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Article *in* Animal Production Science · January 2016

DOI: 10.1071/AN16030

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CSIRO PUBLISHING

Animal Production Science
http://dx.doi.org/10.1071/AN16030

Guardian dogs protect sheep by guarding sheep, not by establishing territories and excluding predators

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Abstract. Guardian animals have been a common non-lethal method for reducing predator impacts on livestock for centuries in Europe. But elsewhere, livestock producers sometimes doubt whether such methods work or are compatible with modern livestock husbandry practices in extensive grazing systems. In this study we evaluate the hypothesis that guardian dogs primarily 'work' by establishing and defending territories from which canid predators are excluded. Eight maremmas and six free-ranging wild dogs of different sexes were fitted with GPS collars and monitored for 7 months on a large sheep property in north Queensland, Australia. Wild dog incursions into the territories of adjacent wild dogs and maremmas were recorded. Wild dog territories never overlapped and their home ranges infrequently overlapped. In contrast, 713 hourly locations from 120 wild dog incursions into maremma territories were recorded, mostly from three wild dogs. These three wild dogs spent a mean of 2.5–5.9 h inside maremma territories during incursions. At this location, maremmas worked by guarding sheep and prohibiting fine-scale interaction between wild dogs and sheep, not by establishing a territory respected by wild dogs. We conclude that shepherding behaviour and boisterous vocalisations of guardian dogs combined with the flocking behaviour of sheep circumvents attacks on sheep but does not prevent nor discourage wild dogs from foraging in close proximity. Certain husbandry practices and the behaviour of sheep at parturition may incur greater predation risk.

Additional keywords: Apex predator, *Canis lupus dingo*, human-wildlife conflict, livestock protection, predator–prey interactions.

Received 15 January 2016, accepted 16 March 2016, published online 23 June 2016

Introduction

Livestock are grazed around the world to provide food, fibre and other important products for people. One of the greatest sources of human–wildlife conflict for livestock producers is predation of livestock by a range of predators, including large felids and canids (Allen and Sparkes 2001; Valeix *et al*. 2012; Hosseini-Zavarei *et al*. 2013; Katel *et al*. 2014). Large predators are often killed in many countries to protect livestock from predation, but lethal control methods can sometimes elicit strong opposition from various stakeholders (e.g. Kellert 1985; Linnell 2011; Bergstrom *et al*. 2014). Non-lethal forms of control are a potential alternative to lethal control, but there is a need to first demonstrate and convince livestock producers that non-lethal methods actually work to mitigate livestock predation on the scales that livestock are produced (Meadows and Knowlton 2000; Shivik 2004; van Bommel and Johnson 2012). Although some non-lethal approaches have shown promise in some small-scale contexts (e.g. Potgieter *et al*. 2013; van Bommel and Johnson 2014*a*), the utility of common non-lethal predator control methods in more extensive livestock grazing systems has received little attention.

Wild dogs *Canis familiaris*, which include dingoes, feral domestic dogs and their hybrid offspring (Jackson and Groves 2015), cause substantial economic loss to Australian sheep and goat producers through predation, opportunity costs and control costs (e.g. McLeod 2004; Hewitt 2009; Lightfoot 2010; Wicks *et al*. 2014). Cattle are also affected by wild dogs to a lesser degree (Fleming *et al*. 2012; Allen 2014). Sheep production in Australia occurs across large rangeland areas, where farm sizes can exceed 20 000 km^2, flock sizes can exceed 40 000 head, and sheep are handled only twice or three times annually. Despite decades of lethal wild dog control, Australia's sheep industry is still contracting towards smaller farm sizes with fewer head in a more geographically concentrated area, due largely or at least in part to the impacts of wild dogs (Allen and West 2013, 2015). Thus, there is great interest in developing a variety of lethal and non-lethal approaches to mitigate the impacts of wild dogs on livestock (Fleming *et al*. 2006, 2014; van Bommel and Johnson 2014*a*).

Livestock guardian dogs of various breeds are used to protect sheep and goats in many parts of the world from canid predators such as wolves *Canis lupus*, coyotes *Canis latrans* and black-backed jackals *Canis mesomelas* (e.g. Smith *et al*. 2000; Andelt 2004; Dawydiak and Sims 2004; Potgieter *et al*. 2013; but see also Linnell and Lescureux 2015), but are not commonly used in Australia. Based on livestock producer surveys and studies examining the management practices and cost-benefits of guardian dogs, best practice guidelines on the use and management of guardian dogs in Australia have been developed to encourage their use (e.g. van Bommel 2010). However, beyond extensive anecdotal reports and case studies (van Bommel and Johnson 2014*c*) few empirical data are available to demonstrate how or why guardian dogs work or how predators interact with them.

Recent studies have suggested that guardian dogs work by establishing and defending territories of their own, which wild dogs respect and are excluded from (van Bommel and Johnson 2014*c*). On the basis of elicited guardian dog responses to simulated wild dog intrusions (i.e. wild dog howl playbacks and the presence of wild dog urine), the researchers discovered that maremmas responded more aggressively when simulated incursions were within maremma core areas compared with when wild dog incursions were on the periphery of their home range. This interpretation assumes that wild dogs living adjacent to or trespassing in the territory of guardian dogs recognise and respond to olfactory cues, vocalisations and the physical presence of guardian dogs as they would other wild dogs. In this study, we test this hypothesis by measuring the frequency and duration of actual wild dog incursions into the territories of adjacent wild dogs and guardian dogs while they protect sheep in open grasslands. Our aim was to determine whether or not wild dogs respond to guardian dog territories in the same way they respond to the territories of other wild dogs.

