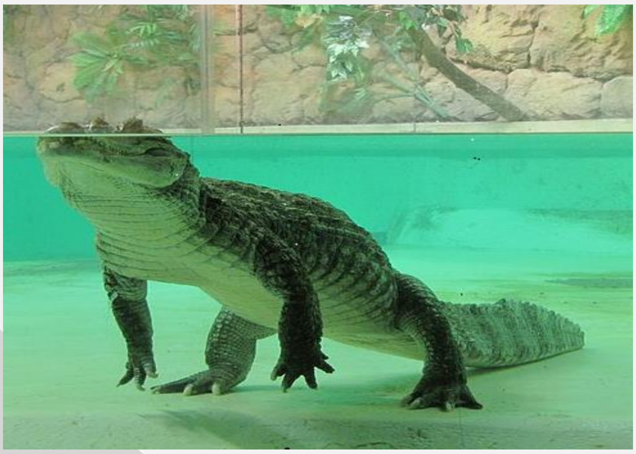
Biosecurity New Zealand

Tiakitanga Pūtaiao Aotearoa

Import risk analysis:

Crocodilia from Malaysia, Singapore, Indonesia, Thailand, Papua New Guinea, northern Australia and the European Union

Draft approved for IHS development



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Version 2.1

March 2019

Approved for public consultation

Steve Hathaway
Director, Science and Risk Assessment
Ministry for Primary Industries

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1.0	First peer-reviewed version	September 2018
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New Zealand is a member of the World Trade Organisation and a signatory to the Agreement on the Application of Sanitary and Phytosanitary Measures ("The Agreement"). Under the Agreement, countries must base their measures on an International Standard or an assessment of the biological risks to animal or human health.

This document provides a scientific analysis of the risks associated with importing Crocodilia from specific countries. It assesses the likelihood of entry, exposure and consequences of organisms should they establish in New Zealand. This biosecurity risk analysis has undergone internal and external technical review.

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1 Executive summary

This risk analysis considers the biosecurity risks associated with the importation of captive hatched and reared, saltwater and freshwater Crocodilia from the European Union (for the purposes of this document referred to as the European Zone), and Malaysia, Singapore, Indonesia, Thailand, Papua New Guinea and northern Australia (collectively referred to as the 'Malaysian Zone').

From a preliminary list of organisms and diseases of concern (potential hazards) associated with crocodilians, sixteen organisms were identified as hazards. Of these, seven (*Chlamydia* spp., coccidia, *Crocodillocapillaria longiovata*, *Paratrichosoma* spp., Ascaridoid nematodes, Dracunculoidea, and trematodes) were assessed as negligible risks on the basis of demonstrated host specificity.

The remaining nine organisms (*Herpesvirus-like viruses*, Poxviruses, *West Nile Virus*, *Edwardsiella tarda*, *Salmonella* spp., *Trichinella papuae*, Pentastomes, *Amblyomma* spp. and the leech, *Placopdelloides stellapapillosa*) were subjected to individual risk assessments.

The risk assessment identified *Edwardsiella tarda*, *Amblyomma* spp. and the leech, *Placopdelloides stellapapillosa* as moderate risks. Risk mitigation options are described for these organisms.

2 Introduction

Zoological Gardens wish to import freshwater Crocodilia for display in their collections as part of a species conservation advocacy programme and may decide to import saltwater Crocodilia at a later stage. Information on the potential hazards from the species of primary interest, *Tomistoma schlegelii* (False gharial) is scarce. Consequently, this risk analysis covers all potential hazards reported from all species of freshwater and saltwater Crocodilia from the geographic regions defined in the commodity definition below.

As the Crocodilia are to be held in containment in zoos in New Zealand, the primary responsibility for crocodile health rests with prospective importers. This risk analysis focuses on the diseases that may be contagious or infest other animals, or adversely affect human health and the environment.

3 Scope

The scope of this qualitative risk analysis is the assessment of the likelihood and consequences of pathogenic agent entry, exposure and establishment that may be associated with Crocodilia (freshwater and saltwater) imported to New Zealand from the geographic regions defined in the commodity definition below.

New Zealand is a signatory to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and international trade in Crocodilia is controlled through this convention. New Zealand's obligations under CITES are implemented through the Trade in Endangered Species Act 1989. However, as indicated above, this risk analysis is concerned only with the biosecurity risks associated with the importation of live Crocodilia.

On arrival in New Zealand, Crocodilia will be housed in a zoo transitional facility. All physical, structural and operational requirements as set out in the Zoo Animals Transitional Facilities standard (https://www.biosecurity.govt.nz/dmsdocument/32662/loggedIn accessed 6 March 2019) must be met in order to obtain biosecurity authorisation into the containment facility. Once authorisation is obtained, Crocodilia will be moved into the containment facility which must meet the Standard for Zoo Containment Facilities (https://www.biosecurity.govt.nz/dmsdocument/1623/loggedIn accessed on 6 March 2019). That standard describes the requirements for building, maintaining, and operating zoo containment facilities to hold new organisms. It is approved by the Environmental Protection Authority under the Hazardous Substances and New Organisms Act 1996 and is enforced by MPI under the Biosecurity Act 1993.

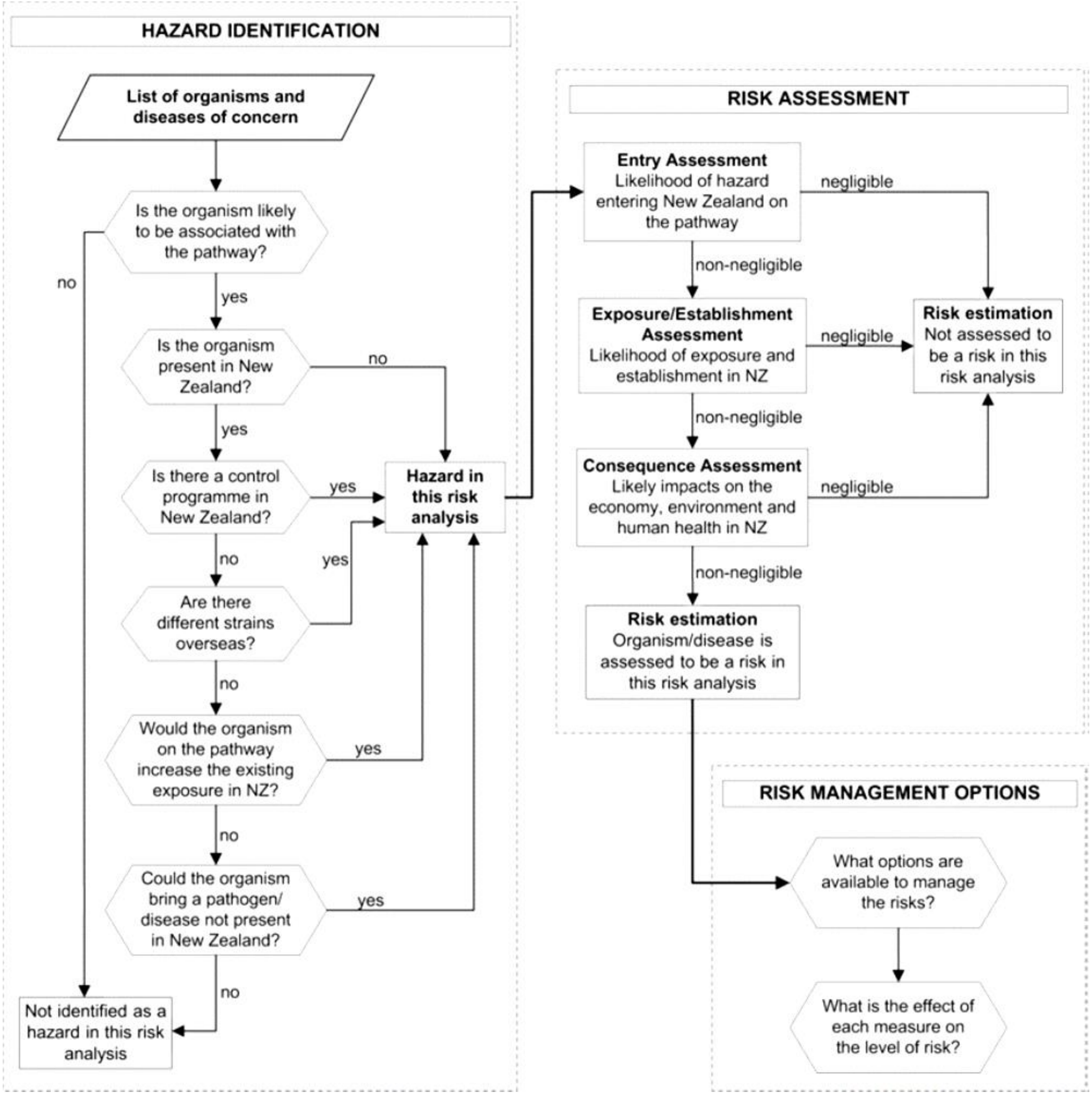
4 Commodity definition

The commodities covered in this risk analysis are freshwater and saltwater animals in the Order Crocodilia which have been hatched and reared in captivity in the European Union, (referenced in this document as the 'European Zone"), and Malaysia, Singapore, Indonesia, Thailand, Papua New Guinea and northern Australia, (collectively referenced in this document as the 'Malaysian Zone'), and which are clinically healthy and free from visible soil contamination.

