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Tiakitanga Pūtaiao Aotearoa

Import Risk Analysis

Crustaceans for human consumption

Version 1.0 approved for IHS development

Prepared for Ministry for Primary Industries

By Animals and Aquatic,
Biosecurity Science and Risk Assessment,
Regulation and Assurance,
Ministry for Primary Industries

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Import Risk Analysis: Crustaceans for human consumption

23 July 2018

Version 1.0 for IHS development

Approved for public consultation

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1 Executive summary

This import risk analysis examines the biosecurity risks associated with the international trade in non-viable crustaceans of freshwater or marine origin that are intended for human consumption. Crustaceans that are cultured or wild-caught for human consumption mainly belong to the order Decapoda (shrimps or prawns, lobsters and crabs) and to a lesser extent the order Euphausiacea (krill) and the order Stomatopoda (mantis shrimps). They may be imported into New Zealand chilled, frozen or processed.

In New Zealand, the Food Act 2014 and the Animal Products Act 1999 manage risks to public health associated with food. Consignments of product imported into New Zealand for human consumption must meet the food safety and suitability requirements of this legislation, in addition to the requirements of the Biosecurity Act 1999.

The human health consequences to New Zealand consumers from the consumption of imported crustaceans (food safety) has previously been evaluated by MPI in 2012. This evaluation formed the basis for the management of food safety risks associated with the consumption of crustaceans imported into New Zealand under the Food Act 2014.
Consequently, food safety risks and additional risk management measures related to imported crustaceans have not been further considered in this IRA.

A preliminary list of hazards comprising of 141 organisms (or groups of organisms) of concern was compiled from the scientific literature, previous risk analyses and consultation with crustacean disease experts. Of these, 25 organisms (including two zoonotic organisms *Angiostrongylus cantonensis,* and *Paragonimus* spp.) were identified as requiring risk assessment:

Viruses:
- Hepatopancreatic parvo-like virus
- Infectious hypodermal and haematopoietic necrosis virus
- Infectious pancreatic necrosis virus
- *Macrobrachium rosenbergii* nodavirus (includes extra small virus)
- Mud crab reovirus
- Mud crab virus
- *Penaeus* monodon-type baculovirus (includes *bennettae* baculovirus and *plebejus* baculovirus)
- Taura syndrome virus
- White spot syndrome virus
- Yellow head virus

Bacteria:
- Exotic rickettsia-like organisms
- Rickettsia-like organism causing milky haemolymph syndrome

Fungi:
- *Acremonium* spp.
- *Aphanomyces astaci*
- *Halocrusticida* spp.
- *Plectosporium oratosquillae*

Protozoa:
- Apostome ciliates
- Holotrich ciliates
- *Hematodinium* and *Hematodinium*-like spp.
- Microsporidians

Metazoa:
- *Angiostrongylus cantonensis* (zoonotic)
- Epicaridean isopods *Paragonimus* spp. (zoonotic)
- Rhizocephalan barnacles

Of these 25 organisms, 4 are assessed to present a non-negligible risk: *Aphanomyces astaci*, *Hematodinium* and *Hematodinium*-like spp., *Angiostrongylus cantonensis* and *Paragonimus* spp. Risk management options are presented for each organism.

The bulk of this import risk analysis was completed prior to 2017.

New information considered since that date has come from MPI's Emerging Risks System – Biosecurity (ERS). The ERS is designed to proactively identify and manage potential and emerging risks to New Zealand's biosecurity. The ERS focusses on plant and animal hazards and other invasive species in the terrestrial and aquatic environments. The current priorities of the ERS are significant changes to the distribution, hosts or virulence of exotic organisms of biosecurity concerns to New Zealand.

Since the end of 2016, there have been five ERS alerts associated with crustacean diseases. Three if these were associated with white spot disease, including the recent outbreak in Australia. This has been addressed by the white spot syndrome virus assessment. One alert was raised following and outbreak of an unknown disease in Bangladesh and the other was the discovery of *Chequa iflavirus* from cultured redclaw crayfish (*Cherax quadricarinatus*) in northern Queensland, Australia. The association of this virus with the stress-related mortalities is unproven (Sakuna *et al.* 2017).

2 Introduction

Significant international movements of crustaceans and crustacean products occur which are driven by economic activity and differences in demand between net producing and net consuming nations (Bondad-Reantaso *et al.* 2012).

The top five producers of cultured crustaceans are from Asia and accounted for 76.5 % (4.9 million tonnes) of the world's production in 2012 (FAO 2014). Crustaceans are a high value commodity and are worth almost a quarter (US$30.9 billion) of the total value derived from aquaculture while only accounting for 9.7 % of production (6.4 million tonnes) (FAO 2014).

A variety of crustacean species are cultured worldwide with 59 currently registered with the Food and Agriculture Organization (FAO 2014).

Of all crustaceans, penaeid shrimps are the most valuable and, in addition to aquaculture production, 3.4 million tonnes of wild shrimp were caught in 2012 (FAO 2014; Lafferty *et al.* 2014).

Trade in crustaceans is linked to the spread of exotic pathogens to new geographic locations (Lightner 1996; Jones 2012). Most notably, a number of shrimp viral diseases have emerged and spread through indiscriminate trade. It has been estimated that viral disease outbreaks cost the shrimp aquaculture industry over US$1 billion dollars each year in lost revenue (Briggs *et al.* 2004). The impact exotic pathogens have on wild-caught crustacean populations and the wider environment is much more difficult to assess (Lightner 1996).

The major pathway for the introduction of exotic crustacean pathogens is through the international trade in live animals intended for use in aquaculture (Flegel 2009; Jones 2012). The trade in non-viable crustacean products intended for human consumption has also been highlighted as a pathway that requires formal risk assessment (Lightner *et al.* 1997; Durand *et al.* 2000; Jones 2012).

The current New Zealand import health standard for crustaceans (crabs, lobsters, prawns, and shrimps) imported for human consumption states that they may be of marine or freshwater origin and must be non-viable. The major crustacean product imported into New Zealand for human consumption is frozen penaeid shrimp.

In 2009, Biosecurity Australia completed a generic risk analysis examining the biosecurity risks associated with the import of prawn and prawn products into Australia. Since then, new crustacean pathogens have been identified through the Ministry for Primary Industries Emerging Risk System, in addition to new epidemiological information about several other known pathogens. In light of this new information, a formal analysis describing the risk posed by the importation of non-viable crustaceans for human consumption into New Zealand has been commissioned to ensure that the identified biosecurity risks are effectively managed by the import health standard (IHS).

3 Commodity definition and scope

This risk analysis assesses the biosecurity risks associated with the importation of non-viable crustaceans (crabs, lobsters, prawns, shrimps and krill) of freshwater, marine and terrestrial origin that are intended for human consumption. They may be imported chilled, frozen or processed.

This commodity definition includes edible crustaceans from all countries from both cultured and wild-caught populations. Cultured crustaceans are likely to be infected with pathogenic agents at a higher prevalence compared to wild crustaceans because they are held at high stocking densities with low levels of water exchange (Biosecurity Australia 2009). These factors can facilitate the multiplication and horizontal spread of pathogenic agents and can cause high rates of morbidity and mortality. The health of cultured populations is easier to monitor and manage compared to wild populations, however this may lead to the practice of emergency harvest of diseased crustaceans. If imported these crustaceans may harbour pathogenic agents at a high prevalence and titre (Biosecurity Australia 2009). Disease is not often observed in wild-caught crustaceans unless there are obvious visible clinical signs (see Shields 2012). Predation of infected wild crustaceans may prevent the detection of disease at a population level (Biosecurity Australia 2009).

Crustaceans that are cultured or wild-caught for human consumption mainly belong to the order Decapoda (shrimps or prawns, lobsters and crabs) and to a lesser extent the order Euphausiacea (krill) and the order Stomatopoda (mantis shrimps).

3.1 HUMAN HEALTH CONSEQUENCES

The human health consequences to New Zealand consumers from the consumption of imported crustaceans (food safety) has previously been evaluated by MPI (2012). This evaluation formed the basis for the management of food safety risks associated with the consumption of crustaceans imported into New Zealand under the Food Act 2014.

Consequently, food safety risks and additional risk management measures related to imported crustaceans have not been further considered in this IRA.

3.1.1 Importation of raw crustaceans

Raw crustaceans, especially those reared in aquaculture, may contain or be contaminated with pathogens associated with foodborne illness, e.g., *Salmonella*, *Vibrio*, and *Shigella*, and significant outbreaks have been recorded worldwide. However, there is little evidence of raw crustaceans being associated with foodborne illness. Raw crustaceans are generally imported frozen and then cooked immediately prior to consumption, which mitigates the risk of parasitic, viral and bacterial foodborne pathogens. Imported raw crustaceans are therefore not identified in the Food Notice: Importing Food 2016 as “High Regulatory Interest” (HRI) food or “Increased Regulatory Interest” (IRI) food, and therefore do not require border clearance (food safety) for entry into New Zealand.

3.1.2 Importation of cooked crustaceans

Crustaceans cooked during commercial manufacture may be re-contaminated with foodborne pathogens, in particular *Listeria monocytogenes, Salmonella* and *Vibrio parahaemolyticus*, if the hygiene of the processing factory is inadequate, and *Vibrio* if cooked product is supplied from a country undergoing a cholera outbreak (MPI 2012). *Listeria* may grow to high numbers during extended refrigerated (not frozen) transport and storage. Imported cooked crustaceans are therefore identified as HRI food and border clearance (food safety) is required for entry into New Zealand.

Schedule 1 of the Food Notice: Importing Food 2016 requires that imported Ready-to-Eat (RTE) Crustaceans – lobsters, crabs, bugs, shrimps and prawns, and their products – are free of *L. monocytogenes* and *Salmonella* https://www.mpi.govt.nz/dmsdocument/10685-foodnotice-importing-food. Similarly, the Australia New Zealand Food Standards Code requires that RTE foods are free of *L. monocytogenes*.

4 New Zealand crustacean fauna

There are approximately 492 species of decapod crustacean species currently recognised in New Zealand, although not all have been sufficiently described (Table 1). The decapod fauna of New Zealand is considered depauperate considering the extent of the exclusive economic zone that ranges over 30 degrees of latitude, the large area of continental shelf and slope, and the variety of ecological niches available (Webber *et al.* 2010). This may be a reflection of New Zealand's prolonged isolation from other landmasses. Approximately 30 % of described decapods are endemic to New Zealand (Webber *et al.* 2010). Even though decapod diversity is low, some faunal groups (e.g. littoral crabs) have a significant impact on the composition of species in habitats where they are present through, for example, predation (Woods 1993). Because of their geographic isolation, impacts on naïve populations of endemic crustacean species from the introduction of new diseases could be significant (MPI 2006a).

There are only two native penaeid species currently identified from New Zealand (*Funchalia villosa* and *F. woodwardi*) and they both occupy offshore deep-water habitats and are not subject to fishing (Webber *et al.* 2010).

In 2009, a non-indigenous penaeid (*Metapenaeus bennettae*) was caught in the Waitemata Harbour in Auckland. This species is native to estuarine waters off the eastern coast of Australia where it is commercially fished. It has been found to be a significant prey species for rig (*Mustelus lenticulatus*) and is likely to have established a self-sustaining population (Getzlaff 2012). It is an edible species and may in the future form the basis of a recreational or commercial fishery.

A freshwater prawn species (*Macrobrachium rosenbergii*) was deliberately imported into New Zealand in 1988 from Malaysia and is cultured on a single site near Taupo in geothermally heated water (Webber *et al.* 2010). Subsequent brood stock has been imported from Hawaii (MPI 2006a). This species will not establish in New Zealand, as it cannot survive in freshwater below 15 °C (MPI 2006a).

The number of mantis shrimps (order: Stomatopoda) described from New Zealand is small (Table 1), however, this may be related to low collecting effort (Webber *et al.* 2010). The only exotic species currently found in New Zealand is the Japanese mantis shrimp (*Oratosquilla oratoria*) which was first caught in the Kaipara Harbour in 2009. Many other individuals have since been caught and it is likely that this species has established a self-sustaining population. It is an edible species and may in the future form the basis of a recreational or commercial fishery (Ahyong 2010).

Krill (order: Euphausiacea) are predominantly oceanic in distribution and no species found occurring in New Zealand waters are endemic (Webber *et al.* 2010).

Commercial and recreational fisheries exist for several crustacean species. For example, the rock lobster (*Jasus edwardsii* and *Sagmariasus verreauxi*, family Palinuridae) fishery is New Zealand's top export earner and was worth NZ$250 million in 2013 (Seafood New Zealand 2014). Scampi (*Metanephrops challengeri*) is another important commercial species with 600-800 tonnes caught per year (Tuck *et al.* 2015). The endemic freshwater crayfish (*Paranephrops zealandicus* and *P. planifrons*) is currently subject to land-based culture with relatively small volumes being produced. It is predicted that significant growth in production will occur to meet demand (McKenna 2008). Freshwater crayfish culture sites have been established near in the South Island (near Blenheim, Alexandra and Kaikoura; Enslow One Ltd. 2016). The paddle crab (*Ovalipes catharus*) is also subject to low levels of commercial harvest (MPI 2009). Finally, the Asian paddle crab (*Charybdis japonica*) has spread to several harbours in north-eastern New Zealand since its initial detection in the Waitamata Harbour in 2002 (Smith *et al.* 2002; Marine Biosecurity Porthole 2016). It is also an edible species overseas and could form the basis of a recreational or commercial fishery in New Zealand (CABI 2016).

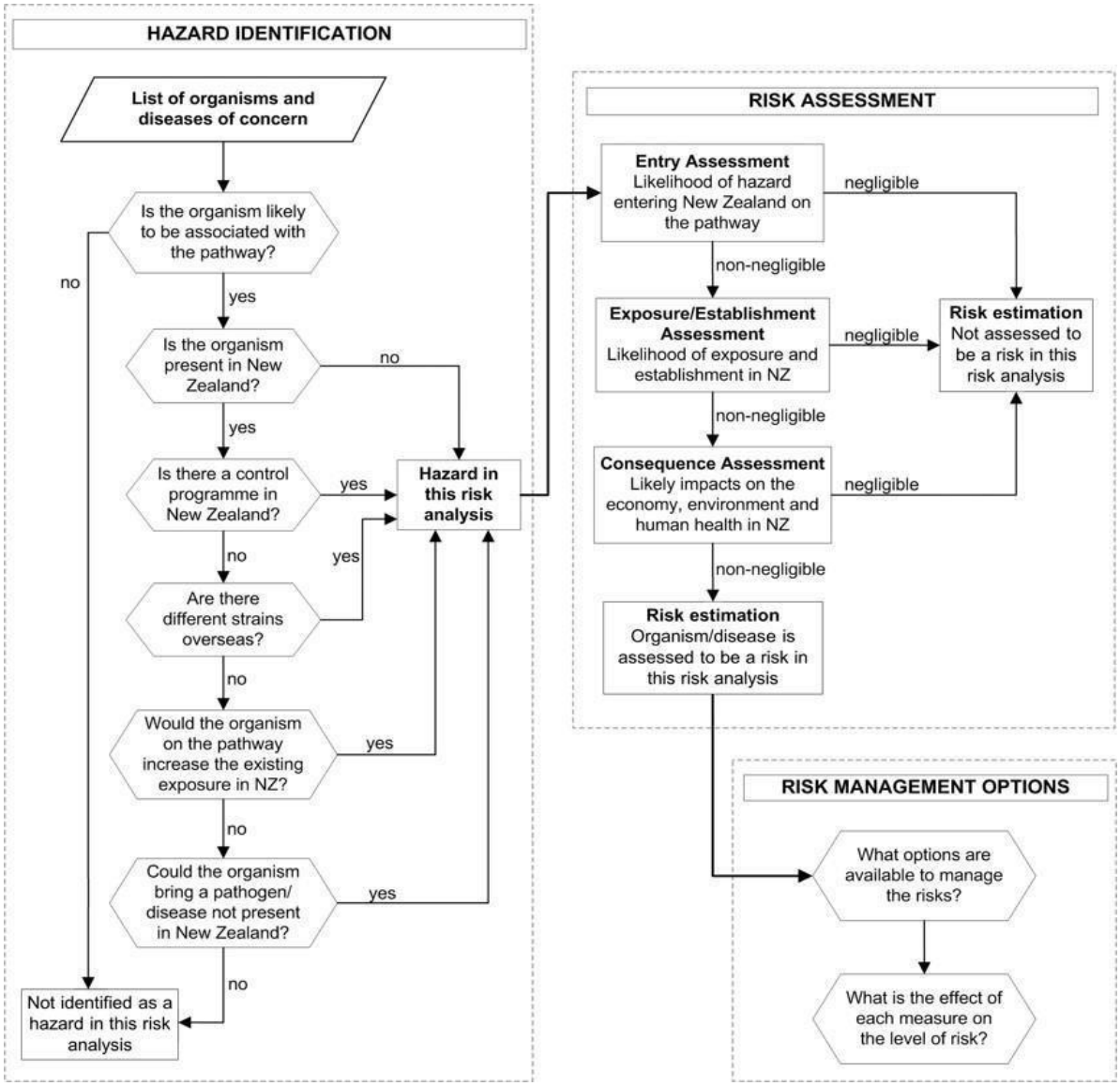
Table 1: Diversity of described crustacean species from New Zealand belonging to the class Malacostraca (Webber *et al*. 2010). Species from orders that are consumed by humans are highlighted in bold.

Order	Described species	Known undescribed or undetermined species	Estimated unknown species	Adventive species named and unnamed	Endemic species	Endemic genera
Amphipoda	439	64	800	11	268	48
Anaspidacea	2	4	5	0	5	1
Bathynellacea	5	3	5	0	8	0
Cumacea	51	24	110	1	66	7
Decapoda	**480**	**12**	**150**	**4**	**147**	**10**
Euphausiacea	**19**	**0**	**15**	**0**	**0**	**0**
Isopoda	358	67	1000	7	331	19
Leptostraca	3	2	2	0	0	0
Lophogastrida	5	1	3	0	0	0
Mysida	17	1	50	0	11	0
Stomatopoda	**8**	**0**	**20**	**1**	**2**	**0**
Tanaidacea	40	77	300	0	12	0
Thermosbaenacea	0	0	5	0	0	0

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* (MPI 2006b) and in Section 2 of the OIE *Aquatic Animal Health Code* (*Code*) (OIE 2014a). The risk analysis process used by the *Code* and adopted by the Ministry for Primary Industries is summarised in Figure 1.

Figure 1: The risk analysis process.



5.1 PRELIMINARY HAZARD LIST (ORGANISM OF POTENTIAL CONCERN)

The first step in the risk analysis process is to compile a preliminary list of hazards containing pathogenic organisms known to infect crustaceans. This list is subjected to the application of several criteria to eliminate those organisms that are not of concern. The remaining organisms are then subjected to the process of hazard identification.

5.2 HAZARD IDENTIFICATION

Hazard identification includes formal identification of the organism, whether it is associated with an OIE listed disease, its New Zealand status, and a discussion on the relevant aspects of the epidemiology and characteristics of the organism. The hazard identification section is concluded by an assessment of whether or not the organism is identified as a hazard.

All hazards are subjected to risk assessment.

5.3 RISK ASSESSMENT

Risk assessment consists of:

1. *Entry assessment*: The likelihood of a hazard (pathogenic organism) being imported with the commodity.
2. *Exposure assessment*: Describes the pathway(s) necessary for exposure of susceptible animals or humans in New Zealand to the hazard. A qualitative estimation of the probability of the exposure occurring is made.
3. *Consequence assessment*: Describes the likely potential consequences of entry, exposure and establishment or spread of an imported hazard.
4. *Risk estimation*: An estimation of the risk posed by the hazard associated with importing crustaceans for human consumption. This is based on the entry, 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 may be justified 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 for a 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 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.

5.4 RISK MANAGEMENT OPTIONS

The options available for managing that risk are presented for each organism assessed to be a risk. Where the *Code* lists recommendations for the management of a risk, these are described alongside options of similar, lesser or greater stringency, where available. In addition to the options presented, unrestricted entry or prohibition may be considered. Recommendations for the appropriate sanitary measures to achieve the effective management of risks will be made when the IHS is drafted.

As obliged under Article 3.1 of the World Trade Organization's Agreement on the Application of Sanitary and Phytosanitary (SPS) measures, the measures adopted in this IHS will be based on international standards, guidelines and recommendations where they exist except as otherwise provided for under Article 3.3. That is, measures providing a higher level of protection than international standards can be applied if there is scientific justification, or if there is a level of protection that the member country considers is more appropriate.

5.5 RISK COMMUNICATION

In drafting an IHS, MPI analyses the options available and proposes measures for the effective management of identified risks. These are then presented in a draft IHS that is released together with a risk management proposal that summarises the options analysis, the rationale for the proposed measures and a link to the risk analysis. The package of documents is released for a six-week period of stakeholder consultation. Stakeholder submissions in relation to these documents are reviewed before a final IHS is issued.

6 Preliminary hazard list

The first step in the risk analysis process is the identification of organisms of concern that are associated with the commodity and the collation of these into a list. A total of 141 organisms (or groups of organisms) of concern have been identified in the preliminary list of hazards (Table 2) which was compiled from the following sources:

- Biosecurity (Notifiable Organisms) Order 2010;
- OIE listed diseases of crustaceans (OIE 2014a);
- Generic import risk analysis report for prawn and prawn products (Biosecurity Australia 2009);
- Import risk analysis: Freshwater prawns (*Macrobrachium rosenbergii*) from Hawaii (MPI 2006a); and,
- Relevant scientific literature on crustacean diseases and parasites.

In addition, organisms of concern suggested by MPI experts and external reviewers are considered.

Each identified organism of concern is then assessed against several criteria to establish whether it requires further assessment.

Organisms in Table 2 are classified as requiring further assessment if they are either:

- Exotic and capable of infecting susceptible host species in New Zealand;
- Present in New Zealand but more virulent strains are present overseas; or,
- Present in New Zealand but subject to domestic regulation.

Table 2: Organisms of potential concern associated with crustaceans

Organism	OIE listed	Host species	Host species present in NZ	Reported in NZ	More virulent strains / species overseas	Expected to cause significant disease	Further assessment required
Viruses							
The agent of abdominal segment deformity disease	No	*Penaeus vannamei*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Bacilliform viruses	No	*Austropotamobius pallipes, Cherax quadricarinatus, Crangon crangon, Cancer pagurus*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Baculovirus midgut necrosis virus (BMNV) (includes BMNV-like viral infections)	No	Various penaeid spp.	No (Monoyama & Sano 1996; Webber *et al.* 2010)	N/A	N/A	No	No
Baculovirus penaei	No	Various penaeid spp.	No (Webber *et al.* 2010; OIE 2012a)	N/A	N/A	No	No
Bay of Piran shrimp virus	No	*Palaemon elegans*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Bunya-like virus	No	Various decapod spp.	No (Webber et al. 2010)	N/A	N/A	No	No

Organism	OIE listed	Host species	Host species present in NZ	Reported in NZ	More virulent strains / species overseas	Expected to cause significant disease	Further assessment required
Cherax giardiaviruslike virus	No	*C. quadricarinatus*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Covert mortality nodavirus	No	*Penaeus chinensis, Penaeus japonicus, P. vannamei*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Crab hemocytopenic virus	No	*Carcinus maenas*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Eriocheir sinensis ronivirus	No	*E. sinensis*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Hepatopancreatic parvovirus & hepatopancreatic parvo-like virus	**No**	**Various penaeid spp., *Macrobrachium rosenbergii, Scylla serrata, C. quadricarinatus, Carcinus aestuarii***	**Yes (*S. serrata, M. rosenbergii*)**	**No**	**N/A**	**Yes**	**Yes**
Herpes-like virus	No	Various decapod spp.	No (Webber *et al.* 2010)	N/A	N/A	No	No
Infectious hypodermal & haematopoietic necrosis virus	**Yes**	**Various penaeid spp. & *M. rosenbergii***	**Yes**	**N/A**	**N/A**	**Yes**	**Yes**
Infectious myonecrosis virus	Yes	*P. vannamei*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Infectious pancreatic necrosis virus	**No**	***Astacus astacus*? *C. maenas, Salmo* spp. & *Oncorhynchus* spp.**	**Yes**	**Nonpathogenic strains (Anderson 1996)**	**Yes**	**Yes**	**Yes**
Irido-like virus	No	*Protrachypene precipua*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Laem-Singh virus & integrase containing element	No	*Penaeus monodon*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Lymphoid organ vacuolization virus	No	*Penaeus stylirostris* & *P. vannamei*	No (Webber *et al.* 2010)	N/A	N/A	No	No

Organism	OIE listed	Host species	Host species present in NZ	Reported in NZ	More virulent strains / species overseas	Expected to cause significant disease	Further assessment required
Lymphoid organ virus	No	*P. monodon*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Lymphoidal parvo-like virus	No	*Penaeus merguiensis, P. monodon* & *P. esculentus*	No (Webber *et al.* 2010)	N/A	N/A	No	No
***Macrobrachium rosenbergii* nodavirus (includes extra small virus)**	**No**	***M. rosenbergii***	**Yes**	**No**	**N/A**	**Yes**	**Yes**
Monodon slow growth syndrome	No	*P. monodon*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Mourilyan virus	No	*P. japonicus, P. monodon* & *P. merguiensis*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Mud crab baculovirus *(Scylla baculovirus)*	No	*S. serrata* & *C. quadricarinatus*	Yes	No	N/A	No (Anderson & Prior 1992; Humphrey *et al.* 2009)	No
Mud crab reovirus	No	*S. serrata*	Yes	No	N/A	Yes	Yes
Mud crab virus	**No**	***S. serrata***	**Yes**	**No**	**N/A**	**Yes**	**Yes**
Panulirus argus virus 1	No	*P. argus*	Not *P. argus* (Webber *et al.* 2010), but other palinurids present	No	N/A	No	No
Paralysis virus	No	*Macropipus depurator*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Penaeid haemocytic rodshaped virus	No	Hybrid *P. esculentus* x *P. monodon*	No (Webber *et al.* 2010)	N/A	N/A	No	No
***Penaeus monodon* type baculovirus (includes *bennettae* baculovirus & *plebejus* baculovirus)**	**No**	**Various penaeid spp. including *Metapenaeus. bennettae* & *M. rosenbergii***	**Yes**	**No**	**N/A**	**Yes**	**Yes**

