Sarcoptic mange in Australian wildlife
Fact sheet

Introductory statement

Sarcoptic mange is an infection of the skin in mammals caused by the parasitic mite *Sarcoptes scabiei*. The parasite can infect both humans and animals, with the disease referred to as scabies and mange respectively. Sarcoptic mange is widely distributed, affecting over 100 species, spanning seven mammalian families. Signs of mange include intense scratching, skin reddening, skin thickening and hair loss. Severity of the infection and mortality rates vary depending on species and geographic location. The mite is invasive to Australia and is believed to have arrived about 200 years ago with European settlers and their domesticated animals. Since its introduction, *S. scabiei* has been documented in a number of native Australian species. Sarcoptic manage can have significant health and welfare impacts on individual animals and can result in the death of affected individuals. Sarcoptic mange has the most significant impacts on wombat populations and can cause local extirpation of populations. Increased management and population scale treatments may be required to protect isolated or small wombat populations.

Aetiology

Mange is caused by the sub-macroscopic (200-500 μm in length), obligate parasitic mite, *Sarcoptes scabiei* (Family *Sarcoptidae*) (Bornstein et al. 2001; Pence and Ueckermann 2002). The burrowing mite creates tunnels in the epidermis, as deep as the stratum germinativum, where adult mites, eggs, larvae, and nymphs can be found. In these tunnels, the mites consume the host's living cells and fluids.

Sarcoptes scabiei infects a variety of different mammalian hosts, and while mites that originate in different host species are morphologically indistinguishable in most cases, they do exhibit a degree of host specificity (Bornstein et al. 2001). The different strains, or varieties, of the mite represent a single, highly diverse species. Varieties are named according to their primary host species (e.g. wombat mange mite, *S. scabiei* var. *wombati*). Cross infection that perpetuates in new host species periodically occurs, although many cross infections are self-limiting.

Natural hosts

Available evidence indicates humans may be the original host of *S. scabiei* (Fraser et al. 2016). If this is correct, it is likely that the mite was historically transferred from humans to domestic animals, and further spilled over into wildlife. The disease affects over 100 mammalian species from at least 10 orders and 7 families, and continues to spread into new hosts, classifying it as an emerging infectious disease (Thompson et al. 2009; Tompkins et al. 2015).

Currently documented host orders include: *Artiodactyla, Carnivora, Diprotodonta, Hyracoidea, Insectivora, Lagomorpha, Perissodactyla, Pinnipedia*, Primates, and *Rodentia*. Some free-living species are particularly susceptible.

World distribution

Worldwide.

Occurrences in Australia

- *Sarcoptes scabiei* and subsequent mange infection is widespread throughout Australia. The mite is invasive to Australia and was likely introduced by European settlers and their domestic animals around 200 years ago (Fraser et al. 2016).
- Since its introduction, mange has spread into several native and non-native Australian mammals.
- Native Australian mammals affected by mange include common wombat (*Vombatus ursinus*) (Hartley and English 2005; Skerratt 2005), southern hairy-nosed wombat (*Lasiorhinus latifrons*), koala (*Phascolarctos cinereus*) (Obendorf 1983), agile wallaby (*Macropus agilis*) (McLelland and Youl 2005), swamp wallaby (*Wallabia bicolor*) (Holz et al. 2011), southern brown bandicoot (*Isoodon obesulus*) (Wicks et al. 2007), dingo (Thomson et al. 1992), long-nosed potoroo (*Potorous tridactylus tridactylus*), brushtail possum (*Trichosurus vulpecula*) and common ringtail possum *(Pseudocheirus peregrinus*).
- Introduced mammals affected include red fox (*Vulpes vulpes*), domestic dog (*Canis familiaris*), pig (*Sus scrofa*), horse (*Equus caballus*), and one-humped camel (*Camelus dromedaries*) (Bornstein et al. 2001; Pence and Ueckermann 2002; Henderson 2009).
- Sarcoptic mange is considered endemic in common wombat populations throughout their range (Martin et al. 1998), but may vary widely in its expression and impact on local populations. The disease is relatively common in invasive red fox populations, which may have a role in disease spread among species in areas where they co-occur.

Epidemiology

Mange infection rates can be high (up to 70%) in populations of common wombats (Martin et al. 1998), and possibly red foxes (Saunders et al. 2010). It may also persist in a stable endemic state. Population declines as a result of mange may be significant and endemic disease may slow, limit, or prevent recovery. Expression of disease may be seasonal in southern hairy-nosed wombats, which is thought to be due to seasonally adverse conditions (droughts) for mite survival, requiring annual re-introductions, possibly by foxes (Ruykys et al. 2009). Lower rates of morbidity and mortality appear to occur in other species in Australia.

