Journal of Arid Environments 133 (2016) 25–28

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Short communication

Why is the marsupial kaluta, *Dasykaluta rosamondae*, diurnally active in winter: Foraging advantages or predator avoidance in arid northern Australia?

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ARTICLE INFO

Article history:
Received 29 January 2016
Received in revised form
9 May 2016
Accepted 25 May 2016
Available online 2 June 2016

Keywords:
Foraging
Torpor
Predation
Competitor
Dasyuridae
Marsupial

ABSTRACT

The majority of animals have a specific activity rhythm over the 24 h daily cycle such that they can be categorised as either diurnal or nocturnal. This stability creates interest in understanding species that can invert their activity rhythm. The kaluta, *Dasykaluta rosamondae*, a small dasyurid marsupial endemic to northern arid Australia, is one such species. In contrast to most other dasyurid species and in fact most small mammals, the kaluta is almost exclusively diurnal in winter. To assess the potential benefits of diurnal activity we examined the diet and assessed potential predators and competitors. We identified 33 food categories including four classes of invertebrates, three classes of vertebrates and plant material. Diet was dominated by Coleoptera (beetles, 26.7% volume) and Formicidae (ants, 25.0% volume). We found no evidence that the prey base of kalutas differed as a consequence of diurnal activity. Likewise, diurnal foraging was probably not driven by competition. A likely explanation of diurnal activity in winter in this species is that it both allows temporal separation in activity from a significant predator, the brush-tailed mulgara, *Dasycercus blythi*, and reduces thermoregulatory foraging costs.

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1. Introduction

The majority of animal species have a specific activity rhythm over the 24 h daily cycle and as a consequence can be categorised as either diurnal or nocturnal (Kronfeld-Schor and Dayan, 2003; Vonshak et al., 2009). In general, diel activity rhythms remain consistent over time with limited seasonal variation (Kronfeld-Schor and Dayan, 2003). Exceptions to this trend occur in extreme situations such as hot or cold environments where species may invert their normal activity rhythm during the most physiologically stressful season (e.g. Lourens and Nel, 1990). The stability in activity rhythms results from differences in selection pressure faced between diurnal and nocturnal activity and the evolution of a complex set of anatomical, physiological and behavioural adaptations to enhance survival during the chosen period of activity (Kronfeld-Schor and Dayan, 2003).

Mammals known to change daily rhythms include heterothermic species. These mammals switch activity periods apparently to minimise thermoregulatory energetic requirements by entering a state of torpor during which body temperature and energy use are substantially reduced (Geiser and Körtner, 2010) and through behavioural adaptations such as basking to passively rewarm from torpor in sunlight (Geiser et al., 2002; Abu Baker et al., 2016). Heterothermic animals may, therefore, adjust foraging activity so that it occurs at a time that enables energy conservation through torpor and basking to be maximised. Inversion of activity patterns during the season of food limitation occurs in several species of small (<50 g body mass) carnivorous marsupial (Dasyuromorphia, Dasyuridae) from arid Australia. This group is typically strictly nocturnal (e.g. Haythornthwaite, 2005). As an example of activity rhythm inversion, a study population of fat-tailed false antechinus, *Pseudantechinus macdonnellensis* (20–45 g), in central Australia foraged during the day and underwent nocturnal torpor in winter (Pavey and Geiser, 2008). Individuals were also active during the

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http://dx.doi.org/10.1016/j.jaridenv.2016.05.006
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first half of the night before entering torpor after midnight and passively rewarming by basking on sun-exposed rocks soon after sunrise (Geiser et al., 2002; Geiser and Pavey, 2007).

