

The impact on native herpetofauna due to traffic collision at the interface between a suburban area and the Greater Blue Mountains World Heritage Area: an ecological disaster?

Danny Wotherspoon^{1,2} and Shelley Burgin^{2,3}

¹ School of Natural Sciences, University of Western Sydney, Locked Bag 1797, South Penrith Distribution Centre, 1797, Australia.

² Abel Ecology, 113 Chapman Parade, Falconbridge, 2776, Australia.

³ Corresponding author: Professor Shelley Burgin, School of Natural Sciences, University of Western Sydney, Locked Bag 1797, South Penrith Distribution Centre, 1797, Australia.

Email: s.burgin@uws.edu.au

ABSTRACT

Vehicle collision resulting in animal mortality is a common daily occurrence, although few studies have considered the impact on herpetofauna in urban areas. Over a 7 year period (2003 - 2010), 1.4 km of suburban streets of Falconbridge that interface with the Greater Blue Mountains World Heritage Area, west of Sydney, was surveyed on foot two to four days a week, typically soon after dawn. Over the period a total of 86 reptiles that represented 20 species: 38% of the lizard and 56% of snake species known from the area were collected as road kills due to collision with vehicles. This equated to approximately one individual per month that was collected across the 7 years. Representatives of six frog species were also identified as road kills (33% of the local frog fauna). In Falconbridge, 20-30 km of 50 km/hr roadways interface with the national park and there are 26 towns within the World Heritage Area. Each of these towns has a network of streets that covers much more than just the perimeter of the town, and there are two major highways that bisect the World Heritage Area. Although an average death rate of one reptile per month may be considered negligible, the cumulative loss of reptiles due to vehicle collision in the region is an ecological disaster.

Key words: reptiles, frogs, World Heritage Area, urban - bushland interface, animal mortality, vertebrate road kill

Introduction

Vehicle collision, resulting in animal mortality, is a common daily occurrence in Australia (Ramp and Roger 2008; Taylor and Goldingay 2004) and beyond (Ashley and Robinson 1996; Glista *et al.* 2007; Smith and Dodd, 2003). Animals ranging in size from invertebrates (e.g., Seibert and Conover 1991) to vertebrates are affected (e.g., macropods – Coulson 1989; Lee and Croft 2008; Ramp and Ben-Ami 2006; Ramp and Roger 2008; birds - Burgin and Brainwood 2005; Loos and Kerlinger 1993; herpetofauna - Glista *et al.* 2007; Langen *et al.* 2009; Szerlag and McRobert 2006).

A substantial number of the previous studies have focused on vehicle collisions with large vertebrates on open roads (e.g., Abu-Zidan *et al.* 2002; Klockeer *et al.* 2006; Lee *et al.* 2004; Ramp and Roger 2008). These studies have often been underpinned by concern for human safety and the associated physical and psychological trauma, and/or property damage, including insurance and economic losses. Such collisions have been responsible for the decline in some populations of native species, including the koala *Phascolarctos cinereus* (ANZECC 1998), Tasmanian devil *Sarcophilus harrisii*, and eastern quoll *Dasyurus viverrinus* (Jones

2000). In addition, a wide range of smaller animals have been reported on, including small mammals, birds, and amphibians (Baker *et al.* 2004; Burgin and Brainwood 2008; Clevenger *et al.* 2003) where the long-term impact on populations is less clear. In general, studies have focused on a single species or limited group of animals, and tend to be based around major transport linkages (e.g., Taylor and Goldingay 2004; Ramp *et al.* 2005), although there are exceptions (e.g., Burgin and Brainwood, 2008).

Less commonly investigated are road kills in peri-urban/urban areas. Exceptions include an investigation of the swamp wallaby *Wallabia bicolor* in southern Sydney (Ramp and Ben-Ami 2006), and deer *Odocoileus* spp. in Edmonton, Canada (Ng *et al.* 2008). Other researchers have investigated a broader range of taxa. For example, Harris *et al.* (2008) surveyed a roadway in the Narrabeen catchment in urban Sydney and reported the numbers of deaths of swamp wallaby, brushtail possum *Trichosurus vulpecula*, and long-nosed bandicoot *Perameles nasuta* but commented on the 'noticeable absence of small fauna'. Brainwood and Burgin (2008) observed that most species found dead on peri-urban roads were native, with approximately equal numbers of mammals and birds.

The main factors that influence fauna mortality on urban/peri-urban roads include distance from vegetative cover, type of road (Clevenger *et al.* 2003), presence/absence of barriers and mown verges, and seasonal activity patterns (Brainwood and Burgin 2008; Clevenger *et al.* 2003) that include a range of behavioural, ecological, and biological behaviours (Fahrig and Rytwinski 2009).

