Biosecurity New Zealand
Tiakitanga Pūtaiao Aotearoa

Rapid risk assessment

Formalin/alcohol preserved molluscs containing pearls

ISBN No: 978-1-77665-807-7 (online)

Version 2.1

5 June 2018

New Zealand Government

Ministry for Primary Industries
Manatū Ahu Matua

Disclaimer

Cover photo: *Pinctada margaritifera* Photo credit: Wikipedia Creative Commons distribution

Recommended citation:
MPI (2018) Rapid Risk Assessment: Formalin/alcohol molluscs containing pearls. Version 2.1, June 2018. Ministry for Primary Industries, New Zealand.

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries website at
http://www.mpi.govt.nz/news-and-resources/publications/

Rapid Risk Assessment: Formalin/alcohol preserved molluscs containing pearls

Version 2.1

5 June 2018

Approved for release

……

Manager, Science and Risk Assessment

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

Version information

Version number	Comments	Date of release
1.0	First peer-reviewed version	22 March 2018
2.0	Peer-reviewed and current at date of release	13 April 2018
2.1	Approved for release	5 June 2018

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

This document provides a scientific analysis of the risks associated with molluscs preserved in formalin and alcohol, containing cultured pearls. It assesses the likelihood of entry, exposure, establishment and spread of various diseases and pests in relation to imported molluscs containing pearls and assesses the potential impacts of those organisms should they enter and establish in New Zealand. The document has been internally peer reviewed.

Contributors to this risk assessment

The following people provided significant input into the development of this risk analysis:

1. Primary contributors

Ron Blackwell	Senior Adviser, Animals and Aquatics team Biosecurity Science and Risk Assessment Group MPI Wellington, New Zealand

2. Internal peer review

Sudharma Leelawardana (Sue)	Manager, Animals and Aquatics team Biosecurity Science and Risk Assessment Group MPI Wellington, New Zealand
Eugene Georgiades	Senior Adviser, Animals and Aquatics team Biosecurity Science and Risk Assessment Group MPI Wellington, New Zealand
Haritina Mogosanu	Senior Adviser, Animals and Aquatics team Biosecurity Science and Risk Assessment Group MPI Wellington, New Zealand
Nasser Ahmed	Senior Adviser, Animal Imports Team 1, Import and Export Animals Group MPI Wellington, New Zealand

Contents

Page

1 Executive summary

MPI's Animal Imports Team has requested risk advice concerning the appropriateness of the biological specimen import health standard (IHS) for imported formalin/alcohol preserved molluscs containing cultured pearls, where the commodity is likely to be discarded in domestic refuse.

The commodity consists of non-viable molluscs grown in marine and fresh waters that may contain natural or implanted "cultured" pearls. These molluscs (whole and shell-on) are fixed in 4% to 10% formalin. They are then preserved in either formalin or formalin/alcohol and individually vacuum packaged in sealed plastic bags, and then bulk packaged for export to New Zealand.

A risk analysis completed in 2005 for non-viable biological products, microorganisms and other viable cells determined that non-viable low-risk biological products could be imported without restriction. The Import health standard (IHS) (*INESPEIC.ALL*) based on the risk analysis specified, allows for non-viable biological products that were identified as low-risk organisms, to be imported without restriction.

To determine the preliminary hazard list (Table 1), for this rapid risk analysis, marine mollusc pathogens listed in the 2017 OIE *Aquatic code*, previous risk assessments and reviews of infectious diseases of freshwater mussels, were used.

At the hazard identification step, the pathogens identified in the preliminary hazard list were assessed as unlikely to remain viable in the commodity (non-viable molluscs processed in formalin/alcohol solution and stored in vacuum packaging).

Formalin fixation requires at least 24 hours to fully penetrate and fix biological tissues. It is reasonable to assume that the time interval including subsequent storage and transport of the commodity in formalin or formalin-alcohol solution, to "shucking" and subsequent disposal, would be least 5 days (120 hours). It is considered unlikely that any mollusc pathogens would remain viable after this time period.

As no hazards have been identified in the commodity under the processing methods described, further risk assessment was not required under the procedures described in the *OIE Aquatic Code*. Thus, no further treatment of the commodity is considered necessary to address biosecurity concerns with the importation.

2 Introduction

The Animal Imports Team of MPI (Ministry for Primary Industries) has requested risk advice to determine the appropriateness of importation of non-viable molluscs containing pearls, under the current provisions of the *Import Health Standard for the Importation into New Zealand of Nonviable Animal Specimens from All Countries* (*INESPEIC.ALL*) (MAF 2004). This IHS was based on a risk assessment for biological products (MAF 2005) which identifies high risk biological products, which require permanent storage in a Transitional Facility (TF), but also identifies low risk biological products that could be imported with no further restrictions.
This rapid risk assessment reviews the risks associated with the importation of non-viable molluscs containing pearls, where the likely pathway for waste materials (shells and mollusc flesh) is through domestic waste disposal.

3 Commodity description

3.1 COMMODITY DEFINITION AND SCOPE

Pearls are formed in bivalve and gastropod molluscs, including clams, oysters, mussels and abalone. While pearls occasionally are recovered from clams, most pearl production in marine waters is focused on the pearl oyster *Pinctada* spp., the winged oyster *Pteria* spp. (Pteridae) and the abalone/paua *Haliotis* spp. (Haliotidae). Freshwater mussels are also used in pearl production including *Margaritifera* spp. (Margaritiferidae) and *Unio* spp. in Europe, *Hyriopsis* spp., *Cristaria* sp. in Asia and China, and *Amblema* spp. in North America (Unionidae) (Bondad-Reantaso *et al.* 2007, Carella *et al*. 2016).

For the purposes of this risk assessment, this commodity is defined as whole (shell-on) non-viable pearl molluscs derived from fresh and marine waters that may contain cultured pearls.

High value cultured pearls are routinely extracted from the host and further processed before sale. These are not considered in this risk assessment.

3.2 PROCESSING METHODS

Whole (shell-on) pearl molluscs are processed as a bulk commodity. They are initially fixed in formalin (4%-10%) and then either preserved in industrial-grade alcohol, or in a mixture of formalin/alcohol. They are individually vacuum packaged in sealed plastic bags, which are then packaged in bulk at room temperature for storage and transport for export.

The length of the fixation treatment is unknown.

Although pearl molluscs are primarily imported as a wholesale bulk commodity, they can also be purchased from overseas suppliers directly over the internet.

3.3 DISTRIBUTION

Pearl molluscs imported into New Zealand through a wholesaler are generally distributed through a network of agents. Wholesale trading of the commodity generally occurs as bulk units of individual vacuum packaged molluscs.

Retail sale may occur over the internet from a New Zealand wholesaler, or through "party plan" sales.
Each individual plastic bag is opened after retail sale, when the mollusc is "shucked" to extract the pearl. The remaining mollusc tissues, including the shell, mantle and internal organs are discarded, generally through the domestic waste pathway.

3.4 FORMALIN FIXATION OF THE COMMODITY

Formalin is a recognised fixative of biological tissues. At a concentration 1.3 molar, 10% formalin is equivalent to 4% formaldehyde in solution (i.e. 4g per 100 ml), it is highly toxic to most organisms. (J. Reeve, Principal Adviser, Toxicology, MPI, p*ers.comm.* 2018).

Formalin at concentrations of 4% or 10% effectively denatures pathogens in biological products (Fox *et al.* 1985, OIE 2017a,b), but is relatively slow acting requiring up to 24 hours to penetrate 20 mm or more into tissues at room temperature (25ºC) (Farmer 1985, Moller *et al.* 2013).