5 Risk analysis methodology

The methodology used in this risk analysis follows the guidelines as described in Biosecurity New Zealand - Risk Analysis Procedures, Version 1 (2006) and in Section 2 of the OIE's *Terrestrial Animal Health Code* (2018). The key elements are shown below in Figure 1.

Figure 1. Risk analysis process



5.1 HAZARD IDENTIFICATION

A preliminary list of organisms and diseases of concern (potential hazards) was compiled from those contagious diseases of Crocodilia identified from searches of the international scientific literature in the:

1. "Web of Science" Internet-based research database of scientific publications
2. Reptile Medicine and Surgery. Mader, D.R. 1996. Saunders Elsevier
3. Reptile Medicine and Surgery, Second Edition. Mader, D.R. 2006. Saunders Elsevier
4. Crocodiles. Biology, Husbandry and Diseases. Huchzermeyer. F.W. 2003. CABI Publishing

5. Import Risk Analysis for Live crocodilians and their Eggs. 2000. Australian Quarantine & Inspection Service.

6. Import risk analysis: Crocodilia and eggs of Crocodilia from Australia. 2007. Biosecurity New Zealand.

From all organisms recorded in Crocodilia, the preliminary list of organisms (potential hazards) were identified and are listed in Table 1 (pp 9 – 24). Searches for potential hazards included the countries and regions of the European and Malaysian Zones as defined in the commodity definition above.

As detailed in Section 2, the hazard identification step involves the application of specific criteria to eliminate those potential hazards that do not constitute any risk to New Zealand. The hazard identification section concludes with an assessment of whether the organism is identified as a hazard or not. All organisms identified as hazards are subjected to a detailed risk assessment.

5.2 RISK ASSESSMENT

Risk assessment consists of:

a) *Entry assessment:* The likelihood of a hazard (pathogenic organism) being imported with the commodity.

b) *Exposure assessment*: Describes the biological pathway(s) necessary for exposure of susceptible animals or humans in New Zealand to the hazard. Further, a qualitative estimation of the probability of the exposure occurring is made.

c) *Consequence assessment*: Describes the likely consequences of entry, exposure and establishment or spread of an imported hazard.

d) *Risk estimation*: An estimation of the risk posed by the hazard based on release, exposure and consequence assessments. If the risk estimate is assessed to be non-negligible, then the hazard is assessed to be a risk and risk management measures could be further considered to reduce the level of risk to an acceptable level.

Not all of the above steps may be necessary in all risk assessments. The OIE methodology makes it clear that if the likelihood of entry is negligible, then the risk estimate is automatically negligible and the remaining steps of the risk assessment need not be carried out. The same situation arises when the likelihood of entry is non-negligible but the exposure assessment concludes that the likelihood of susceptible species being exposed is negligible, or when both entry and exposure are non-negligible but the consequences of introduction are assessed to be negligible.

5.3 RISK MANAGEMENT

For each organism assessed to be a risk, options are identified for managing that risk.

5.4 RISK COMMUNICATION

After a draft import risk analysis has been written, MPI analyses the options available and proposes draft measures for the effective management of the identified risks. These are then presented in a draft Import Health Standard (IHS) that is released for public comment, and provides a link to the draft risk analysis.

6 Hazard identification table

The first step in the risk analysis is hazard identification, to ensure that all organisms of potential concern (potential hazards) associated with the importation of the animals have been subject to assessment. For this risk analysis, organisms of potential concern are all the infectious diseases or disease agents recorded in Crocodilia from the European and Malaysian Zones. Table 2 below lists the disease agents reported from crocodilians. Those potential hazards specific to crocodilian hosts, not reported from the European or Malaysian zones or already present in New Zealand are not identified as a hazard as indicated in the table.

Table 1: Preliminary list of organisms (potential hazards) associated with the Order Crocodilia from the European and Malaysian Zones

Organism	Reported from Crocodilia in European and/or Malaysian zones	Associated with disease in Crocodilia	Disease in other Orders	Recognized as present in NZ	Hazard Yes/No	Comments	References
BACTERIA							
Acinetobacter spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006), (EPA 2015)
Actinobacillus spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006), (EPA 2015)
Aeromonas spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006) (EPA 2015)
Bacteroides spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006) (EPA 2015)
Chlamydophila spp. reported in Crocodilia	Yes	Yes	Yes	No	**Yes**	*Chlamydophila* spp. associated with crocodiles are exotic to NZ and present in the Malaysian zone. Other *Chlamydophila* spp. are present in NZ.	(Jerrett *et al.,* 2008), (Huchzermyer *et al.,* 1994b), Rosenthal and Mader (2006), (Mohan et al., 2005), (Huchzermyer *et al.,* 2008), (Bercier *et al.,* 2017), (EPA 2015)
Citrobacter freundii	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006) (EPA 2015)
Clostridium spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006) (EPA 2015)
Dermatophilus spp.	Yes	Yes	Yes	Yes	No		Buenviaje (2000) (EPA 2015)

Organism	Reported from Crocodilia in European and/or Malaysian zones	Associated with disease in Crocodilia	Disease in other Orders	Recognized as present in NZ	Hazard Yes/No	Comments	References
Edwardsiella tarda	Yes	Yes	Yes	No	**Yes**		(Buenviaje et al., 1964), (Van Damme and Vandepitte, 1980), Rosenthal and Mader (2006) (EPA 2015)
Enterobacter spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006) (EPA 2015)
Klebsiella spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006) (EPA 2015)
Micrococcus spp.	Yes	Yes	Yes	;Yes	No	*Micrococcus dendroporthos, Micrococcus populi, Micrococcus varians* are in the MPI unwanted organisms register.	Rosenthal and Mader (2006); Sawers (2012); Petrovski *et al*., (2009)
Morganella spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006) (EPA 2015)
Mycobacterium spp (*M. avium, M ulcerans*)	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006); Huchzermeyer (2003); (EPA 2015)
Mycoplasma spp. (*M. crocodyli; M. alligatoris)*	No	Yes	Yes	No	No	*M. crocodyli; M. alligatoris* are not in the MPI unwanted organisms register.	Rosenthal and Mader (2006) (EPA 2015)
Pasteurella spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006) (EPA 2015)
Proteus spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006) (EPA 2015)
Providencia spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006) (EPA 2015)
Pseudomonas spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006) (EPA 2015)

Organism	Reported from Crocodilia in European and/or Malaysian zones	Associated with disease in Crocodilia	Disease in other Orders	Recognized as present in NZ	Hazard Yes/No	Comments	References
Salmonella spp. (exotic to NZ)	Yes	Yes	Yes	Yes	**Yes**	*S. abortus ovis, S. arizona, S. dublin, S. enteritidis* phage 4, *S. gallinarum, S. pullorum, S. typhimurium* phage 44 and phage 104 are in the MPI unwanted organisms register.	(Manolis *et al.*, 1991), (EPA 2015)
Serratia spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006) (EPA 2015)
Staphylococcus spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006) (EPA 2015)
Streptococcus spp.	Yes	Yes	Yes	Yes	No		Rosenthal and Mader (2006) (EPA 2015)
VIRUSES							
Herpesviridae (Herpesvirus-like viruses)							
European zone	No	No	No	No	No		(Ritchie, 2006)
Malaysian zone	Yes	Yes	No	No	**Yes**		(McCowan *et al.*, 2004; Hyndman *et al.*, 2015; Shilton *et al.*, 2016) (EPA 2015)
Adenoviridae (Adenovirus and adenovirus-like viruses)							
European zone	No	No	No	No	No		(Jacobson *et al.*, 1984; Huchzermeyer *et al.*, 1994a)
Malaysian zone	No	No	No	No	No		
Poxviridae							
European Zone	No	No	No	No	No		(Huchzermeyer, 2003)
Malaysian zone	Yes	Yes	No	No	**Yes**		(Buenviaje *et al.*, 1998), (McCowan *et al.*, 2014)
Flaviviridae (West Nile Virus)							
European zone	No	No	Yes	No	No		(Scherret et al., 2001)
Malaysian zone	Yes	No	Yes	No	**Yes**		(Scherret *et al.*, 2001), (Ladds and Sims 1990), Melville *et al.*, (2012)

Organism	Reported from Crocodilia in European and/or Malaysian zones	Associated with disease in Crocodilia	Disease in other Orders	Recognized as present in NZ	Hazard Yes/No	Comments	References
FUNGI							
Fungi	Yes	Yes	Yes	Yes	No	All of the fungal genera, or species within genera, reported from Crocodilia (Huchzermyer, 2003) have been identified as present in New Zealand (Landcare Research, 2018) Accordingly, fungi are not considered to be hazards in the commodity.	(Huchzermyer, 2003, Landcare Research, 2018)
PROTOZOA							
Subphylum Mastigophora, *Trypanosoma* spp, *Leishmania*-type spp[1], *Entamoeba invadens*, Haemosporines and *Cryptosporidium* spp.							
European zone	No	No	Yes	No	No		
Malaysian zone	No Yes (*Leishmania*-type spp. only)	No	Yes	No	No		
Coccidia (*Eimeria* spp.)							
European zone	No	No	No	Yes	No		
Malaysian zone	Yes	Yes	No	Yes	**Yes**	*Eimeria* spp. associated with crocodiles are exotic to NZ and present in the Malaysian zone. Other Eimeria spp. are present in NZ.	

