Import risk analysis: Crocodilia and eggs of Crocodilia from Australia

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Policy and Risk
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Approved for General Release

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1 Executive Summary

This risk analysis considers the biosecurity risks associated with the importation of live animals and hatching eggs of species within the Order Crocodilia (Class Reptilia) from Australia. The commodity definitions used were:

1. Animals of species in the Order Crocodilia (Class Reptilia) which have been hatched and reared in captivity in Australia and which are clinically healthy and free from visible soil contamination; and

2. Eggs of Crocodilia laid in captivity in Australia. Eggs must be clean on visual inspection.

From a preliminary hazard list, those organisms considered to be potential hazards in the commodity were subjected to individual risk assessments.

As a result of the individual risk assessments, it was concluded that the risk in live Crocodilia was non-negligible for only one organism; *Edwardsiella tarda*.

The sanitary measures recommended to effectively manage risks are:

Either:

a. The Crocodilia have been reared in an environment with good quality water from a supply not inhabited by fish and have not been fed on fish or been exposed to live fish

Or:

b. Samples from both gular and paracloacal glands have been cultured for *E. tarda* with negative results AND faecal samples collected on two separate occasions have been cultured for *E. tarda* with negative results.

There is no evidence that *Edwardsiella tarda* is transmitted through eggs or that similar organisms are transmitted through eggs either in reptiles or in birds.

It is considered that clean eggs of Crocodilia imported from Australia into New Zealand do not present a biosecurity hazard. No risk mitigation measures are recommended.

2 Introduction

This risk analysis examines the biosecurity risks posed by the importation of live animals and hatching eggs of species within the Order Crocodilia (Class Reptilia) from Australia into New Zealand.

2.1 COMMODITY DEFINITION

The commodities covered in the risk analysis are:

1. Animals of species in the Order Crocodilia (Class Reptilia) which have been hatched and reared in captivity in Australia and which are clinically healthy and free from visible soil contamination; and

2. Eggs of Crocodilia laid in captivity in Australia. Eggs must be clean on visual inspection.

2.2 BACKGROUND

Owners/managers of zoological gardens wish to import Crocodilia for display in their collections and as part of a regional cooperative breeding programme with the objective of species conservation. Acquisition of some species through the importation of hatching eggs is considered feasible.

The risk analysis has assumed that Crocodilia will be held in containment under the provisions of the Hazard Substances and New Organisms Act 1996. Specific provisions for such containment are documented in Standard 154.03.04 Containment Facilities for Zoo Animals issued by Biosecurity Zealand (see: www.biosecurity.govt.nz /files/border/transitional-facilities/animals/154-03-04.pdf).

As the Crocodilia are to be held in containment in zoos in New Zealand, the primary responsibility for crocodile health is considered to rest with prospective importers. This risk analysis focuses on the diseases that may affect human health, industries contributing to the New Zealand economy, or other species valued in the environment.

Crocodilia are currently housed at two locations and the New Zealand population is three animals. There are no reports of health problems in this small number of crocodiles.

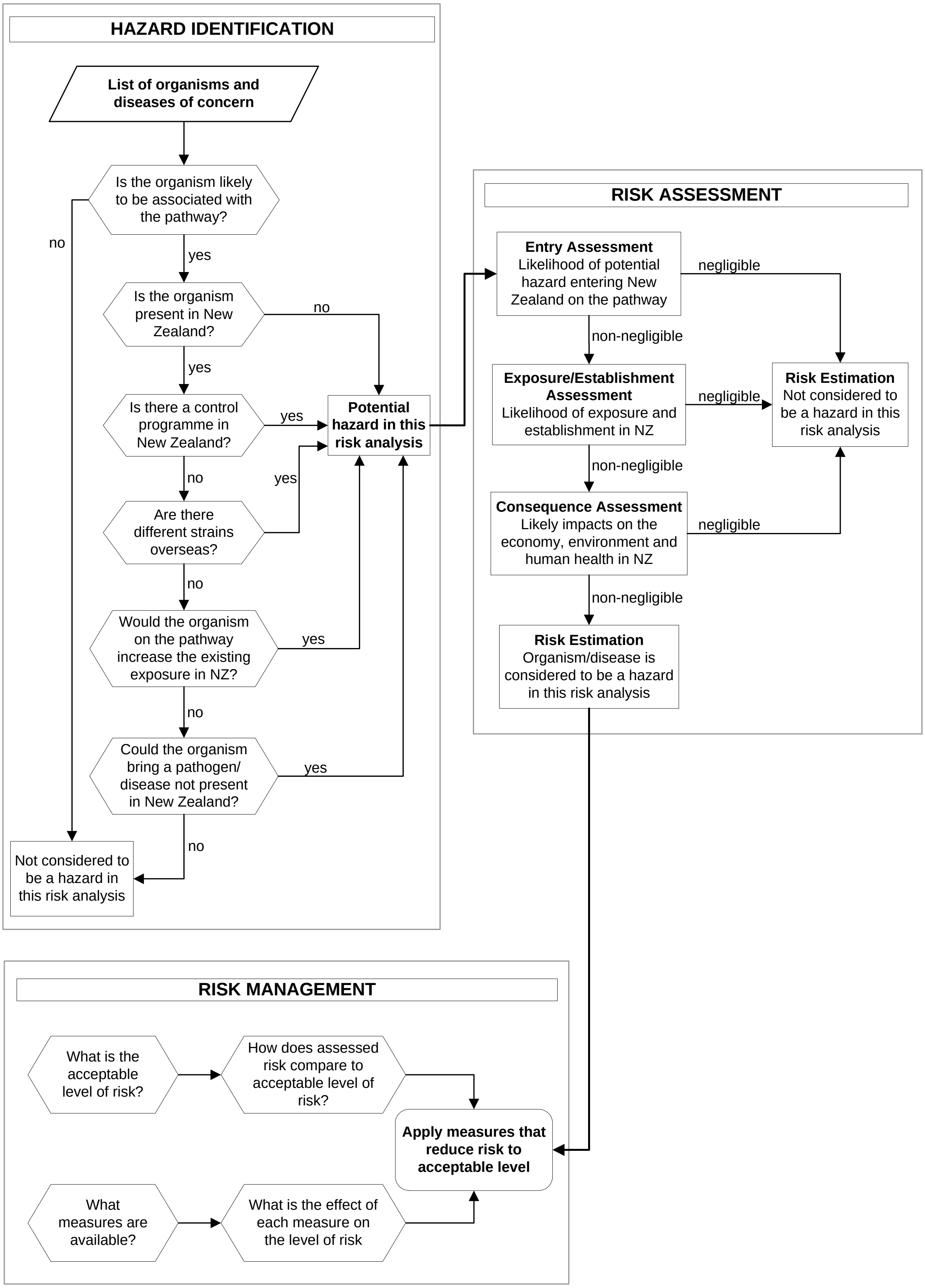
Although surveillance of diseases of reptiles is limited, the need for improved information on the disease status of Crocodilia in Australia became evident with the development of farming industries based on the two local species *Crocodylus porosus* (Australian salt water crocodile) and *Crocodylus johnstoni* (Australian fresh water crocodile). Information collected, predominantly by zoologists, became supplemented by more extensive collection of data particularly from crocodile farms and slaughter houses (Buenviaje *et al*., 1997; Buenviaje *et al*., 1998a; Buenviaje *et al*., 1998b; Buenviaje *et al*., 1992; Buenviaje *et al*., 1994; Ladds *et al*., 1996; Manolis *et al*., 1991). Information from available sources was consolidated by the Australian Quarantine and Inspection Service (AQIS) in their import risk analysis (AQIS, 2000) and this has provided a valuable source document during the preparation of this risk analysis for importations from Australia to New Zealand.

