Fact sheet

Salmonella in Australian macropods

Introductory statement

Macropods are susceptible to infection with Salmonella bacteria, which may result in disease. Macropods may also harbour Salmonella without displaying clinical signs of disease (Samuel 1982). Much of the concern around Salmonella infection in macropods is linked to the possibility of zoonotic transmission to humans. Human salmonellosis is one of the most common and economically important zoonotic diseases in the world (OIE 2016). People may come into direct contact with macropods or their faeces in the urban environment, since kangaroos are commonly found grazing at local parks and golf courses, and wildlife carers often handrear orphaned joeys. There is a potential risk of Salmonella infection in both people and pets through handling and/or consuming kangaroo meat, as carcasses may become contaminated during harvesting and processing. Improved carcass handling procedures have significantly reduced the prevalence of Salmonella in harvested kangaroo meat (Bensink et al. 1991; Eglezos et al. 2007). There are currently no reports in Australia of humans acquiring Salmonella infection through the handling or consumption of macropod carcasses or meat products. There have been no confirmed reports of primary clinical disease in macropods in their natural habitat.

Aetiology (taxonomy and nomenclature)

Salmonella are gram-negative, rod-shaped bacilli belonging to the family Enterobacteriaceae, genus Salmonella (CFSPH 2013). Salmonella nomenclature is complex and evolving. Currently, the genus Salmonella consists of two species, S. enterica and S. bongori. S. enterica is further divided into six subspecies, which are referred to by a Roman numeral and a name (Brenner et al. 2000; OIE 2016). The individual names of each serotype may be used for identification; antigenic formulae are used for unnamed serotypes¹.

¹ At the first citation of a named serotype, the genus name is followed by the word “serotype” or the abbreviation “ser.”, then the serotype name. Subsequently, the name may be written with the genus followed directly by the serotype name. The serotype name is capitalised and not italicised.
Salmonellosis refers to clinical disease associated with *Salmonella* infection (in either humans or animals).

**Natural hosts**

*Salmonella* have been identified in species from all classes of vertebrates (fish, amphibians, reptiles, birds and mammals) and in invertebrates. Serotypes may have predilection for certain species (e.g. *Salmonella* ser. Choleraesuis usually infects pigs) or groups of organisms (e.g. *S. enterica* subsp. *arizonae* is usually found in cold blooded vertebrates). However, most *Salmonella* serotypes can infect a broad range of hosts (CFSPH 2013).

**World distribution**

*Salmonella* have a world-wide distribution, but appear to be most prevalent in areas of intensive animal husbandry, particularly where pigs, calves and poultry are housed in confinement (OIE 2016). *Salmonella* have been detected in opossums (marsupials; family Didelphidae) throughout the Americas (Kourany et al. 1976; Ruiz-Pina 2002; Villafañe et al. 2004; Jijón et al. 2007).

**Occurrences in Australia**

Within Australian macropods, *Salmonella* has been isolated most commonly from hand-reared joeys, pet kangaroos, kangaroos held in captivity and quokkas (*Setonix brachyurus*) (Iveson and Bradshaw 1973; Arundel 1981; Hart et al. 1985; Speare and Thomas 1988). *Salmonella* has been detected at low prevalence in wild western grey kangaroos (*Macropus fuliginosus*) populations (Potter et al. 2011).

*Salmonella* spp. in macropods reported to the National Enteric Pathogens Surveillance Scheme (NEPSS) have also been most frequently isolated from quokkas, kangaroos and wallabies. The majority of reports in kangaroos and wallabies have been of subspecies I serovars, with *S. Muenchen* and *S. Typhimurium* reported most frequently in kangaroos, and *S. Typhimurium* reported most frequently in wallabies. The majority of isolations from quokkas have also been of subspecies I serovars, with *S. Muenchen* and *S. Adelaide* the most frequently reported, although *Salmonella* subspecies II serovar Wandsbek has also been reported frequently (NEPSS 2018).

**Epidemiology**

*Salmonella* spp. are gut-associated bacteria that can be shed in the faeces either continuously or intermittently (CFSPH 2013). Studies on free ranging quokka and western grey kangaroos and on contamination of harvested kangaroo meat show that wild macropods are capable of harbouring the organism. Although theoretically possible under conditions of environmental stress, there have been no confirmed reports of primary clinical disease in macropods in their natural habitat and the morbidity and mortality rates of *Salmonella* infection in wild macropods is believed to be negligible (Speare et al. 1989; Eglezos et al. 2007; Iveson 2007; Potter et al. 2011).