There are 26 towns surrounded by natural vegetation in the Greater Blue Mountains World Heritage Area. Most of these towns are distributed along a highway on the main ridgeline running through the area (Anon. undated). The linear nature of the highway and urban zones in such a vast natural area presumably increases the potential for negative effects of vehicle collision on the local fauna. Reptiles are particularly vulnerable, because roadways offer open, relatively warm basking areas compared to the surrounding landscape (Tanner and Perry 2007). The allure of roadways is likely to be greatest at the edge of settlements where roads are in proximity to natural vegetation.

Herpetofauna tends to be under-reported in studies of road kills due to their seasonality, for example, Burgin and Brainwood (2008) did not collect any because their study was restricted to the cooler months of the year. Reptiles and frogs may also be under-represented in road kill studies as most are small and readily removed from roads by scavengers and predators, or the carcasses may be lost due to further collisions with vehicles. Data are, therefore, lacking on the loss of herpetofauna due to vehicle collision, even in urban areas.

As indicated above, most previous studies of collision with vehicles have been based on accidents on open roads. Despite the ecological significance of the surrounding landscape, no previous studies appear to have addressed road kill in suburban areas surrounded by natural bushland. In this paper we document road mortality of herpetofauna, with particular emphasis on reptiles, due to collision with vehicles at the urban - bushland interface at Falconbridge in the Greater Blue Mountains World Heritage Area. In this paper we quantify the numbers and species of herpetofauna killed in vehicle collision along a low-traffic volume, speed-limited urban road at the interface with the World Heritage Area.

Site Description

The study was undertaken at the interface between the town of Falconbridge, and national estate lands of the Greater Blue Mountains World Heritage Area, west of Sydney. The region is environmentally one of the most highly valued and comprehensively protected areas in Australia. In the 50 years since the initial creation of the Blue Mountains National Park, the conserved area has continued to expand (NPWS 2001). Several adjoining National Parks are now collectively regarded as part of the Greater Blue Mountains area (Jamieson 2001). It has unique geology and biodiversity, and was considered of sufficient international significance to be declared a United Nations Educational, Scientific and Cultural Organization's World Heritage Estate because of the area's natural values (UNESCO 2009; Commonwealth Government 2009).

The park is centred around a deeply-dissected, sandstone plateau covering 247,000 ha with its highest point approximately 1,100 m above sea level (Jamieson 2001). The majority of the area is naturally vegetated 'Sydney Sandstone Ridgetop Woodlands' (*cf.* Benson 2002), with a dominant tree cover composed mainly of *Eucalyptus* species and *Angophora costata* with a shrubby understorey (Dragovich and Morris, 2002). Most of this bushland is in good ecological condition (Commonwealth Government 1998). The region has historically witnessed considerable conflict between development and conservation (Mosely 1999) with increased urban, tourism, and/or infrastructure development frequently the cause of friction within the community. Environmental conflicts most often arise in the 90 km string of settlements, stretching from Penrith in the east to Mt Victoria and Lithgow in the west. The highway and associated ridge-top development bisects the World Heritage Area and houses a population of 74,067 residents at census 2006 (Blue Mountains Local Area; ABS, 2007). It also attracts large, although shrinking number of tourists (TRA, 2010).

Falconbridge (33°42'0S, 150°31'60E) is one of the long-established towns of the area (BMCC, 2002). Approximately 75 km west of Sydney, at an altitude of 400 m, it has an annual average rainfall of 1,275 mm which falls mostly in summer (www.bom.gov.au). In the 2006 census the recorded population was 4,014 (ABS, 2007). Like many urban areas in New South Wales, the speed limit of the streets is 50 km hour. There are also road signs warning of wildlife in the area, and the traffic flow is of low density. Although there is no quantification of traffic volume in the streets used in this study, in consultation with Glenn Sherlock (Strategic Planning Specialist – Transport, Blue Mountains City Council) we estimated that there are approximately 400 vehicle movements per day through the streets sampled for herpetofauna.

Methods

Sampling was repeatedly undertaken between January 2003 and April 2010. Herpetofauna were collected from a 1.4 km length of urban streets in residential Falconbridge within the 50 km/hour speed zone. The streets surveyed were on a ridge top with, at most, a single residential dwelling between the paved roadway and natural bushland. Alternatively, dwellings were restricted to one side of the roadway with bushland to the roadway on the other side. There were equivalent distances of street with and without a dwelling between the paved roadway and the bushland.

