

Activity of dingoes (*Canis familiaris*) and their use of anthropogenic resources in the Strzelecki Desert, South Australia

Paul D. Meek^{A,B,*} , Guy A. Ballard^{B,C} , James Abell^C, Heath Milne^C, Deane Smith^{B,C} and Peter J. S. Fleming^{B,D} 

For full list of author affiliations and declarations see end of paper

***Correspondence to:**

Paul D. Meek
Vertebrate Pest Research Unit, NSW
Department of Primary Industries, PO Box
350, Coffs Harbour, NSW 2450, Australia
Email: paul.meek@dpi.nsw.gov.au

Handling Editor:

Thomas Newsome

Received: 13 February 2023

Accepted: 11 March 2024

Published: 4 April 2024

Cite this: Meek PD *et al.* (2024)
Activity of dingoes (*Canis familiaris*) and
their use of anthropogenic resources in the
Strzelecki Desert, South Australia. *Wildlife
Research* **51**, WR23083. doi:10.1071/WR23083

© 2024 The Author(s) (or their
employer(s)). Published by
CSIRO Publishing.

This is an open access article distributed
under the Creative Commons Attribution-
NonCommercial-NoDerivatives 4.0
International License (CC BY-NC-ND).

OPEN ACCESS

ABSTRACT

Context. Managing human–wildlife conflict where anthropogenic resources are provided is difficult. Providing food, water and shelter can result in over-abundant dingo populations, especially in Australian desert mine sites where managing dingoes, wildlife and humans around waste-management facilities and camps is problematic. **Aims.** To measure and characterise the spatial activities of a population of arid-zone dingoes in relation to resources provided by a Cooper Basin (Strzelecki Desert, South Australia mining operation). The results were used to facilitate effective dingo management. **Methods.** Free-roaming dingoes were captured, their morphometrics and ectoparasite presence recorded, and they were fitted with Iridium (GPS) radio collars. These were used to collect high-fidelity data about individual dingo activity and movements in relation to mine-site infrastructure and the Cooper Basin ecosystem. **Key results.** A high density of dingoes (181 trapped in 2 km² per 4 years) was associated with the mining operation. Home range/activity area sizes and usage of the anthropogenic landscape showed the following three categories of dingo: desert, peripatetic and tip dingoes. Dingoes reliant on food provisioning at the waste-management facility (WMF) displayed activity areas with a strong focus on the WMF (tip dingoes). Temporal activity patterns of another group of dingoes (peripatetic dingoes) were associated with regular waste-dumping times and normal nocturnal activity away from the WMF. Of the 27 dingoes collared, 30% (i.e. desert dingoes) were not dependent on the WMF, spending more time and a greater area of use in the desert dune system than in the mine-site area. **Conclusions.** On the basis of the capture of 181 dingoes over 4 years and home-range analysis, it is likely that anthropogenic resource provisioning has caused an overabundance of dingoes in the Cooper Basin mine site. However, some of the dingo population remains reliant on native wildlife and resources in the surrounding desert. Managing food waste and excluding dingoes from food, water and shelter will result in a change in the prevalence of dingoes in the mine site, and subsequent reduction in the risk of disease transmission, native wildlife impacts, human conflicts and social pressures on dingoes, influencing them to revert to domestic-dog behaviours. **Implications.** Waste-management facilities where food is dumped provide resources that lead to a change in wild-dingo behaviour, on the basis of their acceptance of human-provided resources, and high abundance. Managing access to anthropogenic resources will reduce the population as well as unwanted or aggressive encounters with humans. Dingoes reliant on food scraps will be encouraged to adjust their activity areas to desert habitat, thereby providing natural hunting opportunities and reduced contact rates with conspecifics, thus potentially reducing pathogen transmission.

Keywords: desert, ecology, food and water use, free roaming dog, home range, human–wildlife conflict, management, wild dog.

Introduction

Free-ranging dogs, including dingoes (*Canis familiaris*), are subject to conflict with humans throughout their range. Dingoes are an introduced canid from Asia that have become naturalised in Australia over the past ~5000 years (Jackson *et al.* 2017, 2019). Their ability to adapt to Australian environments, along with their co-occurrence with humans, has led to their widespread distribution. Following their introduction into Australia, the original

canid ancestors became part of Aboriginal culture (Rose 1984), highlighting their domestication tendencies (Diamond 2002; Zeder 2006, 2012). These same tendencies continue today, with free-roaming dogs/dingoes exploiting the provisioning of food, water and shelter in remote areas, particularly near mine sites (Newsome *et al.* 2014, 2015; Déaux *et al.* 2018; Smith *et al.* 2020). In the Cooper Basin, management of dingo numbers is necessary to prevent human attacks such as those that have occurred on K'gari (Fraser Island) (Appleby *et al.* 2017; Tapply 2018; Behrendorff *et al.* 2023), disease spread and general nuisance issues. The provision of anthropogenic resources attracts large numbers of dingoes to occupy focal areas, and thus supports high densities (Becker and Hall 2014) around mining camps (Newsome *et al.* 2013a) and increases the risk of conflict with humans (Herrero and Higgins 2003). Dingoes are commensal with humans and, although they are wild animals, they exhibit many domestic behavioural traits in response to human interactions, including increased rest time (Altmann and Muruthi 1988; Déaux *et al.* 2018). This leads to individual dingoes living largely within human settlements, in some cases entering quarters and stealing food, human clothing and so on, which increases the occurrence of human–wildlife conflict (Newsome and Van Eeden 2017; Behrendorff *et al.* 2023). Further, a reliance on these resources can lead to development of anticipatory behaviour, where animals become reliant on and anticipate when food will be provided (Pini-Fitzsimmons *et al.* 2018). Similarly, provisioning of water in a landscape that was devoid of permanent water prior to European settlement (James *et al.* 1995) provides advantages to Australian wildlife (James *et al.* 1999).

A piosphere effect (Osborn *et al.* 1932) can be evident around anthropogenic food and, to a lesser degree, water-provisioning sites in arid/desert environments. This piosphere effect can even cause deep and obvious dingo walking pads (Eldridge 1996), linking these sites and the desert (P. Meek, pers. obs.). Provisioning of water in dams can help sustain larger numbers of dingoes than normal (Newsome and Corbett 1977) and dingo numbers in arid Australia are higher closer to water bodies (Brawata and Neeman 2011). In the central Australian arid zone, some water is available as either seasonal free water (ephemeral swamps) or agricultural and mining dams (settling ponds), although these are not common.

Managing dingo populations for human health and safety, as well as ecological and cultural goals, is required in the Cooper Basin mine area under management plans (Anon 2017a, 2017b). Controlling the number of dingoes living within waste-management facilities and camps also provides some disease-mitigation benefits for individual dingoes that suffer extreme sarcoptic mange (*Sarcoptes scabiei*) infection (Murray *et al.* 2015) because of high contact rates. The effect on the epidemiology of disease and pathogens of abnormally high animal densities of dingoes resulting from dependence on human resources (Becker and Hall 2014) is under-recognised in Australia. Provision of food and water

can lead to an increase in wildlife population sizes and thus increase pathogen transmission (Becker and Hall 2014). Moreover, although providing food can reduce nutritional stress, this may cause prolonged infection (Becker and Hall 2014). In the case of dingoes, food and water provisioning in the arid zone leads to increased abundance, resting (Newsome *et al.* 2015), use of focal points, and tolerance of conspecifics (Newsome *et al.* 2013b), and probably has a negative effect on biodiversity through increased predation (Harrington *et al.* 1999; Davies *et al.* 2010). Whether undertaken for ecological, human-safety or dingo-welfare reasons, the management of over-abundant populations requires ecological knowledge of dingo ecology.

Understanding how dingoes use the resources available in mining camps and surrounding areas is an important first step in developing strategies for managing an over-abundant population. To this end, we studied a population of dingoes to evaluate their activity, movement patterns and use of the anthropomorphic resources provided in a mining camp. The knowledge gained from this study together with observations and data collected since 2015 will form the foundation of management recommendations for managing dingoes in desert mine sites.

Materials and methods

Study area

The GPS radio-tracking study was conducted in the gas fields of the Cooper Basin (28°07'25.91"S, 140°11'45.65"E) surrounded by the Strzelecki Desert in South Australia (Fig. 1). The Cooper Basin is located in north-eastern South Australia, north of Lyndhurst and south of Innamincka. The weather is predominantly hot and dry, with an annual rainfall of 200–300 mm, and temperature ranging from 0 to 50 degrees Celsius between winter and summer (10 September 2023, Bureau of Meteorology). The soils profile consists mainly of clay-rich vertosols and kandosols, with dune systems and low-lying wetlands. Vegetation is broadly sparse shrublands and scattered grasslands. The gas-field mine site has restricted access and consists of the mine camp which includes residential and industrial infrastructure (roads, airport, gas plant and living quarters) and a waste-management facility (WMF) where all food scraps are deposited daily (food pit), and rubbish is stored prior to recycling or burial (Fig. 1).

