Landscape Ecol (2008) 23:1039–1047
DOI 10.1007/s10980-008-9252-5

RESEARCH ARTICLE

Patterns of bird predation on reptiles in small woodland remnant edges in peri-urban north-western Sydney, Australia

Lyn Anderson · Shelley Burgin

Received: 2 April 2008 / Accepted: 12 August 2008 / Published online: 24 September 2008

Abstract The predator–prey relationship plays an integral role in community structure. In the presence of habitat fragmentation, the dynamic interaction among co-existing species may be disrupted. In this paper we investigated the interaction between small skinks resident in open woodland remnants and the predatory birds that cross-forage between the remnants and the surrounding peri-urban matrix. Skinks were found in significantly fewer numbers in the edge of remnants compared to their core. In contrast, predatory birds were in largest numbers at the edge compared to the core of remnants. We found that there was a strong negative correlation between skink numbers and predatory birds (individually and combined) consistent with higher predation pressure in the edge compared to the core of remnants. Strike rates on decoys that mimicked skinks were also higher in the edge compared to core habitats, consistent with higher predation rates in this edge habitat.

Keywords Edge effects · Skinks · Avian · Remnant habitat · Woodlands · Predation pressure · Competition

L. Anderson · S. Burgin (✉)
College of Health and Science, University of Western Sydney, Locked Bag 1797, South Penrith Distribution Centre, Sydney, NSW, Australia
e-mail: s.burgin@uws.edu.au

Introduction

The predator/prey relationship plays an integral role in community structure: the number of predators and the rate they consume prey determine ecosystem dynamics (Miller et al. 2006). In the process of habitat fragmentation, the dynamic interaction among co-exiting species may be disrupted (Cardinale et al. 2006). Historically, habitat edges have been viewed as problematic in this relationship. They have variously been described as a barrier to predators (Bider 1968), and funnels for predator movement (Dyer et al. 2001). However, in a human-modified environment, predators (e.g. foxes; Molsher et al. 2000; birds; Catterall et al. 1991) may successfully cross forage between a remnant's perimeter and adjacent modified ecosystems. This may increase opportunities for these predators in edge areas (Berry 2001).

Edge habitats are typically inhabited by a suite of omnivorous birds with large body size compared to those in the core of the remnant. These attributes allow for a larger number of avian predators to inhabit edge areas (Major et al. 2001; Shirley and Smith 2005). However, there is a dearth of information on the impact of such species on reptile prey (Barrows et al. 2006).

In Australia, reptiles are key species in endemic ecosystems (Brown and Nelson 1993), however, in fragmented landscapes research on the impact on reptiles, particularly small species that are ready prey to birds, is limited (e.g., Anderson and Burgin 2002; Barrows and Allen 2007).

Anderson and Burgin (2002) observed that the widespread, sympatric and common species of small (snout – vent length ≤55 cm) skinks, *Lampropholis delicata* and *Lampropholis guichenoti*, were significantly more sparse in the edge areas, compared to the core of small woodland remnants in north western Sydney (Australia). Micro-climate (Baiada 2002) and habitat characteristics (Anderson and Burgin 2002) have been previously shown not to have a significant impact on the distribution of skinks between edge and core habitat of remnants. In this paper we investigate if predatory birds influence the abundance of small skinks in these open woodland remnants.

Method

Site description

The study was undertaken in remnant woodlands of the Cumberland Plain. Since European settlement these woodlands have been extensively cleared for agriculture. More recently, urban encroachment has accelerated the woodlands' fragmentation (Benson and Howell 1990; James 1997). As a consequence, by 1990 less than 6% of the original vegetation remained in patchy and isolated remnants (Tozer 2003). The study was undertaken in such remnants on the Hawkesbury campus of the University of Western Sydney, near Richmond, Australia (150°75′ E, 33°62′ S; Fig. 1) commencing with summer of 2000 and finishing at the end of summer 2002.

The eight remnant woodlands sampled ranged in size between 20 and 176 ha and abutted areas of agriculture, power line easements and/or roadways (see Fig. 1). Initial fragmentation occurred almost 120 years ago and, although the intensity of agriculture has waned over time, current land use has been in place since that time, while fire has been excluded for at least 40 years (Burgin in press). Previous research in these open woodland remnants showed that habitat characteristics that are generally used to determine small reptile distribution did not vary between the edge and core of these remnants (Anderson and Burgin 2002). Baiada (2002) also found that microclimate conditions in these remnants did not differ significantly along a gradient between the edge and core of the remnants.