New Zealand is a signatory to the international treaty *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES) and international trade in Crocodilia is controlled through this. 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 import of live Crocodilia and their eggs.

2.3 METHODOLOGY

The methodology used in this risk analysis follows the guidelines as described in *Biosecurity New Zealand - Risk Analysis Procedures, Version 1* (MAF 2006) and in Section 1.3 of the *OIE Terrestrial Animal Health Code* (OIE, 2006), the key elements of which are shown overleaf in Figure 1.

Figure 1. The risk analysis process.



The following aspects must be considered for an organism to be considered a potential hazard:

1) whether the pathway could lead to the introduction of the organism into New Zealand;

AND

2) if the organism requires a vector, whether competent vectors might be present in New Zealand;

AND

3) whether the organism is exotic to New Zealand and likely to be present in the exporting country;

AND

4) if the organism is present in New Zealand:

    a. whether it is "under official control", which could be by government departments, by national or regional pest management strategies, or by a small-scale programme; **or**

    b. whether more virulent strains are known to exist in other countries, **or**

    c. whether the arrival of the organism in association with the pathway would likely increase the existing exposure to the organism in New Zealand.

For any organism, if the answer to item 1 is "yes" (and the answer to item 2 is "yes" in the cases of organisms requiring a vector), and the answer to either item 3 or 4 are "yes", the organism is classified as a potential hazard.

Under this framework, organisms present in New Zealand cannot be considered as hazards unless there is evidence that strains with higher pathogenicity are likely to be associated with the pathway, or the arrival of the organism in association with this pathway would increase the existing exposure to the organism in New Zealand.

Therefore, if risks to human or animal health (or subsequent progeny) posed by the introduction of the organism in association with the pathway, are no different from the existing risks resulting from the current presence of the organism in New Zealand, mitigating measures should be appropriate to good practice irrespective of the importation.

In line with the MAF Biosecurity New Zealand and OIE risk analysis methodologies, for each potential hazard requiring risk assessment the following analysis is carried out:

a)	**Release assessment**	The likelihood of the organism being imported in the commodity.
b)	**Exposure assessment**	The likelihood of animals or humans in New Zealand being exposed to the potential hazard.
c)	**Consequence assessment**	The consequences of entry, establishment or spread of the organism.
d)	**Risk estimation**	A conclusion on the risk posed by the organism based on the release, exposure and consequence assessments. If the risk estimate is non-negligible, then the organism is classified as a hazard.

Because of the scarcity of information relating to transovarial transmission of disease agents in Crocodilia, information pertaining to the transovarial transmission of similar organisms both in other reptiles and in birds has been used as guidance.

In the exposure assessment, an assumption is made that there is potential for contact between imported animals and their offspring and animals in the outside environment. Such contact might be through the movement of effluent or through transfer of fomites, movement of rodents, insects, water birds or other animals.

It is important to note that all of the above steps may not be necessary in all risk assessments. The MAF Biosecurity New Zealand and OIE methodologies make it clear that if the likelihood of release is negligible for a potential hazard, then the risk estimate is automatically negligible and the remaining steps of the risk assessment need not be carried out. The same situation arises where the likelihood of release is non-negligible but the exposure assessment concludes that the likelihood of exposure to susceptible species in the importing country is negligible, or where both release and exposure are non-negligible but the consequences of introduction are concluded to be negligible.

For each organism where risk is estimated to be non-negligible, the risk management step is carried out, comprising the following three sub-steps:

a)	**Risk evaluation**	A determination is made as to whether sanitary measures are necessary.
b)	**Option evaluation**	Identify the options available for managing the risk, and consider risk reduction effects.
c)	**Recommended measures**	The recommendation of the appropriate option or combination of options that achieve a negligible likelihood of entry, spread or establishment, while minimising negative trade effects.

Further details, including the full hazard identification and, where appropriate, the risk assessment and the recommended risk management measures, can be found in the sections on the individual agents.

2.4 IDENTIFICATION OF POTENTIAL HAZARDS

The hazard identification process begins with the collation of a list of organisms possibly associated with the commodities. Table 1 shows this preliminary hazard list, together with some of the key information considered for each organism in determining whether or not it should be classified as a potential hazard in the commodity. This list was compiled from those contagious diseases of Crocodilia identified from the textbook *Reptile Medicine and Surgery* (Mader, 2006), from the Australian import risk analysis paper for live Crocodilia and their eggs (AQIS, 2000) and from searches of the international scientific literature.

Table 1. Preliminary hazard list for species within the Order Crocodilia from Australia.

