Do ecosystems need top predators? A brief review of predator-prey imbalances in south-east Australia with reference to tree dieback on the Mornington Peninsula

By Jeff Yugovic, 6 May 2014

Jeff Yugovic is a senior consultant ecologist with Biosis Pty Ltd
(PO Box 489, Port Melbourne, Victoria 3207, Australia;Email: jyugovic@biosis.com.au)

Summary

The role of top predators in regulating terrestrial ecosystems in south-east Australia is briefly reviewed here. Examples of ecological imbalance associated with overabundant native herbivores are identified. The Mornington Peninsula tree dieback phenomenon, which involves overbrowsing by Common Ringtail Possum, is discussed. Due to the widespread loss of native top predators, in many areas we are left with two unsatisfactory introduced mesopredators, the fox and cat, to regulate herbivores. They have low efficiency in controlling ringtail possums in dense vegetation, and furthermore, without the top predator dingo they may be ecologically released, increasing their impact on sensitive fauna. Management approaches to keeping a balance between predators and herbivores are outlined.

Introduction

Many ecosystems are influenced or shaped by apex or top predators. Large carnivores can control populations of smaller mesopredators and herbivores, preventing them from monopolising or destroying resources needed for overall biodiversity (see Stolzenburg 2008).

This article explores whether top predators play or previously played a role in regulating terrestrial ecosystems in south-east Australia by controlling mesopredators and herbivores.

It is suggested that alien mesopredators have partly replaced the original top predators and mesopredators, and despite their drawbacks they continue the ecological function of herbivore control. Where herbivores, native or introduced, are not top-down controlled by predators, they may be bottom-up controlled by starvation and ecosystems can collapse.

Original top predators and mesopredators of south-east Australia

The original (pre-European) top terrestrial predators of south-east Australia include:

Table 1. Original major top predators of south-east Australia.

Species	Status (Victoria, based on DSE 2013)
Dingo *Canis lupus dingo* (alien species) (Figure 1)	Fragmented, data deficient
Thylacine *Thylacinus cynocephalus*	Extinct
Wedge-tailed Eagle *Aquila audax*	Widespread, secure
Peregrine Falcon *Falco peregrinus*	Widespread, secure
Powerful Owl *Ninox strenua* (Figure 3)	Fragmented, vulnerable
Lace Monitor (Figure 2) *Varanus varius*	Fragmented, endangered

Figure 1. Dingo

Figure 2. Lace Monitor

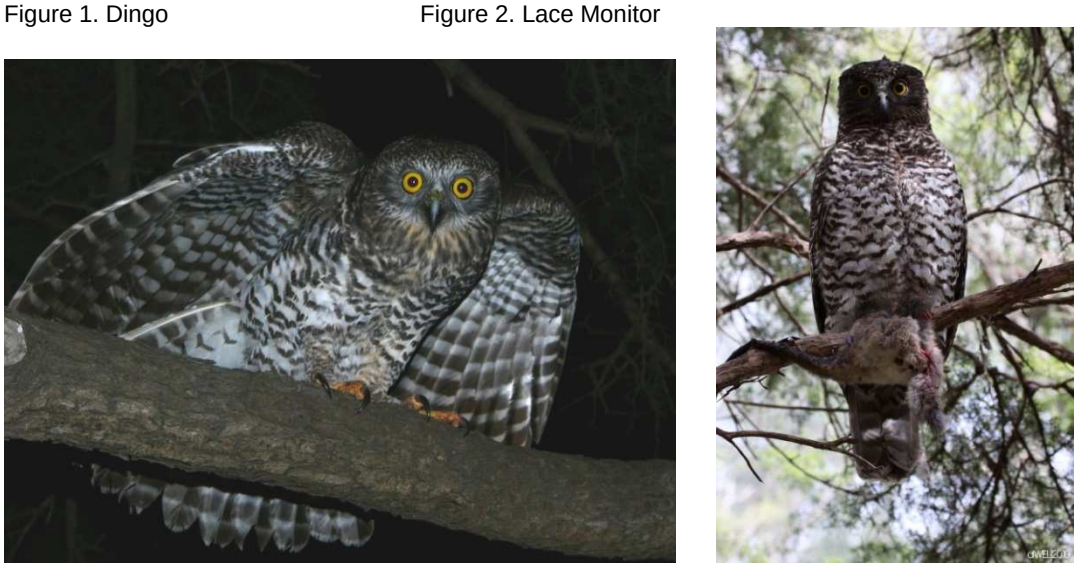

Figure 3. Powerful Owl with a favourite prey item, Common Ringtail Possum.