[1] Ladds et al., (1994) describes a granulomatous enteritis which appeared to be the primary cause of death and ill thrift in hatchlings in farmed C. porosus in Northern Australia and Papua New Guinea. The suspected causative agent resembled the amastigote of Leishmania sp. of mammals. There are however no confirmed reports of Leishmania spp. as a cause of disease in crocodiles in these countries, therefore it is not considered to be a hazard in the commodity.

Organism	Reported from Crocodilia in European and/or Malaysian zones	Associated with disease in Crocodilia	Disease in other Orders	Recognized as present in NZ	Hazard Yes/No	Comments	References
Haemogregarines/Hepatozoon spp.[2]							
European zone	No	No	No	Yes	No		Laird (1950); Alison and Desser (1981)
Malaysian zone	Yes	Yes	No	Yes	No	*C. porous* is included as a host species, but geographical locations are not specified, therefore it is assumed that they occur in the Malaysian zone.	
***Blastocystis* spp. (previously classified as protozoa)**							
European zone	No	No	Yes	Yes	No		(Teow *et al.*, 1992)
Malaysian zone	Yes	No	Yes	Yes	No		(Wright, 1996)
Encephalitozoon hellem (Previously classified in Protozoa)							
European zone	No	No	Yes	No	No	Sp. reported in crocodilians not recorded in European or Malaysian zones	(Scheelings *et al.*, 2015)
Malaysian zone	No	No	Yes	No	No		
NEMATODES							
Capillariidae: *Crocodylocapillaria longiovata*							
European zone	No	No	No	No	No		
Malaysian zone	Yes	Yes	No	No	**Yes**		(Moravec and Spratt, 1998)
Paratrichosoma spp.: *P. crocodilus; P.recurvum*							
European zone	No	No	No	No	No		
Malaysian zone	Yes	Yes	No	No	**Yes**		(Ashford *et al.*,1978; Lott *et al.*, 2015),
Ascaridoid Nematodes: *Gedoelstascaris australiensis; Multicaecum agile; Terranova crocodile*							
European zone	No	No	No	No	No		
Malaysian zone	Yes	Yes	No	No	**Yes**		Sprent, 1978; Sprent, 1979 a; Sprent 1979 b),
Dracunculoidea: *Micropleura australiensis*							
European zone	No	No	No	No	No		
Malaysian zone	Yes	Yes	No	No	**Yes**		(Moravec *et al.*, 2004; Moravec *et al.*, 2006)

[2] According to Huchzermeyer (2003) the parasites of crocodilians formerly referred to as Haemogregarina have been transferred to the genus Hepatozoon.

Organism	Reported from Crocodilia in European and/or Malaysian zones	Associated with disease in Crocodilia	Disease in other Orders	Recognized as present in NZ	Hazard Yes/No	Comments	References
Trichinellidae: *Trichinella papuae*							
European zone	No	No	No	No	No		
Malaysian zone	Yes	Yes	Yes	No	**Yes**		(Pozio *et al.*, 1999), (Pozio *et al.*, 2004)
TREMATODES: *Deurithitrema gingae; Renivermis crocodyli; Griphobilharzia amoena*							
European zone	No	No	No	No	No		
Malaysian zone	Yes	Yes	No	No	**Yes**		(Blair, 1985; Blair *et al.*, 1989)
ARTHROPODS: Pentastoma: *Sebekia* spp. *Leiperia* sp. *Alofia* sp. and *Selfie* sp.							
European zone	No	No	No	No	No		
Malaysian zone	Yes	Yes	No	No	**Yes**		(Ladds and Sims, 1990; Junker and Boomker, 2006)
ARACHNIDS: *Amblyomma* (formerly *Aponomma*) spp.							
European zone	No	No	No	No	No		
Malaysian zone	Yes	No	No	No	**Yes**		(Tucker, 1995)
ANNELIDS							
Leeches: *Placopdelloides stellapapillosa*							
European zone	No	No	No	No	No		
Malaysian zone	Yes	No	Yes	No	**Yes**		(Govedich *et al.*, 2002)

Conclusion:
Sixteen organisms were identified as hazards (*Chlamydia* spp., coccidia, *Crocodillocapillaria longiovata*, *Paratrichosoma* spp., Ascaridoid nematodes, Dracunculoidea, trematodes, *Herpesvirus-like viruses*, Poxviruses, *West Nile Virus*, *Edwardsiella tarda*, *Salmonella* spp., *Trichinella papuae*, Pentastomes, *Amblyomma* spp. and the leech, *Placopdelloides stellapapillosa*) and were subjected to individual risk assessments.

7 Risk assessment – Bacteria

7.1 *CHLAMYDOPHILA* SPP.

7.1.1 Technical review

Aetiological agent

The family members of Chlamydiaceae are intracellular gram-negative bacteria within the two genera, *Chlamydia* and *Chlamydophila*, with considerable conservation of genomes between species. Nomenclature of Chlamydiaceae has changed with time and the use of the generic terms *Chlamydia* and *Chlamydophila* is not consistent.

OIE list

*Chlamydophila abortus (*Enzootic abortion of ewes, ovine chlamydiosis) is included in the OIE-Listed diseases, infections and infestations in force in 2018.

New Zealand status

The presence of *Chlamydia* spp. in different hosts in New Zealand include:
Chlamydophila psittaci in five species of penguins (Duignan, 2001), *Chlamydia psittaci* in caged birds (Bell and Schroeder, 1986), feral pigeons, native psittacines (Motha *et al.,* 1995), cats (Gruffydd-Jones *et al.,* 1995) and a wild native passerine (hihi) (Gartrell *et al.,* 2013), *Chlamydia pecorum* in calves (Hunt *et al.,* 2016), and *Chlamydophila pecorum* in a goat (Mackereth and Stanislawek, 2002).

Epidemiology

There have been a number of reports of Chlamydiosis in Crocodilia with differing environments and differing assessments of Chlamydial species.

1. Chlamydia are common in crocodile farms in Australia, with suggestions that they are present on many crocodile farms in the states of Queensland, Northern Territory and Western Australia (Jerrett *et al.,* 2008).

2. Numerous five-month-old crocodiles (*Crocodylus niloticus*) in a farm in South Africa became ill and many died. Pathology and PCR techniques led to a conclusion that the cause might be an ovine strain of *C. psittaci* (Huchzermyer *et al.,* 1994b).

3. From a number of crocodilian sources in Zimbabwe, tissues were examined for *Chlamydia* using pathology, MZN staining and examination of rRNA sequences. The authors concluded that the tissue infection was “probably caused by a new species” (Mohan *et al.,* 2005).

4. An outbreak of disease in hatchling and juvenile *Crocodylus porosus* lead to high mortality of crocodiles on a farm in Papua New Guinea. Diagnosis of chlamydiosis was based on pathology (Huchzermyer *et al.,* 2008).

5. Identification of non-specified species of *Chlamydia* from Australian crocodiles was attempted using PCR, nucleotide sequence analyses and high melt curve analyses. The results indicated these organisms differed from *C. psittaci* (Robertson *et al.,* 2010).

6. Sariya *et al.,* (2015) isolated Chlamydiaceae from *Crocodylus siamensis* in Thailand. Using PCR techniques, the authors determined that the organism was a new species.

7. Examination of granulomatous encephalitis in *Tomistoma schlegelii* in Florida lead to a conclusion that the lesions were associated with a novel Chlamydial species (Bercier *et al.,* 2017).

These reports, based on crocodilians in South Africa, Zimbabwe, New Guinea, Australia, Thailand and Florida indicate that Chlamydial infections in crocodiles involve chlamydial species that are novel. There is no evidence that *Chlamydia* spp. infecting Crocodilia are able to infect other species.

7.1.2 Risk assessment

Entry assessment

There is scientific evidence that *Chlamydia* spp. are associated with disease in crocodiles in the exporting countries. However, considering the low volume of imports the likelihood of entry of *Chlamydia* spp. in imported Crocodilia is assessed to be low.

