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Movements of feral camels in central Australia determined by satellite telemetry

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Movements of two female one-humped camels in central Australia were tracked using satellite telemetry between March 1986 and July 1987. During that time both animals travelled a minimum distance of over 1000 km within a radius of 125 km for one animal, and 200 km for the other. However, their movements were quite punctuated and both animals spent periods of up to several months in relatively small areas before moving over longer distances to new areas. Both camels moved at greater rates overnight. An activity index, probably measuring feeding rate, declined during the study period for both animals. Patchy and sporadic rainfall may explain some of these results.

Keywords: satellite telemetry; radiotracking; camel; Camelidae; Camelus dromedarius; Australia; movement

Introduction

Feral populations of one-humped camels, *Camelus dromedarius,* in Australia are descendants of animals introduced between 1840 and the early 1900s. They were used primarily for transport, as pack animals and for haulage in the remote, arid regions of the continent. Up to 20,000 animals were imported, mostly from northern India and from Pakistan and a number of breeding stations were set up by governments and by private individuals (McKnight, 1969). By the 1930s, camels had been superseded by motorized transport and comparatively few domesticated camels now remain, mostly employed in the tourist industry. The current feral populations originated from the liberation of previously domesticated, working camels.

Broad scale aerial surveys between 1980 and 1983 of the distribution and abundance of camels in Australia, undertaken opportunistically during surveys of kangaroos, provided a minimum estimate of approximately 43,000 feral camels (Short *et al.,* 1988). The main concentration occurs through the heart of central Australia, from the Simpson Desert on the Queensland, South Australia and Northern Territory border, westwards through the Great Sandy Desert to Port Hedland in Western Australia. Significant numbers of undomesticated camels now occur in Australia only (Siebert & Newman, 1989).

Camels are not considered a major pest in Australia, although damage to fencing and watering points is reported occasionally. They are considered wide ranging and nomadic, not concentrating their feeding activities. Coupled with comparatively low densities and the large distances that they supposedly cover, their potential impact on the vegetation should be less than more sedentary herbivores. However, movement patterns have not been documented and are the subject of this paper.

For studies of mobile large wildlife in remote areas, logistical difficulties and the high cost of tracking animals using conventional VHF radio telemetry, plus the low likelihood of resighting tagged animals, make satellite telemetry an attractive alternative. At the outset of this study, satellite telemetry of wildlife was in its infancy (Harris *et al., 1990).* The study was conceived as a pilot study for a similar study on kangaroos, now in progress. The idea was to test the equipment and come to terms with the logistics by following the movements of two feral camels in central Australia.

Methods

Capture and deployment

Two female camels (now referred to as C4960 and C4961) from two separate herds were captured in March 1986, radio-collared and released approximately 130 km north of Ayers Rock in central Australia. Both animals were pregnant. Capture involved the location of potential herds from a fixed-wing aircraft, driving the herd to a flat open area using motorbikes and then lassoing a suitable animal from a cut-down four-wheel drive vehicle. Details of the capture trip were written up by Grigg (1987).

The study area is dominated by the Macdonnell Ranges in the north-east, the salt lakes of Lake Neale and Lake Amadeus in the south-west and dunefields in between (Fig. 1). The interdune vegetation is characterized by low open woodland dominated by *Casuarina* with a *Triodia* (spinifex) hummock grassland understorey. In the ranges, this woodland is more mixed (Australian Surveying and Land Information Group, 1990). There is some cattle grazing in the north-east. Annual rainfall ranges from an average of 250 mm in the north-east to 200 mm in the south-west and is highly variable.

Each radio collar (Telonics, Mesa, Arizona) incorporated a UHF transmitter (platform transmitter terminal or PTT) operating at 401.65 MHz for satellite uplink and a VHF transmitter in the 150 MHz band for close-range location at the time of recovery. The PTT and its power supply were mounted in a collar of butyl rubber and hung below the neck of the camel. A short whip antenna passed around the neck to one side between the two layers of butyl rubber. The VHF transmitter and battery were mounted to the side of the PTT and its longer whip antenna protruded dorsally for about 20 cm. The whole package weighed approximately 1.6 kg.