The surveys took place at dawn or soon afterwards on two to four days/week; a few surveys were conducted at dusk. Reptiles found dead on the road were collected. Individuals were identified and, where feasible, snout - vent length of lizards was measured. When frogs were found, only the species identity was recorded.

To determine the list of reptile and frog species killed in the wider area, records of the Atlas of New South Wales (NSW) Wildlife (the Atlas) for the lower Blue Mountains from Glenbrook (200 m altitude) to Hazelbrook (700 m altitude) and records of the NSW Wildlife Information and Rescue Service (WIRES) for the years 1991 to 2009

were consulted. These species lists were supplemented with additional species known to be present from casual observations, documented fauna surveys submitted to Blue Mountains City Council, and from the data files of Abel Ecology. The final species list, therefore, was more inclusive than standard references for the area's herpetofauna (Cogger 1992; Swan 1990; Swan *et al.* 2004).

Results

A total of 86 individuals encompassing 20 reptile species: 11 species of lizards (51 individuals) and 9 snake species (35 individuals) were collected (Table 1). Based on these numbers, an average of 12.29 reptiles are killed on the Faulconbridge streets of the study area each year. Freshly-killed animals were found in both early morning and late afternoon. The hard, outer integument of reptiles often survived repeated impacts with vehicles, and exposure to the elements after death, so that identification of complete and partial carcasses was nearly always possible.

The number of road-killed lizard species was equivalent to 38% of those recorded for the area, and the number of snake species was equivalent to 56% of those recorded for the area (see Table 1). Some reptiles were not recorded as road kills, for example, one species of monitor and turtle were observed alive on the road, but not found as road killed animals.

Jacky dragons (24%) were the most commonly encountered reptile species killed on the road. Road-killed Jacky Dragons ranged from 26 - 125 mm, the whole recorded size range of the species. Seven of these dragons (33%) were 100 mm or greater. Snakes were also frequently encountered, most commonly the eastern small-eyed snake *Cryptophis nigrescens* (12%), blind snake *Ramphotyphlops nigrescens* (10%), and golden-crowned snake *Cacophis squamulosus* (6%; Figure 1).

The extent of bushland on either side of the road appears to have had an effect on the types of reptiles found as road-kills. In the study area, two species of snake and two lizard species, representing 5% of the reptile collected, were only found on sections of road with dwellings on both sides. These were red-bellied black snake *Pseudechis porphyriacus*, bandy-bandy snake *Vermicella annulata*, eastern bearded dragon *Pogona barbata*, and gecko *Diplodactylus vittatus*. The remaining 95% of reptiles collected were found both on sections of road with houses both sides, and where there were houses one side and bush on the other side.

Representatives of six species of frogs were found killed by vehicle collision, 33% of the species known for the area (Table 1). While five of the species were considered common, the red-crowned toadlet *Pseudophryne australis* is classified 'vulnerable' under the *New South Wales Threatened Species Conservation Act 1995*.

Table 1. Species list of reptiles collected for the Faulconbridge area (data consolidated from the Atlas of New South Wales, NSW Wildlife Information and Rescue Service, 1991 – 2009, casual observation, documented fauna surveys submitted to Blue Mountains City Council, and data files of Abel Ecology) (*roadkills collected during the current study)

Common name	Scientific name	Conservation status
Reptiles		
diamond python	<i>Morelia spilota spilota</i>	Common
common death adder	<i>Acanthophis antarcticus</i>	Common
*yellow-faced whip snake	<i>Demansia psammophis</i>	Common
*mustard-bellied snake	<i>Drysdalia rhodogaster</i>	Common
green tree snake	<i>Dendrelaphis punctulata</i>	Common
*golden-crowned snake	<i>Cacophis squamulosus</i>	Common
*eastern small-eyed snake	<i>Cryptophis nigrescens</i>	Common
red-naped snake	<i>Furina diadema</i>	Common
*marsh snake	<i>Hemiaspis signata</i>	Common
broad-headed snake	<i>Hoplocephalus bungaroides</i>	1 Endangered, 2 Vulnerable
eastern tiger snake	<i>Notechis scutatus</i>	Common
*red-bellied black snake	<i>Pseudechis porphyriacus</i>	Common
*eastern brown snake	<i>Pseudonaja textilis</i>	Common
black-headed snake	<i>Suta spectabilis ssp dwyeri</i>	Common
*bandy bandy	<i>Vermicella annulata</i>	Common
*blind snake	<i>Ramphotyphlops nigrescens</i>	Common
*stone gecko	<i>Diplodactylus vittatus</i>	Common
*Lesueur's velvet gecko	<i>Oedura lesueurii</i>	Common
broad tailed gecko	<i>Phyllurus platurus</i>	Common
thick tailed gecko	<i>Underwoodisaurus milii</i>	Common
Burton's snake-lizard	<i>Lialis burtonis</i>	Common