Exposure assessment

There are no free-ranging members of this order of reptiles in New Zealand and any imported animals must be held in permanent containment with no contact with the imported crocodiles. Based on scientific evidence, *Chlamydia* spp. of Crocodilia are considered to be host-specific, therefore likelihood of exposure and establishment of this organism in other susceptible species is assessed to be negligible.

Risk estimation

On the basis of a negligible likelihood of exposure, the risk of *Chlamydia* spp. in the commodity is assessed to be negligible.

7.2 *EDWARDSIELLA TARDA*

7.2.1 Technical review

Aetiological agent

Edwardsiella spp. are members of the Enterobacteriaceae family. Based on faecal samples from humans, *Edwardsiella tarda* (*E. tarda),* may be of different genotypes from those infecting fish (Gauthier, 2015). The genetic features of *E. tarda* vary with differences between hosts (Gauthier, 2015; Van Damme and Vandepitte, 1980; Abayneh *et al.,* 2012), differences in geography (Nucci *et al.,* 2002; Griffin *et al.,* 2013), and differences in water characteristics (Maiti *et al.,* 2009). These variations in genetics leave a lack of clarity in determining the primary sources of *E. tarda* that might be surface water, deeper water or fish of many species.

OIE list

Edwardsiella tarda is not included on the OIE-Listed diseases, infections and infestations in force in 2018.

New Zealand status

E. tarda has not been recorded in New Zealand. It is not listed in the unwanted organisms register.

Epidemiology

E. tarda is distributed globally, though not recognised as present in New Zealand. The geographic distribution of *E. tarda* includes Europe (Alcaide *et al.,* 2006), North America (White *et al.,* 1973), South America (Lima *et al.,* 2008), Africa (Kebebe and Habtamu, 2016), Asia (Zhou *et al.,* 2016), Australia (Reddacliff *et al.,* 1996) and Antarctica (Leotta *et al.,* 2009).

Host and Geographic Range:
White *et al.,* (1973) reported *E. tarda* in alligators, brown pelicans, common loons, Sandhill cranes, bald eagles, great blue herons, a ring-billed gull and largemouth bass in numerous lakes and streams in Florida. Also, reptiles, amphibians, snakes, crocodiles, toads, frogs, tortoises and lizards have been identified as hosts to *E. tarda* and other reports have shown significant prevalence of *E. tarda* in gentoo, adelie and chinstrap penguins, brown skua, Southern giant petrels, kelp gulls (Southern black-billed gulls) and Weddell seals in the Antarctic (Leotta *et al.,*2009; Grimaldi *et al.,* 2015).

E. tarda may also cause serious disease in individual humans (Van Damme and Vandepitte, 1980).

E. tarda is considered an opportunist pathogen affecting a wide range of fish and other species in salt water, fresh water, lakes, rivers and ponds. Locations from which *E. tarda* in fish have been reported include Spain, Missouri (USA), Canada, Zaire, Ethiopia, Czech Republic, Malaysia and Australia

(Wyatt *et al.,* 1979; Wei *et al.,* 2010; He *et al.,* 2011; Rehulka *et al.,* 2012; Kumar *et al.,* 2016; Hirai *et al.,* 2015; Gauthier, 2015).

Sensitivity to water temperature:
Environmental temperatures affecting the pathogenicity of *E. tarda* have been demonstrated with frogs, turtles and crayfish in catfish ponds at 15˚C (Wyatt *et al.,* 1979); lethal effects to chinook salmon at 12 – 18˚C in Rouge River (Oregon) (Griffin *et al.,* 2013); brook trout in earthen ponds in Quebec at 18 – 19˚C (Amandi *et al.,* 1982); turbot in Europe at 15˚C (Castro *et al.,* 2011) and Japanese flounder at 15˚C in China (Zheng *et al.,* 2004). These temperatures are below the 24 – 28˚C environmental temperature required for crocodiles by the MPI standard 154.03.04, Containment Facilities for Zoo Animals.

In Australia, small numbers of fish died of *E. tarda* infection in a trout farm with the water temperature at 17 – 19˚C and a slow water flow rate. With a seasonal increase in water flow, accompanied by a decrease in temperature, disease attributable to *E. tarda* abated (Reddacliff *et al.,* 1996). These and other observations suggest *E. tarda* may be present in environments that do not lead to high bacterial numbers and subsequent disease.

Reports from Crocodilia:
No reports of *E. tarda* in Crocodilia have been located in the European Zone.

E. tarda was identified in three crocodiles with hepatitis/septicaemia in a commercial farm in the Northern Territory of Australia. The bacterium was also found contaminating a hatchling pool in the same farm (Buenviaje *et al.,* 1964). A review of causes of septicaemia in farmed *C. porosus* in Northern Australia identified gular and paracloacal glands were the most common sites from which *E. tarda* was isolated in American alligators (*Alligator mississippiensis*) on a crocodile farm in Louisiana, USA (Van Damme and Vandepitte, 1980).

E. tarda was also the cause of infection in 3.7% of 159 cases examined in northern Australia (Benedict and Shilton, 2016) and is considered 'not uncommon' in crocodiles in this part of the world' (Shilton, CM 2018 pers.comm[3]).

7.2.2 Risk assessment

Entry assessment

Based on the reports of *E. tarda* in crocodile farms in northern Australia and its presumptive transmission via soil, water and the intestinal tract of crocodiles and associated aquatic animals there is a moderate likelihood of entry with crocodilians from the Malaysian zone.

Exposure assessment

As *E. tarda* can be spread via water, soil and faeces, there is a moderate likelihood of exposure to animals and humans in close contact with infected animals.

It is acknowledged that some pathogens carried by Crocodilia may pose a risk to humans. Although risks to visitors of the zoo may be negligible because there will be no contact between visitors and crocodiles, carers and handlers may be at risk due to the close contact with these animals. However, carers and handlers of animals at the zoo undergo barrier management and personal hygiene training that is expected to reduce the risk of transmission of zoonotic diseases or parasites that animals may harbour. Therefore, regarding zoonotic diseases, the assumption is made that there is no risk to human health from pathogens carried by Crocodilia.

Consequence assessment

E. tarda is a zoonotic agent with a relatively wide host range and the potential to cause serious illness and mortalities in people, young farmed crocodiles, fish and other animals. Therefore the consequence is assessed to be moderate.

[3] Dr. Cathy Shilton, B.Sc.(Hons), DVM, DVSc (Zoo and Wildlife Pathology); MACVS (Veterinary Pathology), Principal Veterinary Pathologist, Berrimah Veterinary Laboratories, Northern Territory Department of Primary Industries, Darwin, NT, Australia, review comments to Lincoln Broad and Richard Jakob-Hoff, April 2018.

Risk estimation

Based on the above there is a moderate risk from *E. tarda* in the commodity and potential risk mitigation measures are described for crocodilians imported from the Malaysian Zone.

Risk management

The risk could be reduced by:

1. Maintaining crocodilia within the temperature range of 24-28ºC; AND/OR
2. Crocodilia should have been reared in an environment with good quality water from a supply not inhabited by fish (either potable water or water from a bore) and have not been fed on fish or been exposed to live fish; AND/OR
3. Samples from both gular and paracloacal glands should be cultured for *E. tarda* with negative results AND faecal samples collected on two separate occasions and cultured for *E. tarda* with negative results.

7.3 *SALMONELLA* SPP.

7.3.1 Technical review

Aetiological agent

The *Salmonella* genus contains over 2,600 serovars within two species; *S. enterica*, which contains most Salmonellae of veterinary or human interest, and *S. borgori*. *S. enterica* is further divided into subspecies *enterica* (I), *salamae* (II), *arizonae* (IIIa), *diarizonae* (IIIb), *houtenae* (IV), *bongori* (V) and *indica* (VI). Over 2,600 of the serotypes fall within the *S. enterica enterica* subspecies. The commonly used names (e.g. *Salmonella* Typhimurium) identify serotypes within the *Salmonella enterica enterica* sub-species. Some of these serotypes are further partitioned on the basis of phage type. For instance, *Salmonella enterica arizonae* contains over 300 serotypes (Jones *et al.,* 2008).

OIE list

Salmonella serotypes included in the OIE-Listed diseases, infections and infestations in force in 2018 are, *Salmonella abortusovis* (sheep and goats) and Pullorum disease (*Salmonella pullorum – gallinarum*).

New Zealand status

MPI identify *S. abortusovis*, *S. dublin*, *S. gallinarum* and *S. pullorum* as "Notifiable". These same organisms are included in the 2017 OIE list of diseases.

In the list of "Unwanted organisms" *S. dublin*, *S. gallinarum* and, *S. pullorum* are classified as "Notifiable" while *S. arizonae*, *S. enteritidis* phage 4, *Salmonella* spp. (exotic affecting animals) and *S.* Typhimurium phage 44 or phage 104 are classified as "other exotic".

S. Gallinarum has not been detected in NZ and, following an extensive eradication programme operated within the commercial poultry industries; *S. pullorum* was last diagnosed in 1985.