Material and methods

Animal ethics statement

All procedures were undertaken in accordance with the *Australian Code of Practice for the Care and Use of Animals for Scientific Purposes* and were approved by the Department of Agriculture and Fisheries, Community Access Animal Ethics Committee (#CA 2008/10/311).

Study site

The study was conducted on Dunluce station, a mixed sheep- and cattle-producing property of 46 500 ha located west of Hughenden in north Queensland, Australia (20°52′S, 143°51′E). Dunluce is situated on the northern extremity of the Mitchell grass plains bioregion, a vast undulating and sparsely timbered grassland extending from south-west to north-west Queensland and into the Northern Territory. Dunluce comprises of mostly Mitchell grass (*Astrebla* spp.) downs with some timbered boree (*Acacia ephrina*) woodlands along the northern boundary of the property adjacent to the Flinders River (Fig. 1). Immediately north of Dunluce's boundary is the Einsleigh uplands bioregion, a large cattle-producing area of tropical savannahs covering a plateau of eroded basalt. Dunluce receives a mean annual rainfall of 490 mm, ~75% of which falls between November and March during the summer monsoonal wet season (www.bom.gov.au, verified 30 May 2016). At the time of the study Dunluce ran ~13 000 sheep and ~5000 cattle and was the most northern sheep-producing property in Australia. The nearest sheep grazing property was ~40 km away. Sheep were managed in six large ewe flocks rotated irregularly around 20 smaller paddocks that range in size between 800 and 1800 ha, with a few additional small flocks of rams and other sheep.

Wild dog, sheep and maremma management

After suffering annual wild dog predation losses of ~15%, the owners of Dunluce switched from a strategy of regular poison-baiting to using guardian dogs, initially purchasing 24 maremmas in 2002. Since that time, between 18 and 26 maremmas have been used to protect Dunluce's sheep from wild dogs. Sheep losses declined to ~3% within 3 years following the introduction of maremmas (N. Stewart-Moore, unpubl. data); these losses were attributed primarily to natural or non-predation causes, such as mismothering or disease. At the time of the study, lethal control or poison-baiting of dingoes had ceased on Dunluce ~8 years prior, but annual aerial baiting programs still occurred along the adjacent Flinders River and some surrounding properties. Wild dogs were opportunistically shot.

All working maremmas were neutered. Pups were bonded to lambs and livestock, provisioned in-paddock with a dry commercial dog food, and when mature, were integrated into sheep paddocks according to recommended best-practice guidelines (described in van Bommel (2010)). Between one and three maremmas resided with each flock of sheep. Although sheep were confined by fences, maremmas moved freely between paddocks and flocks, and were not contained by fences.

Animal capture and collaring

Eight male and female maremmas, located in the most northern sheep paddocks, adjacent to where wild dogs were expected to harbour, were collared in May 2009 with GPS data-logging collars (Sirtrack, Havelock North, New Zealand) weighing ~500 g. Collars were programmed to record GPS locations every 30 min continuously. Collar batteries were regularly replaced to prevent them expiring, and location data were downloaded every 3 months unless repair was required, necessitating the collar be removed for longer.

Wild dogs, (which were all dingo-like phenotypes, Table 1) were trapped with soft-catch foot-hold traps (Victor #3) on two occasions, in April and July 2010 (four wild dogs captured in April, and another two were captured in July). Trap sites were checked daily, and captured wild dogs were physically restrained, muzzled and had the trap removed from their foot during processing. To reduce potential pain and inflammation, a subcutaneous injection of metacam (meloxicam, Boehringer Ingelheim am Rhein, Germany) was administered (0.5 mL meloxicam/10 kg bodyweight). The captured limb was also sprayed with antiseptic, and was then

