Report on Sooty Owls and Powerful Owls for the Supreme Court proceeding number 8547 of 2009 - Environment East Gippsland v VicForests

Rohan Bilney
P.O. Box 988
Bairnsdale
Vic 3875

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I have read and understand the Expert Witness Code of Conduct and agree to be bound by it.

Qualifications

Education

2005-2009	Doctor of Philosophy **Deakin University, Burwood Campus**
2004	Bachelor of Environmental Science (Honours) **Deakin University, Burwood Campus**
2001-2003	Bachelor of Science (Zoology, Ecology and Evolution) **Monash University, Clayton Campus**

Experience with Sooty Owls and Powerful Owls

Since 2003 I have been studying various ecological aspects of both Sooty Owls and Powerful Owls, mainly from the foothill forests of East Gippsland, Victoria (mainly between the Mitchell River and Snowy River, including Cape Conran). This research was undertaken primarily for an Honours project (2004) and PhD (2005-2009) at Deakin University. Ecological aspects investigated on these owl species included diet (prehistoric, geographical, temporal and sexual variation, prey size, in relation to prey availability), roost and nest site characteristics, breeding seasonality and success, home-range and habitat usage (primarily for the Sooty Owl).

PhD Thesis title (2009)

Sooty Owl ecology and recent small mammal decline. (PhD Thesis, Deakin University, Melbourne)

Honours Thesis title (2004)

Dietary change of Sooty Owls (*Tyto tenebricosa*) since European settlement: their response to fox control and dietary overlap with Powerful Owls (*Ninox strenua*) in East Gippsland, Australia. (Honours Thesis. Deakin University, Melbourne)

Publications relevant to Sooty Owls and Powerful Owls

Bilney, R.J., Cooke, R. and White, J. (under review). Reversed sexual dimorphism and altered prey base: the effect on Sooty Owl (*Tyto tenebricosa*) diet. *Austral Ecology*

Bilney, R.J., White, J., L'Hotellier, F.A. and Cooke, R. (under review). Spatial ecology of Sooty Owls in south-eastern Australian coastal forests: implications for forest management and reserve design. *EMU*

Bilney, R.J., Cooke, R. and White, J. (under review). Potential competition between two top-order predators following a dramatic contraction in the diversity of their prey base. *Animal Biology*

Bilney, R.J., Cooke, R. and White, J. (2010). Underestimated and severe; small mammal decline from forests of south-eastern Australia since European settlement, as revealed by a top-order predator. *Biological Conservation* **143**, 52-59

Bilney, R.J., Kavanagh, R.P. and Harris, J.M. (2007) Further observations on the diet of the Sooty Owl *Tyto tenebricosa* in the Royal National Park, Sydney. *Australian Field Ornithology* **24**, 64-69

Bilney, R.J., Cooke, R., and White, J. (2006) Change in the diet of Sooty Owls since European settlement: from terrestrial prey to arboreal prey and increased dietary overlap with Powerful Owls. *Wildlife Research* **33**, 17-24

The species

Sooty Owl (*Tyto tenebricosa tenebricosa*)

The Sooty Owl is mainland Australia's largest member of the family Tytonidae, and one of the largest Tytonidae species in the world (del Hoyo *et al.* 1999). It is a large nocturnal predator that consumes predominantly mammalian species up to 1.5 kg in body weight, which includes a wide-range of arboreal and terrestrial species such as possums, gliders, rodents, bandicoots and antechinus (Kavanagh 1997; Bilney 2009b). Sooty Owls are highly territorial, sedentary, and naturally uncommon, primarily restricted to heavily forested environments (typically taller and wetter forest types) in eastern Australia, ranging from east of Melbourne along the eastern side of the Great Dividing Range to approximately Mackay in Queensland (Higgins 1999).

The Sooty Owl is considered a habitat specialist, and is considered to be amongst the species most closely associated with elements of old-growth forest due to being hollow-dependant (Kavanagh 2002b; Bilney 2009b). Sooty Owls and many of their important prey species require large hollows for nesting and roosting (or denning) in trees (principally Eucalypts) that are typically several hundred years in age (Gibbons and Lindenmayer 2002).

The Sooty Owl also potentially exhibits the greatest degree of reversed sexual dimorphism of any owl species in the world (Mooney 1993; Kruger 2005), with females almost 1.75 times larger than males (Higgins 1999; Hollands 2008). Considerable ecological differences exist between sexes of Sooty Owls, especially regarding diet, roost site selection and home-range size (Bilney 2009b). Females typically have much smaller home-ranges in the short-term (500-1500ha) compared to males (2000-4000ha), capture on average much larger prey than males, and roost predominantly within hollows in trees (and caves where available) and avoid foliage roosting, unlike males (Bilney 2009b).

There are three subspecies of Sooty Owl, *T.t. arfaki* from New Guinea, *T.t. multipunctata* or Lesser Sooty Owl from northern Queensland and *T.t. tenebricosa* from south-eastern Australia (Blakers *et al.* 1984; Higgins 1999; Barrett *et al.* 2003). Both mainland subspecies of Sooty Owl are allopatric and have considerable morphological, biological and ecological differences (Higgins 1999; Hollands 2008), resulting in conflict regarding taxonomic status. They were originally considered conspecific until taxonomic revision in 1980 (Schodde and Mason 1980) where they were classified as distinct species, however, recent genetic studies indicate that they should be reclassified as conspecific (Norman *et al.* 2002; Christidis and Boles 2007).

In the wild, Sooty Owls appear to have low reproductive output with sporadic aseasonal breeding and long chick dependence (Hyem 1979; Kavanagh 1997; Higgins 1999; Hollands 2008; Bilney 2009b). It is common for a Sooty Owl pair to spend several years without breeding (Higgins 1999; Bilney 2009b). No study has ever been able to estimate breeding success of Sooty Owls due to their elusive behaviour and sporadic aseasonal breeding. However, Bilney (2009b) observed low breeding success with many pairs failing to breed over several years, possibly due to a combination of factors including drought, low prey availability and dietary competition with Powerful Owls. The breeding biology of the Sooty Owl and life history attributes are amongst the most poorly understood of any bird species in Australia. There is therefore no accurate data available on fecundity.

Sooty Owls have traditionally been considered to be rare (Garnett 1992) and elusive (Fleay 1968; Debus 1994), and, due to their nocturnal habits, low population densities and large home-ranges in heavily forested habitats, few detailed ecological studies have been conducted (e.g. Kavanagh 1997; Higgins 1999; Bilney 2009b). Little ecological knowledge existed on the Sooty Owl until the early 1990's (Fleay 1968; Hyem 1979; Schodde and Mason 1980; Smith 1984; Beruldsen 1986; Loyn *et al.* 1986), and even today most ecological information is restricted to dietary studies (Smith 1984; Loyn *et al.* 1986; Lundie-Jenkins 1993; Holmes 1994; Kavanagh 1997, 2002a; Bilney *et al.* 2006; Bilney *et al.* 2007) and naturalist observations (Fleay 1968; Hyem 1979; Beruldsen 1986; Chafer and Anderson 1994; Hollands 2008). Only two studies (Kavanagh 1997; Bilney 2009b) have examined a range of ecological data from a large geographical region. Surveys throughout south-eastern Australia using call playback have identified habitat preferences, distribution, population sizes, and the influence of land management and geographical features (e.g. Kavanagh and Bamkin 1995; Kavanagh *et al.* 1995; Loyn *et al.* 2001; Cann *et al.* 2002; McIntyre and Henry 2002).

Powerful Owl (*Ninox strenua*)

The Powerful Owl is Australia's largest and arguably most charismatic owl species (Higgins 1999; DEC 2006; Hollands 2008). It is widely distributed throughout tall forested habitats of south-eastern Australia, ranging from the Victoria-South Australia border, east along the Great Dividing Range to near Mackay in Queensland (Higgins 1999). Despite its large distribution, the Powerful Owl is naturally uncommon due to being a large territorial top-order predator. Pairs are sedentary, strongly territorial and considered to typically mate for life. The Powerful Owl occupies most large contiguous forested patches where arboreal mammals (its principal dietary item) are located in relatively high abundance. The Powerful Owl is therefore considered a habitat generalist specializing in capturing arboreal mammals and birds as prey (Kavanagh 2002a). They are hollow-dependant, requiring a large hollow for breeding, and roost (when females are not in the nest) exclusively within the foliage of trees (Kavanagh 1997; Higgins 1999; Bilney 2009b). Males are larger than females (Pavey 2008).

There are no subspecies of Powerful Owl (Higgins 1999).

Powerful Owls are strictly seasonal breeders, with most laying of eggs in Victoria during early winter or late Autumn (Fleay 1968; McNabb 1996; Higgins 1999; Hollands 2008). Two eggs are typically laid with between 1-2 young raised with an average of 1.3-1.8 typically recorded per successful breeding event (Debus and Chafer 1994; McNabb 1996; Kavanagh 1997; Cooke 2000; Bilney 2009b). Breeding success has been shown to vary considerably geographically, with very low breeding success recorded in central Victoria (21%) (Hollands 1991, 2004), while being higher around Melbourne 72-94% (McNabb 1996; Cooke 2000), and in south-eastern and central NSW 76-82% (Debus and Chafer 1994; Kavanagh 1997). In East Gippsland, however, Bilney (2009b) reported very low breeding success (at 36-44%), possibly due to a combination of factors including drought, low prey availability and dietary competition with Sooty Owls. Powerful Owl pairs appear to hold strong bonds, and attempt to breed each year. Sexual maturity has been recorded in the wild at just under 12 months of age (McNabb *et al.* 2007), however, typically it is considered to be >2 years (Higgins 1999). Despite relatively limited precise data and great uncertainty, a population viability analysis of Powerful Owls indicated that the risk of decline was low in regions where populations were large (>100 pairs), however, more detailed life history information is required to improve this estimate (McCarthy *et al.* 1999). Large stochastic events, such as extensive wildfire, could dramatically alter this model.

The Powerful Owl has long been considered to have been rare and restricted to old-growth habitats, however, recent research has shown that they can also readily occupy fragmented and highly 'disturbed' environments such as within large cities where densities of arboreal mammals are high (Cooke 2000; Kavanagh 2004). Although they can occupy such landscapes, breeding sites are limited potentially resulting in a sink population (Cooke 2000; Isaac *et al.* 2008).

In contrast to the lack of knowledge about the Sooty Owl, the Powerful Owl is perhaps the most well studied owl species in Australia, and has long been of interest to field naturalists and ornithologists (e.g. Fleay 1968; Hyem 1979; Hollands 2008). The majority of published studies, however, have focused on diet, whereas limited data exists regarding habitat use and home-range size. Most studies have also been conducted in areas close to human habitation, in fragmented landscapes on the fringe of their distribution (e.g.(Seebeck 1976; Van Dyck and Gibbons 1980; Chafer 1992; Traill 1993; Pavey *et al.* 1994; Pavey 1995; McNabb 1996; Cooke *et al.* 1997; Wallis *et al.* 1998; Cooke 2000; Cooke *et al.* 2002; Kavanagh 2004; Cooke *et al.* 2006; Hogan 2007; Isaac *et al.* 2008). There have been very few studies conducted in continuous forested landscapes (considerable distance from urbanised landscapes) where their core population exists, primarily between Melbourne and Brisbane (Kavanagh 1997; Bilney 2009b). Surveys using playback throughout south-eastern Australia have identified habitat preferences, distribution, population sizes, and the influence of land management and geographical features (e.g. Kavanagh and Bamkin 1995; Kavanagh *et al.* 1995; Loyn *et al.* 2001; Cann *et al.* 2002; McIntyre and Henry 2002).

