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Original Investigation

Water use and feeding patterns of the marsupial western grey kangaroo (*Macropus fuliginosus melanops*) grazing at the edge of its range in arid Australia, as compared with the dominant local livestock, the Merino sheep (*Ovis aries*)

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ABSTRACT

Western grey kangaroos (*Macropus fuliginosus melanops*) are large, foregut fermenting herbivores common to Australia's southern woodlands and shrublands, but they extend well into semiarid habitats at the north-eastern edge of their range. At this range boundary, western grey kangaroos occupy open chenopod (saltbush) shrubland, along with Australia's other large native kangaroos, as well as with extensive pastoral stock, primarily the wool-breed merino sheep. In this habitat, within a large naturally vegetated enclosure (16 ha), western grey kangaroos grazing sympatrically with merino sheep spent much of the day resting under shade trees, and fed mainly during the evening and early morning, mainly on grasses and flat-leaved chenopods. On this diet, western grey kangaroos had water turnovers similar to those of red kangaroos, at 1.1 L d^{-1}. Sheep, however, used 7.7 L of water each day. Thus, although the sheep were twice the average body mass of kangaroos, the sheep used more than seven times as much water. This level of water use by sheep was almost half that previously reported for sheep at the same site feeding mainly on salt-laden chenopods (ca. 12 L d^{-1}), but was consistent with other studies showing lower water usage by sheep feeding on trees and low-salt shrubs; foregut (rumen) contents of our sheep comprised 35% tree browse. Overall, our data do not support suggestions that western grey kangaroos are limited mainly by water at this arid range-boundary. Notably, the western grey kangaroos' feeding behaviours were consistent with those of other arid-zone kangaroos, highlighting distinctive differences in the ecological physiology of the foregut fermenting kangaroos and the ruminant sheep.

Introduction

Western grey kangaroos (*Macropus fuliginosus*) are one of the largest extant marsupials and their broad range covers much of southern Australia (Dawson, 2012). They extend from coastal and inland regions of southern Western Australia to the inland rangelands of eastern Australia, and typically occupy woodland, forest, and heath, mallee and chenopod shrub lands. Having originated in Western Australia, the easterly expansion of the species has occurred within the last 50 000 years, and clinal and genetic-subunit variations in mainland animals are noted (Neaves et al., 2009). This paper focuses on the mainland sub-species (*M. f. melanops*), and specifically at the edge of its range in arid eastern Australia.

The north-eastern edge of western grey kangaroo distribution is marked by low rainfall, generally less than 250 mm annually, and western grey kangaroos in this region appear restricted to areas with wooded shelter or low shrub (Dawson, 2012). In this region the western grey kangaroo overlaps with three other large kangaroo species; the more arid-distributed red kangaroo (*M. rufus*), the typically mesic-zone eastern grey kangaroo (*M. giganteus*), and the rangelands euro, or hill kangaroo (*M. robustus erubescens*). What determines the distribution limits of these kangaroo species is not well understood, but differences in diet and thermal biology are apparent.

Western grey kangaroos are primarily grazers, preferring grasses, forbs and sedges when available, but they can subsist on chenopod shrubs and other browse when the availability of preferred diets declines, as occurs with drought in arid areas (Barker, 1987). Similar patterns of diet switching are seen for red kangaroos, which also prefer grasses but can switch to chenopods and other vegetation as needed (Barker, 1987; Munn et al., 2010). There is some evidence that western grey kangaroos are able to digest low-protein (low-quality/high-fibre) diets more efficiently than the

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other arid zone kangaroos, the red kangaroos and euros (Prince, 1976), but whether this is reflected in the field is uncertain; see pages 228 and 309 in Hume (Hume, 1999). Of note, western grey kangaroos at the arid edges of their range typically feed in open grasslands, but they tend to remain close to drainage channels and low-tree stands (Dawson, 2012), possibly using these shelters to manage water losses for thermoregulation. Water, shade and diet, therefore, might interact to limit the western grey kangaroos' range, but little is known of the basic water requirements in the wild, or how this may be related to diet and activity patterns.

At the edge of their arid range in eastern Australia, western grey kangaroos co-habit grasslands with one of Australia's main livestock animals, the wool-breed merino sheep (*Ovis aries*). Both the kangaroo and the sheep are foregut fermenting herbivores, with forestomach fermentation preceding acid digestion in the hindstomach; as distinct from the hindgut fermenting herbivores like horses or rabbits that ferment mainly in the caecum/colon following acid digestion (Hume, 1999). Despite broadly sharing a foregut fermentation strategy, the digestive arrangement of the kangaroo forestomach differs from that of the ruminant sheep; kangaroos possess a tubiform forestomach that resembles the equine colon, whereas the ruminant sheep have a large vat-like structure, i.e. the rumen. Recent studies have shown that the different digestive arrangement in kangaroos and sheep has consequences for their thermal biology, water use and overall grazing patterns (Munn et al., 2008, 2010). For example, sheep must re-chew (ruminate) their food, and therefore they feed in shorter, more frequent bouts compared with red kangaroos. However, there have been no direct comparisons of the feeding biology of sheep with other large rangeland kangaroos, and particularly the western grey kangaroo. Therefore, we have further explored the ecological consequences of basic differences in digestive physiology of the non-ruminant kangaroos and the ruminant sheep (Munn et al., 2008). Specifically, we have examined the body water content, water turnover rate (WTR), diet, diet digestibility and activity patterns of the Australian mainland western grey kangaroo grazing the arid-boundary of their ranges, and compared this with the dominant local livestock, the South Australian merino-breed sheep, grazing sympatrically in a typical chenopod shrubland. Our comparison of western grey kangaroos with sheep provides further evidence for general differences between these two functionally different herbivores (Munn et al., 2010), with implication for their management in Australia's productive rangelands.