The original terrestrial mesopredators include:

Table 2. Original major mesopredators of south-east Australia.

Species	Status (Victoria)
Spot-tailed Quoll *Dasyurus maculatus* (Figure 4)	Fragmented, endangered
Eastern Quoll *Dasyurus viverrinus* (Figure 5)	Regionally extinct (extant in Tasmania)
Western Quoll *Dasyurus geoffroii*	Regionally extinct (extant in WA where threatened)
Tasmanian Devil *Sarcophilus harrisii* (could be considered a top predator)	Restricted to Tasmania where threatened

Figure 4. Spot-tailed Quoll, a predator of possums.

Figure 5. Eastern Quoll, a predator of rats.

Perhaps the ultimate predators were humans. Through hunting and also by imposing fire regimes (see Gammage 2011), Aborigines greatly influenced animal populations. In south-east Australia they traditionally hunted marsupial herbivores and wore brushtail possum skin cloaks. They may have preyed on dingoes as in Western Australia where the puppies were regarded as a delicacy although they were sometimes reared by the Aborigines for hunting (Meagher 1974). Early Europeans were also major predators of marsupials.

Long gone are the Pleistocene giant top carnivores *Thylacoleo*, *Megalania* and *Wonambi* and many of their large prey such as *Diprotodon*. After the extinction of much of the megafauna and later arrival of the Dingo, south-east Australia had a simplified food web until the arrival of Europeans with their introduced predators and herbivores.

Present day predators

Most of the native top terrestrial predators and mesopredators of south-east Australia are extinct or their populations are mostly fragmented and reduced. The Dingo is still the top ground dwelling predator in remote eastern Victoria and adjacent NSW. However, due to persecution it is now absent from most of its former range. Arriving several thousand years ago, the Dingo may have replaced the Thylacine on the mainland. The Dog *Canis lupus familiaris* is widespread and feral dogs are subject to a government bounty.

Two introduced mesopredators are widespread and abundant in south-east Australia and in the effective absence of native top predators are surrogate top predators in some areas:

- Red Fox *Vulpes vulpes*
- Cat *Felis catus*

Native herbivores that may become overabundant without predators

Under low predator pressure, several native herbivorous mammals may increase and become overabundant in areas of south-east Australia, that is, they cause an ecological imbalance leading to loss of species diversity. They include:

Table 3. Native herbivores associated with ecological imbalance.

Species	Original major predators	Examples of ecological imbalance
Common Ringtail Possum *Pseudocheirus peregrinus*	Powerful Owl, Spot-tailed Quoll, Aborigines	Tree canopy loss on northern Mornington Peninsula
Common Brushtail Possum *Trichosurus vulpecula*	Thylacine, Dingo, Spot-tailed Quoll, Lace Monitor, Aborigines	Tree canopy loss in River Red-gum woodland on fringes of Melbourne
Eastern Grey Kangaroo *Macropus giganteus*	Thylacine, Dingo, Aborigines	Overgrazing inside predator exclosures and by very high unrestrained populations in many locations in Victoria, especially on urban fringes
Western Grey Kangaroo *Macropus fuliginosus*	Dingo, Aborigines	Loss of plant diversity in Mallee national parks and reserves
Black Wallaby *Wallabia bicolor*	Dingo, Aborigines	Loss of plant diversity within predator exclosure, Royal Botanic Gardens Cranbourne
Koala *Phascolarctos cinereus*	Dingo, Aborigines	Tree canopy loss in several locations in Victoria
Swamp Rat *Rattus lutreolus*	Eastern Quoll, ?Aborigines	Widespread loss of orchid populations on Mornington Peninsula

Case studies

Koala

Overabundant Koala populations impact on their habitat by overbrowsing preferred food tree species in a few coastal areas and some islands of Victoria including Mount Eccles, Framlingham Forest, the Otway Ranges (Figure 6), French Island and Snake Island (Menkhorst 2008). Coast Manna Gum *Eucalyptus viminalis* subsp. *pryoriana* is particularly at risk, but Koalas can also impact on Swamp Gum *Eucalyptus ovata*, Southern Blue-gum *Eucalyptus globulus* and River Red-gum *Eucalyptus camaldulensis*.

