SHORT COMMUNICATIONS

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Morbidity and Mortality of Reptiles Admitted to the Australian Wildlife Health Centre, Healesville Sanctuary, Australia, 2000–13

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ABSTRACT: Medical records of 931 reptiles admitted to the Australian Wildlife Health Centre, Healesville Sanctuary, Healesville, Victoria, Australia, from 2000 to 2013 were reviewed to determine the causes of morbidity and mortality. Thirty-nine species were presented; the most common were the common long-neck turtle (*Chelodina longicollis*; $n=311$, 33.4%), the eastern bluetongue lizard (*Tiliqua scincoides*; $n=224$, 4.1%), the blotched bluetongue lizard (*Tiliqua nigrolutea*; $n=136$, 14.6%), and the lowland copperhead (*Austrelaps superbus*; $n=55$, 5.9%). Trauma was the most significant reason for admissions, accounting for 73.0% of cases. This was followed by not injured (11.7%), displacement (6.4%), snake removal (4.2%), human interference (3.1%), introduced species (1.1%), sick/diseased (0.2%), and illegal pet (0.2%). Within the category of trauma, impact with motor vehicle (41.0% of trauma cases) and domestic animal attack (33.2% of trauma cases) were the most common subcategories. Our results indicate that indirect anthropogenic factors are a significant cause of morbidity and mortality in Australian reptiles.

Key words: Blotched bluetongue lizard, common long-neck turtle, eastern bluetongue lizard, lowland copperhead, mortality, trauma.

Studies of morbidity and mortality of wildlife have been used as indicators of ecosystem health and to assess the effects of anthropogenic pressures on wild animal populations (Schenk and Souza 2014). However, studies of this nature are rare in reptiles (Hartup 1996). Given that herptiles may occupy vastly different ecological niches from endothermic species, such investigations can provide valuable insight into the complexity of microclimates and complete biodiversity health.

According to the Red List of Threatened Animals (International Union for Conservation of Nature 2014), Australia has one of the highest numbers of threatened reptile species in the world (6.5% of total threatened reptile species). Retrospective analysis of wildlife admissions may aid in categorizing these threats and help to ameliorate continued reptile declines. I assessed causes of morbidity and mortality of reptiles admitted to the Australian Wildlife Health Centre (AWHC), Healesville Sanctuary, Victoria, Australia, from 2000 to 2013.

I examined the medical records of reptiles admitted to the AWHC (38°28′44.0″S, 145°28′11.6″E) from 1 January 2000 until 31 December 2013. Only patients with positive identification of species, and known final case outcomes, were included in this investigation. Any incomplete medical records were excluded, leaving 931 individual reptiles. Additional information collected included medical case identification number, sex (when known), age (adult or juvenile), admission date, and reason for presentation. Cases were predominately presented to the AWHC by good samaritans.

Case presentations were classified as trauma, not injured, displacement, snake removal, human interference, introduced species, sick/diseased, or illegal pet. Trauma was subdivided into impact with motor vehicle, domestic animal (dog or cat) attack, garden equipment trauma, unknown trauma, entanglement (fishing tackle or garden/orchard netting), and burned. Displacement was applied to animals found outside their known geographic range or considered likely to be escaped pets. The category of snake removal was for amateur or professional herpetologists who had

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TABLE 1. Reptile species admitted to the Australian Wildlife Health Centre, Healesville Sanctuary, Healesville, Victoria, Australia, 2000–13.