Formalin denatures most viruses including adenoviruses (Möller *et al.* 2013) and birnaviruses at 2% concentration (Dixon & Hill 1983), iridoviruses (Kirita & Nakajima 2012), noroviruses (Möller *et al.* 2013) and reoviruses (Rivas *et al.* 1994) at 4% to 10% concentration. It is widely used in the production of formalin-inactivated antiviral vaccines (OIE 2017a). Formalin kills and fixes protozoans (Davis 1947), chromistans (Kleeman & Adlard 2000, Bower 2013), Haplosporidians (OIE 2017b), *Rickettsia*-like and *Chlamydia*-like organisms (Dennison *et al*. 2014). It denatures fungi and most bacteria at 10% concentration (Howard & Smith 1983, Farmer 1985).

As formalin requires at least 24 hours to fully penetrate and fix biological tissues (Farmer 1985), it is reasonable to assume that the commodity would be formalin-fixed after storage in a formalin or formalin-alcohol solution for at least 5 days (120 hours) prior to "shucking" and subsequent disposal.

3.5 WASTE DISPOSAL

The commodity is not intended for human consumption, rather it is akin to a small-scale industrial process, where the opening or "shucking" is usually carried out in domestic premises. After each mollusc has been opened, the packaging, the remaining mollusc shell and tissues are most likely to be discarded through the domestic sewage and rubbish disposal.

New Zealand aquaculture occurs largely in open marine and fresh waters and is thus potentially vulnerable to introduced exotic pathogens (Castinel *et al*. 2013, Meyers 2014, Georgiades *et al.* 2016). As each mollusc has a relatively high unit value, the actual quantity of generated waste per mollusc is likely to be small. The likelihood of these waste products and associated viable pathogens entering the aquatic environment is considered to be very low.

4 Preliminary hazard list

Marine mollusc pathogens from the OIE Aquatic Code (OIE 2017a), previous risk assessments (Anon 2002, MPI 2008, Georgiades *et al.* 2016), and reviews of infectious

diseases of freshwater mussels (Grizzle & Brunner 2009, Carella *et al*. 2016) were used to determine the preliminary hazard list (Table 1).

Table 1 also presents a summary of whether these organisms would be likely to represent a hazard in the commodity after treatment. Any organism that is identified as a hazard will be subject to risk assessment.

5 Hazard identification conclusion

None of the pathogens identified in the preliminary hazard list are assessed as likely to remain viable in the commodity (non-viable molluscs processed in formalin/alcohol solution and stored in vacuum packaging), for at least 5 days (120 hours).

6 Risk assessment conclusion

As no hazards have been identified in the processed commodity (formalin fixed and stored in formalin or formalin-alcohol for at least 5 days (120 hours) prior to "shucking" and disposal), under the procedures described in the *OIE Aquatic Code* (OIE 2017a), further risk assessment is not required. No further treatment of the commodity is considered necessary.

1: Preliminary hazard list and hazard identification

Aetiology (Disease)	OIE listed	Aetiological Classification (Family)	Host species	Distribution	Present in New Zealand	Likely to be present in the commodity	Likely to be viable in the commodity	Likely to cause significant disease in New Zealand	Identified as a hazard in the commodity	Reference
Viral diseases										
Abalone viral ganglioneuritis virus (AbHV) (Abalone viral ganglioneuritis)	Yes	Herpesviridae	Abalone (*Haliotis laevigata*, *H. rubra, H. diversicolor* and hybrids	Australia, Taiwan	No	Yes	No	Yes	No	Möller *et al*. 2013, OIE 2017a,b
Akoa oyster virus (Akoa oyster disease)	No	Aquabirnaviridae	Oysters (*Crassostrea gigas*, *Pinctada* spp., scallop (*Chlamys nobilis*)	Japan, China, French Polynesia	No	Yes	No	Yes	No	Dixon & Hill 1983, Bower 2010, Wada 2003, 2007
Bioaccumulated fish virus	No	Aquareovirus	Geoduc (*Panope* sp.) (multiple hosts)	Widespread	No	Yes	No	Yes	No	Tubbs *et al.* 2007, Meyers *et al.* 2009, Meyers 2014
Digestive epithelial virosis	No	Small RNA virus Picorna-like virus	Clam (*Cerastoderma* edule)	Worldwide	Yes	No	No	N/A	No	Tubbs *et al.* 2007, Carrasco *et al.* 2011, Georgiades *et al.* 2016
Intranuclear viral inclusion bodies	No	Uncharacterised virus possibly Adenovirus/ Herpesvirus	Oyster (*Pinctada* spp.)	Australia, Pacific Islands	No	Yes	No	No	No	Diggles *et al.* 2007
Digestive tubule birnavirus	No	Birnaviridae	Clams (*Meretrix lusoria*, *Sinovacura constricta*), oyster (*Pinctada* spp.)	Japan	No	Yes	No	No	No	Bondad-Reantaso *et al.* 2007, Kitamura *et al.* 2000, Jones 2007

Aetiology (Disease)	OIE listed	Aetiological Classification (Family)	Host species	Distribution	Present in New Zealand	Likely to be present in the commodity	Likely to be viable in the commodity	Likely to cause significant disease in New Zealand	Identified as a hazard in the commodity	Reference
Disseminated haemic neoplasia	No	Suspected Retrovirus	Mussels (*M. edulis, M. galloprovincialis* and hybrids), cockles (*Cerastoderma edule*), clams (*Mya arenaria*)	Europe	No	No	No	N/A	No	Tubbs *et al*. 2007, Webb 2008, Castinel *et al.* 2013, Alderman *et al*. 2017
Gill necrosis virus (GNV)	No	Iridoviridae	Oysters (*Crassostrea* spp., *Ostrea* spp.)	Worldwide	No	No	No	N/A	No	Anon 2002, Kurita & Nakajima 2012, Georgiades *et al.* 2016
Haemocytic infection virus (HIV)	No	Iridoviridae	Oysters (*Crassostrea angulate*, *C. gigas*)	Europe	No	No	No	N/A	No	Kurita & Nakajima 2012, Castinel *et al.* 2013, Georgiades *et al.* 2016
Lea virus disease *Hyriopsis cumingii* plague virus (HcPV)	No	Arenaviridae	Freshwater mussel *Hyriopsis cumingii*	China	No	Yes	No	Yes	No	Mendenhall *et al.* 2011, Zhong *et al.* 2011
Larval oyster herpesvirus	No	Herpesviridae	Oysters (*Crassostrea* spp., *Ostrea* spp.)	Worldwide	Yes	No	No	N/A	No	Anon 2002
Isocahedral virus-like agent	No	Picorna-like virus	Clam (*Ruditapes decussatus*), oyster (*Pinctada* spp.)	Europe, Australia	Yes	Yes	No	No	No	Hine & Wesney 1997, Humphrey *et al.* 1998, Anon 2002, Jones 2007

Aetiology (Disease)	OIE listed	Aetiological Classification (Family)	Host species	Distribution	Present in New Zealand	Likely to be present in the commodity	Likely to be viable in the commodity	Likely to cause significant disease in New Zealand	Identified as a hazard in the commodity	Reference
Ostreid Herpesviridae herpesvirus (OsHV 1 µvar)	No	Herpesviridae	Oysters (*Crassostrea angulate*, *C. gigas*), scallops (*Pecten maximus*) Clam (*Ruditapes philippinarum*)	Worldwide	Yes	No	No	N/A	No	Arzul *et al.* 2001, Anon 2002, Georgiades *et al*. 2016, Getchell *et al.* 2016, Tan *et al.* 2015, OIE 2017b
Oyster velar virus (OVVD)	No	Iridoviridae	Oyster (*Crassostrea gigas*)	Widespread	No	No	No	N/A	No	Bower 2001a, Castinel *et al* 2014, Georgiades *et al*. 2016.
Picorna-like virus of pearl oysters	No	Uncertain aetiology	Oyster (*Pinctada margaritifera*)	French Polynesia	No	Yes	No	No	No	Comps *et al.* 1999, Kibenge & Godoy 2016
Shellfish paralysis reovirus	No	Reoviridae	Clams (*Mya* spp., *Ruditapes* spp., *Tellina* spp.), oysters (*Crassostrea* spp., *Ostrea* spp., *Pinctada* spp.)	Europe, United States, Asia	No	Yes	No	Yes	No	Rivas *et al.* 1994, Bower 2013
Tellina birnavirus	No	Birnaviridae	Clam (*Tellina tenuis*)	Europe	No	No	No	N/A	No	Underwood *et al.* 1977, MAF 2005
Viral gametocytic hypertrophy	No	Papova-like virus Papillomaviridae, Polymoaviridae	Oysters (*Crassostrea* spp., *Ostrea* spp., *Pinctada* spp.), clam (*Mya* spp.)	Widespread	No	Yes	No	No	No	Humphrey *et al.* 1998, Jones 2007, Bower 2010, Lopez *et al.* 2012, Georgiades *et al.* 2016