Location data

When transmitting, each PTT sent a unique 1 W signal every 60 s. The signals were received by an Argos Data Collection and Location System aboard one of two polar orbiting NOAA weather satellites. Harris *et al.* (1990) provided a detailed description of the Argos System. Briefly, Argos calculates the location of a PTT from the shape of Doppler frequency shift in its carrier frequency during two sequential passes. Prior to March 1987, Argos rated the quality of locations on a scale of 0 to 3: 0, not located; 1, located over two passes on one satellite; 2, located over two passes on two satellites; 3, located over one pass only. To calculate a location from a single pass, a minimum of five messages was required with a pass duration > 420 s. Fancy et al. (1989) found the mean location error for transmitters placed at known locations in northern Canada to be 760 m. In April 1987, these indices of location quality were revised and became based on the number of messages (four or more), pass duration (greater or less than 420 s), internal consistency and geometric conditions, as follows; 1, not guaranteed, s = 1 km; 2, standard, s = 350 m; 3, accurate, s = 150 m; where s is the standard distribution of locations (Harris *et al.,* 1990).

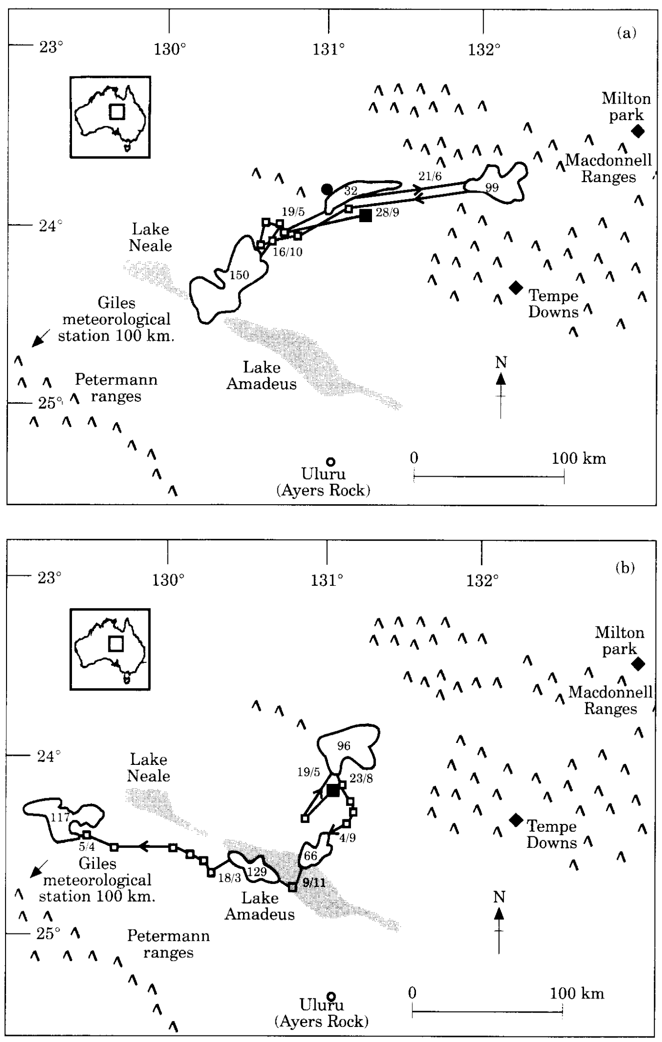

Figure 1. Movements of (a) C4960 and (b) C4961 between May 1986 to August 1987. Enclosed areas encompass a series of locations and the camel's duration in each area in days. Locations outside these areas are three days apart. ♦ indicates a rainfall recording station.• = release point; ■ = recapture point (C4960 only).

The satellites were sun-synchronous satellites, and mornings and evenings were the optimum times for uplink. To conserve batteries, each PTT was programmed to transmit every third day and only between 1530 h and 2030 h (local time) and between 0330 h and 0830 h the following day, giving an expected operational life of approximately 22 months. The battery running the VHF transmitter had a similar lifespan. Such a duty cycle also meant that overnight movement rates could be compared with movements over a 3 day period.

Sensor data

The PTTs also transmitted data from sensors which recorded the internal temperature of the transmitter package as well as the camel's activity. Two types of activity were measured. The first recorded the number of seconds for which a mercury tip switch was closed during the previous minute. The second summed these times over the 24 h prior to 1530 h (local time). Movements from head up to head down closed the switch. The expectation was that this would occur mainly during feeding bouts. Successive counts of zero would indicate collar loss or death of the animal.