Distribution – Victoria

Sooty Owls

The distribution of Sooty Owls is primarily restricted to wetter forest types east of Melbourne, along mountainous regions of the Great Dividing Range, incorporating the Central Highlands, the North-East, and Gippsland (Figure 1). A very small isolated population does exist in south Gippsland (Silveira *et al.* 2003). The main habitat types (Ecological Vegetation Classes or EVCs) that Sooty Owls typically prefer include Wet Forest, Damp Forest, Riparian Forest, Warm Temperate Rainforest and Lowland Forest, however, they can also occupy a range of drier habitat types but typically surround a wetter forest type (Loyn *et al.* 2001; McIntyre and Henry 2002; Bilney 2009b). Their distribution is also closely associated with forests containing elements of old-growth or mixed age/mature/senescent forest (Loyn *et al.* 2001). The probability of Sooty Owls occurring in an area increases with increased diameter of eucalypt trees (older forests) and abundance of dead hollow-bearing trees (Loyn *et al.* 2001).

Powerful Owls

Powerful Owls are distributed from the South Australian/Victoria Border north to approximately the Little Desert National Park across to Echuca, and east along the Great Dividing Range (Figure 1). They are only absent from the north west of the state (Webster *et al.* 1999). Although widely distributed in Victoria, they are forest dependant, and are therefore restricted to large patches of forest. Their populations in western and central Victoria are therefore considerably low due to clearing and forest fragmentation (65% of forest cover in Victoria has been cleared). There is great concern regarding their long-term persistence in these regions, especially considering their extensive home-range sizes, low breeding success and low prey availability in such landscapes (Hollands 1991; McCarthy *et al.* 1999; Webster *et al.* 1999; Hollands 2004). Other issues such as juvenile dispersal in these landscapes are also of great concern, and there is the concern that local extinctions could occur (McCarthy *et al.* 1999; Webster *et al.* 1999; Soderquist and Gibbons 2007; Hollands 2008).

Powerful Owls occupy a wide range of forested habitats in Victoria and are therefore not closely associated with, or avoid, many forest types (Webster *et al.* 1999). They typically occupy regions within close proximity to mixed/mature age forests, box eucalypts and hollow-bearing trees (Loyn *et al.* 1999). In East Gippsland, they are not closely associated with any forest type but rather occupy most forest types, avoiding only heathland and wetlands (McIntyre and Henry 2002).

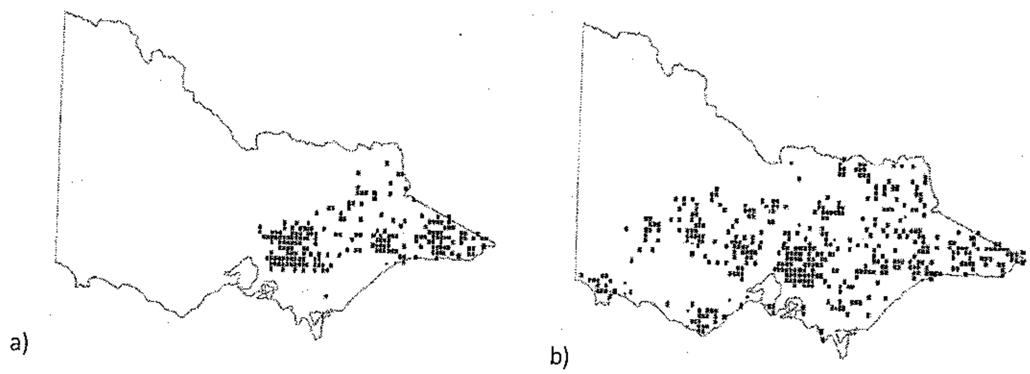

Figure 1. Records (black squares) of Sooty Owls (a) and Powerful Owls (b) in Victoria indicating their distribution (based on Victorian Atlas data from 1998, and sourced from Silveira *et al.* 2003 and Webster *et al.* 1999 respectively).

Question 3c) There are many different survey techniques used to determine the distribution of Sooty Owls and Powerful Owls in Victoria and south-eastern Australia. The most reliable of these is call-playback which has been used extensively throughout south-eastern Australia (e.g. Kavanagh and Peake 1993; Kavanagh and Bamkin 1995; Kavanagh *et al.* 1995; Loyn *et al.* 2001; Cann *et al.* 2002; McIntyre and Henry 2002). As large forest owls are territorial and aggressive they readily respond to pre-recorded calls usually broadcast through a megaphone. It is therefore a very useful and accurate technique for establishing the presence of owls, if conducted by professionals with adequate knowledge of owl calls. Most forested regions of Victoria have been surveyed using this technique, and this data has been submitted to the Victorian Atlas database. Less reliable are records from the general public (especially from sight).

Both Sooty Owls and Powerful Owls have long been considered to be amongst the species most vulnerable to forestry practices (e.g Debus 1994; Debus and Chafer 1994), so it is primarily due to these conservation concerns, surveys have been conducted to determine their distribution, habitat usage and potential population, and less reliably in some circumstances, potential impacts caused by forestry practices (e.g. Kavanagh and Bamkin 1995; Kavanagh *et al.* 1995).

Question 3d) Despite the records displayed in Figure 1 being over 10 years old, the distribution maps still display in my opinion, an accurate representation of the broad regions occupied by both Sooty Owls and Powerful Owls in Victoria, but not all localities where they exist. Further records have been obtained over the past 10 years, but most records fall within the areas already largely described on these maps. Therefore, these maps do not show every locality where the species occur (there should be more black squares), and typically reflect survey bias (e.g. why there are so many records around Melbourne). There are therefore many gaps in the distribution maps which are occupied and should be filled, especially east of Melbourne.

As both Sooty Owls and Powerful Owls are territorial and sedentary, the majority of records shown in Figure 1 should also indicate breeding habitat as well as sites occupied throughout the year. There may however, be the odd record of a dispersing individual in an 'atypical' habitat or region (e.g. Powerful Owls in small isolated forest patches).

Question 3e) These distribution maps show the approximate area where these owls exist. They do not in way indicate how habitat is used, or the densities of populations in an area. Primarily radio-tracking individual birds is required to obtain information on habitat use, while call playback surveys can also indicate broad habitat preferences and population size. Overall, the distribution of these owls is well known and well represented in Figure 1. It would also be worthy to determine the extent of the Sooty Owl population in south Gippsland and whether populations exist in the Otways.

<u>Conservation Status</u>

Question 4 and 5)

Sooty Owl

The Sooty Owl (*T.t. tenebricosa*) is considered of least concern by the IUCN (2008 IUCN Red List of Threatened Species), and although not listed as threatened in Australia under the EPBC Act 1999, it is listed as vulnerable in Victoria (DSE 2007a) and New South Wales (DEC 2006) and rare in Queensland (Olsen 1998). No accurate population estimate has been conducted, with estimates ranging from 2000-7000 pairs for the entire population (Debus 1994). Recent estimates from New South Wales suggest a minimum population of 2000 pairs (DEC 2006) and between 400-900 pairs throughout Victoria (Silveira *et al.* 2003). East Gippsland is considered to contain over 100 pairs (McIntyre and Henry 2002).

Powerful Owl

The Powerful Owl is considered of least concern by the IUCN (2008 IUCN Red List of Threatened Species), and although not listed as threatened in Australia under the EPBC Act 1999, it is listed as vulnerable in Victoria (DSE 2007a) and New South Wales (DEC 2006) and rare in Queensland (Olsen 1998). No accurate population estimate has been conducted, with estimates ranging from 1000-10,000 pairs for the entire population (Debus and Chafer 1994). Recent estimates from New South Wales suggest a minimum population of 2000 pairs (Higgins 1999; DEC 2006) and approximately 500 pairs throughout Victoria (McCarthy *et al.* 1999; Webster *et al.* 1999). East Gippsland is considered to contain over 100 pairs (McIntyre and Henry 2002).

Conservation actions required

As Sooty Owls and Powerful Owls occupy large home-ranges and are naturally uncommon, conservation measures are required across land tenure, because traditional conservation reserves alone (e.g. National Parks) cannot provide sufficient habitat to guarantee their long-term conservation (or cannot maintain a minimum viable population) (Webster *et al.* 1999; Silveira *et al.* 2003; DEC 2006). This therefore requires species specific management to ensure that sufficient habitat exists for at least a minimum viable population. Sooty Owls and Powerful Owls are both considered to be sensitive to forestry practices and are widely distributed throughout commercially viable forests (Kavanagh 1997; McIntyre and Henry 2002; Silveira *et al.* 2003; DEC 2006). A compromise between conflicting management objectives must therefore be met to ensure that deleterious impacts caused by land management practices (such as forestry) on populations of Sooty Owls and Powerful Owls are minimised.

In Victoria in an attempt to cater for conservation concerns, 500 SOMA's (Sooty Owl management areas) and 500 POMA's (Powerful Owl management areas) have been established across their distribution in an attempt to maintain sufficient habitat, primarily by either excluding timber harvesting from particular areas typically 500ha in size (up to 800ha for Powerful Owls in East Gippsland), or modifying timber harvesting within a 1000ha area. Each SOMA or POMA is considered to provide sufficient habitat for a breeding pair of owls. Many SOMA's and POMAs fall within already conserved areas (National Parks), while many fall within state forest in commercially viable forests (79 SOMAs and 68 POMAs in East Gippsland) (DCNR 1995).

Despite a range of potentially threatening processes to these large forest owl species (see section 7), methods to conserve these species throughout south-eastern Australia principally only address concerns regarding forestry operations and the need to secure sufficient habitat. Current conservation measures for both Sooty Owls and Powerful Owls could be vastly improved (e.g. Bilney 2009b).

Question 6) In my opinion, the status (both federally and state) of both Sooty Owls and Powerful Owls is unlikely to change in the foreseeable future. This is primarily because attempts to address conservation concerns have been conducted (via conservation of some habitat) and considered to be sufficient (their effectiveness is however virtually unknown) (e.g. Webster *et al.* 1999; Silveira *et al.* 2003; DEC 2006). However, it is possible with climate change leading to potential increased fire frequency and scale, populations of both owl species could be dramatically affected in the long-term.

Question 7) Threats to owls

There are numerous threats to Sooty Owls and Powerful Owls that exist throughout their distribution. Threatening processes primarily involve actions that impact upon the availability of key resources; especially if they drop below a particular threshold. Overall, the main resource requirements crucial for the conservation of Sooty Owls and Powerful Owls include; 1) large tracts of contiguous forest, 2), hollow-bearing trees and 3) sufficient densities of prey to support breeding. Conservation efforts should therefore focus on maintaining sufficient available resources while mitigating threatening processes (e.g. Bilney 2009b). Many key resources and threats are common between Sooty Owls and Powerful Owls and will therefore be discussed together below.

Clearing and habitat fragmentation

Clearing and habitat fragmentation not only removes potential habitat and resources, but permanently alters the landscape and typically transforms it into an unusable state for Sooty Owls and Powerful Owls (Kavanagh and Stanton 2002; DEC 2006). Limited clearing does still occur in some areas occupied by Sooty Owls and Powerful Owls (DEC 2006), but there is legislation to minimise or prevent clearing (e.g. Native vegetation Act 2003). Whether clearing poses a significant future threat to the overall owl population is unknown, but seems unlikely. Further fragmentation of habitat, and reductions in habitat quality in central and western Victoria could have significant impacts on Powerful Owls persistence in these landscapes.