Aetiology (Disease)	OIE listed	Aetiological Classification (Family)	Host species	Distribution	Present in New Zealand	Likely to be present in the commodity	Likely to be viable in the commodity	Likely to cause significant disease in New Zealand	Identified as a hazard in the commodity	Reference
Virus-like infection of clams	No	Polyomavirus-like, (uncertain aetiology)	Oysters (*Crassostrea virginica*), clams (*Tellina* spp. *Ruditapes* spp.)	Widespread	No	No	No	No	No	Tubbs *et al.* 2007, Bower 2010
Bacterial diseases										
Aeromonas salmonicida	No	Aeromonadaceae	Freshwater mussel (*Amblema* sp.)	United States	No	Yes	No	Yes	No	Johnston 2008, Starliper 2011
Chlamydia-like organisms (CLOs) and Rickettsia-like organisms (RLOs) (Intracellular bacterial diseases)	No	Chlamydiales Rickettsiales	Abalone (*Haliotis tubuculata*), mussels (*Perna* spp.) oysters (*Crassostrea* spp., *Pinctada* spp.), scallops (*Pecten* spp.),	Worldwide	Yes	Yes	No	No	No	Wu & Pan 1999, Diggles *et al*. 2002, Azevedo *et al*. 2006, Tubbs *et al.* 2007, Crockford & Jones 2012, Dennison *et al.* 2014, Georgiades *et al.* 2016
Cytophaga sp. (Hinge-ligament disease)	No	Cytophagaceae: Bacteroidetes	Oysters (*Crassostrea* spp., *Ostrea* spp., *Pinctada* spp.), clams (*Mercenaria* spp, *Tapes* sp., *Siliqua* sp.).	Widespread	No	Yes	No	No	No	Wu & Pan 1999, Bower 2001b, Jones 2007,Castinel *et al*. 2013, Georgiades *et al*. 2016

Aetiology (Disease)	OIE listed	Aetiological Classification (Family)	Host species	Distribution	Present in New Zealand	Likely to be present in the commodity	Likely to be viable in the commodity	Likely to cause significant disease in New Zealand	Identified as a hazard in the commodity	Reference
Extracellular giant *Rickettsia*-like organisms	No	Pleomorphic prokaryote organisms not in family Rickettsiales	Oyster (*Crassostrea gigas*)	Europe (Spain)	No	No	No	N/A	No	Azevado & Villalba 1991, Bower 1996, Georgiades *et al*. 2016
Flavobacterium columnare (Columnaris disease)	No	Flavobacteriaceae	Freshwater mussel (*Amblema plicata*)	North America	Yes (exotic virulent genomovars exist)	Yes	No	Yes	No	Boustead 1982, Starliper *et al*. 1998, Johnston 2008
Micrococcus spp. (Bacterial abscess lesions)	No	Micrococcus	Wide host range including pearl oyster (*Pinctada* spp.)	Widespread	Yes	Yes	No	No	No	Diggles *et al*. 2007
Mycoplasma crassostreae (Mycoplasmosis/ Intercellular bacterial disease)	No	Mollicutes	Oysters (*Crassostrea virginica*), scallops (*Pecten* spp.)	United States, New Zealand	Yes	No	No	N/A	No	Diggles *et al*. 2002, Tubbs *et al*. 2007, Bondad-Reantaso *et al*. 2007, Webb 2008, Bower 2010, Georgiades *et al*. 2016
Oyster oedema disease (OOD)	No	Mollicute-like organism Uncertain aetiology	Oyster (*Pinctada* sp.)	Australia	No	Yes	No	No	No	Goncalves *et al.* 2017)
Nocardia crassostrae (Pacific oyster nocardiosis)	No	Nocardiaceae	Oysters (*Crassostrea gigas*, *Ostrea edulis*)	Canada and Europe	Yes	No	No	N/A	No	Engelsma *et al.* 2008, EURL 2011, Georgiades *et al.* 2016

Aetiology (Disease)	OIE listed	Aetiological Classification (Family)	Host species	Distribution	Present in New Zealand	Likely to be present in the commodity	Likely to be viable in the commodity	Likely to cause significant disease in New Zealand	Identified as a hazard in the commodity	Reference
Plectonema terebrans, *Hyella caespitosa, Mastigocoleus testarum, Mastigocoleus* sp., *Pleurocapsa* sp. (Phototrophic endolith invasion of muscle cells)	No	Cyanobacteriales	Mussels (*Perna* sp., *Mytilus* sp.), oyster (*Pinctada* spp.)	Worldwide	Yes	Yes	No	No	No	Che *et al.* 1996, Georgiades *et al.* 2016
Vibrio harveyi, V. alginolyticus, V. carchariae,. V. parahaemolyticus, V. splendidus (Abalone bacterial disease)	No	Vibrionaceae	Paua (*Haliotis* spp.)	Worldwide	Yes	Yes	No	Yes	No	Georgiades *et al.* 2016
Vibrio tapetis (Brown ring disease, BRD)	No	Vibrionaceae	Clams (*Cerastoderma edule, Ruditapes* sp., *Venerupis* spp.)	Europe and Australia	No	No	No	N/A	No	Anon 2002, *Tubbs et al.* 2007,Castinel *et al* 2013, Georgiades *et al.* 2016

Aetiology (Disease)	OIE listed	Aetiological Classification (Family)	Host species	Distribution	Present in New Zealand	Likely to be present in the commodity	Likely to be viable in the commodity	Likely to cause significant disease in New Zealand	Identified as a hazard in the commodity	Reference
Vibrio tubiashi	No	Vibrionaceae	Oysters (*Crassostrea* spp.), Clams (*Panope* spp.)	Widespread	No	Yes	No	Yes	No	Elsdon *et al*. 2008
Vibrio spp. (Vibriosis)	No	Vibrionaceae	Oysters (*Crassostrea* spp., *Ostrea* spp., *Pinctada* spp., *Saccostrea* spp.) freshwater mussel (*Amblema plicata*)	Worldwide	Yes	Yes	No	Yes	No	Bondad-Reantaso *et al*. 2007, Georgiades *et al.* 2016
Vibrio fluvialis II, *V. harveyi, V. splendidus* (Pustule disease of abalone)	No	Vibrionaceae	Paua (*Haliotis* spp.), oysters (*Pinctada* spp.)	Worldwide	Yes	Yes	No	Yes	No	Diggles *et al.* 2007, Georgiades *et al.* 2016
Xenohaliotis californiensis (Abalone withering syndrome)	Yes	Rickettsiales	Abalone (*Haliotis* spp.)	Europe, North America, Asia and China.	No	Yes	No	Yes	No	OIE 2017a,b
Algal diseases										
Coccommyxa parasitica		Chlorophyta	Geoduc (*Panope abbreviata*)	South America	No	No	No	N/A	No	Vasquez *et al.* 2010