Common name	Scientific name	Conservation status
*scaly-foot lizard	<i>Pygopus lepidopodus</i>	Common
mountain dragon	<i>Amphibolurus diemensis</i>	Common
*Jacky dragon	<i>Amphibolurus muricatus</i>	Common
*bearded dragon	<i>Pogona barbata</i>	Common
eastern water dragon	<i>Physignathus lesueurii</i>	Common
Swanson's limbless skink	<i>Anomalopus swasoni</i>	Common
*eastern blue-tongue skink	<i>Tiliqua scincoides</i>	Common
rainbow skink	<i>Carlia tetradactyla</i>	Common
fence skink	<i>Cryptoblepharus virgatus</i>	Common
striped skink	<i>Ctenotus robustus</i>	Common
coppertail skink	<i>Ctenotus taeniolatus</i>	Common
eastern she-oak skink	<i>Cyclodomorphus michaeli</i>	Common
*pink-tongued skink	<i>Cyclodomorphus gerrardii</i>	Common
Cunningham's skink	<i>Egernia cunninghami</i>	Common
black crevice skink	<i>Egernia saxitilis</i>	Common
White's rock skink	<i>Egernia whitii</i>	Common
eastern water skink	<i>Eulamprus quoyii</i>	Common
*banded skink	<i>Eulamprus tenuis</i>	Common
*grass skink	<i>Lampropholis delicata</i>	Common
*garden skink	<i>Lampropholis guichenoti</i>	Common
*weasel shade skink	<i>Saproscincus mustelina</i>	Common
red-throated skink	<i>Acritoscincus platynota</i>	Common
yellow-bellied three-toed skink	<i>Saiphos equalis</i>	Common
lace monitor	<i>Varanus varius</i>	Common
Frogs		
green tree frog	<i>Litoria caerulea</i>	Common
Blue Mountains tree frog	<i>Litoria citropa</i>	Common
bleating tree frog	<i>Litoria dentata</i>	Common
*eastern dwarf tree frog	<i>Litoria fallax</i>	Common
Jervis Bay tree frog	<i>Litoria jervisiensis</i>	Common
*Peron's tree frog	<i>Litoria peronii</i>	Common
leaf green tree frog	<i>Litoria phyllochroa</i>	Common
laughing tree frog	<i>Litoria tyleri</i>	Common
Verreaux's tree frog	<i>Litoria verreauxii</i>	Common
*common eastern froglet	<i>Crinia signifera</i>	Common
giant burrowing frog	<i>Heleioporus australiacus</i>	1, 2 Vulnerable
*eastern banjo frog	<i>Limnodynastes dumerilii</i>	Common
*brown-striped frog	<i>Limnodynastes peronii</i>	Common
spotted grass frog	<i>Limnodynastes tasmaniensis</i>	Common
Haswell's toadlet	<i>Paracrinia haswelli</i>	Common
*red-crowned toadlet	<i>Pseudophryne australis</i>	1 Vulnerable
smooth toadlet	<i>Uperoleia laevigata</i>	Common
Tyler's toadlet	<i>Uperoleia tyleri</i>	Common