These activity data differed from other studies using satellite telemetry to monitor activity in a range of ungulates, in which much smaller movements were required to close the mercury tip switch (Harris *et al.,* 1990). High values for the activity index in these studies would reflect continuous movement such as walking and running.

Analyses

Full datasets were obtained monthly from the Argos processing centre, although both collars were monitored weekly to ensure continuing operation. For each camel, average locations were calculated separately for a set of evening and a set of morning passes. Minimum distances between sets of passes were then calculated. These were converted to daily rates of movement (i.e. speed in km.day $^{-1}$), providing values for overnight movements and movements between consecutive sets of evening passes (i.e. 24^{-h} movements). For each month, the mean movement rates and the mean activity index were determined. Movement rates were compared between camels, months and time of day (overnight vs. 24 h) using analysis of variance (GLM), performed using SAS (Sas Institute Inc., 1988). Movement rates were log transformed (ln(x + 0.01)) prior to analysis.

Results

Sampling periods and collar recovery

The transmitter on camel C4960 stopped sending messages in late March 1987, having yielded approximately 10 months of data. The last 2 weeks of transmission were sensor data only, suggesting a gradual loss of power preceding battery failure. C4961 stopped transmitting in August 1987, providing approximately 15 months of data. Again, a reduction in the number of messages per satellite pass in the final two weeks of transmission suggested a gradual battery failure. An attempt to recover the collars was made in December 1987 using a VHF scanner/receiver and two antennae attached to the wing struts of a fixed-wing aircraft. The signal from C4960 was acquired at 10,000 feet altitude and, following standard procedures, located 100 km away (Fig. 1(a)), running with a herd. She was successfully relocated two days later after a vehicle search, and recaptured using the method described above. Despite a widespread systematic search covering all of and more than the area circumscribed by the movements of both camels, no signals were heard from C4961 and the search was abandoned.

Accuracy and frequency of locations

During each morning and evening transmitting period, C4960 provided an average of 1.4 ± 0.1 locations (range 0-4). C4961 provided an average of 1.8 ± 0.1 (range 0-4) in the evening and 1-3 ± 0-1 (range 0-3) in the morning. For the period May 1986 to March 1987, the vast majority of locations for both camels in both the morning and the evening were given a rating of 3 by Argos (range: 92% to 98% of locations). From April 1987, when only C4961 was transmitting and Argos had upgraded its location quality index, 85% of evening locations and 69% of morning locations were rated at 1. The remaining locations were rated at 2. The average number of messages per location did not fall, suggesting either a change in other aspects of the signal or a more rigorous assessment of the location quality by Argos. The location data were therefore considered to have a precision (standard deviation) of 1 km or better.

Movement patterns and rainfall

The movements of both camels over the study period are shown in Fig. 1. A precision of 1 km is more than adequate to define such broad scale patterns of movement. For both animals, these patterns are characterized by long distance movements interspersed by relatively long periods of only short distance movements. The long distance movements were clearly directional rather than random.

There is some suggestion that these movement patterns may be related to rainfall. Both animals spent the winter months of 1986 in the ranges, where some rain had fallen the previous summer, but where even more rain fell over June and July 1986 (Fig. 2(a)). By the following summer both animals had moved down to the salt lakes. Sufficient rain fell in these areas in January and February 1987 (Fig. 2(b,c)).

Distance travelled, movement rates and activity

The minimum annual distance travelled can be calculated by summing distances between consecutive evening and morning fixes. These values were 1463 km and 972 km in C4960 and C4961 respectively. C4960 travelled a total minimum distance of 1227 km in its 10 months, within a radius of 125 km from her point of capture. C4961 travelled 1182 km in 15 months, with a greater radius of 200 km.

The movement rates of both camels are shown in Fig. 3. Pooling both camels, overnight movements ranged from 0-4 to 38.4 km.day $^{-1}$, while 24 h rates ranged from 0-1 to 28.4 km.day^{-1}. These rates are an underestimate because they assume straight line movements between points. The more localized the movements, the more substantial the underestimate (Fancy *et al.,* 1989). A three-way analysis of variance showed that overnight rates were greater than average rates for 24 h ($F_{1,366} = 79.9$, $p < 0.001$), implying that most movement occurs during the hours of darkness. C4960 showed higher rates of movement than C4961 ($F_{1,366} = 8.2$, $p < 0\text{-}01$) and there were monthly differences in these rates ($F_{14,366} = 2.6$, $p < 0.01$). No interactions were significant.