Aetiology (Disease)	OIE listed	Aetiological Classification (Family)	Host species	Distribution	Present in New Zealand	Likely to be present in the commodity	Likely to be viable in the commodity	Likely to cause significant disease in New Zealand	Identified as a hazard in the commodity	Reference
Fungal diseases										
Ostracoblabe implexa (Oyster shell disease)	No	Fungi incertae sedis Ostracoblabe	Oysters (*Crassostrea* spp., *Ostrea* spp.) *Pinctada* spp. *Saccostrea* spp.)	Europe, India and Canada	No	Yes	No	Yes	No	Howard & Smith 1983, Bower 2001b
Stenhausia and *Stenhausia*-like organisms (Mussel egg disease)	No	Microsporea: Pseudo-pleistophoridae	Mussels (*Perna* spp.)	Widespread	No	No	No	N/A	No	Georgiades *et al*. 2016
Protozoan diseases										
Apicomplexan parasite X (unidentified myxozoan)	No	Chromista: Apicomplexa	Oysters (*Ostrea chilensis*), mussel (*Perna canaliclus*)	New Zealand	Yes	No	No	No	No	Webb 2008, Suong *et al.* 2017
Apicomplexan-like organisms (Inclusion body disease)	No	Chromista: Apicomplexa	Mussel (*Perna viridis*), clams (*Gafrarium* sp., *Meretrix* sp.)	South east Asia	No	Yes	No	No	No	Azami *et al.* 2014
Aplanochytrium (*Labyrinthuloides*) *haliotididis*	No	Chromista: Thraustochytrida	Paua (*Haliotis* spp.)	widespread	No	Yes	No	No	No	Georgiades *et al.* 2016
Bonamia exitiosa (Bonamiosis)	Yes	Chromista: Haplosporida	Oysters (*Ostrea* spp.)	New Zealand	Yes	Yes	No	Yes	No	Webb 2008, OIE 2017a,b

Aetiology (Disease)	OIE listed	Aetiological Classification (Family)	Host species	Distribution	Present in New Zealand	Likely to be present in the commodity	Likely to be viable in the commodity	Likely to cause significant disease in New Zealand	Identified as a hazard in the commodity	Reference
Bonamia ostreae	Yes	Chromista: Haplosporida	Oysters (*Ostrea stentina*)	New Zealand	Yes	Yes	No	Yes	No	Tubbs *et al.* 2007, OIE 2017a,b
Bonamia perspora	No	Chromista: Haplosporida	Oysters (*Ostrea stentina*)	New Zealand	Yes	Yes	No	Yes	No	Tubbs *et al.* 2007, Bower 2015b
Bonamia (=*Mikrocytos*) *roughleyi* (Australian winter disease)	No	Chromista: Haplosporida	Oysters (*Saccostrea glomeratus*)	Australia	No	No	No	N/A	No	Tubbs *et al.* 2007, Bower 2015a
Clam protozoan unknown (CPX)	No	Unidentified protzoan	Geoduc (*Panope abrupta*)	Canada	No	No	No	N/A	No	Bower & Blackbourn 2003
Conchophthirus spp.	No	Conchophthiridae	Freshwater pearl mussels (Unionidae)	Widespread	No	Yes	No	No	No	Grizzle & Brunner 2009
Haliphthorous milfordensis (Paua shell mycosis - multiple agents)	No	Chromista: Haliphthoraceae	Paua (*Haliotis* sp.)	Widespread	Yes	Yes	No	Yes	No	Diggles & Oliver 2005, Georgiades *et al*. 2016
Haplosporidium nelsoni, *H. amoricanum* (MSX disease)	No	Chromista: Haplosporida	Oysters (*Crassostrea* spp., *Ostrea* spp.)	Widespread	No	No	No	N/A	No	Anon 2002, Burrelson & Stokes 2006
Haplosporidium (*Agrobacterium*) *tumefasciens*	No	Chromista: Haplosporida	Mussels (*Mytilus* spp., *Perna* spp.)	Widespread	Yes	No	No	N/A	No	Georgiades *et al.* 2016

Aetiology (Disease)	OIE listed	Aetiological Classification (Family)	Host species	Distribution	Present in New Zealand	Likely to be present in the commodity	Likely to be viable in the commodity	Likely to cause significant disease in New Zealand	Identified as a hazard in the commodity	Reference
Haplosporidium sp. of pearl oysters	No	Chromista: Haplosporida	Oyster (*Pinctada* spp.)	Australia	No	Yes	No	No	No	Bower 2007, Jones 2007
Haplosporidium sp. of abalone (unidentified)	No	Chromista: Haplosporida	Abalone (*Haliotis* iris)	New Zealand	Yes	No	No	N/A	No	Diggles & Oliver 2005, Bower 2007a
Invasive ciliates (unidentified)	No	Ciliata	Mussels (*Mytilus* spp., *Perna* spp.), oysters (*Pinctada* spp., *Pteria* spp)	Widespread	Yes	Yes	No	No	No	Bondad-Reantaso *et al.* 2007, Georgiades *et al.* 2016
Digestive gland coccidian of pearl oysters (unidentified)	No	Chromista: Aggregatidae	Oyster (*Pinctada* spp.)	Pacific Islands	No	Yes	No	No	No	Diggles *et al.* 2007
Margolisiella (=*Pseudoklossia*) *haliotis* (Kidney coccidiosis of abalone)	No	Chromista: Aggregatidae	Paua (*Haliotis* spp.)	Widespread	Yes	Yes	No	No	No	Georgiades *et al.* 2016
Kidney coccidian of oysters (unidentified)	No	Chromista: Aggregatidae	Oyster (*Crassostrea gigas*, *Ostrea edulis*)	Europe (France)	No	No	No	N/A	No	Bower et al 1994a, Georgiades *et al.* 2016

Aetiology (Disease)	OIE listed	Aetiological Classification (Family)	Host species	Distribution	Present in New Zealand	Likely to be present in the commodity	Likely to be viable in the commodity	Likely to cause significant disease in New Zealand	Identified as a hazard in the commodity	Reference
Pseudoklossia semiluna, *P. pelseneeri*, *Pseudoklossia* sp. (Kidney coccidiosis of mussels)	No	Chromista: Aggregatidae	Mussel (*Mytilus* spp., *Perna* spp.)	Widespread	Yes	No	No	N/A	No	Bower 2001d, Georgiades *et al.* 2016
Mantoscyphidia sp., *Scyphidia*-like and phenophrya-like ciliates	No	Chromista: Scyphiidae	Paua (*Haliotis* spp.), mussel (*Perna* spp.)	Widespread	No	Yes	No	No	No	Georgiades *et al.* 2016
Minchinia sp.	No	Chromista: Haplosporida	Mussel (*Mytilus galloprovincialis*)	Widespread	No	No	No	N/A	No	Comps & Tigé 1997, Webb 2008
Marteilia maurini	No	Chromista: Paramyxida	Mussels (*M. edulis*, *M. galloprovincialis*)	Widespread	No	No	No	N/A	No	Comps *et al*. 1981, Webb 2008
Marteilia refringens (Aber disease)	Yes	Chromista: Paramyxida	Oyster (*Ostrea edulis*), mussels (*Mytilus edulis*, *M. galloprovincialis*)	Europe, United Kingdom	No	Yes	No	Yes	No	Kleeman & Adlard 2000, Tubbs *et al.* 2007, OIE 2017a,b
Marteilia sydneyi (QX disease)	No	Chromista: Paramyxida	Oyster (*Saccostrea glomerata*), mussels (*Mytilus edulis*, *M. galloprovincialis*)	Australia	No	Yes	No	Yes	No	Anon 2002, Tubbs *et al.* 2007, OIE 2017b