¹ New South Wales Threatened Species Conservation Act, 1995

² Environment Protection and Biodiversity Conservation Act, 1999

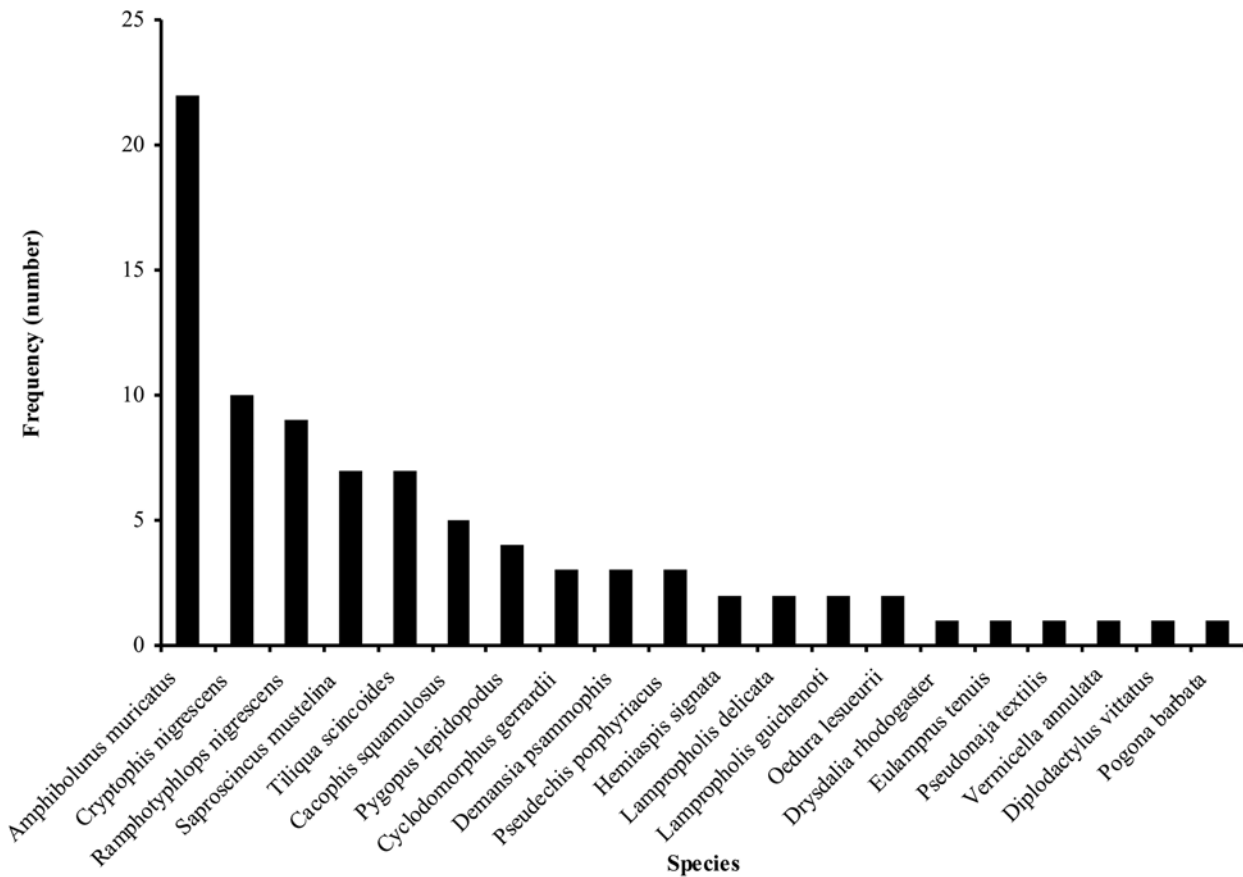


Figure 1. Number of reptile of each species found as road kills on 1.4 km of urban roadway in Falconbridge (Greater Blue Mountains World Heritage Area) between 2003 and 2010 (total number collected = 86; common names, see Table 1)

Discussion

Despite the study being restricted to a 1.4 km stretch of suburban streets on the periphery of Falconbridge, an average of approximately one reptile per month was collected as a result of vehicle collision. This is likely to be a substantial underestimate of mortality because road kills were not collected daily, and the bodies of small animals tend not to persist on roadways after death. For example, Tawny frogmouths *Podargus strigoides* are forest predators and scavengers that are relatively common at Falconbridge; these birds have been observed removing road kills (Burgin and Brainwood 2008). Other bird species, such as the Australian magpie, *Gymnorhina tibicen*; kookaburra, *Dacelo novaeguineae*, Grey butcherbird *Cracticus torquatus*; Anderson and Burgin, 2008), and domestic animals (pers. obs.) also feed on road-killed animals.

Lane and Burgin (2008) reported that there had been a major loss of frogs from both urban and natural areas within the Blue Mountains. The losses were found to be greatest in natural areas. On this basis, they considered that towns of the Blue Mountains could act as a refuge for some species. Other species, such as the vulnerable red-crowned toadlet, are not assisted by residential areas and declines appear to be more pronounced in urban areas.

Species may become locally extinct as a result of new road development (Lunney *et al.* 2002), and the long term viability of some vertebrate populations have been compromised (e.g., Jones, 2000; Ramp and Ben-Ami

2006). The streets sampled for road kills in this study have remained effectively unchanged for over 20 years and, therefore, are not considered to be subject to the impacts that are associated with ‘new’ roads.

Species that are apparently rare in the local area were found in disproportionately higher numbers as road killed animals. For example, two snake species, the eastern small-eyed and blind snakes, are seldom seen in the area (i.e., < 5 individuals of either species over 27 years, Wotherspoon, pers. obs.) but were among the most commonly encountered reptile deaths on the road. These snakes are secretive, nocturnal species that typically shelter under rocks and in crevices during the day (Cogger 2000). In order to be active at night, these snakes require thermal input. Since the black sealed urban roads would be warmer at night than the surrounding light coloured sandstone rocks, we assume that they are attracted to the roadway to thermoregulate. These observations suggest that road kill data may not directly reflect the abundance of reptiles species in an area.