Of the affected native Australian mammals, sarcoptic mange is of greatest impact to wombats. A survey conducted in the 1990s revealed mange to be present in 90% of common wombat populations (Martin et al. 1998). Prevalence within wombat populations is often low (≤ 15%), which could indicate low mortality or intraspecific transmission, or could be due to high mortality of infected individuals. Increased rates of mange disease are often associated with high wombat densities and periods of drought or high stress (e.g. seasonal stress in winter). During outbreaks, mange prevalence can rise to > 50%, with near 100% mortality.

Though not commonly considered an agent for extinction, mange can result in local population declines and extirpations, especially in isolated, naïve or small host populations (Pence and Ueckermann 2002). There are well-documented cases of mange outbreaks overseas driving localized host extinction (in red fox and chamois (*Rupicapra* spp.) populations). In Australia, mange has driven common wombat populations to the edge of localized extirpation, with documented outbreaks causing > 90% decline in wombat abundance (Skerratt 2005; Martin et al. 2018a).

For wombats, the first clinical signs of mange infection develop within 1 – 3 weeks of parasite exposure, with more severe signs appearing by 4 – 5 weeks (Bornstein et al. 2001). Death usually occurs as a result of secondary bacterial infection around 2 – 3 months after infection. The speed and intensity of disease progression is dependent on initial exposure dose (i.e. exposure density of mites) (Skerratt 2003b). In some cases, time to clinical signs for reinfection cases can be as little as 24 hours.

Transmission occurs through:

- direct contact with infected host with exposure to surface dwelling larvae and nymphs, and
- indirect contact through exposure to mites in the environment (Pence and Ueckermann 2002).

Direct transmission is most likely to occur when mite densities are high. High densities of mites (>1000 mites/cm^2) may occur within 2-3 weeks of infection. In the environment, mites are able to persist for up to three weeks when conditions are optimal (high relative humidity, 97%, and low temperature, 10-15°C), with two thirds of mites remaining infectious (Arlian et al. 1984a). Mites in the environment will also actively seek out new hosts, responding to both odour and thermal stimuli, and can migrate up to 15 cm to contact the host (Arlian et al. 1984b).

Most transmission of mites among wombats is thought to predominate through sharing of burrows, likely in the bedding chamber. Synchronous sharing of wombat burrows is infrequent due to the solitary nature of wombats, however, the longevity of mites in the favourable climate of the burrow allows for indirect transmission to occur. Wallabies likely contract mange from infected wombats living in close proximity. Anecdotal reports suggest wallabies periodically enter wombat burrows, making the burrows a pathway for their exposure. Transmission among red foxes can be via direct contact, or indirectly via den usage (Soulsbury et al. 2007). Foxes have been observed using wombat burrows, and may play an integral role in long distance transmission of the mite and seasonal reintroductions to southern hairy-nosed wombats.

Close contact is important for transmission in more gregarious species. Sarcoptic mange can be common among dingo and wild dog populations (Henderson 2009), with relatively low mortality in wild dog and dingoes (Fleming et al. 2001). Scabies mites from red fox can cross infect dogs, but the resulting infection is generally self-limiting (Bornstein 1991).

The severity of disease in wombats is believed to be associated with wombat physiology and their restricted energetic ecology. Mange-driven increases in energy expenditure have a dramatic effect in wombats, who have a typically conservative energy budget, low metabolic rate and graze for limited amounts of time on poor quality habitat compared to many other herbivores (Simpson et al. 2016; Martin et al. 2018b).

Outbreaks in free-living koalas are believed to have originated in feral foxes, although domestic dogs may also have been involved. Male koalas were over-represented in outbreaks, which may be due to their roaming and fighting behaviour. In contrast to wombats, case numbers in koalas were lowest in winter, possibly due to more abundant food resources, and hence more robust host physiology, at that time (Speight et al. 2017).

Clinical signs

For wombats, the first clinical signs of mange infection develop within 1 – 3 weeks of parasite exposure, with more severe signs appearing by 4 – 5 weeks (Bornstein et al. 2001). Death usually occurs as a result of secondary bacterial infection around 2 – 3 months after infection. The speed and intensity of disease progression may be dependent on initial exposure dose (i.e. exposure density of mites) (Skerratt 2003b).