Materials and methods

Study site

The study was conducted at Fowlers Gap Arid Zone Research Station of the University of New South Wales, (31°05′ S, 141°43′ E), located approximately 112 km north-east of the city of Broken Hill, NSW Australia. The station covers approximately 39,200 ha and operates as a commercial sheep station, in addition to supporting unharvested populations of four large kangaroo species (*M. f. melanops, M. rufus, M. giganteus* and *M. r. erubescens*), and feral goats (*Capra hircus*). Vegetation at the study site is dominated by low woody shrubs (<1 m), chiefly of the family Chenopodiaceae. Rainfall at this site is variable, with a yearly average (±standard error) of 237 ± 20 mm and a co-efficient of variation of 54% (1969–2007 inclusive; SILO Patched Point Dataset, Bureau of Meteorology and NHM QLD; data patched for 1971, and February and April 2000). Our study was conducted in late summer (February–March) 2009. Ambient temperature was continuously monitored at the average height of a foraging sheep or kangaroo (50 cm) using a portable weather station, located adjacent to the study enclosure (WeatherHawk Model 232; Logan, UT, USA). Ambient temperatures were recorded at 15 min intervals. The daily average (±standard error) ambient temperature during the experiment was 28.2 ± 6.2 °C, with average (±standard error) daily maxima and minima being 36.0 ± 5.2 °C and 19.8 ± 2.9 °C, respectively.

Study animals

Wild kangaroos ($n = 11$) were captured at Fowlers Gap using a CO_2-powered tranquilliser rifle (X-calibre model, Pneudart, USA; darts were loaded with Zoletil 100, 10 mg kg^{-1}). After capture kangaroos were fitted with a unique colour-coded ear tag (Allflex button tags; Allflex Australia, Capalaba, QLD, Australia). After capture kangaroos were transferred to a large experimental enclosure (see below) and allowed to acclimate for at least 3 weeks before daily observations of grazing behaviour commenced. All kangaroos were mature, non-reproductive (non-lactating or pregnant) females, and at the beginning of the study kangaroos had an average (±SEM) body mass of 25.2 ± 1.3 kg.

After the kangaroos had been acclimated to the experimental enclosure for at least 14 days a small flock of sheep (South Australian Merino breed; $n = 7$) were introduced to the enclosure. The sheep were randomly selected from a maiden ewe flock operated at Fowlers Gap. Sheep carried approximately 5 months' wool during the study, and were fleeced immediately before being killed by rifle shot destroying the brain at the end of the study. At the beginning of the study the sheep had an average (±SEM) fleece-free body mass of 55.2 ± 1.5 kg.

Experimental enclosure

The experiment was carried out in a large (16 ha), herbivore-proof enclosure situated on an alluvial rise that was naturally vegetated with chenopod shrubs (mainly saltbushes), sparse grasses and scattered trees (*Casuarina* sp.). The scattered trees provided adequate shade for all experimental animals during the study. At the beginning of the experiment (i.e. after 3 weeks acclimation of animals) vegetation was examined by point sampling along 20 randomly chosen transects. Point samples were taken every metre along transects using a 5-mm diameter metal spike; a total of 2000 points was sampled. Each point was categorised as bare (including litter) or belonging to the following plant groups: grass, flat chenopod (saltbushes), round chenopod (bluebushes and copper burrs), forb (herbaceous dicots – often annuals), malvaceaous sub-shrub and trees (Dawson and Ellis, 1994, 1996). Grass was mostly dry, and most plants had less than 15% green material. The height of plants in transects was recorded and relative cover subsequently estimated after correction for the size of the spike, which was 5 mm diameter in our case; see Dawson and Ellis (1994). The biomass of each plant category was then calculated using percent cover and plant height (Edwards et al., 1996) and total biomass was estimated to be 33 ± 13 g dry matter m^{-2} (Table 1); this level of biomass was markedly higher than levels outside the enclosure (Munn et al., Pers. Obs.). Water in the enclosure was provided ad libitum via a refilling trough that all animals were observed to use. A centrally placed seven-metre tower provided a platform from which behavioural observations were made (see below, *Behaviour*).

Total body water, water turnover and urine concentration

Total body water (TBW, % initial body mass) and water turnover rate (WTR, L d^{-1}) was measured in kangaroos ($n = 7$) and sheep ($n = 7$) using the doubly labelled water (DLW) method (Speakman, 1997). After acclimation with sheep, kangaroos were tranquilised using chemical restraint darts, and sheep were then mustered into