The climate of the area is temperate with cool, dry winters and hot, wet summers. During the study, average monthly rainfall was 103.2 mm, with unseasonably high rainfall during February 2002 (274.5 mm), while the lowest rainfall (14.3 mm) occurred in September 2001. The average ambient air temperature over the sampling period was 21.1°C. The highest monthly temperature was recorded in December 2001 (40°C) while May 2001 temperature dropped to 0°C. Between mid-December 2001 and early January 2002 bushfires threatened the area.

Sampling

Four perimeter and four core areas of remnants were randomly selected from among those available on the campus. Kremsater and Bunnell (1999) determined that species distribution is most influenced within 50 m of the edge of remnants. We sampled within the outer 10 m wooded perimeter of the remnant, and the core sampling was conducted at ≥150 m from the edge.

At 4 weekly intervals, skinks were sampled over three periods (autumn, spring 2001, and summer 2002). Sampling was undertaken in the mid-morning when small skinks actively forage, generally over 4 consecutive days with some adjustment for inclement weather. Each day two pairs of sites (i.e. edge and core sites arbitrarily paired for efficiency of sampling) were sampled. The sequence of sampling was re-randomised each month. The point of transect survey was used instead of pitfall trapping (e.g. Singh et al. 2002), in part, because of the similarity in distribution of trees and understorey throughout these long-established remnants and limited weed intrusion allowed for equivalent sight lines in both habitat types. Previous experience in these remnants (Anderson and Burgin 2002) had also shown that traps were time consuming to set up and yielded relatively fewer animals than the point of transect survey approach.

Two transects of 20 m length and at least 3 m apart, with points at every 5 m, were randomly chosen within each site on each day of sampling. These distances were based on unpublished observations of home range of these small skinks. To record skink numbers, the researcher crouched for 5 min at each point along the transect to observe the area immediately ahead and to either side. All skinks observed were identified and numbers recorded.

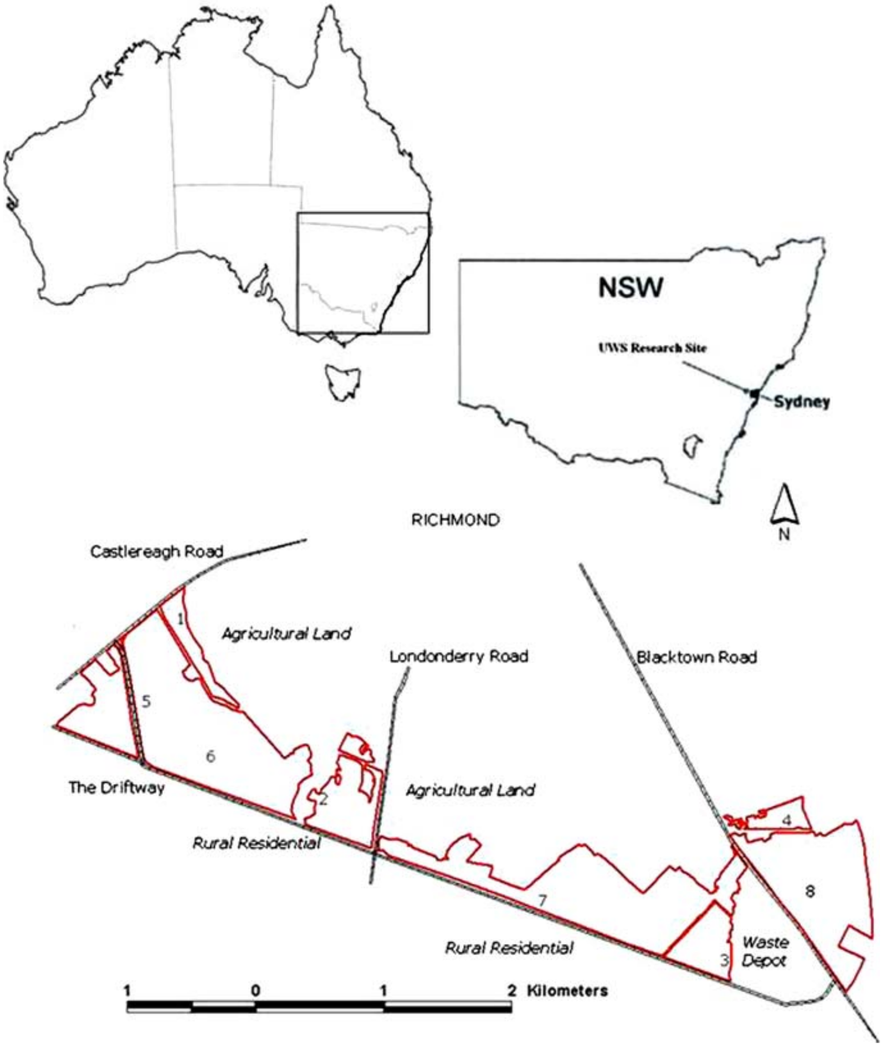

Fig. 1 Map of the study area showing edge (1–4) and core sites (5–8). Inset shows the study site in relation to Sydney, New South Wales and Australia

Since sampling was restricted by line of vision and accuracy of identification was compromised beyond approximately 1.8 m, animals beyond 1.6 m were not included in the census to ensure accuracy of identification.