During 2016, 1091 cases of Salmonellosis in humans were identified in the NZ Enteric Reference Laboratory (ESR) (excluding *S. paratyphi* or *S.* Typhi). Major risk factors were "Consumed food from retail premises", "Travelled overseas during the incubation period" and "contact with farm animals". Over the five-year period, 2012 – 2016, 1044 isolates were typed with a range of types exceeding 25 and with a number of isolates unidentified (ESR, 2016). In April 2018, 46 isolates from non-human sources were typed with 5 types from five animal species and a further three from animal feeds or environmental sources (ESR, 2018).

As many Salmonella infections are subclinical, the full range of serovars and phage types present in New Zealand and the extent of introductions to the country is unknown. The extent to which the range of salmonellae in New Zealand may be understated is illustrated by three serotypes not previously recorded in New Zealand (*S. mountpleasant, S. ondersterpoort and S. biljme*r) being identified in lizards during one year (Public Health Surveillance, 2005).

Epidemiology

The epidemiology of different Salmonella serotypes follows broadly similar patterns. Spread within and between susceptible species is mainly via the faecal-oral route, with bacteria, passed by infected animals, able to survive for varying periods of time in different environmental niches. Host specificity or host preference varies between Salmonella serotypes. Some are highly host specific, while others are less so. It has been thought that some serotypes, especially *S.* Typhimurium, have very little host preference. This view is being revised with the recognition that genetic determinants are contributing to substantial variations in the breadth of host range for many strains (Rabsch *et al.,* 2002).

There have been a number of reports of salmonellae being isolated from Crocodilia, both wild and in captivity. In South Africa, 148 isolates of salmonellae were obtained from wild and farmed crocodiles over a ten-year period. Salmonella groups I, II, IIIa, IIIb and IV were represented with most isolates being from group I. The group I (*Salmonella enterica*) isolates included 57 serovars, many of them being identified from only three or fewer animals (Van der Walt *et al.,* 1997). Examination of samples from slaughtered *C. johnstoni* and *C. porosus* from two crocodile farms in the Northern Territory of Australia (Manolis *et al.,* 1991) revealed Salmonella infection in 11.8 percent of animals. 114 isolates were classified into 20 serotypes. *S. singapore, S. enteritidis* and *S. arizonae* were the most common isolates. The main dietary component for the farmed South African crocodiles had been raw meat from animals dying on farms and it was suggested that this might have been the main source of Salmonella infection. The Australian crocodiles, however, had been fed on chicken pieces (mainly heads) on one farm and gutted whole chickens on the other.

Salmonellae falling within the categories of "*S. arizonae*" and "*Salmonella* spp. (exotic, affecting animals)" included in the register of unwanted organism have been isolated from crocodiles.

It is likely that Salmonella infections of crocodiles include host adapted species and serovars, and serovars acquired from feed or environmental sources.

7.3.2 Risk assessment

Entry assessment

A high proportion of crocodiles are infected with salmonellae. There is a moderate to high likelihood that, within any group of crocodiles imported to New Zealand, Salmonella infection will be present, unless there is sound evidence to the contrary. Manolis *et al.,* (1991) found that cloacal swabs could provide false negative results, especially if there is intermittent feeding (two to three days) and long periods of time between the passings of faeces. Reliable evidence of the absence of salmonellae would require sampling and testing of animals on several occasions.

The likelihood of entry is assessed as moderate - high.

Exposure assessment

The requirement that crocodiles be kept in containment will significantly limit the exposure of either people or other animals to any associated Salmonellae. Irrespective of the Salmonella status of any crocodiles, work-place safety requirements are such that all staff coming into contact with the animals or their environment should be trained in hygiene measures to avoid infection. Containment provisions require that waste be disposed of by deep burial (https://www.biosecurity.govt.nz/dmsdocument/32662/loggedIn, section 3.3).

It is acknowledged that some pathogens carried by Crocodilia may pose a risk to humans. Although risks to visitors of the zoo may be negligible because there will be no contact between visitors and crocodiles, carers and handlers may be at risk due to the close contact with these animals. However, carers and handlers of animals at the zoo undergo barrier management and personal hygiene training that is expected to reduce the risk of transmission of zoonotic diseases or parasites that animals may harbour. Therefore, regarding zoonotic diseases, the assumption is made that there is no risk to human health from pathogens carried by Crocodilia.
There is potential for spread of Salmonella infection from imported crocodiles through wild birds having access to enclosures and through discharge or removal of material from enclosures. However, when viewed in the context of the small number of Crocodilia likely to be imported, the ongoing infection of humans and other species in New Zealand, and the range of pathways available for entry

of salmonellae, it is considered that the presence of salmonellae in live Crocodilia will not significantly increase the current level of exposure of humans or other animal species.

On this basis, the likelihood of exposure and establishment is assessed as negligible.

Risk estimation

On the basis of a negligible likelihood of exposure, the risk of Salmonella in the commodity is assessed to be negligible.

8 Risk assessment – Viruses

8.1 HERPESVIRUS-LIKE VIRUSES

8.1.1 Technical review

Aetiological agent

Herpes viruses are large, enveloped DNA viruses with intranuclear replication and generally very high host specificity requiring close contact for transmission. Latent persistence in neurons, epithelial cells and lymphocytes is typical with sub-clinical infection persisting for life. Young and immunocompromised animals are most susceptible to clinical disease (Ritchie, 2006; Shilton *et al.*, 2016).

Sequencing of PCR amplicons has provided evidence that all three herpesvirus-like viruses found in crocodilians in the Malaysian Zone are novel and differ from a wide range of other species (McCowan *et al.,* 2004; Shilton *et al.,* 2016; Govett *et al.,* 2005). Viruses from saltwater crocodiles (*C. porosus*) were named CrHV 1 and 2 and that from *C. johnstoni* (freshwater crocodile) as CrHV 3.

OIE list

Herpesvirus-like viruses are not included in the OIE-Listed diseases, infections and infestations in force in 2018.

New Zealand status

Herpesvirus-like viruses identified in crocodilians have not been identified in New Zealand.

Epidemiology

Herpesviruses are found worldwide and have been associated with disease in a range of reptiles including snakes, chelonids, lizards and crodcodilians (Ritchie, 2006). Infections can manifest differently depending on various factors, including host age, immune competence, exposure circumstances, and latency status (Shilton *et al.*, 2016). Transmission is most commonly horizontal between individual animals although there is some evidence that more indirect infection via respiratory secretions and faeces can occur. Latent infection is common with virus shedding triggered by stressful episodes such as malnutrition, concomitant disease, and animal movement and breeding (Ritchie, 2006).

Herpesvirus-like viruses in Crocodilia have been reported in diseased farmed *Crocodylius porosus* and *C. johnstoni* in Australia (McCowan *et al.,* 2004; Hyndman *et al.,* 2015; Shilton *et al.,* 2016) and farmed *Alligator mississippiensis* in the USA (Govett *et al.,* 2005).

8.1.2 Risk assessment

Entry assessment

As reported above, there is evidence of Herpesvirus-like viruses in crocodilians in the Malaysian Zone but not in the European Zone. Although the frequency of latent herpesvirus-like infections in crocodilians is high, due to the low volume of crocodilian imports there is a low likelihood that this virus could enter New Zealand with crocodilians imported from the Malaysian Zone.

Exposure assessment

There are no free-ranging members of this order of reptiles in New Zealand and any imported animals must be held in permanent containment with no contact with the imported crocodiles. Based on scientific evidence, herpesvirus-like viruses of Crocodilia are host-specific, therefore likelihood of exposure and establishment of this virus in other susceptible species is assessed to be negligible.

Risk estimation

On the basis of a negligible likelihood of exposure, the risk of Herpesvirus-like viruses in the commodity is assessed to be negligible.

8.2 POXVIRUSES

8.2.1 Technical review

Aetiological agent

A large, enveloped DNA virus whose multiplication in cellular cytoplasm is identified histologically by pathognomonic inclusions called Bollinger bodies. Infections in Crocodilians typically manifest as proliferative epidermal lesions that are self-limiting but can result in life-threatening secondary infections. Generally morbidity is high and mortality low (Ritchie, 2006; Marschang, 2014).

OIE list

Poxviruses are not included in the OIE-Listed diseases, infections and infestations in force in 2018.

New Zealand status

Several poxviruses have been reported in New Zealand, primarily in ruminants (McFadden and Rawdon, 2012), birds (Ha, 2013) and humans (Gupta *et al.,* 2003). Ruminant poxviruses are potentially zoonotic (McFadden and Rawdon, 2012) although many are host specific (Ritchie, 2006). No reports were found of these viruses occurring in reptiles in New Zealand.

Epidemiology

Poxviruses can survive for prolonged periods in the environment and transmission in Crocodilians is reported to be associated with stressors including poor water quality and environmental hygiene (Ritchie, 2006; Marschang, 2016).

