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How to catch red foxes red handed: identifying predation of freshwater turtles and nests

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Abstract

Context. Predation is one of the key contributors to mortality in freshwater turtles. Confirming the identity of predators is an important step towards conservation management action. Throughout Australia, the red fox (*Vulpes vulpes*) is suspected to apply significant and unsustainable predation pressure to turtle populations, killing adults and depredating nests; however methods for confirming this are limited.

Aims. The present study used a range of methods to confirm predation of oblong turtle (*Chelodina colliei*) nests and adults by the introduced red fox.

Methods. First, depredated adult carapaces, and turtle egg-shell fragments from excavated nests were swabbed and analysed for trace DNA. Second, we used artificial turtle nests, monitored by camera traps, to analyse seasonal changes in the behaviour of foxes around sites where turtle nests are present, including over the nesting season. Last, we used scat analysis to identify the prevalence of turtle remains in fox diet.

Key results. Predominantly fox DNA was recovered from both adult carapaces and depredated eggs. In addition, camera traps recorded only foxes depredating artificial nests. Despite this evidence that foxes kill adults and excavated nests, we found that turtle remains were only a small part of the diet of foxes at this study site (hatchling or turtle egg shell were present in only 4% of 230 scats sampled). The diet of these foxes was largely anthropogenic-sourced foods, such as fruit (e.g. figs, grapes, melons; 81% of scats), sheep carrion (41%) and rodents (36%).

Conclusions. We conclude that DNA analysis, camera trapping and scat analysis are effective methods of identifying foxes as predators of adult turtle, and their nests. Furthermore, we found that anthropogenic foods (orchard crops, livestock or synanthropic species) may subsidise greater fox population size than might occur in their absence, thereby increasing potential pressure on these freshwater turtles.

Implications. Our findings give credence to the argument that foxes are effective predators of turtle adults and nests. In addition, the high proportion of anthropogenic food sources in the diet of foxes, and potential subsidisation, is an important consideration for land managers.

Additional keywords: anthropogenic impacts, diet, invasive species, pest ecology, urban ecology, faeces.

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Introduction

Understanding the factors that threaten turtle populations worldwide is key to their management, given that 10% of the 317 recognised species are considered critically endangered on the IUCN Red list of Threatened Species (Buhlmann *et al*. 2009). Predation represents a major risk for both freshwater and marine turtles, with multiple studies reporting a catastrophic predation rate by predators (e.g. Thompson 1983; Spencer and Thompson 2003, 2005). While in nests, eggs are vulnerable to depredation by a wide range of species, such as foxes, raccoons and opossums in North America, jackals in Europe, dogs in Central America and feral pigs in northern Australia (Table 1 and references therein). In addition, predation of adult females is often greater than that of males, because of their leaving water for nesting; this sex-biased mortality can have a major negative effect on population viability (Spencer and Thompson 2005).

Identifying predators of nests can often be difficult, owing to the cryptic nature of the nests themselves precluding identification for monitoring purposes, or a lack of adequate

Table 1. Methods used by previous studies to identify the predators on artificial nests, freshwater turtle nests and marine turtle nests