Logging

Logging impacts upon critical resources required by owls (especially prey densities), in both the short and long-term. Whether logging causes direct mortality to individual owls is, however, unknown. Logging severely depletes the densities of hollow-bearing trees in the landscape which includes the removal of nesting and roosting sites of owls and other hollow-dependant species (Kavanagh 1997; Gibbons and Lindenmayer 2002; Garnett *et al.* 2003), many of which are important prey species for both owl species (e.g. Bilney 2009). In the long-term, clear-fell logging modifies and simplifies vegetation structure and composition, by creating almost single age regrowth forests, often promoting commercially viable eucalypt species to the detriment of numerous eucalypt and understorey species which were on site prior to logging. Logging therefore also disrupts hollow recruitment (Gibbons and Lindenmayer 2002). Regrowth forests provide limited value to Sooty Owls and Powerful Owls, but can be occupied by some prey species that are not hollow-dependant (e.g. Common Ringtail Possums *Pseudocheirus peregrinus*), and the owls can forage within these areas in the long-term (>20 years) (Kavanagh 1997). However, in some regions even 40-50 year old logging regrowth has been shown to be strongly avoided by Sooty Owls, probably due to low prey availability (Bilney 2009b).

Logging wetter forest types can also alter fire dynamics, as logged forests can become more fire prone, burn at increased severity at shorter frequencies, resulting in potential negative ecological consequences (Lindenmayer *et al.* 2009).

How populations of Sooty Owls and Powerful Owls respond to forestry practices is poorly understood. The results of some studies are occasionally conflicting, probably due to spatially varying resource availability and low sample sizes (Kutt 1994; Kavanagh and Bamkin 1995; Kavanagh *et al.* 1995; Kavanagh 1997; Kambouris 2000; Alexander *et al.* 2002; Cann *et al.* 2002). Studies have shown that owls typically occupy selectively logged and unlogged forests at similar frequencies, but at lower frequencies in heavily logged (clear-fell) areas (Kavanagh 2002b). The impact of forestry practices on owl populations appears to be reduced by the retention of stream-side buffers, and retention of significant areas of unlogged habitat surrounding logged areas (Kavanagh 2002b). Studies in south-eastern New South Wales have shown that populations of large forest owls have been increasing over the past two decades in regions subject to extensive logging, primarily because of increasing high densities of non hollow-dependant prey such as Common Ringtail Possums (Kavanagh 1997; 2002b; DEC 2006). What remains unknown however, is what the original population of owls was like prior to logging commencing.

The greatest impact caused to Sooty Owls and Powerful Owls by clear-fell logging will be the impacts on populations of hollow-dependant mammals where they dominate the owls diet, and where non-hollow-dependant prey are uncommon. Greater Gliders (*Petauroides volans*) and Sugar Gliders (*Petaurus breviceps*) are amongst the main species most adversely affected by clear-fell logging (Tyndale-Biscoe and Smith 1969; Lunney 1987; Lindenmayer *et al.* 1997; Kavanagh and Webb 1998; Kavanagh 2000; Gibbons and Lindenmayer 2002), therefore the overall reduction in abundance of these two species following logging will likely have deleterious impacts on the owls in many landscapes. Clear-fell logging has also been shown to deplete populations of terrestrial small mammals in the long-term (Lunney et al. 1987; Lunney et al. 2009) which is likely to impact sooty owls. How the owls respond to particular forestry practices is therefore likely to be strongly dictated by prey availability. Studies have shown that populations of many hollow-dependant mammals is limited by the densities of hollows in the landscape, in other words, there is a strong relationship between the density of hollows in the landscape and populations densities of hollow-dependant mammals (Smith and Lindenmayer 1988; Gibbons and Lindenmayer 2002). Populations of hollow-dependant mammals will therefore remain low in logging regrowth until hollow densities increase, which could take well over 100 years (Gibbons and Lindenmayer 2002).

How individual owls respond to logging is poorly understood, but several individuals have been radio-tracked in areas subject to extensive logging history. Of the few owls radio-tracked in regions subject to logging in south-eastern New South Wales (1 Sooty Owl, 2 Powerful Owls), Kavanagh (1997) found that the owls still foraged in logging regrowth (where densities of Common Ringtail Possums were high and dominated the owls diet), but the owls nested and roosted predominantly in unlogged areas. No statistical analysis was conducted to determine if any selection or avoidance of forest structure was occurring.
Bilney (2009b) radio-tracked two Sooty Owls in East Gippsland that occupied home-ranges subject to extensive logging history. Both owls significantly avoided logging regrowth (primarily <40 year regrowth), primarily because their diet comprised high proportions of hollow-dependant mammals, and species such as Common Ringtail Possums were rare in the region.

Logging occurs throughout forested landscapes in Victoria, primarily only being absent from National Parks, select reserves and in regions where harvesting is difficult (steep terrain), or unproductive. Approximately 32% of public land in East Gippsland is considered to be available for logging (DCNR 1995), representing a considerable conservation concern, especially if owls strongly avoid logging regrowth (e.g. Bilney 2009b). The accumulative affect of logging is therefore likely to have a dramatic impact on owl populations long-term primarily due to the reduction in carrying capacity. It is important that further research investigates the impacts of logging on owl populations and individuals across the landscape.

Fire

Fire is likely to kill individual owls and small mammals, and remove potential habitat in the short-term, potentially resulting in long-term impacts. How owl populations adapt or respond to fire is largely unknown. Fire can consume hollow-bearing trees, while also stimulating hollow formation, but as hollow formation can take decades, frequent fires are likely to result in a net loss of hollow-bearing trees from the landscape (Gibbons and Lindenmayer 2002). This is likely to cause detrimental effects to all hollow-dependant fauna (Catling 1991;

Gibbons and Lindenmayer 2002; Garnett *et al.* 2003). Sooty Owls typically occupy habitats subject to infrequent fire regimes such as wetter forest types, possibly due to higher densities of hollow-bearing trees in such landscapes. Frequent fire regimes also simplify habitat structure, which can cause deleterious impacts on terrestrial mammals (Catling 1991; SAC 2001), which includes increased predation rates by feral predators due to the loss of habitat refuge (Wilson and Friend 1999). Overall, it therefore seems likely that owls and small mammals will be negatively impacted by frequent fire regimes. It is likely, however, that it will be the impacts of fire on prey densities that dictate how the owls respond to fire.

Most species are not adapted to fire *per se*, but adapted to a particular fire regime, which include fire aspects such as intensity, frequency, seasonality and scale (Bradstock *et al.* 2002). Due to variations in the life history requirements of species and their ability to survive fire, particular fire regimes can advantage some species, while being deleterious to others (Bradstock *et al.* 2002; Gill and Catling 2002; Keith *et al.* 2002). Due to the varying ecological responses to fire, it is important for biodiversity conservation that we not only understand species responses to particular fire regimes, but to ensure that appropriate fire regimes are maintained across the landscape. As prescribed fire is used as a management tool for reducing fuel load to minimise fire risk, it is important that its effects on biodiversity are well understood. Unfortunately, knowledge on how native species respond to particular fire regimes is poorly understood, especially for fauna (SAC 2001, 2003; Clarke 2008). So, in the absence of this crucial ecological information it is virtually impossible to implement appropriate fire regimes which will result in minimal negative ecological impacts, let alone enhance biodiversity.

Fire, both prescribed burning and wildfire, can present a threat to owls if conducted at inappropriate seasons, frequency, intensity or scales. It is therefore difficult to quantify the threat. The threat of inappropriate burning at high fire frequencies is likely to be mainly concentrated around human assets and populations, while fires in more remote forested areas will be subject to less frequent fires (DSE 2004). Fire also affects the entire owl population because all habitats occupied by owls is flammable.

Victoria has experienced three catastrophic fire events in the past 7 years, and combined with prescribed burning, approximately three million hectares have been burnt in this time. This equates to approximately 2/3 of potential Sooty Owl habitat in Victoria. How populations of Sooty Owls and many other forest dependant fauna have been affected by these fires remains poorly understood or unknown. The ability for forest fauna to recover is therefore being hampered by further prescribed burning, and recovery is also hampered by reduced fecundity caused by a decade of drought, and for the owls, low prey population densities.

Predation by feral species

It has previously been considered that the main threat posed by feral predators on large forest owls was due to direct predation, such as on recent fledglings (Kavanagh 1997; DEC 2006). It is considered by Bilney (2009b) that predation by foxes (*Vulpes vulpes*) and cats (*Felis catus*) on small native mammals is likely to pose one of the greatest threatening process to owls. Foxes and cats not only consume large numbers of small mammals (Triggs *et al.* 1984; Brown and Triggs 1990; Meek and Triggs 1998) therefore competing with owls, but they are also continuing to suppress small mammal population densities (Murray *et al.* 2006; Roberts *et al.* 2006; Dexter and Murray 2009). As prey population densities are likely to significantly influence the owls population densities, breeding success and how owls respond to particular land management practices and stochastic events, reduced prey availability in the landscape will dramatically affect owl populations. Predation by feral species on small mammals is also likely to have contributed to increased dietary overlap between Sooty Owls and Powerful Owls and the potential for competitive interactions to occur (Bilney *et al.* 2006; Bilney 2009b). Feral predators are also considered to have contributed to major declines in small mammals since European settlement (Short and Smith 1994; Short 1998; Johnson 2006), and it is likely that further small mammal declines will occur if feral predators are uncontrolled. There is no evidence to suggest that small mammal declines have ceased, and feral predators are considered partially responsible for this decline (e.g. Murray *et al.* 2006; Bilney 2009b).

Predation by feral species is continuing across the distribution of all owl species. A large-scale fox control program in East Gippsland is likely to result in population increases of many small mammals (Murray *et al.* 2006) and result in flow-on numerical response in Sooty Owls and Powerful Owls populations (Bilney 2009b).

Additional threats to owls

There are numerous additional factors that can cause the mortality of individual owls (e.g. collision with vehicles, secondary poisoning, disease) (DEC 2006), but the degree of the threat posed by these factors is unknown, and unlikely to pose a significant threat to entire owl populations. Perhaps the greatest threat facing owl conservation in the future is climate change, drought and increased fire frequency. Competitive interactions between Sooty Owls and Powerful Owls (Bilney *et al.* 2006; Bilney 2009b) may not pose a threat to either owl species, however, this interaction is likely to result in overall reduced population densities of both owl species. Herbivory by Sambar (*Cervus unicolor*) also poses a significant threat, as they appear to be the greatest threatening process to warm temperate rainforest communities (a crucial roosting and habitat resource for owls) (Peel *et al.* 2005). Sambar browsing causes rainforest to become more vulnerable to fire (Peel *et al.* 2005), and as rainforest performs vital roles in ecosystems by providing a natural barrier to fire and reducing fire intensity, as well as providing unburnt refuge habitat following fire, the loss of rainforest is therefore a major threat to forested ecosystems.

Question 7b and c) There are measures in place to reduce the impact of some threatening processes to the owls. For example, the threat of logging practices is considered to be minimised by retaining unlogged habitat within SOMA's and POMA's in state forest, as well as retaining streamside vegetation (Riparian buffers) throughout Victoria (e.g. Webster *et al.* 1999; Silveria *et al.* 2003). These measures (both in Victoria and East Gippsland) should *reduce* the threat posed by the forestry industry, but whether they are effective to maintain owl populations at desired levels in the long-term is unknown (Loyn 2004).

There is wide-scale fox baiting (control) in East Gippsland to reduce the impact of the red fox on small mammal populations (Murray *et al.* 2006).