Jacky dragons were the most commonly encountered road killed reptile. Although this species is considered common in the Sydney region, much of its habitat has been replaced by urbanisation. For example, in the highly fragmented vegetation remnants on the Bonny Doon Golf Course in urban Sydney, a lack of large adults (males and females) were found. In addition, the sex ratio of males and females were equivalent, rather than conform to the expectation that there would be more females than

males in this temperature-dependent sex determined species. This may indicate that the population's long term viability has been compromised by the location (Hitchen *et al.* 2011). In the current study, the largest Jacky dragon found was 125 mm snout-vent length. This is equivalent to that previously reported in the literature (e.g., 117 mm - Harlow and Taylor 2001; 125 mm - Greer 1989; Strahan *et al.* 1992). Despite the losses due to vehicle collision, it is unlikely that the long-term viability of Jacky Dragon is being challenged at the current rate of mortality. On the other hand, large, dominant male eastern bearded dragons are killed on roads with greater frequency than females or smaller males (Wotherspoon, 2008). Although the loss of large females may be considered more critical to the long-term viability of a population, the reproductive outcomes of the population could also be affected with the on-going losses of the dominant males, and the associated struggle for supremacy among sub-dominant males.

Conclusion

On this one section of long-established urban street at the edge of a small town in a low-speed zone, there is an on-going loss of individuals from a substantial number of the native species of herpetofauna due to vehicle collision. Using Google Earth to obtain a 'gross' measure of the extent of similar streets on the perimeter of Falconbridge, we calculated that there may be 20 - 30 km of such roadways. Extrapolating from the annual road kill death rate we encountered, we estimated that across

2 - 4 days of the week between 176 and 263 reptiles are killed annually at the urban/bushland interface on these low speed limit roads just within Falconbridge. Since there are 25 other towns and villages that could be considered to average broadly similar perimeters within bushland settings, the road kills of reptiles, just at the interface with the bushland, could conservatively be estimated to be between 4,576 and 6,838 annually. In some areas the loss would be greater, for example, where new roads have been developed (see e.g., Lunney *et al.* 2002), in areas of higher traffic density and/or higher speed zones, and on the wider roads that connect towns and villages (see e.g., Burgin and Brainwood, 2008).

Road kill deaths are also not restricted to reptiles. Data on the number of frogs killed in vehicle collision were not maintained but 33% of local species were represented as road kills. In urban areas, road deaths occurred across all groups of native vertebrate taxa (e.g., Burgin and Brainwood 2008; Harris *et al.* 2008). Our study therefore reveals simply the 'tip of the iceberg' when it comes to the road kill of native species due to collision, even just in the Greater Blue Mountains World Heritage Area. This is because the data that underpin this study were collected from an urban road with a low volume of traffic. Even within Falconbridge, this represents a small fragment of the total street area. Although an average death rate of one reptile per month may be considered negligible, we consider that the cumulative loss of reptiles due to vehicle collision in the region is an ecological disaster.

Acknowledgements

We acknowledge the support of Mrs Annette Wotherspoon who frequently accompanied the senior author on his early morning/dusk ramblings. Dennis Hitchen is also

acknowledged for his thoughtful comments on the draft manuscript.

