



Original Investigation

Sarcoptes mange (*Sarcoptes scabiei*) increases diurnal activity of bare-nosed wombats (*Vombatus ursinus*) in an agricultural riparian environment

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ABSTRACT

Sarcoptes mange is an important disease that affects the health, mobility and longevity of bare-nosed wombats (*Vombatus ursinus*) in Australia. We measured the activity patterns of wombats infected with varying levels of mange in an agricultural riparian environment using motion-sensing cameras. Over a 10 month period we observed a greater increase in nocturnal activity of mange-free wombats than those with mange on six or more body sections. The percentage of mange-infected wombats was greater during the day, but in the 6 h after midnight, wombats were detected with fewer mange-infected segments. Air temperature at the time of wombat detections was generally higher for individuals with mange than those without mange. Our results show that diurnal activity of wombats is likely to increase with higher levels of infection by *sarcoptes mange*. Increased diurnal activity is likely to present serious problems for the persistence of sustainable populations of wild wombats.

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Introduction

Wild vertebrates must live in an environment with the ever present threat of macroparasites (Hart 1992). The effect of parasitic infestation on animal activity has been the focus of several studies for a range of taxa (Poulin 1995). Some animals can tolerate ectoparasite infection through immune system responses and various physiological forms of resistance such as avoidance and controlled exposure to parasites (Hart 1990). For example, varying lemmings (*Dicrostonyx richardsoni*) infected with the protozoan parasite, *Sarcocystis rauschorum*, and rats (*Rattus norvegicus*) infected with *Toxoplasma gondii* are able to survive and reproduce by grooming (Quinn et al. 1987; Berdoy et al. 1995). The only apparent effect on their activity is an increase in their exploratory behaviour (Quinn et al. 1987; Berdoy et al. 1995). Other less fortunate species such as moose (*Alces alces*) are more likely to be shot by hunters when they are infected by the parasite *Echinococcus granulosus* because of an increase in “boldness” (Rau and Caron 1979; Barber and Dingemanse 2010). More recently, parasitism has been described as an ecological factor that not only influences behaviour but also personality (Barber and Dingemanse 2010). Because infection often leads to specific changes in axes of personality, parasite

infections have the potential to decouple behavioural syndromes (Barber and Dingemanse 2010).

In southeastern Australia, bare-nosed wombats (*Vombatus ursinus*) are often heavily infected with *sarcoptes mange* (*Sarcoptes scabiei*). Infection with *sarcoptes mange*, an obligate skin parasite (Arlian 1989; Burgess 1994), leaves wombats in poor physical condition and impairs their ability to reproduce (Skerratt et al. 1999). In response to the constant skin irritation caused by the parasite, wombats seek relief by scratching and rubbing against objects (Triggs 2009). Severely infected wombats are also likely to become blinded because of skin thickening and crusting around the eyes (Skerratt et al. 1999) (Fig. 1). Additionally, severely infected wombats experience pain while moving, and because of their higher energy requirements, these normally nocturnal animals are often observed grazing during the day (Hartley and English 2005; Skerratt et al. 1999). As with other vertebrates such as the red fox (*Vulpes vulpes*), Spanish ibex (*Capra pyrenaica hispanica*) and European lynx (*Lynx lynx*), severe outbreaks of sarcoptidosis in wombats can result in high mortality rates (Overskaug 1994; Alados et al. 1996; Perez et al. 1997; Skerratt et al. 2004b; Pence and Ueckermann 2002).

Wombats can occur in high densities (1.9 individuals ha⁻¹) in agricultural riparian landscapes (Skerratt et al. 2004a). For these wombats, *sarcoptes mange* represents a threatening process for wombat populations (Hartley and English 2005; Martin et al. 1998). *Sarcoptes mange* occurs in wombat populations throughout their range, including Tasmania and Flinders Island (Martin

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Fig. 1. A wombat infected with sarcoptic mange, showing erythema, parakeratosis (scale crust) on the flank, legs and surrounding the eye. Photograph: P. Borchard.

et al. 1998). While sarcoptes mange occurs sporadically throughout wombat populations, the percentage of mange-infected individuals is unknown (Martin et al. 1998). The method of transmission of sarcoptes mange between wombats is not well understood, though overlap in burrow use between individual wombats is thought to be involved in the transmission of mites (Skerratt et al. 2004b). It is unknown whether mange outbreaks in wombats are more prevalent in disturbed environments. High wombat densities and greater multiple occupancy of burrows by wombats in remnant riparian forests that adjoin agricultural grasslands (Skerratt et al. 2004a) suggest the presence of a mutualistic environmental interaction conducive to the spread of the parasite. With increasing degradation and fragmentation of riparian habitat, sarcoptes mange could have serious effects on a species already restricted to remnant riparian forests in a large part of its distribution (Borchard et al. 2008).

