Wildlife Health Australia

Salmonella infection and Australian reptiles

Fact sheet

Introductory statement

Salmonella spp. are commonly detected in captive and free living reptiles, and may be present in both healthy and diseased individuals (Schumacher 2006; Jacobson 2007). In many situations the precise role of these bacteria in reptile illness and death may be difficult to determine (Ladds 2009). *Salmonella* are considered pathogenic for a wide range of both warm-blooded and cold-blooded vertebrates and salmonellosis, or disease resulting from infection with *Salmonella* species of bacteria, is the most widely recognised zoonotic disease associated with reptiles (Johnson-Delaney 1996; Scheelings et al. 2011). Due to the high prevalence of enteric *Salmonella* in both healthy and diseased reptiles and the ability of these bacteria to cause significant disease in humans and a wide range of animals, all reptiles presented for treatment, care or study should be regarded as potential carriers or shedders of *Salmonella*.

Aetiology

Salmonella spp. are gram-negative, rod-shaped bacilli belonging to the family *Enterobacteriaceae* (CDC 2017). *Salmonella* nomenclature is complex and evolving (Brenner et al. 2000). 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 and these are then further divided into serotypes (Brenner et al. 2000; OIE 2016)[1].

Recent studies examining *Salmonella* spp. serotypes in groups of free living and captive reptiles both within Australia and the United States identify *S. enterica* subsp. *enterica* and *S. enterica* subsp. *diarizonae* as the most common isolates (Scheelings et al. 2011; Clancy et al. 2016).

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[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.

Natural hosts

Salmonella have been identified 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 taxa (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).

All reptiles, captive and free living, are considered to be potential carriers and shedders of *Salmonella*. although evidence is emerging both in Australia and overseas that some reptile taxa appear more likely to be infected with *Salmonella*, with some free-living species appearing unlikely to carry *Salmonella* (Scheelings et al. 2011; Clancy et al. 2016). Work by Scheelings et al. (2011) failed to find *Salmonella* in 60 free living, freshwater turtles and 48 free living southern water skinks (*Eulamprus heatwolei*), indicating that some wild Australian reptile species may not be natural carriers of this pathogen.

World distribution

Salmonellosis occurs worldwide in a wide range of warm blooded and cold blooded vertebrates, including reptiles (CFSPH 2013). It appears to be most prevalent in areas of intensive animal husbandry, particularly where pigs, calves and poultry are housed in confinement (Ladds 2009; Scheelings et al. 2011; OIE 2016).

Occurrences in Australia

Several studies have examined the prevalence of *Salmonella* in wild and captive reptiles in Australia. Lee and Mackerras (1955) isolated *Salmonella* from healthy and sick eastern bearded dragons (*Pogona barbata*) in a captive colony, suggesting a reservoir of infection in reptiles. A review of diagnostic records in Queensland, in which *Salmonella* of diverse serotypes were isolated from a variety of reptile species, reinforced this finding (Thomas et al. 2001).

Between January 2007 and June 2008, Scheelings et al. (2011) studied the prevalence of *Salmonella* in reptiles admitted to the Animal Wildlife Health Sanctuary, Healesville Sanctuary, Victoria, as well as those within the sanctuary collection, from private collections and caught during field trips. Results showed captive reptiles (46.9%) were significantly more likely to carry *Salmonella* than their wild counterparts (12.1%). Snakes (captive and wild) had the highest prevalence (69.2%), followed by lizards (21.7%) and turtles/tortoises (0.02%). Interesting findings amongst the free living reptiles included lowland copperhead snakes (*Australaps superbus*) of which 69.2% were positive, some shedding multiple serovars, and lace monitors (*Varanus varius*) of which 30.1% were positive, with 11 of the 17 positives captured in a garbage dump.

In May 2011, McLelland et al. (2015) tested 138 free living reptiles from the Kimberley region of Western Australia for *Salmonella* with positive results in 50.0% of snakes, 39.6% of lizards and 20.0% of turtles. The most common isolate was *Salmonella* Rubislaw. These reptiles came from areas with minimal contact with humans and domestic species, indicating wild reptiles are natural carriers.

Since its establishment in 1978, the National Enteric Pathogens Surveillance Scheme (NEPSS) has received over 2800 reports of *Salmonella* isolates from captive and live reptiles in Australia. Farmed crocodiles are not included. Most reports are of subspecies III serovars (mainly subspecies IIIb) and subspecies I serovars, with low numbers of subspecies II and subspecies IV. The most common subspecies I serovars reported were *Salmonella* Typhimurium, *Salmonella* Muenchen, *Salmonella* Adelaide, and *Salmonella* Paratyphi B biovar Java. The most common subspecies IV serovar reported was *Salmonella* Houten (NEPSS 2018).

Infection with *Salmonella* in reptiles is not an OIE listed disease and is not a nationally notifiable disease.