Clinical signs vary, dependent on host species, level of host naivety to the mite, and overall health of the host (i.e. the host immunological state: compromised or not). General signs of mange include, but are not limited to, intense pruritus (itching), seborrhoea, erythematous eruptions, papule formation and alopecia (hair loss) (Bornstein et al. 2001; Pence and Ueckermann 2002). In more severe cases, there is often hyperkeratosis, thickening of the skin, fissuring and crusting. Host behavioural changes include lethargy, lack of awareness, changes in movement and disrupted circadian rhythm (Simpson et al. 2016). Infected individuals are often easily approached owing to these clinical and behavioural changes.

Clinical signs in wombats include erythema followed by adherent parakeratotic scale and then alopecia (Skerratt 2003a, 2003b). Time spent foraging increases in wombats as mange severity increases: healthy wombats spend 2-4 hours foraging, while mange infected wombats spend up to 14 hours foraging (Simpson et al. 2016). Other species in Australia tend to have less adherent parakeratotic scale than wombats. The parakeratotic scale initially appears as confluent sheets of dandruff. This may build up over time into an adherent crust up to 1 cm thick. Fissures develop in the crust and underlying epidermis resulting in exposure of the dermis, haemorrhage, bacterial infection and sometimes flystrike.

Skin changes in koalas resemble those of wombats, with distribution over distal parts of all limbs (in particular the interdigital areas) and the face (Speight et al. 2017).

Diagnosis

Clinical signs in commonly affected species can be highly suggestive of infection (Fraser et al. 2018). Diagnosis can be by examination by microscopy of deep skin scrapings. Samples collected from living or recently dead hosts can be gently warmed using a light source, causing the mites to become active and easily observed.

Skin scrapings and skin swabs (a less invasive technique) can be analysed by PCR for the presence of mites. The combination of skin scraping and PCR is considered the most sensitive diagnostic method (Fraser et al. 2018).

Skin samples can be stored in a 20% potassium hydroxide (KOH) solution, and digested in a hot water bath (37° C) for several hours. Resulting liquid can be centrifuged and sediment pellet can be observed under a microscope.

Enzyme-linked immunosorbent assays (ELISA) can be used to detect the presence of *S. scabiei* antibodies, and have been developed for several species, including dogs, red foxes and domestic cats (Bornstein et al. 2001; Pence and Ueckermann 2002).

Clinical pathology

Changes consistent with inflammation and emaciation.

Pathology

Epidermal inflammation, immediate and delayed type hypersensitivity dermal responses, secondary bacterial infections of the dermis and emaciation.

Figure 1: Wombat with sarcoptic mange. Note hair loss, thickened skin, skin fissures, and degraded body condition (emaciation). Photos Lee Skerratt.

Figure 2: Wombat after treatment. Note hair regrowth.

Laboratory diagnostic specimens

Deep skin scrapings (10 cm^2) or parakeratotic crust in 70% ethanol.

Laboratory procedures

Skin scrapings: Place a drop of mineral oil on a sterile scalpel blade. Skin scrapings should be taken from a papule, avoiding highly keratinized areas. Scrape papule rigorously, 5 – 8 times, until skin appears pink or blood begins to ooze. Place scraped material and oil onto clean slide for examination, or store in 70% ethanol.

Treatment

There is no accepted global standard treatment regime for mange in wildlife. Effective treatment of wild populations requires an understanding of the epidemiology of the parasite in the population, including transmission pathways and persistent sources of infection. The transmission pathway of *S. scabiei* is particularly important for treatment and prevention efforts, but is not well understood in many host species. For example, treatment of gregarious species where transmission is primarily through direct contact may require intensive population treatment, whereas treatment of solitary species with indirect transmission may include targeted treatments, barriers to pathogen movement, and elimination of environmental reservoirs.

Treatments previously used in wild hosts include a regime of repeated capture and injections of long-acting acaricides, removal of parakeratotic scale crust and systemic antibiotics (Skerratt 2005). More recent and less invasive approaches include the one-off or repeated administration of a topical acaricide. However, topical treatments may not reach mites due to a failure to penetrate parakeratotic scale crust or be adequately absorbed systemically due to a thickened epidermis.

Off-label parasiticidal drugs have been used on Australian wildlife. Moxidectin and Ivermectin have been tested and used effectively in wild wombats (Death et al. 2011), following a regime of weekly treatment for 8 - 12 weeks (Skerratt 2003b). Fluralaner (Bravecto®; MSD Animal Health), a novel isoxazoline class ectoparasiticide has been used more recently in wild common wombats with apparent success (Wilkinson et al. 2021).

Burrow fumigation may also be an option for eliminating mites from the environment (Gerasimoff 1958), but this technique has not been tested on *S. scabiei* in wombat burrows. There are both practical (e.g. determining that the fumigant reaches and kills mites) and ethical considerations (e.g. effects of fumigant on wombats) that warrant research before this technique should be considered.