The Koala overpopulation problem has been much studied (for example Martin 1985a,b, Menkhorst 2008, Todd et al. 2008, Wallis 2013). The Victorian government has moved away from translocation as a management technique and is now using in situ chemical sterilisation to manage overabundant populations in several locations (Menkhorst 2004, 2008).

Several factors control Koala populations, notably predators, road kill, fire, disease and food supply. There is evidence that predation by Aborigines and Dingoes kept Koala numbers very low prior to European settlement (Strahan and Martin 1982, Menkhorst 1995).

Figure 6. Southern Blue-gum forest defoliated by Koala overbrowsing, Kennett River, Otway Ranges.

Possums

Common Ringtail Possum and Common Brushtail Possum are widespread primarily folivorous mammals that feed on many eucalypt and other species. Tree canopy loss due to mammal overbrowsing was not described when the vegetation of Victoria was in its 'original and natural' condition (see Hateley 2010) and seems to have developed since European arrival. As early as the 1870s Aborigines at Framlingham in western Victoria were 'accusing' brushtail possums of killing trees: 'The possums were no longer hunted and their numbers had risen… Possums also benefited when dingoes were culled.' (Low 2002).

Both possum species have been involved in tree canopy loss in many areas of suburban and rural Victoria (e.g. Yugovic 1999b, Carr in Low 2002). Interestingly, *Eucalyptus viminalis* subsp. *pryoriana* (fully rough-barked form), a common tree in heathy woodland in southern Victoria, is relished by Koalas but is avoided by possums (author, pers. obs.).

In suburban Mount Eliza on the Mornington Peninsula an overpopulation of ringtail possum is responsible for an ongoing and unprecedented epidemic of eucalypt tree death. All indigenous eucalypts are susceptible but Swamp Gum *Eucalyptus ovata* and Narrow-leaf Peppermint *E. radiata* are preferred by possums and are defoliated and killed first. With up to 16 ringtail possums per hectare, this is the highest density of ringtail possum recorded in natural eucalypt dominated vegetation in Australia. Brushtail possums are at low density for an urban environment. This is evidenced by detailed observations (Ecology Australia 2014) and the recovery of trees following installation of possum bands (Yugovic 2013b)(Figure 7).

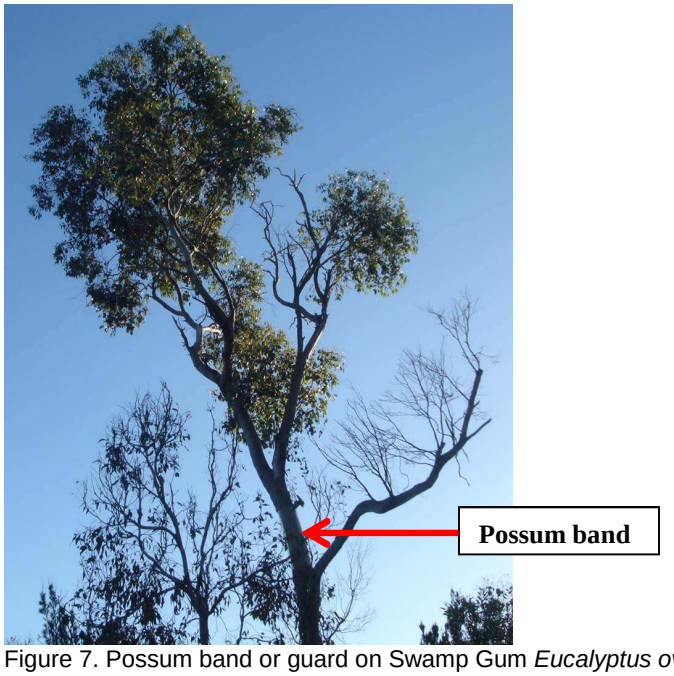

Figure 7. Possum band or guard on Swamp Gum *Eucalyptus ovata*, Mount Eliza. Clear plastic band on trunk (lower centre) protects tree crown from possums while unprotected side limb (on right) has died. Before installation of guard the entire tree was largely defoliated. Recovery took 6–12 months.