Buenviaje *et al.,* (1998), in a retrospective assessment of skin pathology in farmed crocodiles (assumed to be *C. perosus*) from the Northern Territory and Queensland, identified typical pox lesions in 5/180 farmed crocodiles. McCowan *et al.,* (2014) also observed the development of pox-associated erosive skin lesions in young *C. perosus* held in high density following translocation from the Northern Territory to Victoria for a study on the impact of stress.

8.2.2 Risk assessment

Entry assessment

As reported above, poxvirus infections in crocodilians have been reported in the Malaysian Zone but not the European Zone. Although infection is associated with sufficient skin pathology to render this non-commercial (Buenviaje *et al.,* 1998), there is a low likelihood of entry in imported animals in the early, pre-clinical phase of the disease.

Exposure assessment

A recent molecular characterisation of the crocodile poxvirus from Australian *C. perosus* indicated that the host range of crocodile poxviruses is limited to the Crocodilia (Sarker *et al.,* 2018). As the poxviruses of Crocodilia are host-specific, there are no free-ranging members of this order of reptiles in New Zealand and any imported animals must be held in permanent containment, there is a negligible likelihood of exposure and establishment of this virus.

Risk estimation

On the basis of a negligible likelihood of exposure, the risk of poxviruses in the commodity is assessed to be negligible.

8.3 WEST NILE VIRUS

8.3.1 Technical review

Aetiological agent

West Nile Virus (WNV) is an arbovirus within the family *Flaviviridae*. Its common hosts are birds within the Order Passeriformes and its major vectors are mosquitoes of the genera *Culex* and *Aedes*.

OIE list

"West Nile Fever" is included in the OIE-Listed diseases, infections and infestations in force in 2018.

New Zealand status

WNV including the Kunjin variant is not recognised to be present in New Zealand.

Epidemiology

Since the recognition of WNV in Uganda in 1937, this virus has been detected in North and South America, Europe, much of Asia and Australia. Passeriformes birds are major hosts for WNV and migratory viraemic birds are important in the dissemination of virus by mosquito vectors. While birds are the primary hosts other species do become infected. The most commonly affected vertebrates are humans and horses in both of which WNV may cause serious disease or death (Scherret *et al.,* 2001).

Other vertebrates in which the virus remains present and causes clinical disease include alligators, alpacas, dogs, lake frogs, reindeer, and wolves. A larger number of vertebrate species have been identified in which antibodies to WNV are present but without detection of virus and without signs of disease ("incidental hosts") (van der Meulen *et al.,* 2005; Chancey *et al.,* 2015). Strains of WNV have developed in different countries or zones and pathogenicity varies between strains (Scherret *et al.,* 2001; Backonyi *et al.,* 2006; May *et al.,* 2011). Studies have shown that strains of WNV distinct from the Kunjin (1b) lineage are likely to be present in Malaysia (Scherret *et al*., 2001). However, there is currently no literary evidence indicating infection or disease casused by WNV or its variants in crocodiles in Malaysia.

Evidence of infection of WNV in American alligators (*Alligator mississippiensis*) has been gathered through serology or identification of viruses (Miller *et al.,* 2003; Klenk *et al.,* 2004; Nevarez *et al.,* 2005; Jacobson *et al.,* 2005; Nevarenz *et al.,* 2008) in South America or Mexico. The presence of antibodies to WNV in crocodiles (*C. moreletii*, *C. acutus* and *C. acutus-C. morelett* hybrids) has been established in Mexico (Machain-Williams *et al.,* 2013 and Loza-Rubio *et al.,* 2016) and there is a single report of *C. niloticus* seropositive to WNV from Israel (Steinman *et al.,* 2003).

WNV - the Kunjin (1b) lineage, is endemic in Northern Australia (Ladds and Sims 1990). Melville *et al.,* (2012) reported seroconversion of farmed *C. porosus* in the Northern Territory for Kunjin virus. Associated disease was not recognised although there is preliminary evidence that this virus may be involved in skin lesions in farmed saltwater crocodiles. Given the economic value of farmed crocodile skin a multi-million dollar collaborative research effort was launched in 2018, as part of the Australian Cooperative Research Council program for developing the North (Shilton C. pers. comm. 2018). The primary vector of Kunjin virus is the mosquito *Culex annulirostris* which is currently exotic to New Zealand and listed as an unwanted organism.

8.3.2 Risk assessment

Entry assessment

As reported above, there is evidence of sero-conversion of crocodilians to the Kunjin variant of WNV in Northern Australia. Therefore, there is a low likelihood that this virus could enter New Zealand with infected crocodilians imported from the Malaysian Zone.

Exposure assessment

As *Culex annulirostris*, the primary vector of Kunjin virus, is absent from New Zealand there is a negligible likelihood of exposure and establishment of this virus.

Risk estimation

On the basis of a negligible likelihood of exposure, the risk of WNV in the commodity is assessed to be negligible.

9 Risk assessment – Protozoa

9.1 COCCIDIA

9.1.1 Technical review

Aetiological agent

The coccidia reported from crocodilians are in the genus *Eimeria*. These are single-celled organisms in the order Apicomplexa that undergo both asexual and sexual reproduction within the host cells producing oocysts that are shed in the faeces (Land and Mader, 1996).

OIE list

Eimeria spp. are not included on the OIE-Listed diseases, infections and infestations in force in 2018.

New Zealand status

Eimeria spp. have been reported in New Zealand native reptiles (Twentyman, 1999) but individual species are generally highly host-specific.

Epidemiology

Eimeria spp. have a global distribution in a wide range of hosts and transmission is via the faecal oral route. In an investigation of ill thrift and mortality of wild caught juvenile *C. porosus* and *C. novaeguinea* held in a captive facility in Papua New Guinea, Ladds and Sims (1990) found coccidia in 17/30 animals necropsied and considered coccidiosis to be the primary cause of death in seven of these. All but one of these animals had signs of weight loss or emaciation and the organisms were found in multiple organs especially the intestine, liver, lung and spleen.

9.1.2 Risk assessment

Entry assessment

There is scientific evidence that coccidia are associated with disease in crocodiles in the exporting countries. However, considering the low volume expected to be imported, the likelihood of entry of coccidia in imported Crocodilia is assessed to be low.

Exposure assessment

There are no free-ranging members of this order of reptiles in New Zealand and any imported animals must be held in permanent containment with no contact with the imported crocodiles. Based on scientific evidence, coccidia of Crocodilia are considered to be host-specific, therefore likelihood of exposure and establishment of this protozoa in other susceptible species is assessed to be negligible.

Risk estimation

On the basis of a negligible likelihood of exposure, the risk of coccidia in the commodity is assessed to be negligible.

10 Risk assessment – Nematode parasites

10.1 *CROCODYLOCAPILLARIA LONGIOVATA*

10.1.1 Technical review

Aetiological agent

Crocodylocapillaria longiovata is a capillariid nematode commonly found in the stomachs of *C. porsus* and *C. novaeguinae* in Papua New Guinea and Northern Australia (Moravec and Spratt, 1998).

OIE list

C. longiovata is not included in the OIE-Listed diseases, infections and infestations in force in 2018.

New Zealand status

No reports of this nematode in New Zealand were found.

Epidemiology

C. longiovata has been identified from the stomachs of *C. johnsoni*, *C. novaeguineae* and *C. porosus* in northern Australia, Papua New Guinea and Indonesia but not recorded in New Zealand. This nematode has only been found in crocodilians and little is known about its life cycle although, based on the presence of free eggs containing larvae in the stomach of the host, it is suggested that the development of the parasite is without an intermediate host (Moravec and Spratt, 1998).

10.1.2 Risk assessment

Entry assessment

There is scientific evidence that *C. longiovata* are associated with crocodiles in the exporting countries. However, considering the low volume expected to be imported, the likelihood of entry of *C. longiovata* in imported Crocodilia is assessed as low.

Exposure assessment

There are no free-ranging members of this order of reptiles in New Zealand and any imported animals must be held in permanent containment with no contact with the imported crocodiles. Based on scientific evidence, *C. longiovata* of Crocodilia are considered to be host-specific, therefore likelihood of exposure and establishment of this nematode in other susceptible species is assessed to be negligible.

Risk estimation

On the basis of a negligible likelihood of exposure, the risk of *C. longiovata* in the commodity is assessed to be negligible.

10.2 *PARATRICHOSOMA* SPP.

10.2.1 Technical review

Aetiological agent

P. crocodilus; P. recurvum are capillariid nematodes that parasitize the abdominal skin of crocodiles. They are primarily of commercial concern due to the damage to the skin but are of minimal clinical significance (Charruau *et al.,* 2017).

OIE list

Paratrichosoma spp. are not included in the OIE-Listed diseases, infections and infestations in force in 2018.

New Zealand status

No reports of this nematode in New Zealand were found.

Epidemiology

These parasites are restricted to the tropics (Moravec and Vargas-Vazquez, 1998). Although information on lifecycles of *Paratrichosoma* spp. are incomplete there is no evidence that there is an alternative host species. It is known that females deposit eggs in burrows made within the skin of the host but the route by which eggs or larvae return to hosts is not known. Discussion by Lott. *et al.,* (2015) suggests that there are no intermediate hosts.