Wombats are characteristically nocturnal, with peaks of activity at the beginning and end of each night (Evans 2008; Borchard and Wright 2010a). Wombats with sarcoptic mange travel further than those without mange in mid-spring, covering similar distances to wombats without mange in early autumn (Skerratt et al. 1999). However, the distance travelled by mange-infected wombats is greater in mid-spring than in late winter (Skerratt et al. 1999). Less well understood is the effect of sarcoptic mange on seasonal and temporal wombat activity, particularly diurnal movement patterns at the agricultural riparian interface. We predict that with an inability to remove the parasite by grooming, wombats will adapt to mange infection by changing their habits (Hart 1990). Given their increased energy demands, mange-infected wombats are likely to alter their movements both seasonally and temporally (Evans 2008) to compensate for the energy loss caused by the parasite. In this study we examined the effects of temperature, time of day and season on the activity of mange-infected wild wombats and contrasted this with mange-free wombats. By better understanding the activity patterns of wombats infected with sarcoptes mange, we may be able to develop strategies, based on the times of likely activity, to treat infected animals.

Methods

Study area

The study took place between August 2007 and June 2008 in a 22 ha blueberry (*Vaccinium corymbosum*) orchard situated 250 km south of Sydney in the Shoalhaven region of New South Wales, Australia (35°50'S, 150°21'E). The orchard is bounded on

one side by undisturbed eastern riverine forest (Keith 2004) dominated by river oak (*Casuarina cunninghamiana*), river peppermint (*Eucalyptus elata*), black wattle (*Acacia mearnsii*) and water gum (*Tristaniopsis laurina*). Undisturbed dry sclerophyll forest habitat containing white stringy bark (*Eucalyptus globoidea*), large-fruited red mahogany (*E. scias*), grey ironbark (*E. paniculata*), rough-barked apple (*Angophora floribunda*), tick bush (*Kunzea ambigua*), hair pin banksia (*Banksia spinulosa*), and prickly shaggy pea (*Oxylobium ilicifolium*) surrounded the other three sides. Introduced grasses such as kikuyu (*Pennisetum clandestinum*) and narrowleaf carpet grass (*Axonopus affinis*) occurred as a narrow buffer on the outside of the orchard and between the rows of blueberry shrubs within the orchard. Wombat burrows were broadly distributed across the surrounding general landscape but, as in other agricultural riparian landscapes, occurred in high abundance on the surrounding streambanks (Borchard et al. 2008). The blueberry orchard was enclosed by a 2 m high vertebrate (deer) – proof fence and was entirely covered by bird netting. At the commencement of the study 17 wombat breaches of the existing deer fence were recorded around the entire farm, with 14 of these located along the riparian interface. Several of these breaches appeared to be more well-used than others, as identified by deep, hemispherical excavations of soil under the fence and the raised nature of the lower part of the netting (Marks 1998; Marks et al. 1989). At these breach points a combination of exclusion fencing and swinging gates were installed to allow controlled wombat access to the blueberry orchard without damage to the fencing (Borchard and Wright 2010b).

Monitoring wombat activity using camera traps

The activity of wombats at exclusion fencing and wombat gates (Borchard and Wright 2010b) was observed continuously throughout the study using four Moultrie Game Spy I40 heat and motion sensing digital cameras (Moultrie Feeders, Alabaster, USA). The cameras were powered by 12V Panasonic external rechargeable batteries. Battery power was adequate given the service interval of approximately 1–2 weeks. Cameras were secured to permanent steel posts 30 cm above ground level and 1 m away from positions where wombats had breached the vertebrate exclusion fence (breach points). The cameras were positioned at the four most heavily used breach points to test the exclusion fencing first and then the swinging gates. These were approximately 50 m apart. The videos and still images were downloaded every 1–2 weeks and at this time the serviceability and time and date functions were checked. The cameras were set to capture 15-s videos, after being triggered by motion, followed by a still image that contained the time, date and temperature. An image delay of 1 min, determined the number of pictures taken of a detected animal remaining in range. It was not always possible to identify individual wombats; therefore, a 1 min delay was a compromise between capturing the same individual multiple times and missing individuals. To avoid multiple detections of the same animal, other ecological studies have successfully used image delay times ranging from 1 min to 1 h (Otani 2002; Bowkett et al. 2007; Tobler et al. 2008; Borchard and Wright 2010b).