Location	Turtle species	Reference	Primary predator	Camera traps	Tracks and digging	Scats	Direct obs.	DNA
Artificial nests								
Australia	–	Dawson *et al.* (2014)	Red fox (*Vulpes vulpes*)[A]	✓	✓	✓		✓
North America	–	Hamilton *et al.* (2002)	Raccoon (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*)					
	–	Marchand *et al.* (2002)	Raccoon, red fox, grey fox (*Urocyon cineroargenteus*)	✓				
	–	Wilhoft *et al.* (1979)	Raccoon		✓	✓		
Marine								
	Caretta caretta	Trocini (2013)	Ghost crab (*Ocypode ceratophtalma*), perentie (*Varanus gigantus*), red fox[A]		✓		✓	
	Natator depressus, *Eretmochelys imbricata*, *Lepidochelys olivacea*	Whytlaw *et al.* (2013)	Feral pig (*Sus scrofa*)		✓			
Central America	*Chelonia mydas*	Fowler (1979)	Dog (*Canis familiaris*)		✓			
	Chelonia mydas, *Dermochelys coriacea*	Veríssimo *et al.* (2012)	Jaguar (*Panthera onca*)[B]		✓			
	Eretmochelys imbricata	Leighton *et al.* (2011)	Mongoose (*Herpestes javanicus*)		✓			
	Lepidochelys olivacea	Burger and Gochfeld (2014)	Dog, crested caracara (*Caracara cheriway*)[C]		✓		✓	
Turkey	*Caretta caretta*	Yerli *et al.* (1997)	Red fox		✓	✓		
	Chelonia mydas	Brown and Macdonald (1995)	Red fox, golden jackal (*Canis aureus*)		✓	✓		
Semi-aquatic, freshwater								
Australia	*Carettochelys insculpta*	Doody *et al.* (2006)	Yellow spotted monitor (*Varanus panoptes*)		✓			
	Chelodina oblonga	Giles *et al.* (2008)	Red fox[A]		✓			
	Chelodina oblonga	This study	Red fox[A]		✓	✓	✓	✓
	Emydura macquarii,	Spencer (2002)	Red fox[A]		✓	✓		
	Emydura macquarii, *Chelodina expansa*	Spencer and Thompson (2006)	Red fox[A]		✓	✓	✓	
	Emydura macquarii, *Chelodina longicollis*	Thompson (1983)	Red fox[A]		✓	✓		
North America	*Chelydra serpentina*	Congdon *et al.* (1987)	Red fox, raccoon		✓		✓	
	Chrysemys picta	Marchand and Litvaitis (2004)	Raccoon[D]					
	Chrysemys picta marginata	Christens and Bider (1987)	Raccoon		✓			
	Emydoidea bladingi	Congdon *et al.* (1983)	Red fox, raccoon		✓			
	Kinosternon subrubrum, *Pseudemys concinna floridana*, *Trachemys scripta*	Burke *et al.* (1998)	Raccoon					
	Malaclemys terrapin	Burger (1977)	Red fox, raccoon, laughing gull (*Larus atricilla*), American crow (*Corvus brachyrhyncos*)		✓	✓		
	Malaclemys terrapin	Burke *et al.* (2005)	Raccoon		✓			
	Malaclemys terrapin	Feinberg and Burke (2003)	Raccoon		✓	✓	✓	
	Kinosternon flavescens	Christiansen and Gallaway (1984)	Raccoon[E]		✓			
Central America	*Podocnemis unifilis*	Escalona and Fa (1998)	Tegu lizard (*Tupinambis teguixin*)		✓		✓	

[A] The red fox (*Vulpes vulpes*) is introduced to Australia.
[B] Predation of adults, scratch marks.
[C] Observation (birds), digging characters (dog).
[D] As in Marchand *et al.* (2002).
[E] Deduced by predator removal.

techniques to carry out the monitoring itself. Some studies have identified red foxes (*Vulpes vulpes*) as predators of turtle nests, using characteristic diggings, scats left at the site, and, occasionally, direct observation (Thompson 1983; Spencer and Thompson 2003, 2005). However, direct observation is usually opportunistic and rare, whereas identifying predators by their digs is subjective and can also be misleading if excavated nests are scavenged by secondary predators. Analysis of trace DNA has not been used to identify turtle-nest predators previously, although analysable DNA has been collected from avian egg fragments (e.g. Oskam *et al*. 2010) and depredated carcasses (e.g. Williams *et al*. 2003). Use of trace DNA could, thus, be a useful method in the current context when remains are found.

Depredation of nests is most common soon after laying (Burger 1977; Christens and Bider 1987; Congdon *et al*. 1987, 1983; Marchand *et al*. 2002; Burke *et al*. 2005; Dawson *et al*. 2014). This is likely because of the cues used by predators fading with time (Congdon *et al*. 1983); however, it is also possible that predators change their behaviour at different times of year, to maximise efficiency in their search patterns. Camera-trapping is an option for monitoring predation impacts on nests, using infrared remote-sensor cameras that can be left *in situ* monitoring known nest sites for the duration of the nesting season. The advantage with cameras is that they can also capture non-predation events, which might reveal how predators search for and find nests.