In any species, faecal shedding of *Salmonella* is often intermittent and may not be related to the level of stress to which the animal is exposed. For example, healthy macropods (species unspecified) housed in hygienic, large, grassed enclosures were found to have higher rates of faecal shedding than macropods (at a different captive institution), that were regularly exposed to stress associated with handling, fighting and travel. Despite the introduction of a carrier kangaroo (actively shedding) to this latter group, all animals
remained negative. There were no differences in the prevalence (of either shedding or carriage) which could be attributed to the sex, age or species of macropod. Three agile wallabies (*M. agilis*) fed a dose of *S. Infantis* began shedding the organism within 24 hours, despite the absence of clinical signs (Samuel 1982).

The natural history of *Salmonella* in wild macropods has largely been studied in the quokka on Rottnest Island, off the coast of Western Australia (Iveson and Bradshaw 1973; Hart et al. 1985). Despite virtually all individuals showing evidence of faecal shedding throughout the summer months, no evidence of disease has been found in infected quokkas (Hart et al. 1985). On Rottnest Is, quokkas in better body condition were less likely to be subclinically infected with *Salmonella* (Iveson 2007). Whilst no gross or histological changes were noted at post mortem in experimentally infected agile wallabies, *Salmonella* was recovered from the walls of the ileum, caecum, stomach, stomach contents and mesenteric lymph nodes draining the intestine (Samuel 1983).

A study investigated prevalence of *Salmonella* in the faecal matter of western grey kangaroos harvested for consumption in WA and found only 3.6% of animals were positive. In the case of these animals, and the quokkas on Rottnest Is, no disease associated with the infection was detected (Iveson 2007; Potter et al. 2011).

Studies have demonstrated the presence of *Salmonella* carriage in a large number of healthy, captive macropods. Animals in captivity may be exposed to the organism as a result of consumption of contaminated feed or water (Samuel 1982).

Orphaned and hand-raised macropods (joey) are considered more likely to be infected with, and develop clinical disease from *Salmonella*, presumably as a result of poor immune status. Between 1981 and 1985, 65 live and 38 dead orphaned macropod joeys were sampled with 26.8% infected with *Salmonella* and 21.7% actively excreting the bacteria in faeces. The presence of *Salmonella* infection in orphaned joeys is considered to be significant for the individual animal (and associated carers) and a severely ill joey is likely to excrete more *Salmonella* than a healthy joey, with a likely greater zoonotic risk to the carers (Speare and Thomas 1988). Orphaned macropods taken in for hand-raising (particularly those in poor health) should be considered at high risk of carrying and shedding *Salmonella*.

**Clinical signs**

Most wild macropods and many captive macropods that are carrying *Salmonella* exhibit no clinical signs (Samuel 1982; Vogelnest and Woods 2008). Clinical signs, when present, include loose faeces (anywhere from soft and semi-formed through to haemorrhagic diarrhoea) in association with lethargy, anorexia and dehydration. These changes are not pathognomonic and other disease processes should also be considered. Animals may also be found dead with no observed ante mortem clinical signs. Orphaned joeys often present with abdominal pain characterised by teeth grinding and abdominal guarding.

**Diagnosis**

Diagnosis in macropods is based on isolation of the organism from aseptically collected tissue at necropsy or from faeces or rectal swabs. As individuals may be asymptomatic carriers, other evidence of disease compatible with salmonellosis must be present. Prior or current infection of animals by some serovars may be diagnosed serologically (OIE 2016), although this has not been reported in macropods. Carriers often harbour
the organism in their mesenteric and ileocaecal lymph nodes. *Salmonella* has been isolated less commonly from the urine, liver, lung, kidney, heart, abdomen and spleen of macropods (Yuill et al. 2001).

### Clinical and other pathology

In general, haematological and serum biochemical changes in macropods are not well correlated to the severity of underlying disease and results may be unremarkable despite significant bacterial infection. Fibrinogen may be increased with salmonellosis. Neutrophilia and lymphocytosis may be present, but absence of these changes does not rule out bacterial infection (Vogelnest and Woods 2008).