Mange identification

The mange identification of wombats was based on the clinical signs of *Sarcoptes* mange described by Skerratt et al. (1999, 2004b). Using the method described by Skerratt et al. (2004b) the body surface of wombats was divided into 13 sections in order to quantify the extent of sarcoptic mange in wombats (Fig. 2). Each photograph and video of a wombat was examined for erythema, parakeratosis (scale crust) or hair loss and the number of body

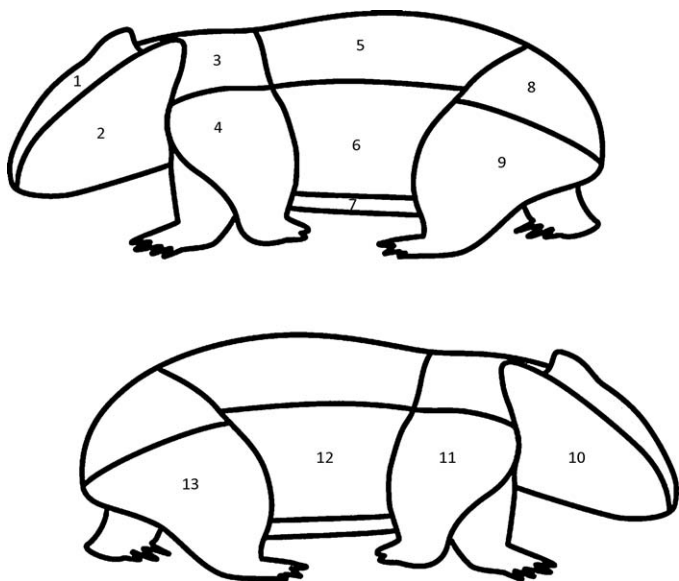


Fig. 2. Body surface of wombats, divided into 13 sections in order to quantify the extent of sarcoptic mange in wombats. Some sections were duplicated on each side of the body: the face (Sections 2 and 10), the foreleg (4 and 11), the flank (6 and 12) and the hindleg (9 and 13). Five other sections included both sides of the body: forehead (1), back (5), rump (8), abdomen (7) and between the shoulders (3) (Skerratt et al. 2004b).

sections infected was tallied. We then converted this data into 5 classes, i.e. no mange, <3, 3–4, 4–6 or >6 segments infected (Table 1). We chose these levels because field observations suggest that animals with half or more of their body sections infected are likely to be in exceptionally poor physical condition.

Statistical analyses

We used log-linear analyses to examine the relationship between the occurrence of wombats with varying amount of mange, and time of day, categorized in two ways: (1) among four, 6-h periods (night, morning, afternoon, evening) and (2) two periods, diurnal and nocturnal (Table 1). Our analysis is similar to that undertaken on a two-way contingency table where the relationship between time period and mange class is analyzed by taking the natural logarithm of the counts within each cell (Agresti 1996). Statistical analyses were carried out using SPSS 10.0 (SPSS 1999). We used the non-parametric Kruskal–Wallis test to examine potential differences in ambient temperature between periods when wombats were detected with and without mange.

Table 1

Contingency table of the number of diurnal and nocturnal observations periods in relation to the number of segments infected by mange.

Period	Number of mange-infected segments				
	Nil	<3	3–4	4–6	>6
Nocturnal					
06:00–24:00 h	219	71	90	10	5
24:00–06:00 h	308	120	76	8	1
Total nocturnal	527	191	166	18	6
Diurnal					
06:00–12:00 h	13	8	5	0	3
12:00–18:00 h	8	12	24	5	1
Total diurnal	21	20	29	5	4
Grand total	548	211	195	23	10

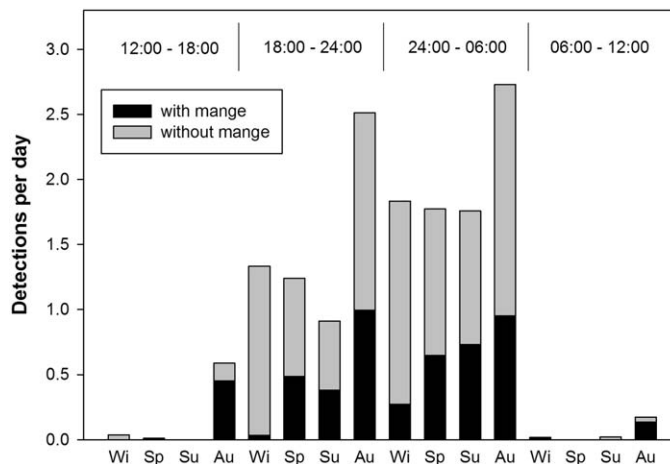


Fig. 3. The mange status of 987 wombat detections across time of day and season (black = mange-infected and grey = non mange-infected), (Wi = winter; Sp = spring; Su = summer; Au = autumn).