References

- ABS. 2007. *2006 Census QuickStats: Blue Mountains* (C) (Statistical Local Area. Australian Bureau of Statistics, Canberra. <http://www.censusdata.abs.gov.au/ABSNavigation/prenav/ProductSelect?newproducttype=QuickStats&btnSelectProduct=View+QuickStats+%3E&collection=Census&period=2006&areacode=105450900&geography=&method=&productlabel=&producttype=&topic=&navmapdisplayed=true&javascript=true&breadcrumb=LP&topholder=0&leftholder=0¤taction=201&action=401&textversion=false>. Accessed 14 April, 2010.
- Abu-Zidan, E.M., Parmar, K.A. and Ross, S. 2002. Kangaroo-related motor vehicle collisions. *Journal of Trauma-Injury Infection and Critical Care* 53: 360-363.
- Anderson, L. and Burgin, S. 2008. Patterns of bird predation on reptiles in small woodland remnant edges in peri-urban north-western Sydney, Australia. *Landscape Ecology* 23(9): 1039-1047.
- Anon. undated. *Falconbridge, Australia page*. <http://www.fallingrain.com/world/AS/02/Falconbridge.html>. Accessed 18 March, 2010.
- ANZECC. 1998. *National Koala Conservation Strategy*. Environment Australia, Canberra.
- Ashley, E.P. and Robinson, J.T. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie. *Canadian Field Naturalist* 110:403-412.
- Baker, P.J., Harris, S., Robertson, C.P.J., Saunders, G. and White, P.C.L. 2004. Is it possible to monitor mammal population changes from counts of road traffic casualties? An analysis using Bristol's red foxes *Vulpes vulpes* as an example. *Mammal Review* 34: 1-16.
- Beckers, 2008. Good from bad: is there an up side to roadkills? Pp. 103-104 in *Too Close for Comfort: Contentious Issues in Human-Wildlife Encounters* edited by Lunney, D., Munn, A., and Meikle, W. Royal Zoological Society of New South Wales, Mosman.
- Benson D. 1992. Natural vegetation of the Penrith 1: 100 000 map sheet. *Cunninghamia* 2: 541-596.
- BMCC. 2002. *State of the Environment Report 2001/2002*. Blue Mountains City Council, Katoomba.
- Burgin, S. and Brainwood, M. 2008. Comparison of road kills in peri-urban and regional areas of New South Wales (Australia) and factors influencing deaths. Pp. 137-144 in *Too Close for Comfort: Contentious Issues in Human-Wildlife Encounters* edited by Lunney, D., Munn, A., and Meikle, W. Royal Zoological Society of New South Wales, Mosman.
- Clevenger, A.P., Chruszcz, B. and Gunson, K.E. 2003. Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations. *Biological Conservation* 109: 15-26.