Organism	OIE listed	Host species	Host species present in NZ	Reported in NZ	More virulent strains / species overseas	Expected to cause significant disease	Further assessment required
Picorna-like viruses	No	*Callinectes sapidus, Hemigrapsus oregonensis, E. sinensis* & *Cherax albidus*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Reo and Reo-like viruses	No	Various crustacean spp.	No (Webber *et al.* 2010)	N/A	N/A	No	No
Rhabdovirus	No	Various crustacean spp.	No (Webber *et al.* 2010)	N/A	N/A	No	No
Spawner isolated mortality virus	No	*P.monodon*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Tegumental gland associated virus	No	*P.monodon*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Taura syndrome virus	**Yes**	**Various penaeid spp., *M. rosenbergii* & *S. serrata***	**Yes**	**N/A**	**N/A**	**Yes**	**Yes**
White spot syndrome virus	**Yes**	**Various crustacean spp.**	**Yes**	**No**	**N/A**	**Yes**	**Yes**
Yellow head virus (all strains)	**Yes**	**Various penaeid spp. including *M. bennettae***	**Yes**	**No**	**N/A**	**Yes**	**Yes**
Bacteria, Rickettsia, Chlamydia, Mycoplasma							
Achromobacter spp.	No	Various aquatic spp.	Yes	Some spp. (NZOR 2016)	No	No	No
Aeromonas spp.	No	Various aquatic spp.	Yes	Some spp. (Diggles *et al.* 2002)	No	No	No
Aerococcus viridans var. *homari* (gaffkemia)	No	Marine lobster (*Homarus* spp.), *Libinia emarginata, C. maenas, Cancer borealis, Penaeus aztecus* & *Pandalus platyceros*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Agrobacterium spp.	No	Various marine spp.	Yes	Somes spp. (MPI 2006a)	No	No	No

Organism	OIE listed	Host species	Host species present in NZ	Reported in NZ	More virulent strains / species overseas	Expected to cause significant disease	Further assessment required
Alcaligenes spp.	No	Various marine spp.	Yes	Some spp. (NZOR 2016)	No	No	No
Arthrobacter spp.	No	*M. rosenbergii*	Yes	Some spp. (MPI 2006a)	No	No	No
Bacillus spp.	No	Various marine spp.	Yes	Some spp. (MPI 2006a)	No	No	No
Benekea spp.	No	Various marine spp.	Yes	Some spp. (MPI 2006a)	No	No	No
Chlamydia spp. (including *Chlamydia*like spp.)	No	Various marine spp.	Yes	Some spp. (Tubbs *et al.* 2007)	No	No	No
Chromobacterium spp.	No	*M. rosenbergii*	Yes	Some spp. (NZOR 2016)	No	No	No
Citrobacter freundii	No	Various spp.	Yes	Yes (MPI 2006a)	N/A	N/A	No
Clostridium botulinum	No	Various marine species	Yes	Yes (Fletcher *et al.* 2008)	No	N/A	No
Coxiella cheraxi	No	*C. quadricarinatus*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Enterobacter spp.	Np	Various spp.	Yes	Yes (MPI 2006a)	No	No	No
Enterococcus faecium	No	Various spp.	Yes	Yes (MPI 2006a)	No	No	No
Exotic rickettsia-like organisms	**No**	**Various decapod spp.**	**Yes**	**No**	**N/A**	**Yes**	**Yes**
Flexibacter spp. / *Flavobacterium* spp. / *Cytophaga* spp.	No	Various aquatic spp. including penaeid & caridean spp.	Yes	Some spp. (Diggles *et al.* 2002)	?	No	No
Hepato-pancreatic brush border lysis bacterium	No	*P. elegans*	No (Webber *et al.* 2010)	N/A	N/A	No	No

Organism	OIE listed	Host species	Host species present in NZ	Reported in NZ	More virulent strains / species overseas	Expected to cause significant disease	Further assessment required
The agent of idiopathic hyaline granulomatous syndrome	No	*P. monodon*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Lactococcus garvieae	No	Various aquatic spp.	Yes	No	Yes	Yes	Yes
Leucothrix spp.	No	Various aquatic spp. including penaeid & caridean spp.	Yes	Some spp. (Diggles *et al*. 2002)	No	No	No
Micrococcus spp.	No	Various spp.	Yes	Some spp. (MPI 2006a)	No	No	No
Moraxella spp.	No	Various spp.	Yes	Some spp. (MPI 2006a)	No	No	No
Mycobacterium spp.	No	Various aquatic spp. including penaeid & caridean spp.	Yes	Some spp. (MPI 2006a)	No	No	No
Mycoplasma spp.	No	Various marine spp.	Yes	Some spp. (Cawthorn 1994)	No	No	No
Necrotizing hepatopancreatitis agent (Candidatus *Hepatobacter penaei*)	Yes	*Penaeus* spp. & *Homarus americanus*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Photobacterium spp.	No	Various spp.	Yes	Some spp. (MPI 2006a)	No	No	No
Planctomycete bacteria	No	*P. monodon*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Pseudomonas spp.	No	Various aquatic spp. including penaeid & caridean spp.	Yes	Some spp. (Young *et al.* 2012)	No	No	No
Rhodobacteriales-like organism	No	*C. maenas*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Rickettsia-like organism causing milky haemolymph syndrome	**No**	***Panulirus ornatus, P. homarus* & *P. stimpsoni* (spiny lobsters), *P. monodon*, & *C. maenas***	**Yes- spiny lobsters (family Palinuridae)**	**No**	**N/A**	**Yes**	**Yes**

Organism	OIE listed	Host species	Host species present in NZ	Reported in NZ	More virulent strains / species overseas	Expected to cause significant disease	Further assessment required
Spiroplasma spp.	No	*E. sinensis, Procambarus clarkii, P. vannamei* & *Rimicaris exoculata*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Staphylococcus spp.	No	Various spp.	Yes	Some spp. (MPI 2006a)	No	No	No
Streptococcus iniae	No	Various fish & mammal spp.	Yes but crustaceans not identified as hosts (Agnew & Barnes 2007)	No	Yes	Yes	No
Streptococcus spp. (other than *S. iniae*)	No	Various spp.	Yes	Some spp. (MPI 2006a)	No	No	No
Vibrio parahaemolyticus (including the agent that causes acute hepatopancreatic necrosis syndrome)		Various marine spp.	Yes	Yes (Cruz *et al.* 2015)	Yes	No	No
Vibrio penaeicida	No	*P. japonicus, P. stylirostris*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Vibrio spp.	No	Various aquatic spp.	Yes	Some spp. (Young *et al.* 2012)	No	No	No
Xanthomonas spp.	No	Various crustacean spp.	Yes	Some spp. (MPI 2006a)	No	No	No
Fungi & water moulds							
Achlya spp.	No	Various aquatic spp. including freshwater & marine crustaceans	Yes	Some spp. (Beever *et al.* 2012a)	No	No	No
***Acremonium* spp.**	**No**	***Oratosquilla oratoria***	**Yes**	**Some spp. (Mahyudin 2008)**	**Yes**	**No**	**Yes**

Organism	OIE listed	Host species	Host species present in NZ	Reported in NZ	More virulent strains / species overseas	Expected to cause significant disease	Further assessment required
Aphanomyces astaci	**Yes**	**Freshwater crayfish & other crustaceans**	**Yes**	**No**	**N/A**	**Yes**	**Yes**
Atkinsiella dubia	No	Various crustacean spp.	?	No (Beever *et al.* 2012a)	No	No	No
Candida sake	No	Various spp.	Yes	Yes (Beever *et al.* 2012b)	N/A	No	No
Cladosporium spp.	No	Various penaeid spp. & other marine spp.	Some spp.	Some spp. (Beever *et al.* 2012b)	No	No	No
Debaryomyces hansenii	No	Various spp.	Yes	Yes (Beever *et al.* 2012b)	N/A	No	No
Endomyces fibuliger	No	Various spp.	Yes	Yes (Beever *et al.* 2012b)	N/A	No	No
Fusarium solani & *Fusarium* spp.	No	Various marine spp.	Yes	Some spp. (Beever *et al.* 2012b)	No	No	No
***Halocrusticida* spp.**	**No**	**Various marine spp.**	**Yes**	**No**	**N/A**	**Yes**	**Yes**
Lagenidium spp.	No	Various marine spp.	Yes	Some spp. (MPI 2006a)	No	No	No
Leptolegnia spp.	No	Various decapod spp.	Yes	Some spp. (Beever *et al.* 2012a)	No	No	No
Leptomitus spp.	No	Various marine spp.	Yes	No	No	No	No
Metschnikowia spp.	No	Various marine spp.	Yes	Some spp. (Beever *et al.* 2012a)	No	No	No

Organism	OIE listed	Host species	Host species present in NZ	Reported in NZ	More virulent strains / species overseas	Expected to cause significant disease	Further assessment required
Plectosporium oratosquillae	**No**	***O. oratoria***	**Yes**	**No**	**N/A**	**Yes**	**Yes**
Plectosporium tebacinum	No	*A. pallipes* & other terrestrial spp.	Yes	Yes (Landcare Research 2016)	No	No	No
Pythium spp.	No	Various marine spp.	Yes	Some spp. (Robertson 1980)	No	No	No
Ramularia astaci & *Didymaria cambari*	No	*Astacus* & *Orconectes limosus*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Saprolegnia spp.	No	Various aquatic animals including freshwater & marine crustaceans	Yes	Yes (MPI 2006a)	N/A	No	No
Sirolpidium spp. (= *Haliphthoros* spp)	No	Various mollusc & crustacean spp. including penaeids	Yes	Some spp. (Diggles 2002)	No	No	No
Trichomaris invadens	No	*Chionoecetes* spp.	No (Webber *et al.* 2010)	N/A	N/A	No	No
Protozoa							
Aggregata spp.	No	Various crustacean spp.	?	No	?	No	No
Apostome ciliates (*Ascophrys* spp. *Synophrya* spp. *Gymnodinoides* spp. & *Collinia* spp.)	**No**	**Marine & freshwater crustaceans**	**Yes**	**Some species (Foissner *et al.* 2012)**	**Yes**	**Yes**	**Yes**
Bodo-like flagellates *Chrysidella* sp.	No	Octopods and decapods	?	?	No	No	No
Dermocystidium like egg parasites	No	Various marine spp.	Yes	No	N/A	No	No
Enterocytozoon hepatopenai	No	*P. monodon* & *P. vannamei*	No	N/A	N/A	N/A	No

Organism	OIE listed	Host species	Host species present in NZ	Reported in NZ	More virulent strains / species overseas	Expected to cause significant disease	Further assessment required
Gregarines (*Nematopsis* sp., *Cephalolobus* sp. & *Paraophioidina* sp.)	No	Various crustacean spp.	Yes	Some spp. (Diggles 2001)	No	No	No
Haplosporidium spp. (= Haplosporidians)	No	Various marine spp.	No	Some spp. (Buchanan *et al.* 2012)	N/A	No	No
***Hematodinium* spp. & *Hematodinium*-like spp.**	**No**	**Various decapod spp.**	**Yes**	**No**	**N/A**	**Yes**	**Yes**
Holotrich ciliates *(Mesanophrys* spp. *Mugardia* spp. *Anophryoides haemophila)*	**No**	**Various crustacean spp.**	**Yes**	**Some spp. (Smith *et al.* 2009)**	**N/A**	**Yes**	**Yes**
Leptomonas spp.	No	Various spp.	Yes	Yes	No	No	No
Microsporidians (including *Ameson*, *Agmasoma*, *Pleistophora*, amongst others), but not *E. hepatopenai*	**No**	**Various crustacean spp.**	**Yes**	**Some spp. (e.g. Stentiford *et al.* 2010)**	**?**	**Yes**	**Yes**
Neoparamoeba pemaquidensis	No	Various marine spp.	Yes	Yes (Munday *et al.* 2001)	N/A	No	No
Paramikrocytos canceri	No	*C. pagurus*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Paramoeba perniciosa	No	*Cancer irroratus, C. sapidus* & *H. americanus*	No (Webber *et al.* 2010)	N/A	N/A	No	No
Parauronema spp.	No	Various molluscs & crustaceans	?	No	?	No	No
Peritrichous & loricate ciliates (*Epistylis* spp.,*Vorticella* spp., *Zoothamnium* spp., *Lagenophrys* spp. & *Cothurnia* spp.)	No	Various marine & freshwater crustacean spp.	Yes	Some spp. (Foissner *et al.* 2012)	?	No	No

Organism	OIE listed	Host species	Host species present in NZ	Reported in NZ	More virulent strains / species overseas	Expected to cause significant disease	Further assessment required
Psorospermium spp.	No	Freshwater crayfish	Yes	No	No	No	No
Rhabdostyla & *Stylohedra* spp.	No	Marine & freshwater crustaceans	Yes	?	No	No	No
Suctorian ciliates (*Ephalota* spp., *Acineta* spp. & *Terebrospira* spp.)	No	Marine & freshwater crustaceans	Yes	Some spp. (Foissner *et al.* 2012)	No	No	No
Thalassomyces spp.	No	Decapods	?	No	?	No	No
Metazoa							
Angiostrongylus cantonensis	**No**	***M. rosenbergii* & other freshwater crustaceans**	**Yes**	**No**	**N/A**	**Yes**	**Yes**
Anisakis simplex & *Anisakis* spp.	No	Various marine spp.	Yes	Some spp. (Hurst 1984)	No	No	No
Ascarophis sp.	No	*P. merguiensis*, *Homarus americanus*	No	No	N/A	No	No
Bulbocephalus inglissi	No	*P. merguiensis*	No	N/A	N/A	No	No
Carcinonemertes & *Pseudocarcinomertes* spp.	No	Various decapod spp.	Yes	Some spp. (Brockerhoff *et al.* 2006)	No	No	No
Choniosphaera spp.	No	Various decapod spp.	?	No	No	No	No
Epicaridean isopods	**No**	**Various crustacean & mollusc spp.**	**Yes**	**Some spp. (e.g. Page 1985)**	**?**	**Yes**	**Yes**
Eutetrarhynchus ruficollis	No	Various marine spp.	Yes	?	No	No	No
Kronborgia sp.	No	Various crustacean spp.	Yes	Some spp (NZOR 2016)	No	No	No

Organism	OIE listed	Host species	Host species present in NZ	Reported in NZ	More virulent strains / species overseas	Expected to cause significant disease	Further assessment required
Levinseniella spp.	No	Various decapod spp.	Yes	Some spp. (Fredensborg & Poulin 2005)	No	No	No
Microphallus spp.	No	Various decapod spp.	Yes	Some spp. (NZOR 2016)	No	No	No
Nectonema spp.	No	Various decapod spp.	Yes	Some spp. (NZOR 2016)	No	No	No
Octolasmis spp.	No	Various decapod spp.	?	?	No	No	No
Opecoeloides spp.	No	Various decapod spp.	Yes	Some spp. (NZOR 2016)	No	No	No
Parachristianella spp.	No	Various decapod spp.	Yes	?	No	No	No
***Paragonimus* spp.**	**No**	**Various aquatic spp. & mammals (including humans)**	**Yes**	**No**	**N/A**	**Yes**	**Yes**
Polypocephalus spp.	No	Various decapod spp.	Yes	?	No	No	No
Prochristianella penaei	No	Various penaeids & Atlantic stingray (*Dasyatis sabina*)	?	No	?	No	No
Pseudoterranova decipiens	No	Various marine spp.	Yes	Yes (Hurst 1984)	N/A	No	No
Pseudophyllodistomum spp.	No	Various decapod spp.	Yes	?	No	No	No
Rhadinorhynchids	No	Various marine spp.	Yes	Some spp. (NZOR 2016)	No	No	No
Rhizocephalan barnacles	**No**	**Various decapod spp.**	**Yes**	**Some spp. (Brockerhoff *et al.* 2010)**	**?**	**Yes**	**Yes**
Temnocephalids (Order Temnocephalida)	No	Various decapod spp.	Yes	Some spp. (Apte *et al.* 2007)	No	No	No

Organism	OIE listed	Host species	Host species present in NZ	Reported in NZ	More virulent strains / species overseas	Expected to cause significant disease	Further assessment required
Tetrarhynchus spp.	No	Various decapod spp.	Yes	Some spp. (NZOR 2016)	No	No	No

6.1 ORGANISMS SUBJECT TO RISK ASSESSMENT

Based on Table 2, the following organisms are identified as requiring further assessment:

Viruses
- Hepatopancreatic parvo-like virus
- Infectious hypodermal and haematopoietic necrosis virus
- Infectious pancreatic necrosis virus
- Macrobrachium rosenbergii nodavirus (includes extra small virus)
- Mud crab reovirus
- Mud crab virus
- Penaeus monodon-type baculovirus (includes bennettae baculovirus & plebejus baculovirus)
- Taura syndrome virus
- White spot syndrome virus
- Yellow head virus

Bacteria
- Exotic rickettsia-like organisms
- Rickettsia-like organism causing milky haemolymph syndrome

Fungi
- Acremonium spp. Aphanomyces astaci Halocrusticida spp.
- Plectosporium oratosquillae

Protozoa
- Apostome ciliates
- Holotrich ciliates
- Hematodinium and Hematodinium-like spp.
- Microsporidians

Metazoa
- Angiostrongylus cantonensis (Zoonotic)
- Epicaridean isopods Paragonimus spp. (Zoonotic)
- Rhizocephalan barnacles

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7 Hepatopancreatic parvovirus and hepatopancreatic parvo-like virus

7.1 HAZARD IDENTIFICATION

7.1.1 Aetiological agent

Hepatopancreatic parovirus (HPV) is a member of the family Parvoviridae and is a single strand non-enveloped icosahedral virus with ten strains currently recognised (Safeena *et al.* 2012).

7.1.2 OIE list

Disease caused by HPV is not OIE listed.

7.1.3 New Zealand Status

Following a review of the literature, HPV has not been reported from the New Zealand aquatic environment.

7.1.4 Epidemiology

HPV was first described in Asia in the early 1980s. It has since spread, via the trade in live Asian shrimp, to North and South America, Australia, Africa, Kenya, Israel and Kuwait (Safeena *et al.* 2012).

A number of penaeid species are hosts for HPV (Safeena *et al.* 2012) as is the mud crab (*Scylla serrata*) (see Owens *et al.* 2010). Experimentally, the Australian redclaw crayfish (*Cherax quadricarinatus*) has been infected with HPV and is likely to only be a short-term carrier of the virus (La Fauce and Owens 2007).

Viruses morphologically similar to HPV are currently called hepatopancreatic parvo-like viruses (HPV-like virus) and they have been found to infect the Mediterranean green crab (*Carcinus aestuarii*) (Mari and Bonami 1988) and the freshwater prawn (*Macrobrachium rosenbergii*) (Anderson *et al.* 1990; Lightner *et al.* 1994; Gangnonngiw *et al.* 2009). The relatedness of these HPV-like viruses to each other is unknown (Biosecurity Australia 2009).

Hosts of HPV or HPV-like viruses that are present in New Zealand include *M. rosenbergii* and *S. serrata* (MPI 2006; Webber *et al.* 2010). It is not known whether the recently introduced penaeid from Australia (*Metapenaeus bennettae*) is susceptible to infection, although a species from the same genus (*M. monoceros*) is a host of HPV (Safeena *et al.* 2012).

HPV infects the hepatopancreatic tubule epithelial cells and adjacent midgut cells (Lightner 1996). Traditionally, diagnosis was reliant on histopathology and the identification of large basophilic intranuclear inclusion bodies in their hypertrophied nuclei (Catap *et al.* 2003). DNA based diagnostic techniques are now available for rapid and easy detection (Safeena *et al.* 2012).

Infection with HPV occurs when the virus attaches to the microvilli of the epithelial cells followed by entry into the host cell by pinocytosis. HPV replication occurs in the nucleoplasm and later accumulates in the main inclusion bodies. This accumulation causes rupturing of the nuclear membrane and the release of virions into the cytoplasm. The virions are then released from the infected cell and go on to infect other host cells (Safeena *et al.* 2012).

Clinical signs of disease in shrimp species are not specific but can include poor growth, anorexia, reduced preening activity, atrophy of the hepatopancreas and increased surface fouling (Biosecurity Australia 2009; Safeena *et al.* 2012). Other than displaying stunting due to poor growth rates, HPV has been reported from shrimp that appear otherwise healthy (Manjanaik *et al.* 2005).

High morbidity has been observed in wild and cultured populations infected with HPV (Biosecurity Australia 2009; Safeena *et al.* 2012). The virulence of HPV is uncertain, however, due to infected shrimp usually being co-infected with a number of hepatopancreatic pathogens (Safeena *et al.* 2012).

In *S. serrata,* infection with HPV is not associated with any clinical signs of disease. In Australia, *S. serrata* and the banana prawn (*Penaeus merguiensis*), which is a host for HPV, occupy similar habitats and each species preys on the other depending on their life-stage. The sharing of viral infections between these two species is possible (Owens *et al.* 2010). It is also not known whether HPV replicates within *S. serrata* as viral titres are lower than that found within *P. merguiensis* (Owens *et al.* 2010).

Infection with HPV-like viruses in *M. rosenbergii* has only been reported from Malaysia and Thailand (Anderson *et al.* 1990; Lightner *et al.* 1994; Gangnonngiw *et al.* 2010). It is not yet known if these two viruses are identical or closely related. Further, their pathogenicity is yet to be determined and requires further investigation (Bonami and Widada 2011).

HPV is transmitted via *per-os* exposure through the ingestion of infected tissue (Catap *et al.* 2003). Transmission by co-habitation has been suggested but is considered unlikely (Paynter *et al.* 1985).

HPV has infected *Penaeus monodon* after they were fed infected tissue that had been frozen at – 80 °C (Catap *et al.* 2003).

7.1.5 Hazard identification conclusion

HPV has been shown to be associated with reduced growth rates in infected penaeid shrimp and mortalities have been observed in shrimp co-infected with other pathogens. Infected shrimp may be smaller in size but otherwise appear clinically healthy. Other infected species may act as carriers of HPV and HPV-like viruses.

HPV and HPV-like viruses are identified as a hazard in the commodity.

7.2 RISK ASSESSMENT

7.2.1 Entry assessment

Imported crustaceans may be infected with HPV or HPV-like viruses. Freezing does not inactivate the virus and susceptible crustacean species have been infected after consuming thawed infected tissue.

The likelihood of entry is assessed to be non-negligible.

7.2.2 Exposure assessment

Crustaceans imported for human consumption can be imported in bulk; heads and tail-on, for further processing (value added) or direct distribution for retail sale to markets, restaurants and supermarkets in New Zealand. The commodities include, prawns, crayfish, scampi, lobster (as lobster tails) and crabs.

It is expected that the majority of fluids derived from chilling, freezing, defrosting, processing and transport of bulk commodities are to be discarded into municipal sewage systems at the point of retail. Processing of raw entire crustaceans (i.e. heads and tails on prawns) by importers and distributors is assumed to be limited as sale of raw unprocessed crustaceans (especially prawns) is common (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018). The majority of head, shell and gut removal is likely to occur within households or trade businesses (i.e. restaurants). The waste generated in this fashion is likely to be disposed of in municipal sewage systems or to municipal landfill. The Food Regulations (New Zealand Government 2015) provide details of what waste disposal requirements restaurants and other retail businesses subject to food control plans need to follow. Waste that was directed to a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the titre of virus present and any remaining viable virus would be diluted within the wastewater (Biosecurity Australia 2009). This rationale is consistent with, and the basis for, the requirements for water treatment and disposal in MPI's transitional facilities standard for ornamental fish (MPI 2017). Similarly, all waste water from live imported freshwater prawns held in a transitional facility is treated according to this standard (MPI 2007).

Growth in the seafood import market may result in importers adding value to products (i.e. by removing heads, shells and gut) and engaging in further processing within New Zealand. It is possible that

discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of exposure of wild or cultured crustaceans to imported crustacean waste products disposed to landfill or municipal sewage systems is assessed to be negligible.

An undefined, yet likely small proportion of crustaceans imported for human consumption may be used as fishing bait (Blackwell 2013). The use of crustaceans, especially shrimp as bait is likely to occur and circumstantial evidence of its use in New Zealand has been identified online (The Fishing Website 2015).

Currently, only one New Zealand species of wild crustacean (*S. serrata*) is known to be susceptible to infection with HPV viruses. *S. serrata* is seldom seen in New Zealand and individuals have only been caught from the top half of the North Island (Dell 1964). It is not known whether *S. serrata* reproduce in New Zealand and exist at a low population density, or if individuals survive and do not reproduce due to unfavourable environmental conditions after drifting on currents as larvae from Australia, or are transported either as ballast water or biofouling (Te Papa 2014). It is unknown if HPV replicates within *S. serrata* and infection may be due to sustained ecological interactions with *P. merguiensis* which is not present in New Zealand (Owen *et al.* 2010; Webber *et al.* 2010). It would be expected that a significant portion of crustaceans used as bait in the marine environment would be consumed by non-susceptible host species, particularly finfish (Biosecurity Australia 2009). The likelihood of exposure, transmission and spread among wild crustacean populations is also expected to be low based on the lower population densities and absence of stressful conditions typically encountered by cultured crustaceans (Walker and Mohan 2009; Department of Agriculture 2013).

Due to *S. serrata* being seldom observed in New Zealand the likelihood of exposure to bait is assessed to be negligible.

The susceptibility of the recently established shrimp *M. bennettae* to HPV is not known, however, infection has been reported from the closely related *Metapenaeus monoceros* (see Safeena *et al.* 2012). Even if *M. bennettae* was susceptible to HPV it would be expected that exposure to crustacean bait would be low (Biosecurity Australia 2009). Further, shrimp only tend to eat the appendages of dead shrimp (Soto *et al.* 2001; Sritunyalucksana *et al.* 2010) and HPV replicates within the hepatopancreatic tubule epithelial cells and adjacent midgut cells.

The likelihood of exposure of HPV in *M. bennettae* is assessed to be negligible.

Macrobrachium rosenbergii is the sole susceptible species cultured in New Zealand. It is cultured at a single aquaculture site and is restricted in its distribution as it survives solely in geothermally heated water from the Waikato River (MacGibbon 2008). The only pathway for exposure is through feeding *M. rosenbergii* infected crustaceans that are intended for human consumption. It is unlikely that the farm operators would buy imported prawns destined for human consumption and subsequently feed these to their stock. This is a well-known exposure pathway for many crustacean pathogens that would endanger their stock and their livelihoods and is considered to be contrary to best aquaculture biosecurity practice (Georgiades *et al.* 2016).