There are few descriptions of pathology associated with salmonellosis in macropods. Changes include focal hepatic necrosis with and without cholangitis, inflammation in the muscularis of the intestine, intussusception of the intestine and suppurative bronchopneumonia (Ladds 2009).

### Differential diagnoses

In captive macropods, differential diagnoses of salmonellosis include other causes of gastroenteritis and diarrhoea, including coccidiosis and campylobacteriosis (Vogelnest and Woods 2008). Toxoplasmosis should be considered in the event of acute death. *Strongyloides* may cause diarrhoea and death (Winter and O'Connor 1957; Arundel 1981). In hand-reared joeys, physiological stress, coccidiosis, yeast/candidiasis, roundworms, antibiotic administration and cryptosporidia are all differential diagnoses of diarrhoea (Mason 2007). Other causes of bacterial diarrhoea, including *E. coli* and *Klebsiella*, should also be considered (Booth 2002).

### Laboratory diagnostic specimens

There are numerous methods for detection of *Salmonella*. In macropods, culture is the most common method of diagnosis and is used to isolate *Salmonella* from tissues collected aseptically at post mortem or from faecal and rectal swabs (Iveson 2007; Potter et al. 2011). Some studies have used PCR as the first method of detection, followed by culture to confirm and further characterise the diagnosis (Eglezos et al. 2007). The relative yield of *Salmonella* isolates in faecal material is greater than from rectal swabs (Hart et al. 1982). Lymph nodes, primarily the mesenteric, commonly harbour *Salmonella* in carrier animals, even when they are not shedding and are particularly useful tissue samples to collect at post mortem. *Salmonella* has also been isolated from ileocaecal lymph nodes, liver, lung, urine kidney, spleen and gall bladder (Samuel 1982; Yuill et al. 2001). Samples should be collected as aseptically as possible during the acute phase of disease or as soon after death as possible. It is also preferable to collect samples prior to the commencement of any antibiotic treatment (OIE 2016).

### Laboratory procedures

Isolation of *Salmonella* can be accomplished using a variety of culture techniques. Success can be increased by employing pre-enrichment to resuscitate sub-lethally damaged organisms, adding inhibitory substances to enrichment media to suppress competing organisms and using selective plating agars, which allow *Salmonella* to be differentiated from other enterobacteria. Care must be taken when selecting an enrichment media as some can be toxic to certain *Salmonella* serovars. More detailed information on the culture of *Salmonella* can be obtained from the ‘Manual of diagnostic tests and vaccines for terrestrial animals’ (OIE 2016).
Other forms of *Salmonella* detection include immunomagnetic separation (IMS), electrical conductance/impedance and PCR. Serological tests to detect infected herds/flocks include the serum agglutination test (SAT) and ELISA (Wynwood et al. 2016), however their use has not been reported in macropods.

**Treatment**

There are no published reports of the efficacy of antibiotics in the treatment of *Salmonella* infection in macropods. Culture and sensitivity is likely to provide a useful means of determining the most effective antibiotics. For clinically affected animals, analgesia is recommended if abdominal pain is apparent, as well as supportive care in the form of SC or IV fluids and removal of stressors (Vogelnest and Woods 2008). There is no requirement to treat asymptomatic infection in macropods, although the potential disease risk to the host, and to humans and other animals, should be considered and managed, through appropriate hygiene practices (see below).

**Prevention and control**

Minimising physiological stress is key to preventing and controlling *Salmonella* spp. in macropods in captivity, especially joeys in care (Booth 2002; Vogelnest and Woods 2008). Strict hygiene, including handwashing, hygiene of pouches, feeding equipment and the environment should be maintained whenever joeys are in care. Macropods in care or captivity should not have direct or indirect contact with domestic or feral animals. *Salmonella* are susceptible to many disinfectants and can also be killed by moist heat (121°C for a minimum of 15 min) or dry heat (160-170°C for at least 1 hour) (CFSPH 2013).

Hygiene should be maintained during processing of kangaroo carcasses. General food safety practices should be followed when handling and storing kangaroo meat to avoid contamination of other foodstuffs. Thorough cooking of meat intended both for human and pet consumption will also reduce the risk of *Salmonella* infection (Potter et al. 2011).

