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The diet of the dingo (*Canis lupus dingo* and hybrids) in north-eastern Australia: a supplement to the paper of Brook and Kutt (2011)

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Abstract. Dingoes and other wild dogs (*Canis lupus dingo* and hybrids) are generalist predators that consume a wide variety of different prey species within their range. Little is known, however, of the diets of dingoes in north-eastern Australia where the potential for impacts by dingoes exists. Recently new information has been provided on the diets of dingoes from several sites in Queensland, Australia, significantly adding to the body of published knowledge on ecosystems within this region. Further information on the diet of dingoes in north-eastern Australia is added from 1460 scats collected from five sites, representing tropical savannahs, tropical offshore islands (and a matched mainland area), dry sclerophyll forests and peri-urban areas on the fringe of Townsville. Macropods, possums and bandicoots were found to be common prey for dingoes in these areas. Evidence suggested that the frequency of prey remains in scats can be an unreliable indicator of predation risk to potential prey and it was found that novel and unexpected prey species appear in dingo diets as preferred prey become unavailable. The results support the generalisation that dingoes prefer medium- to large-sized native prey species when available but also highlight the capacity for dingoes to exploit populations of both large and small prey species that might not initially be considered at risk from predation based solely on data on scats.

Additional keywords: apex predator, *Canis lupus dingo*, diet, faeces, macropod, prey switching, wild dog.

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Introduction

Dingoes and other wild dogs (*Canis lupus dingo* and hybrids) are widely distributed across Australia and currently occupy apex predator status within their range (West 2008; Fleming *et al.* 2011*a*). Owing to their recognised impacts on livestock production, dingoes have been the subject of a considerable number of studies historically focussed on their ecology as it related to their control using best practice (Corbett 2001; Fleming *et al.* 2001). In recent years however, a growing number of reports have focussed on their perceived ability to suppress meso-predators (predominantly foxes *Vulpes vulpes* and feral cats *Felis catus*) and thus provide indirect benefits to faunal biodiversity through trophic cascade effects (Glen *et al*. 2007; Allen *et al.* 2011; Letnic *et al.* 2011). Investigations of the diet and feeding ecology of dingoes have been fundamental to current understanding of their impacts and ecological roles as discussed in these studies.

Knowledge on the diets of dingoes comes from ~32 000 records of prey remains found in dingo scats (faeces) and stomachs collected across Australia since the late 1960s. The results of nearly half ($n = 12\,802$) of such records collected prior to the turn of the century were summarised in Corbett (2001), while the remainder are scattered throughout various published (e.g. Pavey *et al.* 2008; Claridge *et al.* 2010; Cupples *et al.* 2011) and unpublished reports. Studies reporting the diets of dingoes in north-eastern Australia are under-represented, with only three published studies (i.e. Vernes 2000; Vernes *et al.* 2001; Brook and Kutt 2011) currently available from this region, collectively reporting the results of only 612 scat samples, or <5% of all records of the diet of dingoes. Other reports from this region (e.g. Burnett 1995; Pavlov and Heise 1998) contain a similar number of records. North-eastern Australia contains one of the world's greatest biodiversity hotspots (Williams 2006; but see also www.wettropics.gov.au, accessed 3 March 2012) where a large proportion of Australia's beef cattle are also produced (Fleming *et al.* 2011*b*; MLA 2011). Given the impacts dingoes are known to have on cattle production (e.g. Fleming *et al.* 2001; Allen 2005; Hewitt 2009) and some threatened or near-

threatened species (e.g. Vernes 1993; Burnett 1995; Newell 1999; Horsup 2004; Lundie-Jenkins and Lowry 2005) from this region, a greater understanding of the diet of dingoes is necessary in order to assess their potential impacts on livestock production and conservation value.

Brook and Kutt (2011) most recently added to this body of knowledge by reporting the results of 178 dingo scats collected from 22 sites over 6 years. They reported that 'native mammal prey was the most frequent dietary component (69.7%), with large- to medium-sized macropods (*Macropus* spp. and *Wallabia bicolor*) present in the majority of samples (51.1%). Critical Weight Range (35–5500 g; Burbidge and McKenzie 1989) species were found in 18.0% of the records. Introduced species, such as the European hare/rabbit (*Lepus capensis*/*Oryctolagus cuniculus*) and cattle (*Bos taurus*), were found in smaller amounts (14.6 and 10.1%, respectively)' (Brook and Kutt 2011; p. 79). Their results suggested that cattle and threatened species may not be affected by dingoes in north-eastern Australia to any substantial degree. In this paper, we add to this by reporting the results from dingo scats collected from four additional sites in north-eastern Australia, along with more results from one of the sites described in Brook and Kutt (2011).