As crustacean aquaculture is in its infancy in New Zealand and *M. rosenbergii* is cultured by a single company at one location, the likelihood of exposure is assessed to be negligible.

7.2.3 Risk estimation

The likelihood of exposure is assessed to be negligible, therefore the risk is estimated to be negligible.

HPV and HPV-like viruses are assessed not to be a risk in the commodity.

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8 Infectious hypodermal and haematopoietic necrosis virus

8.1 HAZARD IDENTIFICATION

8.1.1 Aetiological agent

Infectious hypodermal and haematopoietic necrosis virus (IHHNV) has recently been classified as *Penaeus stylirostris* denovirus belonging to the genus *Brevidensovirus* and family Parvoviridae (Fauquet *et al.* 2005). It is a single stranded, non-enveloped DNA virus. It is one of the smallest viruses (22 nm average diameter) currently known and the smallest to infect penaeid shrimp. For the purpose of this assessment the virus will be referred to as IHHNV as this is the name most commonly used in the scientific literature (OIE 2015).

8.1.2 OIE list

Infection with IHHNV is listed as a disease of crustaceans by the OIE (OIE 2015).

8.1.3 New Zealand status

Following a review of the literature, infectious hypodermal and haematopoietic necrosis (IHHN) has not been reported from the New Zealand aquatic environment. IHHNV is listed as an unwanted organism (Unwanted Organism Register 1998).

8.1.4 Epidemiology

IHHN was first detected in 1981 in *Penaeus stylirostris* imported to Hawaii from Costa Rica and Ecuador (Lightner *et al.* 1983). The virus has spread to most countries that culture shrimp and can also be found infecting wild species (OIE 2015).

Infection has been reported in cultured penaeid shrimp species (e.g. *P. stylirostris P. monodon* and *P. vannamei*) (Lightner *et al.* 1983*;* Lightner 1996) as well as in sub-adult freshwater shrimp *Macrobrachium rosenbergii* (see Hsieh *et al.* 2006; OIE 2015). A number of other penaeid shrimp species have also been infected experimentally and recently Macias-Rodriguez (2014) detected IHHNV via PCR in a number of species (crabs, fish and shrimp) surrounding infected shrimp culture ponds along the Pacific coast of Mexico.

Transmission of IHHNV occurs horizontally via consumption of infected tissue, direct contact between prawns and indirectly through contaminated water (Lotz 1997). Vertical transmission is suspected (Motte *et al.* 2003).

There are two recognised genotypes of IHHNV (OIE 2015); the Philippines genotype is considered the more virulent to penaeids than the Indian Ocean strain (Primavera and Quinitio 2000; Tang *et al.* 2003). The IHHNV genotype originally identified from Australia was more likely related to the Indian Ocean strain, however, in 2008 a genotype very similar Philippine genotype was found (Biosecurity Australia 2009).

P. stylirostris are most affected by infection with IHHNV with high mortalities occurring in cultured juveniles. Clinical signs in this species are non-pathognomonic and can include anorexia, lethargy, blue colouration, opaque abdominal musculature, reduced feeding and erratic swimming (Biosecurity Australia 2009). Mortalities in this species may be > 90 % (Lightner *et al*. 1983). Despite this, infected adults do not always show clinical signs and may not suffer mortalities (Bell and Lightner 1984, Bell and Lightner 1987). In *P. vannamei*, infection causes runt deformity syndrome which is characterised by retarded growth and cuticle deformities (Primavera and Quinitio 2000). This syndrome also occasionally occurs in infected *P. monodon* (Primavera and Quinitio 2000). Cultured *M. rosenbergii* sub-adults have suffered high rates of mortality (80-100 %) due to infection with IHHNV in Taiwan (see Hsieh *et al.* 2014). The presence of IHHNV in crabs and fish by Macias-Rodriguez (2014) via PCR does not necessarily mean these species are susceptible to infection (Stentiford *et al.* 2009) and the epidemiological importance of these species for the dissemination of disease is unknown. Individual shrimp that survive infection may carry the virus for life (OIE 2015).

The prevalence of infection in shrimp can be highly variable in wild and cultured populations ranging from 0 to 100 % (OIE 2015).

8.1.5 Hazard identification conclusion

IHHNV has been identified as causing mortalities or deformities in a number of shrimp species.

IHHNV is identified as a hazard in the commodity.

8.2 RISK ASSESSMENT

8.2.1 Entry assessment

As infected shrimp can display no clinical signs they are likely to pass visual inspection. IHHNV is extremely stable in frozen tissue and has been found to remain viable when frozen for up to 15 years (Biosecurity Australia 2009).

The likelihood of entry is assessed to be non-negligible.

8.2.2 Exposure assessment

Crustaceans imported for human consumption can be imported in bulk; heads and tail-on, for further processing (value added) or direct distribution for retail sale to markets, restaurants and supermarkets in New Zealand. The commodities include, prawns, crayfish, scampi, lobster (as lobster tails) and crabs.

It is expected that the majority of fluids derived from chilling, freezing, defrosting, processing and transport of bulk commodities are to be discarded into municipal sewage systems at the point of retail. Processing of raw entire crustaceans (i.e. heads and tails on prawns) by importers and distributors is assumed to be limited as sale of raw unprocessed crustaceans (especially prawns) is common (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018). The majority of head, shell and gut removal is likely to occur within households or trade businesses (i.e. restaurants). The waste generated in this fashion is likely to be disposed of in municipal sewage systems or to municipal landfill. The Food Regulations (New Zealand Government 2015) provide details of what waste disposal requirements restaurants and other retail businesses subject to food control plans need to follow. Waste that was directed to a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the titre of virus present and any remaining viable virus would be diluted within the wastewater (Biosecurity Australia 2009). This rationale is consistent with, and the basis for, the requirements for water treatment and disposal in MPI's transitional facilities standard for ornamental fish (MPI 2017). Similarly, all waste water from live imported freshwater prawns held in a transitional facility is treated according to this standard (MPI 2007).

Imported crustaceans disposed of at a landfill will be subject to physical and biochemical processes, which are likely to reduce the titre of virus in any infected waste products. IHHNV in shrimp has been shown to survive for up to a day after passing through the gastrointestinal tract of a seagull (Vanpatten *et al*. 2004). Currently, only one species present in New Zealand (*M. rosenbergii*) has been identified as susceptible to IHHNV. Macias-Rodriquez *et al.* (2014) detected IHHNV in non-penaeid hosts (crabs and fish), however, there is no evidence to suggest non-penaeid hosts as being susceptible to infection or involved in disease transmission. *M. rosenbergii* is cultured at a single aquaculture site and is restricted in its distribution as it survives solely in geothermally heated water from the Waikato River (MacGibbon 2008).

Due to the limited survival time of IHHNV after being passed through a bird and *M. rosenbergii* being cultured at one site, the likelihood of exposure of crustacean waste products disposed of at a landfill is assessed to be negligible.

Growth in the seafood import market may result in importers adding value to products (i.e. by removing heads, shells and gut) and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of exposure of wild or cultured crustaceans to imported crustacean waste products disposed to landfill or municipal sewage systems is assessed to be negligible.

An undefined yet likely small proportion of crustaceans imported for human consumption may be used as fishing bait in saltwater and freshwater environments (Blackwell 2013). The use of crustaceans as bait is likely to occur (Diggles 2011) and there is evidence for the use of crustaceans especially shrimp as bait in New Zealand (Fishing News 2014; The Fishing Website 2015). The use of frozen shrimp intended for human consumption as bait may be associated with the relative low cost and ease of purchase compared to other types of fishing bait (Diggles 2011; Bateman *et al.* 2012). As mentioned previously only one species (*M. rosenbergii*) is identified as susceptible to infection. The only pathway for exposure is through feeding *M. rosenbergii* infected crustaceans that are intended for human consumption. It is unlikely that the farm operators would buy imported prawns destined for human consumption and subsequently feed these to their stock. This is a well-known exposure pathway for many crustacean pathogens that would endanger their stock and their livelihoods and is considered to be contrary to best aquaculture biosecurity practice (Georgiades *et al.* 2016).

Flegel (2009) found no published reports in the peer-reviewed, scientific literature of IHHNV outbreaks in wild or cultivated shrimp imported from shrimp products for human consumption. Despite the use of imported crustaceans as bait, there is a lack of data regarding the epidemiological probability of disease transmission to wild crustaceans (Flegel 2009).

As this species is not present in the wild and no other aquatic species in New Zealand waters are identified as susceptible or mechanical hosts, the likelihood of exposure via the fish bait pathway is assessed to be negligible.

8.2.3 Risk estimation

The likelihood of exposure is assessed to be negligible, therefore the risk is estimated to be negligible.

IHHNV is assessed not to be a risk in the commodity.

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9 Infectious pancreatic and necrosis virus

9.1 HAZARD IDENTIFICATION

9.1.1 Aetiological agent

Infectious pancreatic necrosis virus (IPNV) is the type species for the genus *Aquabirnavirus*. Viruses in this genus are non-enveloped with a double-stranded RNA genome. This genus includes virulent and avirulent viruses and the term infectious pancreatic necrosis (IPN) is only reserved for those that are pathogenic to species within the family Salmonidae (McColl *et al.* 2009).

9.1.2 OIE list

IPN is no longer an OIE listed disease.

9.1.3 New Zealand status

Following a review of the literature, IPNV (pathogenic strains) have not been reported from the New Zealand aquatic environment. An *Aquabirnavirus* has been detected from healthy sea run Chinook salmon (*Oncorhynchus tshawytscha)* from the Rakaia River and Hakataramea River, however, this virus was not associated with disease (Tisdall and Philips 1987; Anderson *et al*. 1994; Anderson 1996). Turbot (*Colistium nudipinnis*) in Wellington Harbour have also been found infected with an *Aquabirnavirus.* The New Zealand strain has been identified as belonging to the IPNV genotype 5 (Davis *et al.* 2010).

9.1.4 Epidemiology

Viruses belonging to the genus *Aquabirnavirus* have been identified from a number of marine and freshwater animals (fish, bivalve molluscs and crustaceans) and these viruses are considered to be ubiquitous in aquatic environments (Hill and Way 1995; Munro and Midtlyng 2011).

IPNV was first recognised as causing an acute contagious disease (IPN) of young salmonid fry in the freshwater stage of production. This disease can result in up to 100 % mortality. Disease associated with mortalities has recently emerged in the post-smolt, seawater stages (Crane and Hyatt 2011). IPN is considered to be the most important disease affecting the culturing of salmonids in the European Union and Norway (Ariel and Olsen 2002; Murray *et al.* 2003; Munro and Midtlyng 2011).

IPNV can be transmitted in salmonids horizontally via faeces, urine, *per-os* exposure and via contaminated gametes and by true vertical transmission (Seeley *et al*. 1977; Bootland *et al*. 1991; Bowden et al. 2002; OIE 2003). IPNV has also been isolated from water (DAFF 2012).

IPNV is known to predominately cause infection in juvenile fish. Juveniles that survive infection can become lifelong carriers and shed virus in urine, faeces, and sexual products (Munro and Midtlyng 2011). Other older age cohorts infected for the first time may be resistant to infection or recover (Novoa *et al.* 1993), although if subject to environmental stressors they can become infected.

In the scientific literature, infection in crustaceans or molluscs with *Aquabirnaviruses* are often referred to as IPNV without evidence of their pathogenicity being determined for salmonids (Biosecurity Australia 2009). Many strains of *Aquabirnaviruses* are serologically related to IPNV but are not pathogenic to salmonids.

There have only been three instances where *Aquabirnaviruses* have been isolated from shrimp. Bovo *et al.* (1984) isolated a virus antigenically related to IPNV via serology from laboratory *Penaeus japonicas* suffering mortality, however, the pathogenicity to salmonids was not established. There was insufficient evidence to determine the cause of mortality in *P. japonicas* and an absence of any pathological signs of infection (Biosecurity Australia 2009).

Giorgetti (1989) also isolated an *Aquabirnavirus* from apparently healthy *P. japonicas* in Italy. This viral isolate was subsequently exposed to post-larval *P. japonicas* with only minor histological differences to the hepatopancreas being observed compared to the controls. The presence of this virus was also unable to be detected in the post-larvae. Mortensen (1993) used an IPNV serotype N1 previously

isolated from scallops (*Pecten maximus*) (Mortensen *et al.* 1990) to contaminate other individuals of the same species. The shrimp (*Pandalus borealis*) was then exposed after consuming the contaminated scallops or ingesting faeces. The virus was subsequently isolated from the visceral mass including the gastrointestinal tract of the shrimp. However, the viral titre decreased rapidly in the shrimp once the scallops were removed. This study did not establish whether shrimp were infected and the isolated virus may have simply been located in the gastrointestinal tract (Biosecurity Australia 2009). Shrimps (*Palaemon elegans* and *P. borealis*) that had consumed contaminated scallops were also fed to brown trout (*Salmo trutta*), however no virus was isolated from any trout (Mortensen 1993). Mortensen *et al.* (1993) isolated an *Aquabirnavirus*, referred to as IPNV, from wild caught *P. elegans* and the shore crabs (*Carcinus maenas*) that had most likely consumed infected turbot fry from an aquaculture facility suffering from a disease outbreak.

Halder and Ahne (1988) demonstrated that freshwater crayfish (*Astacus astacus*) could act as a mechanical vector for an *Aquabirnavirus,* also referred to as IPNV. The virus could be isolated from crayfish which were infected via injection, *per-os* or horizontally through the water. However, the crayfish did not show clinical signs of infection. Effluent water from tanks containing infected crayfish was able to infect 4-6 week old rainbow trout (*Oncorhynchus mykiss*) and trout eggs, however no mortalities were reported. The virus could still be isolated from the haemolymph of one inoculated crayfish 1 year after the infection trial.

9.1.5 Hazard identification conclusion

IPNV has been identified as causing significant mortalities in salmonids and has been identified as present in some crustacean species.

IPNV is identified as a hazard in the commodity.

9.2 RISK ASSESSMENT

9.2.1 Entry assessment

Crustaceans infected with *Aquabirnaviruses* are unlikely to display clinical signs of infection. These viruses are stable and some strains have been shown to survive for at least 130 days in tissue samples at ambient temperatures. They are also stable at commercial freezing temperature, however a loss in titre occurs when freezing and thawing occurs (Mortensen *et al.* 1998).

The likelihood of entry is assessed to be non-negligible.

9.2.2 Exposure assessment

Crustaceans imported for human consumption can be imported in bulk; heads and tail-on, for further processing (value added) or direct distribution for retail sale to markets, restaurants and supermarkets in New Zealand. The commodities include, prawns, crayfish, scampi, lobster (as lobster tails) and crabs.

It is expected that the majority of fluids derived from chilling, freezing, defrosting, processing and transport of bulk commodities are to be discarded into municipal sewage systems at the point of retail. Processing of raw entire crustaceans (i.e. heads and tails on prawns) by importers and distributors is assumed to be limited as sale of raw unprocessed crustaceans (especially prawns) is common (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018). The majority of head, shell and gut removal is likely to occur within households or trade businesses (i.e. restaurants). The waste generated in this fashion is likely to be disposed of in municipal sewage systems or to municipal landfill. The Food Regulations (New Zealand Government 2015) provide details of what waste disposal requirements restaurants and other retail businesses subject to food control plans need to follow. Waste that was directed to a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the titre of virus present and any remaining viable virus would be diluted within the wastewater (Biosecurity Australia 2009). This rationale is consistent with, and the basis for, the requirements for water treatment and disposal in MPI's transitional facilities standard for ornamental fish (MPI 2017). Similarly, all waste water from live imported freshwater prawns held in a transitional facility is treated according to this standard (MPI 2007).

Growth in the seafood import market may result in importers adding value to products (i.e. by removing heads, shells and gut) and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of exposure of wild or cultured crustaceans to imported crustacean waste products disposed to landfill or municipal sewage systems is assessed to be negligible.

An undefined yet likely very small proportion of crustaceans imported for human consumption may be used as fishing bait (Blackwell 2013). Shrimp have been identified as the most commonly used crustacean bait (Diggles 2011) and circumstantial evidence of its use in New Zealand has been identified online (The Fishing Website 2015). The use of frozen shrimp as bait may be associated with the relative low cost and ease of purchase compared to other types of fishing bait (Diggles 2011; Bateman *et al.* 2012).

There are no recent reports in the scientific literature identifying *Aquabirnaviruses* in shrimp other than the three studies previously mentioned. There is no evidence that these viruses can replicate in shrimp and are pathogenic to either shrimp or other aquatic species. Shrimp could act as a mechanical vector of *Aquabirnavirus*, however trout failed to become infected after consuming infected shrimp (Mortensen *et al.* 1990) providing evidence that this is an unlikely pathway of infection.

The likelihood of exposure of *Aquabirnaviruses,* including IPNV, to susceptible species via imported shrimp is assessed to be negligible.

For other crustacean species (crayfish and crabs) it is expected that an even smaller portion imported for human consumption would be used as bait.

The crab (*Carcinus maenas*) and freshwater crayfish (*Astacus astacus*) have been identified as infected with an *Aquabirnavirus* which was referred to as IPNV (Halder and Ahne 1988; Mortensen *et al.* 1993). However, the pathogenicity of these viruses to salmonids were not confirmed.

There is no evidence confirming crustaceans as vectors for *Aquabirnavirus* strains that are pathogenic to salmonids (e.g. IPNV). Therefore, the likelihood of exposure is assessed to be negligible.

9.2.3 Risk estimation

The likelihood of exposure is assessed to be negligible, therefore the risk is estimated to be negligible.

IPNV is assessed not to be a risk in the commodity.

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10 *Macrobrachium rosenbergii* nodvirus (includes eextra small virus)

10.1 HAZARD IDENTIFICATION

10.1.1 Aetiological agent

Two viruses are associated with white tail disease (WTD) and they are *Macrobrachium rosenbergii* nodavirus (MrNV) and extra small virus-like particle (XSV). MrNV is a small, icosahedral non-enveloped particle and is closely related to the family Nodaviridae. XSV is also a non-enveloped icosahedral virus. It has been suggested that XSV may be a satellite virus and MrNV a helper virus, due to XSV's small size and absence of enzymes required for replication (Hameed and Bonami 2012). MrNV is linked to WTD outbreaks, but it is uncertain if XSV is pathogenic (OIE 2012).

10.1.2 OIE list

WTD is an OIE listed disease (OIE 2015).

10.1.3 New Zealand status

Following a review of the literature, MrNV and XSV have not been reported from the New Zealand aquatic environment.

10.1.4 Epidemiology

WTD is responsible for significant mortalities in *M. rosenbergii* (see OIE 2012). Marine shrimp (*Penaeus indicus, P. japonicas* and *P. monodon*) and brine shrimp (*Artemia*) have been experimentally shown to act as carriers of infection, with aquatic insects being natural carriers (Sudhakaran *et al.* 2006; Sudhakaran *et al.* 2008). There has been one documented case of mortalities in naturally infected *P. indicus* and *P. monodon* from a hatchery in India that grew *M. rosenbergii* in close proximity (Ravi *et al.* 2009). It is unknown if other marine shrimp species are capable of being infected (OIE 2012).

WTD was first reported in the French West Indies and has since been described from China, India, Chinese Taipei, Thailand, Australia and Malaysia (Hameed and Bonami 2012). Clinical signs of infection include lethargy and opaqueness of the abdominal muscle, which gave rise to the name of the disease. In severe infections, the telson and uripods may degenerate (Hameed and Bonami 2012). Sites of infection include the gills, head muscle, heart, abdominal muscle, ovaries, pleopods and tail (OIE 2012).

Zhang *et al.* (2006) observed clinical signs of WTD in post-larvae shrimp that were challenged with a high proportion of MrNV and low proportion of XSV. Conversely, there was a reduction in gross clinical signs of WTD when challenged with a higher proportion of XSV than MrNV. This study demonstrates that WTD is associated with MrNV and the pathogenicity of XSV requires further investigation.

The life-stages of *M. rosenbergii* that are most susceptible to infection are larvae, post-larvae and juveniles. High mortalities may occur at these life-stages with peak mortalities occurring 56 days after the appearance of the first clinical signs. Only a small number of infected juveniles survive, but those that do, may grow to reach full size and act as carriers (Bonami and Widada 2011).

Mortalities of 100 % have been reported in naturally infected *P. indicus,* and *P. monodon* displaying clinical signs (Ravi *et al.* 2009). Marine shrimp (*Penaeus indicus, P. japonicas* and *P. monodon*) experimentally infected with MrNV and XSV, however, showed no clinical signs of infection after being exposed via the intramuscular and oral route. These species were deemed carriers of infection as *M. rosenbergii* post-larvae suffered 100 % mortality after being exposed to small quantities of infected marine shrimp tissue via an immersion challenge (Sudhakaran *et al.* 2006). This study provides evidence that the virulence of MrNV and XSV can be maintained in marine shrimp tissue (Bonami and Wildada 2011). Vertical transmission of MrNV and XSV has been experimentally shown to occur in *M. rosenbergii* resulting in 100 % mortality in post-larvae (Sudhakaran *et al.* 2007).

The ability of MrNV to survive outside of the host is unknown, however within tissue homogenate it can remain infective after being stored at – 20 °C (Sudhakaran *et al.* 2006).

10.1.5 Hazard identification conclusion

MrNV has been identified as the aetiological agent responsible for WTD. Infection with MrNV in larvae, post larvae and juveniles of *M. rosenbergii* can cause significant mortality. Adult *M. rosenbergii* that survive infection become carriers. Infected marine shrimp (*P. indicus, P. japonicas* and *P. monodon*) may suffer mortalities or be carriers of infection. The role of XSV in the expression of WTD is not well defined.

As MrNV and XSV are associated with WTD, they are identified as a hazard in the commodity.

10.2 RISK ASSESSMENT

10.2.1 Entry assessment

A small number of juvenile *M. rosenbergii* may survive infection and reach adulthood. *P. indicus, P. japonicas* and *P. monodon* may act as carriers of MrNV and XSV. Freezing of infected individuals will not inactivate the virus.

The likelihood of entry is assessed to be non-negligible.

10.2.2 Exposure assessment

Crustaceans imported for human consumption can be imported in bulk; heads and tail-on, for further processing (value added) or direct distribution for retail sale to markets, restaurants and supermarkets in New Zealand. The commodities include, prawns, crayfish, scampi, lobster (as lobster tails) and crabs.

It is expected that the majority of fluids derived from chilling, freezing, defrosting, processing and transport of bulk commodities are to be discarded into municipal sewage systems at the point of retail. Processing of raw entire crustaceans (i.e. heads and tails on prawns) by importers and distributors is assumed to be limited as sale of raw unprocessed crustaceans (especially prawns) is common (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018). The majority of head, shell and gut removal is likely to occur within households or trade businesses (i.e. restaurants). The waste generated in this fashion is likely to be disposed of in municipal sewage systems or to municipal landfill. The Food Regulations (New Zealand Government 2015) provide details of what waste disposal requirements restaurants and other retail businesses subject to food control plans need to follow. Waste that was directed to a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the titre of virus present and any remaining viable virus would be diluted within the wastewater (Biosecurity Australia 2009). This rationale is consistent with, and the basis for, the requirements for water treatment and disposal in MPI's transitional facilities standard for ornamental fish (MPI 2017). Similarly, all waste water from live imported freshwater prawns held in a transitional facility is treated according to this standard (MPI 2007).

Growth in the seafood import market may result in importers adding value to products (i.e. by removing heads, shells and gut) and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of exposure of wild or cultured crustaceans to imported crustacean waste products disposed to landfill or municipal sewage systems is assessed to be negligible.

An undefined yet likely small proportion of crustaceans imported for human consumption may be used as fishing bait (Blackwell 2013). Currently, only one species present in New Zealand (*M. rosenbergii*) has been identified as susceptible to WTD. *M. rosenbergii* is cultured at a single aquaculture site and is restricted in its distribution as it survives solely in geothermally heated water from the Waikato River (MacGibbon 2008). The only pathway for exposure is through feeding *M. rosenbergii* infected crustaceans that are intended for human consumption. It is unlikely that the farm operators would buy imported prawns destined for human consumption and subsequently feed these to their stock. This is a well-known exposure pathway for many crustacean pathogens that would endanger their stock and

their livelihoods and is considered to be contrary to best aquaculture biosecurity practice (Georgiades *et al.* 2016).

As this species is not present in the wild and no other crustacean species in New Zealand waters are identified as hosts, the likelihood of exposure via the fish bait pathway is assessed to be negligible.

10.2.3 Risk estimation

The likelihood of exposure is assessed to be negligible, therefore the risk is estimated to be negligible.

MrNV and XSV are assessed not to be a risk in the commodity.

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11 Mud crab reovirus

11.1 HAZARD IDENTIFICATION

Mud crab reovirus (MCRV) has a double stranded RNA genome and forms an icosahedral, non-enveloped viral particle 70 nm in diameter (Weng *et al.* 2007). It belongs to the family Reoviridae and forms a distinct genus within the family (Chen *et al.* 2011; Deng *et al.* 2012).

11.1.1 Aetiological agent

Mud crab reovirus (MCRV) has a double stranded RNA genome and forms an icosahedral, non-enveloped viral particle 70 nm in diameter (Weng *et al.* 2007). It belongs to the family Reoviridae and forms a distinct genus within the family (Chen *et al.* 2011; Deng *et al.* 2012).

11.1.2 OIE list

MVRC is not OIE listed.

11.1.3 New Zealand status

Following a review of the literature, MCRV has not been reported from the New Zealand aquatic environment.

11.1.4 Epidemiology

An outbreak of a condition named 'sleeping disease' occurred in cultured mud crabs (*Scylla serrata*) in China in 2004 and a viral causative agent was identified as MCRV (Weng *et al.* 2007; Chen *et al.* 2011; Deng *et al.* 2012). *S. serrata* is the only identified host species. Mortality rates of 70 % have been recorded at affected culture sites and large economic losses are associated with outbreaks of this disease (Weng *et al.* 2007).

MCRV is highly pathogenic in experimentally infected *S. serrata* (orally, intramuscularly or via water exposure), with 100 % mortality occurring within 10 days of exposure. Mortality rates of 80 % occurred in *S. serrata* within 20 days of exposure by cohabitation (Weng *et al.* 2007).

Naturally infected *S. serrata* show aggressiveness, followed by increasing weakness, lack of appetite and no response to stimulation. Internal examination of these individuals showed an atrophied hepatopancreas, empty intestine and yellow gills (Weng *et al.* 2007).