Several factors control populations of ringtail possum including availability of shelter, density of understorey vegetation, predation (originally mainly by humans, dingoes, spot-tailed quolls, large raptors and large owls, and now mainly by cats, foxes, large raptors and large owls where they occur), fire, food quality and availability, and heat waves. Ringtails have high fecundity (Kerle 2001) so populations can rapidly reach habitat carrying capacity.

Both possums have higher densities in urban bushland with increased food resources in adjacent residential areas in Melbourne (Harper et al. 2008). This may contribute to high browsing pressure in Mount Eliza but possum induced tree decline extends across the rural northern Mornington Peninsula from Mornington to Cranbourne and was locally severe in the 1990s (e.g. Yugovic 1999a) before it became severe in urban areas. In Mount Eliza, where previously some trees were killed, entire canopies are now dead or dying, and the 'prognosis for the eucalypts remaining in the landscape is extremely poor' (Ecology Australia 2014).

Described locally as an 'ecological emergency', possum overbrowsing and tree decline was occurring in Mount Eliza as early as the 1980s (author, pers. obs.). It continued through the 1990s and 2000s including during the Millennium drought, and became severe during the 2010–2012 extended La Niña event suggesting that high rainfall may be a factor in the possum population increase. However there were successive years of above average rainfall before the drought during 1991–93 (Bureau of Meteorology, Mornington weather station).

Could a predator-prey imbalance between domestic cats and ringtail possums help explain the late onset of the dieback in Mount Eliza? With the native predators long gone, domestic cats were at artificially high densities due to being fed and sheltered by their owners and were the last remaining major predators until 1997 when they largely disappeared from the landscape due to local control policies and programs including a cat curfew. However, given the possum overpopulation developed some 15 years after the cat curfew was introduced, it seems that some factor(s) other than, or in addition to, lack of cats has caused the increase.

Biomass accumulation is a necessary condition for ringtail possum overpopulation and associated tree decline. Ringtails require a buildup of understorey shrubs and small non-eucalypt trees in the mid-storey or sub-canopy layer. The understorey species can be either indigenous or introduced. The possums construct their dreys in these dense understoreys and can avoid travel across the ground between food trees where they are vulnerable to ground-based predators. Dense understoreys are prevalent on the northern Mornington Peninsula.

Unlike much of the Mornington Peninsula, small tree and shrub cover was low in several of Mount Eliza's bushland reserves in the 1990s (e.g. Yugovic 1995) due to woody weed control carried out by the Mount Eliza Association for Environmental Care over the previous 20 years. This management largely ceased or slowed in the late 1990s and by the 2010s the reserves were generally dense with high native and introduced woody cover. This buildup appears to have contributed to the ringtail possum increase. Biomass reduction in the form of woody weed removal and ecological thinning undertaken by the Shire and local conservation groups has resumed in some reserves in recent years, which is likely to benefit canopy trees.

However, in addition to bushland remnants, street and garden trees in Mount Eliza with unmanaged understoreys are also now severely affected by possum overbrowsing (Ecology Australia 2014). This may be attributable to a general increase in understory biomass on road reserves and in adjacent gardens over time, with the 2010–2012 extended La Niña stimulating growth of the eucalypts and understorey being a possible contributing non-causal factor.

The grassy woodlands of the northern Mornington Peninsula were once much more open than the bushland remnants and gardens of today as evidenced by annotations on historical survey plans. This was likely due to Aboriginal burning and macropod grazing and browsing (Yugovic 2013a). It follows that ringtail habitat carrying capacity was limited at that time which would have assisted in keeping woodland canopies healthy. The carrying capacity is higher now with the mostly dense unburnt and ungrazed understoreys – until the canopy dies.

The northern Mornington Peninsula tree dieback phenomenon is a syndrome of high biomass accumulation and low predator pressure. Low predator pressure is a second necessary condition – if there was high predator pressure there would be no possum overpopulation. However, this assumes the original full suite of predators could control ringtail possums in dense vegetation. The lack of early reports of possum induced tree decline in Victoria and reports of dense understoreys in many areas at the time (Hateley 2010) suggest that they could. The Powerful Owl and Spot-tailed Quoll were likely to be important in particular. Aerial and arboreal predators are now effectively missing from the current predator regime.