The kaluta, *Dasykaluta rosamondae* (20–40 g), a monotypic species endemic to arid northern Australia (Woolley in Van Dyck and Stahan, 2008) is even more extreme, being almost exclusively diurnal in the winter dry season (Körtner et al., 2010). Activity rhythms during the remainder of the year are not documented but it is assumed to be nocturnal. Diurnal activity rhythms were shown both by wild animals radio-tracked using implanted transmitters in winter and captive animals held at room temperature (~19 °C) at a photoperiod of LD 12:12 and later 14:10. Animals tracked in winter typically commenced activity over an hour after sunrise and returned to their burrows immediately prior to sunset before entering torpor during the night (Körtner et al., 2010). Diurnal activity in the kaluta may be selected for by a number of factors including energetically more effective foraging during the day compared to night, temporal partitioning of activity from their main predator(s) and temporal partitioning of activity from potentially competing taxa. To explore these possibilities further we investigated the diet and potential predators and competitors of the population of kaluta studied by Körtner et al. (2010).

2. Materials and methods

The study population of kaluta (average body mass 26.9 g ± 3.0 g SE) was located near Port Hedland, north-west Western Australia (20°24′S, 118°32′E) where it occupied hummock grassland dominated by spinifex (*Triodia* spp.) on a sandplain. Animals sheltered in burrows at night and foraged within the hummocks of spinifex during the day. Bare ground was traversed at high speed.

We assessed the presence of kalutas and other small mammals, both potential predators and competitors, by trapping with aluminium box traps (Type A, Elliott Scientific Equipment, Upwey, Australia). Traps were set over 40 days and nights from 28 May to 16 July 2008 and baited with peanut butter and rolled oats.

Scats were collected from 16 individual kalutas (12 male, 4 female) in June and July 2008. Eleven of these individuals were radio-tracked and exhibited diurnal activity patterns and nocturnal use of torpor (as detailed in Körtner et al., 2010). Fifty scats were analysed from the study population. We broadly followed the faecal analysis methods outlined in Pavey et al. (2009). Prey fragments were identified to the lowest taxonomic level possible by reference to collections in the Queensland Museum, Brisbane. Further, mammal hair was collected and sent for specialist identification (Barbara Triggs, Euroa, Victoria, Australia). The volume of each prey item in each pellet was calculated by spreading all the identifiable fragments in a petri dish with graph paper underneath and estimating for each prey item the space (area) occupied by its fragments (including exoskeleton, hair, scales, feathers). Percentage volume was estimated to the nearest 5%. Taxa that contributed less than 2.5% were not included in percentage volume estimates for a given scat.

We tested for sampling completeness by generating sample-based diet component accumulation curves (1000 randomisations) using the dietary items in Table 1 run in EstimateS version 9.1.0 (Colwell, 2013). We chose the first-order Jackknife richness estimator for this purpose. The percentage of dietary sampling

Table 1
Occurrence of food categories in the diet of the kaluta, *Dasykaluta rosamondae*, from the Pilbara region, northern arid Australia.

Higher classification (class, order, sub-order, superfamily, family)	Prey category	Number of scats
Mammalia	Unidentified mammal	7
Dasyuridae	Unidentified dasyurid	1
Reptilia		
Lacertilia	Unidentified lizard	1
Aves	Unidentified bird	2
Insecta		
Blattodea	Unidentified cockroach	5
Termitoidae	Unidentified termite	32
Termitidae	Unidentified Termitidae	8
	Drepanotermes sp.	11
Orthoptera	Unidentified grasshopper/cricket	13
Caelifera	Unidentified short-horned grasshopper	1
Acridoidea	Unidentified acridoid	2
Hemiptera	Unidentified bug	1
Auchenorrhyncha	Unidentified planthopper	2
Heteroptera	Unidentified true bug	9
Coleoptera	Unidentified beetle	23
Curculionoidea	Unidentified weevil	8
Lepidoptera	Unidentified larvae	18
Hymenoptera	Unidentified wasp	3
Icheumonidae	Unidentified ichneumonid wasp	2
Mutilidae	Unidentified mutillid wasp	2
Formicidae	Unidentified ant	15
	Brachyponera	4
	Crematogaster	6
	Melophorus	1
	Monomorium	2
	Odontomachus	8
	Pheidole	1
	Rhytidoponera	8
	Solenopsis	1
Arachnida		
Aranae	Unidentified spider	13
Chilopoda	Unidentified centipede	12
Malacostraca		
Isopoda	Unidentified isopod	1
Plant	Unidentified plant	4

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