Paratrichosoma spp. have been reported in both *C. novaeguinea* and *C. Porosus* in crocodile farms in Papua New Guinea and Northern Australia (Ashford *et al.,* 1978; Lott *et al.,* 2015) but not in New Zealand.

10.2.2 Risk assessment

Entry assessment

There is scientific evidence that *Paratrichosoma* spp. are associated with disease in crocodiles in the exporting countries. However, considering the low volume expected to be imported, the likelihood of entry of *Paratrichosoma* spp. in imported Crocodilia is assessed as low.

Exposure assessment

There are no free-ranging members of this order of reptiles in New Zealand and any imported animals must be held in permanent containment with no contact with the imported crocodiles. Based on scientific evidence, *Paratrichosoma* spp. of Crocodilia are considered to be host-specific, therefore likelihood of exposure and establishment of this nematode in other susceptible species is assessed to be negligible.

Risk estimation

On the basis of a negligible likelihood of exposure, the risk of *Paratrichosoma* spp. in the commodity is assessed to be negligible.

10.3 ASCARIDOID NEMATODES

10.3.1 Technical review

Aetiological agent

Ascaridoid nematodes are members of the Order Ascaridida. The species that parasitize aquatic animals (e.g. fish, crocodilians and sea mammals) have free-swimming larvae that require various intermediate hosts to complete development (Bowman *et al.,* 2003).

OIE list

The ascarids of Crocodilia are not included in the OIE-Listed diseases, infections and infestations in force in 2018.

New Zealand status

No reports of the ascaridoid nematodes of Crocodilia in New Zealand were found.

Epidemiology

G. australiensis; M. agile; T. crocodili nematodes have been found in the stomach and duodenum of *C. porosus* and/or *C. johnsoni* in estuaries and rivers of northern Australia and the Solomon Islands. *T. crocodili* has also been reported from Palawan Island, Philippines (Sprent, 1978; Sprent, 1979 a; Sprent 1979 b). Thirteen years later, Machida *et al.,* (1992) reported parasites of the same three species all recovered from Palawan Island in the Philippines but with no further information on their behaviour or lifecycles.

The three nematodes recorded in Crocodilia appear to be host specific (Sprent, 1978, Sprent, 1979, Machida *et al.,* 1992).

Reports do not refer to development of disease associated with these parasites nor do they provide information on their lifecycles. Lane and Mader (1996) speculate that, in common with most ascarids, eggs are passed in the faeces and require passage through an intermediate host for larval development to an infective stage.

10.3.2 Risk assessment

Entry assessment

There is scientific evidence that shows that Ascaridoid nematodes are associated with crocodiles in the exporting countries. However, considering the low volume of Crocodilia to be imported, the likelihood of entry of Ascaridoid nematodes in imported Crocodilia is assessed as low.

Exposure assessment

There are no free-ranging members of this order of reptiles in New Zealand and any imported animals must be held in permanent containment with no contact with the imported crocodiles. Based on scientific evidence, Ascaridoid nematodes of Crocodilia are considered to be host-specific, therefore likelihood of exposure and establishment of these nematodes in other susceptible species is assessed to be negligible.

Risk estimation

On the basis of a negligible likelihood of exposure, the risk of Ascaridoid nematodes in the commodity is assessed to be negligible.

10.4 DRACUNCULIDAE: *MICROPLEURA AUSTRALIENSIS*

10.4.1 Technical review

Aetiological agent

Micropleura australiensis is a spirurid nematode described from crocodiles in northern Australia.

OIE list

M. australiensis is not included in the OIE-Listed diseases, infections and infestations in force in 2018.

New Zealand status

No reports of these nematodes in New Zealand were found.

Epidemiology

M. australiensis parasites have only been reported from the peritoneal cavity of wild and farmed crocodilians (*C. johnsoni* and *C. porosus*) in northern West Australia (Moravec *et al.,* 2004; Moravec *et al.,* 2006). Although the lifecycle of this parasite has not been determined, many of the other species within the Nematode superfamily Dracunculoidea, which are parasites of fishes, involve crustaceans as intermediate hosts (Moravec, 2004).

10.4.2 Risk assessment

Entry assessment

There is scientific evidence that Dracunculoidea are associated with crocodiles in the exporting countries. However, considering the low volume expected to be imported, the likelihood of entry of Dracunculoidea in imported Crocodilia is assessed as low.

Exposure assessment

There are no free-ranging members of this order of reptiles in New Zealand and any imported animals must be held in permanent containment with no contact with the imported crocodiles. Based on scientific evidence, Dracunculoidea of Crocodilia are considered to be host-specific, therefore likelihood of exposure and establishment of these nematodes in other susceptible species is assessed to be negligible.

Risk estimation

On the basis of a negligible likelihood of exposure, the risk of *Micropleura australiensis* in the commodity is assessed to be negligible.

10.5 TRICHINELLIDAE: *TRICHINELLA PAPUAE*

10.5.1 Technical review

Aetiological agent

The common factor in *Trichinella* spp. is the presence of first stage larvae in muscles of the initial host, ingestion and passage within the intestinal tract, passing of newly developed larvae via the blood stream, penetration to striated muscles and becoming encapsulated into sarcomella fibres where they may eventually die as a result of calcification.

Consumption of flesh by an alternative species will commonly result in infection of the host and development of larvae. Infection of the host, or an alternative carnivore, will result in infection and development of immunity. Oral ingestion of larvae-contaminated tissue is the usual route of infection, but congenital and mammary transmission can occur in rats.

At least 13 species of *Trichinella* have been named or numbered. The geographic spread of individual species varies in both location and geographic spread (Pozio *et al.,* 2009; Pozio and Zarlenga, 2013).

OIE list

Trichinella spp. are on the OIE-Listed diseases, infections and infestations in force in 2018.

New Zealand status

Trichinella spiralis – is a notifiable organism.

Epidemiology

Trichinella papuae (*T. papuae*) was recognised in 1997 in both domestic and wild pigs in PNG (Pozio *et al.,* 1999) and subsequently identified in meat from *C. porosus* (Pozio *et al.,* 2004). The range of *T. papuae* has extended to an Australian island in the Torres Strait region (Cuttell *et al.,* 2012).

T. papuae is also present in Thailand and was initially attributed to one person from Thailand after travelling to PNG and eating the flesh of a pig in that country (Intapan *et al.,* 2011). Subsequent incidents of trichinellosis in Thailand were attributed to *T. papuae* originating in wildlife (Khumjui *et al.,* 2008; Kusolsuk and Rojekittikhun, 2010).

The major routes of transmission of *T. papuae* are:

1. Consumption of feral pigs by other pigs (feral or domesticated) (Owen *et al*., 2014).
2. Consumption of raw or under-cooked pork by humans (Kumjui *et al.,* 2008; Kusolsuk *et al.,* 2010).
3. Consumption of feral or domesticated pigs by crocodiles (Pozio *et al.,* 2005).

10.5.2 Risk assessment

Entry assessment

T. papuae may be embedded in the flesh of crocodiles. Transmission to other animals can occur if the uncooked, or partially cooked, flesh of a crocodile is consumed by humans, pigs, crocodiles or other carnivores. The likelihood of a crocodile consuming flesh from a crocodile carrying *T. papuae* within its flesh is assessed as low.

Exposure assessment

Trichinella within the muscles of the commodity may survive for considerable periods. Larvae can be distributed, only if muscles of the infected crocodiles are accessible to other carnivores. MPI containment provisions require that carcasses be disposed of by incineration or deep burial.
On that basis, the likelihood of exposure and establishment is assessed to be negligible.

Risk estimation

On the basis of a negligible likelihood of exposure, the risk of *T. papuae* in the commodity is assessed to be negligible.

11 Risk assessment – Trematode parasites

11.1 *DEURITHITREMA GINGAE; RENIVERMIS CROCODYLI; GRIPHOBILHARZIA AMOENA*

11.1.1 Technical review

Aetiological agent

The three Digenean trematodes reported from crocodilians in northern Australia are: *Deurithitrema gingae* (Order Plagiorchioidea); *Renivermis crocodyli* (Order Exotidendriidae); *Griphobilharzia amoena* (Order Schistosomatidae).

OIE list

These trematodes are not included in the OIE-Listed diseases, infections and infestations in force in 2018.

New Zealand status

No reports of these trematodes in New Zealand were found.

Epidemiology

These parasites were discovered in the kidneys of *C. porosus* and *C. johnstoni* in the Northern Territory of Australia (Blair, 1985; Blair *et al.,* 1989). Experimental trials with crocodiles in snail (*Americana* spp.) infested ponds suggested that the life cycle of *Griphobilharzia amoena* included snails (Platt *et al.,* 1991). Lane and Mader (1996) state that “All of the flukes found in crocodilians are digenetic where the snail is the intermediate host. It is unlikely that these flukes are a problem in captive reptiles because of the life cycle of the parasite, which is complex and requires one or two intermediate hosts.”