Aetiology (Disease)	OIE listed	Aetiological Classification (Family)	Host species	Distribution	Present in New Zealand	Likely to be present in the commodity	Likely to be viable in the commodity	Likely to cause significant disease in New Zealand	Identified as a hazard in the commodity	Reference
Marteilia sp.	No	Chromista: Paramyxida	Oysters (*Pinctada* spp.)	Europe	No	Yes	No	Yes	No	Berthe *et al.* 2004, Tubbs *et al.* 2007, Anon 2009
Martelloides spp.	No	Chromista: Paramyxida	Clam (*Venerepus philippinarum*)	Widespread	No	No	No	N/A	No	Bower & Itoh 2005, Tubbs *et al.* 2007
Mikrocytos mackini (Denman disease)	No	Chromista: Rhizaria	Oysters (*Crassostrea* spp., *Ostrea* spp.)	Canada, United States	No	Yes	No	Yes	No	Tubbs *et al.* 2007, OIE 2017b
Nematopsis spp, *Porospora* spp. (Gregarine parasites of molluscs)	No	Chromista: Porosporideae	Mussels (*Mytilus* spp., *Perna* spp.), oysters (*Crassostrea* gigas, *Pinctada* spp.)	Widespread	Yes	Yes	No	No	No	Jones 1975, 2007, Bower & McGladdery 2009, Georgiades *et al.* 2016
Paua haplosporidosis (undescribed haplosporidian]	No	Chromista: Haplosporida	Paua (*Haliotis* spp.)	New Zealand	Yes	No	No	N/A	No	Georgiades et al. 2016
Perkinsus andrewsi, *P. chesapeaki* (Dermo disease)	No	Chromista: Perkinsidae	Oysters (*Crassostrea* spp.), clams (*Macoma* spp., *Mercenaria* spp. *Mya* sp.)	North and South America	No	Yes	No	Yes	No	Anon 2002, Lopez *et al.* 2012, OIE 2017b
Perkinsus honshuensis	No	Chromista: Perkinsidae	Clams (*Venerepus philippinarum*)	Asia, Europe	No	No	No	N/A	No	Lopez *et al.* 2012

Aetiology (Disease)	OIE listed	Aetiological Classification (Family)	Host species	Distribution	Present in New Zealand	Likely to be present in the commodity	Likely to be viable in the commodity	Likely to cause significant disease in New Zealand	Identified as a hazard in the commodity	Reference
Perkinsus olseni, *Perkinsus* sp.	No	Chromista: Perkinsidae	Wide host range including oyster (*Pinctada* spp.)	Widespread	Yes	Yes	No	No	No	Diggles *et al*. 2002, 2007, Jones 2007, Tubbs *et al.* 2007, Webb 2008
Quahog parasite x (QPX disease)	No	Chromista: Thraustochytriales	Clam (*Mercenaria mercenaria*)	Canada, Europe (Portugal)	No	No	No	N/A	No	Bower 2010
Sirolpidium zoophthorum (Oyster larval Mycosis)	No	Chromista: Sirolpidiaceae	Oysters (*Crassostrea* spp.), scallops (*Argopecten* spp.), clams (*Mercenaria* spp., *Ruditapes* spp.)	United States	No	No	No	N/A	No	Howard & Smith 1983, Bower *et al.* 2001c, Tubbs *et al*. 2007,
Trichodina spp.	No	Chromista Trichodinidae	Wide host range including oyster (*Pinctada* spp.)	Widespread	Yes	No	No	N/A	No	Bower et al. 1994b, Tubbs *et al.* 2007
Metazoan pathogens										
Cliona spp. (Shell boring sponge disease)	No	Porifera:: Clionaidae	Oysters (*Ostrea* spp, *Crassostrea* spp, *Pinctada* spp., *Pteria* spp.)	Widespread	Yes	Yes	No	No	No	Bondad-Reantaso *et al*. 2007, Rush & Kelly 2017
Polydora spp., *Boccardia* spp. (Black shell disease)	No	Polychaeta: Spionidae	Oysters (*Ostrea* spp, *Crassostrea* spp, *Pinctada* spp., *Pteria* spp.)	Widespread	Yes	Yes	No	No	No	Bondad-Reantaso *et al*. 2007, Read 2010

Aetiology (Disease)	OIE listed	Aetiological Classification (Family)	Host species	Distribution	Present in New Zealand	Likely to be present in the commodity	Likely to be viable in the commodity	Likely to cause significant disease in New Zealand	Identified as a hazard in the commodity	Reference
Hydroides norvegica, *Dexiospira forminosus*	No	Polychaeta: Serpulidae	Oysters (*Ostrea* spp, *Crassostrea* spp, *Pinctada* spp.)	Widespread	Yes	Yes	No	No	No	Wada 2007
Bucephalus varicus	No	Digenea: Bucephalidae	Oysters (*Ostrea* spp, *Crassostrea* spp, *Pinctada* spp.)	Widespread	Yes	Yes	No	No	No	Hine 1997
Proctoeces ostreae	No	Digenea: Fellodistomidae	Oysters (*Ostrea* spp, *Crassostrea* spp, *Pinctada* spp.)	Widespread	No	Yes	No	No	No	Wada 2007
Mytilicola intestinalis (Red worm disease)	No	Copepoda: Mytilicolidae	Wide host range	Widespread	Yes	Yes	No	No	No	Webb 2008
Leiososolenus malaccanus (*Liithophaga malaccana*)	No	Bivalvia: Mytilidae	Oysters (*Pinctada* spp. *Pteria* spp.)	Southeast Asia	No	Yes	No	No	No	Wada. 2007
Botula cinnamomea (*B. siluca*)	No	Bivalvia: Mytilidae	Oysters (*Pinctada* spp. *Pteria* spp.)	Southeast Asia	No	Yes	No	No	No	Bondad-Reantaso *et al*. 2007
Gastrochaena cuniformis (retzi)	No	Bivalvia: Gastrochaenidae	Oysters (*Pinctada* spp. *Pteria* spp.)	Widespread	Yes	Yes	No	No	No	Bondad-Reantaso *et al*. 2007, WORMS 2018
Balanaus variegatus	No	Cirripedia: Balanidae	Wide host range	Widespread	Yes	Yes	No	No	No	Wada 2007

7 References

Alderman DJ, Green M, Boulet G (2017). Disseminated haemic neoplasia in bivalves. ICES identification leaflets for diseases and parasites of fish and shellfish No. 67. International Council for the Exploration of the Sea (ICES), Copenhagen, Denmark, 11 p.

Anonymous (2002). Import risk analysis (IRA) of Non-Viable Bivalve Molluscs: Technical Issues Paper. Biosecurity Australia. Canberra, Australia, 67 p.

Anonymous (2009). Diagnosis by histo-cytopathology of Marteilia spp. in the flat oyster Ostrea edulis and the mussels Mytilus edulis and M. galloprovincialis. Community Reference Laboratory for Mollusc Diseases, IFREMER, 3pp [Online] Available from: http://www.eurl-mollusc.eu/content/download/15833/236526/version/2/file/Marteilia_2.pdf [Accessed 15 March 2018].

Arzul I, Nicolas JL, Davison AJ, Renault T (2001). French scallops: a new host for ostreid herpesvirus-1. *Virology* 290: 342−349.

Azami N, Ghaffar M, Cob ZC (2014). Apicomplexa-like parasites of economically important bivalves from Merambong shoals, Johor. *Malayan Nature Journal* 66(1-2): 108–120.

Azevado C, Villalba A (1991). Extracellular giant rickettsiae associated with bacteria in the gill of *Crassostrea gigas* (Mollusca, Bivalvia). *Journal of Invertebrate Pathology* 58(1): 75**8**–81.