Data collection

Trapping

Dingoes were trapped between 2015 and 2019 by using Victor Soft Catch #3 traps fitted with a short chain and a double-spring system; they were double-staked to the ground by using 40 cm pegs previously described in Meek *et al.* (2019a). A variety of lures was used, and traps were placed

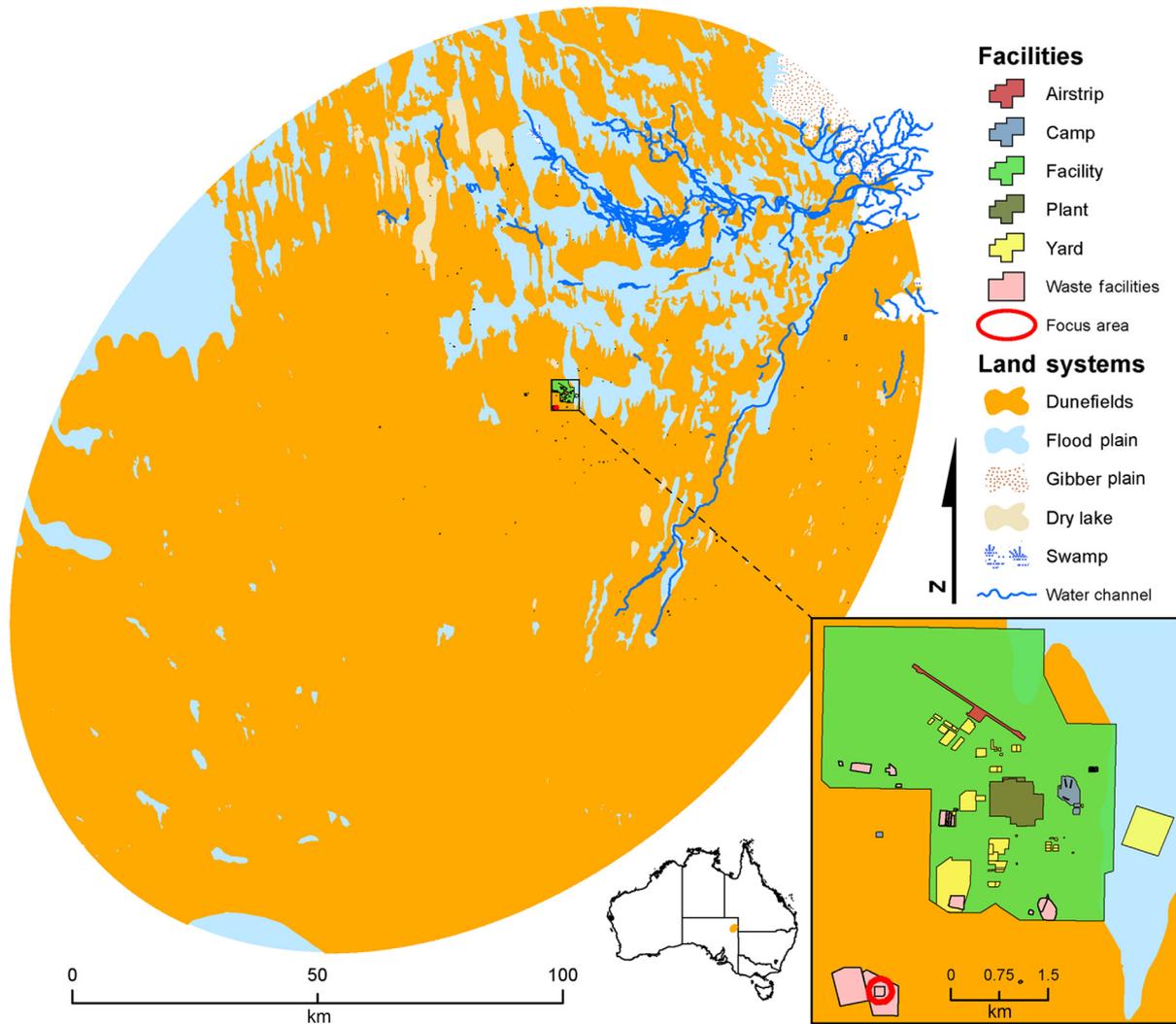


Fig. 1. Location of the study mine site in the Cooper Basin, South Australia.

strategically around pads and tracks in the study site to optimise encounters by dingoes. All dingoes collared in this study were trapped around the mine site within a 2 km² radius of the WMF. Capture success was improved over time by using a skunk lure (Skunkshot™ gel) from Connovation in New Zealand. The smell of this novel lure appeared to stand out above the cornucopia of dingo urine and faeces, and food that is in super high abundance at the site. All traps were checked and cleared throughout the day (sunrise) and early evening between 2000 hours and 2400 hours, depending on capture success. Trapping to fit GPS radio collars was performed over 2 weeks in September 2019.

Handling and collaring

Animal handling and collaring were conducted consistent with standard practice (Fancourt *et al.* 2022; Marrant *et al.* 2022) and in accordance with animal ethics approval. Dingoes captured for collaring were restrained using a Ketch-All pole,

then lifted onto a capture board and restrained with three straps and placed in the shade. The trapped foot was immediately massaged with Hirudoid® cream to reduce any swelling. Animals were offered water in the corner of the mouth and if a swallowing response was observed, this was continued until they stopped drinking. A fabric cover was placed over the dingo's head to block visual stimuli and to assist with calming the animal. In accordance with animal ethics approval, morphological data were collected and a biopsy was collected from the ear with an Allflex sampling kit® and analysed by an independent laboratory Zoological Genetics (South Australia) by using microsatellites (Wilton 2001; Stephens *et al.* 2015). DNA analysis was undertaken to assess kin and subpopulation relationships within the population and elsewhere across Australia, so as to gain understanding of family relationships and lineage (Stephens *et al.* 2022). A small, coloured ear tag was fitted into the biopsy hole to aid identification at a distance and a microchip was

inserted into the nape. A Lotek GPS radio collar (Litetrack/Pinpoint Iridium) with a time-release drop-off (TRD) was fitted to each animal where the collar was <5% bodyweight. The TRD was programmed to release after 12 months to preclude re-trapping each dingo. Transmitters were set to record at 30-min intervals for a settling period and then 5- and 15-min fixes were programmed over the life of the collar to produce high-frequency coordinates. Each collar was also programmed with a mortality function, which sent an email alert to one of the authors (PM) when a collar remained stationary for longer than 24 h.

Morphology, reproductive physiology and disease

Basic morphology data were recorded for each captured animal in this study, including data from dingoes trapped at the study site since 2015 by the authors (Meek and Brown 2017; Meek *et al.* 2019a, 2019b, 2020). All trapped dingoes were weighed, sexed and observations of reproductive physiology and pathology were recorded during 2015–2019, and visual observations during field work and camera-trap monitoring during a technology project until 2021. The extent of mange infection was scored as a proportion of the body infected, i.e. fur loss and ulceration, for each individual.

Home-range/activity-area data collection

GPS-tracking fixes were monitored using the Lotek GPS Web Portal. Where a collar could not be recovered because of transmitter failure, fixes were downloaded from the portal. We programmed a high fix rate (5–15 min) to investigate the relationship between the dingoes and the facilities and resources provided by the mining operation. All collars producing a signal indicating mortality or drop-off because the TRD date had passed were located using a hand-held receiver and Yagi antenna. In cases of collar failure or where battery life had expired, the last known point from the portal was programmed into a GPS and a search was conducted in the vicinity. When collars were located, all fixes were downloaded directly from them by using the Lotek software package Pinpoint Host 2.15.19.0. Fix accuracy was calculated using repeated mortality fixes for each dingo to derive a value in metres.

Quantifying the frequency of food provisioning

Three Swift Enduro 3G camera-traps were placed on the road to the WMF on brackets attached to star pickets at a height of 1.5 m above ground, so as to avoid interference from dingoes. The cameras were attached to a solar panel to prolong battery life and programmed to take one photo per trigger and transmit data via the telecommunications network to the researchers. Photos were reviewed and tagged to collect date- and time-stamped records of movements of the food-waste trailer (FWT) to the WMF. On the basis of this imagery, we generated a data set of visits to the food pit inside the WMF, indicating when food was provided. We calculated from the camera-trap images that there was a 5–20 min gap

between detection of the FWT on the road to the WMF and when the food was deposited. This was due to driver behaviour, gate access and food-pit activity. No data were available on the quantities of food scraps deposited each visit.

Data analysis

GIS layers of assets and structures

GIS files provided by the mining company allowed us to geo-reference human made structures such as roads, easements, buildings, settling ponds and the WMF, which enabled us to overlay dingo location data, and thus measure spatial and temporal use patterns.

GPS data filtering and cleaning

Collar data were returned from the web portal or devices as CSV files. Data were pooled and relevant columns from the data imported into R (v. 4.2.1; RStudio 2022.07.1 + 554) (R Core Team 2022; RStudio Team 2022). Data were first filtered to remove fixes with incomplete records, before fixes with a dilution of precision (DOP) value greater than 10 were filtered out. The remaining fix timestamps were converted to Australian Central Standard Time from Greenwich Mean Time before a custom function was run to remove a single day's worth of fixes from each end of the active dataset for each dingo (24 h post-capture and pre-mortality/collar drop off). Last, fixes were manually assessed to remove any that had escaped the filtering process, but were obviously erroneous; that is, too far away from the previous or subsequent fix to be a biologically plausible movement (hundreds of kilometres away) for a dingo. Only one fix across the entire collared population was removed in this final step.

Home-range/activity analysis

Several home-range analyses were run to evaluate the best-fitting method for the dingo population, including minimum convex polygon (used for comparisons with historical studies), adaptive kernel estimate, kernel estimate, Brownian bridge, biased random bridges and convex hull. Because some of the dingoes at the WMF exhibited small activity areas associated with anthropomorphic resources, we extracted those animals for use in a Brownian bridge analysis to examine, in detail, areas of intense use associated with the food-waste pit. Hereafter, we refer to the area often described as a home range as an activity area because data collection did not span the entire year for the entire population and may not be a complete record of their use of the landscape throughout the year.

We refined the activity-area analysis using three analogous techniques, first 95%, and 50% minimum convex polygons (MCP), 95% and 50% kernel utilisation distribution (UD) and 95% kernel Brownian-bridge utilisation distribution (BB). MCPs, UD and BB were all calculated in R, using package *adehabitatHR* (v-0.4.19, `mcp()`, `kernelUD()` and `kernelBB()` functions respectfully). Simple kernel UD activity areas

were produced with fixed smoothing values calculated within the function (*href* in adehabitatHR documentation). BB activity areas require the input of two smoothing variables (σ_1 and σ_2). The first (σ_1) relates to the speed of the animal between two GPS points and accounts for potential wandering by the animal between points. The second (σ_2) is the error (in metres) of the GPS location produced by the collar. For our purposes, a σ_2 of 5 m was rounded up from 3.79 m for ease of analysis on the basis of a fix accuracy calculated from repeated mortality fixes for each dog (3.76 m; s.d. = 2.83) (see Results). The values of σ_1 were then calculated in R (adehabitatLT v-0.3.25, liker function). Outputs were exported to shapefiles (sf v-1.0.3, st_write function) and scrutinised in ArcMap. Figures were also produced in ArcMap (v-10.6.1).

Anthropogenic impacts were assessed by geofencing all animals' fixes within a 150 m radius of the food pit at the WMF (Fig. 1) and by using the R (package circular) to identify the temporal distribution of food-pit visits by dingoes to examine whether these coincide with the temporal distribution of dumping events.