Materials and methods

Scats were collected on multiple occasions from each of five sites in north-eastern Australia (Fig. 1) between 1994 and 2002. Mount Stuart Training Area (MSTA) lies 12 km south-west of the city centre of Townsville (19.33′S, 146.78′E), and is a military zone managed by the federal Department of Defence for training purposes. Public access to the site is restricted. The area is described as being in the Brigalow Belt bioregion by Brook and Kutt (2011) who collected 27 dingo scats there in June 2000. Scats from this site were collected predominantly from peri-urban areas of the MSTA in July and September 2002 as part of routine dingo control programs (ERM 2003). Mount Owen cattle station is located in south-central Queensland in dry sclerophyll forest habitats (25.51′S, 147.36′E). Scats were collected between May 1994 and August 1998 (range $n = 15$–114 scats from each of 12 surveys) as part of a manipulative experiment investigating the impact of dingoes on beef cattle production (Allen 2005). This experiment was also conducted between July 1995 and September 1998 (range $n = 45$–73 scats from each of six surveys) on Strathmore cattle station in the Gulf of Carpentaria, which is situated on the monsoonal savannah floodplains of the Gilbert and Einasleigh Rivers (17.37′S, 142.40′E), which were sampled upstream by Brook and Kutt (2011) around the same time.

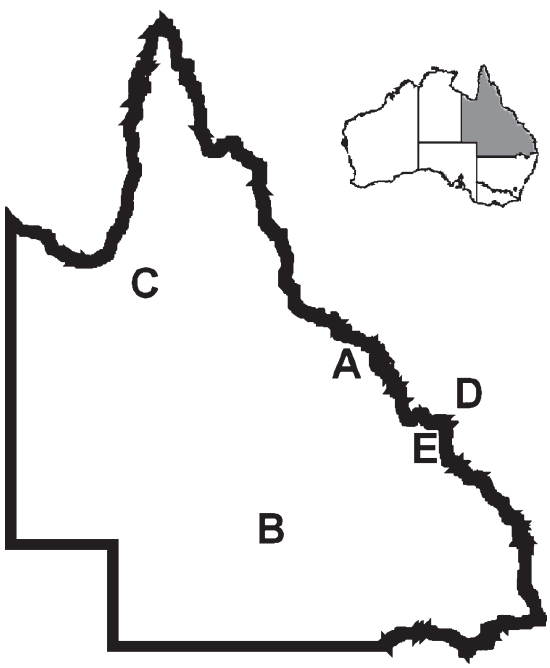

Fig. 1. Location of study sites (A = Mount Stuart Training Area, B = Mt Owen, C = Strathmore, D = Townshend Island and E = Shoalwater Bay Training Area).

Dingo scats were also collected on five occasions from Townshend Island (a 70 km^2 island 150 km north-east of Rockhampton; 22.28′S, 150.51′E) and Shoalwater Bay Training Area (SWBTA, adjacent to Townshend Island on the mainland; 22.41′S, 150.14′E) between 1995 and 1999 (Fig. 1). Both the island and SWBTA are also managed by the Department of Defence as military training areas where public access is restricted. Townsend Island was inhabited by 3000 feral goats (*Capra hircus*). To control these pests, 16 mixed-gender captive-raised/bred dingoes, previously housed at a government research facility on the Darling Downs in south-east Queensland, were released there in December 1993 (Allen *et al.* 1998). The only native mammals recorded on Townsend Island were sugar gliders *Petaurus breviceps* and bats (*Pteropus alecto* and unidentified microchiroptera) (Schodde *et al.* 1992; Allen *et al.* 1998). Dingo scats were collected from the neighbouring SWBTA between May and October 1999 (range $n = 18$–67 scats from each of five surveys) as part of a study investigating the responses of dingo populations to a military exercise at the site (Allen and Gonzalez 2000).

Scats were washed and the remains then analysed under a microscope to identify any food items to the lowest taxonomic level possible. Identification of mammals followed Brunner *et al*. (2002) and primarily relied on diagnostic features of hair, although most other food items were classified simply as reptile, bird, invertebrate or vegetation in most cases. No objective attempts were made to distinguish scavenged items from those that were preyed on by dingoes to avoid the uncertainties associated with this approach (Allen and Fleming 2012). Results are presented as the percent occurrence of prey remains in scats from each site.