Prescribed burning is also conducted in an attempt to minimise high intense fires throughout forested ecosystems, and typically at higher frequencies only around human assets and populations. Although there is legislation acknowledging that inappropriate and frequent fire regimes are threatening processes in the environment (SAC 2001, 2003), they are not adequately understood and cannot affectively be implemented or alleviated. Therefore both wildfire and inappropriate fire regimes presents a considerable threat to owl populations everywhere.

There are currently no measures in place to reduce the increased population density of Sambar, despite the ecological damage they cause (SAC 2007). This is primarily because Sambar are a valuable hunting resource and therefore a protected game species.

Question 7d and e) In my opinion, and as detailed by recent research (Bilney 2009b) the current strategies in place to conserve Sooty Owls and Powerful Owls require vast improvements, primarily because despite the range of potential threats to owls, virtually all conservation measures for Sooty Owls and Powerful Owls only address methods to reduce the impacts caused by forestry practices and the attempt to maintain sufficient owl habitat (Webster *et al.* 1999; Silveira *et al.* 2003; DEC 2006). Not only are current measures unlikely to be adequate to meet conservation concerns (e.g. Bilney 2009b) the effectiveness of current conservation measures remains largely unknown (Loyn 2004).

The research by Bilney (2009b) raised numerous conservation concerns, including;

- That Sooty Owls and Powerful Owls in East Gippsland relied more heavily on hollow-bearing trees than previously considered (average of 75% of diet consisted of hollow-dependant mammals – while individual Sooty Owls required a large number of hollows (up to 13) for roosting).
- home-ranges of both male (2000-4000ha) and female (500-1500ha) Sooty Owls were significantly larger in the short-term than has previously been assumed (200-800ha) (e.g. Higgins 1999).
- radio-tagged Sooty Owls in areas subject to extensive logging history were found to significantly avoid logging regrowth <45 years old.
- prey availability was considerably lower compared to historic times and that feral predators were likely to be affecting owl populations due to reduced prey densities.
- the degree of resource overlap between Sooty Owls and Powerful Owls is considerably high.
- hollows used for roosting/nesting were located throughout the landscape and not confined to riparian areas as previously speculated (e.g. Higgins 1999).

Bilney's (2009b) study raises doubt whether current management strategies to minimise the impacts of logging on Sooty Owls is sufficient in many landscapes. As individual SOMA's typically only provide 500ha to buffer against deleterious impacts of logging on a single pair of Sooty Owls, this would only incorporate 12-26% of the home-range requirements of males detected in that study, in the short-term. This is of concern, especially as Sooty Owls were found to avoid logging regrowth, and because just how effective these SOMA's are is unknown (Loyn 2004).

In the USA, there has been a great deal of controversy concerning the conservation of the Spotted Owl (*Strix occidentalis*), a species that occupies old forest habitats, utilizes large home ranges, and is threatened by habitat loss from logging (e.g.Dixon and Juelson 1987; Simberloff 1987) . In particular, there has been much debate regarding the size, shape, and spacing of habitat reserves to protect individual pairs of Spotted Owls. Some, (e.g. Bingham and Noon 1997) have suggested that conservation areas for individual Spotted Owls should include, at minimum, an area equal to the mean core area size determined from telemetry studies (such as 75% Adaptive Kernel methods). Others (e.g. Ganey and Balda 1989; Buchanan *et al.* 1998; Glenn *et al.* 2004; Forsman *et al.* 2005) have suggested that conservations areas for individual pairs should equal or exceed the average home range size of radio-marked owls or pairs of owls in order to provide critical resource elements for roosting, nesting, and foraging. It is, however, the size requirements of a breeding pair on which reserve design and resource requirements should be based (Bingham and Noon 1997), and home-range areas of a pair of owls typically exceeds that required by an individual because paired individuals often use slightly different areas with some, but not complete, overlap (Carey *et al.* 1990; Ganey *et al.* 1999; Sunde and Bolstad 2004; Forsman *et al.* 2005). As the size of male Sooty Owl home-ranges greatly exceeded the 500ha allocated within individual SOMA's (4-9 times greater), Bilney (2009b) recommended that the size of SOMA's should be increased to approximately 1000ha at a minimum in good habitat, possibly even larger (e.g. 1500ha) in landscapes where hollow-dependant mammals dominate the small mammal community and where Sooty Owls potentially compete for food with Powerful Owls (*Ninox strenua*) (Bilney *et al.* 2006; Bilney 2009). That study highlights the pressing need to base conservation measures on ecological data, rather than assumptions and arbitrary figures, as is currently the case.

Due to high resource overlap between Sooty Owls and Powerful Owls, Bilney (2009b) noted that SOMA's or POMA's should not overlap the same area, as is occasionally currently the case (DSE 2004). At the moment a 500ha special protection zone is considered large enough to provide sufficient habitat for, and support, both owl species, because the owls have long been considered to use different resources. Not only is the effectiveness of a 500ha reserve size questionable for one species (especially when home-ranges of both owl species have been recorded >3500ha in the short-term (Soderquist and Gibbons 2007; Bilney 2009b)), but for a 500ha reserve to contain sufficient resources for both species is highly unlikely, especially when dietary overlap between female Sooty Owls and Powerful Owls was recorded at close to 90%, and they can occupy the same habitat types at the same time and also nest in similar size trees (Bilney 2009b).

Reserve designs for owl conservation must therefore cater for the fact that high levels or resource overlap occurs. It is recommended that where Sooty Owls and Powerful Owls coexist, conservation reserves for each species should not overlap, unless doubled in size, to cater for the individual needs of each species (Bilney 2009b).

It is also important to estimate what potential density of resources may be typically available to owls within a 500ha reserved area. Population densities of Sugar Gliders have been estimated from central Gippsland at 1-2 animals per hectare, while densities of Greater Gliders typically reach 0.6-0.8 (Kavanagh 1984; Menkhorst 1995). Hypothetically, 500ha would therefore contain approximately 500-1000 Sugar Gliders and 300-400 Greater Gliders. Bilney (2009b) detected that approximately 75% of the diet of both Sooty Owls and Powerful Owls (in foothill forest in East Gippsland) constituted Sugar Gliders and Greater Gliders (hollow-dependant mammals). It has been estimated that a single breeding pair of Powerful Owls requires at least 300 large possums or equivalent each year (Seebeck 1976; Tilley 1982; Webster *et al.* 1999)). It could then easily be envisaged that 400-500 gliders would be consumed each year by a breeding pair of coexisting Sooty Owls and Powerful Owls. Even if owls consumed 15-20% of the prey population in a year (which is likely to be a considerable overestimate) a population of 2000-3500 gliders would therefore be required within a home-range. It is therefore clear that 500ha in most areas will be woefully inadequate to contain sufficient prey resources for a pair of breeding owls, and that the owls will require reserves significantly larger than they are currently. Approximately 1000-2000ha seems a more likely estimate of area required for sufficient prey resources by coexisting pairs of Sooty Owls and Powerful Owls where hollow-dependant mammalian prey dominate their diet.

Attention is often given to riparian habitats where resources for owls are considered to be more highly concentrated (Kavanagh 1997; DEC 2006), which although may be true in some areas, radio-tracking studies have shown that the owls forage and also roost and nest throughout their environment. Bilney (2009b) found that of all the eucalypt roosting trees detected for Sooty Owls, 79% of them would fall outside riparian areas, and could potentially be available to logging. It is therefore most important to retain high densities of hollow-bearing trees throughout the landscape, which is recognised under legislation, as the loss of hollow-bearing trees is listed as a threatening process (Garnett *et al.* 2003). Only 5 trees are typically retained in logging coupes after harvesting (DSE 2007b). In some East Gippsland forests, Gibbons (1999) found that in unlogged forests there are approximately 22.0 hollows/per hectare, compared with an average of 2.7 in logged forest (Gibbons and Lindenmayer 2002). If a similar scenario occurs throughout 1/3 of forested ecosystems in East Gippsland, then populations of all hollow-dependant animals will be dramatically affected.

The emphasis on reducing the threat posed by feral predators on small mammals is also limited, and although quite good in East Gippsland (for the fox) (e.g. Murray *et al.* 2006), cat populations are still high, and in other regions in Victoria limited or no targeted control is conducted (except in some regions for some endangered species).

Another questionable factor, is whether aiming to conserve 500 pairs of owls is sufficient to maintain viable populations. Should we not aim to maintain, or improve current population levels? With the large scale fires that have affected Victoria in the past 7 years (burning approximately 3 million hectare – Sooty Owls distribution is less than 4.6 million ha) this will have severely affected populations of both Sooty Owls and Powerful Owls. Aiming to conserve only 500 pairs of each owl species for the state should therefore be questioned, especially if their current population may have fallen dramatically following recent fires. The impact these fires have had on the owls populations remains unknown, however, forest management practices (logging and prescribed burning) continue unchanged, if not increased in the unburnt forest.

Question 8) The impacts of forestry

Much of this question is answered under the Threats to owls (section 7), as forestry practices represent one of the main threats to the populations of both owl species (Webster *et al.* 1999; Silveira *et al.* 2003; DEC 2006).

Question 8b) It is difficult to quantify the impact of forestry practices. First of all, the impact of logging on owls is likely to vary spatially due to varying prey availability (Kavanagh 2002b; Bilney 2009b). Selective logging is likely to have less impact compared to clear-fell harvesting which has the greatest impacts (Kavanagh 2002b).It is also unknown what proportion of the owl population occurs within conservation reserves, or outside conservation reserves in forest subject to logging.

One figure which is apparently unavailable (requests to DSE) or unknown regards the extent of forest previously clear-fell logged in East Gippsland. What is known, however, is that in 1995 it was considered that approximately 1/3 of public land was available for harvesting within East Gippsland Management area (DCNR 1995). Logging 1/3 of East Gippsland is highly likely to have a dramatic, yet unquantifiable affect on population densities of large forest owls in this area.

Question 8c) The impacts of logging on owls at a regional and local scale remains poorly understood (Kavanagh 1997; Bilney 2009b). For an individual/pair of owl, any reduction in habitat quality or loss of habitat will reduce food availability (if not actual loss of nest and roost sites) and therefore reduce carrying capacity in the landscape. This is likely to see an increase in home-range size of the owl, requiring greater energy expenditure and possibly involve a reshaping of home-range and possibly territory. Greater energy expenditure for a female could have a dramatic effect on her body condition and breeding success, while also, reduced prey capture rates of males could also potentially affect breeding success as females are dependent on males to provide food during early stages of breeding. Overall, an increase in territory size should eventually have repercussions regarding population densities of owls at a landscape level. Although owls are likely to be able to tolerate some logging within their home-range, just how much logging an owl can tolerate before being negatively impacted is unknown. This is why it is important to consider the impacts caused by the accumulative effect of clear-logging over the past 50 years, and into the future. All that can be said is that logging will likely result in affected breeding success and reduced population densities of owls to an unknown degree.

In an area subject to extensive clear-fell harvesting in south-east New South Wales, owl populations have been shown to increase over the past two decades (Kavanagh 2002b; DEC 2006), but how their current population compares to the pre-logging population is unknown.

East Gippsland

Question 9) Both Sooty Owls and Powerful Owls have extensive populations in East Gippsland, and are amongst the largest populations and highest densities in south-eastern Australia. A playback survey revealed that of approximately 1.2 million hectares in East Gippsland there was approximately 999,276ha of preferred habitat available for Powerful Owls and 507,778ha for Sooty Owls (McIntyre and Henry 2002). A population estimate was not conducted during this study, but it is considered that over 100 pairs of both species exist in the region (McIntyre and Henry 2002). This indicates that both species are fairly wide-spread in East Gippsland, with Powerful Owls not significantly associated with any particular Ecological Vegetation Type, while Sooty Owls were significantly associated with damp forests and in close proximity to rainforest gullies.