All small skinks observed were recorded and used to establish the initial distribution and diversity patterns of skinks within the woodlands. However, because the numbers of two species were too small to be amenable to statistical treatment, they were excluded from further analyses.

Diurnal bird sampling is traditionally conducted in the early morning as they leave their roosting sites (Pizzey and Knight 1997), however, we sampled mid-morning when skinks were active and therefore potentially available for predation. Birds were also sampled on transect lines, although transects were extended to 50 m with points 10 m apart. Species were identified visually and verified using Pizzey and Knight (1997), and by call recognition. The species numbers, and the number within each species, were recorded. Birds were subsequently categorised as predators, based on information gleaned from the literature (Barker and Vestjens 1984a, b; Higgins 1999; Higgins and Davies 1996; Higgins et al. 2001), and observations made during the study. All potential predators were recorded, although one species (European starling *Sturnus vulgaris*) was not included in the analyses because it was only encountered in low numbers in edge habitats and not in core habitat.

To investigate predation, decoys were used to mimic juvenile, sub-adult and adult small skinks. These were constructed of plastic or latex, and cast in a basking position. They were overlayed with 3-M Blu-tac™ and painted either 'metallic grey' or 'metallic brown' with folk art paint. Finally, each 'animal' was also threaded with '15 lb' fishing line to tether it to the substrate.

Fifteen decoys (five of each size) were tethered at random points along a single transect (1 transect/ week). To mimic basking skinks, the decoys were placed on logs, fallen branches and tree stumps, and they were left in position for 7 days. After collection, decoys were examined for unambiguous beak mark impressions (to calculate attack rates), and the size of the decoy (juvenile, sub-adult, adult) were recorded. The procedure was repeated on new transects in subsequent weeks. These data were collected for 4 weeks each season.

The sampling periods were modified in some seasons. Due to extreme weather conditions sampling in summer 2002 commenced in December 2001, but was interrupted by bush fires and heavy rains which precluded fieldwork until the end of February 2002. This delayed the commencement of the autumn 2002 sampling, and it was abandoned after 2 weeks, due to extreme weather conditions. Overall, decoys were in place for 126 days during the period December 2000 and March 2002.

In spring 2001, and summer and autumn 2002 decoys were further examined for the position of the 'bite mark' on the body (head, torso, tail). Tail attacks were of particular interest because a major anti-predator behaviour displayed by the skinks is tail autotomy. Calculations were made to determine 'escape rate' differences between the edge and core of remnants.

If multiple marks were observed only one attack was counted (usually the most conspicuous), unless one of the marks included the tail. This was because an attack on the tail usually denoted a 'miss' by the predator since these skinks readily drop their tails when they are in a position to escape by this means (pers. obs.).

Data analysis

Reptile and bird distribution were analysed using multivariate analysis within PRIMER, Version 5 (2001) (Clarke and Ainsworth 1993; Clarke and Warwick 2001). Multi-dimensional scaling stress tests were used to test homogeneity of variances. When not homogeneous (tested using Cochran C), a $\log^{10}$ transformation was used. Similarity was tested using one-way ANOSIM.

Interactions between the skinks and birds were analysed using the BIOENV function, also within PRIMER. This function allowed for the generation of multiple correlations (using Spearman's weighted rank correlation) with various combinations of predatory species to identify a best fit explanation for the distribution pattern of skinks.

Where three or more birds were recorded at a site, a Chi-square analysis was used to investigate differences in predatory bird distribution between core and edge of remnants. The same analysis was used on predation based on number of attacks and decoy size. Spearman's rho, rank correlation coefficient was used to examine the relationship between predator–prey abundance and number of attacks.