Results

A total of 1460 dingo scats were collected from the five sites sampled in this study (Table 1). At mainland sites, cattle remains occurred in no more than 2% of scats from any site while macropod remains were present in 11% to at least 82% of scats from each site. Common brush-tail possums (*Trichosurus vulpecular*) were also present in dingo scats from each site. They were rare food items at MSTA (4%) and Strathmore (1%) but were the most frequently occurring prey species at Mt Owen and SWBTA (53 and 54%, respectively). Bandicoots occurred

Table 1. The prey remains found in 1460 dingo scats from five sites in north-eastern Australia
MSTA, Mount Stuart Training Area; SWBTA, Shoalwater Bay Training Area

Common name	Species	MSTA *n* =118	Mt Owen *n* = 653	Strathmore *n* = 350	Townshend Island *n* = 192	SWBTA *n* = 147
Cattle	*Bos* spp.	2	1	1	0	<1
Feral pig	*Sus scrofa*	1	1	27	0	1
Goat	*Capra hircus*	2	0	0	39	0
Eastern grey kangaroo	*Macropus giganteus*	2	0	0	0	0
Dingo/wild dog	*Canis* spp.	1	4	6	1	0
Whiptail wallaby	*Macropus parryi*	15	0	0	0	0
Agile wallaby	*Macropus agilis*	57	0	0	0	0
Macropods	Unidentified	4	29[A]	57[B]	0	11
Allied rock-wallaby	*Petrogale assimilis*	4	0	0	0	0
Feral cat	*Felis catus*	2	<1	0	0	0
Echidna	*Tachyglossus aculeatus*	0	1	0	0	1
Brushtail possum	*Trichosurus vulpecula*	4	53	1	0	54
Rabbit	*Oryctolagus cuniculus*	6	7	0	0	0
Northern brown bandicoot	*Isodon macrourus*	4	0	0	0	0
Bandicoot	Unidentified	0	<1	<1	0	48
Sugar glider	*Petaurus breviceps*	0	3	0	23	16
Rat	*Rattus* spp.	0	2	5	0	7
Dasyurid	Unidentified	0	4	0	0	1
House mouse	*Mus musculus*	0	<1	<1	0	2
Bird	Unidentified	3	2	3	3	0
Lizard	Unidentified	0	2	1	11	0
Fish	Unidentified	0	0	<1	3	0
Frog	Unidentified	0	0	<1	0	0
Crab	*Ocypode* spp.	0	0	0	2	0
Invertebrate	Unidentified	2	4	3	17	5
Fruit	Unidentified	4	0	0	45	0
Chinee apple	*Zyziphus mauritiana*	5	0	0	0	0
Green grass	Unidentified	36	0	0	0	0
Other vegetation	Unidentified	43	<1	0	0	8
Bones	Unidentified	0	10	9	14	0
Other	Unidentified	0	0	0	10	3

[A]Mostly *Macropus giganteus* and *Petrogale herberti*.
[B]Mostly *Macropus agilis*.

in 48% of dingo scats from SWBTA but were detected rarely at all other sites. Critical Weight Range species were present in dingo scats from all sites, though only possums, sugar gliders and bandicoots occurred frequently (Table 1).

On Townshend Island, fruit (45%), feral goats (39%), sugar gliders (23%), invertebrates (17%) and lizards (11%) were the most frequently occurring food items (Table 1) although their relative occurrence in dingo scats changed substantially over the course of the study (Fig. 2). The occurrence of goat remains in dingo scats at the site decreased from 73% in April 1995 to 0% in April 1996 (when aerial surveys found only four goats left on the island; Allen *et al.* 1998). Goat remains were detected for the last time in July 1997 in 9 of 19 (47%) scats after the last four goats had been shot (June 1997) and dingoes had scavenged their carcasses (L. Allen, pers. obs.). Over this same period, the relative importance of sugar gliders, lizards and vegetation (primarily fruit of introduced *Opuntia* spp. and *Passiflora* spp.) increased substantially. Fish and crabs (*Ocypode* spp.) were detected for the first time in scats from the site only after there were no goats left on the island (Fig. 2; but see also Allen *et al.* 1998; for details).

Discussion

The results show that macropods, possums and bandicoots were the principal prey items for dingoes at the mainland sites surveyed in north-east Queensland (Table 1), consistent with other studies from the region (e.g. Burnett 1995; Brook and Kutt 2011), which reported the more frequent occurrence of medium-large mammal species in dingo scats when these species were present at a site. Studies, conducted in temperate (e.g. Newsome *et al*. 1983*b*; Robertshaw and Harden 1985; Claridge *et al*. 2010) and some arid (e.g. Marsack and Campbell 1990; Thomson 1992) areas in Australia, have reported similar results.