Question 10a) The habitat type of Sooty Owls and Powerful Owls is secure, in that no or very limited clearing is continuing. What does change, however, is the forest structure and composition, due to disturbance regimes such as fire and logging, which potentially has deleterious consequences. Although logging may only occur in approximately 1/3 of public land in East Gippsland, this may actually represent a much greater proportion of Sooty Owl habitat. Optimum Sooty Owl habitat is typically on lower elevation (lowland forest), high fertile areas with damp and wet forest types (Loyn *et al.* 2001), which also happens to be high valued forests favoured by the timber industry and is over represented within General Management Zones available for logging in East Gippsland (Appendix D in DCNR 1995). National Parks typically represent a biased proportion of less productive, steep or infertile regions with limited economic value that have typically been subject to considerable selective logging in the past (e.g. Pressey 1995). In particular, a large proportion of the Sooty Owls preferred habitat is therefore going to be subject to considerable changes in structure and composition as well as reductions in hollow-bearing trees and reduced prey availability for the long-term caused by logging.

Question 10b) The population levels of Sooty Owls and Powerful Owls are relatively unknown in East Gippsland, except that it is considered that over 100 pairs of both species occupy the region and that the conservation goal is to conserve at least 131 pairs of Sooty Owls and 100 pairs of Powerful Owls (Webster *et al.* 1999; Silveira *et al.* 2003; McIntyre and Henry 2002).

There is no indication as to whether owl populations have changed overtime. It seems highly likely that populations have declined since European settlement due to declines in prey availability, clearing and logging (Webster *et al.* 1999; Silveira *et al.* 2003; Bilney 2009b), but whether populations are continuing to decline, increase or are stable is unknown.

Question 10c) Based on the owls higher populations in East Gippsland (compared to other regions in south-eastern Australia), it seems unlikely that local extinction of either owl species will occur in the near future (e.g. McCarthy *et al.* 1999). However, a large stochastic event such as wildfire could severely impact their populations.

Although habitat may be relatively secure for Sooty Owls and Powerful Owls in East Gippsland, and that conservation measures are in place, this does not necessarily equate to secure populations of both owl species. The current population of the owls is relatively unknown, indicating that we do not have sufficient baseline data to indicate long-term population trends into the future. Logging is likely to continue to reduce populations of Sooty Owls and Powerful Owls due to changes in habitat quality and loss of carrying capacity. The ability for populations of owls to recover will probably be dictated by population levels of the Common Ringtail Possum (as appears to be the case in south-eastern NSW (Kavanagh 1997; DEC 2006)) and other prey species (Bilney 2009b). Although East Gippsland may have large owl populations at the moment, they are crucial source populations for repopulating other regions of south-eastern Australia that have been dramatically affected by fires over the last 7 years. My main concern therefore, is that if a large wildfire occurs in East Gippsland within the next 20 years or so, this may dramatically affect the owl populations throughout south-eastern Australia. Efforts must therefore be made towards promoting owl populations, requiring that threatening processes including land management practices must be sympathetic to their conservation.

Brown Mountain

Question 11) It is quite easy to determine whether Sooty Owls and Powerful Owls occupy the region around Brown Mountain, primarily by hearing an owl call, either in response to call playback (owl calls broadcast by a megaphone) or by hearing them call during listening surveys on dusk. More difficult to determine, however, is whether the owls forage, roost or nest within the area in question. If an owl responds to playback, this is likely to indicate a territorial response, indicating that the area falls within their territory. If an owl calls on or immediately after dusk, this is likely to indicate that a roost is nearby. More difficult to determine would be whether a nest exists in the area, which would typically require that a large number of listening surveys be conducted throughout the breeding season.

Ultimately to answer these questions radio-tracking all individual owls known to exist in the area would be required, which is well beyond the scope of this report. Even radio-tracking will only indicate the owls activities in the short-term.

Question 12) Whether the owls are likely to be present in the Brown Mountain coupes
Both Sooty Owls and Powerful Owls were recorded in the Brown Mountain area in January 2009 (Bilney 2009a). Sooty Owls twice responded to playback in coupe 840-502-0015, while a Powerful Owl was heard calling towards the northern end of coupes 840-502-0015 and 840-502-0019 and close to 840-502-0026 (Bilney 2009a). In January 2009, Sooty Owls were also heard calling soon after dusk within close proximity of coupe 840-502-0015, indicating that a roost was likely to fall within coupe 840-502-0015 or in surrounding unlogged habitat (regrowth typically does not provide suitable roosting sites for Sooty Owls). The Sooty Owl also responded to call playback within a very short time frame. A Powerful Owl was also recorded by DSE surveys in March 2009 (DSE 2009).

During surveys in November 2009 a Sooty Owl was heard immediately after dusk approximately 500m south of the logging coupe 840-502-0015, indicating that on that occasion a roosting site existed outside the proposed coupe area. Despite the owl known to be in the area and well within hearing distance, the owl did not respond to call-playback on four occasions (once at each proposed logging coupe). It was therefore difficult to determine whether the forests in the additional coupes (840-502-0019, 840-502-0026, 840-502-0027) fell within the territory of the Sooty Owl, but the fact that the owl was present within very close proximity to all coupes indicates a very high likelihood that these areas are used (a single Sooty Owl territory could easily encapsulate this entire area – typically >500ha).

Although a Powerful Owl was detected in January 2009 and March 2009 in the Brown Mountain area, they typically rarely call in Spring and Summer, and were undetected during the November surveys. A negative response however, does not indicate an owls absence, and it has been shown that up to 18 call-playback survey attempts are required to provide a good chance (90% confidence) that a Powerful Owl does not exist in the area (Wintle *et al.* 2005).

The dominant vegetation type (or EVC) from the four proposed logging coupes at Brown Mountain consists of Wet or Damp Forest which almost exclusively falls within 'old-growth forest' as defined by DSE (Interactive Maps). Surveys of arboreal mammals in the region have indicated very high densities of arboreal mammals (Bilney 2009a; DSE 2009; Bilney unpublished recent surveys), including the Greater Glider which are amongst the dominant prey of both Powerful Owls and Sooty Owls (Bilney 2009b). Therefore, the vegetation composition and forest age structure combined with high prey densities indicate that all four proposed logging coupes are highly suitable for both Sooty Owls and Powerful Owls. In my opinion, I have no doubt that these four proposed logging coupes at Brown Mountain will be used by both owl species (at least for foraging), especially as both species do occur in the area.

Question 13) I found conclusive evidence that both owl species occupy the area around Brown Mountain at least for foraging and that a Sooty Owl roosting site is within close proximity to 840-502-0015 (if not within). Whether nesting sites fall within any of the four proposed logging couples is unknown. All four coupes do however, provide high quality habitat for roosting, nesting and prey, for both Sooty Owls and Powerful Owls. All four sites contain high arboreal mammal population densities (Greater Glider, Yellow-bellied Glider, Sugar Glider) (Bilney 2009a; DSE 2009; Bilney unpublished recent surveys), and are also likely to contain abundant terrestrial mammalian densities, based on structural and habitat diversity suitable for Bush Rats (*Rattus fuscipes*), Agile Antechinus (*Antechinus agilis*) and Dusky Antechinus (*Antechinus swainsonii*) (e.g. Catling and Burt 1995).
These four proposed logging coupes will however, only form a fraction of the area used by an individual of either owl species (the four coupes equals about 81ha while home-range could be >500), and although they may still be important areas, they may not be used frequently.

Question 14) Combined, the four logging coupes comprise 81.4ha of forest (Timber Release Plan), which is likely to only contribute to a small fraction of an owls home-range (typically >500ha). It is important however that the cumulative effect of logging in the area is also considered when answering this question. At the moment this 81.4 ha represents the only substantial unlogged old-growth habitat remaining within the (approximate) 500ha area adjacent to the Errinundra National Park. If these four coupes are logged, the only unlogged old-growth habitat remaining within an approximate area of 500ha, will be a 100m wide riparian buffer (if the riparian SPZ is accepted). This area also links two Conservation reserves, potentially providing an important corridor. The logging of 81ha is a large proportion of habitat used by Sooty Owls and Powerful Owls, and will represent a substantial decline in small mammal populations and decline in prey availability for the owls (as it is likely that the density of Greater Gliders in the forest is > 1 per hectare, this could represent the loss of habitat of 80-100 Greater Gliders, and if Sugar Gliders exist at an average population level, 80-160 Sugar Gliders).

Much of this question regarding how logging is likely to affect the owls has been answered in section 8c – 'For an individual/pair of owl, any reduction in habitat quality or loss of habitat will reduce food availability (if not actual loss of nest and roost sites) and therefore reduce carrying capacity in the landscape. This is likely to see an increase in home-range size of the owl, requiring greater energy expenditure and possibly involve a reshaping of home-range and possibly territory. Greater energy expenditure for a female could have a dramatic effect on her body condition and breeding success, while also, reduced prey capture rates of males could also potentially affect breeding success as females are dependent on males to provide food during early stages of breeding. Overall, an increase in territory size should eventually have repercussions regarding population densities of owls at a landscape level. Although owls are likely to be able to tolerate some logging within their home-range, just how much logging an owl can tolerate before being negatively impacted is unknown. This is why it is important to consider the impacts caused by the accumulative effect of clear-logging over the past 50 years, and into the future. All that can be said is that logging will likely result in affected breeding success and reduced population densities of owls to an unknown degree'. Either way, whatever the impact of logging these four proposed coupes would be, it will not be of benefit to the owls in the short or long-term.

Whether the logging of these four coupes (alone) presents a threat to the overall population of Sooty Owls and Powerful Owls is unlikely. However, it is important that the logging of these four coupes should not be considered in isolation, because it is the cumulative effect of all clear-fell logging (in the past and into the future) that must be considered when regarding the impact of logging to large forest owls.

Question 15) The ability of the owls to recover in the Brown Mountain area following logging will be primarily dictated by how small mammal populations (prey availability) respond to logging. Many mammalian species, especially those that are hollow dependant, will suffer considerable population declines following logging of old-growth (e.g. Gibbons and Lindenmayer 2002). Their population density will be dramatically affected for several decades, possibly even centuries, and are unlikely to ever again reach densities similar to what they currently are, especially if forest composition is altered and logging cycles are <80 years.

Typically, the older the forests are, the greater the densities of hollows they contain (Gibbons and Lindenmayer 2002). Forests dominated by *E.fastigata* and *E. obliqua* from East Gippsland (similar to that at Brown Mountain) that are estimated at between 300-360 years old typically contains 5 times more hollows than is present in 60-121 year old forests (Gibbons and Lindenmayer 2002). As the forests at Brown Mountain contain a large proportion of old-growth, some trees of which exceed 500 years in age (based on radiocarbon dating), by logging these forests they are unlikely to ever support a fraction of the original density of hollows again, especially if harvesting rotation periods are <80 years. Typically as there is a strong positive relationship between the density of hollows in the landscape and the population densities of hollow-dependant mammals (e.g. Smith and Lindenmayer 1988; Gibbons and Lindenmayer 2002), populations of many hollow-dependant mammals are likely to decline significantly in production forests long-term (e.g. Lindenmayer *et al.* 1997). This is therefore likely to have a dramatic impact on population densities of owls unless populations of non-hollow dependant mammals can increase dramatically to compensate for the reduction in populations of hollow-dependant mammals.