<table>
<tr><th>Organism</th><th>Reported from Crocodilia in Australia</th><th>Associated with disease in Crocodilia</th><th>Disease in other Orders</th><th>Recognised as present in NZ</th><th>Potential hazard</th></tr>
<tr><td colspan="6">Viruses</td></tr>
<tr><td>Influenza virus</td><td>No</td><td>No</td><td>Not addressed (N.A.)</td><td>N.A.</td><td>No</td></tr>
<tr><td>Paramyxovirus</td><td>No</td><td>No</td><td>N.A.</td><td>N.A.</td><td>No</td></tr>
<tr><td colspan="6">Paramyxoviruses and influenza viruses were identified in the faeces of farmed crocodiles in South Africa. There has been no association of these organisms with disease and there are no reports of the virus from Australian Crocodilians (AQIS, 2000). In 2006 a severe outbreak of disease involving conjunctivitis and 100 percent hatchling mortality (associated with severe exudative (fibrinous) cloacitis and pharyngitis) occurred on several crocodile farms in the Darwin area. Chlamydiosis was suspected on the basis of the conjunctivitis but hepatitis, which has been a major feature in the African incidents of chlamydiosis, was not present and chlamydial organisms were not been found. It has been suggested that the outbreak could have been caused by a Paramyxovirus, but again, there has been no confirmation. No definitive diagnosis was reached and recurrence in 2007 has not been reported. There has been no evidence that this disease spread to involve non-crocodilian species (unpublished data, F. W. Huchzermeyer, personal communication 2007). These viruses are not considered to be potential hazards in the commodity.</td></tr>
<tr><td>Togavirus (EEEV)</td><td>No</td><td>No</td><td>Yes</td><td>N.A.</td><td>No</td></tr>
<tr><td colspan="6">Antibodies to Eastern Equine Encephalitis Virus (EEEV) have been found in alligators in the USA (AQIS, 2000). The geographic distribution of EEEV excludes Australia (CDC, 2006). This virus is not considered to be a potential hazard in the commodity.</td></tr>
<tr><td>Flavivirus (West Nile Virus)</td><td>No</td><td>Yes</td><td>Yes</td><td>N.A.</td><td>No</td></tr>
<tr><td colspan="6">West Nile Virus has been isolated from Crocodilia (Jacobson, 2004; Klenk et al., 2004; Miller et al., 2003) but the geographic distribution of this virus does not include Australia (CDC, 2004). This virus is not considered to be a potential hazard in the commodity.</td></tr>
<tr><td>Poxvirus</td><td>Yes</td><td>Yes</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td colspan="6">Poxviruses have been identified from a number of species of Crocodilia in several countries, including Australia. The earlier report from Australia was of small, localised lesions on single animals on each of two crocodile farms near Darwin (Buenviaje et al., 1992). Recently, more extensive skin lesions suspected to be attributable to an “atypical” poxvirus have been reported from farmed C. porosus in Darwin (F W Huchzermeyer, personal communication, 2007). None of the reports of poxvirus infections in Crocodilia have included references to infections in in-contact species. Although poxvirus-associated lesions have been reported from Crocodilia in Australia, no records of poxvirus infection in other species of reptiles in Australia have been located. Poxviruses of Crocodilia are not considered to be potential hazards in the commodity.</td></tr>
<tr><td>Adenovirus-like</td><td>No</td><td>Yes</td><td>No</td><td>N.A.</td><td>No</td></tr>
<tr><td colspan="6">An Adenovirus-like agent associated with hepatitis and enteritis in Crocodilia elsewhere has not been reported in Australia (AQIS, 2000). This organism is not considered to be a potential hazard in the commodity.</td></tr>
</table>

Table 1 (continued)

Organism	Reported from Crocodilia in Australia	Associated with disease in Crocodilia	Disease in other Orders	Recognised as present in NZ	Potential hazard
Bacteria					
Escherichia coli	No	Yes	Yes	Yes	No
Mycobacterium spp.	Yes	Yes	Yes	Uncertain	No
Streptococcus spp.	No	Yes	Yes	Yes	No
Pseudomonas spp.	No	Yes	Yes	Yes	No
Pasteurella multocida	No	Yes	Yes	Yes	No
Aeromonas spp.	Yes	Yes	Yes	Yes	No
Dermatophilus spp.	Yes	Yes	Yes	Yes	No
Klebsiella spp.	Yes	Yes	Yes	Yes	No
Providencia (Proteus) rettgeri	Yes	Yes	Yes	Yes	No
Serratia liquefaciens	Yes	Yes	Yes	Yes	No
Erysipelothrix insidiosa	No	Yes	Yes	Yes	No
All of the bacteria listed above have been identified from Crocodilia with and without disease. Although bacterial diseases can be major causes of mortality, these bacteria are not considered host specific and cause disease as opportunist pathogens (AQIS, 2000; Buenviaje *et al*., 1994). “Probable mycobacteria” were identified in 2.5 percent of skin lesions of crocodiles examined in Australia (Buenviaje *et al*., 1998b). Although these organisms can be associated with disease in humans, most are already recognised in New Zealand and their presence on or in crocodiles being imported would be unlikely to result in any significant increase in exposure of the human population or other species. The same rationale applies to *Mycobacterium* spp. although the status of some species in New Zealand is uncertain. Although reports of the occurrence of *P. rettgeri* in New Zealand have not been discovered in the scientific literature, the information provided by the Auckland District Health Board’s laboratory (Maree Gillies, pers. comm. to José Derraik, 2007) reports the isolation of this organism from six patients over 13 months (in 2005-6), mostly from urinary tract infections. The bacteria listed above are, therefore, not considered to be potential hazards in the commodity.					
Salmonella spp.	Yes	Yes	Yes	Yes/No	Yes
Salmonellae are common in Crocodilia. Salmonellae cause disease in humans and other animals and some serotypes are included in the register of unwanted organisms. Salmonellae are considered to be potential hazards in the commodity.					

Table 1 (continued)

Organism	Reported from Crocodilia in Australia	Associated with disease in Crocodilia	Disease in other Orders	Recognised as present in NZ	Potential hazard
Edwardsiella tarda	? (But present in fish)	?	Yes	No	Yes
E. tarda has been recognised in fish in Australia (Eaves *et al*., 1990; Humphrey *et al*., 1987; Reddacliff *et al*., 1996). *E. tarda* has been identified in both healthy crocodiles (Williams et al., 1990) and crocodiles with "non-specific" septicaemia (F.W.Huchzermeyer, personal communication, 2007). *E. tarda* is a significant cause of disease in fish and is also a human pathogen. This organism is considered a potential hazard in the commodity.					
Mycoplasma spp.	No	Yes	No	N.A.	No
Mycoplasma spp. have been identified in Crocodilia in North America and in southern Africa. These are believed to be species distinct from those affecting other hosts. *Mycoplasma* infections of crocodiles have not been reported from Australia (AQIS, 2000). *Mycoplasma* spp. are not considered to be potential hazards in the commodity.					
Chlamydia spp.	No	Yes	N.A.	N.A.	No
Chlamydial infections have been reported from Crocodilia on farms in southern Africa. Infections spread to at least four other properties. It has been proposed that the infection may have originated from clawed toads (AQIS, 2000). Chlamydial infections of Crocodilia have not been confirmed in Australia. In 2006 a severe outbreak of disease involving conjunctivitis and 100 percent hatchling mortality (associated with severe exudative (fibrinous) cloacitis and pharyngitis) occurred on several crocodile farms in the Darwin area. Although chlamydiosis was suspected on the basis of the conjunctivitis, hepatitis, which has been a major feature in the African incidents, was not present and chlamydial organisms have not been found. It has been suggested that the outbreak could have been caused by a Paramyxovirus, but again, there has been no confirmation. No definitive diagnosis was reached and recurrence in 2007 has not been reported. (unpublished data, F.W.Huchzermeyer, personal communication, 2007). None of the reports of chlamydial infections, or suspect chlamydial infections, of crocodilia have been associated with infections in humans or other species. *Chlamydia* spp. are not considered to be potential hazards in the commodity.					
Fungi					
Penicillium oxalicum	Yes	Yes	Yes	No	Yes
Curvularia lunata var. *aeria*	Yes	Yes	Yes	No	Yes
Fusarium solani	Yes	Yes	Yes	Yes	No
Aspergillus niger	Yes	Yes	Yes	Yes	No
Fungi from a wide range of genera have been isolated from sporadic incidents of disease and from healthy crocodiles in Australia and elsewhere. These fungi are not host specific. Most are saprophytes and/or common in air, soil or water (AQIS, 2000). From Australia, *Aspergillus niger*, *Penicillium oxalicum*, *Curvularia lunata* var. *aeria* and *Fusarium solani* have been isolated from crocodiles with mycotic diseases (Buenviaje *et al*., 1994). *Penicillium oxalicum* and *Curvularia lunata* var. *aeria* are listed in the register of unwanted organisms; neither has been identified in New Zealand. *Penicillium oxalicum* and *Curvularia lunata* var. *aeria* are considered to be potential hazards in the commodity					