Replication of MCRV occurs in the cytoplasm of connective tissue cells of the hepatopancreas, gills and intestines, resulting in necrosis (Weng *et al.* 2007; Deng *et al.* 2012). MCRV in the early stages of infection can be found in the gill, gut, intestine, heart, muscle, gonad, haemolymph and thoracic ganglion of *S. serrata* when using a RT-PCR detection method. In moribund individuals, the virus can also be detected in the stomach and hepatopancreas (Guo *et al.* 2008).

S. serrata experimentally infected with MCRV displayed no clinical signs until three days post infection (PI) (Weng *et al.* 2007). The transmission of MCRV in naturally infected *S. serrata* is thought to be via body surfaces and enterically (Weng *et al.* 2007).

The persistence of MCRV in the aquatic environment has not been established, however, horizontal transmission has been observed in cultured *S. serrata* and there is experimental evidence to show that it can be transmitted via infected water (Weng *et al.* 2007).

11.1.5 Hazard identification conclusion

MCRV has been associated with significant mortalities in cultured *S. serrata* and can be transmitted through the consumption of infected tissue.

MCRV is identified as a hazard in the commodity.

11.2 RISK ASSESSMENT

11.2.1 Entry assessment

MCRV infects multiple tissues within *S. serrata* and experimentally it has been shown that no clinical signs develop until 3 days PI (Weng *et al.* 2007; Guo *et al.* 2008). It is unknown if MCRV can survive for prolonged periods in non-viable *S. serrata* or whether freezing or chilling inactivates the virus. Viruses belonging to the family Reoviridae are non-enveloped and are likely to be capable of persisting in the environment for an extended period.

The likelihood of entry is assessed to be non-negligible.

11.2.2 Exposure assessment

The only known host of MCRV is *S. serrata* and the majority imported would be expected to be consumed by humans, with associated waste being disposed of at a landfill or in a municipal sewage system.

Any wild *S. serrata* would not be exposed to imported waste product of *S. serrata* disposed of at a landfill. In addition, any waste in a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the titre of virus present and any remaining viable virus would be diluted within the wastewater.

Growth in the seafood import market may result in importers adding value to products (i.e. by removing shells and gut) and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of wild *S. serrata* exposure to crustacean waste products disposed to landfill or municipal sewage systems is assessed to be negligible.

Imported *S. serrata* for human consumption is a high value product (~AUD$ 39 per kilogram; Mud crabs direct 2016) and it would be expected that a very small proportion would be used as fishing bait. An abundance of locally sourced paddle crabs (*Ovalipes catharus*) can be used as bait (The Fishing Website 2016). Only one New Zealand species of wild crustacean (*S. serrata*) is known to be susceptible to infection with MCRV. *S. serrata* is seldom seen in New Zealand and individuals have only been caught from the top half of the North Island (Dell 1964). It is not known whether *S. serrata* reproduce in New Zealand and exist at a low population density, or if individuals survive and do not reproduce due to unfavourable environmental conditions after drifting on currents as larvae from Australia, or are transported either as ballast water or biofouling (Te Papa 2014). It would be expected that a significant portion of *S. serrata* if used as bait in the marine environment would be consumed by non-susceptible host species, particularly finfish (Biosecurity Australia 2009). The likelihood of exposure, transmission and spread among wild crustacean populations is also expected to be low based on the lower population densities and absence of stressful conditions typically encountered by cultured crustaceans (Walker and Mohan 2009; Department of Agriculture 2013).

Due to *S. serrata* being seldom observed in New Zealand waters the likelihood that an individual would be exposed to an infected imported individual used as fish bait is assessed to be negligible.

11.2.3 Risk estimation

The likelihood of exposure is assessed to be negligible, therefore the risk is estimated to be negligible.

MCRV is assessed not to be a risk in the commodity.

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12 Mud crab virus

12.1 HAZARD IDENTIFICATION

12.1.1 Aetiological agent

Mud crab virus (MCV) is a member of the genus *Aparavirus* and family Dicistroviridae and is a non-enveloped single-stranded icosahedral RNA virus (Zhang *et al.* 2011; International Committee on Taxonomy of Viruses 2014). It is also known by the name mud crab dicistrovirus-1 in the literature, however, in this document it will be referred to as mud crab virus.

12.1.2 OIE list

MCV is not OIE listed.

12.1.3 New Zealand status

Following a review of the literature, MCV has not been reported from the New Zealand aquatic environment.

12.1.4 Epidemiology

Scylla serrata is intensively cultured in China. In 2004, mass mortalities, in excess of 70 %, were observed in some culture facilities. Mud crab reovirus (MCRV) was originally identified as the causative agent of the mortality event, however, further investigation showed the presence of a second virus (Guo *et al.* 2013).

Co-infection of *S. serrata* with MCV and MRCV is not restricted to cultured individuals. A survey of wild *S. serrata* along the coast of Yangjiang, China found that the prevalence of MCV as detected using a nested PCR was highest between May and October 2012 (44-100%). Co-infection with MCRV was also detected in June, August and September occurring in ~ 82 % of sampled individuals (Zhang *et al.* 2013).

Guo *et al.* (2013) showed that MCV is pathogenic by injecting the virus into uninfected *S. serrata*. This resulted in 100 % mortality within 7 days.

Signs of infection in both cultured and artificially infected crabs are similar to those originally described for ‘sleeping disease’ and include a lack of appetite, no response to touch and sluggish activity during daylight hours (Guo *et al.* 2013).

Epidemiological information on MCV is scarce due to its recent discovery.

12.1.5 Hazard identification conclusion

MCV is pathogenic to *S. serrata* and is identified as a hazard.

12.2 RISK ASSESSMENT

12.2.1 Entry assessment

MCV has been isolated from the gills of diseased mud crabs (Guo *et al.* 2013). It is unknown if MCV can survive for prolonged periods in non-viable *S. serrata* or whether freezing or chilling inactivates the virus. Viruses belonging to the family Dicistroviridae are non-enveloped and are assumed to be capable of persisting in the environment for an extended period.

The likelihood of entry is assessed to be non-negligible.

12.2.2 Exposure assessment

The majority of imported *S. serrata* would be expected to be consumed by humans, with associated waste being disposed of at a landfill or in a municipal sewage system.

Any wild *S. serrata* would not be exposed to imported waste product of *S. serrata* disposed of at a landfill. In addition, any waste in a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the titre of virus present and any remaining viable virus would be diluted within the wastewater.

Growth in the seafood import market may result in importers adding value to products (i.e. by removing shells and gut) and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of wild *S. serrata* exposure to crustacean waste products disposed to landfill or municipal sewage systems is assessed to be negligible.

Imported *S. serrata* for human consumption is a high value product (~AUD$ 39 per kilogram; Mud crabs direct 2016) and it would be expected that a very small proportion would be used as fishing bait. An abundance of locally sourced paddle crabs (*Ovalipes catharus*) can be used as bait (The Fishing Website 2016). Only one New Zealand crustacean species (*S. serrata*) is known to be susceptible to infection with MCV. *S. serrata* is seldom seen in New Zealand and individuals have only been caught from the top half of the North Island (Dell 1964). It is not known whether *S. serrata* reproduce in New Zealand and exist at a low population density, or if individuals survive and do not reproduce due to unfavourable environmental conditions after drifting on currents as larvae from Australia, or are transported either as ballast water or biofouling (Te Papa 2014). It would be expected that a significant portion of *S. serrata* if used as bait in the marine environment would be consumed by non-susceptible host species, particularly finfish (Biosecurity Australia 2009). Further, the likelihood of exposure, transmission and spread among wild crustacean populations is also expected to be low based on the lower population densities and absence of stressful conditions typically encountered by cultured crustaceans (Walker and Mohan 2009; Department of Agriculture 2013).

Due to *S. serrata* being seldom observed in New Zealand waters the likelihood that an individual would be exposed to an infected imported individual used as fish bait is assessed to be negligible.

12.2.3 Risk estimation

The likelihood of exposure is assessed to be negligible, therefore the risk is estimated to be negligible.

MCV is assessed not to be a risk in the commodity.

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13 Penaeus monodon-type baculovirus (includes *bennetae* baculovirus and plebejus baculovirus)

13.1 HAZARD IDENTIFICATION

13.1.1 Aetiological agent

Shrimp baculoviruses are rod-shaped, singly enveloped and occluded, with double-stranded DNA (Rajendran *et al.* 2012). The taxonomy of these viruses is unclear, however, it has been proposed they be named PmSNPV (singly enveloped nuclear polyhedrosis virus from *Penaeus monodon*; see Mari *et al.* 1993), of which three strains are described; monodon baculovirus (MBV), *bennettae* baculovirus (BBV) and *plebejus* baculovirus (PBV) (Rajendran *et al.* 2012).

The name PmSNPV will be the name used in this assessment, however, it is worth noting that MBV is the most commonly used name in the literature.

13.1.2 OIE list

Disease caused by PmSNPV is not listed by the OIE. It was previously listed by the OIE under the name spherical baculovirosis (OIE 2012).

13.1.3 New Zealand status

Following a review of the literature, PmSNPV has not been reported from the New Zealand aquatic environment.

13.1.4 Epidemiology

PmSNPV was first described in shrimp from Taiwan in 1977. It has since spread to most shrimp producing regions of the world. The strain MBV is the most widely distributed, with BBV and PBV only described from Australia (Span and Lester 1996; Rajendran *et al.* 2012).

This virus has been found to infect a number of penaeid shrimp species (Rajendran *et al.* 2012) including *Metapenaeus bennettae* and the freshwater shrimp *Macrobrachium rosenbergii* (Span and Lester 1996; Gangnonngiw *et al.* 2010). It is the most common virus found in *P. monodon* (see Rajendran *et al.* 2012)

The life-stages of *P. monodon* most susceptible to infection are the late stage larvae through to young juvenile shrimp. The severity of infection is greatest in larval and post-larval shrimp (Lightner *et al.* 1983).

The virus targets the hepatopancreatic tubule and duct epithelium of post-larvae, juveniles and adults and the anterior midgut epithelium of very young post-larvae (Lightner *et al.* 1983). A key cellular clinical sign is the presence of occlusion bodies in the hepatopancreas and anterior midgut epithelial cells. Infected cells are then subject to necrosis and lysis through which inclusion bodies are released into the tubule lumen (Rajendran *et al.* 2012). Gross clinical signs of infection with PmSNPV include lethargy, reduced feeding, preening, growth and potentially increased fouling on the exoskeleton and gills (Vijayan *et al.* 1995).

The most significant mode of transmission is horizontal, with occlusion bodies expelled within faecal matter being ingested by other shrimp. Oral exposure has also been reported via contaminated tissues, fomites, free-living virus and occlusion bodies (Rajendran *et al.* 2012).
There is also evidence for trans-ovarian transmission of PmSNPV in *P. monodon* (see Kanjanasopa *et al.* 2015).

Shrimp that are cultured in optimal conditions can be tolerant to infection with PmSNPV as some studies have found high viral loads in shrimp in the absence of any health impacts. These shrimp may act as lifelong carriers of infection (Fegan *et al.* 1991; Vijayan *et al.* 1995; OIE 2012). Despite this, it has been documented that shrimp reared in sub-optimal conditions or those that are subject to stress can succumb to infection or be more vulnerable to secondary infections (Vijayan *et al.* 1995; Rajendran *et*

al. 2012). Shrimp have been found to be coinfected with PmSNPV and other viruses, making it difficult to attribute mortality to PmSNPV (Wang *et al.* 1997; Chayaburakul *et al.* 2004). For these reasons, the pathogenicity of PmSNPV is not well-defined (Rajendran *et al.* 2012).

The prevalence of PmSNPV can be highly variable ranging from < 1 % to 100 % (OIE 2012).

13.1.5 Hazard identification conclusion

PmSNPV has been associated with mortalities in shrimp culture and it can be transmitted through the consumption of infected tissue.

PmSNPV is identified as a hazard in the commodity.

13.2 RISK ASSESSMENT

13.2.1 Entry assessment

The survival of PmSNPV after freezing for extended periods at – 70 ºC has been reported (Spann et al. 1993, Spann and Lester 1996, Manisseri et al. 1999). Survival at normal commercial freezing temperature (– 18 ºC) has not be assessed in the scientific literature, however, it is assumed that PmSNPV will persist at this temperature and remain viable after thawing.

The likelihood of entry is assessed to be non-negligible.

13.2.2 Exposure assessment

Crustaceans imported for human consumption can be imported in bulk; heads and tail-on, for further processing (value added) or direct distribution for retail sale to markets, restaurants and supermarkets in New Zealand. The commodities include, prawns, crayfish, scampi, lobster (as lobster tails) and crabs.

It is expected that the majority of fluids derived from chilling, freezing, defrosting, processing and transport of bulk commodities are to be discarded into municipal sewage systems at the point of retail. Processing of raw entire crustaceans (i.e. heads and tails on prawns) by importers and distributors is assumed to be limited as sale of raw unprocessed crustaceans (especially prawns) is common (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018). The majority of head, shell and gut removal is likely to occur within households or trade businesses (i.e. restaurants). The waste generated in this fashion is likely to be disposed of in municipal sewage systems or to municipal landfill. The Food Regulations (New Zealand Government 2015) provide details of what waste disposal requirements restaurants and other retail businesses subject to food control plans need to follow. Waste that was directed to a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the titre of virus present and any remaining viable virus would be diluted within the wastewater (Biosecurity Australia 2009). This rationale is consistent with, and the basis for, the requirements for water treatment and disposal in MPI's transitional facilities standard for ornamental fish (MPI 2017). Similarly, all waste water from live imported freshwater prawns held in a transitional facility is treated according to this standard (MPI 2007).

Growth in the seafood import market may result in importers adding value to products (i.e. by removing heads, shells and gut) and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of exposure of wild or cultured crustaceans to imported crustacean waste products disposed to landfill or municipal sewage systems is assessed to be negligible.

An undefined yet likely small proportion of crustaceans imported for human consumption may be used as fishing bait (Blackwell 2013). The use of crustaceans especially shrimp as bait is likely to occur (Diggles 2011) and circumstantial evidence of its use in New Zealand has been identified online (The Fishing Website 2015). The use of frozen shrimp as bait may be associated with the relative low cost and ease of purchase compared to other types of fishing bait (Diggles 2011; Bateman *et al.* 2012).

Only one New Zealand species of wild crustacean (*M. bennettae*) is known to be susceptible to infection with PmSNPV. The prevalence of PmSNPV in shrimp is highly variable (OIE 2012) and a significant portion of shrimp used as bait in the marine environment would be consumed by non-susceptible host species, particularly finfish (Biosecurity Australia 2009). The likelihood of exposure, transmission and spread among wild crustacean populations is also expected to be low based on the lower population densities and absence of stressful conditions typically encountered by cultured crustaceans (Walker and Mohan 2009; Department of Agriculture 2013). Further, shrimp only tend to eat the appendages of dead shrimp (Soto *et al.* 2001; Sritunyalucksana *et al.* 2010) and PmSNPV is found within the hepatopancreatic tubule and duct epithelium of juvenile and adult shrimp.

The likelihood of exposure is assessed to be negligible.

13.2.3 Risk estimation

The likelihood of exposure is assessed to be negligible, therefore the risk is estimated to be negligible.

PmSNPV is assessed not to be a risk in the commodity.

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14 Taura syndrome virus

14.1 HAZARD IDENTIFICATION

14.1.1 Aetiological agent

Taura syndrome virus (TSV) is a non-enveloped icosahedral virus containing a single stranded positive-sense RNA genome, which belongs to the genus *Aparavirus* and family Dicistroviridae (International Committee on Taxonomy of Viruses 2014).

14.1.2 OIE list

Taura syndrome (TS) is an OIE listed disease (OIE 2015).

14.1.3 New Zealand status

Following a review of the literature, TSV has not been reported from the New Zealand aquatic environment.

14.1.4 Epidemiology

TSV primarily infects penaeid shrimps, with *Penaeus vannamei* (Pacific white shrimp) and *P. stylirostris* (Pacific blue shrimp) being the most susceptible to infection (OIE 2015). TSV is the second most important virus of penaeid shrimps after white spot syndrome virus and has caused ~ US$ 1.5 to 3 billion in losses (Lightner 2011). It was first identified in Ecuador in 1991 and now is widely distributed in the major shrimp producing areas of the world (the Americas, South-East Asia and the Middle East) (OIE 2015). There are currently four strains of TSV and they are found in discrete geographic regions (America, Belize, Venezuela and South-East Asia) (Lightner 2011). TSV is present in all life-stages of *P. vannamei* except eggs, zygotes and larvae (OIE 2015).

The spread of TS has been linked to the movement of infected post-larvae and broodstock to uninfected areas (OIE 2015). Once the virus is introduced to naïve cultured populations mortalities can be high (e.g. 40 to 90 % in *P. vannamei*) and sudden (< 24 hours in individual infections) (Lightner 2011; OIE 2015). Infection of TSV in wild shrimp populations (*P. vannamei* post-larvae) has only been identified on one occasion. These shrimp were collected near infected culture sites (Lightner 1995). The impact of TSV on wild shrimp populations is limited (Brock *et al.* 1997).

There are three stages of infection with TSV. In the acute stage, TSV replicates predominately in the cuticular epithelium of the exoskeleton, foregut, hindgut, gills and appendages. Visible gross signs of infection include lethargy, soft exoskeletons, and a red colouration caused by the proliferation of red chromatophores. Within cultured populations, the acute phase of infection typically lasts for less than a few days (Lightner 2011).

In the transition phase of infection, shrimp which have survived acute infection display melanised black spots and the cuticle can be invaded by opportunistic bacteria. Shrimp that survive through to their next moult usually appear normal. However, mortalities can still occur at this stage of infection. Shrimp in the chronic stage of infection show no gross signs and may be lifelong carriers of the virus (Lightner 2011).

Horizontal transmission of TSV occurs (via cannibalism or contaminated water) and vertical transmission is strongly suspected (OIE 2015).

TSV can survive in seawater for up to 48 hours and in shrimp tissue for at least 21 days at 27 ºC (Prior and Browdy 2002). Viable virus has also be found in faeces of sea birds for up to 48 hours after consuming diseased shrimp (OIE 2015).

TSV susceptible host species that are present in New Zealand are *Scylla serrata* and *Macrobrachium rosenbergii*, however, TSV related mortalities have not been reported in either species. *S. serrata* susceptibility to infection was determined experimentally through the consumption of dead infected *P. vannamei* and only one cultured *M. rosenbergii* has tested TSV positive (Nielsen *et al.* 2005;

Kiatpathomchai *et al.* 2008). TS has not been described in cold-water crustacean species (Stentiford *et al.* 2009).

Overstreet *et al*. (2009) demonstrated successful transmission of TSV to parasitic copepods on the gills of fish and parasitic barnacles of the blue crab (*Callinectes sapidus*) fed with TSV infected shrimp. Viral replication occurred in these parasites for at least two weeks resulting in a potential infective dose.

14.1.5 Hazard identification conclusion

TSV is an economically import shrimp pathogen. It is associated with mortalities and can be transmitted through the consumption of infected tissue.

TSV is identified as a hazard in the commodity.

14.2 RISK ASSESSMENT

14.2.1 Entry assessment

TSV is resilient to freezing and can retain viability after freezing to – 70 ºC (Song *et al.* 2003). Survival at commercial freezing temperature (– 18 ºC) has not been assessed in the scientific literature, although, it is assumed that TSV will persist at this temperature and remain viable after thawing.

The likelihood of entry is assessed to be non-negligible.

14.2.2 Exposure assessment

Crustaceans imported for human consumption can be imported in bulk; heads and tail-on, for further processing (value added) or direct distribution for retail sale to markets, restaurants and supermarkets in New Zealand. The commodities include, prawns, crayfish, scampi, lobster (as lobster tails) and crabs.

It is expected that the majority of fluids derived from chilling, freezing, defrosting, processing and transport of bulk commodities are to be discarded into municipal sewage systems at the point of retail. Processing of raw entire crustaceans (i.e. heads and tails on prawns) by importers and distributors is assumed to be limited as sale of raw unprocessed crustaceans (especially prawns) is common (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018). The majority of head, shell and gut removal is likely to occur within households or trade businesses (i.e. restaurants). The waste generated in this fashion is likely to be disposed of in municipal sewage systems or to municipal landfill. The Food Regulations (New Zealand Government 2015) provide details of what waste disposal requirements restaurants and other retail businesses subject to food control plans need to follow. Waste that was directed to a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the titre of virus present and any remaining viable virus would be diluted within the wastewater (Biosecurity Australia 2009). This rationale is consistent with, and the basis for, the requirements for water treatment and disposal in MPI's transitional facilities standard for ornamental fish (MPI 2017). Similarly, all waste water from live imported freshwater prawns held in a transitional facility is treated according to this standard (MPI 2007).

Growth in the seafood import market may result in importers adding value to products (i.e. by removing heads, shells and gut) and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of exposure of wild or cultured crustaceans to imported crustacean waste products disposed to landfill or municipal sewage systems is assessed to be negligible.

An undefined yet likely small proportion of crustaceans imported for human consumption may be used as fishing bait (Blackwell 2013). The use of crustaceans especially shrimp as bait is likely to occur (Diggles 2011) and circumstantial evidence of its use in New Zealand has been identified online (The Fishing Website 2015). The use of frozen shrimp as bait may be associated with the relative low cost and ease of purchase compared to other types of fishing bait (Diggles 2011; Bateman *et al.* 2012).

TSV susceptible host species that are present in New Zealand are *S. serrata* and *M. rosenbergii*.

S. serrata is seldom seen in New Zealand and individuals have only been caught from the top half of the North Island (Dell 1964). It is not known whether *S. serrata* reproduce in New Zealand and exist at a low population density, or if individuals survive and do not reproduce due to unfavourable environmental conditions after drifting on currents as larvae from Australia, or are transported either as ballast water or biofouling (Te Papa 2014). It would be expected that a significant portion of crustaceans used as bait in the marine environment would be consumed by non-susceptible host species, particularly finfish (Biosecurity Australia 2009). Parasitic crustaceans of finfish could theoretically become infected if TSV infected tissue was consumed by the host. The likelihood of exposure, transmission and spread among wild crustacean populations is also expected to be low based on the lower population densities and absence of stressful conditions typically encountered by cultured crustaceans (Walker and Mohan 2009; Department of Agriculture 2013).

S. serrata is seldom observed in New Zealand waters so the likelihood that an individual would be exposed to an infected imported crustacean used as fish bait or an infected crustacean parasite of finfish is assessed to be negligible.

M. rosenbergii is the sole susceptible species cultured in New Zealand. It is cultured at a single aquaculture site and is restricted in its distribution as it survives only in geothermally heated water from the Waikato River (MacGibbon 2008). The only pathway for exposure is through feeding *M. rosenbergii* infected crustaceans that are intended for human consumption. It is unlikely that the farm operators would buy imported prawns destined for human consumption and subsequently feed these to their stock. This is a well-known exposure pathway for many crustacean pathogens that would endanger their stock and their livelihoods and is considered to be contrary to best aquaculture biosecurity practice (Georgiades *et al.* 2016).

As crustacean aquaculture is in its infancy in New Zealand and *M. rosenbergii* is cultured by a single company at one location, the likelihood of exposure is assessed to be negligible.

14.2.3 Risk estimation

The likelihood of exposure is assessed to be negligible, therefore the risk is estimated to be negligible.

TSV is assessed not to be a risk in the commodity.

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15 White spot syndrome

15.1 HAZARD IDENTIFICATION

15.1.1 Aetiological agent

White spot syndrome virus (WSSV) is a double-stranded enveloped DNA virus. It is the sole member of the family Nimaviridae, genus *Whispovirus* (International Committee on Taxonomy of Viruses 2014). WSSV is the causative agent of white spot disease (WSD).

15.1.2 OIE list

Infection with WSSV is listed within the diseases of crustaceans (OIE 2017).

15.1.3 New Zealand status

Following a review of the literature, WSSV has not been reported from the New Zealand aquatic environment. WSSV is a notifiable organism (Biosecurity, notifiable organisms, Order 2016; WAHIS 2018).

15.1.4 Epidemiology

WSSV is a significant pathogen of cultured penaeid crustaceans (prawns and shrimp) resulting in mass mortalities in naïve stock. Production losses of up to 80 % in China were attributed to WSSV occurring in cultured shrimp (*Penaeus chinensis*, *P. japonicus*, and *P. monodon*) (Zhan *et al.* 1998). The disease was first recognised in Taiwan in 1992 (Chou *et al.* 1995) as a newly emerging pathogen of cultured shrimp (including *Penaeus monodon*, *P. japonicus* and *P. penicillatus*) and spread rapidly through Asia. Suspected pathways for this rapid spread include the use of infected broodstock to establish or replenish aquaculture facilities and the use of infected cultured and wild caught crustaceans as feed in aquaculture facilities (Stentiford and Lightner 2011). Other postulated pathways include ballast water from cargo vessels carrying infected crustaceans and the entry of frozen crustacean commodities (mainly prawns and shrimp) into the aquatic environment (Escobedo-Bonilla *et al.* 2008).

WSSV is present in China, Japan, Korea, Chinese Taipei, South East Asia (Vietnam, Thailand, Philippines, Myanmar, Brunei, Malaysia), the Indian Continent, the Mediterranean, Middle East (Iran), Mozambique, Madagascar and the Americas (Mexico, El Salvador, Costa Rica, Colombia, Ecuador, Peru, Brazil, United States of America) (OIE 2017; WAHIS 2018).

In November 2000 in Darwin, Australia, the feeding of WSSV infected imported green prawns (*Penaeus semisulcatus*) to cultured mud crabs (*Scylla serrata*) and tiger prawns (*Penaeus monodon*) resulted in positive detections of WSSV in these cultured species, in the absence of clinical signs (East *et al*. 2004). Following eradication in the culture facilities and surveillance of wild populations (targeted surveillance in crabs, prawns and crayfish), Australia declared freedom from WSSV in May 2002 (East *et al*. 2004). However, a recent outbreak occurred in Queensland, Australia, in November 2016, affecting seven prawn farms (Outbreak 2017).

All life stages of all decapod crustaceans including prawns, shrimp, lobsters and crabs from marine, brackish or freshwater environments and all life-stages are considered to be susceptible to WSSV (Escobedo-Bonilla *et al.* 2008; OIE 2017).
All penaeid crustacean species are highly susceptible to WSSV. WSD is mainly reported in cultured penaeid prawns and shrimp.