Because naturally occurring freshwater turtle nests can be difficult to locate, several previous studies have used artificial 'nests' positioned in suitable habitats (e.g. Wilhoft *et al*. 1979; Hamilton *et al*. 2002; Marchand *et al*. 2002; Dawson *et al*. 2014). Artificial nests allow manipulation of olfactory and visual characteristics to investigate cues used by predators in locating nests (Marchand *et al*. 2002; Spencer 2002; Burke *et al*. 2005; Dawson *et al*. 2014), although they do not directly indicate the depredation rate for real nests (Wilson *et al*. 1998). In a previous study, we used infra-red (IR) camera traps to monitor artificial nests, where foxes were the primary excavators of artificial turtle nests, making up 91% of the total camera sightings of predators and 100% of all nest-depredation events witnessed (Dawson *et al*. 2014).

Analysis of the diet of predator species can also aid in understanding the predator–prey relationship. In addition to identifying the presence of turtles in the diet of predators, this analysis would indicate the relative importance of other food items and may show seasonal shifts, such as, for example, during turtle nesting season. Previous diet studies have found only small amounts of reptiles in fox diet (e.g. Catling 1988), and no studies have reported turtle remains, let alone seasonal shifts in importance. In fact, no Australian studies have reported identifying the relative importance of turtle in the diet of their potential predators at all.

In the present study, we investigated three aspects of the predation of a population of the freshwater turtle *Chelodina colliei*. We used trace DNA analysis to identify the predator species of turtle nests (real and artificial), and adult turtles. We used camera traps monitoring artificial nests to identify differences in predator behaviour during and outside the turtle nesting season. We also used scat analysis to quantify the diet of foxes in an area where they were known to prey on turtle eggs and adults, so as to identify the relative importance of turtles in the diet of these potential predators.

Methods

Study site and study species

The present project identified predators of *C. colliei* within the Chittering Lakes Nature Reserve (241.2 ha), around Lakes Chittering and Needonga. The study site lies 90 km north of Perth, Western Australia (31°25′S, 116°05′E). The vegetation surrounding the Chittering lakes is highly modified and fragmented, owing to proximity to both agricultural lands and a major highway. It consists of woodlands dominated by *Melaleuca* spp. and *Eucalypt* spp.. The vegetation buffer surrounding the two lakes is predominantly narrow (averaging ~40 m), but does broaden to over 300 m wide in some places. Beyond this, native vegetation has been cleared completely and the area is open paddocks, cropping or orchards, with little or no ground cover or canopy.

The Chittering lakes support a population of *C. colliei.* Females oviposit between September and January, and eggs are incubated for 210–222 days (Clay 1981), with hatchlings starting to emerge in mid-August (Clay 1981; McCutcheon 1985). Therefore, females (and newly deposited eggs) may be vulnerable to predation from September to January, whereas eggs (with developing embryos) are present between September and August.

Predator behaviour

As part of an experiment recording depredation of artificial nests (Dawson *et al*. 2014), chicken eggs were buried at each of 145 monitoring sites ($n = 145$; level areas clear of vegetation other than grass, with a diameter of ~5 m, to ensure consistency of conditions among nest sets). Eggs were buried 150 mm deep in pairs, with two pairs per site. Artificial nests were set during 7 months spread throughout the year (Fig. 1). A subset of 60 sites was monitored by motion-sensor camera (Reconyx Hyperfire HC500, Reconyx, Holmen, WI, USA) for a maximum of 60 days

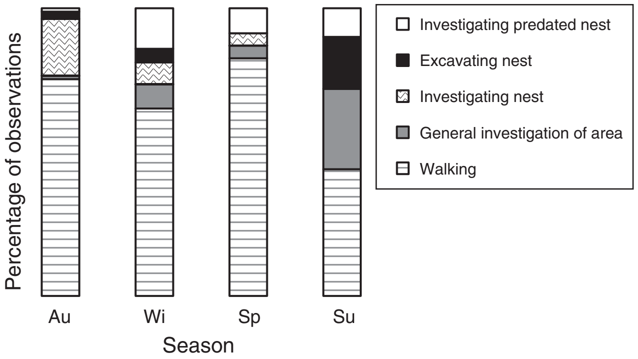

Fig. 1. Proportion of camera records of foxes attributed to each behaviour category across the four seasons that monitoring was undertaken (total number of events presented under the *x*-axis). For each nestset (<60 days since installation), a maximum of one record of each behaviour per night was analysed. New nests were installed over 7 months spread across the duration of the study (autumn: 62, winter: 51, spring: 0, summer: 32).

after installation. Cameras were placed on trees 1–2 m above ground level and were ~5–10 m from the buried eggs. Cameras were set to rapid fire (5 photos after every stimuli detected with no delay). Cameras were checked regularly (weekly or fortnightly). Cameras were set at the same time as nests were installed and were left in position until all nests in the nest set were excavated. Over 100 000 images were analysed over the course of the study to identify the artificial-nest predators (excavating nests).

