Current status and future prospects of reptiles and frogs in Sydney's urban-impacted bushland reserves

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ABSTRACT

Five large (greater than 35 ha) urban bushland reserves in Greater Sydney were selected where herpetofaunal assemblages could be deduced and there were recent herpetofauna surveys. Four reserves (Rockdale Wetlands Corridor, Wolli Creek Valley, Burnt Bridge Creek Corridor and Middle Harbour Bushland Reserves) had been surrounded by residential development for more than 50 years. The fifth (University of Western Sydney, Richmond campus) was surrounded by agricultural and peri-urban development. Records from the scientific literature, local natural history groups, amateur herpetologists and council archives were used to gather historic information on the frogs and reptiles. Interviews were also conducted with researchers and neighbours of the reserves. Eight extant species were common to all reserves while another, predicted to be in all reserves, was universally absent. Despite the relatively large size of these bushland remnants, in all reserves the number of reptile and frog species had declined since urbanisation. The largest losses occurred in the four urban reserves. Seven species predicted to have occurred historically were now only present in the peri-urban site. Some herpetofaunal groups were more vulnerable than others. Goannas were locally extinct in urban reserves. Tree frogs and geckos were depleted while ground frogs and skinks were reduced to approximately half their original species numbers. This is in contrast to the peri-urban site where there had been no loss of tree frogs or goannas and generally more than half of the species in each group were extant. Urban impacts that appeared to relate to herpetofauna decline were direct human intervention that resulted in death or removal of individuals (e.g. goannas, large snakes), interference with habitat such as bush rock removal (e.g. smaller snakes, geckoes, skinks), fire (e.g. non-burrowing small residents), interference with the water cycle including infilling and pollution (e.g. frogs) and exotic predators (e.g. dragons, turtles, skinks). In general, herpetofauna with the least future prospects were those most susceptible to decline. These included the large, conspicuous fauna that required a substantial home range, attracted the attention of humans because of 'pet appeal' or due to their perceived danger; were vulnerable at some stage of the lifecycle to predation by feral species; and had specific habitat requirements for reproduction such as quality water or open sandy banks for egg incubation. Those that are small, generalist and unappealing to humans are most likely to survive. There is, therefore, little doubt that diversity in reserves will continue to dwindle unless strategies are devised to overcome the present trend. Current conservation strategies that generally target single species need to be expanded to ecosystem level to monitor threats and management implemented for their removal.

Key words: frogs, turtles, skinks, goannas, pygopods, geckoes, dragons, snakes, urban bushland, urban impacts.

Introduction

Australia is a highly urbanised country with most of the population clustered along the eastern seaboard, often in areas of historically rich frog and reptile (herpetofauna) habitat. Greater Sydney, with an area of approximately 3,000 km^2, is one such location. It includes the range of some 30 frog and 50 reptile species (Swan 1990; Griffiths 1997). With limited data on the diversity and abundance of herpetofauna at European settlement, historical assessment of their status is relegated to an educated guess and survival prospects surmised from recent studies.

It has been historically recognised (Lockington 1879) that land use changes, associated with urbanisation, impact on herpetofauna and lead to local extinctions (Honeggar 1981). In Australia there has been an effort to obtain information on some aspects of diversity in urban areas (eg. birds this volume, Catterall 2004; Parsons and Major 2004; Howard and Jones 2004) but data are limited for herpetofauna. For example, a published list of all Australian herpetological theses to the mid-1993 (Shea 1993) revealed that the title of only one thesis explicitly mentioned urban impacts (Ferraro 1992) and few appeared to have a human impact focus more generally.

Within Sydney, species such as Red-crowned Toadlet *Pseudophryne australis* (Thumm and Mahony 1999),

Pp 109 - 123 in *Urban Wildlife: more than meets the eye,* edited by Daniel Lunney and Shelley Burgin 2004. Royal Zoological Society of New South Wales, Mosman, NSW.