WSD has been reported in farmed and captive (zoo), North American crayfish (Lightner *et al.* 1997; Baumgartner *et al.* 2009), showing that WSSV infection with clinical disease can occur in both sub-orders of the order Decapoda.

WSSV has been detected in healthy wild prawns, shrimp and crabs in endemic areas of Asia (Lo *et al.* 1996; Lo and Kou 1998), the Americas and in wild crustaceans in the surveillance areas associated with the recent Australian Queensland outbreak (Lightner *et al.* 1997; Lo *et al.* 1996; Baumgartner *et al.* 2009; Outbreak 2017). It has also been found that some wild crustacean species (Crabs: *Charybdis feriatus* and *Portunus sanguinolentus*) have high viral titres in the absence of clinical signs (Lo and Kou

1998). These crustaceans may act as reservoirs for the virus and are often sub-clinically infected. However, the exact epidemiology of WSSV within these wild populations is unknown (Lo and Kou 1998).

Non-penaeid decapod species (e.g. crab, lobster) generally have sub-clinical infections under natural conditions (OIE 2017). WSD has been reproduced in wild caught crustaceans through experimental studies. In these studies WSSV, was transmitted by means of ingestion, injection and exposure to contaminated water (Corbel *et al.* 2001; Escobedo-Bonilla *et al.* 2008). Although these experimental studies could induce disease expression in wild caught crustaceans, clinical WSD in naturally occurring wild crustaceans has not been definitely reported.

Non-decapodal crustaceans, such as copepods, *Artemia salina*, *Balanus* sp., as well as *Tachypleus* sp. (Horseshoe crab) and rotifers, may become wild carriers by latent infection (Yan *et al.* 2004, 2007; Overstreet *et al.* 2009; OIE 2017). The role these play in the epidemiology of WSD is as yet unknown.

Polychaete worms (phylum: Annelida, class: Polychaeta) and insects i.e. *Ephydridae* insect larvae (shore flies) (class: Insecta, order: Diptera) can mechanically carry the virus without evidence of infection (OIE 2017). The role these organisms play in the epidemiology of WSD is undefined in the literature.

There is no evidence in the literature that WSSV replicates in or is pathogenic to non-decapodal crustaceans, mammals, fish or birds. Accordingly, there are no impacts for any other animals, nor human health concerns.

The prevalence of WSSV can be up to 100 % in cultured decapod crustacean species, especially in cultured penaeid prawn and shrimp populations (Lo and Kou 1998). Mortality rates in cultured penaeid prawn and shrimp can be very high with up to 100 % mortality occurring in 3-10 days in susceptible populations (Chou *et al.* 1995; Lightner *et al.* 1998). Mortality rates among other non-penaeid cultured crustacean species (crabs, crayfish, freshwater prawns, spiny lobster and clawed lobsters) is highly variable suggesting that relative susceptibility varies between crustacean taxa (Oidtmann and Stentiford 2011).

The exact route of WSSV entry into susceptible hosts is uncertain. However, good evidence exists to show that primary viral replication occurs in the epithelial cells of the stomach, gastrointestinal tract (foregut) and cells of the gills (Escobedo-Bonilla *et al.* 2008). Therefore, oral exposure is considered the primary route of entry.

The virus has a tropism for tissues of ecto- and mesodermal origin. A study by Lo *et al.* 1997, found WSSV in order of decreasing prevalence in gills, haemolymph, stomach, abdominal muscle, reproductive organs, midgut, heart, periopods, lymphoid organ, integument, nervous tissue, and the hepatopancreas. Viral replication was best supported in cells of the epidermis, stomach, gills and muscles.

Transmission of WSSV could occur horizontally (through the consumption of infected tissues) (Soto and Lotz 2001) or through water-borne transmission (i.e. virus particles are shed at spawning and then ingested by larvae when they first feed). True vertical transmission (transovum) is suspected (Lo and Kou 1998; Oidtmann and Stentiford 2011; Pradeep *et al.* 2012). Transmission can occur from apparently healthy animals (Oidtmann and Stentiford 2011; OIE 2017).

Oral transmission is considered to be the primary route of infection in natural and cultured populations with dead and moribund animals being the principal source of infection (Soto *et al.* 2001; Soto and Lotz 2001; Lotz and Soto 2002; OIE 2017). In the study by Lo *et al.* 1997, individually isolated (WSSV PCR negative) brooder shrimp unexpectedly became PCR positive for WSSV. Investigation into the reason for this unexpected change in viral status revealed that the wild caught crab (*P. sanguinolentus*) used as feed, had very high titres of WSSV with no clinical signs. It was postulated that consumption of infected crab meat resulted in transmission of WSSV to the broodstock.

Persistent infection and lifelong infection occurs (OIE 2017). However, viral titres can be very low and present at levels which are undetectable using current technology (nested PCR) (Walker and Winton 2010; OIE 2017).

Development of clinical disease is associated with various stress factors that are associated with poor animal husbandry practices. Stressors such as handling, transport, pond water temperature, water quality and salinity, population density and biomass play an important part in disease development (Tsai *et al.* 1999; Department of Agriculture 2013). There are seasonal fluctuations in virus prevalence with higher levels seen during spawning (Lo *et al.* 1997). Susceptibility to infection and level of infection also varies between species and wild caught versus cultured decapods (Oidtmann and Stentiford 2011).

Clinical signs are variable, ranging from per acute to chronic (Sudha *et al.* 1998) and even subclinical (Pradeep *et al.* 2012). Clinically infected crustaceans become moribund, anorexic, display reduced preening activities, have a loose cuticle and a reddish to pink body discolouration (Chou *et al.* 1995). A characteristic clinical sign of infection is the development of white spots (1 mm to 1 cm in size) on the exoskeleton, especially on the carapace and last abdominal segment of prawns and shrimp (Chou *et al.* 1995).

It has been observed that the pathogenicity of WSSV is dependent on water temperature. Water temperatures between 18 and 30 °C are most conducive to a WSD outbreak (Jiravanichpaisal *et al.* 2004; Du *et al.* 2008; Gao *et al*. 2011).

WSSV has been shown to remain viable in the laboratory for at least 30 days in seawater held at 30 °C and remains viable in culture ponds for at least 3 days (Nakano *et al.* 1998). WSSV can remain viable and infective in frozen crustacean tissue for up to 2 years at – 70 °C (Nunan *et al.* 1998; Wang *et al.* 1999; Durand *et al.* 2000; Soto *et al.* 2001; Batemen *et al.* 2012).

15.1.5 Hazard identification conclusion

WSD is an OIE listed disease of crustaceans which can cause significant morbidity and mortality. WSSV can be found in cultured and wild crustaceans. WSD is primarily a viral disease affecting members of the penaeid family that are commonly cultured for human consumption. WSSV not a hazard to human health.

WSSV is concluded to be a hazard in the commodity.

15.2 RISK ASSESSMENT

15.2.1 Entry assessment

WSSV is present in the cuticle, appendages and muscles of infected crustaceans.
Crustaceans can be imported as frozen or chilled, consumer packaged and processed (heads, tails and gut removed), ready to eat for retail or as bulk unprocessed (heads and tails on and intact) for further processing or packaging and distribution in New Zealand for retail sale for human consumption.

The prevalence of WSSV in cultured decapod crustaceans can be very high. Mortality rates that are above acceptable levels often prompts an emergency harvest of cultured prawns and shrimp in order to avoid the economic losses associated with mass mortalities. This results in prawns and shrimp entering the market that are smaller in size and likely to have increased viral titres. Extremely high viral titres (10^9 – 10^{10} copy numbers $gram^{-1}$ of tissue) have been measured in body tissues of cultured prawns and shrimp at the beginning of a WSSV outbreak (Oidtmann and Stentiford 2011). The viral titre in wild or cultured crustaceans that survive infection is usually lower (Oidtmann and Stentiford 2011).

WSSV can survive freezing and has been propagated from prawns that were frozen for 2 years at – 70 °C (Wang *et al.* 1999). McColl *et al.* (2004) found that WSSV remained viable after several freeze and thaw cycles, although it is assumed that a reduced titre of viable virus would remain in crustacean tissue. Corbel *et al.* (2001) observed high rates of mortality in five European crustacean species that were experimentally fed thawed WSSV infected shrimp.

Frozen uncooked prawns and shrimp imported for human consumption have tested positive for WSSV with Polymerase Chain Reaction (PCR), in-situ Hybridization and bioassay (Lightner *et al.* 1997; Durand *et al.* 2000; McColl *et al.* 2004; Reville 2005; Biosecurity Australia 2009; Flegel 2009; MPI unpublished data).

In the USA, Reville *et al.* (2005) randomly sampled shrimp from supermarkets and found that the prevalence of WSSV PCR positive samples ranged from 0 – 37 % with larger sized shrimp displaying a higher prevalence of infection compared to small shrimp. Of these, shrimp imported from Thailand had the highest prevalence of WSSV PCR positive results (Reville *et al.* 2005).

Bateman *et al.* (2012) found that 66 % (4/6) and 10 % (1/10) of shrimp batches (imported from Ecuador and Vietnam) tested positive for WSSV (using nested PCR and bioassays) from supermarkets and fish markets within the United Kingdom, and the within batch prevalence ranged from 0 – 100 %. In Australia, imported frozen uncooked prawns from Southeast Asia contained viable WSSV detected through PCR, in-situ Hybridization and bioassay (McColl *et al.* 2004).

Since frozen or chilled decapod crustaceans, especially prawns and shrimp, imported from WSSV endemic territories may harbour viable virus, the likelihood of entry is assessed to be non-negligible.

15.2.2 Exposure assessment

Crustaceans imported for human consumption can be imported in bulk; heads and tail-on, for further processing (value added) or direct distribution for retail sale to markets, restaurants and supermarkets in New Zealand. The commodities include, prawns, crayfish, scampi, lobster (as lobster tails) and crabs.

Personal communication with an importer and internet searches of importers and distributors of seafood into New Zealand, revealed that crustacean commodities can be imported in a range of products up to 5 kg in sealed plastic bags, as well as consignments of entire raw black tiger prawns (*P. monodon*) up to 12 kg, in plastic lined cartons (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018).

It is expected that the majority of fluids derived from chilling, freezing, defrosting, processing and transport of bulk commodities are to be discarded into municipal sewage systems at the point of retail. Processing of raw entire crustaceans (i.e. heads and tails on prawns) by importers and distributors is assumed to be limited as sale of raw unprocessed crustaceans (especially prawns) is common (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018). The majority of head, shell and gut removal is likely to occur within households or trade businesses (i.e. restaurants). The waste generated in this fashion is likely to be disposed of in municipal sewage systems or to municipal landfill. The Food Regulations (New Zealand Government 2015) provide details of what waste disposal requirements restaurants and other retail businesses subject to food control plans need to follow. Waste that was directed to a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the titre of virus present and any remaining viable virus would be diluted within the wastewater (Biosecurity Australia 2009). This rationale is consistent with, and the basis for, the requirements for water treatment and disposal in MPI's transitional facilities standard for ornamental fish (MPI 2017). Similarly, all waste water from live imported freshwater prawns held in a transitional facility is treated according to this standard (MPI 2007).

Growth in the seafood import market may result in importers adding value to products by removing heads, shells and gut, and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

New Zealand has a long history of importing cultured prawns for human consumption, from a number of countries (i.e. Thailand, Vietnam), many in which WSSV is considered endemic. To date, there is no evidence for the establishment of WSSV in New Zealand's aquatic environment and WSD has not been reported in cultured or wild crustaceans.

New Zealand aquaculture facilities are limited with one thermally heated prawn farm near Taupo (Webber *et al.* 2010) and inland freshwater kōura farms in the South Island (near Blenheim, Alexandra and Kaikoura; Enslow One Ltd. 2016). There are no fisheries processing facilities near these aquaculture facilities and the risk of discharge contaminating these premises is minimal.

Furthermore, the decapod fauna of New Zealand is considered depauperate considering the extent of the exclusive economic zone that ranges over 30 degrees of latitude, the large area of continental shelf and slope, and the variety of ecological niches available (Webber *et al.* 2010). Compared to intensive

farming, which may include high population densities and stressful rearing conditions, there is a low likelihood of exposure to WSSV infected material and lower likelihood of direct transmission in wild populations (Tsai *et al.* 1999; Walker and Mohan 2009; Department of Agriculture 2013). Average New Zealand coastal marine water temperatures are also not conducive to WSSV replication, apart from Northern parts of the
North Island where water temperatures in summer may reach > 20 ˚C (NIWA 2013). Expression of WSSV would likely be limited to summer months in northern parts of New Zealand.

The likelihood of significant volumes of solid waste or effluent being discharged, resulting in exposure of farmed or wild crustaceans and subsequent establishment of infection with WSSV, is assessed to be negligible.

Any waste generated from pre-packaged retail ready imported crustaceans for human consumption is likely to be associated with households, and will be minimal. Disposal is likely to be to municipal landfill and municipal sewage system. Exposure of susceptible species is unlikely with waste disposed at landfill.

The likelihood of exposure through crustacean waste products disposed of by these two pathways is assessed to be negligible.

An undefined yet likely small proportion of crustaceans imported for human consumption may be used as fishing bait (Blackwell 2013). The use of crustaceans especially shrimp as bait is likely to occur (Diggles 2011) and circumstantial evidence of its use in New Zealand has been identified online (Fishing News 2014; The Fishing Website 2015). The use of frozen shrimp intended for human consumption as bait may be associated with the relative low cost and ease of purchase compared to other types of fishing bait (Diggles 2011; Bateman *et al.* 2012). Despite the use of imported crustaceans as bait there is little data on the likelihood of disease transmission to wild crustaceans (Flegel 2009; Karunasagar and Ababouch 2012). A significant portion of shrimp used as bait in the marine environment would be consumed by nonsusceptible host species, particularly finfish (Biosecurity Australia 2009).

Hasson *et al.* (2006), postulated that imported penaeid shrimp used as bait may have introduced WSSV to the Gulf of Mexico and Texas, USA (Hasson *et al.* 2006). The more recent WSSV outbreak in Australia has similarly been attributed to the use of imported crustaceans as fishing bait (Outbreak 2017). However, there is no definitive evidence to confirm this exposure pathway.

Crabs and lobster are known scavengers they could be exposed to bait not consumed by nonsusceptible host species. While the minimum infectious oral dose required to initiate infection in crustaceans is unknown (Oidtmann and Stentiford 2011), several studies have demonstrated that oral consumption of infectious tissue does not guarantee infection, even in controlled experimentation (Durand *et al.* 2000; Hasson *et al.* 2006; Bateman *et al.* 2012). The amount of crustacean bait that enters New Zealand's aquatic environment is undefined though likely small (Blackwell 2013). Further, the likelihood of exposure, transmission and spread among wild crustacean populations is also expected to be low based on the lower population densities and absence of stressful conditions typically encountered by cultured crustaceans (Walker and Mohan 2009; Department of Agriculture 2013).

Accordingly, there is no, or at best, only circumstantial evidence that supports prawns and shrimp used as bait as having been implicated in the spread of WSSV. This pathway is not scientifically supported through substantiated reports. Thus, under the circumstances outlined above, the likelihood of exposure and spread of WSSV internationally through the use of imported chilled or frozen crustaceans as fish bait is assessed to be so low as to be negligible.

The use of imported crustaceans as feed for broodstock and maturing stock in aquaculture facilities is a significant pathway of exposure as the oral consumption of infected crustacean tissue successfully transmits WSSV.

However, the commodity is imported for human consumption and retail trade and not intended for use as feed in aquaculture premises. Furthermore, the crustacean aquaculture industry in New Zealand is very small with just one major prawn farm at Taupo (Webber *et al.* 2010) and four freshwater inland kōura farms in the South Island (Enslaw One Ltd. 2016). It is unlikely that the farm operators would buy imported prawns destined for human consumption and subsequently feed these to their stock. This is a

well-known exposure pathway for many crustacean pathogens that would endanger their stock and their livelihoods and is considered to be contrary to best aquaculture biosecurity practice (Georgiades *et al.* 2016).

It is considered to be unlikely that imported prawns for human consumption would be used as feed in an aquaculture facility in New Zealand. Therefore, the likelihood of exposure through this pathway is assessed to be negligible.

In summary, viable virus can be maintained in a number of frozen and chilled imported crustacean species.

The overall likelihood of exposure is assessed to be negligible.

15.2.3 Risk estimation

The likelihood of entry is assessed to be non-negligible. However, the likelihood of susceptible crustaceans, either cultured or wild in New Zealand, being exposed with subsequent infection resulting is assessed to be negligible.

Accordingly, the risk estimate for WSSV in crustaceans imported for human consumption is estimated to be negligible.

Since the risk estimate is negligible, risk management measures are not justified.

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16 Yellow head virus

16.1 HAZARD IDENTIFICATION

16.1.1 Aetiological agent

Yellow head virus complex consists of 7 genotypes of which genotype 1 is named yellow head virus (YHV) and is the only known agent of yellow head disease (YHD) (OIE 2015). All other genotypes (genotype 2 named gill-associated virus (GAV) and genotypes 3-7) are associated with chronically infected *Penaeus monodon* and are not associated with high mortalities (Spann *et al.* 1995; Wijegoonawardane *et al.* 2008; Cowley *et al.* 2009; Mohr *et al.* 2015). YHD in *P. monodon* sampled from the Indo-Pacific region found that was only detected in shrimp infected with genotype 1 (Wijegoonawardane *et al.* 2008).

The International Committee on Taxonomy of Viruses (2014) currently classifies the yellow head virus complex as a single species named *Gill-associated virus* belonging to the genus *Okavirus,* family Roniviridae, and order Nidovirales. For the purpose of this assessment, YHV will refer to only the pathogenic genotype 1.

YHV is an enveloped single stranded positive sense RNA virus and forms rod-shaped particles. Envelopes are studded with prominent peplomers and nucleocapsids appear as rods (OIE 2015).

16.1.2 OIE list

Infection with YHV is an OIE listed disease (OIE 2015).

16.1.3 New Zealand status

Following a review of the literature, YHV has not been reported from the New Zealand aquatic environment. YHV is an unwanted notifiable organism (Unwanted Organism Register 2010).

16.1.4 Epidemiology

Outbreaks of virulent YHD have only been reported from the black tiger prawn (*Penaeus monodon*) and the white shrimp (*P. vannamei*) (see Chantanachookin *et al.* 1993; Senapin *et al.* 2010). The first YHD mortality event was reported in *P. monodon* from Thailand in 1990 (Limsuwan 1991). YHD has since been recorded in Chinese Taipei, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand, Vietnam, and Mexico (OIE 2015a).

Natural infections have also been detected in a number of other penaeid shrimp species, mysid shrimp and freshwater shrimp (Castro-Longoria *et al.* 2008; Stentiford *et al.* 2009). The daggerblade grass shrimp (*Palaemonetes pugio*) has also been identified as a reservoir host (Ma *et al.* 2009).

YHV does not appear to infect crabs. No natural infections were detected in 16 crab species surveyed near shrimp culture sites in Thailand. Further, injection of crabs with YHV did not result in infection (Longyant *et al.* 2006). However, under experimental conditions the blue crab (*Callinectes sapidus*) was been shown to be a short-term carrier of YHV (Ma *et al.* 2009). Recently, the Australian red claw crayfish (*Cherax quadricarinatus*) has been experimentally identified as a host of YHV but is highly tolerant to infection and is capable of transmitting the virus to *P. monodon* via co-habitation (Soowannayan *et al.* 2015).

Stentiford *et al.* (2009) critically assessed the host range for the YHV species complex (Genotypes 1-6) against the following objective susceptibility criteria: evidence of replication or growth of the organism, presence of a viable organism, presence of specific clinicopathological changes and specific location of the pathogen within the host. The species assessed included, the greasyback prawn (*Metapenaeus bennettae*) and freshwater shrimp (*Macrobrachium rosenbergii*) which are present in New Zealand. *M. bennettae* was identified as having no scientific data available to make an assessment of species susceptibility. Walker *et al.* (2001) reported that *M. bennettae* had been experimentally infected with GAV, although, no data was presented. Despite the lack of evidence *M. bennettae* was listed as a host species of YHV by the OIE (2015a). *M. rosenbergii* has been experimentally infected with YHV via injection and it was determined using RT-PCR and immunohistochemistry that it was resistant to infection (Longyant *et al.* 2005). *M. rosenbergii* is not

listed as a host species by the OIE (2015a). There is no evidence that cold-water penaeid species are susceptible to infection with YHV (Stentiford *et al.* 2009).

Gross clinical signs of infection are first identified by an increase in feeding for several days followed by a sudden decline. Around one day after feeding ceases individuals begin to swim atypically near the edge of the pond and die shortly thereafter. The virus is named after the yellow colouration of the dorsal cephalothorax and gills that can be seen through the bleached carapace (Chantanachookin *et al.* 1993; Cowley *et al* 1999).

YHV was one of the most virulent viruses affecting *P. monodon* in Thailand (Sithigorngul *et al.* 2000). In the early outbreaks, 100 % mortality occurred within 5 days of the appearance of clinical signs (Chantanachookin *et al.* 1993). Within approximately 2 years after the first outbreaks the severity of infection declined and it is thought this has been achieved through the arthropod immune response mechanism called 'active accommodation' that is triggered during the early stages of development (Flegel 2007). Pathogenicity is likely to be influenced by the viral load in broodstock, initial load in post-larvae, presence of co-infecting viruses and environmental stressors that may facilitate the expression of disease (Munro and Owens 2007).

In Asia and Australia, there are now numerous examples of *P. monodon* being chronically infected with YHV in the absence of significant mortalities (Munro and Owens 2007). Experimentally, YHV can also persist in individuals that have survived infection (Longyant *et al.* 2005; 2006).

The prevalence of YHV in infected populations can range from 100 % in an outbreak to < 1 % in healthy wild or cultured *P. monodon* (see OIE 2015a). In areas in which YHV is endemic, the virus has been isolated from wild shrimp resident in and around culture ponds (Longyant *et al.* 2005).

Transmission of YHV can occur horizontally via ingestion of infected tissue, injection, immersion in infected seawater, or cohabitation (OIE 2015a). In cultured populations, contaminated pond water facilitates the rapid transmission of disease and this is further enhanced through cannibalism of weak or moribund shrimp (Stentiford *et al.* 2009).

The lymphoid organ, gill and head muscle contain the highest number of infectious virions, with replication occurring in the cytoplasm of cells in the lymphoid organ, gills, haemocytes and connective tissues (Cowley *et al.* 2001; Munro and Owens 2007). Persistent infections with YHV can only be easily detected in the lymphoid organ, while acute infections can be detected in a number of tissues (Longyant *et al.* 2005).

YHV is viable in seawater for up to 72 hours and can be inactivated by exposure to 60 °C for 15 minutes (OIE 2015a). The infectious dose for YHV is unknown (Stentiford *et al.* 2009).

Introduction of YHV into new areas has primarily been attributed to the movement of live animals, particularly broodstock and post-larvae (Briggs *et al.* 2004).

16.1.5 Hazard identification conclusion

Infection with YHV in penaeid shrimps has been associated with significant mortalities and can be transmitted through the consumptions of infected tissue.

YHV is identified as a hazard in the commodity.

16.2 RISK ASSESSMENT

16.2.1 Entry assessment

Viable YHV has been identified from frozen commodity shrimp (see Nunan *et al.* 1997; Durand *et al.* 2000).

As shrimp can be infected without displaying clinical signs (Castro-Longoria *et al.* 2008), the likelihood of entry is assessed to be non-negligible.

16.2.2 Exposure assessment

Crustaceans imported for human consumption can be imported in bulk; heads and tail-on, for further processing (value added) or direct distribution for retail sale to markets, restaurants and supermarkets in New Zealand. The commodities include, prawns, crayfish, scampi, lobster (as lobster tails) and crabs.

It is expected that the majority of fluids derived from chilling, freezing, defrosting, processing and transport of bulk commodities are to be discarded into municipal sewage systems at the point of retail. Processing of raw entire crustaceans (i.e. heads and tails on prawns) by importers and distributors is assumed to be limited as sale of raw unprocessed crustaceans (especially prawns) is common (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018). The majority of head, shell and gut removal is likely to occur within households or trade businesses (i.e. restaurants). The waste generated in this fashion is likely to be disposed of in municipal sewage systems or to municipal landfill. The Food Regulations (New Zealand Government 2015) provide details of what waste disposal requirements restaurants and other retail businesses subject to food control plans need to follow. Waste that was directed to a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the titre of virus present and any remaining viable virus would be diluted within the wastewater (Biosecurity Australia 2009). This rationale is consistent with, and the basis for, the requirements for water treatment and disposal in MPI's transitional facilities standard for ornamental fish (MPI 2017). Similarly, all waste water from live imported freshwater prawns held in a transitional facility is treated according to this standard (MPI 2007).

Growth in the seafood import market may result in importers adding value to products (i.e. by removing heads, shells and gut) and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of exposure of wild or cultured crustaceans to imported crustacean waste products disposed to landfill or municipal sewage systems is assessed to be negligible.

An undefined yet likely small proportion of crustaceans imported for human consumption may be used as fishing bait (Blackwell 2013). The use of crustaceans especially shrimp as bait is likely to occur (Diggles 2011) and circumstantial evidence of its use in New Zealand has been identified online (The Fishing Website 2015). The use of frozen shrimp as bait may be associated with the relative low cost and ease of purchase compared to other types of fishing bait (Diggles 2011; Bateman *et al.* 2012).

Only one species present in New Zealand (*M. bennettae*) is known to be susceptible to infection with YHV. *M. bennettae* is an established non-indigenous species found in the wild.

The prevalence of YHV in shrimp is highly variable (see OIE 2015a) and a significant portion of shrimp used as bait in the marine environment would be consumed by non-susceptible host species, particularly finfish (Biosecurity Australia 2009). The likelihood of exposure, transmission and spread among wild crustacean populations is also expected to be low based on the lower population densities and absence of stressful conditions typically encountered by cultured crustaceans (Walker and Mohan 2009; Department of Agriculture 2013). Further, shrimp only tend to eat the appendages of dead shrimp (Soto *et al.* 2001; Sritunyalucksana *et al.* 2010) and YHV is found within the lymphoid organ, gill and head muscle.

Flegel (2009) found no published reports in the peer-reviewed, scientific literature of YHV outbreaks in wild or cultivated shrimp from shrimp products imported for human consumption. Despite the use of imported crustaceans as bait, there is a lack of data regarding the epidemiological probability of disease transmission to wild crustaceans (Flegel 2009).