The percentage of days each animal attended the WMF (within 150 m radius) of all days recorded was also calculated. These values were correlated to activity-area sizes and movement for each animal in R (package geosphere v1.5-14, distm() function). Here, daily displacement was defined as the largest distance (calculated pairwise) between all fixes in a single day and daily distance as the length of the track taken over a 24-h period. Finally, the distance of every fix from the waste facility was calculated within ArcMap (Generate Near Table; Analysis Tools). From this analysis, the maximum, mean and minimum were averaged for each individual for each time of day and scrutinised. These individual values were then combined to assess the average distances from the WMF over time for the entire collared population. Outcomes of this analysis showed three potential types of dingoes, the results are presented cognisant of these findings. These groupings were validated using an ANOVA; proportion of days spent in the WMF, 95% utilisation distribution and average daily distance travelled).

Ethics statement

All capture and handling procedures were undertaken in accordance with NSW Department of Primary Industries Orange Animal Ethics Committee Approval number ORA 19/22/013.

Results

Dingo density estimates, genetics, morphology and reproduction

Between 2015 and 2019, 181 dingoes were trapped within a 2 km² area associated with the mining operation, including 27

that were radio collared. This resulted in a high annual average density of dingoes (22.625 dingoes/km².year). Analysis of 125 DNA samples was conducted for purity, including all collared animals ($n = 27$). Using the classification system of Stephens *et al.* (2015) and Wilton *et al.* (1999), 97.6% of tested animals were pure dingoes or possibly pure dingoes (i.e. 80–100% dingo genetics classification system), only three animals were dingo × modern dog hybrids and DNA could not be extracted from one sample.

The mean weight of adult dingoes ($n = 162$) was 15.9 kg, with female mean weight being 14.1 kg (range 9–20 kg) and males 15.9 kg (range 11–24.5 kg). Nineteen individuals were removed from the sample because they were pups or subadults, or weighed less than the 5% collar-to-body weight threshold required for collaring. The mean weight of the adult female dingoes collared in 2019 was 12.1 kg (range 9–16.5 kg); males were larger, with a mean weight of 17.1 kg (range 11–24 kg).

In total, 2 (7%) of the 27 collared animals were black or black and tan; the remaining animals had ginger coats, which is consistent with predominance of ginger coats in the larger population sample of the 181 dingoes from the Cooper Basin (Table 1).

The reproductive physiology of the Cooper Basin dingoes ($n = 181$) was comparable to that of dingoes in other habitat types and arid-zone sites (Van Dyck and Strahan 2008; Baker and Gynther 2023); that is, they produced one litter per year, with pups being recorded mostly in the August–October period, lactating females seen from early August into September and whelping occurring from September until December. Litters of five to six were common, although observations (PM) suggested that survival was mostly one or two pups reaching maturity.

GPS radio tracking data

GPS collars were fitted to 20 males and seven females. Animal ethics approval allowed trapping of 30 dingoes. After filtering steps, collars returned an average of 15,014 fixes per dingo (min = 2399, max = 18,843; Table 2). Dingoes were radio tracked for 13–347 days (Table 2), with three collars failing and dropping off within 29 days (13–29 days). Dingoes were named for the purposes of engagement with mine

Table 1. Coat morphology of Cooper Basin dingoes trapped between 2015 and 2020.

Coat colour	Number	Percentage
White	7	4
Brindle	11	6
Black/black and tan	19	10
Ginger	144	80
Total	181	

Table 2. GPS-tracking statistics and activity-area analysis of 27 dingoes collared between 14 and 18 September 2019 in the Cooper Basin, Strzelecki Desert, South Australia.

Name	Sex	Number of fixes	Number of days collared	Minimum convex polygon 95% (km ²)	Utilisation distribution 95% (km ²)	Brownian bridge kernel 95% (km ²)
Desert dingoes						
Julie	Female	16,607	252	800.0	588.9	335.3
Holly	Female	17,047	253	740.8	607.2	124.4
Dozer	Male	17,364	340	2400.2	2526.1	1078.0
Sunny	Male	16,666	131	1830.6	1350.6	525.3
Jamo	Male	18,101	171	1470.6	902.4	500.5
Sarge	Male	18,580	280	801.9	741.1	489.7
RikMan	Male	18,845	338	703.1	677.5	403.4
Yuley	Male	8909	29	510.6	1014.5	NA
Peripatetic dingoes						
CeeCee	Male	17,373	341	485.7	211.9	238.1
Durian	Male	17,448	341	359.8	166.4	249.0
Clearasil	Male	9984	225	339.5	313.6	259.1
Hurricane	Male	17,423	340	271.4	258.5	234.3
Shauno	Male	17,331	341	232.0	123.3	229.2
Leonardo	Male	17,075	246	115.6	74.2	267.8
Tip dingoes						
Mooka	Female	16,536	131	230.5	212.1	86.7
Demelza	Female	10,237	167	90.1	50.5	71.3
Mabel	Female	16,561	133	64.5	61.0	39.4
Shadow	Female	16,460	125	58.2	34.2	20.4
Heather	Female	17,275	347	17.4	11.5	16.3
Bernie	Male	18,376	229	94.9	58.5	82.5
MickTaylor	Male	16,558	106	66.4	31.4	21.9
Ibrahim	Male	5029	18	62.6	99.6	17.8
Wesley	Male	9975	154	31.1	16.7	19.5
Hun	Male	16,955	218	21.8	13.4	16.4
Obsidian	Male	3536	13	19.3	15.0	7.0
Capybara	Male	16,433	133	16.3	18.1	25.0
Schwob	Male	16,305	130	9.0	7.4	NA

workers and will be referred to hereafter by using those names. Summary data are provided in subsequent sections.

Dingo classifications based on activity-area analysis

The activity areas of dingoes in the Cooper Basin mine site ranged from 9 to 2400 km² (95% MCP), with each of the dingoes using the WMF compared with the desert in different proportions. By analysing GPS fixes in relation to the distance that each dingo roamed from the WMF area, and by evaluating the proportion of location points in the landscape (i.e. WMF vs desert) used to generate activity areas (Table 2, Fig. 2), we separated dingoes into the following three classifications: tip,

peripatetic and desert dingoes. Tip dingoes were those that focussed the largest proportion of their time (proportion of fixes) in the WMF or within a 20 km radius of it (Fig. 2). Peripatetic dingoes were those that showed a predisposition to share their activity between the desert and the WMF (<40 km), with a stronger association with the desert ecosystem than the food pit (Fig. 3). Desert dingoes were animals that utilised the WMF only rarely, with activity mostly occurring within 80 km of the mine site (Fig. 2). These classifications were validated further by testing the relationship among classifications and the amount of time spent in the WMF ($F_{2,24} = 18.4, P < 0.05$) and the size of individual dog-activity areas ($F_{2,24} = 20.9, P < 0.05$). Correlation of 'percentage days spent at WMF'

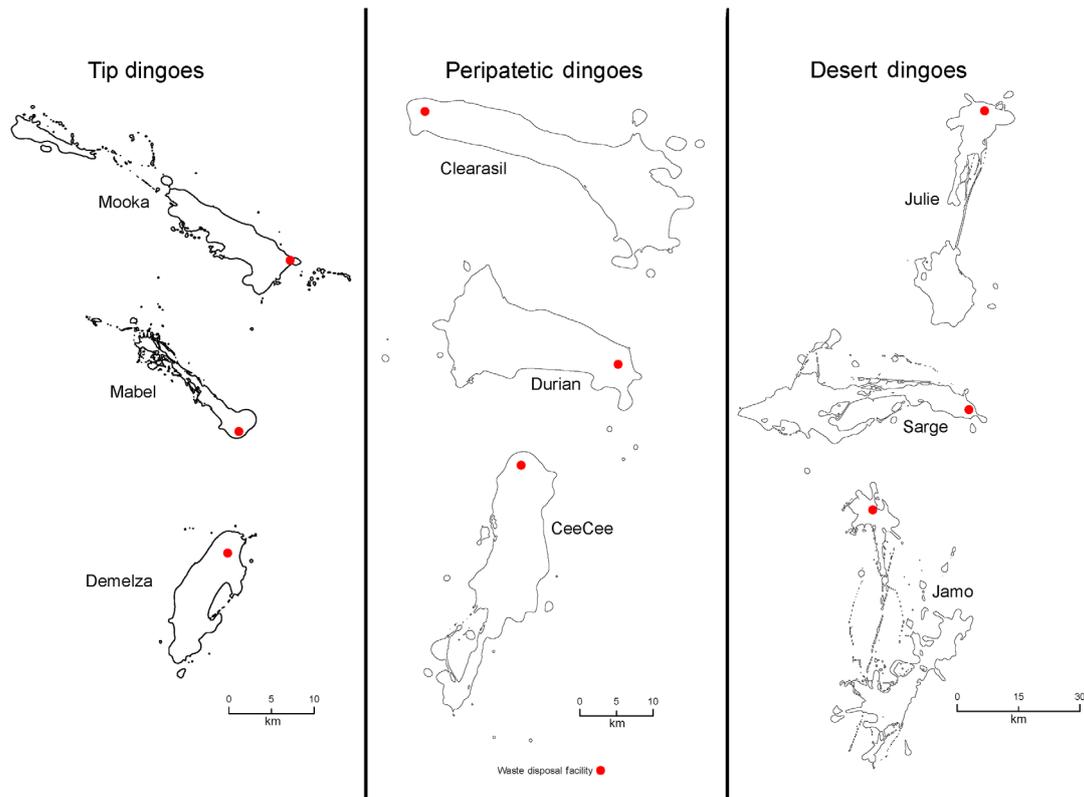


Fig. 2. Activity areas of representatives of three dingo groups (tip, peripatetic and desert dingoes) using Brownian bridge 95% analysis to calculate activity areas in the Cooper Basin. Red dots represent the mine WMF.

and activity size and daily movement resulted in significant negative correlations ($R^2 = 0.40$, $F_{1,25} = 16.63$, $P < 0.05$ and $R^2 = 0.16$, $F_{1,25} = 5.12$, $P < 0.05$ respectively).

Desert dingoes had larger activity areas than did the other dingoes that utilised the WMF, regardless of the method used to calculate area (UD95%, $F_{2,24} = 20.9$, $P < 0.05$). We could not calculate a meaningful activity area for dingo Yuley by using BB95% because the distribution of his fixes did not fit the methodology assumptions. Likewise, this method was not accurate in calculating activity areas for Schwob, because he had a strong affinity with the WMF. Desert dingoes had activity areas ranging from 589 to 2526 km² (UD95%)/125–1078 km² (BB95%), compared with the activity areas of 74–314 km² (UD95%)/229–268 km² (BB95%) for peripatetic dingoes and of 12–212 km² (UD95%)/7–87 km² (BB95%) for tip dingoes (see Supplementary Material Table S1).