- Cogger, H. G. 2000. *Reptiles and Amphibians of Australia*. 6th Edition. Reed New Holland, Sydney.
- Commonwealth Government. 1998. *The Greater Blue Mountains Area: World Heritage Nomination*. Prepared by the New South Wales National Parks and Wildlife Service and Environment Australia. Australian Commonwealth Government, Canberra.
- Commonwealth Government. 2009. Greater Blue Mountains, available on <http://www.environment.gov.au/heritage/places/world/blue-mountains/index.html>. Accessed 17 March, 2010.
- Coulson, G. 1989. The effect of drought on road mortality of macropods. *Australian Wildlife Research* 16: 79-83.
- Dragovich, D. and Morris, R. 2002. Fire intensity, slopewash and bio-transfer of sediment in Eucalypt forest, Australia. *Earth Surface Processes and Landforms* 27, 1309-1319.
- Fahrig, L. and Rytwinski, T. 2009. Effects of roads on animal abundance: an empirical review and synthesis. *Ecology and Society* 14: 21. <http://www.ecologyandsociety.org/vol14/iss1/art21/>
- Glista, D.J., DeVault, T.L. and DeWoody, J.A., 2007. Vertebrate road mortality predominately impacts amphibians. *Herpetological Conservation and Biology* 3: 77-87.
- Greer, A. 1989. *The Biology and Evolution of Australian Lizards*. Surrey Beatty and Sons Pty Ltd, Chipping Norton.
- Harlow, P.S. and Taylor, J.E. 2001. Reproductive ecology of the jacky dragon (*Amphibolurus muricatus*): an agamid lizard with temperature-dependent sex determination. *Austral Ecology* 25: 640-652.
- Harris, C., Marlow, J. and Harris, A. 2008. No prescription yet to counter the roadkill of our native fauna: a study of roadkill in the Narrabeen Catchment of Sydney. Pp. 96-102 in *Too Close for Comfort: Contentious Issues in Human-Wildlife Encounters* edited by Lunney, D., Munn, A., and Meikle, W. Royal Zoological Society of New South Wales, Mosman.
- Hitchen, D., Burgin, S. and Wotherspoon, D. 2011. Notes on the population structure of the jacky dragon *Amphibolurus muricatus* in a small urban remnant. *Pacific Conservation Biology* 16: 237-243.
- Jamieson, R. 2001. *Canyons Near Sydney*. 4th Edition. Rick Jamieson, Kurrajong Heights.
- Jones, M.E. 2000. Road upgrade, road mortality and remedial measures: impacts on a population of eastern quolls and Tasmanian devils. *Wildlife Research* 27: 289-296.
- Klocker, U., Croft, D.B. and Ramp, D. 2006. Frequency and causes of kangaroo-vehicle collisions on an Australian outback highway. *Wildlife Research* 33 : 5-15.
- Lane, A. and Burgin, S. 2008. Comparison of frog assemblage structure between urban and non-urban habitats in the upper Blue Mountains (Australia). *Freshwater Biology* 53: 2484-2493
- Langen, T.A., Ogden, K.M. and Schwarting, L.L., 2009. Predicting hot spots of herpetofauna road mortality along highway networks. *The Journal of Wildlife Management* 73: 104-114.
- Lee, T. and Croft, D.B. 2008. The effects of an arid-zone road on vertebrates: what are the priorities for management? Pp. 105-117 in *Too Close for Comfort: Contentious Issues in Human-Wildlife Encounters* edited by Lunney, D., Munn, A., and Meikle, W. Royal Zoological Society of New South Wales, Mosman.
- Lee, E., Klocker, U., Croft, D.B. and Ramp, D. 2004. Kangaroo-vehicle collisions in Australia's sheep rangelands, during and following drought periods. *Australian Journal of Mammalogy* 26: 215-226.
- Loos, G. and Kerlinger, P., 1993. Road mortality of saw-whet and screech-owls on the Cape May Peninsula. *Journal of Raptor Research* 27: 210-213.
- Lunney, D., O'Neill, L., Matthews, A. and Sherwin, W. B. 2002. Modelling mammalian extinction and forecasting recovery: koalas at Iluka (NSW, Australia). *Biological Conservation* 106: 101-113.
- Mosely, G. 1999. *Battle for the Bush: The Blue Mountains, the Australian Alps and the Origins of the Wilderness Movement.*, Colong Foundation/Envirobook. The Colong Foundation for Wilderness, Sydney.
- Ng, W.J., Nielsen, C. and St Clair, C.C. 2008. Landscape and traffic factors influencing deer-vehicle collisions in an urban environment. *Human-Wildlife Conflicts* 2: 34-37.
- NPWS. 2001. *Blue Mountains National Park Plan of Management*. National Parks and Wildlife Service, Blue Mountains Heritage Centre, Blackheath, NSW.
- Ramp, D. and Ben-Ami, D. 2006. The effect of road-based fatalities on the viability of a peri-urban swamp wallaby population. *Journal of Wildlife Management* 70: 1615-1624.
- Ramp, D., Caldwell, J., Edwards, K.A., Warton, D. and Croft, D.B. 2005. Modelling of wildlife fatality hotspots along the Snowy Mountain Highway in New South Wales, Australia. *Biological Conservation* 126: 474-490.
- Ramp, D. and Roger, E. 2008. Frequency of animal-vehicle collisions in NSW. Pp. 118-126 in *Too Close for Comfort: Contentious Issues in Human-Wildlife Encounters* edited by Lunney, D., Munn, A., and Meikle, W. Royal Zoological Society of New South Wales, Mosman.
- Seibert, H.C. and Conover, J.H. 1991. Mortality of vertebrates and invertebrates on an Athens Country, Ohio, highway. *Ohio Journal of Science* 91: 163-166.
- Smith, L.L. and Dodd, C.K., 2003. Wildlife mortality on U.S. Highway 441 across Paynes Prairie, Alachua County, Florida. *Florida Scientist* 66: 228-140.
- Strahan, R., Ehmann, H., Tyler, M. J., Lindsey, T. and Strahan, R., 1992. *Encyclopaedia of Australian Animals*. Angus and Robertson, Pymble.
- Swan, G. 1990. *A field Guide to the Snakes and Lizards of New South Wales*. Three Sisters Productions, Winnalee.
- Swan, G., Shea, G. and Sadlier, R. 2004. *A field Guide to Reptiles of New South Wales*. 2nd edition. Reed New Holland, Frenchs Forest.
- Szerlag, S. and McRobert, S. 2006. Road ecology of the northern diamondback terrapin, *Malaclemys terrapin*. Pp. 634-637 in 2005 *International Conference on Ecology and Transportation* edited by Irwin, C. L., Garrett, P. and McDermott, K. P. North Carolina State University, Raleigh.
- Taylor, B.D. and Goldingay, R.L. 2004. Wildlife road-kills on three major roads in north-eastern New South Wales. *Wildlife Research* 31: 83-91.
- TRA, 2010. National Visitor Survey. Tourism Research Australia, Canberra.
- Tunner, D. and Perry, J. 2007. Road effects on abundance and fitness of Galápagos lava lizards (*Microlophus albemariensis*). *Journal of Environmental Management* 85: 270-278.
- UNESCO. 2009. *Greater Blue Mountains Area*. United Nations Educational, Scientific, and Cultural Organisation, Gland. <http://whc.unesco.org/en/list/917/> Accessed 17 March, 2010.
- Wotherspoon, A. D. 2008. *Ecology and management of Eastern Bearded Dragon Pogona barbata*. Penrith: University of Western Sydney.