We performed an activity index of all potential predators, scoring the event as 1 (walking), 2 (investigating the general area), 3 (investigating the nests), 4 (excavating the nests; depredation) or 5 (investigating an excavated nest; see definitions of behaviour categories in Table 2). Separate camera events were identified as records of the same species separated by >1 h to take into account multiple trigger events. So as to avoid repeated captures of the same behaviour skewing the data (e.g. a nest can be excavated only once, but investigated hundreds of times), a maximum of one record of each behaviour per night was analysed. In other words, data were recorded as binary, whether that behaviour was recorded at that nest on that night, or not. Camera data were analysed by chi-square analysis by season, where expected values were calculated assuming an equal proportion of observations in each behaviour category across seasons.

Predator identification

During monitoring of artificial nests (Dawson *et al*. 2014), we collected any evidence of predated adults or excavated turtle nests. Egg fragments from 16 turtle nests, and 13 artificial nests (chicken eggs) that appeared to have been preyed on in the previous 4 days, were collected, stored in plastic bags and frozen until DNA analysis. During collection, gloves were worn by the researcher, and all care was taken to protect the sample from contamination. Sterile moistened swabs were used to collect DNA from the bite sites of three relatively fresh (~2 weeks since death) turtle carcasses. Both egg fragments and carapace swabs were sent for predator-DNA analysis (Helix Solutions, University of Western Australia, Perth, WA, Australia).

DNA was isolated from shell fragments and carapace swabs (COPAN Diagnostics, Murrieta, CA, USA) using the Qiagen DNeasy tissue kit (Qiagen, Valencia, CA, USA). Predator DNA was identified using melt-curve analysis based on quantitative polymerase chain reaction (PCR) amplification of species-diagnostic mitochondrial DNA (mtDNA) fragments (Berry and Sarre 2007). The analysis was capable of distinguishing among a suite of predators known to occur in the area, on the basis of the diagnostic melt temperature of the DNA of each species. These were red fox, cat (*Felis catus*), dog (including dingo) and chuditch (*Dasyurus geoffroii*). Positive controls for all species were included in the analysis and each sample was analysed twice to confirm results. All DNA analyses were conducted in a laboratory dedicated to trace DNA samples, and PCR negative controls were included.

The amount of target DNA detected in each sample is represented by cycle threshold (CT) values. A lower CT value generally indicates a greater quantity of target DNA being present. A sample was considered to have a positive identification with an observed CT value between 20 and 35 and a DNA melting temperature that matched the positive control. Amplification failure for a sample may be the result of predation from a non-target species or degraded or no DNA present.

Fox-diet analysis

Fox scats were collected during searches on foot of the areas surrounding the Chittering lakes between March and September in 2012 ('winter', when nests in the ground but no new nests; $n = 113$ scat samples) or November 2012–February 2013 ('summer', which includes nesting time; $n = 117$ scat samples). Fox scats were identified by shape and size according to Triggs (2004), and stored frozen until analysis. Domestic dogs were present in the area (working dogs on farms, and pets on walking trails); however, we expected to have little to no misidentified scats because of the obvious differences in size, and also the associated physical signs (i.e. a large percentage of fox scats were located adjacent to predated nests, monitored by cameras).

All scats were gently macerated and washed through a 1-mm Endecott sieve with tap water, and analysis was conducted on the remaining matter. Faecal pellets were separated into hair, bone, plant matter, fruit, feathers and invertebrates. Any material that could be used for identification (seed, hair, bone, egg shell) was stored for microscope analysis. Hair was examined under a microscope and identified to species (Brunner and Triggs 2002). Turtle egg shell was identified by colour and texture, and by comparison with egg shells recovered from excavated turtle nests.