Table 1 (continued)

Organism	Reported from Crocodilia in Australia	Associated with disease in Crocodilia	Disease in other Orders	Recognised as present in NZ	Potential hazard
Protozoa					
Subphylum Mastigophora	No	No	No	N.A.	No
Protozoa from this subphylum infect Crocodilia and other reptiles and are considered harmless commensals of low or nil pathogenicity (AQIS, 2000). These organisms are not considered to be potential hazards in the commodity.					
Trypanosoma spp.	No	No	No	N.A.	No
Trypanosoma spp. have been identified in Crocodilia in Africa and in South / Central America. They were not associated with clinical disease (AQIS, 2000). No reports of *Trypanosoma* spp. in Australian crocodiles have been located. These organisms are not considered to be potential hazards in the commodity.					
Leishmania- like organism.	Yes	Yes	No	No	No
A Leishmania-like organism has been identified as a cause of giant cell enteritis in young *C. porosus* crocodiles in the region of the Gulf of Carpentaria in Australia and Papua New Guinea (Ladds *et al*., 1994). None of the cases occurred in "fresh water" crocodiles (*C. johnstoni* and *C. novaeguineae*) even though these species were present. This organism is not considered to be a potential hazard.					
Haemogregarines	No	No	Yes	No	No
Haemogregarine infections of Crocodilia are usually subclinical. Disease may occur when infection is transferred to non-natural hosts. Haemogregarines have not been reported in crocodiles in Australia (AQIS, 2000). Haemogregarines are not considered to be potential hazards in the commodity.					
Entamoeba invadens	No	No	Yes	No?	Yes
AQIS cites references proposing that *E. invadens* may be able to infect all reptile species. Although it does not cause disease in Crocodilia, it is said to be a significant pathogen in other reptiles. *E. invadens* has not been reported from crocodiles in Australia, but it has been reported from captive reptiles in Australian zoos (AQIS, 2000). It is considered to be a potential hazard.					
Coccidia	Yes	Yes	No	No	No
Coccidia seldom cause disease in wild Crocodilia (AQIS, 2000). Although coccidia cause disease in captive Crocodilia, the suggestion by AQIS (AQIS, 2000) that they were reported as one of the major diseases of farmed crocodiles in Queensland and Northern Territory is erroneous. Buenviaje et al. (1994), the source referred to as the basis for the AQIS statement, reported that their only evidence for coccidial infection of crocodiles between 1988 and 1991 was from a single animal on one farm. Coccidial species have high levels of host-specificity (most commonly infecting only one species of host or very closely related hosts) although Huchzermeyer (personal communication, 2007) states that a *Goussia* sp. reported in Nile crocodiles might have low host specificity. Coccidia are not considered to be potential hazards in the commodity.					
Haemosporines	No	No	No	N.A.	No
Progarnia sp. And *Plasmodium* sp. have been reported from Crocodilia in South and Central America. They are considered to be of low or nil pathogenicity (AQIS, 2000). They have not been reported from crocodiles in Australian. Haemosporines are not considered to be potential hazards in the commodity.					

Table 1 (continued)

Organism	Reported from Crocodilia in Australia	Associated with disease in Crocodilia	Disease in other Orders	Recognised as present in NZ	Potential hazard
Blastocystis spp.	No	No	?	N.A.	No
There has been one report of a *Blastocystis* sp. from an individual healthy crocodile in Singapore (AQIS, 2000). *Blastocystis* spp. are not considered to be potential hazards in the commodity.					
Cryptosporidium spp.	No	No	N.A.	Yes	No
A single reference to infection of a Nile crocodile with a *Cryptosporidium* spp. has been located (Siam *et al*., 1994). The authors suggested that this organism was able to infect the crocodile, a human and mice. Given the more recent recognition of host specificity and host preferences of cryptosporidia (Hajdusek *et al*., 2004; Ramirez *et al*., 2004; Sunnotel *et al*., 2006; Xiao *et al*., 2004a; Xiao and Ryan, 2004; Xiao *et al*., 2004b) it is likely that this was not a Crocodilia species of *Cryptosporidium*. Xiao *et al*. (2004b) suggested that *C. muris* and *C. parvum* in the faeces of carnivorous reptiles might be the result of infection in prey. *Cryptosporidium* spp. are not considered to be potential hazards in the commodity.					
Helminth parasites					
Nematodes	Yes	Yes	No ?	No	Yes
Although the adult stages of nematode parasites of Crocodilia have restricted host ranges, the larvae of some have been reported from fish and from birds. Nematodes are considered to be potential hazards in the commodity.					
Filarid worms	Yes	No	No	No	No
A filarid parasite, *Oswaldofilaria kanbaya*, has been reported from a single *Crocodilius porosus* in Australia (Manzanell, 1986). Disease was not reported to be associated with the infection and no other reports of this parasites have been traced in the world literature. Filarid worms are not considered to be potential hazards in the commodity					
Trematodes	Yes	No	No	No	No
All of the species of trematodes identified in the AQIS risk analysis (AQIS, 2000) have been reported only from Crocodilia and, with the exception of the filarid parasite referred to above, have not been reported from Australia. Trematodes are not considered to be potential hazards in the commodity.					
Kidney fluke (*Renivermis* spp.)	Yes	No	No	N.A.	No
There is only one report of this species and that was from saltwater crocodiles in Northern Australia (Blair *et al*., 1989). This organism is not considered to be a potential hazard in the commodity.					
Acanthocephala	No	Yes	No	N.A.	No
Acanthocephala have been reported only rarely from Crocodilia and there have been no reports from Australia (AQIS, 2000). Acanthocephala are not considered to be potential hazards in the commodity.					