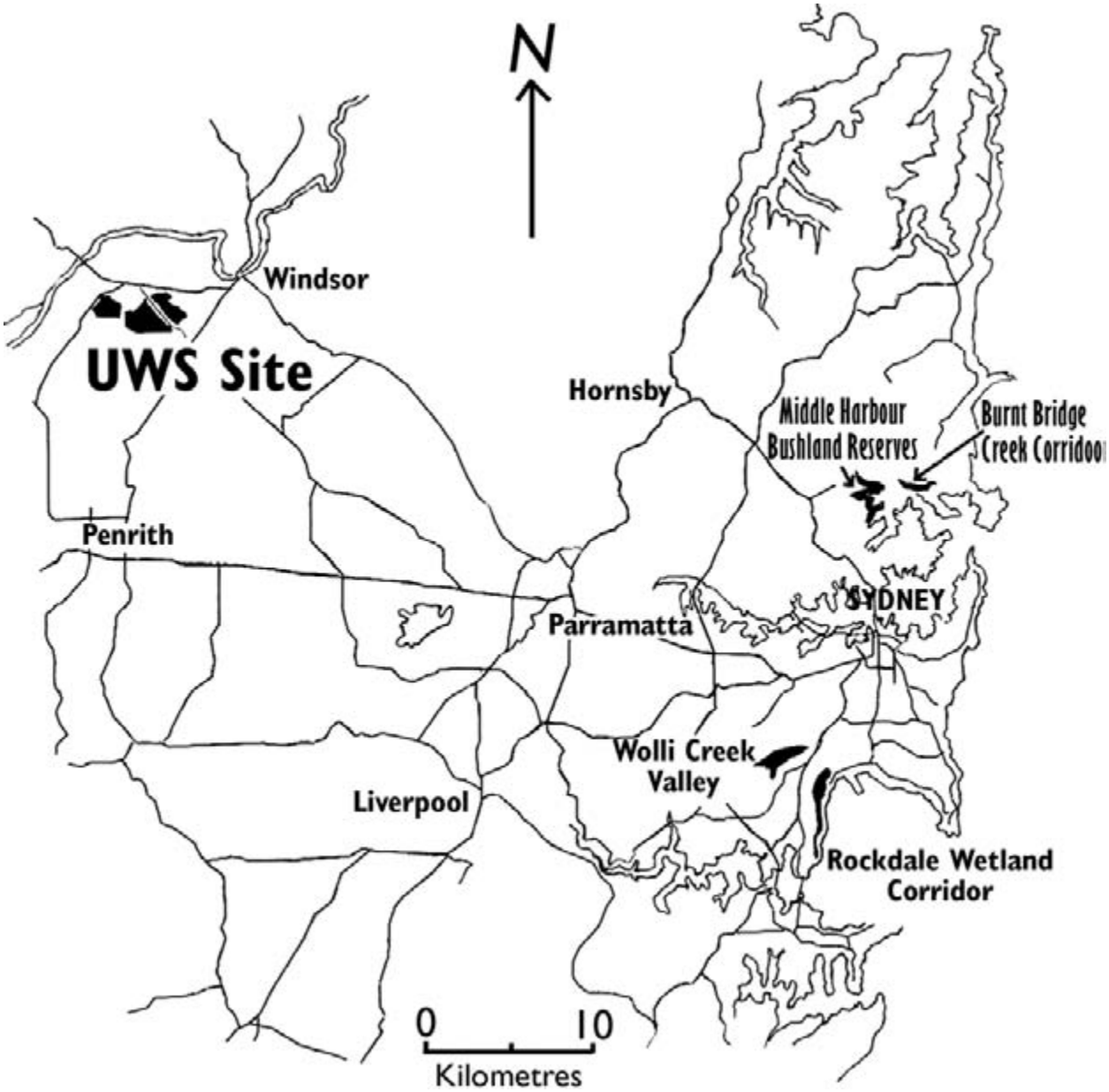

Figure 1. Location of the five urban bushland reserves.

Giant Burrowing Frog *Heleioporus australiacus* (Gillespie and Hines 1999), Green and Golden Bell Frog *Litoria aurea* (White and Pyke 1996), Broad-headed Snake *Hoplocephalus bungaroides* (Shine and Fitzgerald 1989) and Heath Monitor *Varanus rosenbergi* (Green and King 1993), have declined across their range, but are particularly at risk in urban areas. Some taxa are common in specific locations or widespread but uncommon in developed areas for example, the Eastern Longneck Turtle *Chelodina longicollis* (Burgin *et al*. 2001) and Eastern Blue-tongue Lizard *Tiliqua scincoides* (Shea 1998). Others, such as the Brown Striped Marsh Frog *Limnodynastes peronii* (Ferraro and Burgin 1993; Hengl and Burgin 2002) and the small skinks, Delicate Skink *Lampropholis delicata*, and Garden Skink *L. guichenoti* (Burgin 1993) appear to be pre-adapted for living in urban habitats. However, although currently resisting urban impacts, they may be the last dominos to fall in the decline of endemic herpetofauna (see *e.g.* Anderson and Burgin 2002).

In response to urban herpetofaunal loss, some major conservation initiatives have been undertaken. In Sydney, the rapid decline of the once-widespread Green and Golden Bell Frog sparked conservation programs to protect dwindling populations (Greer 1995; Pyke 1995; White 1993, 1998a, 1998b, 2001) but relatively few herpetofauna have evoked such attention. Data are limited on the current status of most species. Frequently relevant information is thinly scattered through the scientific literature, consultancy reports, natural history writing or remains in the minds of individuals.

To investigate changes in herpetofauna diversity since European settlement in Sydney's urban reserves, we reviewed available information for five large (greater than 35 ha) bushland reserves in Greater Sydney (Figure 1). They were selected because at least one of the authors was familiar with the herpetofauna of these reserves and had been involved in their recent survey, and historical data (oral and/or written) were available.

Figure 2. Freshwater wetland, Hawthorne Street Natural Area, Rockdale Wetland Corridor

Figure 3. Patmore Swamp, Rockdale Wetland Corridor

Figure 4. Sandstone escarpment, Wolli Creek Valley, Earlwood.

Figure 5. Path through Girrahween Park, Wolli Creek Valley, Bardwell Park.

Four of the reserves had been ringed by residential development for over 50 years while the University of Western Sydney, Richmond Campus (UWS) was in peri-urban Sydney. All of these sites suffer continual disturbance. By contrasting the herpetofauna of the four more urban 'island' reserves with the peri-urban UWS site, a pattern of species susceptibility to urban influences was identified. Our aims were to 1) identify species at risk from urbanisation, and 2) highlight the plight of urban herpetofauna and the need for conservation.

Study Sites

Rockdale Wetland Corridor

The Rockdale Wetland Corridor runs parallel with the western shoreline of Botany Bay (Figure 1). It extends from Arncliffe to Sans Souci, a distance greater than six kilometres. The corridor consists of a string of wetlands surrounded by areas of reclaimed swampland. It is interrupted in several places by major roads, playing fields and building encroachment. The corridor includes Eve and Marsh Street wetlands, Barton Park, Riverine Park, Whiteoak Reserve, Kings Road wetland, Patmore Swamp, Scarborough Park, Hawthorn Street Natural Area and Roads and Traffic Authority (RTA) reserved land in Sans Souci.

The areas near the wetlands were first settled in the 1820s and by the 1870s the wetlands were surrounded by farmland and residential development and isolated from other natural areas (Rathbone 2000). More recently the wetlands' core (Figure 2) have been dredged to create open lagoons. Land reclamation and residential development has narrowed the wetland corridor to an average width of 50 metres. Eighty hectares of undeveloped land remains (Figure 3).

Benson and Howell (1994) recognised two main vegetation associations within the corridor: Estuarine complex 4a and Coastal Dune Forest 9t. The dominant species of the Estuarine Complex are Grey Mangrove *Avicenna marina* in tidal channels, *Sarcocornia quinqueflora* in saltmarsh, *Phragmites australis* in rushland and *Casuarina glauca* in low, open forest. The Coastal Dune Forest association, confined to Holocene sand beds, has as its dominant species Sydney Red Apple *Angophora costata,* Bangalay *Eucalyptus botryoides*, Swamp Mahogany *E. robusta*, Blackbutt *E. pilularis* and Red Bloodwood *Corymbia gummifera*. This association also has a tall understorey of Old Man Banksia *Banksia serrata*, Heath Banksia *B. ericifolia*, various wattles (*Acacia longifolia*, *A. buxifolia*, *A. sopharae* and *A. terminalis*) and a ground cover dominated by bracken *Pterydium esculentum* and epacrids. The rest of the wetland corridor has widely spaced endemic trees, often separated by expanses of exotic grassland or native sedges and rushes (Biosphere 1999).

Wolli Creek Valley

Wolli Creek Valley, south of Port Jackson, occupies a widening sandstone gully (Figure 4) that opens onto a small floodplain (Figure 5) before joining the Cooks River Valley (Figure 1). It extends from Bexley North to Undercliffe and runs in a north-easterly direction.

Agricultural and residential development began in the early 1800s when the western ridge, comprising the modern suburbs of Earlwood and Kingsgrove, were established. Settlement along the Valley's eastern ridge was slower because of the low-lying, swampy nature of the land at Arncliffe. By the 1860s, Wolli Creek Valley had been encircled by altered land use and isolated from other natural lands (Rathbone 1999). Forty-five hectares of bushland remain in the valley.