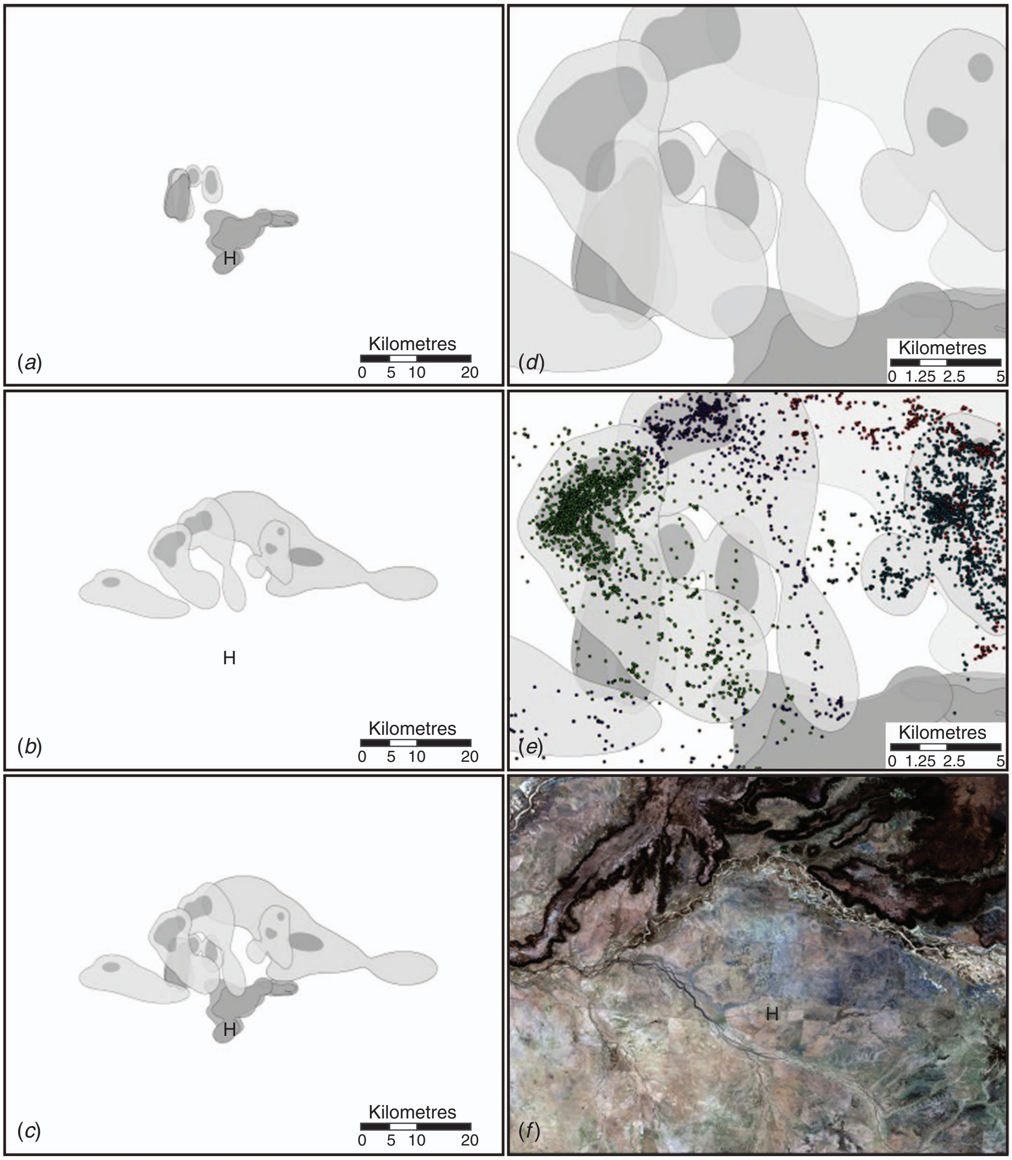

Fig. 1. Home range (light grey areas) and territory (dark grey areas) sizes of (*a*) maremmas, (*b*) wild dogs and (*c*) maremmas and wild dogs, with (*d*) a more detailed view of areas of territory overlap and (*e*) wild dog movements (coloured dots) within maremma territories at (*f*) the study site, on Dunluce Station, 2010 (H = Dunluce homestead).

massaged to restore peripheral blood flow and reduce the likelihood of infection in any associated abrasions. Each wild dog was weighed, ear tagged (with a large numbered Allflex cattle tag) and fitted with an Argos-linked GPS collar (Sirtrack) weighing ~450 g. Wild dog collars were programmed to record GPS locations every 60 min continuously. The age of wild dogs was estimated based on tooth eruption, wear and physical characteristics. Where possible, age estimates were later corrected with measurements taken from radiographs of upper canine teeth extracted from the deceased wild dog (Kershaw *et al*. 2005). Handling time between restraint and release was typically 10–20 min.

Wild dogs were monitored for 62–172 days (Table 1). If collared wild dogs did not die from natural causes during the course of the study they were destroyed at the conclusion of the study.

Statistical analyses

ArcGIS version 9.1 (ESRI, Redlands, CA, USA) was used to conduct spatial analyses in association with the XTools Pro version 7.0 (Data East LLC 2005), Hawth's Tools (Beyer 2004) and Home Range Tools version 3 (Rodgers and Carr 1998) extension packages.

Home ranges are larger shared areas inclusive of places used for foraging and resource acquisition, whereas territories (or core areas) are smaller defended areas within the home range (Burt 1943; Krebs 2008). The home ranges of wild dogs and maremmas

Table 1. Details of collared wild dogs and maremmas

ID	Sex	Weight	Age (months)	Start date	End date	Days monitored	GPS points obtained	% expected GPS points	Mean horizontal dilution of precision	Home-range size (km^2)	Territory size (km^2)
Wild dog 83	M	18.5	15	20 April 2010	9 October 2010	172	3773	91.4%	1.5	103.2	22.8
Wild dog 84	F	13.0	23	22 April 2010	9 October 2010	170	4070	99.8%	2.8	62.0	4.6
Wild dog 86	F	14.0	8	28 April 2010	13 July 2010	76	811	44.5%	2.6	343.4	17.2
Wild dog 87	M	15.5	17	13 July 2010	13 September 2010	62	1338	89.9%	1.7	100.2	4.5
Wild dog 88	M	17.0	12	18 July 2010	9 October 2010	83	1877	94.2%	1.6	111.6	16.3
Edwardo	M	>40.0	>60	23 May 2010	12 October 2010	142	4421	64.9%	3.1	26.5	26.5
Fabiola	F	>40.0	>60	15 April 2010	10 July 2010	86	1165	28.2%	1.7	62.0	62.0
Nunzio	M	>40.0	>84	25 April 2010	23 July 2010	89	4204	98.4%	3.1	9.8	9.8
Ringo	M	>40.0	>84	20 May 2010	12 October 2010	145	6706	96.4%	3.0	29.4	12.4
Rosa	F	>40.0	>84	20 May 2010	12 October 2010	145	6019	86.5%	3.1	92.8	92.8
Sophia	F	>40.0	>84	28 April 2010	10 October 2010	165	7184	90.7%	3.0	41.6	41.6
Stephano	M	>40.0	>60	23 April 2010	3 June 2010	41	1596	81.1%	3.1	30.0	12.5