Table 1 (continued)

<table>
<tr><th>Organism</th><th>Reported from Crocodilia in Australia</th><th>Associated with disease in Crocodilia</th><th>Disease in other Orders</th><th>Recognised as present in NZ</th><th>Potential hazard</th></tr>
<tr><td colspan="6">Arthropods</td></tr>
<tr><td>Pentastoma</td><td>Yes</td><td>Yes</td><td>Yes ?</td><td>No</td><td>Yes</td></tr>
<tr><td colspan="6">Pentastoma of the family Sebekidae (genera Alofia and Leiperia) have been identified in crocodiles in Australia (Riley, 1994; Riley and Huchzermeyer, 1996). Pentastoma were amongst the parasites identified as causing serious disease in crocodile farms in Australia (Buenviaje et al., 1994). Fish are recognised as intermediate hosts (Riley and Huchzermeyer, 1996) and human infections are said to occur (AQIS, 2000). Pentastoma are considered to be potential hazards in the commodity.</td></tr>
<tr><td>Ticks</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td><td>Yes</td></tr>
<tr><td colspan="6">There are a very small number of reports of ticks on Crocodilia. Given the ability of many tick species to act as disease vectors these are regarded as potential hazards on the commodity.</td></tr>
<tr><td>Leeches</td><td>Yes</td><td>No</td><td>No</td><td>N.A.</td><td>No</td></tr>
<tr><td colspan="6">Leeches are relatively common on Crocodilia in some environments (AQIS, 2000) and, in the USA have been found to be vectors of Haemogregarina sp. (Glassman et al., 1979). In Australia, leeches have been reported from crocodiles in the Northern Territory (Webb and Manolis, 1983). The prevalence varied greatly between habitats, reflecting the generally free living nature of leeches and their dependence on suitable environments. Although leeches must feed on blood to complete their lifecycle, they are not regarded as pathogenic. Leeches are not considered to be potential hazards in the commodity.</td></tr>
</table>

3 Organism Risk Analyses

3.1 BACTERIA

3.1.1 Salmonellae

3.1.1.1 *Hazard identification*

Aetiological agent

The *Salmonella* genus contains over 2,400 serotypes 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 2,300 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. *Salmonella enterica arizonae* contains over 300 serotypes (Brenner *et al*., 2000; OIE, 2004).

OIE List

Salmonella serotypes other than *S.* Gallinarum-Pullorum are not included in the OIE list of notifiable diseases.

New Zealand Status

S. Gallinarum, *S.* Pullorum, *S.* Abortusovis, *S. arizonae*, *S.* Dublin, *S.* Typhimurium DT 104, *S.* Typhimurium DT 44, *S.* Enteritidis pt 4 and *Salmonella* spp. (exotic, affecting animals) are included in the register of unwanted organisms.

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

Over the past eight years *Salmonella* isolates from humans in New Zealand yielded over 140 serotypes/phage types. During the same period, typing of isolates from animals, their feeds, and their environment yielded over 80 serotypes/phage types. The frequency with which specific types were isolated each year varied greatly and many of the serotypes/phage types were isolated from human or non-human sources on only one occasion. Each year, three to five serovars or phage types not previously identified in New Zealand were reported. Most were from humans, most of whom were travellers or immigrants (ESR, 2006).

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 an incident investigated by Biosecurity New Zealand in 2005, in which three serotypes new to New Zealand (*S*. Mountpleasant, *S*. Onderstepoort and *S*. Biljmer) were identified in lizards on the one property.

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 head) on one farm and gutted 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.

Conclusion

Salmonellae are potential hazards in the commodity requiring further risk assessment.

3.1.1.2 *Risk assessment*

Release 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 passing of faeces. Reliable evidence of the absence of salmonellae would require sampling and testing of animals on several occasions.

Although no published records of *Salmonella* transmission via the eggs of Crocodilia could be found, vertical transmission of *Salmonella* spp. is well documented in avian species (Gast 2003) so the likelihood of transmission in crocodile eggs should be considered low but non-negligible.

The release assessment is non-negligible.

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 measures to avoid infection. Containment provisions require that carcasses be disposed of by incineration or deep burial.

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 not considered that the presence of salmonellae in live Crocodilia or their eggs will significantly increase the current level of exposure of humans or other animal species. On this basis, the exposure assessment is negligible.

Risk estimation

On the basis of the negligible exposure assessment, the risk estimate is negligible and salmonellae are not considered a hazard in the commodity.

3.1.2 Edwardsiella tarda

3.1.2.1 *Hazard identification*

Aetiological agent

Edwardsiella spp. are members of the Enterobacteriaceae.

OIE List

Edwardsiella tarda is not included on the OIE list of notifiable diseases.

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 considered to be an opportunist pathogen mainly affecting fish. It is one of the major diseases in aquaculture systems in Japan, affecting a variety of species (Kusuda and Salati, 1993). It is a significant pathogen of Channel Catfish (Meyer and Bullock, 1973), Largemouth Bass (*Micropterus salmoides*) (Francis-Floyd *et al*., 1993) and other fish species. *E. tarda* has been isolated from the gular and paracloacal glands of clinically healthy American alligators (*Alligator mississippiensis*) (Williams *et al*., 1990) and from crocodiles with “non-specific” septicaemia in southern Africa (F. W. Hutchzermyer, personal communication, 2007). Likely sources of *E. tarda* infection of crocodiles are soil, water or fish. *E. tarda* is a relatively infrequent cause of human infections, most commonly causing gastro-intestinal disease. It is uncommon outside tropical and subtropical regions, and fish and water contaminated by fish are considered the most common sources of human infections (Clarridge *et al*., 1980; Novotny *et al*., 2004).

Conclusion

E. tarda is considered a potential hazard in the commodity.

3.1.2.2 *Risk assessment*

Release assessment

In Australia, *E. tarda* has been reported from a diseased native eel (*Anguilla reinhardtii*) (Eaves *et al*., 1990), diseased stressed rainbow trout (*Oncorynchus mykiss*) (Reddacliff *et al*., 1996), samples from a farmed Golden Tiger Barb (*Barbus tetrazona*), and one other piscine sample (Akinbowale *et al*., 2006). Buenviaje *et al*. (1994) reported three isolates of *Edwardsiella* sp. from farmed crocodiles in northern Australia with bacterial hepatitis/ septicaemia. The species of these Australian crocodile isolates is unknown, however it is considered that these were most likely to be *E. tarda*.

There is no evidence that *Edwardsiella tarda* is able to be transmitted through eggs.
The release assessment is non-negligible for live Crocodilia.

The release assessment for Crocodilia eggs is considered to be negligible. Under the methodology used in this risk analysis, the risk estimation for *E. tarda* in Crocodilia eggs is therefore considered to be negligible.

Exposure assessment

Crocodiles imported with *E. tarda* infection will shed organisms into the environment. Water is recognised as a habitat in which *E. tarda* will survive and exposure of fish or other animal species may occur.

The exposure assessment for live Crocodilia is non-negligible.

Consequence assessment

The consequences of the establishment of *E. tarda* in New Zealand are unclear. Human infections have mainly been reported from the tropics and sub-tropics but infection, and disease, in fish have been reported from other environments. *E. tarda*-related diseases have been reported from both rainbow trout and eels in Australia. New Zealand freshwater eels of the same genus as the Australian species have cultural, conservation, and economic values and the rainbow trout fishery is of major economic and recreational importance. Following establishment, human disease incidents may occur, but are likely to be few in number.

The consequence assessment for live Crocodilia is non-negligible.