We calculated the presence of each diet item as a proportion of the total number of scats, and as an average of the estimated proportion of the total volume of each scat (% of surface area of dish taken up by each item in the sieve once washed). Unidentified plant material was excluded from the totals used for analyses.

General methods

Data are presented as means ± 1 standard deviation. Statistical significance was accepted when $\alpha < 0.05$. Analyses were

Table 2. Definition of the terminology used in the present study to describe predator behaviour in camera traps

Description	Activity
Excavating nest	Animal was seen digging a hole at the nest site. The presence of a spoil pile aided identification of digging
Investigating nest	Nose close to the ground, investigating the specific area around where a nest was placed
General Investigation of area	Nose close to the ground, investigating the area in the camera's field of view, but no specific action directed towards one nest
Investigating excavated nest	Head close to the ground, investigating a nest that had previously been excavated
Passing	Captured by camera, but not stopping or showing any interest in nest site

performed using Statistica 8.0 (StatSoft Inc. 2007), except where indicated otherwise (above).

Results

Predator behaviour

Foxes were the most common species recorded on camera around the nests (94% of all sightings). Other potential nest predators captures were dog, human (*Homo sapiens*), pig (*Sus scrofa*), rat (*Ratus* spp.) and Australian raven (*Corvus coronoides*); however, we recorded no evidence (photo or digging characteristics) of other species excavating nests. In total, 579 separate camera events of foxes were recorded and only foxes were witnessed excavating artificial nests (26 separate camera events). Seasonal changes in fox activities recorded are shown in Fig. 1. At the commencement of the study, when artificial nests were newly installed around the lakes, 20% of the records of fox activities at these sites were foxes investigating the nests ($\chi^2_1 = 8.66$, $P = 0.003$), whereas only 2% of the sightings were records of foxes depredating the nests (not significantly different from the average across all seasons). In winter, we recorded more incidences of foxes investigating nests that had already been excavated, whereas the incidence of nest depredation was lower for spring. In summer, 18% of the records of foxes captured them excavating nests ($\chi^2_1 = 11.40$, $P < 0.001$).

Predator identification

We located 63 turtle carcasses from around the Chittering lakes. One group of 29 carcasses was located within a 100 m^2 area. Of the three carcasses analysed for predator DNA, fox DNA was confirmed from one. The other two samples failed to amplify for any of the known target species, which may be due to degradation of any residual saliva DNA collected or predation from a non-target species.

Seventy-four excavated turtle nests were identified, of which 16 were less than ~4 days old. Of the 16 samples of turtle eggs analysed, DNA identified as originating from fox DNA was amplified from nine (69%). Of 13 chicken-egg fragments (from artificial nests) analysed, DNA was amplified from only one (8%), and was identified as dog DNA. A fox was captured on a camera trap excavating the nest from which the sample was recovered, whereas no dog was ever seen on camera at this site. In addition, the initial photos of the fox showed an undisturbed nest, before the fox excavating it, indicating that the dog interaction with the eggs must have occurred after. We conclude that this result is due to a dog scavenging a nest already excavated by a fox, despite no dog being caught on this camera. It was not uncommon for cameras to miss capturing events, highlighting the benefits associated with using multiple methodologies. Of the 29 turtle and chicken eggs analysed, 19 (65%) resulted in ‘unknown’ readings. An unknown reading represents either a failed amplification because of the absence of, or degraded nature of, the DNA, or predation from a non-target species. All identified CT values are reported in Table S1, available as Supplementary material for this paper.

Fox-diet analysis

The most common food categories identified from fox scats were invertebrates (present in 52.8% of the 230 scat samples analysed), sheep (41.5%) house mouse (34.1%), fruit and seeds (24.0%; principally figs and grapes), bird (16.2%), rabbit (11.4%) and reptile (5.7%; Fig. 2). Bird remains included domestic chicken on at least one occasion. Reptile remains could not be identified to any taxonomic level. Only one native mammal, the brushtail possum (*Trichosurus vulpecula*), was identified from scat analysis (present in 1.7% of scats). By contrast, introduced species (including sheep, house mouse, rabbit) were present in 46% of scats. Anthropogenic sources of food (orchard crops, livestock, synanthropic rodents) were present in 97.4% of all scats.