Furthermore many areas elsewhere in south-east Australia including sites supporting Swamp Gum currently have dense understoreys and native and introduced predators (Victorian Biodiversity Atlas, data) with ringtail possums and tree canopies in balance. Certainly the best management response on the northern Mornington Peninsula now is to reopen understoreys as culling of possums and reintroducing predators are impractical. This also has benefits for groundlayer flora diversity, which slowly declines under shady scrub.

In the Melbourne region, however, large River Red-gums *Eucalyptus camaldulensis* with open grassy understoreys have been killed by brushtail possums that den in natural hollows. Dense understoreys are not needed by the less arboreal (scansorial) brushtails.

Discussion

It is widely accepted that introduced predators threaten many native species in south-east Australia, particularly mammals (e.g. Dickman 1996), but how does predator pressure differ now from originally? Often a predisposing problem underlying local extinction is isolation of habitat which is either natural or more usually is caused by land clearing and disturbance. Would the original suite of predators cause the same local extinctions if they were still present? These and similar questions of predator ecology need further research.

Based on extensive observations, it appears that in some areas the introduced predators are not, or are not capable of, keeping up with key native and introduced herbivores (such as rabbits) which are overabundant and causing ecological damage. Depending on the situation, low predation rates are partly due to predator inefficiency (for example the fox and cat have low efficiency with ringtail possum in dense mid-layer vegetation), and partly due to control which may in some cases leave some areas effectively without predators.

For example, Mount Eliza has bushland reserves where there are no threatened species and possums and swamp rats are the only native mammals apart from bats and occasional sugar gliders, and where cats are largely absent due to the local cat curfew. Foxes and cats are also actively controlled. These effectively predator free areas are undergoing eucalypt canopy loss caused by possums and orchid colony losses caused by swamp rats (Yugovic 2013b). In these unusual situations removing all predators when possums are killing the canopy trees and dependent species including sugar glider and orchids are going locally extinct is questionable.

Systems without top predators are likely to undergo trophic imbalance with adverse ecological cascade effects on flora and fauna (see Stolzenberg 2008). Whether the predators or prey are native or introduced during trophic imbalance seems to make little difference to overall biodiversity – overabundant herbivores, native or introduced, inevitably degrade ecosystems. Current land management is pushing systems towards domination by browsing and grazing mammals, with other influences such as predation and regular fire being reduced.

A feature of the introduced mesopredators is their apparently higher predation rates on certain native species compared to the original suite of predators, for example the fox appears to have eliminated the pademelon on mainland Australia. This increased predation may be related to particular efficiencies in new predator-prey relationships, but may also be related to 'mesopredator release' (Crooks and Soulé 1999). Mesopredator release is thought to operate extensively in Australia in areas where the top predator Dingo is rare or absent, resulting in higher mesopredator populations and predation rates (Johnson et al. 2007).

For example, outside the 5,600 km arid zone dingo fence dingoes appear to suppress fox populations and thereby assist small to medium native mammals (Letnic et al. 2009). Similarly, there is evidence from south-east Australia that dingoes suppress macropods and foxes and thus generate strong indirect and beneficial effects on the prey of foxes (Letnic et al. 2009). This suggests that mesopredator release of the fox operates extensively in south-east Australia where dingoes are absent, to the detriment of small and medium mammals.

An interesting predator manipulation experiment in semi-arid WA found that when dingoes and foxes were both removed cats increased and predation on small mammals increased further (Risbey et al. 2000), suggesting a hierarchy of predators (dingo, fox, cat) and ecological release processes. As the authors acknowledge, this needs replication. The evidence for an increase in cat abundance following fox control is inconsistent between studies, and there is also limited knowledge on the impacts of feral cats and foxes on native predators (Robley et al. 2004). Interactions between predators such as aggression, competition for prey and predation on juveniles need further research.

According to proponents, 'rewilding' with apex predators has benefits for ecosystem stability and diversity (e.g. Soulé and Nos 1998, Monbiot 2013). The predators are either regionally extinct or are related to extinct Pleistocene predators. For example Komodo dragon could replace *Megalania* in order to control feral water buffalo in northern Australia (Flannery 1994, Bowman 2012). However, many people would find it unacceptable to replace extinct marsupial predators with placental predators such as large cats in south-east Australia, although they could provide a means of controlling populations of feral pigs, horses and deer.