Azevedo C, Conchas RF, Tajdari J, Montes J (2006). Ultrastructural description of new Rickettsia-like organisms in the commercial abalone *Haliotis tuberculata* (Gastropoda: Haliotidae) from the NW of Spain. *Diseases of Aquatic Organisms* 71: 233– 237.

Barteling SJ, Woortmeyer R (1984). Formaldehyde inactivation of foot-and-mouth disease virus. Conditions for the preparation of safe vaccine. *Archives of Virology* 80: 103–117.

Berthe FCP, LeRoux F, Adlard RD, Figueras A (2004). Marteiliosis in molluscs: a review. *Aquatic Living Resources* 17: 433–448.

Berthe FCP, Prou J (2007). The French Polynesian experience, pp 103–109 *In*: Bondad-Reantaso MG, McGladdery SE, Berthe FCJ (*Eds*.) Pearl oyster health management: a manual. *FAO Fisheries Technical Paper No*. 503, Food and Agriculture Organisation of the United Nations (FAO), Rome, Italy, 120 p.

Bondad-Reantaso MG, McGladdery SE, Ladra D, Chongming W (2007). Pearl oyster health: experiences from the Philippines, China, the Persian Gulf and the Red Sea, pp 111–121 *In*: Bondad-Reantaso MG, McGladdery SE, Berthe FCJ (*Eds*.) Pearl oyster health management: a manual. *FAO Fisheries Technical Paper No*. 503, Food and Agriculture Organisation of the United Nations (FAO), Rome, Italy, 120 p.

Boustead NC (1982). Fish diseases recorded in New Zealand, with a discussion on potential sources and certification procedures. Fisheries Research Division Occasional Publication No. 34, Wellington, New Zealand, 29 p.

Bower SM (1996). Synopsis of infectious diseases and parasites of commercially exploited shellfish: extracellular giant "Rickettsiae" of oysters [Online] Available from: http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/egroy-eng.html [Accessed 12 March 2018].

Bower SM (2001a). Synopsis of infectious diseases and parasites of commercially exploited shellfish: Oyster velar virus disease (OVD) [Online] Available from: http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/oovvdoy-eng.html [Accessed 7 March 2018].

Bower SM (2001b). Synopsis of infectious diseases and parasites of commercially exploited shellfish: Hinge ligament disease of juvenile oysters [Online] Available from: http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/hldjoy-eng.html. [Accessed 12 March 2018].

Bower SM (2001b). Synopsis of infectious diseases and parasites of commercially exploited shellfish: *Ostracoblabe implexa* (Shell disease) of oysters [Online] Available from: http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/oioy-eng.html [Accessed 7 March 2018].

Bower SM (2001c). Synopsis of infectious diseases and parasites of commercially exploited shellfish: *Sirolpidium zoophthorum* (larval mycosis) of oysters. [Online] Available from: http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/sirozoy-eng.html. [Accessed 12 March 2018].

Bower SM (2001d). Synopsis of Infectious Diseases and Parasites of Commercially Exploited Shellfish: Kidney Coccidia of Mussels [Online] Available from: http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/kidcocmu-eng.html. [Accessed 12 March 2018].

Bower SM (2006a). Synopsis of Infectious Diseases and Parasites of Commercially Exploited Shellfish: Haplosporidian parasite of abalone [Online] Available from: http:// http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/haploab-eng.html [Accessed 13 March 2018].

Bower SM (2006b). Synopsis of Infectious Diseases and Parasites of Commercially Exploited Shellfish: Fungal Diseases of Abalone [Online] Available from: http:// http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/fungusab-eng.html [Accessed 13 March 2018].

Bower, SM (2007). Synopsis of Infectious Diseases and Parasites of Commercially Exploited Shellfish: *Haplosporidium* sp. of Pearl Oysters [Online] Available from: http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/happearloy-eng.html [Accessed 13 March 2018].

Bower SM (2010). Synopsis of infectious diseases and parasites of commercially exploited shellfish [Online] Available from: http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/papovcc-eng.html [Accessed 7 March 2018].

Bower SM (2013). Synopsis of infectious diseases and parasites of commercially exploited shellfish: *Perkinsus* of clams and cockles [Online] Available from http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/perkincc-eng.html [Accessed 7 March 2018].

Bower SM (2015a). Synopsis of Infectious Diseases and Parasites of Commercially Exploited Shellfish: *Bonamia* (=*Mikrocytos*) *roughleyi* (Australian Winter Disease) of Oysters

[Online] Available from http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/mikrouoy-eng.html [Accessed 7 March 2018].

Bower SM (2015b). Synopsis of infectious diseases and parasites of commercially exploited shellfish: *Bonamia perspora* of *Ostrea stentina* [Online] Available from: http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/bonamperspoy-eng.html. [Accessed 15 March 2018].

Bower SM, McGladdery SE, Price IM (1994a). Synopsis of infectious diseases and parasites of commercially exploited shellfish: kidney coccidia of oysters [Online] Available from: http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/kidcocoy-eng.html. [Accessed 15 March 2018].

Bower SM, McGladdery SE and IM Price (1994b). Synopsis of infectious diseases and parasites of commercially exploited shellfish: Gill trichodina of clams and cockles [Online] Available from: http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/gilltrcc-eng.html. [Accessed 13 March 2018].

Bower SM. Blackbourn J (2003). Geoduck clam (*Panopea abrupta*): Anatomy, histology, development, pathology, parasites and symbionts: APX - Apicomplexan (gregarine) spores in geoduck clams [Online] Available from: http://www.dfo-mpo.gc.ca/science/aah-saa/species-especes/shellfish-coquillages/geopath/apicomplex-eng.html. [Accessed 15 March 2018].

Bower SM, Itoh N (2005). Synopsis of infectious diseases and parasites of commercially exploited shellfish: *Marteilioides* sp. of clams [Online] Available from: http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/martioidcc-eng.html. [Accessed 13 March 2018].

Bower SM, McGladdery SE (2009). Synopsis of infectious diseases and parasites of commercially exploited shellfish: Gregarine parasitism of oysters [Online] Available from http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/gregpoy-eng.html [Accessed 13 March 2018].

Bower SM, Itoh N, Choi D.-L and MS Park, (2011). Synopsis of infectious diseases and parasites of commercially exploited shellfish: *Marteilioides chungmuensis* of oysters [Online] Available from: http://www.dfo-mpo.gc.ca/science/aah-saa/diseases-maladies/mcoy-eng.html**.** [Accessed 7 March 2018].

Burrelson EM, Stokes NA (2006). Haplosporidiosis of oysters. Fishery disease resource. American Fisheries Society [Online] Available from http://afs-ahs.org/perch/resources/14069252585.2.2haplosporid2014.pdf [Accessed 7 March 2018].

Carrasco N, Roque A, Andree KB, Rodgers C, Lacuesta B, Furones MD (2011). A *Marteilia* parasite and digestive epithelial virosis lesions observed during a common edible cockle *Cerastoderma edule* mortality event in the Spanish Mediterranean coast. *Aquaculture* 321: 197–202.

Carella F, Villari G, Maio N, De Vico G (2016). Disease and disorders of freshwater Unionid Mussels: A brief overview of recent studies. *Frontiers in Physiology* 7: 489 [Online] Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5088359/#B36 [Accessed 8 March 2016].

Castinel A, Forrest B, Hopkins G (2013). Review of disease risks for New Zealand shellfish aquaculture: perspectives for management. Prepared for Ministry for Business, Innovation and Employment. *Cawthron Client Report* No. 2297, 31 p.

Che LM, le Campiion-Alumsard, Boury-Esnault N, Payri C, Golubic S, Bezac C (1996). Biodegradation of shells of the black pearl oyster, *Pinctada margaritifera var. cumingii*, by microborers and sponges of French Polynesia. *Marine Biology* 126: 509– 519.