Results

Over the 10 month study period we made a total of 1043 wombat detections. However, due to wombat orientation, photographic resolution and framing, only 987 images were of sufficient quality to make a confident assessment of the mange status of each animal detected. There were significantly more nocturnal (908) than diurnal (79) detections (log-linear $\chi^2 = 817.8$, $df = 1$, $P < 0.001$). Similarly, we recorded a seasonal peak of over 2.5 wombat detections between 18:00 h and midnight, and midnight to 06:00 h over the autumn months (Fig. 3). There was also a significant difference in the number of segments detected, with 954 detections (96.7%) with fewer than four infected sections compared with 33 detections (3.3%) with five or more infected sections (log-linear $\chi^2 = 983.8$, $df = 4$, $P < 0.001$; Table 1). The significant period by infection class interaction (log-linear $\chi^2 = 817.8$, $df = 1$, $P < 0.001$) can be interpreted as the increase in wombat activity at night was much higher in animals in the low level of mange classes (<4 segments) than for wombats with five or more infected segments. Thus the percentage of animals active during the daytime changed from about 4% for animals with no mange, to 15% for 3–4 mange-infected sections, to 40% when animals have more than six sections infected by mange.

Examining in more detail the activity of wombats in various mange-infected classes in relation to 6-h time periods showed a similar trend to the diurnal–nocturnal analysis. Here we found more detections in the 6 h after midnight for animals with few (<3) infected segments, but a greater relative number of more heavily infected animals (3–6 sections) prior to midnight (active in the early evening; log-linear period by mange class interaction: $\chi^2 = 73.1$, $df = 12$, $P < 0.001$). The air temperature at the time of wombat detections was generally higher (mean = 14.1 °C) for individuals with mange than animals without mange (10.5 °C; Kruskal–Wallis $H = 96.45$, $df = 1$, $P < 0.001$).

Wombats with no mange were also detected at the lowest air temperature (−2 °C) at which wombats were recorded. Twenty-percent of the wombats with no mange were recorded at 5 °C or less. In comparison the lowest 20th percentile of wombats with mange were at 10 °C or less, with one mange-infected wombat detected at minimum of 0 °C. The mange-infected wombats were more active at higher temperatures with 20% detected at air temperatures above 19 °C, and one from the highest temperature of 30 °C. In comparison, only 5% for non mange-infected wombats were detected at temperatures above 19 °C, and the highest temperature of a non mange-infected wombat was 24 °C.

Discussion

This study showed that mange in wombats is associated with a change in their seasonal and diurnal activity. Although most wombat detections in this study were at night, the wombats detected during daylight hours were more likely to have signs of mange. This effect was consistent whether we examined broad differences between night and day, or more detailed effects among six-hourly periods. We believe that the change in temporal activity patterns is associated with the effects of the disease. One possible reason for this change in diurnal behaviour is likely to be that mange-infected animals have a higher energy requirement necessitating the continuous search for food (Skerratt et al. 1999; Hartley and English 2005). However, wombats with severe sarcoptic mange are more active during the day and possibly eat less (Skerratt et al. 1999). The increased daylight activity by mange-infected wombats may also be related to the vision impairment of severely mange-infected wombats. A study of the activity of non mange-infected wombats showed an increase in activity at dusk with reduced activity close to dawn (Evans 2008). Our study showed that heavily infected wombats were more active before midnight and less infected wombats were active after midnight. One possible explanation for this difference in activity may be that if heavily infected wombats graze during the daytime they may not be able to continue to maintain activity through to dawn because of the physical demand imposed by the parasite (Skerratt et al. 1999; Hartley and English 2005).

At our study location, the availability of introduced grass species between the rows of blueberry plants within the orchard may have provided a seasonally attractive food supply, increasing wombat movements, and therefore reducing the energy required to search for isolated clumps of grasses in the surrounding forest. Both mange-infected and non-infected wombats in our study were significantly more active during the autumn months. We measured a spike in daylight activity in autumn, which was mostly attributed to mange-infected wombats, suggesting a possible greater transmission rate from infected to non-infected animals in the preceding months. Other studies have reported no difference in the size or location of home ranges, ranging behaviour or feeding areas across seasons between mange-infected and non-infected wombats (Skerratt et al. 2004b; Evans 2008). The increase, however, in the blueberry farm visitations in our study area suggests that the site was probably unique because there was either little competition between mange-infected and non-infected animals or any competition with macropods (Woolnough and Johnson 2000) during a period when food resources were declining with the onset of autumn, a period of increasing plant dormancy.