Sarcoptic mange outbreaks in previously stable host populations are often left to progress without intervention and have been generally considered to have little effect on the long-term longevity of healthy host populations (Pence and Ueckermann 2002). However, the impacts on wildlife populations are rarely measured and are thus unknown in most cases. In isolated, fragmented, or genetically weakened populations there may be a risk of localized extinction (Martin et al. 2018a). Recent research suggests wombat populations can also persist despite mange being present (Carver et al. 2021).

Within Australia, there has been increasing interest, by the public and focus groups, in options for treatment of mange in free-living wombats. Several community groups are active in advocating treatment of wild wombats. The long-term success of such interventions has not been determined.

Mange Management (MM) (http://mangemanagement.org.au/) and the Wombat Protection Society (www.wombatprotection.org.au/mange-disease) recommend treatment with topical acaricides once weekly for eight weeks, followed by four fortnightly treatments. This treatment regime has been permitted by the Australian Pesticides and Veterinary Medicines Authority (APVMA) (http://permits.apvma.gov.au/PER82844.PDF). Recommended treatment methods are via a flap over the wombat burrow that doses the wombat as it exits or enters the burrow, or by direct pour-on application via a pole and scoop.

The Tasmanian Department of Primary Industries, Parks, Water, and Environment has information on their website https://dpipwe.tas.gov.au/wildlife-management/fauna-of-tasmania/mammals/possums-kangaroos-and-wombats/wombat/wombat-mange.

At times, with consideration to animal welfare, severely affected wombats may be euthanased. This generally occurs on an individual basis scenario by Parks and Wildlife staff (by firearm) or at local veterinary clinics. Mange Management (MM) advocate burial of the carcass following euthanasia to prevent pathogen spread.

Of the advocacy groups, MM and the WPSA have the broadest community outreach and highest engagement in treating wombats with sarcoptic mange. This includes engagement with government organisations and the scientific community. Treatment methods advocated by community groups are partially derived from the scientific literature (Skerratt 2003b; Death et al. 2011; Wilkinson et al. 2021); however, with increased community participation and unrequired follow-up with animal ethics committees, there is risk of unintentional failure to execute protocols effectively. The main risks include i) accidental overdosing of individual wombats, underdosing of individual wombats or missed repeat treatments, and ii) development of mite resistance arising from inadequate treatments. MM and WPSA have been awarded three year permits by the APVMA for off-label use of Cydectin (moxidectin) to treat mange in common wombats (http://permits.apvma.gov.au/PER82844.PDF). As part of this permit community groups are given responsibility for authorising other groups to engage in mange treatment programs involving Cydectin. Bravecto® is not currently licensed for use in wombats in Australia and, until an APVMA permit has been issued, Bravecto® can only be used to treat wombats under the direct supervision of a veterinarian. "Guidelines for the use of Fluralaner to treat sarcoptic mange in wombats" are available on the University of Tasmania website https://eprints.utas.edu.au/36130.

Two population level treatment experiments of mange in common wombats using 1-2ml/10kg Cydectin were undertaken by research groups in 2015-16 (Martin et al. 2019): the University of Tasmania at Narawntapu National Park, Tas; and a collaboration between The University of Sydney and the NSW Environment Protection Authority at Bents Basin National Park, NSW (publication in preparation). Both treatments utilized the burrow flap technique. Results of these population treatments suggest that the burrow flap method can be effective at population scales, but also highlight significant logistical challenges of treating all individuals in a population.

Reinfection of individuals can occur post-treatment if a) infected individuals remain; b) other untreated hosts continue to transmit the mite; or c) the mite remains viable and infectious in the environment through persistence or spillover from other hosts. Thus, further consideration of treating larger numbers of individuals in an area may be warranted. Continuous treatment regimes are discouraged, as prolonged exposure of the mite to treatment may result in mite resistance (Currie et al. 2004). Instead, burst treatments may be more appropriate.

Further information is available in the "National Mange Report" https://taswildlife.org/wp-content/uploads/2018/10/National-Mange-Report-V2.0-FINAL-5-October-2018.pdf and "Sarcoptic mange in wombats: a review and future research directions" (Old et al. 2018).

Prevention and control

Prevention of mange outbreaks in wildlife populations is difficult, unless all direct and indirect contact with hosts carrying the mite can be stopped. In the mainland Australia context, given the widespread occurrence of foxes, dingoes, feral and domestic dogs, prevention of mange is considered almost impossible unless at risk populations can be fully isolated from transmission pathways.