Waste management-facility use and associations with dingo activity

There was a relationship between the daily distance travelled and type of dingo on the basis of their use patterns of the WMF ($F_{2,24} = 6.18$, $P < 0.05$; Fig. 4). Tip dingo movement was mostly short-distance travel around the WMF and in the vicinity of established infrastructure and the food pit (Fig. 5). Peripatetic dingoes were recorded using more of the

surrounding dune ecosystem, but spent a similar amount of time around the infrastructure of the WMF, which includes the food pit. The desert dingoes did not show any specific tendency to utilise infrastructure or the WMF and spent most of their time in the dune system (see Figs 2 and 3). Dozer and Sunny appeared not to have a strong use pattern around the WMF. Wesley was observed on camera-trap (data collected for a separate study) returning to the WMF periodically for months after his collar failed. Only one dingo used the camp infrastructure, whereas 10 dingoes visited water bodies on the outskirts of the camp boundary, using well-worn dingo pads connecting the two sites. Uncollared dingoes were common in the mine site camp throughout the day, but the highest activity was early morning and night.

Long-range movements

Eight dingoes conducted long-distance forays (Fig. 6). A male dingo (Sunny) walked from his activity area towards Innamincka (Figs 3, 6), a linear distance of ~100 km from capture site to township. Seven dingoes displayed regular long-distance movements, travelling >45 km between the WMF and their preferred desert activity area (Fig. 6). A male dingo (Dozer) that was trapped in the WMF (but rarely seen in the area thereafter) occupied a largely desert home range (Fig. 6) where his collar dropped off ~125 km from the

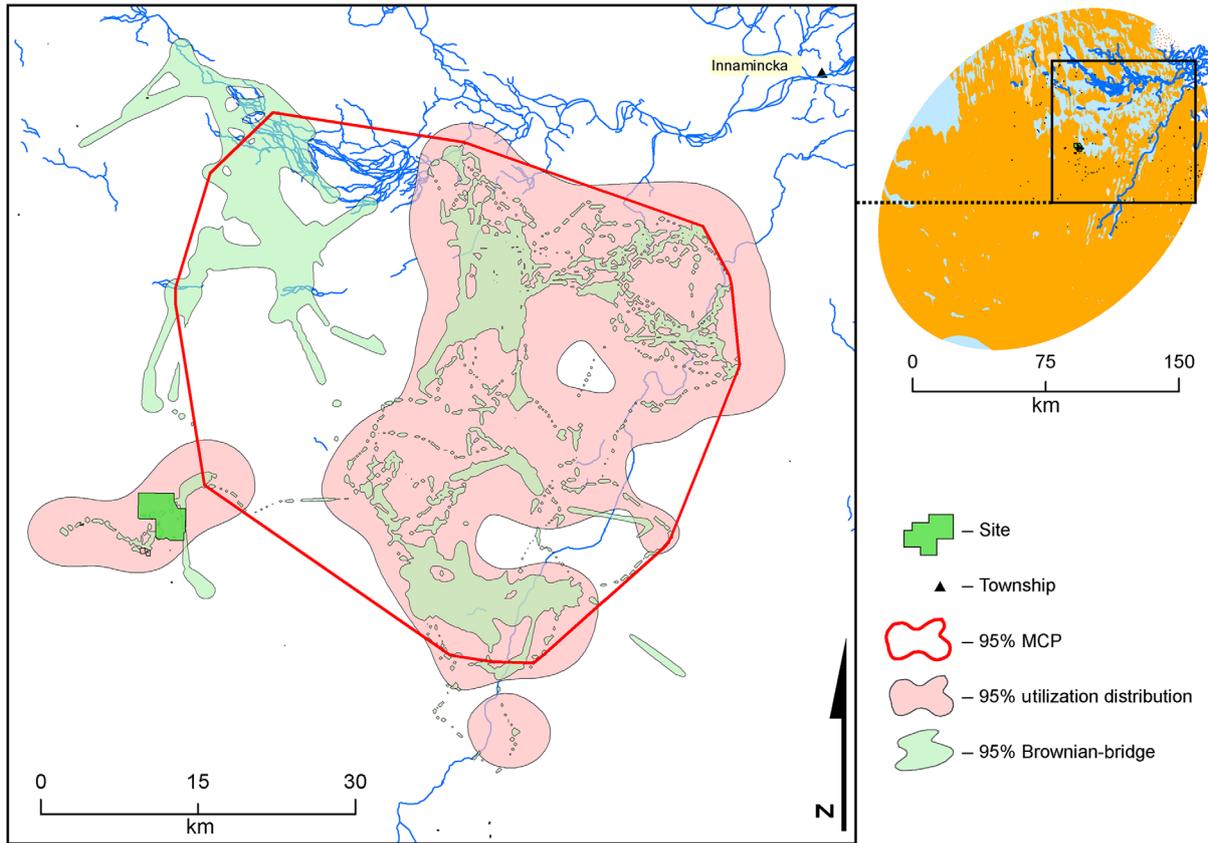


Fig. 3. The activity area and movement by a male dingo (Sunny, desert dog) over 131 days from early spring to mid-summer from the mine camp towards Innamincka.

mine site in an extremely remote location only reachable by foot.

Food provisioning

On the basis of the output from kernel density estimates over time, dingoes most commonly accessed the WMF at night, despite the FWT depositing food waste from the mine camp mess hall twice daily. On average, the FWT entered the WMF at 0600 hours and 1200 hours, which corresponded with food-hall closure times (Fig. 7).

Once we accounted for the time delay of 5–20 min between when the camera-traps detected a FWT driving to the pit and when the food was actually dropped in the pit; four dingoes showed clear peaks in activity at the corresponding times (Fig. 7), especially in the early morning (breakfast). Visitation to the food pit was also high during the evening and night (sunset–sunrise) when dingoes are most active (Thomson 1992).

The WMF was used by all the collared dingoes to varying extents, with only one animal (Sunny) never returning to the WMF after being caught and released. Although the desert dingoes infrequently used the WMF (Fig. 2), they did make occasional sallies to the food pit. Analysis showed that the vast majority of dingoes were more likely to be closer to the WMF at night and further from the WMF in the early

afternoon. These results were consistent throughout the population, and so were averaged across all dingoes and plotted to visualise the trend (Fig. 8).

Despite a few permanent water bodies (settling ponds) being accessible to all the collared dingoes, 13 of them visited these sites infrequently. Eight dingoes visited water bodies multiple times, but there was no focus in activity associated with permanent water bodies. Uncollared dingoes were observed drinking from buckets of water and leaking garden taps at the WMF on occasions during summer.

Time-release drop-off (TRD) and GPS radio-collar failures

A failure of the time-release drop-offs (TRD) resulted in collars falling off prematurely or failing to fall off altogether. Wesley’s and Demelza’s collars both failed to drop-off and, despite extensive searching, VHF failure prevented uploading of data from the collars and had to be downloaded from the Lotek portal. This reduced the number of location data points we could analyse for those dingoes because we discovered there were more data stored on the collars than were uploaded to the Lotek portal server. The difference in the number of data points between the collar and the portal was likely a combination of the high frequency of data points

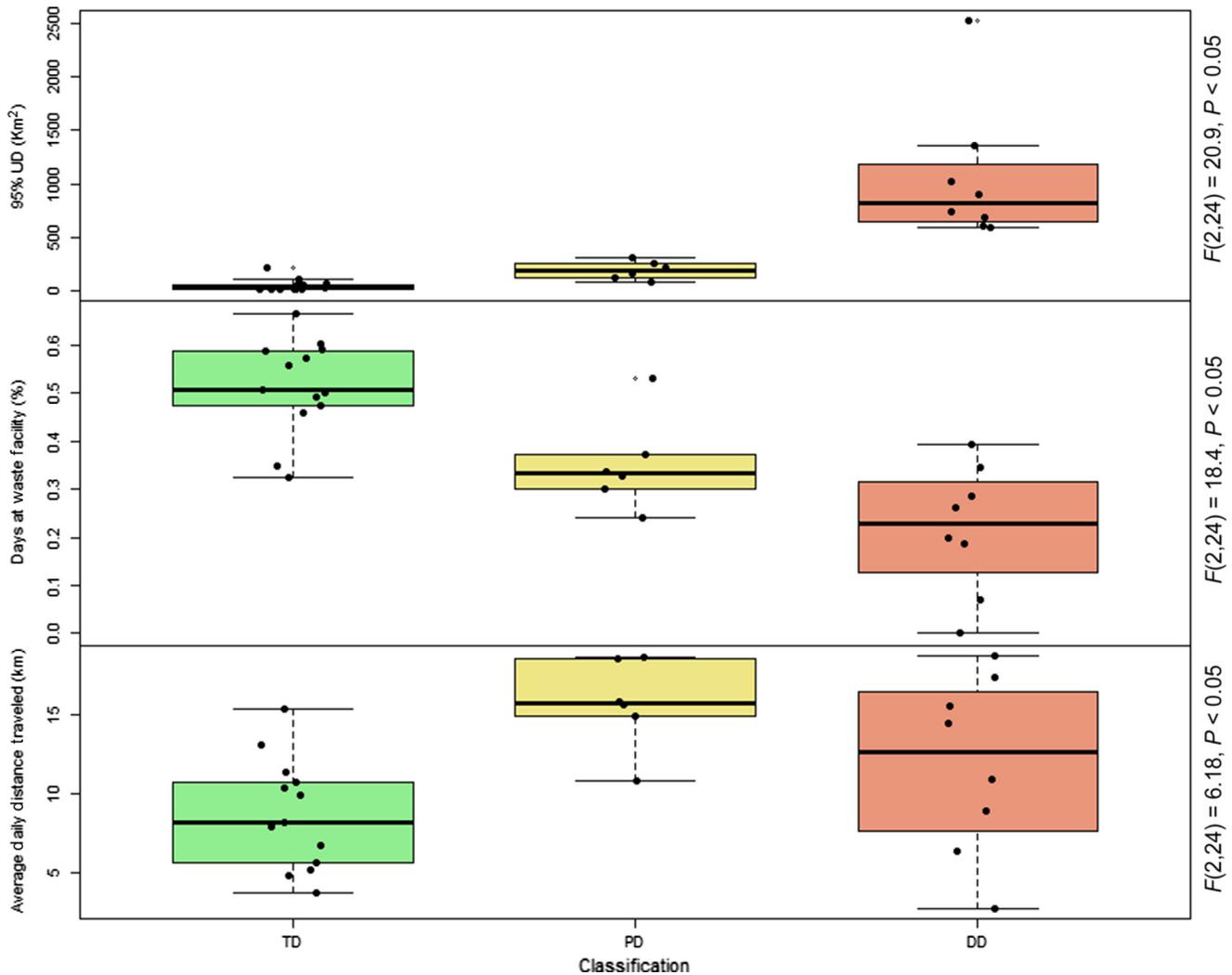


Fig. 4. The utilisation-distribution (UD) activity area, percentage of time spent in the waste-management facility (WMF) and average daily distance travelled by dingoes in the Cooper Basin. TD, tip dingo; PD is peripatetic dingo; and DD, desert dingo. 95% UD refers to the activity-analysis method utilisation distribution.

being stored on board the collar and the low trajectory of the satellite, which reduced the upload time between the collar and the satellite (Ben McCleave, pers. comm. 2020). Recovery of collars was further complicated by battery failure of the VHF transmitter in the collar. Fortunately, the low-lying topography of the desert permitted quite accurate location data when the collars were in mortality mode (3.76 m, s.d. = 2.83 m), so walking to the site and visually finding collars was often possible. These issues are consistent with those reported elsewhere (Matthews *et al.* 2013), but highlighted the need for continued improvement in wildlife-research equipment to match costs with data quality.