Species	No.	Reptile cases (%)
Chelonians		
Common long-necked turtle (*Chelodina longicollis*)	311	33.4
Macquarie River turtle (*Emydura macquarii*)	30	3.2
Mary River turtle (*Elusor macrurus*)	1	0.1
Leatherback turtle (*Dermochelys coriacea*)	1	0.1
Lizards		
Eastern bluetongue lizard (*Tiliqua scincoides*)	224	24.1
Blotched bluetongue lizard (*Tiliqua nigrolutea*)	136	14.6
Lace monitor (*Varanus varius*)	25	2.7
Shingleback lizard (*Tiliqua rugosa*)	16	1.7
Marbled gecko (*Christinus marmoratus*)	10	1.1
Asian house gecko (*Hemidactylus frenatus*)	10	1.1
Eastern bearded dragon (*Pogona barbata*)	8	0.9
Eastern water dragon (*Intellagama lesueurii lesueurii*)	7	0.8
Gippsland water dragon (*Intellagama lesueurii howittii*)	6	0.6
Black rock skink (*Egernia saxatilis*)	6	0.6
Southern water skink (*Eulamprus tympanum*)	5	0.5
Central bearded dragon (*Pogona vitticeps*)	4	0.4
Tree dtella (*Gehyra variegata*)	4	0.4
Jacky lizard (*Amphibolurus muricatus*)	3	0.3
Cunningham's skink (*Egernia cunninghami*)	2	0.2
Tree skink (*Egernia striolata*)	2	0.2
Alpine water skink (*Eulamprus kosciuskoi*)	1	0.1
Black-headed monitor (*Varanus tristis*)	1	0.1
Golden spiny-tailed gecko (*Strophurus taenicauda*)	1	0.1
Gould's monitor (*Varanus gouldii*)	1	0.1
Spotted dtella (*Gehyra punctata*)	1	0.1
Swamp skink (*Egernia coventryi*)	1	0.1
Snakes		
Lowland copperhead (*Austrelaps superbus*)	55	5.9
Eastern tiger snake (*Notechis scutatus*)	27	2.9
Alpine copperhead (*Austrelaps ramsayi*)	6	0.6
Brown tree snake (*Boiga irregularis*)	6	0.6
Eastern small-eyed snake (*Cryptophis nigrescens*)	4	0.4
Coastal carpet python (*Morelia spilota mcdowelli*)	4	0.4
White-lipped snake (*Drysdalia coronoides*)	3	0.3
Eastern brown snake (*Pseudonaja textilis*)	2	0.2
Little whip snake (*Parasuta flagellum*)	2	0.2
Red-bellied black snake (*Pseudechis porphyriacus*)	2	0.2
Green tree snake (*Dendrelaphis punctulata*)	1	0.1
Boa constrictor (*Boa constrictor*)	1	0.1
Corn snake (*Pantherophis guttatus*)	1	0.1
Total	931	100

captured snakes to relocate them from suburban gardens. Human interference referred to cases where people had deliberately removed animals from their environment to translocate without permission or to keep as pets. Animals were deemed as illegal pets if they were a species not permitted to be kept legally in the state of Victoria and had been surrendered to the AWHC. Reptiles were categorized as not injured if they were presented with no obvious signs of physical harm or on the assumption from the donor that they were "lost."

After presentation, all reptiles were given a thorough physical examination by the attending veterinarian, and the diagnosis

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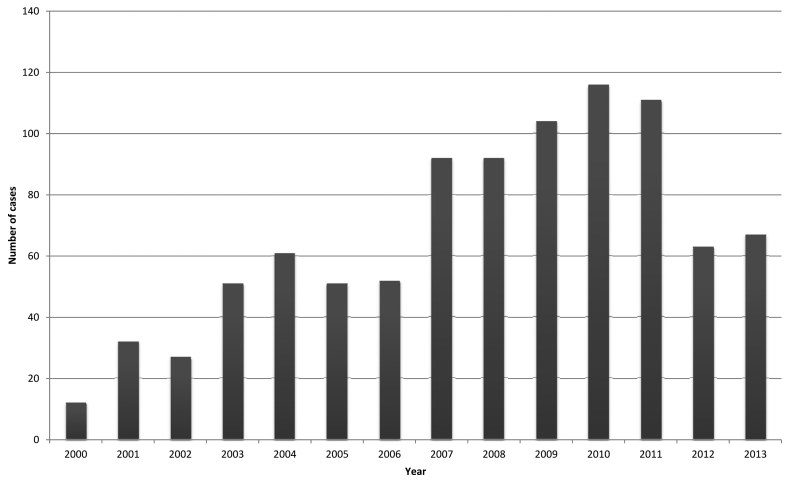

FIGURE 1. Total number of reptiles admitted each year to the Australian Wildlife Health Centre, Healesville Sanctuary, Healesville, Victoria, Australia, 2000–13.

of case presentation was confirmed based on case history, clinical findings, and any ancillary diagnostic tests. Animals were treated according to individual clinician's discretion. Final case outcomes included released, died naturally (without euthanasia), euthanasia, or retained in captivity.