Wombats were detected across a wide range of air temperatures (-2°C to 30°C), but only mange-infected animals were detected at air temperatures above 24°C . This activity in warm to hot weather may contribute to the physiological stress resulting in the mange-related mortality. It is known that temperature and relative humidity directly affect the viability of mites, especially when they leave the host (Perez et al. 1997). Periods with low temperatures and high relative humidity levels are favourable for the parasites (Fain 1978; Arlian et al. 1984; Ibrahim and Abu-Samra 1987; Arlian 1989). It is worth noting that non-infected wombats in this study preferred cooler conditions, with 11°C the most frequently detected temperature. Preceding dry years have been considered as a possible explanation for the slow spread of sarcoptic mange in Sierra Nevada ibex populations (Perez et al. 1997). In our study, however, the year prior to the study was relatively dry (2006 – 884 mm, Bureau of Meteorology 2011) possibly explaining the relatively slow spread of the disease. In 2007 a relatively high summer rainfall coincided with increasing detections of mange-infected wombats in the following autumn months. Fig. 4 shows the rainfall recordings for the study area in 2007. That

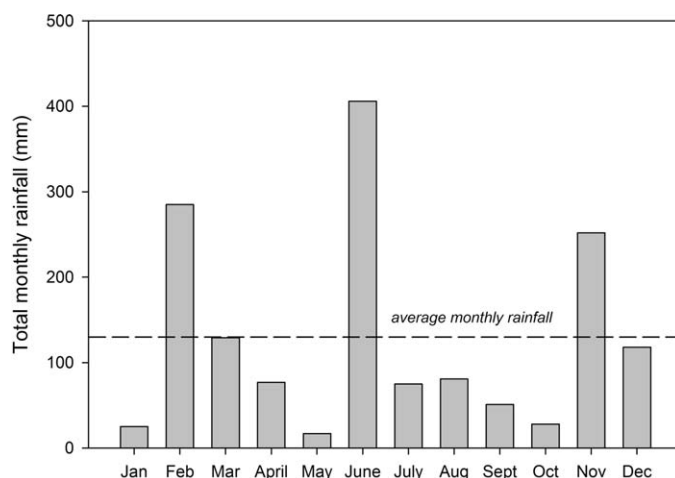


Fig. 4. Total monthly rainfall (mm) at study site in 2007.

only mange-infected animals were detected at temperatures above 24°C suggests to us that the association with air temperature may be influenced by their higher energy requirements and an unseasonal increase in food availability in the summer months (Hartley and English 2005).

Management implications

Until recently, our knowledge of the activity of mange-infected wombats has been gained generally by radio tracking a small number of mange-infected individuals (Skerratt et al. 1999). The camera trapping method used in this study provided an opportunity to assess the activity of a much larger number of mange-infected animals, simultaneously.

Sarcoptes mange has been identified as a major hazard to the viability of bare-nosed wombat populations (Hartley and English 2005), but this assessment is often based on opportunistic visual signs of mange-infected wombats. This study shows that it is possible to gain a misleading impression of mange prevalence from daylight observations. We suggest that monitoring of mange in wombat populations using motion sensing cameras offers a robust methodology for the assessment of the extent of infections. The extent of this disease is unknown, and we recommend that widespread disease surveillance be carried out, across points of their distribution. Given that the disease has fatal consequences, the need for clear information on this disease is urgent. The conservation of bare-nosed wombats from mange may need action to prevent another Australian vertebrate species joining the list of other species in major decline such as Tasmanian devils (*Sarcophilus harrisii*) in Tasmania (Jones et al. 2008).

At a broader scale, further research should focus on how the incidence of mange changes with populations in natural ecosystems. Additionally, we need to determine whether wombat grazing activity in managed agricultural land encourages the spread of mange. It is possible that in more natural settings the grazing pressure is more uniformly dispersed in quality and in wombat visitation. At a finer scale, the high activity of mange-infected wombats at the riparian/agricultural interface may provide an opportunity to develop a focused strategy to treat mange-infected wombats. In a previous study, Borchard and Wright (2010b) demonstrated that the movement of wombats through agricultural fencing could be controlled, in part, by strategically positioned swinging gates. An automatic application of an insecticide to the back of a wombat using a gate may effectively treat the wombat while breaking the cycle of the spread of the parasite. To avoid 'overdosing' individual animals, however, much preparatory work needs to be undertaken

to determine how often an individual wombat uses a gate as well as how many wombats share a gate.

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