Dingo pathology

Of the 27 dingoes trapped and collared, 43% showed evidence of sarcoptic mange; only two animals were affected over more

than 50% of their body mass. Mange has been common in the Cooper Basin dingo population since the authors commenced research at this site in 2015. Severity of infection has resulted in serious disfigurement of some animals and the production of large joint lesions and disfigurement of the claw anatomy. The most likely cause of the cyst-like lesions are hygromas, which are connective tissue sacs of synovial fluid that often form around elbow joints as swollen bursae (Johnston 1975).

Discussion

In comparison to other dingo-density estimates (i.e. 0.01–0.7 individuals/km²; Gabriele-Rivet *et al.* 2019, 2020) and similarly to some other studies of arid-zone dingoes near mine sites (Newsome *et al.* 2013a; Smith *et al.* 2020), the density of our study dingo population was very high at the

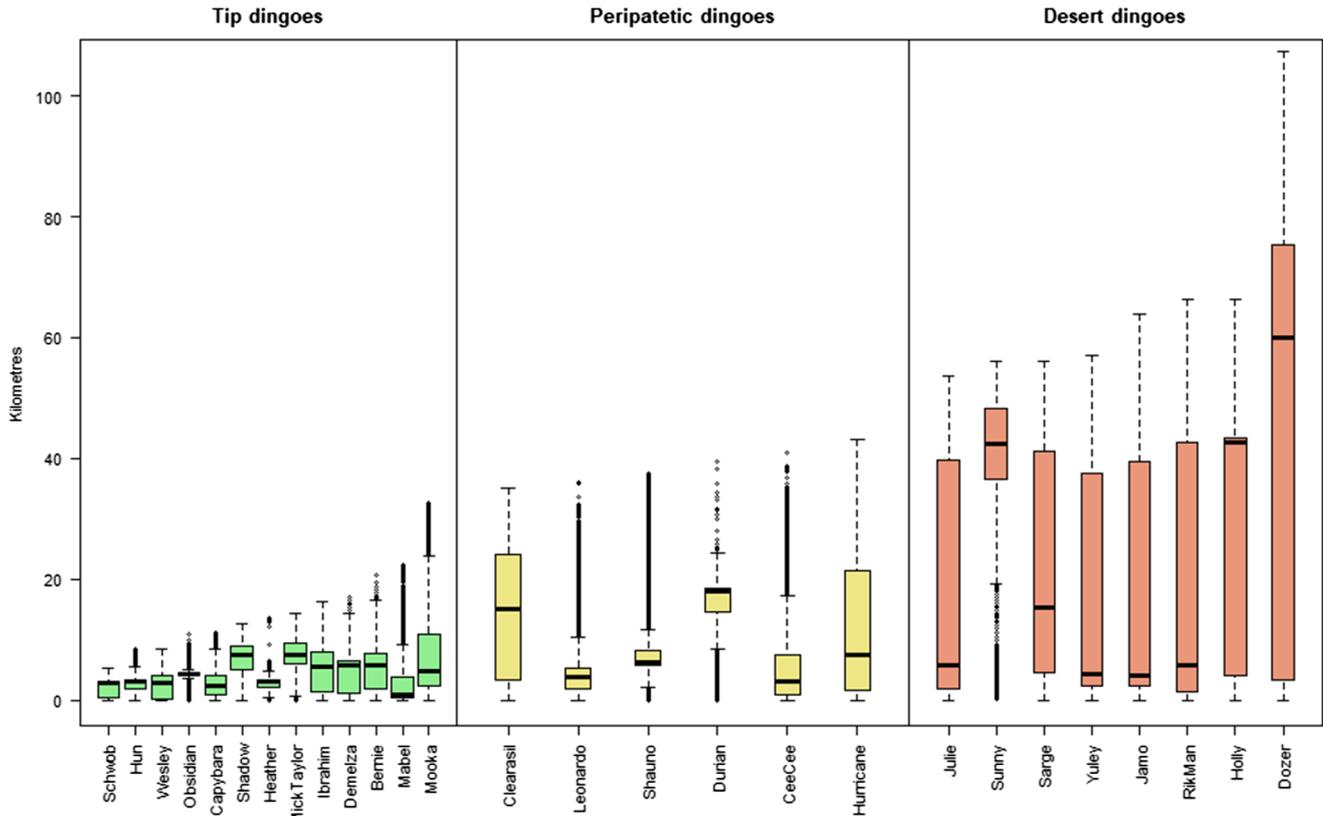


Fig. 5. Boxplot of the three classifications of dingoes in a Cooper Basin mine site and the distances in kilometres between the waste-management facility (WMF) and each of their fixes as a measure of their activity range and use of the surrounding landscape.

mine site. This anomalous high density was likely to be attributable to anthropogenic resourcing, as was found by Newsome *et al.* (2013a) in a similar central Australian situation. Our dingo population displayed high purity, as has been found elsewhere in central Australia (Newsome *et al.* 2013a; Stephens *et al.* 2015), which justifies direct comparisons with previous studies.

We classified the Cooper Basin dingoes into three types according to their use of the WMF and surrounding desert habitat (Figs 2, 4, 5). There were differences in the size of the activity areas of the three dingo groups, with desert dingoes occupying a much larger area (mean = 494 km²) than did tip dingoes (mean = 35 km²) and peripatetic dingoes (mean = 246 km²), being similar to area occupied by dingoes in the Tanami Desert (Newsome *et al.* 2013b) and wolves (*Canis lupus*) in North America (Petroelje *et al.* 2019). Our observed difference was also reflected in the WMF visitation rates of the different dingo classifications, which was much higher in the tip population than the other groups (Fig. 3).

A classification of Mine and Away dingoes has been used for Tanami Desert dingoes (Newsome *et al.* 2013b). Dingoes living close to the mine site in the Tanami Desert recorded kernel home ranges of 0.68–10.8 km² (mean 10 km²); Cooper Basin dingoes had larger activity areas of 7–87 km² (BB95%;

Fig. 2). Cooper Basin dingoes that relied less on the WMF and more on the desert had a mean home-range/activity area of 494 km² (range = 124–1078 km²), similar to the mean home range size of 403 km² for Tanami dingoes (range = 79.5–999 km²). Dingoes in the Western Australian desert had larger average activity areas (seasonal home range using kernel density) of 480–1020 km² (Wysong *et al.* 2020), whereas Allen (2012) estimated that dingo packs in the Strzelecki Desert had activity areas of only ~24 km².

Several dingoes in the current study exhibited long movements into the desert, with distances covering >200 km (Figs 3, 6).

GPS data and observations of dingoes in the Cooper Basin (Fig. 8) were consistent with those in other studies in that they identified crepuscular–nocturnal peaks and inactivity mostly during the day (Tatler *et al.* 2021), especially in the summer. We found that dingoes were closer to and more likely to visit the food pit during the period from 2200 hours to 0200 hours. This corresponds with direct observations of increased numbers of dingoes and vocalisations occurring from sunset to sunrise, and is further supported by trapping records from previous studies (Meek and Brown 2017; Meek *et al.* 2019a, 2019b). On sunset, dingoes were consistently observed heading from within the WMF and the surrounding areas to the food pit during this study and in the 7 years we have

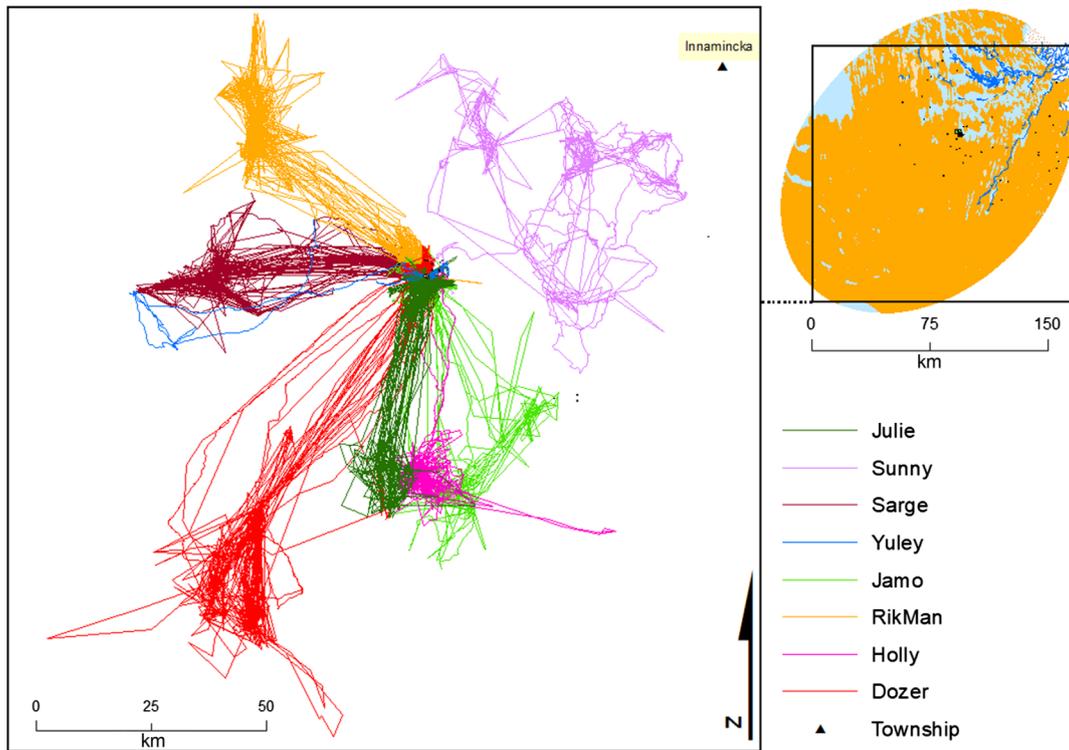


Fig. 6. Long-range movements exceeding a 45-km straight-line distance from the waste-management facility (WMF) of eight Desert dingoes in the Cooper Basin.