Results

Skink distribution

Overall 486 skinks, representing four species *Lampropholis guichenoti, Lampropholis delicata, Cryptoblepharous virgatus* and *Saproscincus mustelina* were encountered: 352 in the core and 134 on the edge of sites (Fig. 2). Within habitat type (edge,

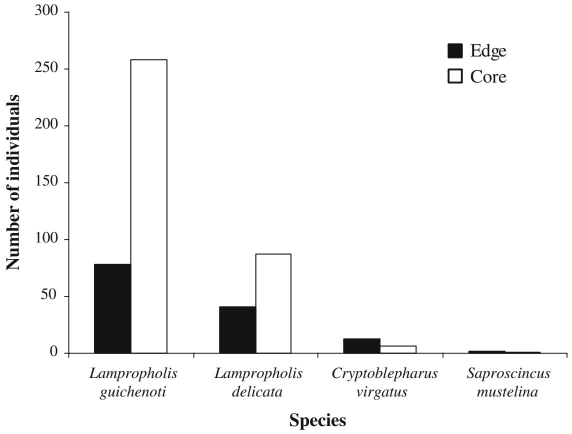

Fig. 2 Total number of skinks of each species that were encountered in edge and core habitat of woodland remnants in peri-urban north-western Sydney in 2001–2002

core), skink numbers were more similar among replicates than habitat types (global $R = 1$, $P = 0.029$), although core sites were more similar (group average 97%) than edge areas (88.8%). Most individuals (95%) were one of the two *Lampropholis* species, and both *L. guichenoti* ($\chi^2_{1, 0.0001} = 96.43$) and *L. delicata* ($\chi^2_{1, 0.0001} = 68.36$) varied significantly between the habitat types.

Bird distribution

A total of 445 predatory/omnivorous birds, encompassing seven species were countered: 311 in edge and 134 in core habitats (Fig. 3). There was a significant difference in bird numbers between habitat types (global $R = 0.427$, $P = 0.029$): substantially more predatory birds were present in edge than in core areas. In contrast to the skinks, the edge diversity and abundance were more similar (84.2%) than core sites (72.7%). Four of these six species that preyed on skinks (grey butcherbird, noisy miner; magpie and raven; see Table 1), and were common to both habitat types, were in significantly greater numbers in edge compared to core habitat. While individually species showed a strong relationship between bird and skink distribution, Spearman's rank correlation coefficient indicated that the strongest correlation was a combination of five species ($\rho = 0.894$; Table 2).

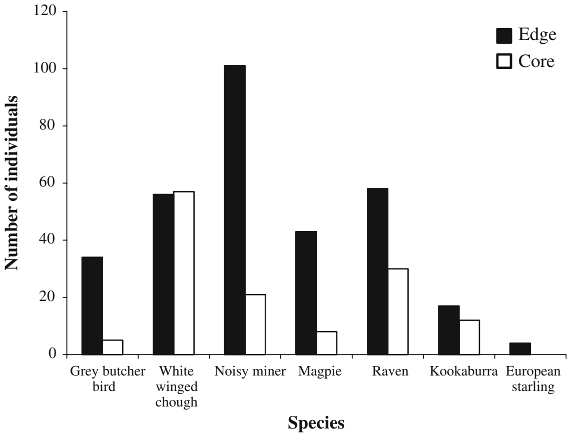

Fig. 3 Total number of birds in each species identified as predators of skinks encountered in edge and core habitats of woodland remnants in peri-urban north-Western Sydney, collected in 2001–2002

Predation rate

Overall, 704 decoys were unambiguously attacked by birds: 411 on the edge, and 293 in the core of remnants. Attack rate was significantly different between edge and core habitats ($\chi^2_{2, 0.001} = 23.31$). A similar number of 'adult' (259), 'sub-adult' (231) and 'juvenile' (214) decoys were attacked. There was no significant difference in attack due to size of decoy, or due to zone of attack.

Attack correlation

Analysis indicated that the number of attacks was negatively correlated with prey abundance ($r = -0.455$, $P < 0.257$), and there was a strong and significant negative correlation between predator and prey numbers ($r = -0.810$, $P < 0.015$), and the number of attacks was strongly and significantly positively correlated ($r = 0.790$, $P < 0.02$) with the number of predators.

