticus tibicen*	300	Non-WL	0.01	0	0.75	0.24	17	3
Pied Currawong	*Strepera graculina*	300	Non-WL	0.09	0.18	0.18	0.48	4	1
Grey Fantail	*Rhipidura albiscapa*	8	Woodland	0.83	0.51	0.57	1.11	4	2
Willie Wagtail	*Rhipidura leucophrys*	20	Non-WL	0.33	0.07	0.39	0.24	10	1
Australian Raven	*Corvus coronoides*	650	Non-WL	0.02	0.01	0.23	0	3	2
Leaden Flycatcher	*Myiagra rubecula*	12	Woodland	0.20	0.09	0.03	0		
Restless Flycatcher	*Myiagra inquieta*	14	Non-WL	0.07	0.02	0.01	0	3	1
Magpie-lark	*Grallina cyanoleuca*	85	Non-WL	0.01	0.01	0.15	0.24	24	3
White-winged Chough	*Corcorax melanorhamphos*	360	Woodland	0.13	0.01	0.38	0.80	22	6
Apostlebird	*Struthidea cinerea*	135	Non-WL			0.09		1	
Jacky Winter	*Microeca fascinans*	16	Woodland	0.14	0.04	0.30	0.16	6	1
Red-capped Robin	*Petroica goodenovii*	9	Woodland	0.23	0.15	0.04	0.16		
Hooded Robin	*Melanodryas cucullata*	22	Woodland			0.01			
Eastern Yellow Robin	*Eopsaltria australis*	20	Woodland	0.68	0.54	0.41	0.80	7	2
Rufous Songlark	*Cincloramphus mathewsi*	30	Non-WL	0.06	0.05		0		

				Birds per hectare				No. in pellets	
Common Name	**Scientific Name**	Mass grams	Group	With owls	No owls	Liv. Plain	Yarindury	Pilliga	Yarindury
Silvereye	*Zosterops lateralis*	13	Woodland	0.09	0.02	0.18	0.08		
White-backed Swallow	*Cheramoeca leucosterna*	14	Non-WL	0.00					
Welcome Swallow	*Hirundo neoxena*	15	Non-WL	0.01	0.01				
Tree Martin	*Petrochelidon nigricans*	16	Woodland			0.09	0		
Common Starling*	*Sturnus vulgaris*	80	Non-WL			0.19			
Mistletoebird	*Dicaeum hirundinaceum*	9	Woodland	0.44	0.21	0.40	0.16	1	
Double-barred Finch	*Taeniopygia bichenovii*	10	Non-WL	0.08	0.02	0.20		12	2
Diamond Firetail	*Stagonopleura guttata*	17	Woodland			0.01	0		
Unidentified birds	Variable mass (mean given)	41						188	51
Mammals				Mammals per hectare					
Yellow-footed Antechinus	*Antechinus flavipes*	40						3	
Common Dunnart	*Sminthopsis murina*	20						4	1
Eastern Pigmy-possum	*Cercartetus nanus*	24						2	
Feathertail Glider	*Acrobates pygmaeus*	15						13	9
Sugar Glider	*Petaurus breviceps*	125						201	10
Squirrel Glider	*Petaurus norfolcensis*	250*						*	
Common Brushtail Possum	*Trichosurus vulpecula*	1000						2	2
Little Red Flying-fox	*Pteropus scapulatus*	450						6	
Yellow-bellied Sheathtail-bat	*Saccolaimus flaviventris*	50						29	
White-striped Mastiff-bat	*Nyctinomus australis*	40						2	
Gould's Wattled Bat	*Chalinolobus gouldii*	14						15	
Chocolate Wattled Bat	*Chalinolobus morio*	7						3	
Little Pied Bat	*Chalinolobus picatus*	7						2	
Lesser Long-eared Bat	*Nyctophilus geoffroyi*	8						6	
Gould's Long-eared Bat	*Nyctophilus gouldi*	12						4	
Greater Long-eared Bat	*Nyctophilus corbeni (timoriensis)*	15						9	
Unknown Long-eared Bat	*Nyctophilus spp.*							2	
Inland Broad-nosed Bat	*Scotorepens balstoni*	8						3	
Little Broad-nosed Bat	*Scotorepens greyii*	6						7	
Little Forest Bat	*Vespadelus vulturnus*	4						108	4
Unknown Bat	Mostly mid-small species							141	7
Pilliga Mouse	*Pseudomys deliculata (pilligaensis)*	12						2	
House Mouse	*Mus domesticus*	14						11	11
Rabbit	*Oryctolagus cuniculus*	800						1	4
Unidentified Mammal	Mostly mixed samples							56	21