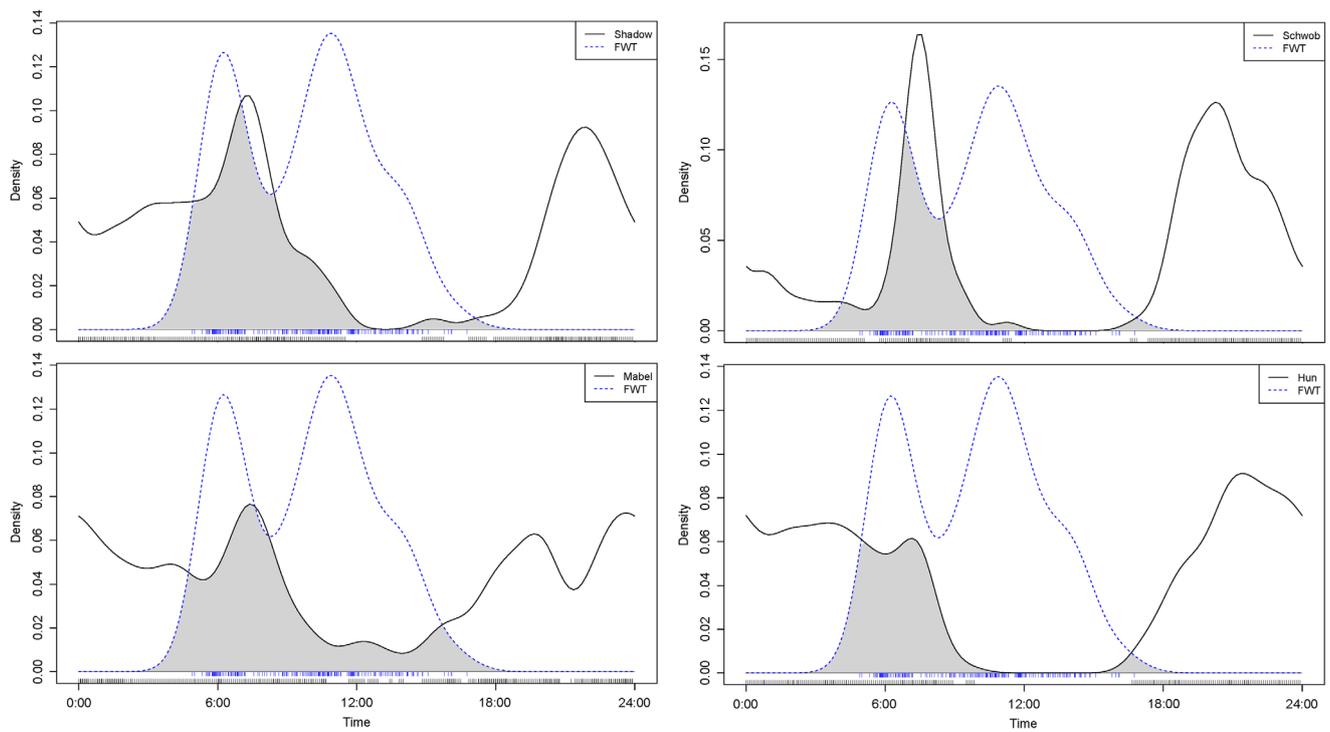


Fig. 7. Temporal activity of four tip dingoes showing a strong relationship with their fixes within 150 m of the food pit when the food truck unloaded mess-hall food in the morning.

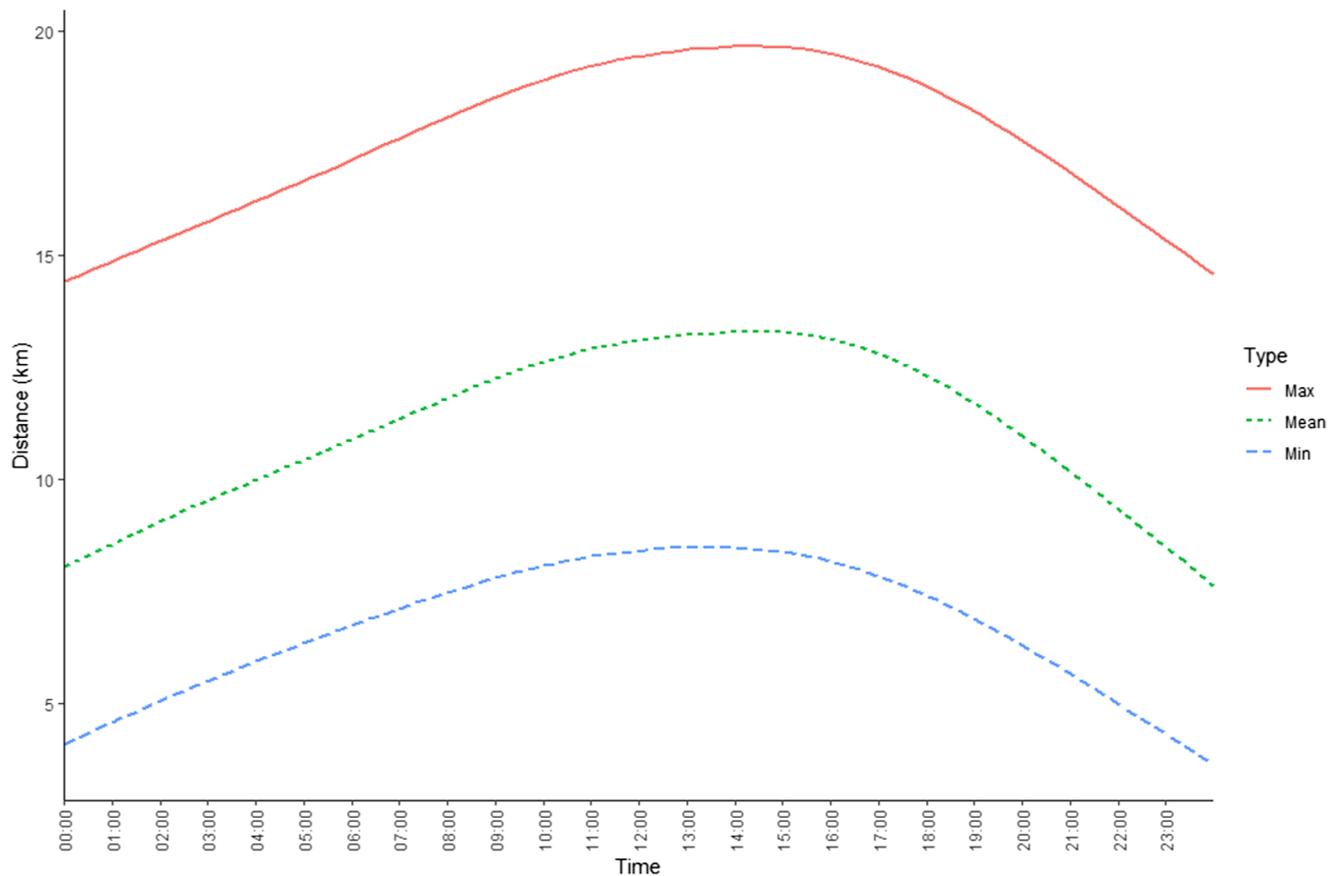


Fig. 8. The average minimum, maximum and mean distance (km) of the dingo population in the Cooper Basin from a waste-management facility (WMF) throughout a 24-h period.

been working at this site. During the day, some tip dingoes did display increased activity close to the food pit mid-morning and around midday when the FWT was dumping mess-hall food waste (Figs 7, 8). On the basis of collared dingo data and observations of uncollared dingoes close to the food pit, some dingoes displayed learned behaviour when the food truck approached the WMF. Competition to access freshly dumped food by other dingoes and an abundance of raptors and corvids could have influenced this behaviour. Even when machinery was used to cover freshly deposited food, dingoes and birds would immediately scavenge in the area, often at the risk of being run over and killed by the tracked excavator. This reliance on food (anticipatory behavioural development) by some dingoes was apparent by the focus of their activity around the WMF. However, although some of the study animals were recorded visiting settling ponds where water was freely accessible, their activity was not as focussed on water sites as it was food.

It was not within the scope of this study to analyse the diet of the dingoes in the Cooper Basin. However, the WMF was littered with dingo scats at an extremely high density throughout 2015–2021 and none had the appearance of normal, well-composed scat with digested flesh. Instead, a

very high occurrence of rubbish (plastic bags) and litter in scats was evident. These observations concur with dingo scats collected in the Tanami (Newsome *et al.* 2019). In 2021, one of the authors (PM) observed a lactating female successfully hunting burrowing dragon lizards 20 km away from the WMF. Also, like Newsome *et al.* (2019) and (Smith *et al.* 2020), who reported cannibalism among dingoes when food resources were provided, aggressive behaviours towards constrained (trapped) dingoes as well as cannibalism did occur at this site (Meek and Brown 2017). Nonetheless, given the high density of dingoes and high contact rates among individuals, aggressive behaviour was rare and was observed only in the food pit and when trapped.

Mange was common in the dingo population trapped and observed between 2015 and 2021. A study of coyotes (*Canis latrans*) in Canada showed that animals that relied on anthropogenic food subsidies tended to have higher levels of mange, and the resultant poorer health reduced their activity patterns and the size of their home range, which in turn facilitated their continued dependence on anthropogenic resources (Murray *et al.* 2015). Throughout the years 2015–2021, one of the authors (PM) made one or two field visits each year to the site for various research projects. Anecdotal data

collected from trapping and camera trapping studies (Meek and Brown 2017; Meek *et al.* 2018, 2019a) suggested that dingoes that are almost hairless and ulcerated from severe mange and associated infection rarely moved far from the WMF. On several occasions, PM was required to euthanise dingoes with severe mange-related infection such that the animal's spine was deformed, and large lesions developed on the legs affecting movement. There is a clear relationship between wildlife and anthropogenic resource provisioning on the health of wildlife populations. The additional resources often affect population demography by improving reproductive success and thus contact rates, resulting in amplified pathogen transmission (Becker and Hall 2014). Our sample size for each dingo classification was too small to enable any assessment of mange infection among dingo types with confidence. However, in terms of pathology, it might be expected that dingoes living in close contact with conspecifics would show a higher incidence of mange and animals with severe infection would not travel far from food and water.