Data were imported into Excel 2007 (Microsoft Corporation, Redmond, Washington, USA), and statistical analysis was performed using SYSTAT® (Systat Software Inc., Chicago, Illinois, USA). Data were assessed for normality with the Shapiro-Wilk test. Fisher's exact test was used to assess categorical variable associations and significance was accepted if $P \leq 0.05$.

The 931 individual animals were comprised of three families, 27 genera, and 39 species (Table 1). The most frequent species admitted included the common long-neck turtle (*Chelodina longicollis*), the eastern bluetongue lizard (*Tiliqua scincoides*), the blotched bluetongue lizard (*Tiliqua nigrolutea*), and the lowland copperhead (*Austrelaps superbus*).

Overall, the number of reptiles presented from 2000 to 2011 increased; however, from 2012 to 2013, numbers declined slightly (Fig. 1). Reptiles were more frequently presented during the warmer months (October–March), with peak admissions during November and December (Fig. 2).

Adult reptiles were the most common life stage presented to the AWHC, comprising 96.2% of admissions. Sex was not recorded in the majority of cases ($n=588$, 63.2%), and detailed analysis of sex predisposition was not possible. Of the remaining animals, 168 (18%) were male and 175 (18.8%) were female.

Trauma was the most common reason for reptile admissions, accounting for 73.0% of all cases. Within the category of trauma, impact with motor vehicle and domestic animal attack were the most common subcategories (Table 2). Differences existed for reasons for presentation between the most common species admitted. Common long-neck turtle was more likely to be presented for impact with motor vehicles than the other species ($P<0.0001$). Frequency of domestic animal attack was similar between eastern bluetongue lizards and blotched bluetongue lizards ($P=0.43$), and more common in these species than in chelonians ($P<0.0001$) and lowland copperheads ($P=0.02$). Common long-neck turtle was more likely to be presented for impact

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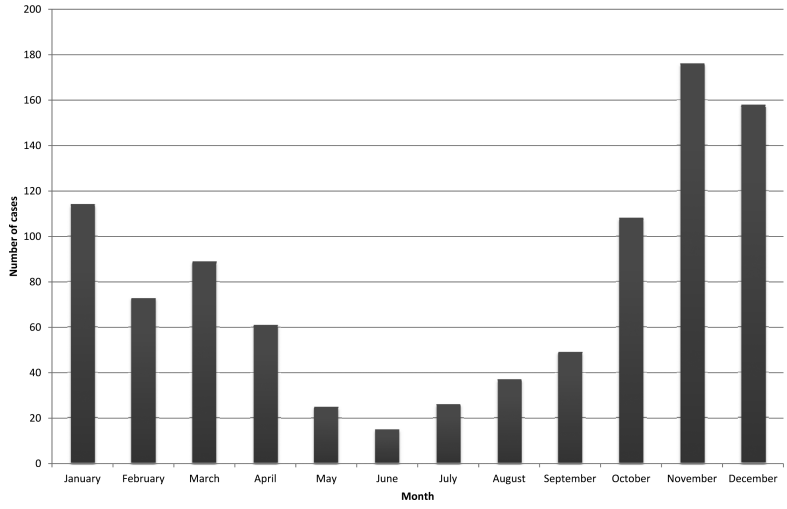

FIGURE 2. Monthly distribution of reptile cases presented to the Australian Wildlife Health Centre, Healesville Sanctuary, Healesville, Victoria, Australia, 2000–13.

with a motor vehicle than any other species ($P<0.0001$). Common long-neck turtle was also more regularly admitted without injuries ($P<0.0001$; Table 3).