were first calculated using adaptive kernel density isopleths in increments of 10 (AK, h = 1; Harris *et al*. 1990), where the 90% density isopleth was used to define the home range. To avoid defining the territory as some arbitrary value (such as the 50% density isopleth), territories were defined by calculating the total area enclosed by each isopleth, and when the cumulative area doubled between two consecutive isopleths, the smaller of the two isopleths was determined to represent the territory (Barg *et al*. 2005).

Territory overlap between wild dogs, between maremmas, and between wild dogs and maremmas was assessed visually in ArcGIS. All wild dog GPS points occurring within maremma territories were then identified and further analysed to determine the frequency, timing and duration of wild dog incursions into maremma territories. For each incursion observed, the location and timing of wild dog and maremma activity was assessed to determine the location of maremmas, the number of maremmas present, and the movements of maremmas and wild dogs in relation to each other. In other words, we sought to quantify how often wild dogs entered maremma territories and how long wild dogs stayed within those territories, in order to determine whether or not maremmas worked by 'excluding' wild dogs from their territories. We predicted that if maremmas worked by excluding wild dogs in the same way wild dog packs exclude each other from their territories (e.g. Claridge *et al*. 2009; Robley *et al*. 2010; Newsome *et al*. 2013; Allen *et al*. 2014), then wild dogs would not trespass maremmas' territories and/or would spend little time there.

Results

We collared six wild dogs and seven maremmas between April and October 2010 (Table 1). Of the six wild dogs collared, one collar (dog 85) failed shortly after deployment and was not relocated. Dog 86 died of unknown causes 76 days after release, and the stored data was partly corrupted, preventing complete analyses. Dog 87 was shot in sheep paddocks 62 days after release, and dog 88 (along with a female companion) was shot 83 days after collaring. We obtained a total of 43 163 GPS points for wild dogs (n = 11 869) and maremmas (n = 31 295) during the study, or 80.5% (range 28.2–99.8%) of expected GPS points. Mean horizontal dilution of precision values were 3.0 (s.e. = 0.01) for maremmas and 2.1 (s.e. = 0.02) for wild dogs, indicative of excellent spatial accuracy, or ~20–50-m on-ground error.

Home-range sizes, territory sizes and overlap

Home-range size varied between 62.0 km^2 and 343.4 km^2 for wild dogs and 9.8 km^2 and 92.8 km^2 for maremmas (Table 1, Fig. 1). Territory sizes varied between 4.5 km^2 and 22.8 km^2 for wild dogs. Territory size varied between and 9.8 km^2 and 92.8 km^2 for maremmas, indicating that maremma kernel isopleths seldom doubled between consecutive isopleths. In other words, maremma core areas were more or less identical to their calculated home ranges. Wild dog territories never overlapped, although small portions of their home ranges did overlap, as expected (Fig. 1). Maremma territories overlapped considerably, as expected, given that they are all associates or members of the same 'pack'. Maremmas typically showed strong site fidelity to sheep paddocks (Nunzio, Eddie, Sophia and Ringo), but individual maremmas (Stephano, Romana and Freddie) occasionally ranged between sheep paddocks up to 15 km away. Collared wild dogs harboured in the more timbered Finders River riparian areas; four of the five wild dogs displayed (centripetal) movement patterns indicative of stable pack members in (mostly) non-overlapping yet adjacent home ranges. The largest 'home range' (343 km^2) was that of an 8-month-old female wild dog that most likely incorporates pre-dispersal forays (Thomson *et al*. 1992). The territory of one collared wild dog overlapped considerably with the shared territory of two collared maremmas (Fig. 1).

Movements, incursions and interactions

There was a difference in the mean distance individual maremmas travelled each day (range 4.9–9.5 km/day, F_6 = 2.24, P = 0.04), but not between individual wild dogs (range 12.2–18.4 km/day, F_3 = 2.49, P = 0.07); gender differences were not detectable for maremmas or wild dogs (female maremmas

8.8 km/day, males 6.7 km/day, $F_1 = 2.32$, $P = 0.13$; female wild dogs 15.9 km/day, males 14.6 km/day, $F_1 = 0.32$, $P = 0.57$). On average, wild dogs travelled twice the distance that maremmas travelled each day (mean 15.3 km/day compared with 7.6 km/day, respectively; $F_1 = 18.91$, $P = <0.0001$). Both wild dogs and maremmas were crepuscular, although wild dogs were more active during the night than maremmas, the movement of maremmas presumably dictated by the movement of the sheep (Fig. 2).