Table 1 Overall number (n) of each avian species recorded in remnant woodland habitat in 2001–2002 that were identified as skink predators, the mean number and standard deviation (SD) among replicates in edge and core habitat types, and statistical comparison of bird numbers between habitat types (** = 0.01 significance level, *** = 0.001 significance level; NS = not significant)

Species	Common name	Edge (n)	Edge mean (SD)	Core (n)	Core mean (SD)	Statistic
Corcorax melanocephala	White winged chough	56	14 (15.10)	57	14.3 (6.40)	0.82 NS
Corvus coronoides	Raven	58	14.5 (11.09)	30	7.5 (1.92)	48.91**
Cracticus torquates	Grey butcherbird	34	8.5 (3.97)	5	1.3 (0.96)	21.57***
Gymnorhina tibcen	magpie	43	10.8 (8.18)	8	5.3 (6.65)	32.32***
Manorina melanocephala	Noisy miner	101	25.3 (7.37)	21	5.3 (6.65)	49.24***
Dacelo novaeguineae	Kookaburra	17	4.3 (5.32)	12	3 (3.16)	0.86 NS
Sturnus vulgaris	European starling	4	1 (2)	0	0	–

Table 2 Spearman's rank correlation coefficient on up to six identified avian predators on small skinks, compared with skink census data

Number of species in analysis	*P* Value	Grey butcherbird	White winged chough	Noisy miner	Magpie	Raven	Kookaburra
1	0.589	X	–	–	–	–	–
2	0.723	–	X	X	–	–	–
3	0.791	X	–	X	X	–	–
4	0.870	X	–	X	X	X	–
5	0.894	X	–	X	X	X	X
6	0.866	X	X	X	X	X	X

The results presented are the combinations (donated by X) that best explains skink distribution between edge and core areas of woodland remnants in peri-urban north-western Sydney during 2001–2002

Discussion

The two *Lampropholis* species that dominate the woodlands we studied are common, widespread, and generally the first species to re-establish, even after major disturbance such as logging (Goldingay et al. 1996; Lunney et al. 1991; Webb 1995), fire (Lunney et al. 1991; Taylor and Fox 2001), mine rehabilitation (Bragg et al. 2005; Taylor and Fox 2001), and grazing (Abensperg-Traun et al. 1996; Fischer et al. 2004). They also commonly inhabit urban gardens (Burgin 1993). However, in the small remnant woodlands of the Cumberland Plain where we undertook this study, their numbers in edge areas were approximately one third of overall numbers. Based on the previous study by Anderson and Burgin (2002), this is the established pattern of skink distribution in these woodlands.

In contrast to the skink distribution, the abundance and diversity of avian predators were greater in edge areas, compared to core habitat. Chace and Walsh (2006) suggested that the abundance of avian predators in edge habitats was due to their ability to cross-forage, and thus take advantage of adjacent urban areas. Barrows et al. (2006) demonstrated that this occurred. They noted that cross foraging between remnants and the adjacent human-modified landscape resulted in increased avian predator numbers, compared to those present pre-fragmentation. In their study this resulted in increased predation on the flat-tail horned lizard (*Phrynosoma mcalli*).

The species that we observed to prey on skinks (e.g., magpies, butcherbirds, kookaburras) use man-made structures (e.g., power lines, fences) in their daily routine, at least as effectively as they use natural habitat. Sewell and Catterall (1998) suggested that manmade structures provided these bird predators with an advantage. We observed birds perched on powerlines and fences, scanning the interface between the remnant edge and the peri-urban matrix surrounding the remnants and, when movement was identified, the bird swooped to collect their prey, usually a small skink.

The adjacent modified habitat, particularly urban backyards, provides supplementary food for these birds. For example, noisy miners were common in the remnants. Although typically considered honey eaters, they supplement their diet with arthropods and small reptiles (Grey et al. 1998). Parsons et al. (2006) observed that noisy minors were more abundant in gardens where meat was available than in those where only seed or nectar was present. They concluded that the minors were more carnivorous than previously assumed. We also observed them prey on skinks. Other species that are common visitors to urban gardens include the starling, magpie, kookaburra and butcherbird (Catterall et al. 1991, 2001; White et al. 2005) and none that foraged at the edge of woodland remnants were obligate skink predators. All were dietary generalists (see Barker and Vestjens 1984a, b). This cross-foraging tactic enables predators to persist despite low prey numbers (Andrén and Angelstam 1988; Norrdahl and Korpimaki 2000). Predation pressure would therefore not be released due to predators dispersing from the site because of depleted prey numbers (Norrdahl and Korpimaki 2000).

Previous research (e.g., Bagchi and Sankar 2003) has shown that most predators take prey in proportion to their abundance. This was not our observation. The use of decoys to mimic small skinks, showed that the pattern of bird attack was consistent with greater predation pressure in edge areas compared to the core of remnants, despite the density of skinks being much lower in the edge.

The avian predators showed no preference for zone of attack (head, body, tail). Caudal autotomy is a defence mechanism against predation in many species (Downes and Shine 2001; Lin et al. 2006), and many avian predators direct attacks preferentially towards the prey's head (Langkilde and Shine 2004; Shepard 2007). There was no evidence that this occurred: decoy skinks were equally likely to sustain a strike on the head, body or tail.