Flannery (1994) also proposes reintroducing the long extinct Tasmanian Devil to mainland Australia where it could play a role in checking foxes and cats. Devils are thought to enter fox dens and eat the cubs (DSEWPaC 2012), which may explain why fox introductions to Tasmania have not been successful. Devils also prey on possums. There have been moves to reintroduce devils to Wilsons Promontory but no program has been formalised.

Conclusion

Many ecosystems in south-east Australia appear to benefit from or require top predators in maintaining stability and complexity as do ecosystems elsewhere (see Stolzenburg 2008). Whether the introduced mesopredators have net benefits is an open question given their high toll on native wildlife but they do carry on the necessary function of herbivore control.

Unlike North America and Europe where top predators such as wolves, lynx, cougars, jaguars and bears are being returned to ecosystems with beneficial effects, the return of the dingo is impractical in much of Victoria as it can prey on livestock and interbreed with domestic dogs to produce packs of wild dogs. However the dingo survives in remote eastern Victoria.

Due to the widespread loss of native top predators and mesopredators, in many areas we are left with two unsatisfactory introduced mesopredators (the fox and cat) to control herbivores. They have low efficiency in controlling ringtail possums in dense understorey vegetation, and furthermore, without the top predator dingo they appear to be ecologically released, increasing their impact on sensitive fauna.

Some suggested management approaches to maintaining a balance between predators and herbivores are as follows:

- Land managers should be aware of the complexities of predator ecology and feral animal control, and should anticipate and look for ecosystem responses including changes in herbivore pressure on vegetation.
- Predator control should be undertaken strategically where identified significant fauna are under identified predator threat, in combination with monitoring of canopy health, sensitive plant populations and other ecological indicators.
- Where necessary, large trees should be protected from mammal folivores, especially in prominent locations. This is happening in Mount Eliza with the Mornington Peninsula Shire installing possum bands on trees on roadsides and in reserves, with excellent results.
- Due to their potential detrimental effect on canopy trees, constructed nest boxes for brushtail and ringtail possums are often not appropriate. Release of rescued or trapped possums into bushland should not be undertaken where habitats are already at carrying capacity for possums. The protected status of these species in areas with possum induced tree decline should be reviewed in order to protect trees and biodiversity, with a view to extending the current permission to trap brushtail possums to include ringtail possums.
- Managing woodlands towards their original open structure through biomass reduction counters the impact of ringtail possums by reducing habitat carrying capacity.
- We should redouble our efforts to protect all native apex predators in order to allow these keystone species to perform their important ecological role of controlling herbivore pressure within natural areas.

Acknowledgments
Thanks to Ian Lunt and Peter Menkhorst for valuable comments and suggestions.

Photo credits
Figure 1: Peter Menkhorst, Figure 2: Dan Gilmore, Figure 3: Andrew McCutcheon, Dan Weller, Figure 4: Dan Gilmore, Figure 5: OzAnimals.com, Figure 6: Peter Menkhorst

References

Bowman D. M. J. S. (2012) Bring elephants to Australia? *Nature* **482** (7383), 30–30.

Crooks K. R. and Soulé M. E. (1999) Mesopredator release and avifaunal extinctions in a fragmented system. *Nature* **400**, 563–566.

Dickman C. (1996) Overview of the impacts of feral cats on Australian native fauna. Australian Nature Conservation Agency, Canberra.

DSE (2013) Advisory list of threatened vertebrate fauna in Victoria. Victorian Government Department of Sustainability and Environment, Melbourne.

DSEWPaC (2012) Species Profile and Threats Database: *Sarcophilus harrisii* – Tasmanian Devil. Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Ecology Australia (2014) Evaluation of tree dieback in Mount Eliza, Mornington Peninsula, Victoria. Authors: Carr G., Schmidt B., Quin D. and Sutton F. Report to Mornington Peninsula Shire Council, Ecology Australia Pty Ltd, Fairfield, Victoria.

Flannery T. (1994) *The Future Eaters: An Ecological History of the Australasian Lands and People*. Reed Books Australia.

Gammage B. (2011) *The Biggest Estate on Earth: How Aborigines Made Australia*. Allen & Unwin.

Harper M. J., McCarthy M. A. and van der Ree R. (2008) Resources at the landscape scale influence possum abundance. *Austral Ecology* **33**, 243–252.