A total of 713 wild dog GPS points (or hourly locations) occurred within maremma territories, representing 120 recorded incursions, mostly from three of the five collared wild dogs (Table 2, Fig. 3). These three wild dogs spent a mean of 5.9 h (range 1–36), 5.4 h (range 1–17) and 2.5 h (range 1–6) inside maremma territories during their incursions. At least one of the five collared wild dogs was found within maremma territories ~5–6 days each week, on average (Fig. 3). Wild dog activity between 2000 hours and 0600 hours (mean speed = 0.78 km/h) was nearly four times higher than maremma activity (mean speed = 0.22 km/h). During this time, maremmas seldom moved very far, even when wild dogs were within maremma core areas and nearby (Fig. 2). Conversely, wild dogs frequently made forays of over 20 km from their core areas into sheep paddocks 'guarded' by maremmas (Fig. 1).

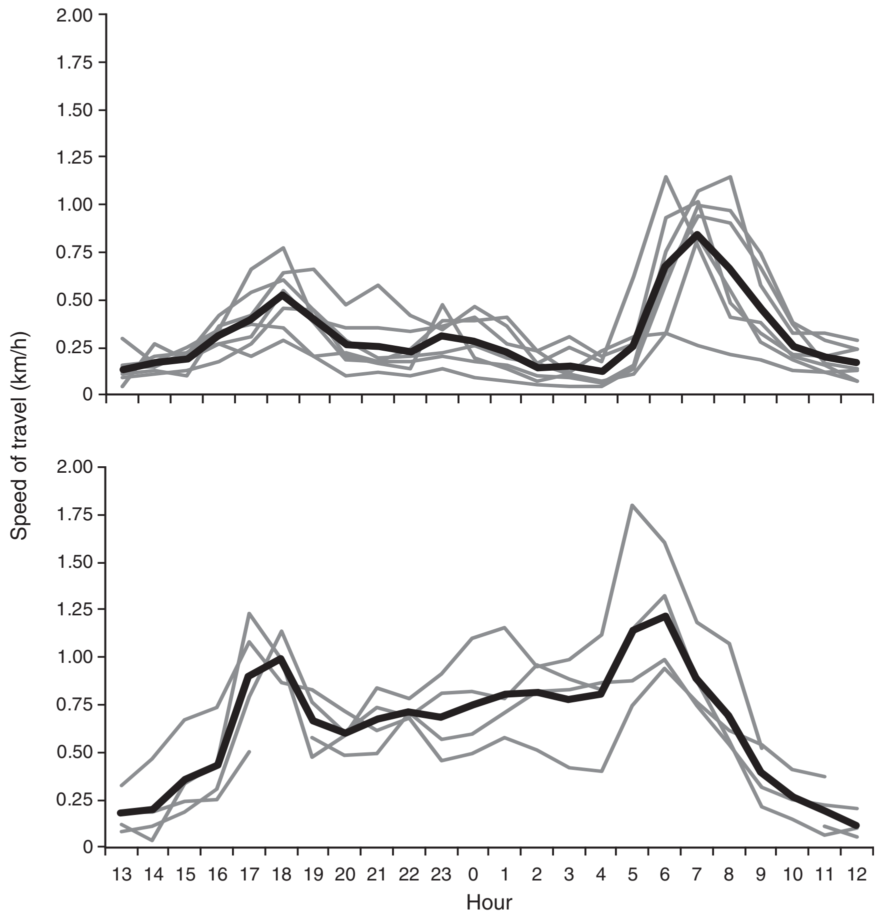

Fig. 2. Activity patterns of collared maremmas (top) and wild dogs (bottom) at Dunluce, 2010 (thin grey lines = individual animal activity patterns, solid black line = mean activity pattern).

Table 2. Details of wild dog incursions into maremma territories

ID	No. (and %) of days in maremma territories	Mean no. of days per week in maremma territories	Mean no. of hours (and range) in maremma territories	Total time spent in maremma territories (h)
Wild dog 83	97 (56%)	3.95	5.9 (1–36)	630
Wild dog 88	13 (16%)	1.10	5.4 (1–17)	54
Wild dog 87	9 (15%)	1.02	2.5 (1–6)	27
Wild dog 84	1 (1%)	0.04	2	2
Wild dog 86	0 (0%)	0.00	0	0