There was also no preference shown for animal size, although it had previously been determined (Anderson and Burgin 2002) that there were substantially greater numbers of sub-adults in the edge compared to core habitats of these remnants. In the absence of evidence for selection by the avian predators, it is assumed that the sub-adults disperse outwards from the core and thus the edge acts as a 'sink' similar to that described by Delibes et al. (2001). In this case, skinks may be attracted to edges because of the relatively low density of skinks present and, as a result, are exposed to relatively greater predator pressure than in the core remnant from which they migrated.

Conclusions

We have demonstrated that in the remnants studied, at least in edge areas, the resident small skinks were under substantial predation pressure from birds commonly found to cross-forage between bushland remnants and the urban/agricultural matrix that surrounds them. These avian predators are widespread and abundant in the peri-urban/urban matrix (e.g., see Catterall 2004), and small skinks are also common throughout most human modified landscapes of Australia (see Cogger, 2000 for examples of distributions).

It is generally assumed that the two *Lampropholis* species studied are widespread and abundant, even in urban areas (Burgin 1993; Cogger 2000) and, therefore, would not attract the concern of more vulnerable species. However while *L. guichenoti* is apparently genetically similar across its range (Burgin 1989), there is evidence that *L. delicata*, as described, encompasses a genetically diverse group (Burgin 1989; Donnellan 1985; Hutchinson et al. 1990) with the species boundaries only delineated for a few taxa (see Mather 1990; Mather and Hughes 1992). There are also many other small skinks that have a restricted distribution in areas of increasing human population, particularly along the coastal fringe of Queensland and New South Wales (see Cogger 2000). It can therefore be assumed that predation pressure is occurring wherever there are small skinks on the edge of habitat remnants and avian predators that can cross-forage at the interface of remnants and its surrounding matrix, particularly when such areas are in close proximity to urban areas. Under such circumstances, the remnant edges act as a sink for these small skinks, and presumably other species that these generalist avian predators consume.

References

Abensperg-Traun M, Smith GT, Arnold GW, Steven DE (1996) The effects of habitat fragmentation and livestock-grazing on animal communities in remnants of gimlet *Eucalyptus salubris* woodland in the Western Australian wheat belt I Arthropods. J Appl Ecol 33:1281–1301. doi:10.2307/2404770

Anderson L, Burgin S (2002) The influence of woodland remnant edges on small skinks (Richmond, New South Wales). Austral Ecol 27:630–637. doi:10.1046/j.1442-9993.2002.01224.x

Andrén H, Angelstam P (1988) Elevated predation rates as an edge effect in habitat islands: experimental evidence. Ecology 69:544–547. doi:10.2307/1940455

Bagchi S, Sankar K (2003) Prey abundance and prey selection by tigers (*Panthera tigris*) in a semi-arid, dry deciduous forest in western India. J Zool 260:285–290. doi:10.1017/S0952836903003765

Baiada A (2002) Determining biological indicators to define edge-zones within remnants of the Cumberland Plain. Honours, University of Western Sydney, Richmond

Barker RD, Vestjens WJM (1984a) The food of Australian birds, non-passerines. Melbourne University Press, Melbourne

Barker RD, Vestjens WJM (1984b) The food of Australian birds, passerines. Melbourne University Press, Melbourne

Barrows CW, Allen MF (2007) Persistence and local extinctions of endangered lizard *Uma inornata* on islated habitat patches. Endanger Species Res 3:61–68. doi:10.3354/esr003061

Barrows CW, Allen MF, Rotenberry JT (2006) Boundary processes between a desert sand dune community and an encroaching suburban landscape. Biol Conserv 131:486–494. doi:10.1016/j.biocon.2005.12.024

Benson DH, Howell J (1990) Sydney's vegetation 1788–1988: utilization, degradation and rehabilitation. Proc Ecol Soc Aust 16:115–127

Berry L (2001) Edge effects on the distribution and abundance of birds in a southern Victorian forest. Wildl Res 28:239–245. doi:10.1071/WR00057

Bider JR (1968) Animal activity in uncontrolled terrestrial communities as determined by a sand transect technique. Am Midl Nat 97:216–221

Bragg JG, Taylor J, Fox BJ (2005) Distributions of lizard species across edges delimiting open-forest and sand-mined areas. Austral Ecol 30:188–200. doi:10.1111/j.1442-9993.2005.01436.x