Dingoes are expected to suppress large macropod abundance in open areas (e.g. Caughley *et al*. 1980; Pople *et al*. 2000; Fillios *et al*. 2010) and have also been implicated in the historical declines of small macropods, possums and bandicoots across such areas (e.g. Kerle *et al.* 1992; Allen 2011). Dingoes have been identified as a potential threat to golden bandicoots (*Isoodon auratus*) in north-western Australia (Palmer *et al.* 2003) with similar species predicted to be at high risk of dingo predation in south-eastern Australia (Coutts-Smith *et al.* 2007; Allen and Fleming 2012). The present distribution and persistence of these

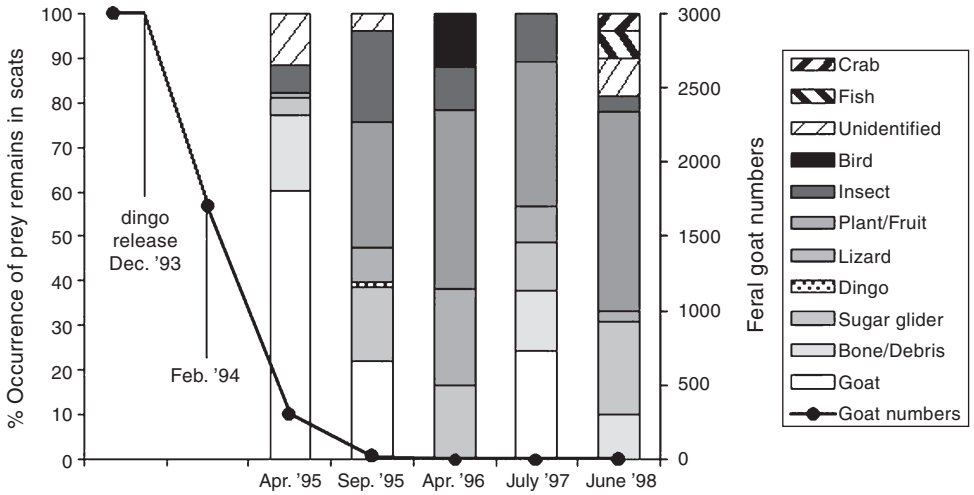

Fig. 2. Temporal changes in the diet of dingoes on Townshend Island following the release of 16 mixed-gender captive-raised/bred dingoes onto the island in December 1993 (Allen *et al.* 1998; sample sizes for the five surveys in chronological order are: 67, 39, 18, 19 and 49). Note: goats were the only terrestrial mammals on the island at the time of release.

species is related to the density and complexity of the habitat available to protect these species from predation by dingoes and other predators (Burbidge and McKenzie 1989; Corbett 2001; McKenzie *et al.* 2007).

Species, which are rabbit-sized and smaller, occurred rarely in dingo scats from the sites during the course of the study (Table 1), which contrasts with results from most other areas which show small mammals and in some cases reptiles to be common prey species of dingoes (Corbett 2001; but see also Newsome *et al.* 1983*a*; Pavey *et al.* 2008; Newsome 2011). The only exception to this in this study was the frequent occurrence of sugar gliders at SWBTA and Townshend Island. At SWBTA on the mainland, sugar gliders occurred in dingo scats (16% of scats) more frequently than macropods but occurred much less frequently than possums and bandicoots (Table 1). On Townshend Island, sugar glider remains (23% of all scats) were present in scats collected during each survey, but only became important once feral goat abundance had markedly declined (Fig. 2), probably leaving sugar gliders as the sole mammalian prey species on the island (Schodde *et al.* 1992; Allen *et al.* 1998). While arboreal species are unlikely to experience predation-driven declines (Burbidge and McKenzie 1989; McKenzie *et al.* 2007) they probably became exposed to dingo predation at these sites when feeding in low coastal heaths species (L. Allen, pers. obs.).

The data are insufficient to reliably inform assessments of dingo predation risks to sugar gliders, but their relatively frequent occurrence in dingo scats from SWBTA and Townshend Island highlights the capacity of dingoes to exploit them should the need and opportunity arise. While the absence of small terrestrial mammals during trapping programs is not uncommon even when they are known to be present (e.g. Dickman *et al.* 1999; Mifsud 1999; Moseby *et al.* 2006), terrestrial mammals were not recorded on Townshend Island in the earlier study of Schodde *et al.* (1992) or just prior to the release of dingoes (Allen *et al.* 1998), nor were they detected in dingo scats following their release (Table 1). Together, these data strongly suggest that terrestrial mammals were indeed absent from the island. Thus, dingoes exploited arboreal sugar gliders in the absence of terrestrial mammal species preferred elsewhere.