The bushland consists of Sydney Sandstone Gully Forest 10ag (Benson and Howell 1994). Dominant species in closed gullies are Water Gum *Tristania laurina* with occasional Coachwood *Ceratopetalum apetaulm*. Open gullies are dominated by Turpentine *Syncarpia glomulifera* and Blackbutt while dominant species in the more open, flatter woodland areas are Sydney Red Apple and Red Bloodwood.

Middle Harbour bushland reserves

The western edge of Middle Harbour is flanked by a series of connected heavily wooded bushland reserves (H.D. Robb Reserve, Explosives Reserve, North Arm Reserve, Willis Park, Harold Reid Reserve, Castlecrag Northern Escarpment) with a combined area of 265 ha. They occupy sandstone headlands (Figure 6) and there is 13 km of continuous shoreline (Figure 7) from Roseville Chase south to Castlecrag. The area was first settled in the 1830s but was not surrounded by urban development until the 1930s.

The major vegetation associations are Sydney Sandstone Gully Forest 10ag and Sydney Sandstone Complex 10ar (Benson and Howell 1994). The Sydney Sandstone Gully Forest covers 90% of the bushland reserves. In predominantly ridge top woodland the dominant species are Sydney Red Apple and Red Bloodwood. In sheltered, wet gullies Water Gum and Coachwood are the dominant canopy species, while in more exposed gullies Turpentine and Blackbutt are dominant.

The Sydney Sandstone Complex occurs on shallow soils (eg. exposed ridge tops, steep hill sides). The dominant species in these woodlands are Red Bloodwood, Scribbly Gum *Eucalyptus haemastoma* and often a heath understorey is present that contains Heath

Figure 6. H.D.Robb Reserve, Middle Harbour Bushland Reserves, Castle Cove.

Figure 7. Angophora woodland, Explosives Reserve, Middle Harbour Bushland Reserves, Castle Cove.

Figure 8. Burnt Bridge Creek Corridor, Balgowlah Road, Balgowlah.

Figure 9. Burnt Bridge Creek Corridor, Baringa Avenue, North Balgowlah.

Figure 10. University of Western Sydney, Richmond campus site looking from agricultural lands at abutting woodlands of the Cumberland Plain.

Figure 11. Castlereagh woodlands, one of the transition vegetation types of the Cumberland Plain, present in the University of Western Sydney, Richmond campus site showing representative structure of the woodland.

Banksia, Dagger Hakea *Hakea teretifolia*, Black She-oak *Allocasuarina littoralis* and various epacrids.

Burnt Bridge Creek corridor

This is the smallest of the bushland reserves, covering 35 ha. This corridor, which occupies a narrow sandstone valley (Figure 8), straddles Burnt Bridge Creek as it passes from Seaforth to North Balgowlah (Figure 1). The reserve is heavily vegetated by native and exotic species (Figure 9).

This area of northern Sydney was first settled in the 1820s and quickly converted from rural to residential development. By 1900 it was completely separated from other bushland areas (Benson and Howell 1995).

Sandstone Complex 10ar (Benson and Howell 1994) is the only endemic vegetation association present. Red Bloodwood, Scribbly Gum and Sydney Red-apple are the dominant species in the Seaforth area (northern end of corridor) while in the southern segment (near Balgowlah) exotic species are dominant as canopy and understorey species.

University of Western Sydney, Richmond campus

The UWS site is in the north-western sector of Sydney, adjacent to Richmond (Figure 1). Originally part of Ham Common, designated by Governor King in 1804 for settlers to graze domestic stock, a large segment was excised in 1891 for agricultural teaching (Barkley and Nichols 1994). These lands have remained outdoor agricultural teaching facilities, although since the early 1990s they have also been utilised as outdoor laboratories for environmental biology.

Situated on the core of the Richmond campus, the site covers about 575 ha of bushland, incorporating the university farm's 'Bush Block', and adjacent vegetated areas. In addition to this remnant bushland (Figure 10), the core campus incorporates university infrastructure, a working dairy farm and other bushland remnants. Surrounded by roads it abuts the township of Richmond, university farmland, remnant bushland and rural residential development. The area is flat (i.e. elevation changes by less than 10 m across the site), with a large ephemeral wetland at the edge.

Benson (1992) reported that there were three main associations of Castlereagh Woodlands at the site: Castlereagh Scribbly Gum Woodland (14a) (Figure 11), Shale/Gravel Transition Forest (9a) and Swamp Woodland (14c). Dominant species include Hard-leafed Scribbly Gum *Eucalyptus sclerophylla*, Narrow-leafed Apple *Angophora bakeri* (Castlereagh Scribbly Gum Woodland), Broad-leaved Ironbark *Eucalyptus fibrosa*, Grey Box *E. moluccana* (Sale/gravel Transition Forest) and White Feather Honeymyrtle *Melaleuca decora* (Swamp Woodland).

Methods

Historical Data

Historical information on herpetofauna was gleaned from isolated notes from local archives and field diaries of amateur natural historians (especially A. Keast and P. Rankin), interviews with residents with appropriate knowledge of specific reserves (see Table 1 source summary). Historical information was available from published sources (eg. Krefft 1863, 1886; Fletcher 1890, 1891; Harrison 1922), while more recent data were gleaned from Copland (1957), Moore (1961), Worrell (1963), Green (1973) and Murphy (1996). Records for all reserves were incomplete due, in part, to taxonomic rearrangements that create confusion and because cryptic species go undetected in the absence of targeted searches. To underpin these historical data, information available on habitat preference and distribution were used to underpin historical information.

Current herpetofaunal records

Recent fauna surveys were available for all reserves. These included Rockdale Wetlands Corridor (Biosphere 1999), Wolli Creek Valley (Manidis Roberts 1996), Middle Harbour Bushland Reserves (Biosphere 2001a), Burnt Bridge Creek Corridor (Biosphere 2001b) and a range of research projects for UWS (eg. reptiles - Giffney 1997; Jelbart 1998; Burgin unpubl.data: frogs - Ferraro 1992, Ferraro and Burgin 1993a; Schell 1997; Burgin unpubl. data).