Brown GW, Nelson JL (1993) Influence of successional stage of *Eucalyptus regnans* (Mountain Ash) on habitat use by reptiles in the Central Highlands, Victoria. Aust J Ecol 18:405–417. doi:10.1111/j.1442-9993.1993.tb00468.x

Burgin S (1989) The taxonomy and phylogenetic relationship of Australian Scincid lizards (Scincidae: Lygosominae). Ph.D., Macquaire University: Sydney

Burgin S (1993) *Lampropholis*: the new laboratory animals. In: Lunney D, Ayers D (eds) Herpetology in Australia: a diverse discipline. Transactions of the Royal Zoological Society of N.S.W. Royal Zoological Society of NSW, Mosman, pp 279–282

Burgin S (in press). A natural history of the Ham Common, the lands sandwiched between Richmond and Windsor – two of Governor Macquarie's five towns. In: Lunney D, Hutchings P, Hochuli D (eds) A natural history of Sydney. Royal Zoological Society of NSW, Mosman

Cardinale BJ, Weis JJ, Forbes AE, Tilmon KJ, Ives AR (2006) Biodiversity as a cause and consequence of resource availability: a study of reciprocal causality in a predator-prey system. J Anim Ecol 75:497–505. doi:10.1111/j.1365-2656.2006.01070.x

Catterall C (2004) Birds, garden plants and suburban bushlots: where good intentions meet unexpected outcomes. In: Lunney D, Burgin S (eds) Urban wildlife: more than meets the eye. Royal Zoological Society of NSW, Mosman, pp 21–31

Catterall CP, Green RJ, Jones DN (1991) Habitat use by birds across a forest-shrub interface in Brisbane: implications for corridors. In: Saunders DA, Hobbes RJ (eds) Nature conservation 2: the role of corridors. Surrey Beatty and Sons Pty Ltd, Chipping Norton, pp 247–258

Catterall CP, Piper SD, Bunn SE, Arthur JM (2001) Flora and fauna assemblages vary with local topography in a subtropical Eucalypt forest. Austral Ecol 26:56–69. doi:10.1046/j.1442-9993.2001.01074.x

Chace JF, Walsh JJ (2006) Urban effects on native avifauna: a review. Landsc Urban Plan 74:46–69. doi:10.1016/j.landurbplan.2004.08.007

Clarke KR, Ainsworth M (1993) A method linking multivariate community structure to environmental variables. Mar Ecol Prog Ser 92:205–219. doi:10.3354/meps092205

Clarke KR, Warwick RM (2001) Changes in marine communities: an approach to statistical analysis and interpretation, 2nd edn. Plymouth Marine Laboratory , Plymouth

Cogger HG (2000) Reptiles and amphibians of Australia. Reed New Holland, Sydney

Delibes M, Ferreras P, Gaona P (2001) Attractive sinks, or how individual behavioural decisions determine source-sink dynamics. Ecol Lett 4:401–403. doi:10.1046/j.1461-0248.2001.00254.x

Donnellan SC (1985). The evolution of sex chromosomes in Scincid lizards. PhD, Macquarie University, Sydney

Downes S, Shine R (2001) Why does tail loss increase a lizard's later vulnerability to snake predators? Ecology 82:1293–1303

Dyer SJ, O'Neil JP, Wasel SM, Boutin S (2001) Avoidance of industrial development by woodland caribou. J Wildl Manage 65:531–542. doi:10.2307/3803106

Fischer J, Lindenmayer DB, Cowling A (2004) The challenge of managing multiple species at multiple scales: reptiles in an Australian grazing landscape. J Appl Ecol 41:32–44. doi:10.1111/j.1365-2664.2004.00869.x

Goldingay R, Daly G, Lemckert F (1996) Assessing the impacts of logging on reptiles and frogs in the Montane forests of southern New South Wales. Wildl Res 23:495–510. doi:10.1071/WR9960495

Grey MJ, Clarke MF, Loyn RH (1998) Influence of the noisy miner *Manorina melanocephala* on avian diversity and abundance in remnant Grey Box Woodland. Pac Conserv Biol 4:55–69

Higgins PJ (ed) (1999) Handbook of Australian, New Zealand and Antarctic Birds: parrots to dollarbirds. Oxford University Press, South Melbourne

Higgins PJ, Davies SJJF (eds) (1996) Handbook of Australian, New Zealand and Antarctic Birds: snipe to pigeons. Oxford University Press, South Melbourne

Higgins PJ, Peter JM, Steele WK (eds) (2001) Handbook of Australian, New Zealand and Antarctic Birds: tyrant to flycatchers. Oxford University Press, South Melbourne