The overabundance of dingoes at mine sites presents many management problems as discussed; however, the ecological consequences may also be problematic. Newsome *et al.* (2014) noted that the provisioning of resources at mine sites alters dingo diets and may result in higher predation on small mammals, but diet analysis (scat and stomach) would be required to confirm such increased predation. There is no evidence to suggest in the Cooper Basin that food provisioning will result in a decline in the abundance of dingoes as reported for other species that have declined as a result of ecological and behavioural changes (Peterson *et al.* 2005; Senigaglia 2020). In fact, the provision of easily accessible food and water to desert dingoes almost certainly causes a higher than normal abundance in the Cooper Basin (this study) and Tanami dingoes (Newsome *et al.* 2019). One explanation not previously explored is whether the provisioning of resources by humans and the safety afforded them by occupying a human settlement triggers an ancient domestic trait. Given dingoes are domestic dogs gone wild (Jackson *et al.* 2017, 2019, 2021), it is feasible that these dingoes revert to their domestic traits and behaviours of dependence, tolerance and acceptance of humans. Artificial food resources thus might essentially be triggering a re-taming of dingoes back to a more domestic type and re-igniting the artificial selection process that led to their domestication from wolf to dog approximately 17,000 years ago (Driscoll and Macdonald 2010). In the Cooper Basin, dingoes are commonly seen around people and some individuals become pet-like, hovering around doors to food halls and selected living quarters where mine workers feed them like pets. One of the authors (PM) has sat on the ground near one such dingo and photographed the animal licking his knee in anticipation of food. Many domestic-dog behavioural traits were recorded of dingoes in the mine site, such as playing with food wrappers and playing with humans in the manner of puppies. Similar behaviours are displayed by feral cats re-adjusting from

wild-living to a stray and domestic existence (Serpell 2000), although this has not occurred in true wild introduced animals such as foxes (*Vulpes vulpes*), despite concerted efforts (Macdonald 1987; Trut 1999). If this is a valid proposition, then tip and peripatetic dingoes in the Cooper Basin, and similar types of dingoes in the Tanami (Newsome *et al.* 2013b), may have the genetic edge over desert dingoes as they revert to their domestic behaviours in response to anthropogenic food provisioning.

Analysis of the DNA from collared individuals confirmed that 97.6% of the collared population had a high percentage of dingo genes (Stephens *et al.* 2015), indicating that there has been little ingress from pastoralist domestic working dogs and that the isolation and security of the mine means that dingoes cannot inter-breed with any domestic dogs. Research is warranted to assess familial genetics among the three categories of dingo at the Cooper Basin, to determine whether behavioural traits such as dependency on anthropogenic resources are passed on to progeny within the tip and peripatetic dingoes.

Conclusions

Dingoes have adapted to and rely on anthropogenic food and other resources provided by human occupation in the arid zone, which has implications for population abundance, human-wildlife conflict and disease transmission (Newsome and Van Eeden 2017). This study found three types of dingoes in the Cooper Basin and a dependence by a proportion of the collared dingoes in using food, water and shelter provided by human presence. Excluding dingoes from food and water is a crucial first step in mitigating the consequences of providing resources to an animal that is highly susceptible to domestication. Exclusion fencing around waste facilities has proven to reduce dingo occupancy (Behrendorff *et al.* 2016; Newsome *et al.* 2019; Behrendorff *et al.* 2023) and should be a mandatory requirement in mine management planning. Ongoing efforts to process food waste to reduce the attraction of the food pit to wildlife should continue. Providing access to food, water and shelter, and the common practice of mine staff feeding dingoes will continue to encourage over-breeding, survival and behavioural attraction to mine workers, potentially leading to increasing levels of quasi-domestic behaviours that increase contact rates between humans and dingoes and causing over-abundant populations.

Supplementary material

Supplementary material is available [online](#).

References

- Allen BL (2012) Do desert dingoes drink daily? Visitation rates at remote waterpoints in the Strzelecki Desert. *Australian Mammalogy* 34, 251–256. doi:10.1071/AM12012

- Altmann J, Muruthi P (1988) Differences in daily life between semiprovisioned and wild-feeding baboons. *American Journal of Primatology* 15, 213–221. doi:10.1002/ajp.1350150304
- Anon. (2017a) Environmental impact report: production and processing operations, South Australia Cooper Basin. Adelaide. (Santos Ltd, Australia)
- Anon. (2017b) Statement of environmental objectives: production and processing operations: South Australian Cooper Basin. Adelaide. (Santos Ltd, Australia)
- Appley R, Smith B, Bernede L, Jones D (2017) Utilising aversive conditioning to manage the behaviour of K'gari (Fraser Island) dingoes (*Canis dingo*). *Pacific Conservation Biology* 23, 335–358. doi:10.1071/PC17017
- Baker AM, Gynther IC (2023) 'Strahan's mammals of Australia.' (Reed New Holland Publishers: Sydney, NSW, Australia)
- Becker DJ, Hall RJ (2014) Too much of a good thing: resource provisioning alters infectious disease dynamics in wildlife. *Biology Letters* 10, 20140309. doi:10.1098/rsbl.2014.0309
- Behrendorff L, Leung LK-P, McKinnon A, Hanger J, Belonje G, Tapply J, Jones D, Allen BL (2016) Insects for breakfast and whales for dinner: the diet and body condition of dingoes on Fraser Island (K'gari). *Scientific Reports* 6, 23469. doi:10.1038/srep23469
- Behrendorff L, King R, Allen BL (2023) Efficacy of management efforts to reduce food-related dingo–human interactions and conflict on K'gari (Fraser Island), Australia. *Animals* 13, 204. doi:10.3390/ani13020204
- Brawata RL, Neeman T (2011) Is water the key? Dingo management, intraguild interactions and predator distribution around water points in arid Australia. *Wildlife Research* 38, 426–436. doi:10.1071/WR10169
- Davies KF, Melbourne BA, James CD, Cunningham RB (2010) Using traits of species to understand responses to land use change: birds and livestock grazing in the Australian arid zone. *Biological Conservation* 143, 78–85. doi:10.1016/j.biocon.2009.09.006
- Diamond J (2002) Evolution, consequences and future of plant and animal domestication. *Nature* 418, 700–707. doi:10.1038/nature01019
- Driscoll CA, Macdonald DW (2010) Top dogs: wolf domestication and wealth. *Journal of Biology* 9, 10. doi:10.1186/jbiol226
- Déaux EC, Crowe T, Charrier I (2018) Recreational fishing alters dingo foraging behavior on Fraser Island. *The Journal of Wildlife Management* 82, 85–92. doi:10.1002/jwmg.21340
- Eldridge DJ (1996) Distribution and floristics of terricolous lichens in soil crusts in arid and semi-arid New South Wales, Australia. *Australian Journal of Botany* 44, 581–599. doi:10.1071/BT9960581
- Fancourt BA, Allen BL, Jackson SM, Meek PD, Zewe F, Ballard AG, Behrendorff L, Claridge AW, Fleming PJS (2022) Eutherian carnivores. In 'Wildlife research in Australia: practical and applied method'. (Ed. BP Smith, HP Waudby, C Alberthsen, JO Hampton) pp. 428–436. (CSIRO Publishing: Melbourne, Vic., Australia)
- Gabriele-Rivet V, Arsenault J, Wilhelm B, Brookes VJ, Newsome TM, Ward MP (2019) A scoping review of dingo and wild-living dog ecology and biology in Australia to inform parameterisation for disease spread modelling. *Frontiers in Veterinary Science* 6, 47. doi:10.3389/fvets.2019.00047
- Gabriele-Rivet V, Arsenault J, Brookes VJ, Fleming PJS, Nury C, Ward MP (2020) Dingo density estimates and movements in equatorial Australia: spatially explicit mark–resight models. *Animals* 10, 865. doi:10.3390/ani10050865
- Harrington R, Owen-Smith N, Viljoen PC, Biggs HC, Mason DR, Funston P (1999) Establishing the causes of the roan antelope decline in the Kruger National Park, South Africa. *Biological Conservation* 90, 69–78. doi:10.1016/S0006-3207(98)00120-7
- Herrero S, Higgins A (2003) Human injuries inflicted by bears in Alberta: 1960–98. *Ursus* 14, 44–54.
- Jackson SM, Groves CP, Fleming PJS, Aplin KP, Eldridge MDB, Gonzalez A, Helgen KM (2017) The wayward dog: is the Australian native dog or dingo a distinct species? *Zootaxa* 4317, 201–224. doi:10.11646/zootaxa.4317.2.1
- Jackson SM, Fleming PJS, Eldridge MDB, Ingelby S, Flannery T, Johnson RN, Cooper SJB, Mitchell KJ, Souilmi Y, Cooper A, Wilson DE, Helgen KM (2019) The dogma of dingoes: taxonomic status of the dingo: a reply to Smith *et al.* *Zootaxa* 4564, 198–212. doi:10.11646/ZOOTAXA.4564.1.7
- Jackson SM, Fleming PJS, Eldridge MDB, Archer M, Ingelby S, Johnson RN, Helgen KM (2021) Taxonomy of the dingo: it's an ancient dog. *Australian Zoologist* 41, 347–357. doi:10.7882/AZ.2020.049
- James CD, Landsberg J, Morton SR (1995) Ecological functioning in arid Australia and research to assist conservation of biodiversity. *Pacific Conservation Biology* 2, 126–142. doi:10.1071/PC960126
- James CD, Landsberg J, Morton SR (1999) Provision of watering points in the Australian arid zone: a review of effects on biota. *Journal of Arid Environments* 41, 87–121. doi:10.1006/jare.1998.0467
- Johnston DE (1975) Hygroma of the elbow in dogs. *Journal of the American Veterinary Medical Association* 167, 213–219.
- Macdonald DW (1987) 'Running with the fox.' (Unwin Hyman: London, UK)
- Matthews A, Ruykys L, Ellis B, FitzGibbon S, Lunney D, Crowther MS, Glen AS, Purcell B, Moseby K, Stott J, Fletcher D, Wimpenny C, Allen BL, Van Bommel L, Roberts M, Davies N, Green K, Newsome T, Ballard G, Fleming P, Dickman CR, Eberhart A, Troy S, McMahon C, Wiggins N (2013) The success of GPS collar deployments on mammals in Australia. *Australian Mammalogy* 35, 65–83. doi:10.1071/AM12021
- Meek PD, Brown SC (2017) It's a dog eat dog world: observations of dingo (*Canis familiaris*) cannibalism. *Australian Mammalogy* 39, 92–94. doi:10.1071/AM16018
- Meek PD, Shorter K, Falzon G (2018) Do lethal trap devices threaten foothold-trap capture efficacy? *International Journal of Pest Management* 65, 66–71. doi:10.1080/09670874.2018.1462538
- Meek PD, Brown SC, Wishart J, Milne H, Aylett P, Humphrys S, Ballard G, Fleming P (2019a) Efficacy of lethal-trap devices to improve the welfare of trapped wild dogs. *Wildlife Research* 46, 89–95. doi:10.1071/WR18129
- Meek PD, Shorter K, Falzon G (2019b) Do lethal trap devices threaten foothold trap capture efficacy?. *International Journal of Pest Management* 65, 66–71. doi:10.1080/09670874.2018.1462538
- Meek PD, Ballard GA, Falzon G, Williamson J, Milne H, Farrell R, Stover J, Mather-Zardain AT, Bishop J, C. Ka-Wai Cheung E, Lawson CK, Munezero AM, Schneider D, Johnston BE, Kiani E, Shahinfar S, Sadgrove EJ, Fleming PJS (2020) Camera trapping technology and advances: into the new millennium. *Australian Zoologist* 40(3), 392–403.
- Morant DS, Meek PD, Jensen MA (2022) Telemetry devices attached with collars. In 'Wildlife research in Australia: practical and applied methods'. (Eds HPW Bradley, P Smith, C Alberthsen, JO Hampton) pp. 185–190. (CSIRO Publishing: Melbourne, Vic., Australia)
- Murray M, Edwards MA, Abercrombie B, St. Clair CC (2015) Poor health is associated with use of anthropogenic resources in an urban carnivore. *Proceedings of the Royal Society B: Biological Sciences* 282, 20150009. doi:10.1098/rspb.2015.0009
- Newsome AE, Corbett LK (1977) The effects of native, feral and domestic animals on the productivity of the Australian rangelands. In 'The impact of herbivores on arid and semi-arid rangelands'. pp. 331–356. (Australian Rangeland Society, Perth)
- Newsome TM, Van Eeden LM (2017) The effects of food waste on wildlife and humans. *Sustainability* 9, 1269. doi:10.3390/su9071269
- Newsome TM, Ballard G-A, Dickman CR, Fleming PJS, Howden C (2013a) Anthropogenic resource subsidies determine space use by Australian arid zone dingoes: an improved resource selection modelling approach. *PLoS ONE* 8, e63931. doi:10.1371/journal.pone.0063931
- Newsome TM, Ballard G-A, Dickman CR, Fleming PJS, van de Ven R (2013b) Home range, activity and sociality of a top predator, the dingo: a test of the Resource Dispersion Hypothesis. *Ecography* 36, 914–925. doi:10.1111/j.1600-0587.2013.00056.x
- Newsome TM, Ballard G-A, Fleming PJS, van de Ven R, Story GL, Dickman CR (2014) Human-resource subsidies alter the dietary preferences of a mammalian top predator. *Oecologia* 175, 139–150. doi:10.1007/s00442-014-2889-7
- Newsome TM, Dellinger JA, Pavey CR, Ripple WJ, Shores CR, Wirsing AJ, Dickman CR (2015) The ecological effects of providing resource subsidies to predators. *Global Ecology and Biogeography* 24, 1–11. doi:10.1111/geb.12236
- Newsome TM, Howden C, Wirsing AJ (2019) Restriction of anthropogenic foods alters a top predator's diet and intraspecific interactions. *Journal of Mammalogy* 100, 1522–1532. doi:10.1093/jmammal/gyz125
- Osborn TGB, Wood JG, Paltridge TB (1932) On the growth and reaction to grazing of the perennial saltbush, *Atriplex vesicarium*. An ecological