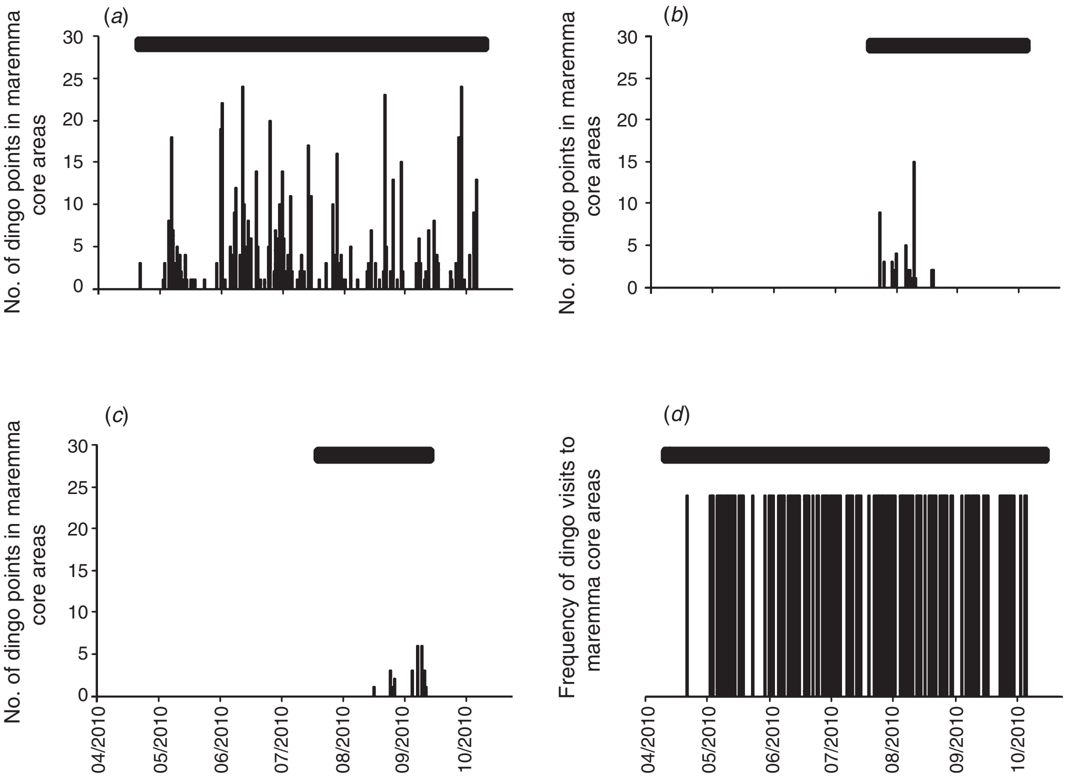

Fig. 3. Frequency of incursions by wild dog 83, 88 and 87 (*a*–*c*) and combined (*d*) into maremma territories. (Thin vertical lines represent the number of wild dog GPS locations within maremma territories, thick horizontal lines represents monitoring period).

GPS collar data suggested that physical altercations between collared maremmas and wild dogs seldom occurred. However, Nunzio, a 10-year-old male maremma that guarded a flock mostly on his own for many years, died 6 h after dog 84 and Nunzio were within 100 m of each other (locations recorded 6 min apart), in the early hours of the morning (Fig. 4). When dog 84 was shot 3 months later, she had seven placental scars and was accompanied by a juvenile wild dog, suggesting that at the time of the encounter with Nunzio (July) she would have been heavily lactating[1] and probably in the company of other adult (and un-collared) wild dogs. These observations strongly suggest that Nunzio was killed by dog 84 and/or her companions. During a separate incident, dog 88 circled within 750 m of three near-stationary maremmas for an 8-h period, indicative of fine-scale interactions between wild dogs and maremmas (Fig. 5).

The loss of between only 10 and 15 individual sheep were attributable to wild dog predation during the entire course of the study (N. Stewart-Moore, unpubl. data).

Discussion

Our results indicate that maremmas do not exclude wild dogs from their territories as wild dogs do with adjacent packs. Wild dogs harbouring in timbered riparian areas were frequently found leaving those areas and entering maremma territories, or sheep paddocks (Fig. 1). At least one of the five wild dogs we monitored was found within maremma territories 5–6 nights a week (Table 2, Fig. 3). Considering the many other un-collared wild dogs likely to be present in the area, this suggests that wild dogs are probably ever-present in sheep paddocks or within maremma territories at the site. Moreover, wild dog incursions into maremma territories were not mere brief trespasses, but rather typically lasted several hours, and regularly lasted overnight, or from one night to the next, harbouring within maremma territories or sheep paddocks during the day (Table 2). Maremma movements were modest relative to those of wild dogs (Fig. 1), and wild dogs were much more active (or moved greater distances) at night (Fig. 2). When wild dogs foraged close by (e.g. Fig. 5), maremma movements were minimal.

Wild dogs made relatively few incursions into the home ranges of neighbouring wild dogs and never did enter their territories (Fig. 1). In contrast, wild dogs made frequent and lengthy incursions into maremma territories and remained there for up to 36 h (Table 2), suggesting that wild dogs either do not recognise or they ignore the boundaries established by maremmas (assuming they even establish them). These findings indicate that maremmas do not work by excluding wild dogs from their territory as we found no evidence that maremmas actually establish clear, defensible territories. One apparent lethal encounter was recorded (Fig. 4), along with several non-

[1]Wild dogs are monoestrus and most whelp in June–July.