(Figure 2 follows next page)

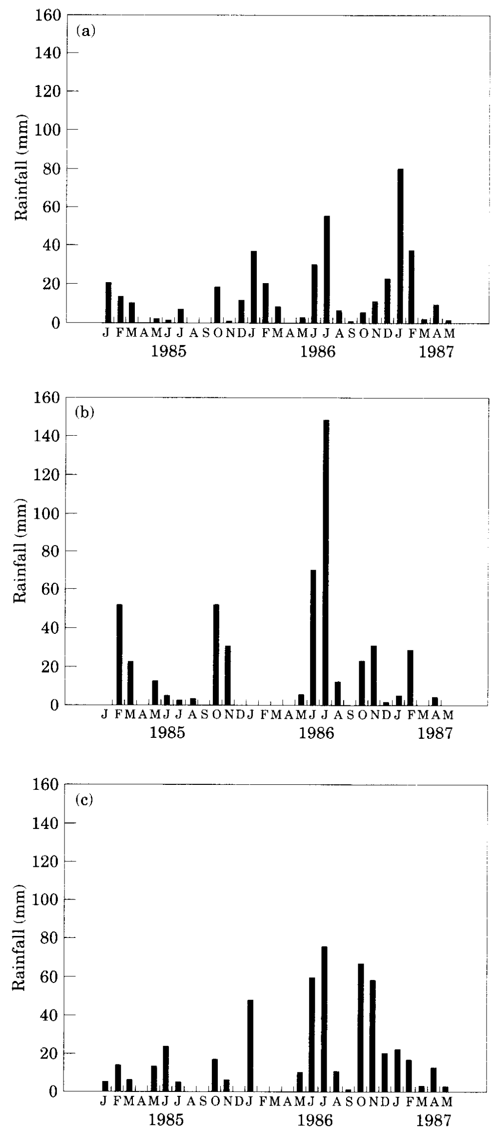

Figure 2. Monthly rainfall for rainfall recording stations, (a) Giles Meteorological Station, (b) Milton Park, and (c) Tempe Downs, in the study area. Their locations are shown in Fig. 1.

The camels appeared to move at greater rates overnight. However, this result is confounded by the different time periods that the two rates are calculated on. The overnight rate is based on a 12-h period, while the 24-h rate is from a 72-h period. A camel's evening location may be well removed from the following morning location, but two consecutive sets (3 days apart) of evening locations may not be far apart. The problem is most pronounced for sedentary animals where locations at the same time each day are not independent. Such difficulties are avoided when considering the longer, directional movements rather than movements within a relatively small area (Fig. 1). The dataset is much smaller (C4960: n = 10; C4961: n = 13) and the results quite different for C4960. When travelling over these longer distances, C4960 moved at an average rate of 8.2 ± 2.6 km.day-1 overnight and 12.9 ± 2.7 $km.day^{-1}$ over 3 days. Long distance movements by C4961 were at an average rate of 11.6 ± 3.0 $km.day^{-1}$ overnight and 5.1 ± 0.9 $km.day^{-1}$ over 3 days. At least some long distance movements, therefore, were made during the day.