Comps M, Pichot Y, Papagianni P (1981). Research on *Marteilia maurini* n. sp. parasite the mussel *Mytilus galloprovincialis* Lmk. *Revue des Travaux de l'Institut des Pêches Maritimes* 45: 211–214 (in French, with English abstract).

Comps M, Tigé G (1997). Fine structure of *Minchinia* sp., a haplosporidan infecting the mussel *Mytilus galloprovincialis L. Systematic parasitology* 38(1): 45– 50.

Comps M, Herbaut C, Fougerouse A (1999). Virus-like particles in pearl oyster *Pinctada margaritifera*. *Bulletin of the European Association of Fish Pathologists* 19: 85–88.

Crockford M, Jones B (2012). Aquatic Animal Health Subprogram: Investigation of Chlamydiales-like organisms in pearl oysters, *Pinctada maxima*, FRDC Project 2008/031. Fisheries Research Report No. 232, Department of Fisheries, Government of Western Australia, 40 p.

Davis HS (1947). Studies of the protozoan parasites of freshwater fishes. *Fishery Bulletin* 41. United States Fish and Wildlife Service, Washington, United States of America, 61 p.

Dennison AM, Amin BD, Nicholson WL, Paddock CD (2014). Detection of *Rickettsia rickettsii, Rickettsia parkeri*, and *Rickettsia akari* in skin biopsy specimens using a multiplex real-time polymerase chain reaction assay. *Clinical and Infectious Diseases* 59(5): 635–642.

Diggles BK, Hine PM, Handley S, Boustead NC (2002). A handbook of diseases of importance to aquaculture in New Zealand. *NIWA Science and Technology Series No.* 49, 200 p.

Diggles BK, Oliver M (2005). Diseases of cultured paua (*Haliotis iris*) in New Zealand, pp. 275-287 *In:* Walker PJ, Lester RG, Bondad-Reantaso MG (*Eds*.) Diseases in Asian Aquaculture V. Proceedings of the 5th Symposium on Diseases in Asian Aquaculture. Fish Health Section, Asian Fisheries Society, Manila.

Diggles B, Hine MP, Carson J (2007). The Cook Islands experience: pearl oyster health investigations, pp 71–85 *In:* Bondad-Reantaso MG, McGladdery SE, Berthe FCJ (*Eds*.) Pearl oyster health management: a manual. *FAO Fisheries Technical Paper No.* 503, Food and Agriculture Organisation of the United Nations (FAO), Rome, Italy, 120 p.

Dixon PF, Hill BJ (1983). Inactivation of infectious pancreatic necrosis virus for vaccine use. *Journal of Fish Diseases* 6(5): 399–409.

Elston RA, Hasegawa H, Humphrey KL, Polyak IK, Hase CC (2008). Re-emergence of *Vibrio tubiashii* in bivalve shellfish aquaculture: severity, environmental drivers, geographic extent and management. *Diseases of Aquatic Organisms* 82: 119–134.

Engelsma MY, Roozenburg I, Joly JP **(2008).** First isolation of *Nocardia crassostreae* from Pacific oyster *Crassostrea gigas* in Europe, *Diseases of Aquatic Organisms* 80: 229–234.

EURL (2011). Mollusc diseases: *Nocardia crassostrae.* European Union Reference Laboratory (EURL) [Online] Available from: http://www.eurl-mollusc.eu/Main-activities/Tutorials/Nocardia-crassostreae [Accessed 8 March 2018].

Farmer JJ (1985). Formalinised bacterial 'antigens" as a potential infection hazard. *Journal of Clinical Microbiology* 2(4): 359–360.

Fox CH, Johnson FB, Whiting J, Roller PP (1985). Formaldehyde fixation. *The Journal of Histochemistry and Cytochemistry* 33(8): 845–853.

Georgiades E, Fraser R, Jones B (2016). Options to Strengthen On-farm Biosecurity Management for Commercial and Non-commercial Aquaculture. *MPI Technical Paper* No. 2016/47. Ministry for Primary Industries, Wellington, New Zealand, 360 p.

Getchell RG, Smolowitz RM, McGladdery SE, Bower SM (2016). Chapter 10: diseases and parasites of scallops, pp. 425-468 *In:* Shumway SE, Parsons GJ (*Eds*.) Developments in Aquaculture and Fisheries Science 40. Scallops – biology, ecology, aquaculture and fisheries (Third edition). Elsevier, Netherlands.

Goncalves P, Raftos D, Jones D, Anderson K, Jones B, Snow M (2017). Identifying the cause of Oyster Oedema Disease (OOD) in pearl oysters (*Pinctada maxima*), and developing diagnostic tests for OOD. Final report for FRDC Project No 2013/002. Fisheries Research and Development Corporation, Government of Western Australia, Australia, 95 p.

Grizzle JM, Brunner CJ (2009). Infectious diseases of freshwater mussels and other freshwater bivalve molluscs. *Reviews in Fishery Science* 17(4): 425–467.

Hine MP (1997). Health status of commercially important molluscs in New Zealand. *Surveillance* 24(1): 25–28.

Hine PM, Wesney B (1997). Virus-like particles associated with cytopathology in the digestive gland epithelium of scallops *Pecten Novaezelandiae* and toheroa *Paphies ventricosum*. *Diseases of Aquatic Organisms* 29: 197–204.

Howard DW, Smith CS (1983). Histological techniques for marine bivalve molluscs. *NOAA Technical Memorandum* NMFS-F /NEC- 25. United States Department of Commerce, Oxford, Maryland, United States of America, 102 p.

Humphrey JD, Norton JH, Jones JB, Barton MA, Connell MT, Shelley CC, Creeper JH (1998). Pearl oyster (*Pinctada maxima*) aquaculture: Health survey of Northern Territory, Western Australia and Queensland pearl oyster beds and farms. *Fisheries Research Development Corporation Final Report* 94/079, 108 p.

Johnston C (2008). Import risk analysis: Frozen, skinless and boneless fillet meat of *Oreochromis* spp. from China and Brazil for human consumption. Biosecurity New Zealand, Ministry of Agriculture and Forestry, Wellington, New Zealand, 95 p.

Jones JB (1975). *Nematopsis* n. sp. (Sporozoa: Gregarinia) in *Perna canaliculus.* Note. *New Zealand Journal of Marine and Freshwater Research* 9: 567–568.

Jones JB (2007). The Australian experience: pearl oyster mortalities and disease problems, pp 87–93 *In:* Bondad-Reantaso MG, McGladdery SE, Berthe FCJ (*Eds*.) Pearl oyster health management: a manual. *FAO Fisheries Technical Paper* No. 503, Food and Agriculture Organisation of the United Nations (FAO), Rome, Italy, 120 p.

Jones JB, Creeper J (2006). Diseases of pearl oysters and other molluscs: A Western Australian perspective. *Journal of Shellfish Research* 25: 233–238.

Kibenge FSB, Godoy M (2016). Picornalike viruses of mollusks, pp 525–531 *In:* Aquaculture Virology. Academic Press, New York, United States of America, 568 p.

Kitamura SI, Jung SJ, Suzuki S (2000). Seasonal change of infective state of marine birnavirus in Japanese pearl oyster *Pinctada fucata. Archives of Virology* 145: 2003–2014.

Kleeman SN, Adlard RD (2000). Molecular detection of *Marteilia sydneyi*, pathogen of Sydney rock oysters. *Diseases of Aquatic Organisms* 40: 137–146.

Kurita J, Nakajima K (2012). Megalocytiviruses. *Viruses* 4(4): 521–538.

Lopez C, Darriba S, Navas JI (2012). Chapter 5 clam symbionts, pp. 107 – 148 *In*: da Costa Gonzalez, F (*Ed*.) Clam fisheries and aquaculture. Nova Science Publishers Inc., New York.