Hutchinson MN, Donnellan SC, Baverstock PR, Krieg M, Simms S, Burgin S (1990) Immunological relationships and generic revision of the Australian lizards assigned to the genus *Leiolopisma* (Scincidae: Lygosominae). Aust J Zool 38:535–554. doi:10.1071/ZO9900535

James T (1997) Urban bushland biodiversity survey: Western Sydney. NSW National Parks and Wildlife Service, Hurstville

Kremsater L, Bunnell FL (1999) Edge effects: theory, evidence and implications to management of western North American forests. In: Wisniewski J, Rochelle J, Lehmann L (eds) Forest fragmentation: wildlife and management implications. Leiden, Boston, pp 117–153

Langkilde T, Shine R (2004) Competing for crevices: interspecific conflict influences retreat-site selection in montane lizards. Behav Ecol 140:684–691

Lin LJ, Qu Y-F, Ji X (2006) Energetic and locomotor costs of tail loss in Chinese skink Eumeces chinensis. Comp Biochem Physiol A 143:503–513

Lunney D, Eby P, O'Connell M (1991) Effects of logging, fire and drought on three species of lizards in Mumbulla State Forest on the south coast of New South Wales. Aust J Ecol 16:33–46. doi:10.1111/j.1442-9993.1991.tb01479.x

Major RE, Christie FJ, Gowing G (2001) Influence of remnant and landscape attributes on Australian woodland bird communities. Biol Conserv 102:47–66. doi:10.1016/S0006-3207(01)00090-8

Mather PB (1990) Electrophoretic and morphological comparisons of *Lampropholis delicata* (Lacertilia: Scincidae) populations fro east Australia, and a resolution of the taxonomic status of the species. Aust J Zool 37:561–574. doi:10.1071/ZO9890561

Mather PB, Hughes JM (1992) Genetic variations in three species in the *Lampropholis delicata* (Lacertilia: Scincidae) complex. Biol J Linn Soc Lond 47:135–146. doi:10.1111/j.1095-8312.1992.tb00660.x

Miller DA, Grand JB, Fondell TF, Anthony M (2006) Predator functional response and prey survival: direct and indirect interactions affecting a marked prey population. J Anim Ecol 75:101–110. doi:10.1111/j.1365-2656.2005.01025.x

Molsher RL, Gifford EJ, McIlroy JC (2000) Temporal, spatial and individual variation in the diet of red foxes (*Vulpes vulpes*) in central New South Wales. Wildl Res 27:593–601. doi:10.1071/WR99015

Norrdahl K, Korpimaki E (2000) Do predators limit the abundance of alternative prey? Experiments with vole-eating avian and mammalian predators. Oikos 91:528–540. doi:10.1034/j.1600-0706.2000.910315.x

Parsons H, Major RE, French K (2006) Species interaction and habitat associations of birds inhabiting urban areas of Sydney, Australia. Austral Ecol 31:217–227. doi:10.1111/j.1442-9993.2006.01584.x

Pizzey G, Knight F (1997) The field guide to birds of Australia. Angus and Robertson, Pymble

Sewell SR, Catterall CP (1998) Bushland modification and styles of urban development: their effects on birds in south-east Queensland. Wildl Res 25:41–63. doi:10.1071/WR96078

Shepard DB (2007) Habitat but not body shape affects predator attack frequency on lizard models in the Brazilian Cerrado. Herpetologica 63:193–202. doi:10.1655/0018-0831(2007)63[193:HBNBSA]2.0.CO;2

Shirley SM, Smith JNM (2005) Bird community structure across riparian buffer strips of varying width in a coastal temperate forest. Biol Conserv 125:475–489. doi:10.1016/j.biocon.2005.04.011

Singh S, Smyth AK, Blomberg SP (2002) Effect of a control burn on lizards and their structural environment in a Eucalypt open-forest. Wildl Res 29:447–454. doi:10.1071/WR01015

Taylor JE, Fox BJ (2001) Disturbance effects from fire and mining produce different lizard communities in eastern Australian forests. Austral Ecol 26:193–204. doi:10.1046/j.1442-9993.2001.01105.x

Tozer M (2003) The native vegetation of the Cumberland Plain, western Sydney: systematic classification and field identification of communities. Cunninghamia 8:1–155

Webb GA (1995) Effects of logging on lizards in Eucalypt forest at Eden, New South Wales. Aust For 58:155–159

White JG, Antos MJ, Fitzsimons JA, Palmer GC (2005) Non-uniform bird assemblage in urban environments: the influence of streetscape vegetation. Landsc Urban Plan 97:123–135. doi:10.1016/j.landurbplan.2004.02.006