The likelihood of exposure is assessed to be negligible.

16.2.3 Risk estimation

The likelihood of exposure is assessed to be negligible, therefore the risk is estimated to be negligible.

YHV is assessed not to be a risk in the commodity.

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17 Exotic rickettsia-like organisms

17.1 HAZARD IDENTIFICATION

17.1.1 Aetiological agent

Rickettsia-like organisms (RLOs) are obligate intracellular alpha-proteobacteria (Weinert 2015). RLOs differ from extracellular bacteria due to the absence of a true bacterial wall (Wang 2011). The taxonomy of this group is uncertain and it is likely that RLOs encompass many species.

17.1.2 OIE list

No crustacean RLOs are listed by the OIE except Candidatus *Hepatobacter penaei* for which there are no host species present in New Zealand (OIE 2017).

17.1.3 New Zealand status

Following a review of the literature, all pathogenic crustacean RLOs are considered exotic to New Zealand's aquatic environment. Pathogenic RLOs are listed as unwanted organisms (Unwanted Organism Register 1998).

17.1.4 Epidemiology

Infection with RLOs has been reported in a number of crustacean species. Infection resulting in disease is seldom reported in crabs and have only been identified from shore crabs (*Carcinus mediterraneus*), blue king crabs (*Paralithodes platypus*) and golden king crabs (*Lithodes aequispina*) (Wang 2011). Infection with RLOs in these species were assumed to be fatal (Wang 2011). In cultured species infection with RLOs are apparently rare, although an infection rate of 2.3 % was found in blue crabs (*Callinectes sapidus*) from Maryland (USA) with the infection resulting in no mortality and only minor pathology (Messick and Kennedy 1990). Recently, a novel intracellular bacterial infection was identified from the edible crab (*Cancer pagurus*) and was found to be a member of the order Rhizobiales and, therefore, distinct from bacteria classified as rickettsia (Thrupp *et al.* 2016). An RLO recently found in the sand crab (*Portunus pelagicus*) in Darwin Australia, with collected individuals dying soon after capture (Diggles *et al.* 2013).

Freshwater crustaceans have been found to be infected with RLOs, with mortalities in redclaw crayfish (*Cherax quadricarinatus*) being associated with two different species (Edgerton *et al.* 2004). RLO associated mortalities of commercially reared *Macrobrachium rosenbergii* larvae ranged from 40 to 95 % (Cohen and Isaar 1990).

RLOs appear to infect the majority of internal organs and tissues of crustaceans such as muscles, gonads, pereiopods, midgut, hepatopancreas nerves, terminal hepatic arterioles, heart, gills and haemolymph (Romero *et al.* 2000; Gollas-Galvan *et al.* 2013).

Clinical signs that are associated with infection with an RLO are not pathognomonic and may include, for example, lethargy, lack of appetite, poor growth and an atrophied hepatopancreas (Biosecurity Australia 2009). Infection with RLOs, however, can occur in healthy crustaceans or in diseased shrimp that are co-infected with viruses and other disease agents (Anderson *et al.* 1987). It has been suggested that RLOs are ubiquitous in the environment, but only cause disease when poor nutritional and environmental conditions interact to increase pathogenicity (Vogt and Strus 1998).

Nunan *et al.* (2003) innoculated penaeid shrimp (*P. vannamei*) with an RLO (not *H. penaei*) from *P. monodon* resulting in 97 % mortality. In contrast, oral exposure did not transmit the RLO. The relationship between RLOs in penaeids and other crustaceans remains unknown (Biosecurity Australia 2009).

M. rosenbergii and *P. pelagicus* are the only New Zealand species that have been identified as susceptible to exotic RLOs.

17.1.5 Hazard identification conclusion

RLOs have been identified as causing mortality in crustaceans and are identified as a hazard.

17.2 RISK ASSESSMENT

17.2.1 Entry assessment

A RLO infecting the spot prawn (*Pandalus platyceros*) was shown to retain infectivity for at least 10 days after being frozen at - 10 °C (Bower *et al.* 1996). Another RLO was found to be infectious following freezing in prawn tissue at - 70 °C (Brock *et al.* 1986). Nunan *et al.* (2003) found that infection with a RLO frozen to -70 ºC was only possible via injection and not *per-os*.

Commercial freezing typically occurs at - 18 °C (Diggles 2011).

The likelihood of entry of exotic RLOs is assessed to be non-negligible.

17.2.2 Exposure assessment

Crustaceans imported for human consumption can be imported in bulk; heads and tail-on, for further processing (value added) or direct distribution for retail sale to markets, restaurants and supermarkets in New Zealand. The commodities include, prawns, crayfish, scampi, lobster (as lobster tails) and crabs.

It is expected that the majority of fluids derived from chilling, freezing, defrosting, processing and transport of bulk commodities are to be discarded into municipal sewage systems at the point of retail. Processing of raw entire crustaceans (i.e. heads and tails on prawns) by importers and distributors is assumed to be limited as sale of raw unprocessed crustaceans (especially prawns) is common (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018). The majority of head, shell and gut removal is likely to occur within households or trade businesses (i.e. restaurants). The waste generated in this fashion is likely to be disposed of in municipal sewage systems or to municipal landfill. The Food Regulations (New Zealand Government 2015) provide details of what waste disposal requirements restaurants and other retail businesses subject to food control plans need to follow. Waste that was directed to a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the number of bacteria present and any remaining viable bacteria would be diluted within the wastewater (Biosecurity Australia 2009). This rationale is consistent with, and the basis for, the requirements for water treatment and disposal in MPI's transitional facilities standard for ornamental fish (MPI 2017). Similarly, all waste water from live imported freshwater prawns held in a transitional facility is treated according to this standard (MPI 2007).

Growth in the seafood import market may result in importers adding value to products (i.e. by removing heads, shells and gut) and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of exposure of wild or cultured crustaceans to imported crustacean waste products disposed to landfill or municipal sewage systems is assessed to be negligible.

An undefined yet likely small proportion of crustaceans imported for human consumption may be used as fishing bait (Blackwell 2013). The use of crustaceans especially shrimp as bait is likely to occur (Diggles 2011) and circumstantial evidence of its use in New Zealand has been identified online (The Fishing Website 2015). The use of frozen shrimp as bait may be associated with the relative low cost and ease of purchase compared to other types of fishing bait (Diggles 2011; Bateman *et al.* 2012). It is assumed that a significant portion of crustaceans used as bait in the marine environment would be consumed by non-susceptible host species, particularly finfish (Biosecurity Australia 2009). Crabs and lobster are known scavengers they could be exposed to bait not consumed by non-susceptible host species. However, the likelihood of exposure, transmission and spread among wild crustacean populations is also expected to be low based on the lower population densities and absence of stressful conditions typically encountered by cultured crustaceans (Walker and Mohan 2009; Department of Agriculture 2013).

Currently, only one New Zealand species of wild crustacean (*P. pelagicus*) has been identified as susceptible to an exotic RLOs. The other identified species (*M. rosenbergii*) is cultured at a single aquaculture site and is restricted in its distribution as it survives in geothermally heated water from the Waikato River.

It is extremely rare to find adult *P. pelagicus* occurring in New Zealand with only larvae being found off eastern Northland (Te Papa 2014). *M. rosenbergii* is cultured at a single aquaculture site and is restricted in its distribution as it survives in geothermally heated water from the Waikato River. The sole pathway for exposure is through feeding *M. rosenbergii* infected crustaceans that are intended for human consumption. It is unlikely that the farm operators would buy imported prawns destined for human consumption and subsequently feed these to their stock. This is a well-known exposure pathway for many crustacean pathogens that would endanger their stock and their livelihoods and is considered to be contrary to best aquaculture biosecurity practice (Georgiades *et al.* 2016).

Adult *P. pelagicus* are rarely found occurring in New Zealand and *M. rosenbergii* is cultured by a single company at one location, therefore, the likelihood of exposure of these two species to imported crustaceans via the bait pathway is assessed to be negligible.

For other crustacean present in New Zealand there are a number of factors that in addition to the low volume of bait expected to be used and likely consumption of by non-crustacean species (e.g. finfish), which would reduce the likelihood of exposure to RLOs:

- the prevalence of infection in imported crustaceans would be expected to be low;
- host specificity of exotic RLOs is not well characterised in the scientific literature with only RLOs from penaeid shrimps being shown to infect other species of penaeids (Brock *et al.* 1986; Nunan *et al.* 2003). These species are not present in New Zealand; and,
- Infectivity may be reduced in frozen crustaceans which are the main bait type in use (Diggles 2011), as Nunan *et al.* (2003) found that infection of a RLO frozen to -70 ºC was only possible via injection and not *per-os* exposure.

Considering all of the above these factors together, the likelihood of exposure is assessed to be negligible.

17.2.3 Risk estimation

The likelihood of exposure is assessed to be negligible, therefore the risk is estimated to be negligible.

RLOs are assessed not to be a risk in the commodity.

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18 Rickettsia-like organism causing milky haemolymph syndrome

18.1 HAZARD IDENTIFICATION

18.1.1 Aetiological agent

Milky haemolymph disease of spiny lobster (MHD-SL) is caused by a rickettsia-like organism (RLO), which has been isolated but not named (Nunan *et al.* 2010). Rickettsia-like organisms are obligate intracellular alpha-proteobacteria (Weinert 2015). They differ from extracellular bacteria due to the absence of a true bacterial wall (Wang 2011). The agent identified is likely to represent a species within a new genus (Lightner *et al.* 2008).

18.1.2 OIE list

MHD-SL was considered by the OIE as a disease 'under study' due to it briefly threatening the spiny lobster aquaculture industry in Vietnam (OIE 2009). The 'under study' classification has since been removed and MHD-SL is no longer listed by the OIE.

18.1.3 New Zealand status

Following a review of the literature, milky haemolymph disease of spiny lobsters has not been reported from the New Zealand aquatic environment.

18.1.4 Epidemiology

MHD-SL caused by a rickettsia-like organism affects species belonging to the genus *Panulirus* from Vietnam. MHD-SL was first identified in 2006, and in 2007 the economic cost of infection was estimated to be USD$ 23 million (Hung and Tuan 2009).

Gross signs of MHD-SL infection in spiny lobsters include: a swollen abdomen, milky haemolymph exuding from wounds which may not clot, white hypertrophied connective tissues of all major organs and tissues, lethargy and a cessation of feeding. The progression of infection is rapid with milky haemolymph and swollen abdomens being observed 3 to 5 days after individuals become lethargic and cease feeding. Mortalities of ≤ 30 % occur soon after clinical signs are observed (Lightner *et al.* 2008; Hung and Tuan 2009).

It is assumed that horizontal transmission occurs by direct contact or contact with contaminated water. Experimentally, the disease has been transmitted by cohabitation and injection of milky haemolymph into healthy spiny lobsters (Lightner *et al.* 2008).

Similar diseases have been observed in the shrimp (*Penaeus monodon*) and shore crab (*Carcinus maenas*). The RLOs responsible for infection in each of these species are distinct (Nunan *et al.* 2010).

Since the initial outbreak of MHD-SL in Vietnam, the disease has been effectively controlled via the use of antibiotics (OIE 2007).

18.1.5 Hazard identification conclusion

An unnamed RLO has been identified as causing mortality in spiny lobsters.

The RLO that causes MHD-SL is identified as a hazard in the commodity.

18.2 RISK ASSESSMENT

18.2.1 Entry assessment

MHD-SL has only been identified from spiny lobsters from Vietnam. Disease progression is rapid (3 to 5 days) and can be controlled by antibiotic treatment. Therefore, the likelihood of entry is assessed to be negligible.

18.2.2 Exposure assessment

The likelihood of entry is assessed to be negligible, therefore the risk is estimated to be negligible.

RLO causing MHD-SL is assessed not to be a risk in the commodity.

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19 *Acremonium* spp. and *Plectosporium oratosquillae*

19.1 HAZARD IDENTIFICATION

19.1.1 Aetiological agent

There are approximately 95 identified fungal species belonging to the genus *Acremonium*. These organisms are some of the most simply structured of all filamentous anamorphic fungi (Summerbell *et al.* 2011).

Plectosporium oratosquillae is an obligate marine fungus belonging to the phylum Ascomycota and is the first *Plectosporium* species detected from the marine environment (Duc *et al.* 2009).

19.1.2 OIE list

Acremonium spp. and *P. oratosquillae* are not OIE listed.

19.1.3 New Zealand status

There are a number of *Acremonium* spp. found in terrestrial (Siegel *et al.* 1985) and marine environments in New Zealand (Mahyudin 2008). There have been no reports of infection occurring in crustaceans attributed to *Acremonium* spp.

Following a review of the literature, *P. oratosquillae* has not been reported from the New Zealand aquatic environment.

19.1.4 Epidemiology

A black gill disease has been reported as causing mortalities in Japanese mantis shrimp (*Oratosquilla oratoria*) since the 1980s. The incidence of disease has increased throughout the Pacific coast of Japan (Duc *et al.* 2009).

Duc *et al.* (2009) sampled *O. oratoria* showing signs of gill lesions from the Yamaguchi and Aichi Prefectures of Japan and isolated the fungi *Acremonium* spp. and *P. oratosquillae* (Duc *et al.* 2010). In some *O. oratoria* they were co-infected with both fungal species. The level of mortality was not reported and for wild *O. oratoria* it is unknown.

Duc and Hatai (2009) injected *O. oratoria* with *Acremonium* spp. or *P. oratosquillae* at a high dose (5.0×10^6 conidia/mL) and a low dose (5.0×10^4 conidia/mL). *O. oratoria* infected with *P. oratosquillae* suffered a cumulative mortality of 100 % (high dose) and 60 % (low dose) at day 25, respectively. For *O. oratoria* infected with *Acremonium* spp., a cumulative mortality of 100 % (high dose) and 80 % (low dose) occurred after day 25, respectively.

Gross clinical signs in naturally infected *O. oratoria* are brown or black discolouration on the gills due to melanisation, and disappearance due to deliquescence (Duc *et al.* 2009). These signs of infection were replicated in *O. oratoria* experimentally injected with each fungi (Duc and Hatai 2009).

Histopathological examination of experimentally infected *O. oratoria* showed a number of hyphae of both fungi species in the gill filaments 7 days after inoculation. Encapsulated hyphae were observed in the gills and their base. Further, hyphae were observed in the heart. No fungi, however, were found in internal organs, which suggests (Duc and Hatai 2009) that both species are parasitic to the circulatory system of *O. oratoria*.

O. oratoria infected with these two fungi have been found from temperate zones of Japan (water temperature of Tokyo Bay ranges from 12 to 22 ºC; Duc *et al.* 2009).

Kuruma prawn (*Penaeus japonicus*) have also suffered mortalities after being experimentally injected with either fungus (Duc *et al.* 2010).

Of the 2,284 *O. oratoria* sampled in Japan 25 % were infected with either or both fungi (Duc and Hatai 2009).

Freshwater crayfish (*Astacus leptodactylus*) from Egirdir Lake in Turkey have been found to be infected with *Acremonium* spp. Signs of infection included: swollen, pale and bilateral lesions on the thorax and melanised spots on the gills (Diler and Bolat 2001). The authors considered *Acremonium* spp. to be an opportunistic pathogen and no mortalities were attributed to this fungal species.

In New Zealand *O. oratoria* is a recently established species and is the only crustacean known to be susceptible to infection with either fungus (Ahyong 2010). There are estimated to be fewer than 20 native mantis shrimp species in New Zealand (Webber *et al.* 2010). It is not known if New Zealand freshwater crayfish are susceptible to infection with *Acremonium* spp. from *Astacus leptodactylus*.

19.1.5 Hazard identification conclusion

Infection with *Acremonium* spp. or *P. oratosquillae* has caused mortalities in experimentally infected *O. oratoria*.

Acremonium spp. and *P. oratosquillae* are identified as hazards in the commodity.

19.2 RISK ASSESSMENT

19.2.1 Entry assessment

The degree of melanisation on the external gills of *O. oratoria* and *A. leptodactylus* may determine their commercial value, with heavily infected individuals less likely to pass visual inspection. Despite this, there is likely to be an undefined portion of *O. oratoria* and *A. leptodactylus* that are in the early stages of infection and do not display gross signs of infection.

The likelihood of entry is assessed to be non-negligible.

19.2.2 Exposure assessment

Crustaceans imported for human consumption can be imported in bulk; heads and tail-on, for further processing (value added) or direct distribution for retail sale to markets, restaurants and supermarkets in New Zealand. The commodities include, prawns, crayfish, scampi, lobster (as lobster tails) and crabs.

It is expected that the majority of fluids derived from chilling, freezing, defrosting, processing and transport of bulk commodities are to be discarded into municipal sewage systems at the point of retail. Processing of raw entire crustaceans (i.e. heads and tails on prawns) by importers and distributors is assumed to be limited as sale of raw unprocessed crustaceans (especially prawns) is common (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018). The majority of head, shell and gut removal is likely to occur within households or trade businesses (i.e. restaurants). The waste generated in this fashion is likely to be disposed of in municipal sewage systems or to municipal landfill. The Food Regulations (New Zealand Government 2015) provide details of what waste disposal requirements restaurants and other retail businesses subject to food control plans need to follow. Waste that was directed to a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the number of pathogen present and any remaining viable pathogen would be diluted within the wastewater (Biosecurity Australia 2009). This rationale is consistent with, and the basis for, the requirements for water treatment and disposal in MPI's transitional facilities standard for ornamental fish (MPI 2017). Similarly, all waste water from live imported freshwater prawns held in a transitional facility is treated according to this standard (MPI 2007).

Growth in the seafood import market may result in importers adding value to products (i.e. by removing heads, shells and gut) and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of exposure of wild or cultured crustaceans to imported crustacean waste products disposed to landfill or municipal sewage systems is assessed to be negligible.

An undefined yet likely small proportion of crustaceans imported for human consumption may be used as fishing bait (Blackwell 2013). The use of crustaceans especially shrimp as bait is likely to occur (Diggles 2011) and circumstantial evidence of its use in New Zealand has been identified online (The

Fishing Website 2015). The use of frozen shrimp as bait may be associated with the relative low cost and ease of purchase compared to other types of fishing bait (Diggles 2011; Bateman *et al.* 2012).

It would be expected that the majority of *O. oratoria* and *A. leptodactylus* used as bait would be consumed by non-susceptible species, particularly finfish (Biosecurity Australia 2009). Further, the likelihood of exposure, transmission and spread among wild crustacean populations is also expected to be low based on the lower population densities and absence of stressful conditions typically encountered by cultured crustaceans (Walker and Mohan 2009; Department of Agriculture 2013).

As the volume of infected *O. oratoria* and *A. leptodactylus* used as bait would be expected to be very low and the majority of bait would be consumed by non-susceptible species the likelihood of exposure to *Acremonium* spp. and *P. oratosquillae* via bait is assessed to be negligible.

19.2.3 Risk estimation

The likelihood of exposure is assessed to be negligible, therefore the risk is estimated to be negligible.

Acremonium spp. and *P. oratosquillae* are assessed not to be a risk in the commodity.

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20 *Aphanomyces astaci*

20.1 HAZARD IDENTIFICATION

20.1.1 Aetiological agent

Aphanomyces astaci is a fungi belonging to the genus *Aphanomyces* and order Saprolegniales. *A. astaci* is the causative agent of crayfish plague.

20.1.2 OIE list

Crayfish plague (*Aphanomyces astaci*) is an OIE listed disease (OIE 2015).

20.1.3 New Zealand status

Following a review of the literature, *Aphanomyces astaci* has not been reported from the New Zealand aquatic environment.

20.1.4 Epidemiology

Crayfish plague is the most serious disease of freshwater crayfish. To date all species investigated are susceptible to infection. Freshwater crayfish species native to Europe, Asia and Australia are especially vulnerable to infection. North American species appear to have a more balanced host-parasite relationship, which rarely results in mortalities, suggesting that they have co-evolved (Alderman 1996). In susceptible crayfish populations, mortality is usually 100 % and all life-stages are likely to be susceptible to infection (OIE 2015). Other freshwater crustaceans recently been identified as hosts of *A. astaci*, include: the Chinese mitten crab (*Eriocheir sinensis*), the freshwater shrimp (*Macrobrachium dayanum*) and the semi-terrestrial crab (*Potamon potamios*) (Schrimpf *et al.* 2014; Svoboda *et al.* 2014a, b). It is likely that additional freshwater decapods will be identified as hosts.

For part of its life-cycle *A. astaci* exists as a free-swimming biflagellate zoospore that is chemotactically attracted to crayfish cuticle (Cerenius and Söderhall, 1984). The zoospore attaches to the cuticle of crayfish and grows vegetative hyphae that extend into the body cavity. In freshwater crayfish not native to North America, this growth causes the infected individual to die within a few days (Unestam and Weiss 1970). North American crayfish species have a naturally evolved resistance to *A. astaci* and only die from infection when stressed (Söderhall and Cerenius 1992). In un-stressed individuals, melanin is produced when infection occurs and it is deposited in the hyphae, which prevents further growth into the body cavity. However, *A. astaci* can still survive and produce free swimming biflagellate zoospores thus enabling it to complete its life-cycle. The free-swimming biflagellate zoospores have the ability to survive for prolonged periods outside a host by transforming from a zoospore to a cyst and back again multiple times. This process is called ‘repeated zoospore emergence’ and allows *A. astaci* to maintain viability outside the host for up to several weeks (Cerenius and Söderhall 1985).

Field observations show that *A. astaci* can cause outbreaks of disease at water temperatures between 4 to 20 °C. At lower temperatures mortalities within a population occur at a slower rate (months) compared to outbreaks in warmer water (OIE 2015).

There are multiple strains of *A. astaci* and growth patterns are both temperature and strain specific (Dieguez-Uribeondo *et al.* 1995). Different strains have different virulences (Makkonen *et al.* 2012).

Gross clinical signs are variable and depend on the strain of *A. astaci* and water temperature. For most populations of crayfish the first sign of infection is usually the presence of dead individuals. For populations that are monitored, early signs of infection include diurnal activity and individuals may be observed on their back unable to right themselves (OIE 2015). Once a new population of freshwater crayfish is infected, a wave of mortality will rapidly spread downstream from the source infection. Upstream spread is a lot slower as it is dependent on the movement of infected individuals rather than the downstream movement of free-living zoospores (OIE 2015).

Oral infection through the consumption of infected crayfish tissue can occur and it has been found that *A. astaci* can remain infectious in non-viable tissue for at least three days (Oidtmann *et al.* 2002).

The main pathways for introduction of *A. astaci* to naïve crayfish populations is through the movement of infected individuals by humans, movement of spores with contaminated water or equipment, and through the natural secondary spread of invasive resistant host species (e.g. North American crayfish, Chinese mitten crab) once introduced to a new area (OIE 2015; Schrimpf *et al.* 2014).

A. astaci can be inactivated through heating to 60 °C or freezing at - 20 °C for 72 hours (Oidtmann *et al*. 2002; OIE 2015).

20.1.5 Hazard identification conclusion

A. astaci is the most significant pathogen of freshwater crayfish. Mortality can reach 100 % in naïve populations of crayfish. North American crayfish species can be lifelong carriers of infection and display no specific gross clinical signs.

A. astaci is identified as a hazard in freshwater crayfish.

20.2 RISK ASSESSMENT

20.2.1 Entry assessment

A study investigating the survival of *A. astaci* from artificially infected narrow-clawed crayfish (*Astacus leptodactylus*) frozen at - 20 °C found that no viable fungi could be recovered after three hours (Alderman 2000). Oidtmann *et al.* (2002) were able to cultivate *A. astaci* from naturally infected noble crayfish (*Astacus astacus*) that had been frozen for 48 hours at - 20 °C, however, after 72 hours no viable *A. astaci* was found.

Frozen freshwater decapods imported into New Zealand will be frozen for > 72 hours, therefore, the likelihood of entry via frozen crayfish is assessed to be negligible.

A. astaci was found to remain viable in agar plates for at least 14 days when stored at temperatures of - 5, 0 and 5 °C (Oidtmann *et al.* 2002).

As freshwater crayfish may also be imported chilled, the likelihood of entry is assessed to be non-negligible.

20.2.2 Exposure assessment

The majority of imported freshwater decapods intended for human consumption would be expected to be consumed by humans, with associated waste being disposed of at a landfill or in a municipal sewage system. An undefined amount of crustacean products intended for human consumption could be used as fishing bait.

New Zealand has two endemic freshwater crayfish species (*Paranephrops planifrons* and *P. zealandicus*) and one native species of freshwater crab (*Amarinus lacustris*). These species are found in both freshwater rivers and lakes (Whitmore *et al.* 2000; Bruce and MacDiarmid 2012).

It is expected that the majority of fluids derived from chilling, freezing, defrosting, processing and transport of bulk commodities are to be discarded into municipal sewage systems at the point of retail. Processing of raw entire crustaceans (i.e. heads and tails on prawns) by importers and distributors is assumed to be limited as sale of raw unprocessed crustaceans (especially prawns) is common (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018). The majority of head, shell and gut removal is likely to occur within households or trade businesses (i.e. restaurants). The waste generated in this fashion is likely to be disposed of in municipal sewage systems or to municipal landfill. The Food Regulations (New Zealand Government 2015) provide details of what waste disposal requirements restaurants and other retail businesses subject to food control plans need to follow. Waste that was directed to a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the amount of pathogen present and any remaining viable pathogen would be diluted within the wastewater (Biosecurity Australia 2009). This rationale is consistent with, and the basis for, the requirements for water treatment and disposal in MPI's transitional facilities standard for ornamental fish (MPI 2017). Similarly, all waste water from live imported freshwater prawns held in a transitional facility is treated according to this standard (MPI 2007).

Growth in the seafood import market may result in importers adding value to products (i.e. by removing heads, shells and gut) and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

An undefined yet likely small proportion of chilled freshwater crustaceans imported for human consumption may be used as fishing bait (Blackwell 2013). The use of freshwater crustaceans as bait (especially shrimp) is likely to occur (Diggles 2011) and circumstantial evidence of their use has been identified online (Fishing News 2014; New Zealand Fishing 2016).