- study of the biotic factor. *Proceedings of the Linnean Society of New South Wales* 57, 377–402.
- Peterson MN, Lopez RR, Laurent EJ, Frank PA, Silvy NJ, Liu J (2005) Wildlife loss through domestication: the case of endangered key deer. *Conservation Biology* 19, 939–944. doi:10.1111/j.1523-1739.2005.00069.x
- Petroelje TR, Belant JL, Beyer DE Jr, Svoboda NJ (2019) Subsidies from anthropogenic resources alter diet, activity, and ranging behavior of an apex predator (*Canis lupus*). *Scientific Reports* 9, 13438. doi:10.1038/s41598-019-49879-3
- Pini-Fitzsimmons J, Knott NA, Brown C (2018) Effects of food provisioning on site use in the short-tail stingray *Bathytoshia brevicaudata*. *Marine Ecology Progress Series* 600, 99–110. doi:10.3354/meps12661
- R Core Team (2022) 'R: a language and environment for statistical computing.' (R Foundation for Statistical Computing: Vienna, Austria)
- Rose DB (1984) Dingo makes us human: being and purpose in Australian aboriginal culture. PhD thesis, Bryn Mawr College, Pennsylvania, USA.
- RStudio Team (2022) 'Rstudio: integrated development environment for R.' (RStudio PBC, Boston, MA, USA) Available at <http://www.rstudio.com/>
- Senigaglia V (2020) Ecological consequences and social drivers of human-wildlife interactions: the case of food-provisioning of bottlenose dolphins in Bunbury, Western Australia. PhD thesis, Murdoch University, WA, Australia.
- Serpell JA (2000) Domestication and history of the cat. In 'The domestic cat: the biology of its behavior. Vol. 2'. (Eds DC Turner, P Bateson) 180–192. (Cambridge University Press)
- Smith BP, Marrant DS, Vague A-L, Doherty TS (2020) High rates of cannibalism and food waste consumption by dingoes living at a remote mining operation in the Great Sandy Desert, Western Australia. *Australian Mammalogy* 42, 230–234. doi:10.1071/AM19033
- Stephens D, Wilton AN, Fleming PJS, Berry O (2015) Death by sex in an Australian icon: a continent-wide survey reveals extensive hybridization between dingoes and domestic dogs. *Molecular Ecology* 24, 5643–5656. doi:10.1111/mec.13416
- Stephens D, Fleming PJS, Sawyers E, Mayr TP (2022) An isolated population reveals greater genetic structuring of the Australian dingo. *Scientific Reports* 12, 19105. doi:10.1038/s41598-022-23648-1
- Tapply J (2018) Contemporary dingo management on K'gari (Fraser Island, Great Sandy National Park) under the Queensland Parks and Wildlife Service. *Australasian Journal of Environmental Management* 25, 119–131. doi:10.1080/14486563.2017.1422042
- Tatler J, Currie SE, Cassey P, Scharf AK, Roshier DA, Prowse TAA (2021) Accelerometer informed time-energy budgets reveal the importance of temperature to the activity of a wild, arid zone canid. *Movement Ecology* 9, 11. doi:10.1186/s40462-021-00246-w
- Thomson PC (1992) The behavioural ecology of dingoes in north-western Australia. II. Activity patterns, breeding season and pup rearing. *Wildlife Research* 19, 519–529. doi:10.1071/WR9920519
- Trut L (1999) Early canid domestication: the farm-fox experiment: foxes bred for tamability in a 40-year experiment exhibit remarkable transformations that suggest an interplay between behavioral genetics and development. *American Scientist* 87, 160–169. doi:10.1511/1999.20.160
- Van Dyck S, Strahan R (2008) 'The mammals of Australia.' 3rd edn. (New Holland Publishers: Australia)
- Wilton AN, Steward DJ, Zafiris K (1999) Microsatellite variation in the Australian dingo. *Journal of Heredity* 90(1), 108–111. doi:10.1093/jhered/90.1.108
- Wilton AN (2001) DNA methods of assessing dingo purity. In 'A Symposium on the Dingo', Sydney, NSW, Australia. (Eds CR Dicman, D Lunney) pp. 49–56. (Royal Zoological Society of New South Wales)
- Wysong ML, Hradsky BA, Iacona GD, Valentine LE, Morris K, Ritchie EG (2020) Space use and habitat selection of an invasive mesopredator and sympatric, native apex predator. *Movement Ecology* 8, 18. doi:10.1186/s40462-020-00203-z
- Zeder MA (2006) 13. Archaeological approaches to documenting animal domestication. In 'Documenting domestication: new genetic and archaeological paradigms'. (Eds AZ Melinda, B Daniel, E Eve, DS Bruce) pp. 171–180. (University of California Press)
- Zeder MA (2012) Pathways to animal domestication. In 'Biodiversity in agriculture: domestication, evolution, and sustainability. Vol. 10'. (Eds P Gepts, T Famula, R Bettinger, S Brush, A Damania, P McGuire) pp. 227–259. (Cambridge University Press: Cambridge) doi:10.1017/CBO9781139019514.013

Data availability. Data will be provided upon request and remains the property of the NSW Government.

Conflicts of interest. The authors declare no conflicts of interest.

Declaration of funding. Funding for this research and previous projects was provided by the Department of Agriculture and Water Resources brokered via the Centre for Invasive Species Solutions. In-kind funding support was provided by Santos, project funding was also provided by NSW Department Primary Industries.

Acknowledgements. This research would not have been possible without the support of the Cooper Basin staff (too many to list); their assistance and friendship was paramount to the implementation of this project, and thanks go to Julie, Yuley, Wes, Rick, Shaun, Jamo and Andrew for field support. Thanks go to Donell Hole and Ben McCleave from Lotek for attempting to resolve our radio-tracking problems.

Author affiliations

^AVertebrate Pest Research Unit, NSW Department of Primary Industries, PO Box 350, Coffs Harbour, NSW 2450, Australia.

^BSchool of Environmental and Rural Sciences, University of New England, Armidale, NSW 2351, Australia.

^CVertebrate Pest Research Unit, NSW Department Primary Industries, University of New England, Armidale, NSW 2351, Australia.

^DVertebrate Pest Research Unit, NSW Department of Primary Industries, Forest Road, Orange, NSW 2800, Australia.