Table 1. Summary of Information Sources

Bushland Reserve	Major Information Sources
Rockdale Wetland Corridor	Rockdale City Council Archives Rockdale Wetlands Preservation Society Residents data used: P. Martyn, S. Martyn, C. Latta, R. Wellington, P. Straw, A. Keast.
Wolli Creek Valley	Rockdale City Council Archives Field notes of Peter Rankin. Wolli Creek Protection Society Residents data used: N. Little, M.Dawes.
Middle Harbour Bushland Reserves	Willoughby Wildlife Protection Society Willoughby City Council Wildlife Watch Residents data used: C. Bohm, G. Spis, A. James, L. Mitchell, W. Smith, H. Johnston.
Burnt Bridge Creek Corridor	Manly City Council Archives Residents data used: P. Jeffreys, M. Robinson.
University of Western Sydney Richmond campus bush block	Hawkesbury Herpetological Society Records of UWS-Centre for Integrated Catchment Management, predominantly T. Ferraro. D. Houston, J. Jelbart, C. Schell

Species loss

Information on species loss was based on data obtained from interviews (Urban reserves, White; UWS, Burgin). The causes of the loss of species were explored, particularly when the activities (eg. collection, hunting) may have led to a species' demise. This information was most readily available for the Middle Harbour reserves where information could be cross-checked among interviewees. Information on the UWS site was obtained from comparison of information collected during ecological research (particularly pitfall trapping) and outdoor teaching, together with consensus of 15 – 20 knowledgeable members of the Hawkesbury Herpetolological Society. These data were supplemented by review of the distribution and habitat requirements for species of the region using published field guides (eg. Swan 1990; Tyler 1992; Ehmann 1992; Griffiths 1997; Cogger 2000).

Analyses

Based on the probable species numbers in each group, the percentage survival was calculated for each reserve. For analysis, frogs were divided into two groups: tree frogs (Hylidae) and ground frogs (Myobatrachidae) while reptiles were divided into snakes (Boidae, Colubridae, Elapidae, Typhlopidae), goannas (Varanidae), geckoes (Geckonidae), dragons (Agamidae), pygopods (Pygopodidae), skinks (Scincidae) and turtles (Chelidae). Common names (Tyler 1998; Cogger 2000) were used in preference to scientific names because these were frequently used in interviews and data searches.

Results

Fate of herpetofauna

Data collected on the presence of herpetofauna are presented in Table 2 (Summary Table 3). Eight species, one tree frog, one ground frog, five skinks and one turtle, were common to all reserves (Tables 2, 3) while pygopods (1 – 2 species predicted to occur in all reserves), were absent. Seven species, historically predicted to be resident in all reserves, were now restricted to the least urbanised reserve (UWS).

In general, a greater proportion of most groups has persisted in the peri-urban area compared to urban reserves. With the exception of skinks (50-57% extant) and turtles (no loss), there were generally fewer than half of the original species in urban reserves. In contrast, most groups had suffered less impact in the peri-urban reserve. With the exception of geckos and pygopods (one species each predicted and not extant), at least 50% of all groups had been retained. In some groups (eg. Tree frogs) no loss was established (Table 3). Among the more specious groups, snake survivorship overall was low. Species have been extirpated in two urban reserves (Table 3).

Species loss due to human intervention

The most valid information derived from interviews is for the larger, more obvious species such as the snakes, dragons and skinks because the smaller, more cryptic species were frequently unnoticed. The larger snakes, particularly the Eastern Brown *Pseudonaja textilis* and Red-bellied Black snakes *Pseudechis porphyriacus*, were routinely killed by residents living on the boundaries of the reserves and by farm staff on the UWS site because of their perceived danger to humans. At Middle Harbour, this activity continued into the 1980s when snake numbers had declined and community attitudes towards them had softened. Most deaths are now due to road kills. Although snakes are still occasionally killed, it is viewed as an act of wanton destruction by other residents, rather than an act of self-defence. At UWS, snakes are killed surreptitiously by farm staff although more frequently 'snake catchers' remove unwanted animals and release them elsewhere.

Table 2. List of Extant, Historically Known and Predicted Herpetofauna in Urban Bushland Reserves.

Group	Species	Rockdale Wetland Corridor	Wolli Creek Valley	Middle Harbour Bushland Reserves	Burnt Bridge Creek Corridor	University of Western Sydney (Richmond)
Tree Frogs	Bleating Tree Frog	Extant	Historically Recorded	Historically Recorded	Historically Recorded	Extant
	Eastern Dwarf Tree Frog	Extant	Extant	Historically Recorded	Historically Recorded	Extant
	Freycinets Frog	Predicted	Never Present	Never Present	Never Present	Never Present
	Green and Golden Bell Frog	Extant	Historically Recorded	Never Present	Never Present	Never Present
	Green Tree Frog	Extant	Historically Recorded	Historically Recorded	Historically Recorded	Extant
	Jervis Bay Tree Frog	Predicted	Never Present	Never Present	Never Present	Never Present
	Leaf-green Tree Frog	Historically Recorded	Historically Recorded	Extant	Extant	Never present
	Littlejohns Tree Frog	Never Present	Predicted	Never Present	Never Present	Never Present
	Lesueurs Frog	Historically Recorded	Historically Recorded	Historically Recorded	Historically Recorded	Never present
	Perons Tree Frog	Extant	Extant	Extant	Extant	Extant
	Rocket Frog	Never Present	Never Present	Never Present	Never Present	Never present
	Tylers Tree Frog	Predicted	Predicted	Never Present	Never Present	Extant
	Verreauxs Frog	Never Present	Never present	Predicted	Predicted	Extant
Ground Frogs	Bibrons Toadlet	Predicted	Predicted	Historically Recorded	Historically Recorded	Predicted
	Common Eastern Froglet	Extant	Extant	Extant	Extant	Extant
	Eastern Banjo Frog	Historically Recorded	Historically Recorded	Historically Recorded	Extant	Extant
	Haswells Frog	Historically Recorded	Historically Recorded	Historically Recorded	Never Present	Predicted
	Ornate Burrowing Frog	Never Present	Never Present	Never Present	Never Present	Historically Recorded
	Red-crowned Toadlet	Never present	Never Present	Extant	Predicted	Never present
	Red-groined Toadlet	Historically Recorded	Historically Recorded	Historically Recorded	Historically Recorded	Extant
	Spotted Grass Frog	Predicted	Predicted	Never Present	Never Present	Extant
	Striped Marsh Frog	Extant	Extant	Extant	Extant	Extant
Snakes	Black-bellied Swamp Snake	Historically Recorded	Historically Recorded	Predicted	Predicted	Predicted
	Broad-headed Snake	Never Present	Never Present	Historically Recorded	Never Present	Never Present
	Eastern Blind Snake	Predicted	Predicted	Predicted	Predicted	Predicted
	Eastern Brown Snake	Historically Recorded	Historically Recorded	Historically Recorded	Historically Recorded	Extant
	Diamond Python	Predicted	Predicted	Extant	Historically Recorded	Extant
	Golden-crown Snake	Predicted	Predicted	Extant	Historically Recorded	Predicted
	Green Tree Snake	Historically Recorded	Historically Recorded	Extant	Historically Recorded	Extant
	Mainland Tiger Snake	Historically Recorded	Predicted	Never Present	Never Present	Never Present
	Masters Snake	Predicted	Predicted	Never Present	Never Present	Never Present
	Red-bellied Black Snake	Historically Recorded	Historically Recorded	Extant	Historically Recorded	Extant
	Red-naped Snake	Predicted	Predicted	Historically Recorded	Historically Recorded	Predicted
	Yellow-faced Whip Snake	Extant	Historically Recorded	Predicted	Historically Recorded	Extant