It would be expected that a small quantity of chilled freshwater crustaceans used as bait would be exposed to freshwater environments. The likelihood of exposure, transmission and spread among wild crustacean populations is also expected to be low based on the lower population densities and absence of stressful conditions typically encountered by cultured crustaceans (Walker and Mohan 2009; Department of Agriculture 2013). However, freshwater crustaceans are opportunistic omnivores they could be exposed to bait not consumed by non-susceptible host species, the minimum infectious dose may be as small as a single spore (OIE 2015) and *A. astaci* may maintain viability outside the host for up to several weeks (Cerenius and Söderhall 1985). The entry of chilled freshwater decapods into freshwater environments or contaminated waste water may facilitate the release of free-swimming biflagellate zoospores. These zoospores can remain viable outside their host for several weeks and are chemotactically attracted to crayfish cuticle. Therefore likelihood of exposure via the waste and bait pathway is assessed to be non-negligible.

20.2.3 Consequence assessment

The introduction of *A. astaci* to a naïve population can result in a disease outbreak causing mortality rates that may reach 100 % (OIE 2015).

High rates of mortality would be expected to occur in New Zealand freshwater crayfish species. In wild populations after the initial disease outbreak, *A. astaci* may be able to persist in the environment due to the presence of resistant host species (e.g. freshwater crabs), with outbreaks re-emerging when the freshwater crayfish population subsequently increases in density. This situation occurs in Europe where introduced American crayfish can be persistently infected and continually transmit *A. astaci* to native crayfish.

The endemic freshwater crayfish (*P. zealandicus* and *P. planifrons)* is currently subject to landbased culture with relatively small volumes being produced. It is predicted that significant growth in production will occur to meet demand (McKenna 2008). Freshwater crayfish culture sites have been established in the South Island (near Blenheim, Alexandra and Kaikoura; Enslow One Ltd. 2016).

Ecologically, freshwater crayfish are an important component of freshwater habitats. They are considered ecosystem engineers, as they modify substrate through bioturbation and influence the distribution of benthic invertebrates by predation (Kusabs *et al.* 2015). They also consume stream detritus and increase its rate of decay (Parkyn *et al.* 1997). Freshwater crayfish, collectively known as kōura by Māori, were an important food source and today are considered a ‘taonga’ or ‘heritage’ species. In some locations these species support important customary fisheries (Kusabs *et al.* 2015).

There are no human health effects associated with *A. astaci*.

The consequences are assessed to be non-negligible.

20.2.4 Risk estimation

The likelihood of entry and exposure, and the consequences are assessed to be non-negligible, therefore the risk is estimated to be non-negligible.

A. astaci is assessed to be a risk in the commodity.

20.3 RISK MANAGEMENT

20.3.1 Options

The *Code* chapter for crayfish plague states that the disease status of a country, zone or compartment can be determined after considering the criteria listed in Articles 9.2.4, 9.2.5 and 9.2.6.

The *Code* sets out recommendations that allow for a country, zone or compartment to be considered free from crayfish plague provided one of the following conditions are met:

- no susceptible species have been present in the country, zone or compartment and basic biosecurity conditions have been continuously met for at least the last two years, or
- there has been no observed occurrence of the disease for at least the last 25 years despite conditions that are conducive to its clinical expression and basic biosecurity conditions have been continuously met for at least the last ten years, or
- basic biosecurity conditions have been continuously met for at least the last ten years and targeted surveillance has been in place for at least the last five years without the detection of crayfish plague.

The *Code* also provides guidance on how to regain a disease free status after an outbreak has occurred in a country, compartment or zone.

The *Code* gives recommendations for the importation of susceptible species intended for human consumption from a country, zone or compartment *not* declared free from crayfish plague in Article 9.2.11. This includes the recommendation that *no conditions* be applied to listed commodities that are prepared and packaged for human consumption. Despite this recommendation the *Code* does not list any safe commodities.

For the importation of freshwater crustaceans for human consumption, one or a combination of, the following options could be considered to effectively manage the risk:

Option 1

Freshwater crustaceans could be imported only from countries, zones or compartments that have been officially recognised by the OIE as being designated free from crayfish plague (Article 9.2.7).

Option 2

The following freshwater crustacean products could be imported from countries, zones or compartments where crayfish plague *is* present (Article 9.2.3):

a) heat sterilised hermetically sealed crayfish products (i.e. a heat treatment at 121 °C for at least 3.6 minutes or any time/temperature equivalent that has been demonstrated to inactivate *A. astaci*);
b) cooked crayfish products that have been subjected to heat treatment at 100 °C for at least one minute (or any time/temperature equivalent that has been demonstrated to inactivate *A. astaci*);
c) pasteurised crayfish products that have been subjected to heat treatment at 90 °C for at least ten minutes (or any time/temperature equivalent that has been demonstrated to inactivate *A. astaci*);
d) frozen crayfish products that have been subjected to minus 20 °C or lower temperatures for at least 72 hours;
e) crayfish oil;
f) crayfish meal;
g) chemically extracted chitin.

Option 3

Freshwater crustacean products could be imported from areas where *A. astaci* is present provided it is prepared and packaged for retail trade for human consumption (Article 9.2.11) *and* the associated packaging is clearly marked with the words "*for human consumption only, not to be used as bait or feed for aquatic animals.*"

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21 *Halocrusticida* spp.

21.1 HAZARD IDENTIFICATION

21.1.1 Aetiological agent

Halocrusticida spp. are marine fungi that belong to the order Lagenidiales (Hatai 2012).

21.1.2 OIE list

Halocrusticida spp. are not associated with an OIE listed disease.

21.1.3 New Zealand status

Following a review of the literature, *Halocrusticida* spp. have not been reported from the New Zealand aquatic environment.

21.1.4 Epidemiology

Halocrusticida spp. are opportunistic marine fungi which have been isolated from the eggs and zoeal larvae of *S. serrata* (Bian and Egusa 1980; Roza and Hatai 1999).

Infected eggs are filled with hyphae that emerge from the egg to form discharge tubes. Motile zoospores are then produced and released into the environment, infecting other eggs (Bian and Egusa 1980). Zoea larvae normally appear transparent, but infected individuals appear white in colour, with all dead zoeae being filled with aseptate stout hyphae (Hatai *et al.* 2000).

The rate of mortality in eggs and zoeal larvae can approach 100 % (Bian and Egusa 1980; Hatai *et al.* 2000). Roza and Hatai (1999) found that the mortality rate of *S. serrata* was positively correlated to the number of zoospores the zoea larvae were exposed to. Mortality was also highest in stage 1 zoea larvae and lowest in stage 4 zoea larvae.

There are no reports to indicate that *Halocrusticida* spp. infect adult *S. serrata*, other than the eggs associated with berried females.

21.1.5 Hazard identification conclusion

Halocrusticida spp. are fungi which infect *S. serrata* eggs and zoea larvae causing mortality. These fungi do not infect adult female crabs directly except for their eggs.

Halocrusticida spp. are identified as a hazard in the commodity.

21.2 RISK ASSESSMENT

21.2.1 Entry assessment

Ovigerous *S. serrata* obtain low prices when sold for human consumption (FAO 2016). It would be expected that some eggs would be infected with *Halocrusticida* spp.

The likelihood of entry is assessed to be non-negligible.

21.2.2 Exposure assessment

The only known host of *Halocrusticida* spp. is *S. serrata* and the majority imported would be expected to be consumed by humans, with associated waste being disposed of at a landfill or in a municipal sewage system.

It is expected that the majority of fluids derived from chilling, freezing, defrosting, processing and transport of bulk commodities are to be discarded into municipal sewage systems at the point of retail. Processing of raw entire crustaceans (i.e. heads and tails on prawns) by importers and distributors is assumed to be limited as sale of raw unprocessed crustaceans (especially prawns) is common (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018). The majority of head, shell and gut removal is likely to occur within households or trade

businesses (i.e. restaurants). The waste generated in this fashion is likely to be disposed of in municipal sewage systems or to municipal landfill. The Food Regulations (New Zealand Government 2015) provide details of what waste disposal requirements restaurants and other retail businesses subject to food control plans need to follow. Waste that was directed to a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the amount of pathogen present and any remaining viable pathogen would be diluted within the wastewater (Biosecurity Australia 2009). This rationale is consistent with, and the basis for, the requirements for water treatment and disposal in MPI's transitional facilities standard for ornamental fish (MPI 2017). Similarly, all waste water from live imported freshwater prawns held in a transitional facility is treated according to this standard (MPI 2007).

The likelihood of exposure of wild *S. serrata* to imported crustacean waste products disposed to landfill or municipal sewage systems is assessed to be negligible.

Imported *S. serrata* for human consumption is a high value product (~AUD$ 39 per kilogram; Mud crabs direct 2016) and it would be expected that a very small proportion would be used as fishing bait. Further, there is an abundance of locally sourced paddle crabs (*Ovalipes catharus*) that can be used as bait (The Fishing Website 2016). Currently only one New Zealand species of crustacean (*S. serrata*) is known to be susceptible to infection with *Halocrusticida* spp. *S. serrata* is seldom seen in New Zealand and individuals have only been caught from the top half of the North Island (Dell 1964). It is not known whether *S. serrata* reproduce in New Zealand and exist at a low population density, or if individuals survive and do not reproduce due to unfavourable environmental conditions after drifting on currents as larvae from Australia, or are transported either as ballast water or biofouling (Te Papa 2014). It would be expected that a significant portion of *S. serrata* if used as bait in the marine environment would be consumed by non-susceptible host species, particularly finfish (Biosecurity Australia 2009). Further, the likelihood of exposure, transmission and spread among wild crustacean populations is also expected to be low based on the lower population densities and absence of stressful conditions typically encountered by cultured crustaceans (Walker and Mohan 2009; Department of Agriculture 2013).

Due to *S. serrata* being seldom observed in New Zealand waters the likelihood that an individual would be exposed to an infected imported individual used as fish bait is assessed to be negligible.

21.2.3 Risk estimation

The likelihood of exposure is assessed to be negligible, therefore the risk is estimated to be negligible.

Halocrusticida spp. is assessed not to be a risk in the commodity.

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22 Exotic apostome ciliates

22.1 HAZARD IDENTIFICATION

22.1.1 Aetiological agent

Apostome ciliates are protozoan organisms belonging to the phylum Chiliphora. Ciliates are distinguished by three major features; the presence of cilia for locomotion, nuclear dimorphism and reproduction through conjugation (Lynn 2008). Species belonging to the genus *Collinia* are considered capable of producing significant mortalities (Morado and Small 1995).

22.1.2 OIE list

Disease caused by apostome ciliates are not OIE listed.

22.1.3 New Zealand status

Following a review of the literature, apostome ciliates are present in New Zealand, however, some pathogenic species have not been identified from the New Zealand aquatic environment.

22.1.4 Epidemiology

In the early 2000s a mass mortality event in three species of euphausiids (*Euphausia pacifica*, *Thysanoessa spinifera*, and *T. gregaria*) occurred off the Oregon coast of the United States. Gomez-Gutierrez *et al.* (2006) identified the causative agent as the parasitoid ciliate *Collinia oregonensis*.

Uninfected euphausiids have semi-transparent organs that are visible in the cephalothorax and abdomen. Under laboratory conditions, Gomez-Gutierrez *et al.* (2006) observed that in the early stages of infection euphausiids turn yellow in colour and display a swollen carapace with 12-24 hours. These changes are due to the large number of motile trophonts present in the cephalothorax. As the trophonts increase in size and number, the cephalothorax swells and changes colour from pale white to bright orange. As infection progresses to an advanced stage, all organs are replaced by the ciliate. As the mature trophont increases in cell volume it reaches its reproductive stage (tomont) where it divides by palintomy to form a non-feeding, free-living life-stage (tomite). The increase in the number of tomites may cause a rupturing at the cephalothorax-abdomen junction, killing the host and releasing the tomites into the water column. Under laboratory conditions the rupturing of infected individuals was observed to occur approximately 2 days after visual signs of infection. In 15 % of infections, rupturing does not occur with tomites only exiting the exoskeleton once the entire host has been consumed (Gomez-Gutierrez *et al.* 2006). It is assumed that the free-living tomite completes the life-cycle by locating the exoskeleton of a new host to encyst as a phoront. In the field it is only possible to visually identity infected individuals late in the parasitoid's life-cycle (i.e. orange and swollen carapace; Gomez-Gutierrez *et al.* 2006).

Drivers of mortality in euphausiids are poorly understood. Euphausiids are a key prey species for a number of marine predators (e.g. whales, penguins), however, the ecological impact of epizootics caused by apostome ciliates including *Collinia* species is not well understood.

Endoparasitoid ciliates from the genus *Collinia* are considered the most virulent of all apostome ciliates. To maintain a stable parasitoid-host relationship it is likely that members of this genus need to be able to infect more than one species (Gomez-Gutierrez *et al.* 2006).

Synophrya hypertrophica is example of another apostome ciliate that was previously considered pathogenic, infecting the gills of crabs belonging to the genus *Macropipus* and genus *Ovalipes* (Morado and Small 1995). Infection in adult crabs is limited to the gills while, infection of the carapace may occur in post-larval juvenile crabs (Johnson and Bradbury 1976). An intense host response may occur causing melanisation of large areas of the gills. Because of this host reaction it was previously thought that *S. hypertrophica* was an important pathogen of crabs (Johnson and Bradbury 1976). It has since been found that heavy infection does not induce mortality and it is essentially benign even though large areas of gills may be infected (Johnson and Bradbury 1976; Haefner and Spacher 1985).

22.1.5 Hazard identification conclusion

Infection with *C. orgonensis* results in mortality as the parasitoid must kill its euphausiid host in order to fulfil its life-cycle.

C. orgonensis is identified as a hazard in the commodity.

Infection with *S. hypertrophica* does not cause mortality in host crab species. Infection is now recognised to be benign.

S. hypertrophica it is not identified as a hazard in the commodity.

22.2 RISK ASSESSMENT

22.2.1 Entry assessment

Under laboratory conditions, the average time between early stage *C. orgonensis* infection of *Euphausia pacifica* to death was 41 hours, for individuals that ruptured, and 77 hours, for those that did not (Gomez-Gutierrez *et al.* 2006). The progression of disease appears to be relatively rapid reducing the likelihood of infected individuals being caught. However, due to the swarming nature of euphausiids and the occasionally high prevalence of infection (range 0-100 %), it is likely that within an infected swarm a portion of the population may be infected at any one time.

Euphausiids are required to be processed (cooked or frozen) within 1 to 3 hours after capture due to rapid enzymatic breakdown. This process renders *C. orgonensis* non-viable (FAO 1997; 2016).

As euphausiids are processed soon after capture, the likelihood of entry is assessed to be negligible.

22.2.2 Risk estimation

The likelihood of entry is assessed to be negligible, therefore, the risk is estimated to be negligible.

C. orgonensis is assessed not to be a risk in the commodity.

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23 Exotic holotrich ciliates

23.1 HAZARD IDENTIFICATION

23.1.1 Aetiological agent

Holotrich ciliates belong to the class Oligohymenophorea, and family Orchitophryidae and consist of two closely related genera *Mesanophrys* (= *Paranophrys* = *Anophrys*) spp. and *Mugardia* (= *Paranophrys* = *Anophrys*) spp. (Bower 2006a).

The taxonomy of holotrich ciliates infecting crustaceans is uncertain (Morado and Small 1994; Song and Wilbert 2000; Paramá *et al*. 2006).

23.1.2 OIE list

Diseases caused by holotrich ciliate infections are not OIE listed.

23.1.3 New Zealand status

Mesanophrys carcini has been reported in New Zealand and associated with rotifer mortality (Smith *et al.* 2009). This species has been identified as a pathogen of the crab (*Cancer pagurus*) in the Northern Hemisphere (Bower 1996b).

23.1.4 Epidemiology

Infections with holotrich ciliates have been identified in many crustacean species (Morado and Small 1995; Bower 1996a; Bower 1996c*;* Longshaw 2011).

The route of infection is not well described and appears to occur opportunistically via the exoskeleton either after moulting or due to mechanical injury. The ciliate can then multiply and spread via the haemolymph resulting in a systemic infection that can cause death. In cultured populations 100 % mortality has been recorded (Bower 1997). It is unlikely that oral infection occurs as Morado *et al.* (1999) found a higher rate of infection in wild crabs (*Cancer magister*) that had recently moulted. Mortality can be rapid with experimentally infected *C. magister* dying after two weeks (Morado and Small 1995). Due to the uncertain taxonomy of holotrich ciliates host specificity is not described (Morado and Small 1995).

Gross signs of infection include lethargy and turbid haemolymph that does not clot (Bower 1996b, 1997).

23.1.5 Hazard identification conclusion

Holotrich ciliates have been identified as causing mortality in crustaceans, therefore, they are identified as a hazard in the commodity.

23.2 RISK ASSESSMENT

23.2.1 Entry assessment

Due to the rapid rate of mortality, infected crustaceans are unlikely to be imported. Individuals in the early stages of infection, especially wild-caught species may pass inspection.

The likelihood of entry is assessed to be non-negligible.

23.2.2 Exposure assessment

Crustaceans imported for human consumption can be imported in bulk; heads and tail-on, for further processing (value added) or direct distribution for retail sale to markets, restaurants and supermarkets in New Zealand. The commodities include, prawns, crayfish, scampi, lobster (as lobster tails) and crabs.

It is expected that the majority of fluids derived from chilling, freezing, defrosting, processing and transport of bulk commodities are to be discarded into municipal sewage systems at the point of retail.

Processing of raw entire crustaceans (i.e. heads and tails on prawns) by importers and distributors is assumed to be limited as sale of raw unprocessed crustaceans (especially prawns) is common (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018). The majority of head, shell and gut removal is likely to occur within households or trade businesses (i.e. restaurants). The waste generated in this fashion is likely to be disposed of in municipal sewage systems or to municipal landfill. The Food Regulations (New Zealand Government 2015) provide details of what waste disposal requirements restaurants and other retail businesses subject to food control plans need to follow. Waste that was directed to a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the amount of pathogen present and any remaining viable pathogen would be diluted within the wastewater (Biosecurity Australia 2009). This rationale is consistent with, and the basis for, the requirements for water treatment and disposal in MPI's transitional facilities standard for ornamental fish (MPI 2017). Similarly, all waste water from live imported freshwater prawns held in a transitional facility is treated according to this standard (MPI 2007).

Growth in the seafood import market may result in importers adding value to products (i.e. by removing heads, shells and gut) and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of exposure of wild or cultured crustaceans to imported crustacean waste products disposed to landfill or municipal sewage systems is assessed to be negligible.

An undefined yet likely small proportion of crustaceans imported for human consumption may be used as fishing bait (Blackwell 2013). The majority of bait would be expected to be consumed by non-susceptible host species, particularly finfish (Biosecurity Australia 2009). The likelihood of exposure, transmission and spread among wild crustacean populations is also expected to be low based on the lower population densities and absence of stressful conditions typically encountered by cultured crustaceans (Walker and Mohan 2009; Department of Agriculture 2013). Crabs and lobster are known scavengers they could be exposed to bait not consumed by non-susceptible host species, however as oral transmission is considered unlikely the likelihood of exposure is assessed to be negligible.

23.2.3 Risk estimation

Since the likelihood of exposure is assessed to be negligible, the risk is estimated to be negligible.

Exotic holotrich ciliates are assessed not to be a risk in the commodity.

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24 *Hematodinium* spp. and *Hematodinium*-like spp.

24.1 HAZARD IDENTIFICATION

24.1.1 Aetiological agent

Hematodinium spp. or *Hematodinium*-like species are parasitic dinoflagellates and only two species have been formally described (*H. perezi* and *H. australis*; Small 2012).

24.1.2 OIE list

Hematodinium spp. or *Hematodinium*-like species are not listed by the OIE.

24.1.3 New Zealand status

Following a review of the literature, *Hematodinium* spp. or *Hematodinium*-like species have not been reported from the New Zealand aquatic environment.

24.1.4 Epidemiology

This assessment is based on the review article by Small (2012), unless otherwise stated. *Hematodinium* spp. have recently been identified as important pathogens of decapod crustaceans with several commercially exploited species from the USA, Europe and Australia being affected (Stentiford and Shields 2005). Infection with *Hematodinium* spp. in wild crustacean fisheries may lead to population level effects, such as a decrease in recruitment due to the prevalence of infection being highest in unfished juveniles and females. For example, Messick and Shields (2000) identified reduced annual catches of crabs from the same location linked to *Hematodinium* infection. Further, a 96 % reduction in velvet swimming crabs (*Necora puber*) in a fishery in France between 1984 and 1988 was correlated with the identification of a *Hematodinium* spp. that infected 80 % of sampled individuals (Wilhelm and Mialhe 1996). Significant mortality in wild hosts is likely to occur and up to 100 % mortality has been observed in laboratory studies (Stentiford and Shields 2005).

Hematodinium spp. multiply in the haemolymph of crustaceans and can infect other tissue such as cardiac and skeletal muscle. In latent infections the parasite can also infect the hepatopancreas, eye stalk and gut connective tissue. The life-cycle of *Hematodinium* is complex and not well described, most likely involving several life history stages including dinospores, prespores, trophonts and plasmodia (Frischer *et al.* 2006).

Infected hosts usually display clinical signs of lethargy and the carapace is hyper-pigmented appearing ‘cooked’. High levels of infection cause the haemolymph to become cream coloured and muscle tissue to degenerate (Stentiford and Shields 2005). Several million parasite cells per millilitre of haemolymph occur in advance stages of infection (Field *et al.* 1992). Heavy infections result in bitter tasting meat preventing it from being sold as the bitter taste can remains after cooking. This condition is known as bitter crab disease or bitter crab syndrome. Signs of infection are not always present in all host species or those that are lightly infected. There is evidence that in some crustaceans, infection may be sub-clinical with disease only being expressed after exposure to physiological or environmental stress (Eigemann *et al.* 2010). Infected crabs may also suffer from higher rates of secondary bacterial infections (Frischer *et al.* 2006). There is no treatment available.

The first cultured crustacean species to be found infected with a *Hematodinium* spp. was the horse crab (*Portunus trituberculatus*) from China in 2004. The next year the mud crab (*Scylla serrata*) was found to be infected in two aquaculture facilities in China that were separated by hundreds of kilometres. Clinical signs were similar to other outbreaks with crabs suffering from ‘milky blood’ and displaying a cooked appearance. Ridgetail prawns (*Exopalaemon carinicauda*) cultured in the same location suffered mortalities of up to 100 % and clinical signs were similar to that observed in *S. serrata*. Genetic analysis showed that the parasite infecting *E. carinicauda, S. serrata* and *P. trituberculatus* from the same area shared > 99 % similarity, suggesting the *Hematodinium* spp. was capable of infecting all three host species. This was the first documented case of a shrimp being a host of a *Hematodinium* sp. (Xu *et al.* 2010). Pagenkopp-Lohan *et al.* (2012) sampled a number of crustaceans species via histology and PCR from the Delmarva Peninsula, Virginia, USA and found that a *Hematodinium* sp. infecting the blue crab (*Callinectes sapidus*) was highly similar (> 98 %) to that infecting 6 other species (spider crabs: *Libinia dubia*, *L. emarginata*; mud crabs: *Eurypanopeus depressus, Panopeus herbstii*; hermit crab: *Pagurus pollicaris*). Additionally, Sheppard *et al.* (2003)

found the same or very similar *Hematodinium* sp. infecting multiple crab species from a Georgia estuary (USA). There is also PCR evidence that the *Hematodinium* sp. is capable of infecting the caprellid amphipod (*Caprella geometrica*). It has long been speculated that amphipods and plankton may act as alternate or reservoir hosts for *Hematodinium* spp. (Hudson and Shields 1994; Shields 1994; Frischer *et al.* 2006). These examples suggest that *Hematodinium* parasites are host generalists (Stentiford and Shields 2005). Davies and Rowley (2015), however, failed to detect infection in juvenile European lobster (*Homarus gammarus*) after injection of a *Hematodinium* sp. from the edible crab (*Cancer pagurus*), showing that some host specificity is present.

Susceptible crustacean species may become infected after moulting when the cuticle is soft (Messick 1994; Shields *et al.* 2005; 2007), suggesting an integumentary route of invasion by the potentially infectious dinospore stage (Stentiford and Shields 2005; Frischer *et al.* 2006; Rowley *et al.* 2015). Sheppard *et al.* (2003) and Walker *et al.* (2009) have demonstrated the transmission of a *Hematodinium* sp. to uninfected individuals via consumption of infected tissue. Some studies have not been successful in transmitting disease via this route (Li *et al.* 2011), however, cannibalism is suspected to be an alternative route of infection (Stentiford and Shields 2005; Frischer *et al.* 2006).

Despite the significance of infection with *Hematodinium* spp., only two species have been formally identified from the > 40 crustacean hosts. This is due to difficulties identifying distinctive characteristics and obtaining representative type material.

It appears that the worldwide distribution, rate of infection and host range of *Hematodinium* spp. is increasing. Crustaceans infected with *Hematodinium* spp. are found in a number of countries in the Northern Hemisphere, with Australia being the only known country in the Southern Hemisphere to harbour infection. The current distribution is likely an artefact of sampling and not a true representative of the actual range of *Hematodinium* spp. Infections are fatal and there is no treatment available.

24.1.5 Hazard identification conclusion

Hematodinium spp. cause significant mortalities in an increasing number of crustacean hosts and are identified as a hazard in the commodity.

24.2 RISK ASSESSMENT

24.2.1 Entry assessment

Crustaceans that are heavily infected with *Hematodinium* spp. would not be imported into New Zealand due to the degeneration of body tissues and creamy appearance of the haemolymph resulting in a food product that is undesirable in appearance and unpalatable. For lightly infected crustaceans, these signs may not be as obvious or completely absent. Infected crustaceans that were frozen would not be expected to maintain viable *Hematodinium* spp. as inactivation of most protozoa occur via cell wall disruption (Jones and Gibson 1997). Additionally, cooking would be expected to inactive any viable *Hematodinium* spp. (Erickson and Ortega 2006).

The likelihood of entry for frozen and cooked crustaceans is assessed to be negligible.

The likelihood of entry for chilled crustaceans is assessed to be non-negligible.

24.2.2 Exposure assessment

Crustaceans imported for human consumption can be imported in bulk; heads and tail-on, for further processing (value added) or direct distribution for retail sale to markets, restaurants and supermarkets in New Zealand. The commodities include, prawns, crayfish, scampi, lobster (as lobster tails) and crabs.