Turtle egg-shell remains were detected in three faecal samples collected over ‘winter’ (1.3% of total of 230 scats), and the remains of a small turtle were found in one faecal sample (0.4%); it is unknown whether this was a hatchling turtle or a late-term embryo.

Discussion

Unequivocal evidence for turtle depredation is difficult to obtain, and most studies have to resort to the characteristic signs as indications of predator species. Here, we found that DNA analysis and camera-trap monitoring of artificial nests indicated that red foxes were the major nest predators and adjusted their behaviour around turtle nesting sites seasonally, whereas DNA evidence also implicated foxes as predators of adult turtles. These are important findings because appropriate methods to confirm the identification of nest predators, especially one as prolific and common as the red fox, will have broad applicability and can contribute towards management strategies for freshwater turtles. By contrast, despite considerable effort, we found only little evidence of turtle depredation from scats, with foxes instead relying on a high preponderance of foods that originate from anthropogenic sources.

Of the three turtle carcasses and 16 turtle depredated turtle-egg samples tested by DNA analysis, the only predator identified was red fox. To our knowledge, this is the first study to use trace DNA methods to identify the predator from depredated turtle-egg remains. Our results confirmed those of previous studies (Table 1), and indicated that DNA analysis may be useful in areas where multiple predator species are present (e.g. both pet dogs and urban foxes around urban lakes). The recovery of dog DNA from a nest known to be initially excavated by a fox highlighted the benefits of multiple complimentary methods, such as camera traps, to validate results.

DNA was amplified from 10 of the 29 turtle-egg samples collected. Amplifiable predator DNA was recovered more often from turtle eggs than from chicken eggs, suggesting the possibility that some feature of turtle egg-shell material may better preserve DNA. Future studies may benefit from exploring alternative types of eggs, or additional material to ‘trap’ DNA from predator species.

We recorded a higher incidence of investigation of artificial nests at the commencement of the study, suggesting that perhaps the novelty of our presence and construction of artificial nests could have sparked investigative behaviour by resident foxes. By contrast, we recorded a greater proportion of general investigation of artificial nest sites and artificial nest depredation during summer, at the time when turtle females

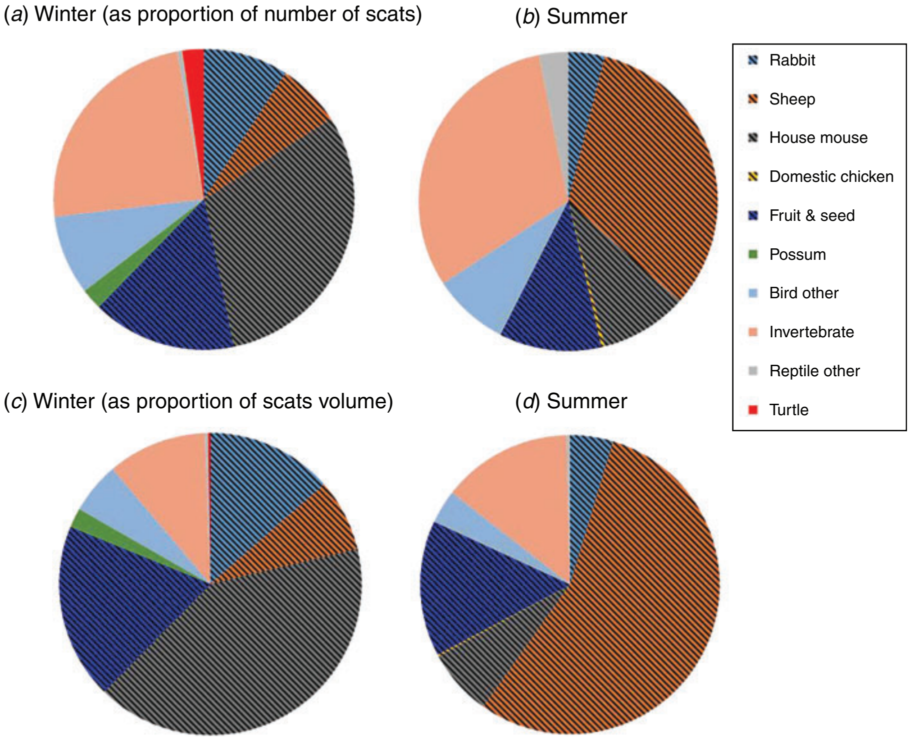

Fig. 2. Diet of red foxes (*Vulpes vulpes*) around the Lake Chittering Nature Reserve analysed from $n = 230$ scats collected during winter and summer. Top graphs show breakdown of diet according to the proportion of scats, and the bottom graphs show breakdown according to the approximate proportion of scat volume. Hatched area represents food items ultimately from anthropogenic sources.

were nesting. This may suggest that foxes increased their search efforts for buried nests around the lakes at this time. Foxes have been shown to shift their search patterns depending on seasonal food events (Stickney 1991).