Four outcomes were identified in this investigation: released, died naturally, euthanasia, and retained in captivity. When animals that were unable to be released were subtracted from the total admissions (displacement, introduced species, illegal pet), the overall release rate of reptiles admitted to the AWHC was 45.2%. Total mortality rate of all reptile admissions was 47.5%. Trauma patients were more likely to be euthanized or die, whereas uninjured animals were more likely to be released. For snakes captured by removalists, release was the most

TABLE 2. Reason for presentation and case outcomes for reptiles presented to the Australian Wildlife Health Centre, Healesville Sanctuary, Healesville, Victoria, Australia, 2000–13.

Presentation	No. (%)	Case outcome				Mortality (%)
		Released	Died	Euthanasia	Captivity	
Trauma	680 (73.0)[a]	253	59	348	20	59.9
Impact with motor vehicle	279 (41.0)	103	19	151	6	60.9
Dog attack	203 (30.0)	62	12	124	5	70.0
Cat attack	22 (3.2)	8	1	13	0	63.0
Unknown trauma	91 (13.3)	27	18	42	4	70.0
Entanglement	59 (8.7)	43	9	2	5	18.6
Garden equipment	22 (3.2)	8	0	14	0	63.4
Burnt	3 (0.4)	1	0	2	0	66.7
Not injured	109 (11.7)	98	0	0	11	0.0
Displacement	60 (6.4)	0	5	2	53	11.7
Snake removal	39 (4.2)	31	0	0	8	0.0
Human interference	29 (3.1)	6	5	10	8	51.7
Introduced species	10 (1.1)	0	0	10	0	100.0
Sick/diseased	2 (0.2)	0	0	2	0	100.0
Illegal pet	2 (0.2)	0	0	1	1	50.0
Total	931	388	69	373	101	47.5

[a] Subcategories of trauma are listed as percentage of total cases of trauma.

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TABLE 3. Reason for presentation in the most frequently encountered reptile species at the Australian Wildlife Health Centre, Healesville Sanctuary, Healesville, Victoria, Australia, 2000–13.

Presentation	Common long-necked turtle (*Chelodina longicollis*)	Eastern bluetongue lizard (*Tiliqua scincoides*)	Blotched bluetongue lizard (*Tiliqua nigrolutea*)	Lowland copperhead (*Austrelaps superbus*)
Trauma[a]	216 (69.5)[b]	210 (93.8)	124 (91.2)	35 (63.6)
Impact with motor vehicle	178 (82.3)	42 (20.0)	26 (21.0)	3 (8.6)
Dog attack	13 (6.0)	110 (52.4)	61 (49.2)	6 (17.1)
Cat attack	0 (0)	8 (3.8)	3 (2.4)	6 (17.1)
Unknown trauma	12 (5.6)	30 (14.3)	28 (22.6)	5 (14.3)
Entanglement	12 (5.6)	7 (3.3)	1 (0.8)	15 (42.9)
Garden equipment	1 (0.5)	11 (5.5)	5 (4.0)	0 (0.0)
Burnt	0 (0.0)	1 (0.5)	0 (0.0)	0 (0.0)
Not injured	82 (26.4)	6 (2.7)	7 (5.1)	0 (0.0)
Snake removal	0 (0.0)	0 (0.0)	0 (0.0)	20 (36.4)
Human interference	9 (2.9)	8 (3.5)	5 (3.7)	0 (0.0)
Sick/diseased	2 (0.6)	0 (0.0)	0 (0.0)	0 (0.0)
Displacement	2 (0.6)	0 (0.0)	0 (0.0)	0 (0.0)
Total	311 (100)	224 (100)	136 (100)	55 (100)

[a] Subcategories of trauma are listed as percentage of total cases of trauma.

[b] Number of cases by species; percentage of each species.

common case outcome. Of the subcategories of trauma, unknown trauma, burned, and attack by domestic animal had the highest mortality rates (Table 2).