Outbreaks in populations that normally maintain low mange prevalence (8-20%) are often preceded by environmental stresses, such as droughts. However, these dynamics need additional research, as understanding which environmental variables result in population stress and subsequent outbreaks is crucial for control. For example, water and/or food supplementation may be a useful management method to reduce risk of mange outbreaks after a drought event.

Surveillance and management

There is no targeted surveillance program for sarcoptic mange in Australian wildlife and it is not a nationally notifiable animal disease. However, cases detected during general surveillance, in particular new reports for species or geographic areas, should be captured by the national surveillance system.

Surveillance also occurs in an *ad hoc* manner by wildlife and land managers, wildlife carers and advocacy groups, researchers, farmers, naturalists and biologists.

- WomSAT (wombat survey and analysis tools) is a community-driven program that documents wombat sightings, burrow locations, and mange status. The program was created by researchers at Western Sydney University primarily to map mange incidence across wombat ranges, as well as document other threats, such as road collisions. Community members can document wombat and burrow sightings through the WomSAT website (https://womsat.org.au/womsat/default.aspx), or using the mobile phone application.

- The Tasmanian Department of Primary Industries, Parks, Water and Environment established a Wombat Working Group in 2016 in response to concerns of mange in wombats. Goals of the working group include assessing the status of wombat populations, and distribution and severity of mange across the state, as well as providing advice to the community on treatment of wombats.
- The Australian Capital Territory government has also recently (2020) established a wombat mange working group involving researchers and community members.

Statistics

Wildlife disease surveillance in Australia is coordinated at a national level by Wildlife Health Australia. The National Wildlife Health Information System (eWHIS) captures information from a variety of sources including Australian government agencies, zoos and wildlife parks, wildlife carers, universities and members of the public. Coordinators in each of Australia's States and Territories report monthly on significant wildlife cases identified in their jurisdictions. NOTE: access to information contained within the National Wildlife Health Information System dataset is by application. Please contact admin@wildlifehealthaustralia.com.au.

In eWHIS, there are numerous reports of sarcoptic mange in wild common and southern hairy-nosed wombats, predominantly from Tas, Vic, SA and NSW. There are also reports in koalas from SA and Vic, in agile wallabies in the NT and in a swamp wallaby from Vic and an unidentified *Macropus* wallaby species. There are reports of sarcoptic mange in brushtail possums (multiple) in SA and a single common ringtail possum in Tas, a southern brown bandicoot from WA and a long-nosed potoroo (*Potorous tridactylus tridactylus*) from Tas.

Research

Further research is required in the following areas:

- Modes and degree of transmission between and within species
- Evolutionary history of mange mite in Australia
- Physical and behavioural impacts of mange on hosts
- Understanding dynamics of impacts of mange at the population level
- Understanding the environmental factors that exacerbate impacts of mange on host populations
- Understanding of the host immunological response to mange and other factors that determine the range of host species
- Distribution and monitoring of mange presence and prevalence within Australian mammal populations
- Clinical pathology associated with mange in the host
- Best treatment regimens for mange at an individual and population scale.

Human health implications

Human scabies contracted from wildlife is generally a self-limiting and short-term zoonotic disease. Infection from mites of animal origin often presents differently than infection from the human strain of scabies. Symptoms often dissipate within two weeks. In some cases, a hypersensitivity response occurs, resulting in greater levels of inflammation. Crusted scabies tends to occur only in immunologically compromised humans. Treatment can reduce duration of clinical signs of infection.

Conclusions

Sarcoptic mange is an emerging invasive disease in Australian wildlife, impacting wombats, dingoes, wild dogs, foxes, with occasional reports in koalas, wallabies and possums. The transmission of mange within and between host species is complex. Mange poses a particular threat to common and southern hairy-nosed wombats, where outbreaks can result in significant local population declines. The disease has been attributed to localized declines of common wombats throughout their range and may be in-part responsible for the overall range decline. There are significant welfare concerns with wild hosts and chronic mange infestations. Continued monitoring of the distribution of mange and prevalence in affected species, along with ongoing work on practical, ethical and effective treatments, are vital.

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To provide feedback on this fact sheet

We are interested in hearing from anyone with information on this condition in Australia, including laboratory reports, historical datasets or survey results that could be added to the National Wildlife Health Information System. If you can help, please contact us at admin@wildlifehealthaustralia.com.au.

Wildlife Health Australia would be very grateful for any feedback on this fact sheet. Please provide detailed comments or suggestions to admin@wildlifehealthaustralia.com.au. We would also like to hear from you if you have a particular area of expertise and would like to produce a fact sheet (or sheets) for the network (or update current sheets). A small amount of funding is available to facilitate this.

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