11.1.2 Risk assessment

Entry assessment

There is scientific evidence that trematodes are associated with crocodiles in the exporting countries. However, considering the low volume of imports, the likelihood of entry of trematodes in imported Crocodilia is assessed as low.

Exposure assessment

There are no free-ranging members of this order of reptiles in New Zealand and any imported animals must be held in permanent containment with no contact with the imported crocodiles. Based on scientific evidence, trematodes of Crocodilia are considered to be host-specific, therefore likelihood of exposure and establishment of these trematodes in other susceptible species is assessed to be negligible.

Risk estimation

On the basis of a negligible likelihood of exposure, the risk of trematode parasites in the commodity is assessed to be negligible.

12 Risk assessment – Arthropods

12.1 PENTASTOMA

12.1.1 Technical review

Aetiological agent

Pentastomid parasites have characteristics of both Arthropoda and Annelida and are primarily parasites of reptiles (Johnson-Delany, 1996).

OIE list

These parasites are not included in the OIE-Listed diseases, infections and infestations in force in 2018.

New Zealand status

No reports of these pentastomids in New Zealand were found.

Epidemiology

The common lifecycle for pentastomids involves adults in the lungs of the primary host depositing eggs that contain larvae. The eggs are coughed up, swallowed and passed in faeces. A secondary host consumes eggs. In the case of crocodilians the secondary host will always be fish. Larvae develop to become infective nymphs and are eaten by the crocodile host, penetrate the intestinal wall, enter the blood stream and migrate to the lungs (Greiner and Mader, 2006). Young hatchling Crocodilians are most susceptible to clinical infections but adults are generally asymptomaic (Lane and Mader, 1996).

Ten Pentastomid parasites from four genera (*Sebekia* spp. *Leiperia* sp. *Alofia* sp. and *Selfie* sp.) have been identified in crocodiles in northern Australia, south East Asia, the Philippines and PNG (Ladds and Sims, 1990; Junker and Boomker, 2006).

Carnivores, non-human primates and humans can become incidental hosts through ingestion of contaminated water or after handling infected reptiles although these hosts generally remain asymptomatic (Johnson-Delany, 1996).

12.1.2 Risk assessment

Entry assessment

As infected adult crocodilians are generally asymptomatic there is high likelihood of entry with animals imported from the Malaysian Zone.

Exposure assessment

Pentastomids are zoonotic, however imported crocodilians must be maintained in permanent containment and any handling restricted to their carers.

It is acknowledged that some pathogens carried by Crocodilia may pose a risk to humans. Although risks to visitors of the zoo may be negligible because there will be no contact between visitors and crocodiles, carers and handlers may be at risk due to the close contact with these animals. However, carers and handlers of animals at the zoo undergo barrier management and personal hygiene training that is expected to reduce the risk of transmission of zoonotic diseases or parasites that animals may harbour. Therefore, regarding zoonotic diseases, the assumption is made that there is no risk to human health from pathogens carried by Crocodilia.

Risk estimation

On the basis of a negligible likelihood of exposure, the risk of Pentastoma in the commodity is assessed to be negligible.

13 Risk assessment – Arachnids

13.1 *AMBLYOMMA* SPP.

13.1.1 Technical review

Aetiological agent

Amblyomma spp. are blood sucking Ixodid ticks with some species acting as vectors of diseases such as Rocky Mountain spotted fever in Brazil and ehrlichiosis in the United States.

OIE list

These parasites are not included in the OIE-Listed diseases, infections and infestations in force in 2018.

New Zealand status

Amblyomma spp. are listed on the unwanted organisms register.

Epidemiology

All ticks depend on blood to survive and go through a series of larval and nymphal stages before reaching adulthood (Heath and Hardwick, 2011). *Amblyomma* spp. ticks vary in their host specificity with some, such as the neotropical *A. parvum* being host generalists whose distribution is governed more by environmental factors than hosts (Olegario *et al.,* 2011).

The majority of New Zealand ticks are sea bird ticks. The exceptions are the host-adapted *Amblyomma sphenodonti* (tuatara tick), *Haemaphysalis longicornis* (cattle tick), and *Ixodes anatis* (kiwi tick) (Heath, 2006; Heath and Hardwick, 2011).

An *Amblyomma* spp. tick has been recorded on a single crocodile (*C. johnstoni*) located in north central Queensland (Tucker, 1995) and the author considered that the usual host for this tick would have been a goanna (Australian monitor lizard). The species was not identified and, currently the only tick of this genus recorded in New Zealand is the endemic *Amblyomma* (formerly *Aponomma*) *sphenodonti* on tuatara (*Sphenodon punctatus*).

13.1.2 Risk assessment

Entry assessment

Although to date there is only one published record of an *Amblyomma* sp. tick on a crocodilian this may be an under-representation and there is a low likelihood of entry with animals imported from the Malaysian Zone.

Exposure assessment

Although there is one endemic host-specific *Amblyomma* species in New Zealand, some exotic members of this genus are host generalists and, consequently, there is a moderate likelihood of exposure and establishment of these parasites in New Zealand.

Consequence assessment

One Australian member of this genus, *Amblyomma triguttatum triguttatum,* is a vector of Q fever and has been expanding its range from northern Australia to South Australia (McDiarmid *et al.,* 2000). The establishment of these ticks could pose a risk to public health and therefore the consequence assessment is moderate.

Risk estimation

As the exposure and consequence assessment are moderate, *Amblyomma* spp. are assessed as a risk in the commodity and potential risk mitigation measures are described for crocodilians imported from the Malaysian Zone.

Risk management

Risk mitigation measures could include a combination of pre-export quarantine in a tick-free environment and the application of topical permethrin-based ectoparasiticide treatment.

14 Risk assessment – Annelids

14.1 LEECHES: *PLACOPDELLOIDES STELLAPAPILLOSA*

14.1.1 Technical review

Aetiological agent

Placopdelloides stellapapillosa is one of 22 genera of leech belonging to the widely distributed family Glossiphoniidae. This family is cosmopolitan in distribution and currently has 22 recognized genera. They are described as “predacious or facultative sanguivores, or both: feeding on a variety of vertebrates and invertebrates” (Govedich *et al.,* 2002, McKenna *et al.,* 2005).

OIE list

These organisms are not included in the OIE-listed diseases, infections and infestations in force in 2018.

New Zealand status

Placopdelloides maorica has been reported from waterfowl in New Zealand (McKenna *et al.,* 2005). No reports of *P. stellapapillosa* from New Zealand were found and they are not included in the MPI list of unwanted organisms.

Epidemiology

Leeches are hermaphrodite and most occur in freshwater environments although New Zealand has three native terrestrial species that feed on the blood of seabirds and one, *Richardsonianus mauianus,* which inhabits streams, ponds and lakes from northern New Zealand to the Waikato. (T.E.R:R.A.I.N., (2018). The introduced Asian freshwater leech, *Barbronia weberi*, is closely associated with pond weeds in the Auckland and Waikato regions. It has a rapid reproductive and growth rate and its distribution is facilitated by the removal of pond weed for the aquarium trade and possibly by attachment to waterfowl (Mason, 1976). Leeches have been identified as vectors of some haemoparasites in crocodilians including haemogregarines and trypanosomes (Lane and Mader, 1996).

P. stellapapillosa were identified on crocodiles (*C. porosus*, and *Tomistoma schegelii*) following the introduction of Malay River Turtles (*Orlitia borneensis*) to the Singapore Zoo. Although the authors note that there is no evidence that *C. porosus* is a common host for *P. stellapapillosa,* this species of leech has not been identified in New Zealand (Govedich *et al.,* 2002).

14.1.2 Risk assessment

Entry assessment

As *P. stellapapillosa* has been reported attached to crocodilians in the Malaysian Zone there is a low likelihood of entry with crocodilians imported from this zone.

Exposure assessment

The Asian leech *Barbronia weberi* has established in New Zealand and the full host range of *P. stellapapillosa* is not known. Consequently, they have the potential to establish in New Zealand and the likelihood of exposure is assessed to be moderate.

Consequence assessment

The haemogregarines and trypanosomes found in reptiles and may be vectored by leeches, are generally non-pathogenic and their presence “more academic than hazardous” according to Lane and Mader, (1996). Therefore the consequence assessment in regard to vector potential of *P. stellapapillosa* is negligible.

However, as this is a haemophagous leech whose full host range is unknown there is a moderate consequence assessment for its potential to establish and parasitize other organisms living in and around New Zealand waters.

Risk estimation

On the basis of a moderate consequence assessment, *P. stellapapillosa* is assessed as a risk in the commodity and potential risk mitigation measures are described for crocodilians imported from the Malaysian zone.

Risk management

Risk mitigation measures could include acombination of pre-export quarantine in a leech-free environment and the topical application of vinegar and alcohol (Lane and Mader, 1996).

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