We found evidence of turtle eggs ($n = 3$) or an embryo or hatchling ($n = 1$) in scats collected during winter, when turtle nests were in the ground but there was no active laying by females. By contrast, predation of turtle nests or artificial nests is greater for recently buried eggs (Burger 1977; Christens and Bider 1987; Congdon *et al*. 1987, 1983; Marchand *et al*. 2002; Burke *et al*. 2005; Dawson *et al*. 2014). However, identification of reptile remains in scats is limited to indigestible skin and bone fragments, and, hence, scats would not be a useful method for identifying ingestion of undeveloped egg contents. Therefore, early term *C. colliei* eggs would not be likely to be evident in faeces where foxes ingest the contents but not the shells of eggs. This bias towards indigestible fragments, therefore, limits the use of scat analysis as a measure of the impact of depredation to being useful only for depredation of late-term embryos or hatchlings. Biases resulting from differences in digestibility can be addressed using DNA analysis, such as gel-based PCR detection systems; however, these are limited to detecting a single, or small number of, prey items (King *et al*. 2008). Future research into the diet of predators could include novel techniques such as next-generation sequencing (NGS), as a possible method of identifying easily digested food items in scats of predators (e.g. De Barba *et al*. 2014). Furthermore, given that it will take an extended period of time for the food item to progress through the digestive track of the predator, the scat will likely be deposited in an area different from that where the food was consumed. We expect that the home ranges of the individual foxes present in our study area were larger than the area searched (resulting in scats outside this area being missed). However, we believe the number of scats collected in the study account for this reduced sample area, and that the low amount of turtle remains seen in scats is representative of their digestibility.

We located 63 turtle carcasses of varying age of depredation from around the Chittering lakes, 29 of which were located within a 100-m^2 area, suggestive of caching, a behaviour common in the red fox (Macdonald 1976). We also obtained DNA evidence of fox depredation for an adult turtle. Adult turtles are unlikely to be eaten whole, with turtle remains found around the Chittering lakes indicating that only the head, neck and limbs are consumed. This partial ingestion makes identification of adult turtle remains in scats difficult. The importance of turtles in the fox diet found in the present study may, therefore, be underestimated because of the methodological issues of scat analyses (inflated importance of indigestible items; absence of items that are readily digested) and seasonality of nesting females being out of the water.

Although scat analysis does not provide a reliable indication of the volume of food items consumed, or indeed the absence thereof, it can provide information regarding presence of food types. The present data indicated a significant presence of anthropogenic food sources in fox scats collected from around the Chittering lakes. This result is consistent with the findings of other studies, which similarly identified a substantial proportion of anthropogenic food in the diets of foxes at various locations across Australia (Scott 1943; Coman 1973; Brunner *et al*. 1975; Short *et al*. 1999; White *et al*. 2006; Crawford 2010). The present results suggested that there is a possibility of 'hyperpredation', where inflated predator numbers are artificially maintained by an anthropogenic resource, or a single introduced species (e.g. fox numbers being sustained by rabbits; Johnson 2006; Pedler *et al*. 2016).

Conclusions

In the present study, scat analysis, motion-sensing cameras and DNA analysis were used to confirm the occurrence of fox predation of artificial nests and turtle nests. Turtle-egg remains were found in fox scats, even though the survey was conducted outside the period were fox predation on turtles was most likely. Given that *C. colliei* largely exists in managed wetlands across the Swan Coastal Plain, where there is a high impact from urbanisation, identifying its potential predators is important for creating effective and accurate management plans. The importance of anthropogenic food sources in the diet of the red fox indicates that the fox population is subsidised by human activities and land use in the area surrounding the lakes, potentially negatively affecting the native fauna assemblage, especially the oblong turtle population.

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