Epidemiology

In general, reptiles are asymptomatic carriers of *Salmonella* in the gastrointestinal tract where it is considered by some to be part of the normal gut flora (Schumacher 2006; Jacobson 2007). *Salmonella* can be shed in the faeces either continuously or intermittently (CFSPH 2013). Invasion of the pathogen beyond the GI tract into other tissues (where it can cause overt disease) appears to occur when other factors allow it to penetrate the mucosal barrier of the intestine. These factors include stressors such as parasitism, trauma, inappropriate husbandry and other infectious disease (Ladds 2009; Scheelings et al. 2011). Transmission of the organism commonly occurs by direct contact or the faecal/oral route (CFSPH 2013).

Various factors have been associated with higher *Salmonella* shedding and/or illness by reptiles, including species group, diet and environment. Snakes appear more likely to shed *Salmonella* and be ill from the infection than lizards and turtles/tortoises (Scheelings et al. 2011; Clancy et al. 2016). Reptiles with a carnivorous diet are more likely to shed bacteria than those that are insectivorous or vegetarian, and in some cases being carnivorous is associated with a higher risk of *Salmonella* associated illness (Scheelings et al. 2011; Clancy et al. 2016). Environment also plays a role: in a study Scheelings et al. (2011), captive reptiles demonstrated higher levels of shedding than free living; in a study of zoo reptiles in Denmark, those in the education unit were more likely to be shedding *Salmonella* than those in display enclosures (Hydeskov et al. 2013); and reptiles with a history of confiscation were more likely to become ill with *Salmonella* in a study at the Bronx Zoo (Clancy et al. 2016). Shipping, overcrowding and suboptimal environmental conditions are also associated with increased shedding (Schumacher 2006).

Clinical signs

The majority of reptiles positive on culture for enteric *Salmonella* display no signs of disease (Jacobson 2007). Reptiles that develop salmonellosis commonly show signs of septicaemia (characterised by anorexia and listlessness), pneumonia, coelomitis and hypovolaemic shock. Osteomyelitis, osteoarthritis, necrotising enteritis and subcutaneous and internal granulomas or abscesses are reported (Jacobson 2007; CFSPH 2013).

Bone infections have been seen in snakes, with progression to death in some cases (Isaza et al. 2000; Ramsay et al. 2002). In a free-living population of turtles, clinical signs including emaciation, lesions of the plastron, discoloured carapace and intestinal, respiratory and hepatic lesions were attributed to *Salmonella* infection (Dodd 1988).

Diagnosis

Diagnosis of enteric carriage of *Salmonella* is based on microbiological culture or PCR of cloacal swabs (Mitchell 2006). As *Salmonella* spp. are often shed intermittently in the faeces of reptiles, it may be challenging to confirm that an individual live reptile is free of *Salmonella* infection. Bacterial culture of faecal specimens from pet reptiles to determine *Salmonella* infection status is discouraged, as false negatives are common and misleading (Mitchell 2006; CFSPH 2013).

Diagnosis of disease resulting from *Salmonella* infection in reptiles is based on a combination of clinical history, signs, sampling for bacteriology and supportive investigations such as haematology and imaging. It may be difficult to interpret the clinical significance of *Salmonella* in a sick reptile (Clancy et al. 2016).

Clinical pathology

Haematological data in reptiles is difficult to interpret given the lack of normal reference values. General changes may be seen in various bacterial infections, including *Salmonella*, but these can also occur with other diseases. Included are anaemia, which tends to be regenerative in cases of septicaemia and non-regenerative with more chronic infections, and variation in the white blood cell count. Heterophils may be increased or decreased, with or without increased immature cells (left shift), and azurophils, lymphocytes and monocytes may be increased. A normal leukogram can also occur. Thrombocytopaenia can occur in cases of severe septicaemia (Stacy et al. 2011; Nardini et al. 2013).

Pathology

Necropsy lesions are not pathognomonic in reptiles with clinical salmonellosis and visible changes may be confounded by concurrent disease. Animals may be in good body condition or debilitated. Severe diffuse or focal hepatitis with enlargement, paleness or mottling of the liver, excess serous or blood-stained fluid in body cavities, subcutaneous oedema and haemorrhages are indicative of *Salmonella* spp. related septicaemia (Ladds 2009).

Microscopic changes may be obscured by rapid autolysis. Typical changes include focal hepatic necrosis, tissue infiltration by mononuclear cells, myocarditis and fibrinous epicarditis. Gram-negative bacteria, sometimes intracellular, are present in necrotic areas in the liver or throughout the body. In more chronic cases, intestinal granulomas may form, sometimes leading to obstruction (McCracken 1994; Ladds 2009).

Differential diagnoses

Any cause of sudden death, diarrhoea, listlessness or anorexia. Many infections in reptiles are asymptomatic.

Laboratory diagnostic specimens and procedures

Swabs from faecal cloacal (or enteric at necropsy) samples for bacterial culture and/or PCR. Samples for *Salmonella* culture may need transport media, so contact the submitting lab prior to collection. Blood should be collected for haematology, biochemistry and blood culture, as well as bacterial culture of lesions, if indicated, in sick individuals (Paré et al. 2006).