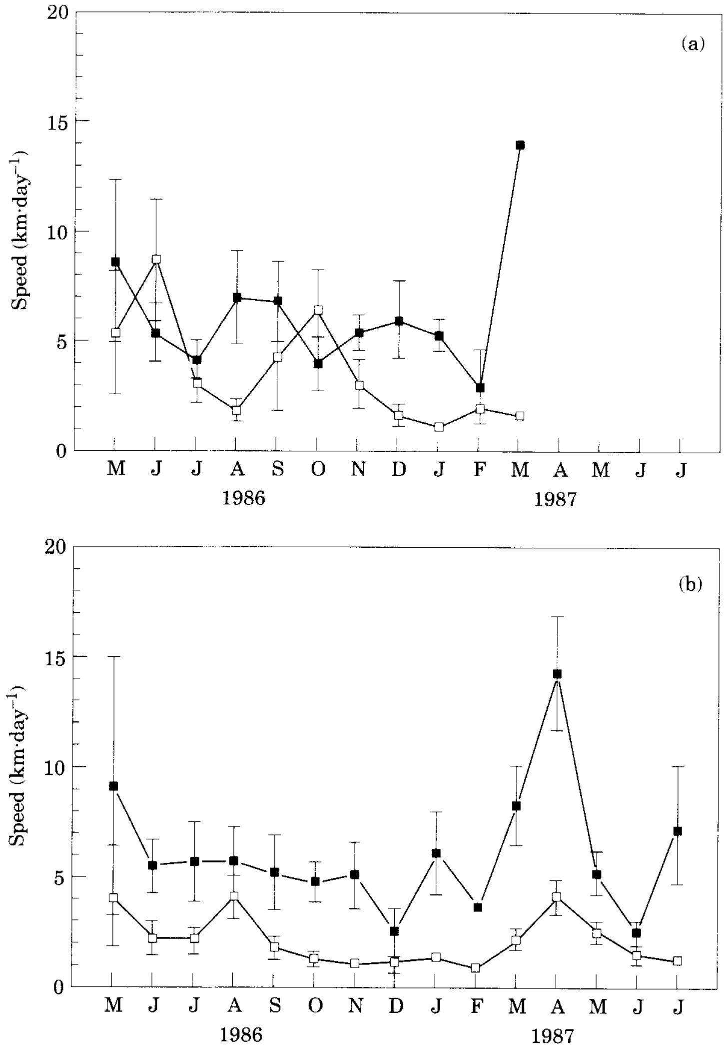

Figure 3. Monthly mean movement rates,
= overnight and
= 24 hour, (± S.E.) for (a) C4960 and (b) C4961 from May 1986 to July 1987.

The movement rates of both camels were significantly lower during the hot summer months than during most other months (Duncan's Multiple Range test). This trend tended to be more pronounced for the 24 h movements and in camel C4960. However, whether these monthly differences in movement rates reflect true seasonal differences would require data spanning several years. Frequency distributions of these movement rates highlight the differences between overnight and 24 h movements and between camels (Fig. 4). As mentioned above, the bulk of movements were short, with only the occasional movements at a faster rate.

Coinciding with higher movement rates of camel C4960 compared with camel C4961 was a higher overall activity (Fig. 5). Activity showed a steady decline over time for both camels with only an occasional rise. For C4960, the 24 h activity index was highly correlated with both the 24 h movement rate (R = 0.39, $p < 0.001$) and the overnight rate (R = 0.35, $p < 0.01$), but there was no relationship for C4961.

Collar temperatures

Collar temperatures, although only an approximation of ambient temperature (Harris *et al.,* 1990), tracked expected seasonal and daily fluctuations (Fig. 6). For C4960, there was a significant negative correlation between 24 h activity and both morning (R = -0.30, p < 0-01) and evening (R = -0.24, p <

0.05) collar temperatures. There were no significant relationships between temperature and activity for C4961, or between rate of movement and temperature for either camel.

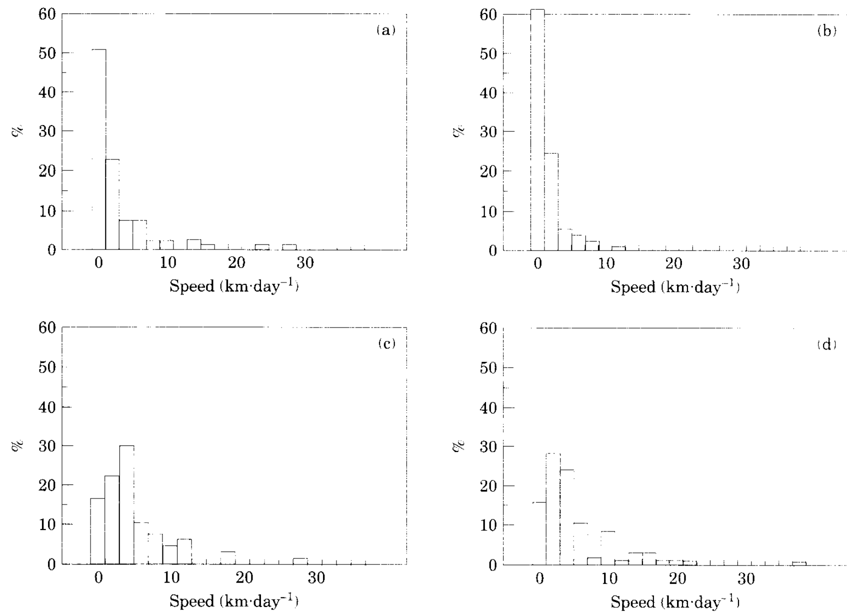

Figure 4. Frequency histograms of the movement rates (speed) of C4960 over (a) 24 h (n = 79) and (c) overnight (n = 68), and C4961 over (b) 24 h (n = 96) and (d) overnight (n = 124). The study period was 10 months for C4960 and 15 months for C4961.