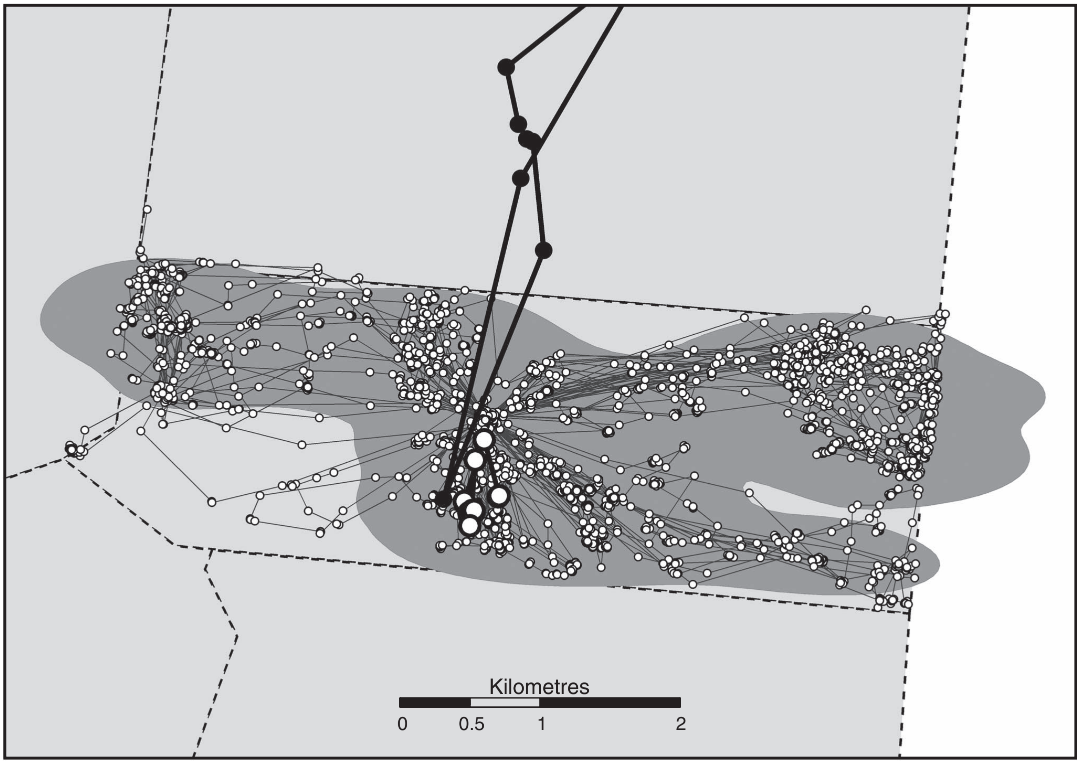

Fig. 4. GPS data associated with the physical encounter between wild dog 84 and (maremma) Nunzio that concluded with Nunzio's death, occurring between 0200 hours and 0800 hours on 21 July 2010 (light grey area and dashed lines = sheep paddocks and fences, dark grey area = Nunzio's territory, small hollow marks and interconnecting lines = Nunzio's movements, large black marks and interconnecting lines = movements of dog 84 during the altercation, large hollow marks and interconnecting lines = Nunzio's movements during the altercation).

lethal close encounters (Fig. 5). We conclude that maremmas work by shepherding sheep, by preventing sheep from fleeing or scattering and/or by preventing wild dogs from coming into direct contact with sheep.

Although wild dogs frequently entered maremma-patrolled sheep paddocks surprisingly few sheep were discovered killed by wild dogs during the study (or at any other time). The few sheep losses that did occur coincided with shearing, a time when maremmas had been temporarily removed to the homestead and sheep were gathered into lane ways or holding paddocks to facilitate handling. Opportunistic observations indicate that maremmas camped amongst the sheep at night in large single flocks, and when disturbed by spotlights, sheep reacted by tightly clustering together – so tight that some sheep towards the centre of the group were held upright on their hind legs (L. Allen, pers. obs). All attending maremmas barked aggressively and circled the perimeter of the rotating flock, whereas a single maremma left the flock a short distance (<100 m) and challenged the source of the disturbance (i.e. the spotlight), similar to the behaviours described in McGrew and Blakesley (1982), van Bommel (2010) and van Bommel and Johnson (2014*c*). This type of behaviour is also reflected in Fig. 5, where dog 88 invaded the sheep paddock from ~10 km away at dusk and spent a few hours circling three experienced maremmas, which exhibited highly restricted movements, presumably guarding the sheep. This type of 'raid' behaviour characterised wild dog incursions into sheep paddocks occupied by maremmas. Given the constant threat of wild dogs to sheep, the separation of guardian dogs from sheep presents an opportunity for wild dogs to attack sheep. Such separation could occur during shearing (as above) or during parturition when ewes (and nanny goats) seek shelter and/or isolate themselves from the rest of the flock (Winfield *et al*. 1969; Lynch and Alexander 1977). Maintaining high maremma-sheep ratios may be one way of minimising this separation (van Bommel and Johnson 2012).

The shepherding behaviour and aggressive vocalisations of guardian dogs, combined with the flocking behaviour of sheep, might circumvent attacks on sheep but obviously does not prevent nor discourage wild dogs from routinely foraging in close proximity to sheep (Fig. 1). Observed individual differences in the distance maremmas travelled each day (Fig. 2) and differences in the fidelity that certain maremmas have to particular sheep paddocks (also reported by van Bommel and Johnson (2014*c*)), suggest differences in the defensive roles taken by individual maremmas, although gender does not seem to be a factor in this behaviour (Fig. 1). Dawydiak and Sims (2004) describe instances of guardian dogs crossing fences to patrol paddocks some distance away as 'exceptional protective behaviour', which was considered to be a 'problem' needing correction by van Bommel (2010). Shifting between paddocks may be characteristic of how some individual