Populations of non-hollow-dependant mammals will increase substantially following logging (but whether they can reach or exceed population densities prior to logging remains poorly understood, yet populations of terrestrial species are likely to decline over the long-term (Lunney *et al.* 2009)). Species such as Common Ringtail Possums can increase in logging regrowth several decades after logging, and can become an important dietary items for both owl species (Kavanagh 1997; DEC 2006). Despite whatever prey populations densities reach in logging regrowth, the dense structure of regrowth is however, likely to hamper prey accessibility (or availability) to the owls. Where Common Ringtail Possums (and other non-hollow-dependant mammals) are rare, regrowth that is 40-50 years old can still be strongly avoided by owls (Bilney 2009b) and these areas will provide low prey populations for possibly centuries and may actually be permanently altered.

If forest composition is altered by logging (which is typically the case) (e.g. Mueck and Peacock 1992; Lindenmayer and Franklin 2002; Lindenmayer et al. 2009) this can dramatically affect the carrying capacity of forests and have dramatic effects on populations of arboreal mammalian herbivores such as Greater Gliders and Common Ringtail Possums. Many of the eucalypt species promoted by harvesting practices (or dominate logging regrowth, especially in foothill forests of East Gippsland) include species such as Silvertop Ash (*Eucalyptus sieberi*) and stringybark species (e.g. McKinty 1969; Mueck and Peacock 1992; Lindenmayer *et al.* 2009) which not only contain very low nutritional benefit to herbivores and are typically avoided (Braithwaite *et al.* 1988), but these species also appear to provide few hollows (pers. obs). If populations of highly nutritional and hollow forming eucalypt species are replaced with less nutritional species, this will irreversibly alter the carrying capacity of the landscape for both arboreal folivore mammals and their main predators (Sooty Owls and Powerful Owls).

Logged coupes are unlikely to ever provide suitable sites for nesting or roosting (in hollows - except if a retained habitat tree is used), especially if the intention is to harvest the forest again within the next 200 years (until hollows form). Powerful Owls in particular are unlikely to ever nest in a retained habitat tree, due to their requirements of suitable foliage roosting locations nearby to the nest tree (e.g. Kavanagh 1997; Cooke 2000; DEC 2006), which is not catered for in logging coupes.

Overall, it seems highly likely that populations of small mammals will be permanently reduced following logging, therefore impeding recovery of the owls.

Question 16) No. Even if harvesting adheres to these guidelines, there will still be a significant reduction in hollow densities (e.g. Gibbons and Lindenmayer 2002), a reduction in prey availability and probably loss of roosting sites. Although the populations of some small mammals will recover in the short-term (following harvesting and coupe burn), it is unlikely that population densities of hollow-dependant mammalian prey will ever recover.

The action statement

Question 18a and b) A specific record of an owl will most likely be an observation based on hearing or sight of an individual (very rarely would it be a roost or other sign of the owl). Some records may be incidental (a bird calling unprovoked), but I suspect most records have been obtained via call-playback and the detection of individuals based on the owls territorial response to call-playback.

Habitat modelling has used the information from broad-scale call-playback surveys, and based on habitats surrounding each owl record this is used to produce a habitat model to predict other areas of suitable habitat with the high probability of detecting the presence of an owl.

From my understanding, 131 SOMA's were to be established in East Gippsland, which actually exceeds the number of confirmed Sooty Owl records in the area. Therefore, based on surveys and habitat prediction, suitable habitat will be conserved as SOMA's in some areas even though the owls have not been officially recorded in those areas (but there is a high probability that there is).

The main weakness of habitat models is that where a SOMA has been devised based purely on this habitat model, it is unknown whether a Sooty Owl actually occupies the area. This could potentially result in a false pretence that populations are being conserved based purely on speculation that preserving habitat is sufficient. The strength of habitat models is that in areas where surveys are impossible to conduct (remote access), suitable habitat can still be reserved.

Question 18c) My understanding of the 3.5km radius used to establish a SOMA from an actual site record of an owl is basically an arbitrary figure, but considered an estimate that an owls home-range falls somewhere within this area (of 3800ha). As 500ha only represents less than 1/7th of this area, the likelihood of a 500ha reserve actually being positioned in an area that contains substantial resources currently used by an individual is highly unlikely, especially when they utilize such large home-ranges (2000-4000ha). The 500ha reserve is supposed to be positioned in an area likely to contain high habitat values.

Question 18d) The habitat from Brown Mountain and the proposed logging coupes contains virtually the highest quality habitat for Sooty Owls, being old-growth (with high densities of hollow-bearing trees) wet forest (with abundant silver wattles, tree ferns and blanket-leaf) with high prey (small mammal) densities.

Question 18e) Sooty Owls are amongst the species most closely associated with old-growth habitats, so large and/or dead hollow-bearing tree provide suitable sites for nesting and roosting, while a large proportion of their diet can consist of hollow-dependant mammals (such as Greater Gliders and Sugar Gliders). Hollows can take many hundreds of years to form (Gibbons and Lindenmayer 2002), especially those large enough to be occupied by owls. This also indicates that preferred habitat has been subject to minimal disturbance in the long-term (logging or wildfire). The age of old-growth was traditionally considered to be 200-300 years old (Scotts 1991; Gibbons and Lindenmayer 2002), however, evidence obtained by Environment East Gippsland (using radiocarbon dating) revealed that a large healthy tree was over 500 years in age, indicating that many trees in the Brown Mountain area will be significantly older. If the age of the forest is much older than previously considered, this may mean that the age at which hollows begin to form is also much older than we currently speculate. Therefore, the age of forests typically preferred by Sooty Owls is also much older that originally considered.

Question 19a) Adequate populations of prey for a Sooty Owl must be able to support successful breeding in the long-term. Not only is this figure unknown, but virtually impossible to assess. However, it could be considered that an entire home-range, long-term, covers an area with sufficient prey densities and as home-ranges typically greatly exceed 1000ha (probably 2000-3000ha), having modified timber harvesting in this area is highly unlikely to retain *sufficient* numbers of prey. Just because an owl can breed in an area provides no measure of breeding success. Breeding success is strongly influenced by prey availability (the greater the prey densities the higher breeding success will be). Any reduction in prey availability will therefore likely impact on the breeding success of a pair of owls.

Question 19b) The predominant prey of Sooty Owls is medium size (50-400g) mammals, of which 5-6 species dominate in their diet throughout south-eastern Australia, being the arboreal Sugar Glider and Greater Glider, the scansorial Common Ringtail Possum and Agile/Brown Antechinus, and the terrestrial Dusky Antechinus and Bush Rat (Kavanagh 2002a; Bilney 2009b). A wide-range of additional mammalian species (virtually any small mammal species under 1.5kg) are occasionally consumed, but rarely constitute a major dietary item.

Question 19c) To my knowledge (or understanding), no modified timber harvesting occurs within SOMA's (at least in East Gippsland) and that all SOMA's are treated as Special Protection Zones (which exclude timber harvesting). Therefore the prescriptions to retain adequate populations of terrestrial and arboreal prey are not relevant.

<u>The precautionary principal</u>

Question 20) My understanding of the precautionary principal (from an environmental perspective) is that – if a particular action has the potential to cause environmental impacts and the degree of those impacts are unknown or uncertain, caution should be taken in advance so that any potential impacts are avoided. i.e. If there is pressure to instigate a particular action, it should therefore be the responsibility of the action takers to determine that the action will not result in any (unacceptable) harm.

For example, if the precautionary principal was to be applied to this court case –VicForests should be able to prove that their actions are not threatening threatened species.

Question 21a) In my opinion, in many circumstances the precautionary principal has not been considered in the development of the East Gippsland Forest Management Plan (EGFMP). Overall, there is a strong commitment to ensure a long-term supply of timber/wood products (until 2030), but the actual ecological impacts caused by logging is poorly understood or in many circumstances unknown, let alone what any potential ecological impacts may be caused by the accumulation of logging in the long-term (by 2030 that will be ~70 years of clear-fell logging history). Reference to 'sustainability' primarily therefore refers to the actual timber industry, and not necessarily ecological sustainability (because this in many cases cannot be proved).

Although the EGFMP does recognise some environmental concerns (mainly for threatened species or key biological values), minimalist measures are often taken to negate some potential impacts of logging. Whether these strategies are sufficient to meet conservation concerns is also poorly understood or unknown.

Question 21b) Many of the conservation measures for Sooty Owls outlined in the Action Statement could actually be considered to be based on the precautionary principal. For example, although the actual impacts caused by logging on Sooty Owls is poorly understood (on populations and individuals), the fact that logging reduces the density of hollow-bearing trees, some key prey species, and modifies their habitat, there is a high likelihood that logging has some impact on Sooty Owls. The implementation of SOMA's provides some attempt to ease the conservation concern of the impacts of logging on the Sooty Owl, and could therefore be considered a conservation measure instigated based on the precautionary principal.

Question 21c) Although many threats to the Sooty Owl and Powerful Owl are known and have been documented (see section 7 above), the actual degree of the threat that they impose is not well understood. It is therefore important that based on the precautionary principal that although a threat may be poorly understood, measures must be taken to alleviate the threat, no matter how small it could be considered.

Question 21d) The precautionary principal in relation to the owls at Brown Mountain should cover - that although the exact extent to which the owls utilize this area could not be ascertained, the area contains highly suitable resources for foraging, roosting and nesting for both Sooty Owls and Powerful Owls and therefore there is a high likelihood that the logging of this area will have some negative impact on the owls.

Question 21e) Based on the precautionary principal - is it acceptable to allow land management practices, that have the potential to cause significant ecological harm (especially logging and fuel reduction burning), to occur at such an extent across the landscape, when the actual impacts they cause are poorly understood and there is little commitment to ascertaining their threat? Especially, when there are many 'unknowns' regarding the ecology, status and threatening processes to many threatened species, and that many threatened species are directly affected by these practices.

If it cannot be proved that logging does not impact threatened species (such as Sooty Owls and Powerful Owls), the logging of the coupes at Brown Mountain is therefore not consistent with the precautionary principal.

If the precautionary principal was considered, adequate ecological surveys would first be conducted to establish what exists within coupes before logging commences (pre-logging surveys), while also conducting post logging surveys to determine how ecosystems recover from logging and the effectiveness of conservation measures. As limited ecological surveys are typically conducted, the ecological impacts of logging remains poorly understood. Therefore, whether management goals (such as conservation objectives) have actually been met also remains largely unknown. Without this knowledge, management actions cannot be refined in the future to improve conservation outcomes (adaptive management). Understanding environmental impacts and recovery is a fundamental process for any responsible management action.

<u>References</u>

Alexander J.S.A., Scotts D.J. and Loyn R.H. (2002). Impacts of timber harvesting on mammals, reptiles and nocturnal birds in native hardwood forests of East Gippsland, Victoria: a retrospective approach. *Australian Forestry*, 65, 182-210.

Barrett G., Silcocks A., Barry S., Cunningham R. and Poulter R. (2003). *The new atlas of Australian birds*. Royal Australasian Ornithologists Union, Hawthorn East, Victoria.

Beruldsen G.R. (1986). Observations on the Sooty Owl in south-east Queensland. *Australian Bird Watcher*, 11, 230-236.

Bilney R.J. (2009a). Nocturnal surveys for arboreal mammals and large forest owls from Brown Mountain, East Gippsland. Unpublished report for Environment East Gippsland.