The data presented here are based on a large number of cases from a diverse range of reptile species (39) over a long period (14 yr). Descriptive studies such as this can be useful tools for monitoring ecosystem health and determining anthropogenic effects on wildlife populations (Schenk and Souza 2014). Some bias is associated with this type of study due to a lack of randomization, and the potential for overrepresentation of human-induced trauma (Spalding and Forrester 1993). Nonetheless, the majority of reptiles were presented to the AWHC because of human-mediated effects on their environment, which represents a significant cause of morbidity and mortality. Many of the reasons for reptile admissions would be considered indirect anthropogenic pressures, rather than direct persecution and deliberate harming of free-ranging reptiles (Table 1).

Reptile admissions gradually increased from 2000 until 2011 and may represent an increase in reptile mortalities during this period or possibly an increase in public awareness of reptile welfare. This increase may also be reflective of environmental factors that predisposed wild reptiles to injury. It is unclear why there was a decrease in admissions from 2012 to 2013. The peak in admissions during the warmer months is consistent with the biology of herpetofauna in temperate southeastern Australia (Cogger 2014). Presentation during winter may be representative of early emergence during warm periods or possibly disturbance of hibernacula.

The predominance of trauma as a reason that reptiles were presented to AWHC supports results of Hartup (1996) who found that traumatic conditions accounted for the majority of hospitalized reptiles. The nature of the traumatic incident differed among the most common species examined. Differences in predisposition to injury might be attributed to variations in species natural history, which may expose reptiles to different human-related activities. For example, bluetongue lizards are common inhabitants of suburban gardens (Hammer and McDonnell 2010), with

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high site fidelity and small home ranges (Koenig et al. 2001). Therefore, they are more likely to come into contact with domestic animals or to be removed due to being perceived as a pest. Conversely, common long-necked turtles are aquatic and adapted to fluctuating water resources. Consequently, they are often forced to undertake large terrestrial migrations between water bodies (Kennett and Georges 1990), potentially increasing their risk of being struck by motorists.

Domestic animal attack has been implicated as a major risk factor for bluetongue lizards in other parts of Australia. Koenig et al. (2002) found that seasonality affected the age class of animals presented for medical attention and hypothesized that juveniles were at greater risk as they posed an easier target for domestic animal predators than larger adults. Adult lizards were the predominate age class presented to the AWHC, perhaps indicating that predators do not select prey based on size or that the age of eastern bluetongue lizards is misclassified when they are admitted for treatment.

Elapid snakes are commonly targeted for removal from urban environments in Australia due to their perceived risk to humans (Shine and Koenig 2001). Removal is supported by our findings that the majority of elapid snakes were presented uninjured to the AWHC as a result of capture by removalists. Of these snakes, 31 (79.4%) were released close to their point of origin as required by Victorian State Legislation (Department of Environment and Primary Industries 2014). Translocation of Australian elapid snakes has been shown to significantly affect their behavior and is likely to increase the issue of problem snakes in urban environments (Butler et al. 2005). Therefore, snake welfare and possible human interactions are optimized by releasing elapid snakes where they originated (Butler et al. 2005).

A high proportion of reptiles admitted to the AWHC were uninjured. These snakes were typically presented by good samaritans on the assumption that animals they had found were injured, displaced, or "lost." Staff at the AWHC take this opportunity to discuss basic reptile biology with donors in an attempt to foster interest in their conservation and to educate them on how their actions can affect wildlife populations.

In conclusion, continued urban sprawl and habitat fragmentation have resulted in diminished reserves for wild animals and forced cohabitation of humans and reptiles. Inevitably, this has lead to an increase in frequency of human-reptile conflict situations. As a result, reptiles presented to the AWHC primarily had traumatic injuries. Most of these injuries were attributed to indirect anthropogenic factors such as motor vehicles and domestic animal attacks. This indicates that human activity has an effect on the health of wild reptiles, although the effects on population dynamics cannot be determined from this study. Further investigation is required to determine how anthropogenic pressures affect wild reptile populations and how continued urban development is likely to impact local reptile ecology.

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