Group	Species	Rockdale Wetland Corridor	Wolli Creek Valley	Middle Harbour Bushland Reserves	Burnt Bridge Creek Corridor	University of Western Sydney (Richmond)
Goannas	Lace Monitor	Historically Recorded	Historically Recorded	Historically Recorded	Historically Recorded	Extant
Dragons	Bearded Dragon Eastern Water Dragon Jacky Lizard	Historically Recorded Historically Recorded Historically Recorded	Historically Recorded Extant Historically Recorded	Historically Recorded Extant Historically Recorded	Historically Recorded Extant Predicted	Extant Never Present Predicted
Geckos	Lesueurs Velvet Gecko Southern Leaf-tail Gceko Stone Gecko	Never Present Never Present Never Present	Predicted Extant Never Present	Predicted Extant Predicted	Predicted Extant Predicted	Never Present Never Present Predicted
Pygopods	Burtons Legless Lizard Common Scalyfoot	Never present Historically Recorded	Predicted Historically Recorded	Historically Recorded Historically Recorded	Predicted Historically Recorded	Never Present Predicted
Skinks	Bar-sided Skink Black-footed Rock Skink Casuarina Skink Common Blue-tongue Lizard Copper-tail Skink Delicate Skink Eastern Water Skink Garden Skink Glebe Gully Skink Robust Skink Snake-eyed Skink Three-toed Skink Weasel Skink Whites Skink	Historically Recorded Never Present Historically Recorded Extant Historically Recorded Extant Extant Extant Never Present Predicted Extant Historically Recorded Extant Never Present	Historically Recorded Predicted Historically Recorded Extant Historically Recorded Extant Extant Extant Never Present Predicted Extant Extant Extant Predicted	Historically Recorded Predicted Historically Recorded Extant Extant Extant Extant Extant Predicted Predicted Extant Extant Extant Historically Recorded	Historically Recorded Predicted Predicted Extant Extant Extant Extant Extant Predicted Never Present Extant Historically Recorded Historically Recorded Predicted	Extant Never Present Never Present Extant Extant Extant Extant Extant Never Present Predicted Extant Predicted Extant Never Present
Turtles	Eastern long-necked Turtle Sydney Short-necked Turtle	Extant Never Present	Extant Never Present	Extant Extant	Extant Never Present	Extant Never Present

Table 3. Percentage of Surviving Species of Herpetofauna in Urban Bushland Reserves

Herpetofaunal Groups	Rockdale Wetland Corridor	Wolli Creek Valley	Middle Harbour Reserves	Burnt Bridge Corridor	UWS Bushland Site
Tree Frogs	50.0 (10)	22.2 (9)	28.6 (7)	28.6 (7)	100 (6)
Ground Frogs	28.6 (7)	28.6 (7)	42.9 (7)	50.0 (6)	62.5 (8)
Snakes	9.1 (11)	0 (10)	40.0 (10)	0 (9)	55.6 (9)
Goannas	0 (1)	0 (1)	0 (1)	0 (1)	100.0 (1)
Dragons	0 (3)	33.3 (3)	33.3 (3)	33.3 (3)	50 (2)
Geckos	0 (0)	50.0 (2)	33.3 (3)	33.3 (3)	0 (1)
Pygopods	0 (1)	0 (1)	0 (2)	0 (2)	0 (1)
Skinks	54.6 (9)	53.8 (13)	57.1 (14)	46.2 (13)	80.0 (10)
Turtles	100.0 (1)	100.0 (1)	100.0 (2)	100.0 (1)	100.0 (1)

The first figure is the percentage of surviving species; the figure in brackets is the total number of species that occurred historically at the site.

Goannas *Varanus varius* were also routinely killed historically. In post World War II Sydney, residents frequently kept poultry. To protect the hens, the raiding goannas were often killed. They were also killed because of the belief that their bite resulted in an incurable wound. Goannas are not viewed as a threat at UWS and tend to be treated as a novelty, despite (until recently) large free-range chicken operations adjacent to the bushland.

The Common Blue-tongue Lizard was also killed post-World War II because of the misapprehension that they were poisonous and a bite would produce a festering sore that could lead to death. They are also inadvertently killed while basking on roads and savaged by dogs (Shea 1998). Around UWS, Common Blue-tongue Lizards and Bearded Dragons *Pogona barbata* are frequent road casualties (Burgin pers. obs.).

Reptile collecting occurred in all reserves, although with assumed minimal impact on UWS. The area is out-of-bounds (although not particularly well policed) to the general public and non-researcher students. Most animals collected are for ecological research and re-released at the point of capture. Despite restrictions, some species, particularly turtles and Green Tree Frogs *Litoria caerulea*, are taken and kept as pets (Burgin pers. obs.).

Species preferred by collectors include the medium-sized snakes and larger lizards (eg. Diamond Python *Morelia spilota*, Green Tree Snake *Dendrelaphis punctulata*, Broad-headed Snake, Common Blue-tongue Lizard, Bearded Dragon and Common Scalyfoot *Pygopus schraderi*). Of the smaller species, geckoes and pygopods were kept and small skinks continue to be collected as 'snake food'.

The Eastern Long-neck Turtle was often kept as a backyard pet, tethered by inserting a chain link through a hole drilled in the margin of the shell (Cann 1998). In peri-urban Western Sydney, outdoor pens, with in-built ponds, are often still used to retain them (Burgin pers. obs.).

Frogs are apparently not often kept as pets, although tadpole collection was common and remains a widespread activity. Tree frogs that occasionally enter homes (particularly outside toilets and laundries) are generally tolerated, although some were killed. At UWS they are largely ignored unless perceived to be 'sick', in which case they are collected for disease assessment. However, until about 20 years ago, Green Tree Frogs were considered sufficiently common to be routinely collected for teaching frog dissection. Attitudes have subsequently changed and the university is now interested in maintaining their breeding habitat, including a favoured area in a disused agricultural shed.

Dogs, cats and foxes appear to take a heavy toll on reptiles on UWS. Current research on small skinks (Anderson in prep.) has indicated that foxes and cats prey on small skinks while foxes destroy turtle and Bearded Dragon egg nests (Wotherspoon pers. comm.). Cats also kill small snakes (Burgin pers. obs.).