Bilney R.J. (2009b). Sooty Owl ecology and recent small mammal decline. PhD thesis, Deakin University, Melbourne.

Bilney R.J., Cooke R. and White J. (2006). Change in the diet of Sooty Owls (*Tyto tenebricosa*) since European settlement: from terrestrial to arboreal prey and increased overlap with Powerful Owls. *Wildlife Research*, 33, 17-24.

Bilney R.J., Kavanagh R.P. and Harris J.M. (2007). Further observations on the diet of the Sooty Owl *Tyto tenebricosa* in the Royal National Park, Sydney. *Australian Field Ornithology*, 24, 64-69.

Bingham B.B. and Noon B.R. (1997). Mitigation of habitat "take". Application to habitat conservation planning. *Conservation Biology*, 11, 127-139.

Blakers M., Davies S.J.J.F., Reilly P. and Royal Australasian Ornithologists' Union. (1984). *The atlas of Australian birds*. Melbourne University Press, Carlton, Vic.

Bradstock R.A., Williams J.E. and Gill A.M. (2002). *Flammable Australia: the fire regimes and biodiverstiy of a continent*. Cambridge University Press, Cambridge.

Braithwaite L.W., Binns D.L. and Nowlan R.D. (1988). The distribution of arboreal marsupials in relation to Eucalypt forest types in the Eden (N.S.W.) woodchip concession area. *Australian Wildlife Research*, 15, 363-73

Brown G.W. and Triggs B.E. (1990). Diets or wild canids and foxes in East Gippsland 1983-1987, using predator scat analysis. *Australian Mammalogy*, 13, 209-213.

Buchanan J.B., Fredrickson R.J. and Seaman D.E. (1998). Mitigation of habitat "take" and the core area concept. *Conservation Biology*, 12, 238-240.

Cann B., Williams J. and Shields J.M. (2002). Monitoring large forest owls and gliders after recent logging in production regrowth forests in the mid-north coastal regions of New South Wales. In: *Ecology and conservation of owls* (eds. Newton I, Kavanagh RP, Olsen J and Taylor I). CSIRO Publishing Melbourne, pp. 255-264.

Carey A.B., Reid J.A. and Horton S.P. (1990). Spotted owl home-range and habitat use in Southern Oregon Coast Ranges. *Journal of Wildlife Management*, 54, 11-17.

Catling P.C. (1991). Ecological effects of prescribed burning practices on mammals of south eastern Australia. In: *Conservation of Australia's Forest Fauna* (ed. Lunney D). Royal Zoological Society of New South Wales Mosman, NSW, pp. 353-363.

Catling P.C. and Burt R.J. (1995). Studies of the ground-dwelling mammals of Eucalypt forests in south-eastern New South Wales: The effect of habitat variables on distribution and abundance. *Wildlife Research*, 22, 271-288.

Chafer C.J. (1992). Observations of the Powerful Owl *Ninox strenua* in the Illawarra and Shoalhaven Regions of New South Wales. *Australian Bird Watcher*, 14, 289-300.

Chafer C.J. and Anderson M. (1994). Sooty Owls in the Hacking River catchment *Australian Birds*, 27, 77-84.

Christidis L. and Boles W. (2007). *Systematics and taxonomy of Australian birds*. CSIRO Publishing, Collingwood, Vic.

Clarke M.F. (2008). Catering for the needs of fauna in fire management: science or just wishful thinking? *Wildlife Research*, 35, 385-394.

Cooke R. (2000). Ecology of Powerful Owls (*Ninox strenua*) in contrasting habitats of the Yarra Valley Corridor, Victoria, Australia. PhD thesis, Deakin University Melbourne.

Cooke R., Wallis R., Hogan F., White J. and Webster A. (2006). The diet of Powerful Owls (*Ninox strenua*) and prey availability in a continuum of habitats from disturbed urban fringe to protected forest environments in south-eastern Australia. *Wildlife Research*, 33, 199-206.

Cooke R., Wallis R., Webster A. and Wilson J. (1997). Diet of a family of Powerful Owls (Ninox strenua) from Warrandyte, Victoria. *Proceedings of the Royal Society of Victoria*, 109, 1-6.

Cooke R., Wallis R. and White J. (2002). Use of vegetative structure by Powerful Owls in outer urban Melbourne, Victoria, Australia - Implications for management. *Journal of Raptor Research*, 36, 294-299.

DCNR (1995). *Forest Management Plan for the East Gippsland Forest Management Area.* Department of Conservation and Natural Resources, Melbourne.

Debus S.J.S. (1994). The Sooty Owl (*Tyto tenebricosa*) in New South Wales. *Australian Birds (supplement)*, 28, 4-19.

Debus S.J.S. and Chafer C.J. (1994). The Powerful Owl (*Ninox strenua*) in New South Wales. *Australian Birds (supplement)*, 28, 21-38.

DEC (2006). NSW Recovery plan for the large forest owls: Powerful Owl (*Ninox strenua*), Sooty Owl (*Tyto tenebricosa*) and Masked Owl (*Tyto novaehollandiae*). Department of Environment and Conservation, Sydney.

del Hoyo J., Elliot A., Sargatal J. and (eds.) (1999). *The handbook of the birds of the world, Vol. 5.* Lynx Edicions, Barcelona.

Dexter N. and Murray A.J. (2009). The impact of fox control on the relative abundance of forest mammals in East Gippsland, Victoria. *Wildlife Research*, 36, 252-261.

Dixon K.R. and Juelson T.C. (1987). The political economy of the spotted owl. *Ecology*, 68, 772-776.

DSE (2004). *Forest management plan for Gippsland.* Department of Sustainability and Environment, Melbourne.

DSE (2007a). Advisory list of Threatened vertebrate fauna in Victoria. Department of Sustainability and Environment. East Melbourne, Victoria.

DSE (2007b). *Code of practice for timber production.* Department of Sustainability and Environment, Melbourne.

DSE (2009). Surveys for arboreal mammals, Long-footed Potoroo and Spiny Crayfish in proposed logging coupes 840-502-0015 and 840-502-0019, Brown Mountain Creek catchment, Brodribb Forest Block, Errinundra Plateau. Department of Sustainability and Environment, Melbourne.

Fleay D. (1968). *Nightwatchmen of bush and plain.* Jacaranda, Brisbane.

Forsman E.D., Kaminski T.J., Lewis J.C., Maurice K.J., Sovern S.G., Ferland C. and Glenn E.M. (2005). Home range and habitat use of northern spotted owls on the Olympic Peninsula, Washington. *Journal of Raptor Research*, 39, 365-377.

Ganey J.L. and Balda R.P. (1989). Home-range characteristics of Spotted Owls in Northern Arizona. *Journal of Wildlife Management*, 53, 1159-1165.

Ganey J.L., Block W.M., Jenness J.S. and Wilson R.A. (1999). Mexican Spotted Owl home range and habitat use in Pine-Oak forest: implications for forest management. *Forest Science*, 45, 127-135.

Garnett S. (1992). *Threatened and extinct birds of Australia.* Royal Australian Ornithological Union Melbourne.

Garnett S.T., Loyn R.H. and Lowe K. (2003). *Loss of hollow-bearing trees from Victorian native forests and woodlands. Action Statement, No. 192.* Department of Sustainability and Environment, Melbourne.

Gibbons P. (1999). Habitat-tree retention in wood production forests. PhD thesis, Australian National University Canberra.

Gibbons P. and Lindenmayer D. (2002). *Tree hollows and wildlife conservation in Australia.* CSIRO Publishing, Collingwood, Victoria.

Gill A.M. and Catling P.C. (2002). Fire regimes and biodiversity of forested landscapes of southeastern Australia. In: *Flammable Australia: The fire regimes and biodiversity of a continent* (eds. Bradstock RA, Williams JE and Gill AM). Cambridge University Press Cambridge, pp. 351-369.

Glenn E.M., Hansen M.C. and Anthony R.G. (2004). Spotted owl home-range and habitat use in young forests of western Oregon. *Journal of Wildlife Management*, 68, 33-50.

Higgins P. (1999). *Handbook of Australian, New Zealand and Antarctic birds, Volume 4: Parrots to Dollarbird.* Oxford University Press, Melbourne.

Hogan F.E. (2007). DNA fingerprinting the Powerful Owl (*Ninox strenua*). PhD thesis, Deakin University Melbourne.

Hollands D. (1991). *Birds of the night.* Reed Books, Sydney, Australia.

Hollands D. (2004). *Owls, journeys around the world.* Bloomings Books, Melbourne.

Hollands D. (2008). *Owls, frogmouths and nightjars of Australia.* Bloomings Books, Richmond, Victoria.

Holmes G. (1994). Prey of the Sooty Owl in subtropical Australia. *Sunbird*, 24, 25-27.

Hyem E.L. (1979). Observations on the owls in the upper Manning River District N.S.W. *Corella*, 3, 17-25.

Isaac B., Cooke R., Simmons D. and Hogan F. (2008). Predictive mapping of Powerful Owl (Ninox strenua) breeding sites using Geographical Information Systems (GIS) in urban Melbourne, Australia. *Landscape and Urban Planning*, 84, 212-218.

Johnson C.N. (2006). *Australia's Mammal Extinctions: A 50 000 year history.* Cambridge University Press, Melbourne.

Kambouris P. (2000). Large forest owls in Special Management Zones, East Gippsland Forest Management Area. East Gippsland Flora and Fauna Group Report No.8. Department of Natural Resources and Environment Orbost, Victoria.

Kavanagh R.P. (1984). Seasonal changes in habit use by gliders and possums in southeastern New South Wales. In: *Possums and Gliders* (eds. Smith AP and Hume ID). Australian Mammal Society Sydney, pp. 527-543.

Kavanagh R.P. (1997). Ecology and management of large forest owls in south-eastern Australia. PhD thesis, University of Sydney.

Kavanagh R.P. (2000). Effects of variable-intensity logging and the influence of habitat variables on the distribution of the Greater Glider *Petauroides volans* in montane forest, southeastern New South Wales. *Pacific Conservation Biology*, 6, 18-30.

Kavanagh R.P. (2002a). Comparative diets of the Powerful Owl (*Ninox strenua*), Sooty Owl (*Tyto tenebricosa*) and masked owl (*Tyto novaehollandiae*) in southeastern Australia. In: *Ecology and conservation of owls* (eds. Newton I, Kavanagh RP, Olsen J and Taylor I). CSIRO Publishing Melbourne, pp. 175-191.

Kavanagh R.P. (2002b). Conservation and management of large forest owls in southeastern Australia. In: *Ecology and conservation of owls* (eds. Newton I, Kavanagh RP, Olsen J and Taylor I). CSIRO Publishing Melbourne, pp. 201-219.

Kavanagh R.P. (2004). Conserving owls in Sydney's urban bushland: current status and requirements. In: *Urban Wildlife: More than Meets the Eye* (eds. Lunney D and Burgin S). Royal Zoological Society of New South Wales Mosman, pp. 93-108.

Kavanagh R.P. and Bamkin K.L. (1995). Distribution of nocturnal forest birds and mammals in relation to the logging mosaic in south-eastern New South Wales, Australia. *Biological Conservation*, 71, 41-53.

Kavanagh R.P., Debus S., Tweedie T. and Webster T. (1995). Distribution of nocturnal forest birds and mammals in north-eastern New South Wales: Relationships with environmental variables and management history. *Wildlife Research*, 22, 359-377.

Kavanagh R.P. and Peake P. (1993). Distribution and habits of nocturnal forest birds in south eastern New South Wales. In: *Australian Raptor Studies* (ed. Olsen P). Australian Raptor Association, RAOU Melbourne, pp. 101-125.