It is expected that the majority of fluids derived from chilling, freezing, defrosting, processing and transport of bulk commodities are to be discarded into municipal sewage systems at the point of retail. Processing of raw entire crustaceans (i.e. heads and tails on prawns) by importers and distributors is assumed to be limited as sale of raw unprocessed crustaceans (especially prawns) is common (personal communication: Vicki Melville (MPI) and Gavin Kempthorne (Shore-mariner), 2018; Nishin, 2018). The majority of head, shell and gut removal is likely to occur within households or trade businesses (i.e. restaurants). The waste generated in this fashion is likely to be disposed of in municipal sewage systems or to municipal landfill. The Food Regulations (New Zealand Government

2015) provide details of what waste disposal requirements restaurants and other retail businesses subject to food control plans need to follow. Waste that was directed to a municipal sewage system would be exposed to a number of physical and biochemical processes that are likely to significantly reduce the amount of parasites present and any remaining viable parasites would be diluted within the wastewater (Biosecurity Australia 2009). This rationale is consistent with, and the basis for, the requirements for water treatment and disposal in MPI's transitional facilities standard for ornamental fish (MPI 2017). Similarly, all waste water from live imported freshwater prawns held in a transitional facility is treated according to this standard (MPI 2007).

Growth in the seafood import market may result in importers adding value to products (i.e. by removing heads, shells and gut) and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of exposure of wild or cultured crustaceans to imported crustacean waste products disposed to landfill or municipal sewage systems is assessed to be negligible.

An undefined, yet likely small, proportion of crustaceans imported for human consumption may be used as fishing bait (Blackwell 2013). The use of crustaceans as bait is likely to occur and has been identified online (The Fishing Website 2016). The amount of imported crustaceans (crab and crayfish) used as bait would be expected to be low as there is an abundance of locally sourced paddle crabs (*Ovalipes catharus*) that can be used (The Fishing Website 2016). Two crustacean species identified from New Zealand, *S. serrata* and the blue crab (*Portunus pelagicus*) are known to be susceptible to infection with *Hematodinium* spp.

Other species of crabs and crayfish may also be susceptible due to the wide host range of *Hematodinium* spp. It is difficult to predict exactly which crustacean species would be susceptible to infection in New Zealand and it would be expected that this would be dependent on the *Hematodinium* sp. introduced.

Once exposed to the marine environment it would be expected that a significant portion of crustacean diverted for use as bait would be consumed by non-susceptible host species, particularly finfish (Biosecurity Australia 2009).

The oral infectious dose is unknown for *Hematodinium* spp. and as crabs and lobster are known scavengers they could be exposed to bait not consumed by non-susceptible host species. The likelihood of exposure, transmission and spread among wild crustacean populations is also expected to be low based on the lower population densities and absence of stressful conditions typically encountered by cultured crustaceans (Walker and Mohan 2009; Department of Agriculture 2013). However, if an individual or small number of individuals were to become infected transmission could occur as free-living *Hematodinium* spp. can remain viable in seawater for 5 days (Meyer *et al.* 1987). Long-term self-sustaining transmission in wild populations of temperate and cold-water crustaceans has been demonstrated in several countries (Stentiford and Shields 2005, Morado *et al.* 2012).

The likelihood of exposure is assessed to be non-negligible.

24.2.3 Consequence assessment

If a *Hematodinium* sp. was to establish in New Zealand the impact on wild crustacean species could be significant. Overseas, several crab and lobster fisheries have been severely impacted by infection with a *Hematodinium* spp. leading to reduced yields (see Meyers *et al*. 1987; Messick 1994; Wilhelm and Mialhe 1996; Stentiford *et al.* 2002; Pestal *et al.* 2003). Further, in some fisheries, seasonal *Hematodinium* epidemics or even longer-term disease cycles exist and may be responsible for decreased abundance (Messick and Shields 2000). If a self-sustaining *Hematodinium* infection were to establish, significant impacts on commercial and recreational fisheries and the environment would be expected, however the extent of the impact would be dependent on the host range.

The future ability to culture marine crustaceans in New Zealand could be affected as these artificial environments facilitate the transmission of parasites. There is no control methods available so infection of susceptible species would result in financial losses (Li *et al.* 2008b).
The extent of the impact would be dependent on the pathogenicity of the *Hematodinium* sp. and the crustacean species being cultured. Some crab species have been observed as resistant to infection (Stentiford and Shields 2005).

No *Hematodinium* spp. are listed by the OIE so trade in crustaceans would not be expected to be impacted.

As wild and cultured crustacean populations could be affected by the establishment of a *Hematodinium* sp., the consequences are assessed to be non-negligible.

24.2.4 Risk estimation

The likelihood of entry and exposure, and the consequences are non-negligible, the risk is estimated to be non-negligible. Therefore *Hematodinium* spp. is assessed to be a risk in the commodity.

24.3 RISK MANAGEMENT

24.3.1 Options

There is little information in the scientific literature about inactivating *Hematodinium* spp. in crustacean products. There is also no *Code* chapter on *Hematodinium* spp. Despite this, cooking is considered very effective for inactivating protozoan parasites (Erickson and Ortega 2006).

For the importation of crabs or lobsters, one or a combination of the following measures could be considered to effectively manage the risk.

Option 1

Crabs and lobsters could be imported from areas free of *Hematodinium* spp.

Option 2

Crabs and lobsters could be frozen to at least – 18 °C.

Option 3

Crab or lobsters could be cooked. Precautions must be taken to avoid any post-processing contamination (e.g. contact with raw crustaceans).

N.B. Exposing crabs or lobster to boiling water until cooked through (i.e. protein is coagulated) will ensure inactivation of *Hematodinium* spp.

Option 4

Crab or lobsters could be imported from areas where *Hematodinium* spp. is present provided it is prepared and packaged for retail trade for human consumption *and* the associated packaging is clearly marked with the words "*for human consumption only, not to be used as bait or feed for aquatic animals.*"

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25 Microsporidians (not including *Enterocytozoon hepatopenaei*)

25.1 HAZARD IDENTIFICATION

25.1.1 Aetiological agent

Microsporidians are a phylum of obligate intracellular spore-forming parasitic fungi (Malone and Charleston 2012).

25.1.2 OIE list

Microsporidian infections of crustaceans are not listed by the OIE.

25.1.3 New Zealand status

In New Zealand, the species *Myospora metanephrops* has been recorded infecting the marine lobster *Metanephrops challengeri* (Stentiford *et al.* 2010) and *Thelohania* spp. have been found infecting native freshwater crayfish *Paranephrops planifrons* and *P. zealandicus* (Quilter 1976, Jones 1980). It is likely there are other undescribed species present in the New Zealand aquatic environment

25.1.4 Epidemiology

Microsporidian infections have been found to be associated with numerous crustacean species worldwide, with 43 microsporidian genera currently described. The most common genera include *Agmasoma*, *Ameson*, *Enterocytozoon*, *Enterospora*, *Flabelliforma*, *Glugoides*, *Indosporus*, *Nadelspora*, *Nosema*, *Ordospora*, *Pleistophora*, *Thelohania, Vavraia*, *Tuzetia,* and others (Wang *et al.* 2013). The taxonomy of microsporidians is unclear with species being differentiated by the size and number of spores on each sporont and on the host species and organ that is infected (Biosecurity Australia 2009). The future taxonomic classification of these organisms is very likely to change with the application of molecular techniques (Biosecurity Australia 2009).

The life histories of microsporidians vary and researchers have suggested that both indirect and direct life-cycles may occur (Morado 2011). In wild caught decapod species the prevalence of infection is generally very low (< 5 %). Infections are seldom described from cultured populations (Biosecurity Australia 2009). For example, the maximum prevalence of *Enterospora canceri* in *Cancer pagurus* was found to be 3.45 % (Stentiford *et al.* 2007).

Crustaceans infected with microsporidians tend to have opaque skeletal muscle that may affect marketability, however, infection has seldom been associated with significant disease and mortality (Biosecurity Australia 2009, Morado 2011).

25.1.5 Hazard identification conclusion

Due to the unclear taxonomy, uncertainty over the life history, low prevalence of infection in crustaceans, the presence of some microsporidian species in New Zealand, microsporidians are not identified as a hazard in the commodity.

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26 Angiostrongylus cantonensis

26.1 HAZARD IDENTIFICATION

26.1.1 Aetiological agent

Angiostrongylus cantonensis is a zoonotic nematode belonging to the family Angiostrongylidae (Cowie 2013).

26.1.2 OIE list

Disease caused by *Angiostrongylus cantonensis* is not listed by the OIE.

26.1.3 New Zealand status

Following a review of the literature, *Angiostrongylus cantonensis* has not been reported from the New Zealand aquatic environment.

26.1.4 Epidemiology

Angiostrongylus cantonensis is a parasitic nematode and is a major cause of eosinophilic meningitis in humans (Alicata 1991). It is an emerging zoonosis that has spread to a number of countries (Cowie 2013). It was first described in rats from China in 1935 and the first human case was reported in Taiwan in 1945 (Chang *et al.* 2013).

Definitive hosts of *A. cantonensis* include a number of rat species, which become infected by ingesting terrestrial or aquatic gastropods (intermediate hosts). Paratenic hosts (e.g. frogs, freshwater and terrestrial crabs, shrimp, planarians) contain the infectious third stage larvae (Wallace and Rosen 1966; Richards and Merritt 1967). The third stage larvae develop in rats into adults and reproduce by laying eggs in the pulmonary arteries. They then travel through the circulatory system to the lungs, where they hatch and develop into first stage larvae. The larvae then move up the trachea to be swallowed and excreted in faeces. The faeces containing first stage larvae are ingested by a gastropod and go through two moults to become third stage larvae. A paratenic host can consume the infected gastropod. To complete the parasite's lifecycle a rat must consume the intermediate or paratenic host (Cowie 2013).

Humans, other mammals and birds are dead end hosts of *A. cantonensis* and become infected by eating raw or undercooked intermediate or paratenic hosts containing infectious third stage larvae. In dead end hosts, the third stage larvae die upon reaching the central nervous system, such as the brain, which can cause eosinophilic meningitis (Kim *et al.* 2013). Symptoms in humans can range from headaches through to death. The severity of infection is likely linked to the number of larvae ingested, their location in the body, and the individual's inflammatory reaction to infection (Cowie 2013). Human infections are most prevalent in Southeast Asia and the Pacific (Chang *et al.* 2013).

Crustacean paratenic hosts that are consumed by humans as food include *Macrobrachium rosenbergii* and *M. lar* (Wallace and Rosen 1966*;* Alicata 1967). As *A. cantonensis* has a wide host range it is likely that other freshwater and terrestrial crustacean species consumed by humans will be identified as paratenic hosts in the future.

In New Zealand a well-known intermediate host, the freshwater snail (*Melanoides tuberculata*) was discovered in a geothermally heated stream near Taupo in 2001 (Duggan 2002).

26.1.5 Hazard identification conclusion

Freshwater and terrestrial crustaceans may serve as a paratenic host for *A. cantonensis.* This parasite is an emerging zoonotic agent capable of causing human mortalities.

A. cantonensis is identified as a hazard.

26.2 RISK ASSESSMENT

26.2.1 Entry assessment

Freshwater and terrestrial crustaceans are likely to be imported from countries where *A. cantonensis* is endemic.

Freezing *M. rosenbergii* at – 15 °C for 12 hours or boiling for 1 minute renders third-stage larvae incapable of infecting other hosts (Alicata 1967).

The likelihood of entry for crustaceans imported frozen or cooked is assessed to be negligible.

M. rosenbergii refrigerated at 0 °C for 24 hours maintained infectious third stage larvae. Third stage larvae remained viable in a snail (*Achatine fulica*) when refrigerated at 0 °C for 7 days (Alicata 1967). Wallace and Rosen (1966) showed that larvae of *A. cantonensis* can survive for up to 29 days in both the cephalothorax and in the stomach and intestine in live freshwater shrimp (*M. lar*). However, the numbers of surviving larvae decreased markedly 3 days after infection.

The likelihood of entry for chilled crustaceans is assessed to be non-negligible.

26.2.2 Exposure assessment

Prior to human consumption it can be assumed that the vast majority of freshwater and terrestrial crustaceans imported chilled would be cooked, inactivating the infectious third stage larvae. However, exposure to viable larvae may occur if freshwater and terrestrial crustaceans were consumed raw or inadequately cooked.

A small proportion of chilled freshwater and terrestrial crustaceans would be disposed of uncooked (spoiled) at a landfill. Crustacean tissue in general, rapidly decomposes if exposed to ambient temperatures and this biochemical process may lead to the inactivation of some third stage larvae (Biosecurity Australia 2009). At a landfill, however, crustacean tissue may be scavenged by a suitable definitive host (i.e. rats). For *A. cantonensis* to become established a suitable intermediate gastropod host would need to consume infected rat faeces and then itself be consumed by a rat. There are several terrestrial and aquatic snails that could act as intermediates hosts (MPI 2006).

This above scenario could also occur for chilled freshwater and terrestrial crustaceans used as bait, as rats could scavenge any that was discarded. In freshwater environments some bait would be expected to be consumed by non-susceptible host species, particularly finfish (Biosecurity Australia 2009).

Growth in the seafood import market may result in importers adding value to products by removing heads, shells and gut, and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of establishment of *A. cantonensis* present in chilled freshwater or terrestrial crustaceans is assessed to be non-negligible.

26.2.3 Consequence assessment

The establishment of *A. cantonensis* in New Zealand would be expected to cause life threatening neurologic disease in birds, dogs, horses, possums, bats and animals in zoological collections (particularly monkeys) (Monk *et al.* 2005; Lunn *et al.* 2012).

In humans, infection can cause neurologic disease, which can result in death. High-risk groups include infants and inebriated adult males who may consume snails or slugs as a dare (Lunn *et al.* 2012).

The consequences are assessed to be non-negligible.

26.2.4 Risk estimation

The likelihood of entry and exposure, and the consequences are non-negligible, therefore the risk is estimated to be non-negligible.

A. cantonensis is assessed to be a risk in the commodity.

26.3 RISK MANAGEMENT

26.3.1 Options

The freezing of freshwater crustaceans (e.g. *M. rosenbergii*) at – 15 °C for 12 hours or boiling for 1 minute renders third-stage larvae incapable of infecting other hosts (Alicata 1967). Commercial freezing is typically at – 18 °C (Diggles 2011) for > 12 hours for imported crustacean commodities. Cooking crustaceans normally occurs via exposure to boiling water (100 ºC) for 3 to 5 minutes until the protein is coagulated (Biosecurity Australia 2009).

There is no *Code* chapter on *A. cantonensis*.

For the importation of chilled freshwater or terrestrial crustaceans, the following measures could be considered to effectively manage the risk:

Option 1

Freshwater or terrestrial crustaceans could be imported from areas free of *A. cantonensis*.

Option 2

Freshwater or terrestrial crustaceans could be frozen to at least – 18 °C for > 12 hours.

Option 3

Freshwater or terrestrial crustaceans could be cooked. Precautions must be taken to avoid any post-processing contamination (e.g. contact with raw crustaceans).

N.B. Exposing freshwater or terrestrial crustaceans to boiling water until protein has coagulated will ensure inactivation of *A. cantonensis*.

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27 Epicaridean isopods

27.1 HAZARD IDENTIFICATION

27.1.1 Aetiological agent

Epicaridean isopods are parasitic to crustaceans. There are more than 790 described species (Williams and Boyko 2012).

Epicaridean isopods are separated into two superfamilies Bopyroidea (696 species belonging to 3 families) and Crytoniscoidea (99 species belonging to 7 families) (Williams and Boyko 2012; Boyko *et al.* 2013).

Most species that belong to Bopyroidea are ectoparasites with only two species (subfamily Entophilinae) being endoparasitic. Species belonging to Crytoniscoidea are endoparasitic (Williams and Boyko 2012).

27.1.2 OIE list

Epicaridean isopods are not OIE listed.

27.1.3 New Zealand status

A number of epicaridean isopods have been described from crustacean hosts in New Zealand (Page 1985; Brockerhoff, 2004).

27.1.4 Epidemiology

Epicaridean isopods have a two-host life history. Pelagic calanoid copepods act as the intermediate host and another crustacean is the definitive host. The host specificity of the intermediate host is not well studied (Williams and Boyko 2012).

The life-cycle of Bopyroidea species is well known. Crytoniscoidea species are less understood, however, the small number that have been studied exhibit a similar life-cycle to Bopyroidea species (Williams and Boyko 2012; Boyko *et al.* 2013).

The life-cycle of Bopyroidea species starts with the sexually mature male fertilising the eggs of the female which is attached to the definitive host. Larvae then develop (epicaridium larval stage) and are released into the water column to infect the copepod intermediate host. The larvae feed on the blood of the copepod and metamorphose into microniscus larvae that then detach and metamorphose into cryptoniscus larvae. The cryptoniscus larvae settle on the definitive host where they metamorphose into the juvenile form and move to the final attachment site. Females penetrate the host's cuticle to feed on haemolymph or ovarian fluids. Males reside on females and do not appear to feed on the host (Willams and Boyko 2012).

The two known endoparasitic species belonging to Bopyroidea create a pore in the definitive host from which larvae are thought to be released into the water column. The rest of the lifecycle is the same as ectoparasitic Bopyroidea species (Willams and Boyko 2012).

Epicaridean isopods can castrate their host by feeding on the haemolymph and ovarian fluids of the definitive host. In addition, they may affect their host's morphology due to the energy burden they impose (Willams and Boyko 2012).

27.1.5 Hazard identification conclusion

As epicaridean isopods feed on haemolymph and ovarian fluids, they require a viable definitive host in order to survive. Crustaceans imported for human consumption will be non-viable (as described in the commodity definition).

Epicaridean isopods are identified as not a hazard in the commodity.

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28 *Paragonimus* spp.

28.1 HAZARD IDENTIFICATION

28.1.1 Aetiological agent

Paragonimus spp. belong to the trematode family Troglotrematidae of which more than 50 species have been reported worldwide. They are commonly referred to as lung flukes (Van Andel *et al.* 2011).

28.1.2 OIE list

Paragonimus spp. are not OIE listed.

28.1.3 New Zealand status

Paragonimus spp. are listed in New Zealand as exotic unwanted organisms (Unwanted Organism Register 1998). In November 2010, two dogs imported into New Zealand from South Africa were identified as infected with a *Paragonimus* sp. This was the first report of this parasite in New Zealand. The biosecurity risk was managed by treating both dogs with antihelminthics (Van Andel *et al.* 2011).

28.1.4 Epidemiology

Paragonimiasis is a zoonotic infection caused by a parasite with a complex life-cycle which includes two intermediate hosts (freshwater molluscs and freshwater and terrestrial crustaceans) and a definitive host (terrestrial mammals, including humans). The life-cycle involves adult trematodes residing within the lungs of the definitive mammalian host and producing fertilised eggs that are expelled via the oral cavity or swallowed and passed in faeces. Eggs that are released into fresh or brackish water hatch and infect a suitable aquatic mollusc species, the first intermediate host. Upon infection, the parasite develops and after 70-90 days, swimming cercariae emerge from the molluscan host. The cercaria then infect a suitable crustacean, which is the second intermediate host. This may occur when the crustacean consumes the tissue of an infected mollusc or via direct penetration of the crustacean by the cercaria. The definitive mammalian host becomes infected by consuming the infectious metacercariae life-stage, present in raw or undercooked (in the case of humans) infected crustaceans (Procop 2009).

The genus *Paragonimus* is endemic in Asia, Africa and the Americas, infecting more than 20 million people worldwide (Singh *et al.* 2005). A large proportion of human infections are located in countries that have a tradition of consuming raw crustaceans (e.g. Vietnam, Thailand and Laos) (Procop 2009).

Clinical signs in humans may include weight loss, chronic coughing, blood-tinged sputum and exercise intolerance (Procop 2009; Van Andel *et al.* 2011). The central nervous system of humans may be invaded and cause symptoms similar to meningitis (Van Andel *et al.* 2011). Despite this, many human infections are sub-clinical resulting in only minor disease (Procop 2009).

The frequency of infection in humans with *Paragonimus* spp. is increasing and may be related to the increase in aquaculture in many Asian countries (Procop 2009).

In 2001, the tropical snail *Melanoides tuberculata* was identified for the first time in a geothermally warmed stream near Taupo (Duggan 2002). It is a first intermediate host in the life-cycle of a number of *Paragonimus* spp. The current distribution of this species is unknown but likely to be restricted to a small number of geothermally heated streams (Derraik 2008).

28.1.5 Hazard identification conclusion

Paragonimus spp. in the form of the infectious metacerariae life-stage are present in crustaceans. Ingestion of viable metacerariae by mammals, including humans can, in extreme cases, result in death.

Paragonimus spp. are identified as a hazard.

28.2 RISK ASSESSMENT

28.2.1 Entry assessment

Crustaceans that are intermediate hosts of *Paragonimus* spp. will be imported from countries where these parasites are endemic.

The majority of crustaceans imported into New Zealand will be frozen. Metacercariae of trematodes are more resistant to freezing compared to other endoparasites such as nematodes (EFSA 2010).

Most frozen crustaceans imported into New Zealand will be transported at < 18 °C (Diggles 2011) and may be held in storage for several months (Australian Quarantine and Inspection Service 1999). The temperature and duration required to inactivate metacercariae of *Paragonimus* spp. is not well defined. Trematode species from the genus *Clonorchis* and *Opisthorchis* were found to be inactivated after exposure to – 10 °C for 5 days (EFSA 2010). *Clonorchis sinensis,* however, was found to remain viable after freezing at – 12 °C for 10 to 18 days and – 20 °C for 3 to 7 days (Fan 1998). The definitive hosts in this study (rats and rabbits) were infected with metacercariae via inoculation. This represents an artificial infection pathway which bears no resemblance to natural infections that would occur via oral ingestion.

The likelihood of entry in crustaceans that have been frozen at < – 18 °C is assessed to be negligible.

Cooking crustaceans to at least 63 °C prior to importation will inactive any *Paragonimus* spp. metacercariae present (Centers for Disease Control and Prevention 2013).

The likelihood of entry in cooked crustaceans is assessed to be negligible.

Crustaceans that are imported chilled are likely to contain viable metacercariae. Therefore, the likelihood of entry in chilled crustaceans is assessed to be non-negligible.

28.2.2 Exposure assessment

The quantity of chilled crustaceans to be imported for human consumption is undefined but likely small. Prior to consumption by humans it can be assumed that the vast majority of chilled crustacean product would be cooked, inactivating the metacercariae. However, exposure to viable metacercariae may occur if crustaceans were consumed raw or inadequately cooked.

Chilled crustaceans that spoil are most likely be disposed of at a landfill. The process of decomposition may lead to the inactivation of some metacercariae. At a landfill, a definitive (e.g. cats) or paratenic host (e.g. rodents) may scavenge crustacean tissue. The paratenic host may then be eaten by a definitive host, which would then need to defecate in, or near, an aquatic habitat. This would enable the expelled parasitic eggs to infect a suitable molluscan host. The parasite would then be required to infect a suitable second intermediate host (crustacean) which finally must be consumed by an appropriate mammalian host to fulfil the parasites' life-cycle.

This above scenario could also occur for chilled crustaceans used as bait, as rats could scavenge discarded bait. In freshwater environments the majority of bait would be consumed by nonsusceptible host species, particularly finfish (Biosecurity Australia 2009).

Growth in the seafood import market may result in importers adding value to products by removing heads, shells and gut, and engaging in further processing within New Zealand. It is possible that discharging of wastes from larger processors to the environment can occur where premises are situated at or near waterways (rivers or seaside) (Biosecurity Australia 2009).

The likelihood of establishment of *Paragonimus* spp. in chilled crustaceans is assessed to be non-negligible.

28.2.3 Conequence assessment

Various mammalian species may become infected with *Paragonimus* spp., particularly cats and dogs. *Paragonimus kellicotti* may develop as cysts in the lungs of cats and dogs and may be asymptomatic or present respiratory signs of infection such as coughing, dyspnea or pneumothorax (Companion Animal Parasite Council 2016). The use of antihelminthics readily treats infection.

In humans, infection with *Paragonimus* spp. is usually associated with very limited morbidity and rarely causes death (Procop 2009).

The consequences are assessed to be non-negligible.

28.2.4 Risk estimation

The likelihood of entry and exposure, and the consequences are assessed as non-negligible, therefore, the risk is estimated to be non-negligible.

Paragonimus spp. is assessed to be a risk in the commodity.

28.3 RISK MANAGEMENT

28.3.1 Options

Paragonimus spp. in freshwater and terrestrial crustaceans can be inactivated by freezing at commercial temperatures (< – 18 °C) and cooking (> 63 °C).

Option 1

Importation of freshwater crustaceans could occur from *Paragonimus* spp. free areas

Option 2

Freshwater crustaceans could be frozen to at least – 18 °C.

Option 3

Freshwater crustaceans could be cooked. Precautions must be taken to avoid any postprocessing contamination (e.g. contact with raw crustaceans).

N.B. Exposing freshwater crustaceans to boiling water until protein has coagulated will ensure inactivation of *Paragonimus* spp.

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29 Rhizocephalan barnacles

29.1 HAZARD IDENTIFICATION

29.1.1 Aetiological agent

Rhizocephalan barnacles belong to the super-order Rhizocephala that contains more than 250 species. Rhizocephalan barnacles are parasites of a number of crustacean species (Walker 2001).

29.1.2 OIE list

Rhizocephalan barnacles are not listed by the OIE.

29.1.3 New Zealand status

Ten species of rhizocephalan barnacles are reported from New Zealand (Brockerhoff *et al.* 2010).

29.1.4 Epidemiology

Rhizocephalan barnacles are parasites of several commercially fished crustacean species (Walker 2001; Shields 2012). These parasites castrate, feminise, stunt, cause anecdysis, and can kill their hosts (Shields 2012). Both sexes of crustacean hosts are infected after a female cyprid larva attaches to the cuticle of the host. The parasite then moults twice into vermigon larvae. At this stage, the cuticle is penetrated and an internal root system develops followed by the growth of an externally visible female egg sac (externa). Males are dwarfs and attach to the externa and fertilise the eggs, which are reared by the host. Larvae are released into the environment to grow and locate a new host (Brockerhoff *et al.* 2010).

29.1.5 Hazard identification conclusion

Infection with rhizocephalan barnacles causes stunted growth and a cessation in moulting. Hosts that survive infection may also display brown scars on tissue directly exposed to infection (Bower and Meyer 1998). These factors will reduce the marketability of infected individuals. Rhizocephalan barnacles feed on the haemolymph of their crustacean host and thus require a viable host in order to survive. According to the commodity definition, crustaceans imported into New Zealand for human consumption will be non-viable resulting in the death of the parasitic rhizocephalan barnacles.

Rhizocephalan barnacles are not identified as a hazard in the commodity.

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