Bush rock removal has been recognised as a 'key threatening process' under Schedule 3 of the *New South Wales Threatened Species Conservation Act 1995* for some species (eg. Red-crowned Toadlet, Broad-headed Snake). Removal of loose rocks deprives animals of their shelter sites and associated prey (Schlesinger and Shine 1994). While impossible to ascertain the extent of past rock collection in urban reserves, few 'cartable' rocks remain. Because of the alluvial derived soils in UWS bushland (Benson 1992), historically there was no bushrock to remove.

Past drainage works have changed wetland hydrology and reduced the extent of swampy areas in the Rockdale Wetlands and at UWS. In addition, approximately 20 dams have been constructed across the UWS core campus (sometimes by modification of natural waterbodies), most during the 1960s and 1970s (Dalem 1998). Pasture adjacent to the bushland is irrigated. Past clearing and agriculture, subsequent regeneration adjacent to woodlands, together with poor irrigation practices, have resulted in weed infestation along one side of the reserve. Associated hydrological changes could have impacted on local biodiversity (eg. Spotted Grass Frog, Schell and Burgin 2003). Other species (*e.g.* Eastern Long-necked Turtle, Dalem 1998) have probably benefitted but for most species the changes would have been, at best, marginally beneficial.

Discussion

Vulnerability of herpetofauna

Bushland islands, surrounded by a 'sea' of urbanisation, have higher herpetofauna extinction rates than similar areas in the peri-urban environment. Species that have been most affected include the snakes, goannas and pygopods although even more common, generalist species (*e.g.* skinks, frogs) are not immune to local extinction.

Some snakes and goannas have been targeted for removal (*i.e.* collection, death). In isolation, such activities are unlikely to have been responsible more broadly for the demise of herpetofauna in bushlands. Snakes and goannas prey on small mammals and herpetofauna (Greer 1997). Prey decline associated with urban impacts, compounded by deliberate removal, could accelerate local extinctions. However, this would not account for the demise of pygopods. They have different diets (*e.g.* Burton's Legless Lizard *Lialis burtonis*, small lizards; Common Scalyfoot, spiders and insects; Patchell and Shine 1986; Greer 1989) and are less likely to be targeted by humans because of their cryptic nature. However, they were not recorded in any reserve.

Current studies on the impact of habitat fragmentation on small skinks at UWS (Anderson 1999; Anderson and Burgin 2002; Anderson in prep.) have revealed that predation (*e.g.* birds, foxes, cats) has reduced small skink abundance in perimeters, compared to core areas of woodlands. Pygopods are nocturnal and are at particular risk of predation from such exotic predators as cats and foxes.

Dragons and skinks are diurnal hunters that prey on a wide range of terrestrial insects (Greer 1989) and are also susceptible to predation by exotic mammals, particularly in the egg and juvenile stages. In 2001-2002 on the UWS site, all Bearded Dragon nests were destroyed by foxes within 24 hours of laying (Wotherspoon pers. comm.).

Frogs, particularly ground frogs, and geckos have also declined. Together with the pygopods, these animals prey on nocturnal invertebrates (Tyler 1989, Greer 1997) and their diversity has decreased. A plausible explanation for their demise is predation by exotic species. However, in our view, the most significant factor in frog decline is the loss of breeding sites and deterioration of water quality. Many species need semi-permanent breeding sites because of their long larval stages (Anstis 2002). With urban expansion, low-lying sites that historically held storm water for prolonged periods after rain have been in-filled. Alternatively they have been managed to reduce the incidence of insect pests, such as mosquitoes (Pyke and White 2001). In addition, paved surfaces, roads, gutters and channels now facilitate rapid runoff of stormwater. At UWS, where the water table is shallow, drainage works have reduced water levels in the soil profile and, therefore, shortened the duration of standing water.

Contamination of urban stormwater further reduces potential breeding sites (White 1998b). It has been demonstrated (Ferraro and Burgin 1993a; Schell 1997; Schell and Burgin 2004) that diversity is reduced in degraded wetlands while Ferraro (1992; Ferraro and Burgin 1993b) reported that changes in pH and salinity could be detrimental to tadpoles with effects being species-dependent.

Ground frogs are less susceptible to stormwater pollution than tree frogs (White 1998b) because they breed in a wider range of aquatic sites. At UWS, Schell and Burgin (in press) observed lower recruitment in recent years of the Spotted Grass Frog, an animal with a relatively long larval period (6-8 months, Tyler 1989; Anstis 2002). The authors concluded that past drainage operations, coupled with drought, were probably responsible for the change.

Changing ecosystem dynamics can also favour one species over another. Pyke and White (1999) found that the Striped Marsh Frog displaced Green and the Golden Bell Frog in degraded wetlands. Striped Marsh Frogs survived in shallow, more thickly vegetated sites while Green and Golden Bell Frogs preferred deeper water bodies with less dense fringing vegetation. Siltation will, therefore, favour the survival of the Striped Marsh Frog.

In contrast to other aquatic species, the two species of endemic turtles have been apparently unaffected by urbanisation. There has been no loss of species in any reserve. This does not mean that turtles were not adversely affected by urbanisation. Burgin *et al.* (1999; Ross 2000) showed that in north-western Sydney, recruitment of Eastern Long-necked turtles was substantially below expectations. The impact of foxes, via nest predation, has been more widely documented (Thompson 1983; Marks and Short 1996) and continues to be a major factor at UWS (Burgin pers. obs.).

In urban Sydney, Rosser (1997) reported Environmental Disease among Lane Cove River turtles that was not observed elsewhere (*e.g.* Upper Parramatta Catchment, Ross 1997; Longneck Lagoon Catchment, Wong and Burgin 1997; UWS, Dalem 1998, unpubl. data; Eastern Creek Catchment, Betts 1995, Burgin *et al.* 1999, Burgin unpubl. data). However, Wong and Burgin (1997) did find emaciated turtles in the Longneck Lagoon Catchment.

The Sydney Short-necked Turtle *Emydura macquarii dharuk*, effectively unknown to science until the late 1970s (Cann 1998), appears to be widespread in appropriate habitat. For example, Ross (2000) found healthy populations, with equivalent population profiles to the Eastern Long-necked Turtle, in the four sites he studied in the upper Parramatta River catchment.

Feral turtles (*e.g.* Red-eared Slider *Trachemys scripta elegans*) have been identified as inhabitants of larger water bodies (*e.g.* Griffiths 1997; Ross 2000; Burgin unpubl. data). While these animals have been presumed to be escapees, data held by Burgin indicates that they are breeding, at least in one site in Southern Sydney. Once established this feral species may place an additional pressure on endemic species.