MAF (2004). Import health standard for the importation into New Zealand of nonviable animal specimens from all countries. Biosecurity New Zealand, Ministry of Agriculture and Forestry, Wellington, New Zealand. Available from https://www.mpi.govt.nz/dmsdocument/1840-preserved-animal-specimens-from-all-countries-import-health-standard [Accessed 9 March 2018].

MAF (2005). Import Risk Analysis: Non-viable biological products, microorganisms and cell cultures. Biosecurity New Zealand, Ministry of Agriculture and Forestry, Wellington, New Zealand, 73 p.

Mendenhall M, Russell A, Juelich T, Messina EL, Smee DF, Freiberg AN, Holbrook MR, Furata Y, de la Torre JC, Nunberg JH, Gowen BB (2011). T-705 (Favipiravir) inhibition of Arenavirus replication in cell culture. *Antimicrobial Agents and Chemotherapy* 55(2): 782–787.

Meyers T (2014). Policies and guidelines for Alaska fish and shellfish health and disease control. Alaska Department of Fish and Game, *Regional information report* no. 5J14-04, Anchorage, Alaska, 55 p.

Meyers TR, Burton T, Evans W, Starkey N (2009). Detection of viruses and virus-like particles in four species of wild and farmed bivalve molluscs in Alaska, USA, from 1987 to 2009. *Diseases of Aquatic Organisms* 88: 1–12.

Möller M, Schünadel L, Nitsche A, Schwebke I, Hanisch M, Laure1 M (2013). Evaluation of virus inactivation by formaldehyde to enhance biosafety of diagnostic electron microscopy. *Viruses* 7(2): 666–679 [Online] Available from http://www.doi: 10.3390/v7020666 [Accessed 9 March 2017].

Molloy SD, Pietrak MR, Bricknell I, Bouchard D (2013). Experimental transmission of infectious pancreatic necrosis virus from the blue mussel, *Mytilus edulis*, to cohabitating Atlantic salmon (*Salmo salar*) smolts. *Applied and Environmental Microbiology* 79(19): 5882–5890 [Online] Available from: http://www.doi:10.1128/AEM.01142-13 [Accessed 12 March 2018].

MPI. 2008. *Import Risk Analysis: Fish Food.* Biosecurity New Zealand, Ministry of Agriculture and Forestry, Wellington, New Zealand, 69 p.

OIE (2017a). Aquatic animal health code (2017 Edition). World Organisation for Animal Health (OIE), Paris, France [Online] Available from: http://www.oie.int/en/about-us/director-general-office/ [Accessed 9 March 2018].

OIE (2017b). Manual of diagnostic tests for aquatic animals (2017 edition). World Organisation for Animal Health (OIE), Paris, France [Online] Available from: http://www.oie.int/en/international-standard-setting/aquatic-manual/access-online/ [Accessed 9 March 2018].

Read GB (2010). Comparison and history of *Polydora websteri* and *P. haswelli* (Polychaeta: Spionidae) as mud-blister worms in New Zealand shellfish. *New Zealand Journal of Marine and Freshwater Research* 44(2): 83–100.

Rush N, Kelly M (2017). Splendid sponges - A guide to the intertidal sponges of new Zealand. Identification guides and fact sheets. NIWA, National Institute for Water and Atmospheric Research, Auckland, New Zealand. [Online] Available from: https://www.niwa.co.nz/static/web/ MarineIdentificationGuidesandFactSheets/ Splendid_Sponges_Intertidal_Version_1.0_2017.pdf [Accessed 12 March 2018].

Rivas C, Bandin I, Cepeda C, Dopazo CP (1994). Efficacy of chemical disinfectants against Turbot Aquareovirus. *Applied and Environmental Microbiology* 60(6): 2168–2169.

Salk JE, Gori JB (1960). A review of the theoretical, experimental and practical considerations in the use of formaldehyde for the inactivation of poliovirus. *Annals of the New York Academy of Science* 83: 609–637.

Starliper CE, Villella R, Morrison P, Mathias J (1998). Studies on the bacterial flora of native freshwater bivalves from the Ohio River. *Biomedical Letters* 58: 85–95.

Starliper CE (2011). Pathogens and diseases of freshwater mussels in the United States: studies on bacterial transmission and depuration, pp 47–55 *In*: Cipriano RC, Bruckner AW, Shchelkunov IS (*Eds*.) *Bridging America and Russia with Shared Perspectives on Aquatic Animal Health*. Proceedings of the Third Bilateral Conference between Russia and the United States, 12-20 July, 2009, Shepherdstown, West Virginia.

Suong NT, Webb S, Banks J, Wakeman KC, Lane H, Jeffs A, Brosnahan C, Jones B, Fidler A (2017). Partial 18S rRNA sequences of apicomplexan parasite 'X' (APX), associated with flat oysters *Ostrea chilensis* in New Zealand. *Diseases of Aquatic Organisms* 127(1): 1–9. [Online] Available from http://www.doi: 10.3354/dao03175 [Accessed 8 March 2018].

Tan TL, Paul-Pont I, Evans OM, Watterson D, Young P, Whittington R, Fougerouse A, Bichet H, Barnes AC, Dang C (2015). Resistance of black-lip pearl oyster, *Pinctada margaritifera*, to infection by Ostreid herpes virus 1µvar under experimental challenge may be mediated by humoral antiviral activity. *Fish and Shellfish Immunology* 44(1): 232–240 [Online] Available from: http://www.doi: 10.1016/j.fsi.2015.02.026 [Accessed 14 March 2018].

Tubbs L, Lee P, Diggles B, Jones JB, Sheppard M, Sim-Smith C (2007). A review of aquatic diseases of significance to New Zealand. Final Research Report for MAF Biosecurity New Zealand. NIWA Project No. ZBS 2005-17, 461 p.

Underwood BO, Smale CJ, Brown F, Hill BJ (1977). Relationship of a virus from *Tellina tenuis* to Infectious Pancreatic Necrosis Virus. *Journal of General Virology* 36: 93–109.

Vazquez N, Rodriguez F, Ituarte C, Klaich J, Cremonte F (2010). Host-parasite relationship of the geoduck *Panopea abbreviata* and the green alga *Coccomyxa parasitica* in the Argentinean Patagonian coast. *Journal of Invertebrate Pathology* 105: 254–260.

Wada KT (2003). Okoya oyster disease-disease card. Developed to support the NACA/FAO/OIE regional quarterly aquatic animal disease (QAAD) reporting system in the Asia-Pacific. NACA, Bangkok, Thailand, 3 p.

Wada KT (2007). The Japanese experience: pearl oyster mortalities and constraints, pp 95–101 *In:* Bondad-Reantaso MG, McGladdery SE, Berthe FCJ (*Eds*.) Pearl oyster health management: a manual. *FAO Fisheries Technical Paper* No. 503, Food and Agriculture Organisation of the United Nations (FAO), Rome, Italy, 120 p.

Webb S (2008). Pathogens and parasites of the mussels *Mytilus galloprovincialis* and *Perna canaliculus*: Assessment of the threats faced by New Zealand aquaculture. *Cawthron Report* No. 1334. Cawthron Institute, Nelson, New Zealand, 36 p.

WORMS (2018). World register of marine species. Flanders Marine Institute (VLIZ) [Online] Available from: http://www.marinespecies.org/ [Accessed 20 March 2018].

Wu X, Pan J (1999). Studies on *Rickettsia*–like Organism disease of the tropical marine pearl oyster. Part 1: The fine Structure and morphogenesis of the *Pinctada maxima* pathogen (*Rickettsia*–like Organism). *Journal of Invertebrate Pathology* 73(2): 162–172.

Zhong L, Xiao TY, Huang J, Dai LY, Liu XY (2011). Histopathological examination of bivalve mussel *Hyriopsis cumingii* Lea artificially infected by virus. *Acta Hydrobiolica. Sinatica* 35: 666–671.