The introduction of naive dingoes to Townshend Island offers valuable insight into the capacity of dingoes to detect and exploit unfamiliar and presumably less-preferred prey species when preferred prey resources become unavailable. Initially, the predominant prey items were feral goats (Fig. 2) but, as the goat population declined, the diet of the dingo shifted to less preferred prey/food items. Fruits and vegetable matter quickly became the most significant dietary items in terms of frequency of occurrence, yet lizards, sugar gliders and invertebrates were undoubtedly important sources of protein. In the 1998 survey, when goats were no longer present, fish remains (presumably scavenged from the shoreline) and ghost crabs (dug up on sandy beaches, L. Allen, pers. obs.) were first discovered in dingo scats (Fig. 2). The pursuit and unearthing of crabs (evident from dingo tracks and digging on the beach and in three scats in 1998) probably shows their recent exploitation of a food resource which was previously undetected in scats. This small and not commonly detected species (Table 1) might not have been previously considered at risk of dingo predation based on previous information on the diet of dingoes.

Smaller livestock, such as sheep and goats, are highly susceptible to dingo predation (Thomson 1984; Fleming *et al.* 2001). In other words, 'dingoes and sheep do not mix' (Newsome 2001) and dingoes have the capacity to completely extirpate them (e.g. Payne *et al.* 1930; Allen *et al.* 1998). These small livestock were once common in north-eastern Australia in the past (e.g. Barnard 1962), although beef cattle production is now the primary land use in the region (Hamblin 2001; Allen 2011; Fleming *et al.* 2011*b*). Cattle are less prone to predation by dingoes than sheep or goats (Allen and Sparkes 2001; Corbett

2001), yet dingo predation still costs the cattle industry tens of millions of dollars annually in lost production (e.g. Gong *et al.* 2009; Hewitt 2009). The occurrence of livestock remains in dingo diet is sometimes used to gauge the impact of dingo predation on them (e.g. Brook and Kutt 2011; Newsome 2011) but, while livestock remains may appear insignificant in terms of its frequency as a prey item in dingo diets (e.g. cattle remains in 10% of dingo scats in Brook and Kutt 2011; and <2% in this study), predation of livestock can still be economically significant for the producer.

For example, at Mt Owen and Strathmore sites, Allen (2005) demonstrated by measuring cow lactation failures between confirmed pregnancy diagnosis and branding in paired dingo-baited and unbaited areas that up to 15% (Mt Owen) and 32% (Strathmore) of calves may be killed by dingoes in some circumstances, though only 1% of dingo scats collected over the same period contained cattle remains (Table 1). Conversely, cattle remains were detected in up to 27% of dingo scats from cattle stations in central Australia where a similar experimental design was applied, but dingo predation on calves was apparently negligible (Eldridge *et al.* 2002). The reason for such dichotomy between inferences drawn from diet studies versus measured predation impacts on specific species is unclear. However, the influence of predator–prey ratios (Wagner and Conover 1999), propensity for surplus killing (Short *et al.* 2002) and the representativeness of scat samples (Allen and Fleming 2012) may be likely causes. Cattle remains are also scavenged (e.g. Byrne 2009; Allen 2010), potentially leading to overestimates of cattle in scats and weakening the reliability of inferences about the risk of dingo predation to them. Similar observations can be drawn from the results at Townshend Island. The occurrence of goats in dingo scats mid-way through the study (first sample of scats collected) and the associated collapse of the goat population demonstrate high predation rates of goats by dingoes but their remains were also detected relatively frequently even after all goats had been destroyed (Fig. 2). The latest samples collected showed goats to be absent in dingo diets. Thus, results from diet studies simply indicate the food items eaten by dingoes under the conditions present at the time of the study, and may not be indicative of what dingoes did, do or could eat at a different time and/or place.

Consistent with the assertions of Allen and Fleming (2012), the results of this study highlight some of the pitfalls of making inferences about the risk of dingo predation to potential prey species from species detected in scats. This is because their absence may imply that dingoes have already exterminated them, suppressed them or have not begun to exploit them yet while more preferred prey remain available. Consistent with Brook and Kutt (2011), our data support the generalisation that medium- to large-sized mammals are important prey for dingoes in north-eastern Australia. However, while knowledge of common prey items of dingoes is fundamental to understanding the ecology of dingoes, perhaps it is the infrequent occurrence of the uncommon food items from the suite of prey species available that may be most indicative of dingoes' predatory capacity. Cattle and threatened species in north-eastern Australia might still be susceptible dingo predation under current and future ecological conditions.

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