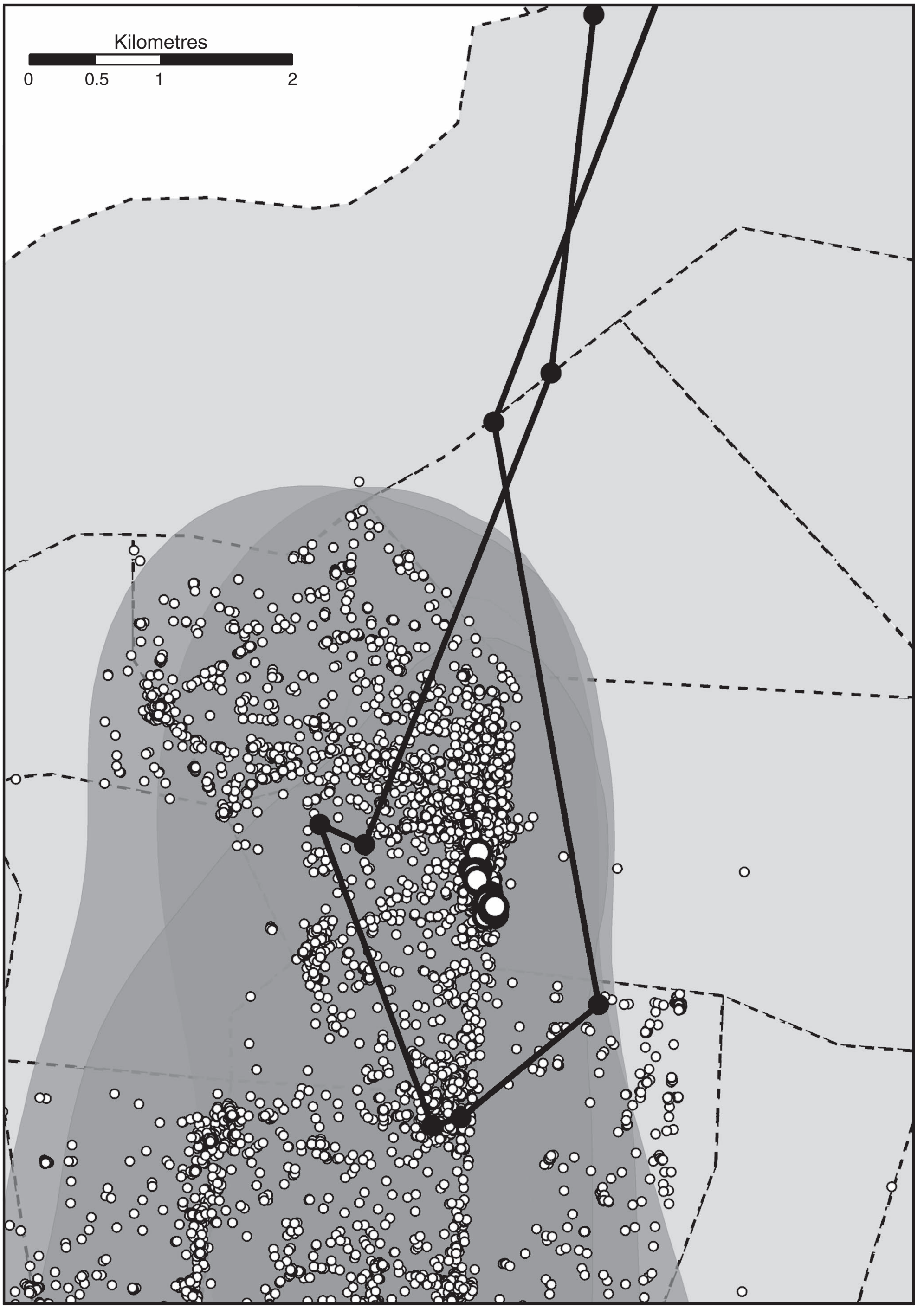

Fig. 5. GPS data associated with an interaction between wild dog 88 and (maremmas) Edwardo, Sophia and Ringo, occurring between 1700 hours and 0300 hours on the night of 31 July 2010 (light grey area and dashed lines = sheep paddocks and fences, dark grey area = maremma territories, small hollow marks and interconnecting lines = maremma movements, large black marks and interconnecting lines = movements of dog 88 during the interaction, large hollow marks and interconnecting lines = maremma movements during the interaction period).

guardian dogs cooperatively respond to nearby predator threats, whereby distant vocalisations prompt their movement. Van Bommel and Johnson (2014*c*) also reported a maremma making an immediate and rapid straight-line movement from 6 km away towards the source of maremmas' vocalisations in response to simulated wild dog howls. The maremma movements recorded in this study are consistent with these and other anecdotal observations that certain individuals move between paddocks to assist each other, whereas other maremmas do not.

These results have important implications for sheep producers operating in areas where wild dogs occur. If sheep are not separated from wild dogs, wild dogs will eliminate sheep sooner or later (Thomson 1984; Allen and West 2013). This separation has historically been created through the use of extensive wild dog-proof fencing at local, regional and national scales (McKnight 1969; Yelland 2001; Perkins 2013). The use of property-level fencing is again becoming increasingly important, but is hindered by cost (Perkins 2013), so guardian dogs may be one attractive alternative to fencing or additional to other control methods in many cases (van Bommel and Johnson 2014*a*; Linnell and Lescureux 2015). We encourage the increased use and exploration of guardian dogs to address some community concerns about the use of lethal predator control approaches to mitigate predation of sheep by wild dogs.

Acknowledgements

Funding for the project was provided by the Bureau of Rural Sciences under the Australian Pest Animal Management Program and Queensland Department of Agriculture and Fisheries. The Invasive Animals Cooperative Research Centre supported B. Allen during the production of this report. Joe Scanlan and Tony Pople provided helpful comments on earlier drafts of the manuscript. The authors declare no conflict of interest.

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