Treatment

Veterinarians should be discouraged from treating healthy reptiles with antibiotics to eliminate *Salmonella* spp. from the intestine. Attempts to treat reptiles with antibiotics to eliminate *Salmonella* carriage or to raise *Salmonella*-free reptiles have been unsuccessful. Antibiotics can favour the persistence of *Salmonella* in the intestines after recovery, affect the intestinal flora, and increase the emergence of antibiotic-resistant strains (CFSPH 2013; Clancy et al. 2016).

In sick reptiles, fluid replacement, correction of electrolyte imbalances and other supportive care, such as heat, is important. Septicaemic salmonellosis may be treated with a number of antibiotics including ampicillin, amoxicillin, gentamicin, trimethoprim/sulfamethoxazole, third generation cephalosporins, chloramphenicol and fluoroquinolones (CFSPH 2013). Many isolates are resistant to one or more antibiotics, and the choice of drugs should, if possible, be based on culture and antimicrobial susceptibility testing. In many cases, however, antibiotics are not successful, with infection resurging even after months of treatment (Ramsay et al. 2002; Clancy et al. 2016).

Prevention and control

As a general rule, all reptiles should be considered to be potential sources of *Salmonella.* In most cases, elimination of *Salmonella* infections is impractical, and control is limited to preventing clinical disease and/or the transmission of bacteria to humans.

Scheelings et al. (2011) and Clancy et al. (2016) identified husbandry issues including cleanliness and appropriateness of enclosures and stressful events such as handling and co-housing of reptiles as risk factors for shedding of *Salmonella* and development of clinical salmonellosis. These findings emphasise that the impacts of *Salmonella* infection in reptiles can be decreased by good hygiene and minimising stressful events.

Salmonella spp. are susceptible to many disinfectants including 1% sodium hypochlorite, 70% ethanol, 70% propanol, 2% glutaraldehyde, iodine-based disinfectants, phenolics, peracetic acid, hydrogen peroxide, quaternary ammonium compounds and formaldehyde. They are susceptible to ozone but resistant to nitrites. They 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).

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, 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* in Australia. *Salmonella* isolates are submitted to these laboratories by primary diagnostic laboratories throughout the country.

Statistics

Information on *Salmonella* reports from reptiles in Australia is collected by the NEPSS.

The National Wildlife Health Surveillance Database holds a number of cases of *Salmonella* in reptiles. Most cases involve captive reptiles, but a significant number involved free living animals. Host species commonly reported include pythons, breaded dragons, skinks, and to a lesser extent crocodiles, marine turtles and elapids. Presentation ranges from asymptomatic to systemic signs such as weakness, lethargy and emaciation.

The Australian Registry of Wildlife Health holds a number of records of *Salmonella* spp. causing illness in reptiles including ten cases in snakes and seven in lizards between the years of 1998 and 2017, but none in turtles and tortoises. All cases are in captive animals. Detailed case records, blocks and glass slides are held in the Australian Registry of Wildlife Health (http://arwh.org/).

Research

Continuing research, (following, for example, the approach of Scheelings et al. (2011), who examined incidence and epidemiology of *Salmonella* spp. in captive and free-living reptiles in Victoria) is required to better understand the roles of this pathogen in reptiles in other areas of Australia. Additional questions recently raised in the literature include examination of the risk of *Salmonella* infection from frozen whole prey and assessment of husbandry factors in risk of shedding and illness (Scheelings et al. 2011; Clancy et al. 2016).

Human health implications

Salmonellosis is a zoonotic disease and acquisition of *Salmonella* spp. infection from reptiles is considered the most likely route for zoonotic salmonellosis. Pet owners and their families, zoo keepers, researchers and veterinarians are considered at risk of infection. In humans, salmonellosis varies from a self-limiting gastroenteritis to invasive infections that can lead to septicaemia. Salmonellosis acquired from reptiles is often severe, and may be fatal due to septicaemia or meningitis (Johnson-Delaney 1996; AVMA 2016).

With the growth of reptiles as pets in the second half of the 20th century, cases of zoonotic salmonellosis from exposure to fresh water turtles rose significantly according to US data (Johnson-Delaney 1996). More recently, the US CDC reports outbreaks of *Salmonella* Cotham and *Salmonella* Kisarawe in humans related to pet inland bearded dragons (*Pogona vitticeps*), *Salmonella* Muenchen from pet crested geckos (*Correlophus ciliatus*) and *Salmonella* spp. related to small turtles (AVMA 2016; CDC 2017).

Most cases of reptile-associated salmonellosis are seen in children under 10 and people who are immunocompromised. Children who have contact with reptiles as pets, or through zoo education programs are considered particularly at risk unless appropriate personal hygiene measures (thorough hand washing) are followed (CFSPH 2013; AVMA 2016).

Conclusions

Salmonellosis is the most important zoonotic disease of reptiles. Humans who handle or have contact with reptiles, or who provide reptile contact programs for members of the public, including children, should be aware of the risk of zoonosis. Ongoing, systematic sampling for *Salmonella* spp. in both captive and wild animals, healthy and sick, is required to assess the prevalence of the organism in Australian herpetofauna.

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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. Negative data are also valuable. 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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Wildlife Health Australia

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