Hateley R. F. (2010) *The Victorian Bush: Its 'Original and Natural Condition'*. Polybractea Press, Melbourne.

Johnson C. N., Isaac J. L. and Fisher D. O. (2007) Rarity of a top predator triggers continent-wide collapse of mammal prey: dingoes and marsupials in Australia. *Proc. R. Soc. B* **274**, 341–346.

Kerle J. A. (2001) *Possums: The Brushtails, Ringtails and Greater Glider*. UNSW Press.

Letnic M., Baker L. and Nesbitt B. (2009) Keystone effects of an alien top-predator stem extinctions of native mammals. *Proc. R. Soc. B* **276**, 3249–3256.

Low T. (2002) *The New Nature.* Viking.

Martin R.W. (1985a) Overbrowsing and decline of a population of the koala, *Phascolarctos cinereus*, in Victoria. I. Food preference and food tree defoliation. *Wildlife Research* **12**, 355–365.

Martin R.W. (1985b) Overbrowsing and decline of a population of the koala, *Phascolarctos cinereus*, in Victoria. III. Population condition. *Wildlife Research* **12**, 377–385.

Meagher S. J. (1974). The food resources of the Aborigines of the south-west of Western Australia. *Rec. West. Aust. Mus.* **3(1)**,14–65.

Menkhorst P. W. (1995) *Mammals of Victoria: Distribution, Ecology and Conservation*. Oxford University Press, Melbourne.

Menkhorst P. (2004) Victoria's koala management strategy. Department of Sustainability and Environment, Victoria.

Menkhorst P. (2008) Hunted, marooned, re-introduced, and contracepted: A history of Koala management in Victoria. In *Too Close for Comfort: Contentious Issues in Human-wildlife Encounters*, Eds D. Lunney, A. Munn and W. Meikle, pp. 73–92, Royal Zoological Society of NSW, Mosman, NSW.

Monbiot G. (2013) *Feral: Rewilding the Land, Sea and Human Life*. Allen Lane.

Risbey D. A., Calver M. C., Short J., Bradley J. S. and Wright I. W. (2000) The impact of cats and foxes on the small vertebrate fauna of Heirisson Prong, Western Australia. II. A field experiment. Wildlife Research **27**, 223–235.

Robley A., Reddiex B., Arthur T., Pech R. and Forsyth D. (2004) Interactions between feral cats, foxes, native carnivores, and rabbits in Australia. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Melbourne.

Stolzenburg W. (2008) *Where the Wild Things Were: Life, Death, and Ecological Wreckage in a Land of Vanishing Predators*. Bloomsbury USA.

Strahan R. and Martin R. W. (1982) The Koala: Little fact, much emotion. In *Species at Risk: Research in Australia*. Eds R. H. Groves and W. D. L. Ride, pp 147–155, Australian Academy of Science, Canberra.

Soulé M. and Nos R. (1998) Rewilding and biodiversity: complementary goals for continental conservation. *Wild Earth* **8** (Fall 1998) 19–28.

Todd C. R., Forsyth D. M. and Choquenot M. (2008) Modelling the effects of fertility control on koala-forest dynamics. *Journal of Applied Ecology* **45**, 568–578.

Wallis R. L. (2013) Koalas *Phascolarctos cinereus* in Framlingham Forest, south-west Victoria: introduction, translocation and the effects of a bushfire. *The Victorian Naturalist* **130**, 37–40.

Yugovic J. (1995) Moorooduc Quarry Flora and Fauna Reserve (Botanical Reference Area): Flora, monitoring program and management recommendations. Report to Mount Eliza Association for Environmental Care, Biosis Research Pty Ltd.

Yugovic J. (1999a) Assessment of proposed water tank, Bittern, Victoria. Report to GHD Pty Ltd, Biosis Research Pty Ltd.

Yugovic J. (1999b) Mount Martha Park, Victoria: Vegetation assessment and management recommendations. Report to Mornington Peninsula Shire Council, Biosis Research Pty Ltd.

Yugovic J. (2013a) Aboriginal fire on the Peninsula, Ron Hately and Bill Gammage. *Newsletter of the Southern Peninsula Indigenous Flora and Fauna Association* **24(4)**, 2–3.

Yugovic J. (2013b) Do ecosystems need top predators? *Indigenotes* **24(1)**, 8–14.