Bushland fragmentation, associated with urbanisation, has created land units that are vulnerable to species loss, due to their isolation from other remnants (Saunders 1994) and increased exposure to external impacts (Saunders 1994; Anderson and Burgin 2002). Species re-colonisation may be prevented and metapopulations may become extinct (Saunders 1989).

We believe that factors most strongly impacting on the endemic herpetofauna within these remnants are direct human threats that result in death or removal, predation by feral species and loss of breeding habitat (at least for some species).

The survivors

Several patterns emerged from this study. Survival in urban reserves has been generally more difficult for tree frogs than ground frogs. This is attributed to the greater sensitivity of tree frogs to polluted water, their greater dependence on open water breeding sites and sometimes long larval stage (Anstis 2002). However, Peron's Tree Frog and the Leaf-green Tree Frog have coped better with urban impacts than others. Other species (eg. Striped Marsh Frog; Common Eastern Froglet; Eastern Banjo Frog) have persisted in all of the reserves and some, such as the Striped Marsh Frog (White 1998b; Hengl and Burgin 2002), may be expanding their range.

With only a slow change in the attitude that, 'the only good snake is a dead snake', snakes have a bleak future and some long-term, resident herpetologists associated with the Hawkesbury Herpetology Society believe that populations across western Sydney have 'crashed', despite their apparent stronghold on UWS. Based on their current distribution among reserves, the species that apparently have the best chance of survival are the Yellow-faced Whip Snake, Golden Crown Snake, Green Tree Snake and the Red-bellied Black Snake. However, since the Green Tree Snake feeds almost exclusively on frogs (Greer 1997), the demise of frogs will ultimately impact on this species. Because of its wider dietary range, the Red-bellied Black Snake will be less at risk in this regard (Greer 1989).

By comparison to many other groups, skinks have tended to persist, although one species (White-barred Skink), that would have historically inhabited all reserves, has disappeared. Species remaining are small, generalist species (e.g. Garden Skinks, Snake-eyed Skink). These lizards prey heavily on small house ants that are in high numbers in urban areas (Greer 1989) but also consume a wide range of other invertebrates (Burgin 1993; Warner 1995). They are also able to use gaps between bricks and walls as communal egg-laying sites.

With the exception of the Eastern Water Skink, other medium-sized skinks have not survived. The largest of the local skinks, the Common Blue-tongue Lizard, was found in all reserves. Koenig *et al.* (2001) hypothesised that it had characteristics that assisted its urban survival. These include preying on garden molluscs (*e.g.* slugs, snails) and being able to inhabit artificial ground cover. They also have a large number of offspring and are reticent to remain exposed for long. Evidence of their ability to cope with heavily modified areas was provided in western Sydney where their range extended into open farmland adjacent to bushland (Burgin pers. obs.).

Dragons have also diminished in number. One previously widespread species (Jackie Lizard) was locally extinct across the four urban reserves. Although probably never present at UWS, it persists in surrounding areas and in the nearby Blue Mountains bushland (Burgin pers. obs.) indicating that it persists in non-urban areas.

Previously found in all reserves, the Bearded Dragon is now restricted to UWS. However, its numbers have crashed in recent years (Burgin pers. obs.; HHS members pers. comm.). Once a common sight, it now takes a team of experienced herpetologists approximately 100 hours to find one animal (D. Wotherspoon pers. comm.). Juveniles are rare, although five years ago they were collected in pitfalls traps and seen basking on a roadway adjacent to the bushland (Burgin pers. obs.).

The Eastern Water Dragon was found in all urban reserves and, although not present on the UWS site due to the lack of appropriate habitat, there are several large populations nearby indicating that it has a stronghold in peri-urban Sydney.

Only one species of gecko (Southern leaf-tail Gecko *Phyllurus platurus*) appears to be surviving in urban-impacted reserves. This may be due to its predilection for sandstone crevices and its diet of small skinks and insects. Its adaptability was apparent to one of us (SB). One was observed to live for several years with a resting site behind a poster hung on an outside wall. Other geckos are apparently locally extinct.

The cryptic, nocturnal-feeding pygopods were not recorded recently from any of the reserves but they are unlikely to be observed casually. However, their demise at UWS seemed certain since widespread pitfall trapping in a variety of habitats, over the last decade, has failed to capture a single animal.

Goannas similarly have poor survival prospects. Although relatively harmless to humans, they are often feared, even more than snakes. Their decline in urban reserves appears to be related to their diurnal habitats. Goannas need to forage over large areas in search of food, this makes them conspicuous and prone to encounter on roads, paths and public spaces (especially if food scraps are available). In addition to accidental or deliberate death, goannas may have declined because of a reduction in senescent trees with hollow branches and split trunks that can be used for shelter (Greer 1989).

Factors that affect vulnerability

Factors that increase a species' vulnerability to decline in urban bushland include size, perceived nuisance value, catchability, dietary range, choice of breeding site and 'pet appeal'. Larger reptiles tend to be more vulnerable in urban-impacted reserves than smaller species: they are more obvious and, by virtue of their size, may be deemed a threat. Animals perceived to be dangerous (*e.g.* larger snakes) have low survival potential.

Larger species (*e.g.* Bearded Dragon, Red-bellied Black Snake, Goanna) need to bask longer than smaller species to maintain active body temperatures (Greer 1989). Constant disruption during basking by humans or domestic animals may reduce basking time, food gathering efficiency, and subsequently reduce their ability to withstand unfavourable conditions. Larger animals also tend to have a larger home range (Rose 1982) and are more likely to have detrimental encounters. Remnant bushland may also be too small to support prey or provide sufficient habitat for wide-foraging reptiles.

Frogs, pygopods, dragons and some skinks are often exposed while hunting. This increases vulnerability to predator attack by cats and foxes (Biosphere 1999, 2001a, b). Dogs, left unattended, scavenge and seek animals to chase (Biosphere 2001a). Dog attacks on Common Blue-tongue Lizards and

Water Dragons *Physignathus lesueurii* were observed by both authors. Dog presence may also cause basking reptiles to seek shelter (and cease basking), stop foraging or generally disrupt normal behaviour patterns. They may also scare potential prey (*e.g.* smaller lizards, insects).

Species that have very specific breeding requirements are also at greater risk. Tree Frogs require unpolluted, relatively still, fish-free sites in which to breed and urban bushland reserves have frequently lost these habitats (Tyler 1989). For example, exotic fish, that predate tadpoles and eggs, have colonised urban waterbodies and may have a substantial impact on endemic frogs (Pyke and White 1999).