Kavanagh R.P. and Stanton M.A. (2002). Response to fragmentation by the Powerful Owl (*Ninox strenua*), Sooty Owl (*Tyto tenebricosa*), Masked Owl (*Tyto novaehollandiae*) and other nocturnal fauna in southeastern Australia. In: *Ecology and conservation of owls* (eds. Newton I, Kavanagh RP, Olsen J and Taylor I). CSIRO Publishing Melbourne, pp. 265-276.

Kavanagh R.P. and Webb G.A. (1998). Effects of variable-intensity logging on mammals, reptiles and amphibians at Waratah Creek, southeastern New South Wales. *Pacific Conservation Biology*, 4, 326-347.

Keith D.A., Williams J.E. and Woinarski J.C.Z. (2002). Fire management and biodiversity conservation: key approaches and principals. In: *Flammable Australia: The fire regimes and biodiversity of a continent* (eds. Bradstock RA, Williams JE and Gill AM). Cambridge University Press Cambridge, pp. 401-425.

Kruger O. (2005). The evolution of reversed sexual size dimorphism in hawks, falcons and owls: A comparative study. *Evolutionary Ecology*, 19, 467-486.

Kutt A.S. (1994). Arboreal marsupials and nocturnal birds in thinned regrowth, un-thinned regrowth and old lowland forest, East Gippsland, Victoria. *Australian Forestry*, 57, 123-130.

Lindenmayer D.B. and Franklin J.F. (2002). *Conserving forest biodiversity: a comprehensive multiscaled approach*. Island Press, Washington, D.C.

Lindenmayer D.B., Cunningham R.B. and Donnelly C.F. (1997). Decay and collapse of trees with hollows in eastern Australian forests: Impacts on arboreal marsupials. *Ecological Applications*, 7, 625-641.

Lindenmayer, D.B., Hunter, M.L., Burton, P.J. and Gibbons, P. (2009). Effects of logging on fire regimes in moist forests. Conservation Letters (in-press)

Loyn R.H. (2004). Research for ecologically sustainable forest management in Victorian Eucalypt forests. In: *Conservation of Australia's forest fauna: Second edition* (ed. Lunney D). Royal Zoological Society of New South Wales Mosman, NSW, pp. 783-806.

Loyn R.H., McNabb E.G., Volodina L. and Willig R. (2001). Modelling landscape distributions of large forest owls as applied to managing forests in north-east Victoria, Australia. *Biological Conservation*, 97, 361-376.

Loyn R.H., Traill B.J. and Triggs B.E. (1986). Prey of the Sooty Owl in East Gippsland Victoria Australia before and after fire. *The Victorian Naturalist* 103, 147-149.

Lundie-Jenkins G. (1993). The diet of the Sooty Owl *Tyto tenebricosa* in the Blue Mountains, NSW. *Emu*, 93, 124-127.

Lunney D. (1987). Effects of logging, fire and drought on possums and gliders in the coastal forests near Bega, NSW. *Australian Wildlife Research*, 16, 207-215.

Lunney D., Cullis B. And Eby, P. (1987). Effects of logging and fire on small mammals in Mumbulla State Forest. Near Bega, New South Wales. *Australian Wildlife Research* 14, 163-181

Lunney D., Matthews A., Eby P. and Penn A.M. (2009). The long-term effects of logging for woodchips on small mammal populations. *Wildlife Research* 36, 691-701

McCarthy M.A., Webster A., Loyn R.H. and Lowe K.W. (1999). Uncertainty in assessing the viability of the Powerful Owl Ninox strenua in Victoria, Australia. *Pacific Conservation Biology*, 5, 144-154.

McIntyre A. and Henry S.R. (2002). Large forest owl conservation in the East Gippsland Forest Management Area, Victoria. In: *Ecology and conservation of owls* (eds. Newton I, Kavanagh RP, Olsen J and Newton I). CSIRO Publishing Melbourne, pp. 220-232.

McKinty J.A. (1969). Forestry in East Gippsland. In. *Proceedings of the Royal Society of Victoria, East Gippsland Symposium,* pp. 129-139.

McNabb E.G. (1996). Observations on the biology of the Powerful Owl *Ninox strenua* in southern Victoria. *Australian Bird Watcher*, 16, 267-295.

McNabb E.G., Kavanagh R.P. and Craig S.A. (2007). Further observations on the breeding biology of the Powerful Owl Ninox strenua in south-eastern Australia. *Corella*, 31, 6-9.

Meek P.D. and Triggs B. (1998). The food of foxes, dogs and cats on two peninsulars in Jervis Bay, New South Wales. *Proceedings of the Linnaean Society of New South Wales*, 120, 117-127.

Menkhorst P.W. (1995). *Mammals of Victoria: distribution, ecology and conservation.* Oxford University Press, Melbourne.

Mooney N. (1993). Diet of the Masked Owl in Tasmania: past and present. In: *Australian Raptor Studies* (ed. Olsen P). RAOU Melbourne, pp. 160-174.

Murray A.J., Poore R.N. and Dexter N. (2006). Project Deliverance - the response of 'critical weight range' mammals to effective fox control in mesic forest habitat in far East Gippsland, Victoria. Department of Sustainability and Environment Melbourne.

Mueck S.G. and Peacock R. (1992) Impacts of intensive timber harvesting on the forests of East Gippsland, Victoria. VSP technical report no. 15. Department of Conservation and Environment, Melbourne, Australia.

Norman J.A., Christidis L., Joseph L., Slikas B. and Alpers D. (2002). Unravelling a biogeographical knot: origin of the 'leapfrog' distribution pattern of Australo-Papuan Sooty Owls (Strigiformes) and logrunners (Passeriformes). *Proceedings of the Royal Society of London Series B-Biological Sciences*, 269, 2127-2133.

Olsen P. (1998). Australia's raptors: diurnal birds of prey and owls. In: *Birds Australia Conservation Statement No. 2.* Birds Australia Melbourne, Australia.

Pavey C.R. (1995). Food of the Powerful Owl *Ninox strenua* in suburban Brisbane, Queensland. *Emu*, 95, 231-232.

Pavey C.R. (2008). Evolution of prey holding behaviour and large male body size in Ninox owls (Strigidae). *Biological Journal of the Linnaean Society*, 95, 284-292.

Pavey C.R., Smyth A.K. and Mathieson M.T. (1994). The breeding season diet of the Powerful Owl *Ninox strenua* at Brisbane, Queensland. *Emu*, 94, 278-284.

Peel B., Bilney R.J. and Bilney R.J. (2005). Observations of the ecological impacts of Sambar *Cervus unicolor* in East Gippsland, Victoria, with reference to destruction of rainforest communities. *The Victorian Naturalist*, 122, 189-200.

Pressey B. (1995). Conservation Reserves in NSW, Crown jewels or leftovers? *Search*, 26, 47-51.

Roberts M.W., Dexter N., Meek P.D., Hudson M. and Buttemer W.A. (2006). Does baiting influence the relative composition of the diet of foxes? *Wildlife Research*, 33, 481-488.

SAC (2001). *Final recommendation on a nomination for listing: High frequency fire resulting in disruption of life cycle processes in plants and animals and loss of vegetation structure and composition (Potentially Threatening Process)(Nomination no. 565). Scientific Advisory Committee, Flora and Fauna Guarantee.* Department of Natural Resources and Environment, Melbourne.

SAC (2003). *Final Recommendation on a nomination for listing: Inappropriate fire regimes causing disruption to sustainable ecosystem processes and resultant loss of biodiversity (Potentially Threatening Process)(Nomination no. 664) Scientific Advisory Committee, Flora and Fauna Guarantee.* Department of Sustainability and Environment, Melbourne.

SAC (2007). *Final recommendation on a nomination for listing: Reductions in biodiversity of native vegetation by Sambar (Cervus unicolor). Potentially Threatening Process (Nomination no. 756). Flora and Fauna Guarantee, Scientific Advisory Committee.* Department of Sustainability and Environment, Melbourne.

Schodde R. and Mason I.J. (1980). *Nocturnal birds of Australia*. Lansdowne, Melbourne.

Scotts D.J. (1991). Old-growth forests: their ecological characteristics and value to forest-dependant vertebrate fauna of south-east Australia. In: *Conservation of Australia's Forest Fauna* (ed. Lunney D). Royal Zoological Society of New South Wales Mosman, NSW, pp. 147-159.

Seebeck J. (1976). The diet of the Powerful Owl, *Ninox strenua*, in western Victoria. *EMU*, 76, 167-170.

Short J. (1998). The extinction of rat-kangaroos (Marsupialia: Potoroidae) in New South Wales, Australia. *Biological Conservation*, 86, 365-377.

Short J. and Smith A. (1994). Mammal decline and recovery in Australia. *Journal of Mammalogy*, 75, 288-297.

Silveira C.E., Clemann N. and Loyn R.H. (2003). Sooty Owl *Tyto tenebricosa*. FFG Action Statement. Department of Natural Resources and Environment Melbourne.

Simberloff D. (1987). The spotted owl fracas: Mixing academic, applied, and political ecology. *Ecology*, 68, 766-772.

Smith A.P. and Lindenmayer D. (1988). Tree hollow requirements of Leadbeater's Possum and other possums and gliders in timber production ash forests of the Victorian central highlands *Australian Wildlife Research*, 15, 347-362.

Smith P. (1984). Prey items of the Sooty Owl and Barn Owl at Bega, New South Wales. *Corella*, 8, 71-72.

Soderquist T. and Gibbons D. (2007). Home-range of the Powerful Owl (*Ninox strenua*) in dry sclerophyll forest. *Emu*, 107, 177-184.

Sunde P. and Bolstad M.S. (2004). A telemetry study of the social organisation of a tawny owl (*Strix aluco*) population. *Journal of Zoology*, 263, 65-76.

Tilley S. (1982). The diet of the Powerful Owl, *Ninox strenua*, in Victoria. *Australian Wildlife Research*, 9, 157-175.

Traill B.J. (1993). The diet and movements of a pair of Powerful Owls *Ninox strenua* in dry eucalypt forest. In: *Australian Raptor Studies* (ed. Olsen P). Royal Australian Ornithological Union Melbourne, pp. 155-159.

Triggs B., Brunner H. and Cullen J.M. (1984). The food of the fox, dog and cat in Croajingalong National Park, south-eastern Victoria. *Australian Wildlife Research*, 11, 491-499.

Tyndale-Biscoe C.H. and Smith R.F.C. (1969). Studies on the marsupial glider, *Schoinobates volans* (Kerr). III. Response to habitat destruction *Journal of Animal Ecology*, 38, 651-659.

Van Dyck S. and Gibbons D. (1980). Tuan predation by Powerful Owls. *The Victorian Naturalist*, 97, 58-63.

Wallis R., Cooke R. and Webster A. (1998). Diet of Powerful Owls *Ninox strenua* in the Yarra Valley, Victoria. *Australian Bird Watcher*, 17, 395-397.

Webster A., Humphries R. and Lowe K. (1999). Powerful Owl *Ninox strenua*. Action Statement, No. 92. Department of Natural Resources and Environment Melbourne.

Wilson B.A. and Friend G.R. (1999). Responses of Australian mammals to disturbance: A review. *Australian Mammalogy*, 21, 87-105.

Wintle B.A., Kavanagh R.P., McCarthy M.A. and Burgman M.A. (2005). Estimating and dealing with delectability in occupancy surveys for forest owls and arboreal marsupials. *Journal of Wildlife Management*, 69, 905-917.