Risk estimation

On the basis of the non-negligible release, exposure and consequence assessments, the risk estimate for live Crocodilia is non-negligible. *E. tarda* in live Crocodilia is considered to be a hazard to the economy, the environment and to human health.

As indicated above, because the release assessment for Crocodilia eggs is considered to be negligible, under the methodology used in this risk analysis, the risk estimation for *E. tarda* in Crocodilia eggs is considered to be negligible.

3.1.2.3 Risk management

Risk evaluation

Since *E. tarda* is considered to be a hazard in live Crocodilia, sanitary measures will be needed to effectively manage the risk.

Risk management objective

To ensure that importation of live Crocodilia does not result in biosecurity release of individuals infected with *E. tarda*.

Risk management options

The likelihood of *E. tarda* infection can be reduced to a negligible level by either of the two requirements:

1. That the live Crocodilia to be imported have been reared in an environment with good quality water (either potable water or water from a bore) and have not been fed on fish or been exposed to live fish.

   These requirements are consistent with common practice for the rearing of hatchlings to 12 months old in the commercial crocodile industry in Australia (Peucker, 1997).

   OR

2. That samples from both gular and paracloacal glands of live Crocodilia have been cultured for *E. tarda* with negative results AND faecal samples collected on two separate occasions have been cultured for *E. tarda* with negative results.

Recommended sanitary measures

It is recommended that:

1. Live Crocodilia to be imported 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; **OR**

2. samples from both gular and paracloacal glands should cultured for *E. tarda* with negative results AND faecal samples collected on two separate occasions cultured for *E. tarda* with negative results.

3.2 FUNGI AND YEASTS

3.2.1 Fungi and yeasts of Crocodilia

3.2.1.1 *Hazard identification*

Aetiological agent

Penicillium oxalicum and *Curvularia lunata* var. *aeria* are saprophytic fungi capable of acting as opportunist pathogens in plants and, rarely, in animals. *C. lunata* is the anamorph of *Cochliobolus lunatus*.

OIE List

Neither of these organisms is included in the OIE list of notifiable diseases.

New Zealand Status

Neither *Penicillium oxalicum* nor *Curvularia lunata* var. *aeria* have been reported in New Zealand and both are listed in the register of unwanted organisms which contains some 1760 fungal species.

Although it seems difficult to preclude the possibility that these organisms might be present in New Zealand, given the absence of records of identification together with their inclusion in the register of unwanted organisms, the position adopted in this risk analysis is that they are not present.

Epidemiology

P. oxalicum is present in China, India, Israel, UK, Nigeria, Canada, Mexico, USA and Brazil. *C. lunata* is found in Bangladesh, China, India, Indonesia, Iran, Iraq, Japan, Korean Republic, Malaysia, Pakistan, Philippines, Saudi Arabia, Singapore, Sri Lanka, Thailand, Turkey, Vietnam, USSR, former Yugoslavia, Italy, Netherlands, Benin, Burkina Faso, Egypt, Ghana, Niger, Nigeria, South Africa, Mexico, USA, Panama, Puerto Rico, Argentina, Brazil, Chile, Peru, Venezuela, Australia and Papua New Guinea.[1] Based on a general scan of the literature, *C. lunata* var. *aeria* has a comparably wide geographic distribution.

C. lunata infects a wide range of angiosperms. It is a facultative pathogen causing leaf spot and seedling blight, mainly on monocotyledons. The sclerotia may survive in soil for up to two years (Anonymous, 1975).

P. oxalicum is found in soil, especially in the tropics. It is common on pre-harvest and fresh post-harvest maize. It is also found on other cereals, spices, fennel, yams and cheese (Anonymous, 1992).

Reports of either *C. lunata* var. *aeria* or *P. oxalicum* infecting animals are rare. *P. oxalicum* has been reported from a case of metritis in a buffalo in India (Sambyal *et al*., 1987), a case of post-traumatic ocular mycosis in a human in Argentina (Kopp and Vidal, 1998) and in artificially reared flies in Nigeria (Banjo *et al*., 2005). *C. lunata* var. *aeria* was isolated from mycotic keratitis in a man in Argentina (Luque *et al*., 1986).

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[1] Report from crop protection compendium - www.cabi.org/compendia/cpc/index.htm

Conclusion

The listing of both *P. oxalicum* and *C. lunata* var. *aeria* in the register of unwanted organisms supports a conclusion that they are potential hazards in the commodity which require further risk assessment.

3.2.1.2 *Risk assessment*

Release assessment

Both *P. oxalicum* and *C. lunata* var. *aeria* have been reported from mycotic skin disease in Crocodilia in Australia (Buenviaje *et al*., 1994). Huchzermeyer (personal communication, 2007) commented on both *Curvularia* and *Penicillium* species being identified in the intestinal flora of wild-caught African dwarf crocodiles. The species of these fungi is unknown.

Although the commodity definition requires that Crocodilia to be imported are healthy and free of visible contamination with soil, the possibility that either *P. oxalicum* or *C. lunata* var. *aeria* might be present on, or in, the imported animals cannot be excluded. The likelihood of this, however, is considered no greater than the carriage of the spores of other saprophytic fungi. Such spores are common environmental contaminants. *C. lunata* is said to be common in the hair of healthy dogs (Swift et al., 2006) and bird feathers (Namita *et al*., 1998), while spores and hyphae of *Curvularia* spp. are major contributors to environmental allergic load world-wide (Horner et al., 1995). *P. oxalicum* is comparably ubiquitous as demonstrated by its presence in the hair of sheep in Saudi Arabia (Nasser and Abdel-Sater, 1997) and the air of grain shops in India (Sawane and Saoji, 2005). *Penicillium* spp. are common components of dust, both in the air and in carpets, in the United States of America (Chew et al., 2003; Solomon, 1976) and hypersensitivity to *P. oxalicum* is common in Malaysia (Wan Ishlah and Gendeh, 2005).

It is concluded that that spores of *Curvularia* spp. (including those of *C. lunata* var. *aeria*) and *Penicillium* spp. (including those of *P. oxalicum*) are likely to be transported world wide on animals, humans and other fomites. The likelihood of these fungal species entering and establishing in New Zealand in association with imported live Crocodilia or their eggs which meet the commodity definition is no greater than their entry by many other means. On that basis, the release assessment is concluded to be negligible.

Risk estimation

On the basis of the negligible release assessment, the risk estimates for both *Penicillium oxalicum* and *Curvularia lunata* var. *aeria* are negligible and they are considered not to be hazards in the commodity.

3.3 HELMINTH PARASITES

3.3.1 Nematodes

3.3.1.1 *Hazard identification*

Aetiological agent

The section covers all nematode parasites relevant to the importation of the commodity.

OIE List

There are no nematodes of Crocodilia in the OIE list.

New Zealand Status

No records of nematodes of Crocodilia in New Zealand have been discovered. No nematodes of Crocodilia are listed in the register of unwanted organisms.