**Surveillance and management**

Wildlife disease surveillance in Australia is coordinated by the Wildlife Health Australia. The National Wildlife Health Information System (eWHIS) captures information from a variety of sources including Australian government agencies, zoo 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.

Since 1978, the National Enteric Pathogens Surveillance Scheme (NEPSS) has collected data on human and non-human isolations of enteric bacterial pathogens in Australia, including information on *Salmonella* serotypes identified in Australian animals and wildlife. Reports of isolates are voluntarily submitted by the five laboratories capable of serotyping and phage typing *Salmonella* within Australia. *Salmonella* isolates are submitted to these laboratories by primary diagnostic laboratories throughout the country.

to food products. Results are announced quarterly, and annual reports have been published in *CDI* since 2002 and their “Human and Non-human Annual Reports” are available on their website or on request.

Cases of *Salmonella* infection and of disease associated with the presence of *Salmonella* in macropods are reported in eWHIS, primarily in hand-raised juveniles.

**Statistics**

WHA provides reports on wildlife isolates to the NEPSS, which maintains a summary database of *Salmonella* isolates from wildlife in Australia. This is a valuable resource for Australia and people seeking detailed information on *Salmonella* isolates from wild animals in Australia are referred to this source.

**Research**

Iveson et al. (2007) identified a need to better understand the source of infection of *Salmonella* in free living Australian mammals. Potter et al. (2011) investigated the prevalence and speciation of *Salmonella* in western grey kangaroos in WA. Similar work on other species of macropods (and other Australian native mammals) across Australia would provide a better picture of the natural levels of asymptomatic infection in these animals. The potential for these animals to act as a zoonotic source of *Salmonella* was identified by Thomas et al. (2001), who saw a need for more investigations into human cases to examine contact with domestic and wild animals and animal products.

**Human health implications**

Various *Salmonella* serotypes that have been isolated from macropods are also documented human pathogens (Iveson and Bradshaw 1973; Yuill et al. 2001). Three main potential routes of *Salmonella* transmission from Australian macropods to humans have been identified. On Rottnest Is, with *Salmonella* prevalence in quokkas reaching nearly 100% at certain times of year, combined with the close proximity of the macropods to human visitors, there is concern of transmission via faecal contamination. Cases of human salmonellosis with the same serovars as those identified in quokkas have been traced back to the island (Iveson 2007). Transmission to humans in other areas of the country where there is extensive macropod faecal contamination (e.g. some parks and public spaces) is also possible, but has not been reported. An outbreak of *Salmonella* Java in humans was linked to indirect exposure to the faeces of long-nosed bandicoots (*Perameles nasuta*) (Staff et al. 2012).

Close contact between wildlife carers, owners of pet kangaroos or zoo keepers and macropods is a potential route of zoonotic exposure to *Salmonella* in Australia. Orphaned joeys in particular are considered a significant risk as they experience physiological stress related to sudden loss of their mother, a change in nutrition and unaccustomed exposure to humans and possibly other animals. Appropriate risk management measures should be used when caring for orphaned macropods (e.g. excellent hygiene, minimising all other stressors).

Kangaroo meat intended for human and pet food consumption is the third potential route of human exposure. Whilst early studies reported contamination rates as high as 44.9% (Suzuki et al. 1967), enforced regulatory standards within the industry have seen this figure decrease significantly. More recent studies have reported contamination rates between 0.84% and 18% (Bensink et al. 1991; Eglezos et al. 2007; Holds et
Post processing measures, such as thorough cooking of kangaroo meat prior to consumption, also reduces the likelihood of transmission through the oral route.

Conclusions

Salmonella infections in production animals (such as chickens and pigs) are considered to be a major source of salmonellosis in humans. Macropods have not been linked to cases of human salmonellosis, however these animals do present a potential risk of infection both to people and pets. Macropods in the wild are capable of harbouring Salmonella and studies have demonstrated that high rates of infection occur in orphaned joeys and some captive macropods. Although there are no reports in Australia of humans acquiring Salmonella infection through the handling or consumption of macropod carcasses, meat products or hand-raised macropods, it is important for all individuals coming into close contact with macropods, or kangaroo meat products to practice appropriate hygiene measures at all times.

References and other information


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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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