Many reserves also contain sewer easements or stormwater overflow watercourses (Biosphere 1999, 2001a). During heavy rain, overflow and sewage spills are common. The resulting effluent frequently flows into local watercourses. These streams also may collect runoff from industrial or residential areas while the water carried during times of low flow is often highly contaminated with a variety of petro-chemicals, household chemicals (*e.g.* detergents, fertilisers, industrial chemicals such as solvents and inorganic salts; Sydneywater.com.au/stormwater).

Many dragons (Greer 1989) and turtles (Cann 1998) require sandy, sunny banks for nesting sites, but they are rarely retained or protected from predation. A change in land use (*e.g.* reduced grazing pressure) may result in weed invasion of nesting sites and an associated increased competition for egg laying sites (Burgin pers. obs.).

Species with specific diets may be affected by changed bushland dynamics. Broad-headed Snakes feed on rock-dwelling geckos, such as Lesueur's velvet gecko *Oedura lesueurii* (Webb and Shine 1994). Velvet geckos decline due to bush rock removal (Schlesinger and Shine 1994) and there have been an associated decline in snake numbers (Cogger *et al.* 1993).

The widespread (and now illegal) practice of bush rock removal (especially Hawkesbury Sandstone) from bushland reserves has resulted in a loss of habitat for a range of species (eg. Broad-headed Snake, Lesueur's Velvet Gecko, Eastern Small-eyed Snake *Rhinoplocephalus nigrescens*, Yellow-faced Whip Snake *Demansia psammaphis*, Red-crowned Toadlet, Red-groined Toadlet, Eastern Banjo Frog, Common Eastern Froglet) because of reduced shelter sites and an associated increased chance of predation. Such interference also disrupts the seasonal dispersal routes and increases the time spent exposed while searching for shelter sites (Cogger *et al.* 1993).

Red-crowned Toadlets prey on small insects that occur in leaf litter on Hawkesbury Sandstone. Changes in moisture levels due to expansion of hard surfaces or development sites on ridge-tops reduces leaf litter, and associated insect biomass, and may also result in the loss of toadlet breeding sites (Thumm and Mahony 1999).

Reptiles (and to a lesser extent frogs) have been collected as pets from Sydney's urban bushland since at the least the early 1900s (McPhee 1963). Species targeted by collectors include Bearded Dragons (*e.g.* Daly 1997), Eastern Water Dragons (eg. Harlow and Harlow 1997), Eastern Bluetongue Lizards (Shea 1998), Broad-headed Snakes (Shine 1990), Diamond Pythons and Green Tree Snakes (Worrell 1963). Over-collection of Broad-headed Snakes is considered a reason for its decline (Shine and Fitzgerald 1989), however, the overall impact of collection is unknowable.

Urbanisation has resulted in changed fire regimes in bushland reserves. Some areas are now burnt more frequently (*e.g.* parts of the Rockdale Wetlands Corridor, C. Cunnningham pers. comm.) while others have not been burnt for over 40 years (*e.g.* parts of the Middle Harbour Bushland; A. Bernhard pers. comm.; UWS Burgin pers. obs.). Reptiles that utilise leaf litter or dry habitats, occur on ridges and/or are arboreal are most susceptible to fire (Lunney *et al.* 1991; Tolhurst 1996). Reptiles that utilise burrows or use rock shelters are less directly impacted but may have reduced prey availability immediately after fire. Larger species flee from fire and shelter in unburnt areas (Friend 1993). In urban areas this frequently results in movement into residential areas or enforced road crossings. For many the result is death (Griffiths pers. comm.).

Urban impacts that appeared to relate to herpetofauna decline were direct human intervention that resulted in death or removal of individuals (*e.g.* goannas, large snakes), interference with habitat such as bush rock removal (*e.g.* smaller snakes, geckos, skinks), fire (*e.g.* non-burrowing small residents), interference with the water cycle including infilling and pollution (*e.g.* frogs) and exotic predators (*e.g.* dragons, turtles, skinks). To survive the best characteristics are to be small, not perceived to be a threat or menace, not have 'pet appeal' and avoid feral predators.

The future of the herpetofauna in urban bushland reserves

Herpetofauna loss in urban reserves has been substantial across effectively all groups although it has been generally lower in the peri-urban area. Some species have either universally persisted (*e.g.* turtles, some frogs) or declined (*e.g.* pygopods, geckoes) and, in terms of diversity, do not provide useful information to underpin recommendations for future sustainability of urban remnants.

In general, it would appear that the UWS herpetofauna has survived because urban pressures have been less intense. Although adjacent farming practices have taken a major toll, bushland and nearby habitat is generally less hostile than in the more urban areas. Distance between adjacent habitat patches and the likelihood of road kills are diminished compared to urban remnants. Within the bushland, direct human interference (*e.g.* fire, physical removal of individuals, disturbance, human-induced water pollution, light pollution) are presumably all less threatening forces then in more urbanised sites. In contrast, feral predators are common and clearly having a substantial impact on many local populations (*e.g.* turtles, Bearded Dragons, small skinks). These observations imply that improved management of feral predators would strengthen the future prospects of the local herpetofauna. However, increased urban density, without appropriate management, would apparently negate benefits gained from reduced predation.

Despite increased community awareness and expanded scientific knowledge of the herpetofauna across greater Sydney, species will continue to be lost under current management regimes and can only be prevented through greater active management of these 'urban islands'. Several examples of effective management have resulted in the maintenance of remnant herpetofauna populations and even an increase in population size in some species. Notable examples include the rehabilitation of the Botany Wetlands by Sydney Water Corporation, the creation of the Chullora Wetlands and the creation of habitat for Green and Golden Bell Frogs at the Sydney Olympic Site at Homebush Bay (White pers. obs.). However, such intervention requires appropriate baseline data and on-going monitoring to identify species in decline and develop appropriate remediation techniques for their survival. Comparative datasets, such as those generated here, require substantial time and resources, but are necessary to highlight the status and future prospects of species within urban ecosystems.

Acknowledgements

This study could not have been completed without the assistance of many people. The authors would like to thank Cindy Cunningham and the staff of Rockdale City Council, Jennie Minifie and James Rennie and the staff of Manly Council, Alfred Bernhard, Rebecca Wilkinson and Di Eva and the staff of Willoughby City Council, the Hawkesbury Herpetological Society, the Frog and Tadpole Study Group of New South Wales, the Rockdale Wetlands Preservation Society, Wolli Creek Protection Society, Willoughby Wildlife Protection Society, students of the UWS Centre for Integrated Catchment Management and the many residents who assisted in providing information about the past history of the bushland reserves. We are also deeply indebted to the anonymous reviewers, Dan Lunney as editor and to Lyn Anderson for her careful review of the revised manuscript.

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