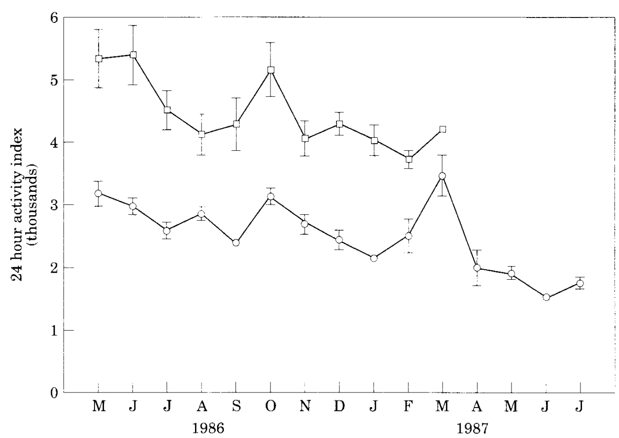

Figure 5. Monthly mean 24 h activity index (± S.E.) for C4960 (□) and C4961 (○) from May 1986 to July 1987.

Discussion

As we monitored only two camels, it is difficult to make generalizations. Because females are not solitary, it is reasonable to assume that the movements record the movements of herds, though not necessarily the same two herds, as females are known to change herds. Whether the overall movements of both camels are migratory rather than nomadic would require data from a longer time span. Their movements are certainly not restricted to a home range, though they are punctuated. Siebert & Newman (1989) described camel movements as frequently being 50 to 70 km per day, with animals rarely spending long in one location. The results presented here differ from that description on both counts, though Siebert & Newman do mention camels spending longer periods in an area that has received heavy rain. In red kangaroos, Denny (1985) and Croft (1991) have documented long distance movements to areas of good rainfall, though such movements are considered uncommon in adult red kangaroos, which are described as sedentary, occupying well-defined home ranges (Priddel, 1987; Croft, 1991).

A strategy of detecting and moving to areas of good rainfall is clearly advantageous in arid central Australia, where rainfall is both sporadic and patchy. Whether camels show this ability is unknown, but our data are coincident with that as a hypothesis. Camels are certainly capable of long distance movements of over 100 km.day $^{-1}$ and appear to be capable of detecting distant water and fresh pasture (Gauthier-Pilters & Dagg, 1981).

Fancy et al. (1989), using similar methodology, reported mean annual distances of 3000-4500 km travelled by migratory caribou in arctic Alaska, some travelling as much as 5000. These represent the largest movements yet documented for any terrestrial animal.

The activity index probably largely reflected the number of feeding bouts (feeding rate) rather than any continuous movement such as walking or running (see above). Observations on collared camels would be needed to confirm this. Assuming the 24 h activity index did correspond to feeding rates, then one can speculate on their relationship with forage condition, as the activity index appeared to show an inverse relationship with rainfall (Fig. 2 and Fig. 5). Camels take fewer bites per hour when feeding on relatively rich vegetation, although time spent grazing does not seem to change with pasture condition (Gauthier-Pilters & Dagg, 1981), so there is some support for this hypothesis.