Epidemiology

AQIS (AQIS, 2000) reported that gastrointestinal nematodes of the genera *Dujardinascaris*, *Eustrongylus*, *Contracaecum*, *Physaloptera*, *Paratrichosoma*, *Crocodylocappillaria* and *Goezia* have been identified from crocodiles in Australia.

Although most adult *Dujardinascaris* spp. have been reported only from crocodiles some species have been reported from fish. It is considered that these are different species from those infecting Crocodilians (Paperna, 1996). In Australia members of this genus were common in *C. johnstoni* examined in the Northern Territory (Webb *et al*., 1982). It is thought that fish act as intermediate hosts and that, for some species, copepods (small marine crustacea) may act as pre-intermediate paratenic hosts (Moravec, 2001).

Eustrongylides spp. were found in 14 percent of *C. johnstoni* examined in the Northern Territory (Webb *et al*., 1982). These parasites appear to have a three host life cycle through oligochaetes and fish (Coyner *et al*., 2003) with birds being the most commonly recognised definitive hosts. Parasites of this genus have been reported from Australasian bittern, Black shags and Spotted shags in New Zealand (McKenna, 1998).

The most commonly reported hosts for adult *Contracaecum* spp. are birds, with copepods and fish as intermediate hosts (Huizinga, 1967; Koie and Fagerholm, 1995; Moravec, 2001). Webb *et al.* (1982) reported larval *Contracaecum* spp. from crocodiles. It has been suggested that Crocodilia may act as paratenic hosts for members of this nematode genus (Moravec, 2001).

Physaloptera spp. were identified in 2 percent of crocodiles examined by Webb *et al*. (1982). Most reports of adult *Physaloptera* spp. are from mammals and a range of insects have been identified as intermediate hosts (Lincoln and Anderson, 1975; Petri and Ameel, 1950). Information on the lifecycle of *Physaloptera* spp. infecting crocodiles has not been located.

Paratrichosoma spp. have been identified only from crocodiles in which they cause skin lesions of concern to those involved in commercial production (Moravec and Vargas-

Vazquez, 1998). Webb *et al*. (1982) reported finding *Paratrichosoma* spp. in 2 percent of the crocodiles they examined. The life cycle of *Paratrichosoma* spp. remains uncertain.

Crocodylocapillaria spp. infect only crocodiles and the only report of this genus located is from Australia and New Guinea (Moravec and Spratt, 1998). These authors suggested that the parasite probably has a direct life cycle (i.e. without an intermediate host). Autoinfection was considered possible.

Webb *et* al. (1982) reported finding *Goezia fluviatis* in 2 percent of the crocodiles (*C. johnstoni*) they examined from the Northern Territory. Sprent, however, considered that the *Goezia* spp. examined by him and coming from crocodiles (*C. porosus*) and several species of aquatic snakes in areas not far from those sampled by Webb *et al*. were of a previously undescribed species which he named *G. holmesi* (Sprent, 1978). *Goezia fluviatis* were reported from fish in the lower Murray River (Johnston and Mawson, 1940), far to the south of the habitat range of crocodiles in Australia. Sprent suggested that fish may act as intermediate hosts for *Goezia holmesi* and the parasite does not cause harm to crocodiles.

Gastrointestinal parasites seldom cause disease in crocodiles (AQIS, 2000), the ability of some of these species to infect other species, as intermediate hosts, is the basis for considering that they might be potential hazards in the commodity.

Conclusion

Those nematodes of Crocodilia, requiring intermediate hosts, are considered to be potential hazards in the commodity which require further risk assessment.

Those nematode parasites of Crocodilia not requiring intermediate hosts are host specific within the Crocodilia and are not hazards in the commodity.

3.3.1.2 *Risk assessment*

Release assessment

Crocodiles captured from the wild are likely to be infected with species of gastrointestinal nematodes. Maintenance of captive populations in areas remote from the species required by nematodes as intermediate hosts will lead to decline and extinction of most gastrointestinal nematode species in these populations. It is feasible that some of the nematode genera could be maintained in captive populations through the feeding of fish harvested in areas populated by crocodiles.

The release assessment for wild-caught crocodiles is non-negligible.

Although the likelihood of infection of crocodiles bred in captivity is lower than for wild-caught crocodiles, it is also considered to be non-negligible.

Eggs are not considered to be vehicles for nematode transmission, therefore the release assessment for Crocodilia eggs is negligible. Under the methodology used in this risk analysis, the risk estimation for nematodes in Crocodilia eggs is therefore considered to be negligible.

Exposure assessment

The likelihood of transmission of gastrointestinal nematodes infecting live crocodiles imported to New Zealand will be limited by requirements that the animals and their progeny be held indefinitely in containment. The likelihood of infection of competent intermediate hosts is low and the likelihood that crocodiles might gain access to infected intermediate hosts is even lower. The likelihood of a sustainable life cycle for species requiring intermediate hosts is considered negligible.

The exposure assessment for nematodes requiring intermediate hosts is negligible for live Crocodilia.

Risk estimation

As the release assessment for Crocodilia eggs is negligible and the exposure assessment for live Crocodilia is negligible, gastrointestinal nematodes are not considered hazards in the commodity.

3.4 PROTOZOA

3.4.1 Entamoeba invadens.

3.4.1.1 *Hazard identification*

Aetiological agent

The genus *Entamoeba* is within the Phylum Sarcomastigophora and the kingdom Protozoa.

OIE List

Entamoeba invadens is not included in the OIE list of notifiable diseases.

New Zealand Status

E. invadens is not included in the register of unwanted organisms.

Entamoeba sp. has been identified in the common gecko (*Hoplodactylus maculatus*). The species identity of this organism is unknown (McKenna, 2003).

Epidemiology

E. invadens, like other *Entamoeba* spp., has a direct life cycle with cysts being ingested by the host, development and reproduction of trophozoites in the intestinal tract and cysts being passed in faeces. Trophozoites may invade the mucosa, causing damage and allowing bacterial invasion. Trophozoites may also locate in the liver, kidney or lung. *E. invadens* causes disease and mortality in lizards, snakes and tortoises, particularly those in captive collections (Greiner and Mader, 2006; Hernandez-Divers, 2006; Martinez-Palomo, 1993).

E. invadens is said to be a common inhabitant of the intestinal tract of Crocodilia, in which it causes no disease (AQIS, 2000; Cubas, 1996; Lane and Mader, 1996; Lloyd, 2003). Crocodilia are also said to be a source of infection for other reptilian species susceptible to infection and disease. All of the discoverable references proposing this relationship have been textbooks or review articles. None has provided references to the source of their information, although Lloyd (2003) states that *E. invadens* was identified in Crocodilia in the late 1950s. Lane and Mader (1996), in Reptile Medicine and Surgery, indicated that Crocodilia could act as reservoirs for *E. invadens*, but no such statement is made in the second edition of this text (Greiner and Mader, 2006). Extensive searches of the scientific literature, including CAB Abstracts and Biological Abstracts over their full date ranges and Index Veterinarius and the Veterinary Bulletin over the period 1954 to 1961 have failed to find records of the identification of *E. invadens* in Crocodilia or reports of their being the source of infection leading to disease in snakes or lizards.

Meerovitch (Meerovitch, 1958, 1961) studied host-parasite relationships of *E. invadens* and concluded that the parasite is a commensal in turtles, using ingested plant polysaccharides as a source of nutrients. She further concluded that pathogenicity arose very commonly in snakes because they are carnivores and, in the absence of plant polysaccharides, the organism obtained its polysaccharide requirements from mucous secretions in the gut, thus rendering the mucosa susceptible to bacterial invasion. Meerovitch considered that this explanation was consistent with the general pattern of *Entamoeba* spp. being commensals in strictly herbivorous mammals but pathogenic in carnivores, and with a pattern of *E. invadens* infections causing disease in carnivorous lizards but being associated with no clinical signs in herbivorous species. This proposed relationship between host diet and pathogenicity of *E. invadens* is not consistent with Crocodilia, which have a carnivorous diet, acting as reservoir hosts for the parasite in the absence of disease.

While there is a single report suggesting that *E. invadens* may be present in captive reptiles in Australia (William Meikle, personal communication. Cited by AQIS, 2000), this parasite has not been reported as present in Crocodilia in Australia (AQIS, 2000).

Based on:

1. the lack of evidence that *E. invadens* infects Crocodilia in Australia;

2. the lack of published evidence that *E. invadens* is carried by Crocodilia;

3. the lack of published evidence that Crocodilia have been sources of infection for other reptilian species; and

4. the carnivorous nature of the diet of Crocodilia and the proposed relationship between such diets and susceptibility of other reptiles to *E. invadens*-induced disease;

it is concluded that the likelihood of *E. invadens* infection in Crocodilia is negligible.

Conclusion

It is concluded that *E. invadens* is not a hazard in the commodity.

3.5 ARTHROPODS

3.5.1 Pentastomida

3.5.1.1 *Hazard identification*

Aetiological agent

The subclass Pentastomida is within the phylum Arthropoda. Adults from within the family Sebekidae are almost exclusively found in crocodiles. The one exception is a species found in chelonians.

OIE List

No Pentastomida of Crocodilia are included in the OIE list of notifiable diseases.

New Zealand Status

No members of the Pentastomida are included in the unwanted organisms register.

Epidemiology

Pentastoma of the genera *Alofia* and *Leiperia* have been reported from crocodiles in Australia (Riley, 1994; Riley and Huchzermeyer, 1996). Information on the life cycles of these parasites in Australia is not available but immature nymphs of *Leiperia* spp. are found in numerous species of fish in South America and Africa. Adult Pentastoma in the lungs of their primary host deposit eggs containing larvae. After being coughed from the lungs, the eggs are swallowed, passed in faeces and develop to infective stages. These are taken up by intermediate hosts (fish), undergo further larval development and become infective to the primary host. Following ingestion by the primary host, the larvae penetrate the intestinal wall, migrate through the body and enter the lungs. Most pentastomid infections are subclinical but severe pulmonary pathology may develop in heavily infected animals (Greiner and Mader, 2006). Although pentastomids may infect humans (AQIS, 2000), no reports suggesting human infection by species with Crocodilia or other reptiles as their hosts have been located.

No reports of disease in fish as a result of infection with larval stages of Sebekidae have been located.

Buenviaje *et al*. (1994) identified Pentastoma as the cause of a serious health problem in hatchlings on one crocodile farm in northern Australia. The hatchlings were being fed on fresh and frozen fish and prawns. Although it is not stated, it is assumed that these products were derived from the fisheries industry in an area where wild crocodiles were common. The authors proposed that fish should be frozen to –10^{o}C for at least 72 hours. Greiner and Mader (2006) stated that Pentastoma in captive animals should be easily controlled through hygiene and the feeding of safe foods. Given these conditions, completion of the life cycle of penastomids, which might infect crocodiles imported to New Zealand, is highly unlikely.

The likelihood of Sebekidae being a hazard to human health, the environment or other species is considered to be negligible.

Conclusion

It is concluded that pentastomids are not hazards in the commodity.

3.5.2 Ticks

3.5.2.1 *Hazard identification*

Aetiological agent

Ticks are arthropods in the Class Arachnida. They are grouped in two families; Ixodidiae (hard ticks) and Argasidae (soft ticks).

OIE List

No species of ticks are included in the OIE list of notifiable diseases.

New Zealand Status

The ticks *Amblyomma* spp., *Boophilus* spp., *Ixodes* spp., *Rhipicephalus* spp. and *Dermacantor* spp. are listed in the register of unwanted organisms.

Nine *Ixodes* species, one *Ornithodorus* species, species of *Argasidae* and *Haemaphysalis longicornis* are established in New Zealand (Bishop and Heath, 1998). Of these, all but *H. longicornis* are parasites of birds.

Epidemiology

The lifecycles of ticks have a general form of adults falling from their primary hosts to the ground and laying eggs; larvae hatching and gaining access to a host on which they feed; larvae either falling to the ground or remaining on the host, moulting to become adults; and those that have left their initial hosts regaining access to the primary host on which mating takes place.

From the literature review by Burridge (Burridge, 2001) and the introduction to an article by Rainwater et al. (Rainwater et al., 2001) tick species reported from Crocodilia appear restricted to *Amblyoma grossum*, *Amblyomma dissimile*, *Amblyomma* sp. *Aponomma exornatum* and *Aponomma flavomaculatum*. One of these reports (that of *Amblyomma* sp.) was of a single tick on a *C. johnsoni* (freshwater crocodile) in northern Queensland, Australia. Rainwater *et al*. (2001) proposed that tick infestations of Crocodilia are only likely in situations where dry conditions cause Crocodilia to move from their aquatic habitats to environments where other animals will have contributed to environmental infestation with ticks.

Conclusion

It is concluded that ticks are potential hazards on the commodity which require further risk assessment.

3.5.2.2 *Risk assessment*

Release assessment

As tick infestations of Crocodilia are only likely in situations where dry conditions cause Crocodilia to move from their aquatic habitats to environments where other animals will have contributed to environmental infestation with ticks, and as Crocodilia to be imported from Australia will come from captive populations, the likelihood of tick infestation is considered to be negligible. In his review of the role of trade in reptiles as a means of international spread of ticks, Burridge (2001) does not suggest that Crocodilia play a part.
Eggs are not considered to be vehicles for tick transmission.
The release assessment is considered to be negligible for live Crocodilia and their eggs.

Risk estimation

On the basis of the negligible release assessment, the risk estimate is negligible and ticks are not considered hazards in the commodity.

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Only abstracts have been seen for those references marked with two asterisks (**). Information has been used from abstracts only if it is considered clear and unambiguous.

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