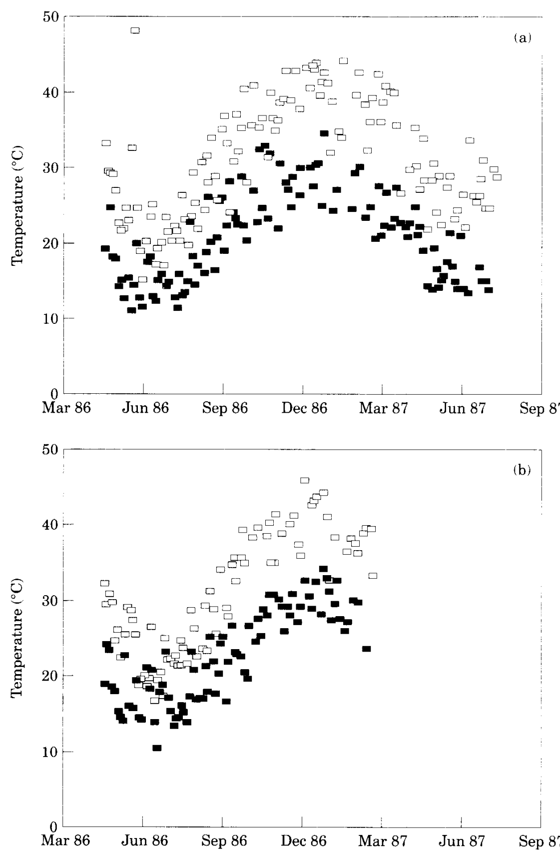

Figure 6. Morning and evening temperatures (°C) of the PTT canister for (a) C4960 and (b) C4961 between May 1986 and July 1987. Temperatures are averages of a set of morning (■) or evening (□) passes.

Considerable distances can be covered by camels while feeding (Gauthier-Pilters & Dagg, 1981), which occurs at night in free-ranging camels (Wilson, 1990). The results of this study fit well with these observations. One might expect movement rates to be closely related to feeding rates as measured by the activity index, but the results here are inconclusive. Factors other than feeding rate will no doubt also influence the rate of movement.

The costs and relative merits of satellite telemetry compared to more conventional methods of animal tracking have been identified elsewhere (Fancy et al., 1989; Marsh & Rathbun, 1990), but this study further confirms the value of the technique as a research tool. While limited in its conclusions, the study has been able to identify some of the scope and patterns of camel movements. Furthermore, it has opened up a range of hypotheses that could be tested. These include examining the seasonal energetics of wild or feral camels in an arid environment and a further examination of movement patterns and habitat use, both using satellite telemetry.

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References

Australian Surveying and Land Information Group *(1990). Atlas of Australian Resources (third series). Vol 6. Vegetation.* Canberra: Australian Government Publishing Service. *64 pp.* Croft, D.B. *(1991).* Home range of the red kangaroo, *Macropus rufus. Journal of Arid Environments, 20: 83-98.*

Denny, M.J.S. *(1985).* The red kangaroo and the arid environment. In: Lavery, H.T. (Ed.), *The Kangaroo Keepers, pp. 56-74.* St. Lucia: University of Queensland Press. *211 pp.*

Fancy, S.G., Pank, L.F., Whitten, K.R. & Regelin, W.L. *(1989).* Seasonal movement patterns of caribou in arctic Alaska as determined by satellite. *Canadian Journal of Zoology, 67: 644-650.*

Gauthier-Pilters, H. & Dagg, A.I. *(1981). The Camel. Its evolution, ecology, behaviour, and relationship to man.* Chicago: The University of Chicago Press. *208 pp.*

Grigg, G.C. *(1987).* Camels by satellite. *Australian Geographic, 5: 42-45.*

Harris, R.B., Fancy, S.G., Douglas, D.C., Garner, G.W., Amstrup, S.C., McCabe, T.R. & Pank, L.F. *(1990). Tracking Wildlife by Satellite: Currentsystems and performance. U.S.* Fish and Wildlife Service Technical Report *30. 52 pp.*

Marsh, H. & Rathbun, G.B. *(1990).* Development and application of conventional and satellite radio tracking techniques for studying dugong movements and habitat use. *Australian Wildlife Research, 17: 83-100.*

Priddel, D. *(1987).* The mobility and habitat utilisation of kangaroos. In: Caughley, G., Shepherd, N. & Short, J. (Eds), *Kangaroos: Their ecology and management in the sheep rangelands of Australia, pp. 100-118.* Cambridge: Cambridge University Press. *253 pp.*

Sas Institute Inc. *(1988). SAS/STAT User's Guide, Release 6-03 Edition.* Cary, NC: SAS Institute. *1028 pp.*

Siebert, B.D. & Newman, D.M.R. *(1990).* Camelidae. In: Walton, D.W. & Richardson, B.J. (Eds), *Fauna of Australia. Mammalia, pp. 1050-1053.* Canberra: Australian Government Publishing Service. *1227 pp.*

Short, J., Caughley, G., Grice, D. & Brown, B. *(1988).* The distribution and relative abundance of camels in Australia. *Journal of Arid Environments, 15: 91-97.*

Wilson, R.T. *(1990).* Natural and man-induced behaviour of the one humped camel. *Journal of Arid Environments, 19: 325-340.*