Import risk analysis: Ornamental Fish

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Approved for general release

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EXECUTIVE SUMMARY

This risk analysis has been undertaken to review and evaluate the current state of knowledge of diseases of the ornamental fish species listed in the Import Health Standard for the Importation into New Zealand of Ornamental Fish and Marine Invertebrates from all Countries (issued pursuant to Section 22 of the Biosecurity Act 1993).

The permitted list of freshwater ornamental species comprises 178 genera and 99 species (total 277 taxa). The list of permitted marine species comprises a further 113 genera and 4 species (total 117 taxa). From this list of 394 taxa a comprehensive host and disease based hazard identification process identified over 500 parasites and disease agents for consideration in the risk assessment. These diseases and parasites were then sorted further, using various qualifying criteria, to eliminate many of the insignificant or irrelevant diseases and parasites to provide a concise list of relevant disease agents and parasites to be considered in the risk assessment. A total of 35 parasites and disease agents fulfilled the qualifying criteria and were included in the main risk assessment. The risk assessment qualitatively assessed the risks involved with each of these disease agents, to determine whether current risk mitigation methods in use for ornamental fishes are adequate, or whether additional risk management is warranted.

The following recommendations are made:

1. That temperate and sub-tropical cyprinids (the genera *Barbus, Puntius, Varicorhinus, Barbodes* and *Capoeta*) should no longer be eligible for import.

2. That Biosecurity New Zealand and ERMA determine which species of ornamental fish were in New Zealand before July 1998. Those not present before July 1998 should not be eligible for import unless approved by ERMA as a new organism.

3. That the post-arrival quarantine period should be consistent for both freshwater and marine species.

4. That Biosecurity New Zealand develop appropriate training resources about the identification of fish species and the diagnosis of key diseases for MAF Quarantine Services Biosecurity Officers, supervisors and operators of Transitional Facilities.
5. That Biosecurity New Zealand work with the Department of Conservation to inform the Federation of New Zealand Aquatic Societies of the need to actively discourage their members from releasing unwanted fish into the wild.
6. That Biosecurity New Zealand work with the Ministry of Health to inform retail outlets selling ornamental fish of potential public health issues.
7. That targeted passive surveillance be conducted for the following disease agents: aquabirnaviruses, iridoviruses, grouper nervous necrosis virus, viral haemorrhagic septicaemia, *Edwardsiella ictaluri, Edwardsiella tarda, Lactococcus garvieae*, *Aphanomyces invadans, Enteromyxum leei, Glugea heraldi*, *Bothriocephalus acheilognathi*, *Capillaria philippinensis* and *Argulus foliaceus*.
8. That when cumulative mortalities of 20% or greater occur among any species of imported ornamental fishes during quarantine, suitable samples (moribund, freshly dead, or 10% formalin-fixed) must be sent to the Investigation and Diagnostic Centre (IDC) of Biosecurity New Zealand, or a laboratory regarded by them as competent.
9. That the post-arrival quarantine period may be reduced for both freshwater and marine fish from 6 weeks to 4 weeks, provided that consignments are accompanied by an international aquatic animal health certificate for live fish, signed by the competent authority in the exporting country, stating that the fish are free from specified disease agents or are sourced from populations or zones free from specified disease agents.
10. That for consignments where the post arrival quarantine period is reduced to 4 weeks, the cutoff cumulative mortality rate for the taking of samples be reduced to 10%.
11. That aquarium water from the quarantine period must be disinfected prior to disposal.

GLOSSARY OF TERMS

Acute	A rapid onset of disease with a short, but severe, course.
Anaemia	A deficiency in the number of red blood cells, or haemoglobin.
Apicomplexan	A group of obligate pathogens including *Toxoplasma gondii* (causes coccidiosis) and *Plasmodium* (causes malaria).
Asymptomatic carrier	An individual infected with a disease agent, but not exhibiting any signs of disease.
Atrophy	Abnormally small size of cells or tissues.
Bacteria	Unicellular (rarely multicellular) organisms which lack a membrane bound nucleus (i.e. prokaryotes).
Benign	Harmless.
Chronic	Lingering, long lasting.
Definitive host	The host in a parasite lifecycle where reproduction of the adult parasite occurs.
Endemic	A species, either native or introduced, currently present in New Zealand.
Enteritis	An infection of one or more parts of the gut.
Exotic	Of foreign origin, not native or endemic.
Granulomatous	A type of cellular reaction associated with a chronic lesion.
Haematopoietic	Tissues that produce red blood cells .
Horizontal transmission	Transmission of disease from animal to animal by cohabitation or via water.
Hypertrophy	Increase in the size of cells or tissues.
Intermediate host	A host in a parasite lifecycle in which the parasite does not undergo sexual reproduction
Introduced	A species which has been introduced into New Zealand by humans
Lesion	A localised area of pathological change in structure of an organ, tissue, or cell.

Moribund	Near death.
Native	A species for which its presence in New Zealand predates human habitation.
Necrosis	Cell or tissue death.
OIE	Office International des Epizooties, the World Animal Health Organization, based in Paris, France.
Parasite	An organism which lives on or inside another organism (the host), deriving nutrition from the host to the detriment of that host.
Pathology	The study of structural and functional changes caused by disease.
Prepatent	Period early in a disease process when disease cannot be detected.
Presumptive diagnosis	A tentative or provisional identification of the cause of a disease based on limited information.
Protozoan	A unicellular organism with a membrane bound nucleus.
Reservoir host	A host in which a disease agent normally resides and can act as a vector
Septicaemia	An infection of the bloodstream.
Targeted passive surveillance	Certain disease agents on a priority list are specifically looked for whenever there is an outbreak of disease in aquarium fishes. Educational materials developed for the industry focus on these disease agents to increase awareness among fish importers and aquarists .
Vertically transmitted	Transmission of disease from adults to offspring through the egg or sexual fluids.
Vector	A living organism that carries disease causing organisms to new hosts.
Virus	Tiny organisms consisting of nucleic acid (RNA or DNA) surrounded by a protein or protein/lipid coat, which infect cells of bacteria, plants and animals, using the host cell machinery for replication.
Zoonotic	Diseases of animals which can also infect humans.

1. INTRODUCTION

The global industry in ornamental fishes is unique in that while many countries impose strict requirements on nearly all imported animal and plant products, live ornamental fish are commonly imported in large volumes without similar controls.

In New Zealand, importations of ornamental fish are controlled by having lists of permitted genera and species of freshwater and marine fishes, under the Biosecurity Act 1993[1]. All other genera and species are not permitted entry, however there is evidence that a broader variety of species than that in the approved list is arriving here, via the official and approved channels for importations (McDowall 2004). Since the introduction of the Hazardous Substances and New Organisms Act 1996, any applications for genera or species that were not in the country before July 1998, or which are not on the permitted list, have been dealt with by the Environmental Risk Management Authority (ERMA). The genera and species on the original permitted lists were generally those considered unlikely to become established in New Zealand, usually because most were tropical species that could not survive the New Zealand temperate climate. However, geothermal streams in the central North Island simulate tropical streams, and now at least 4 species of tropical ornamental fish (guppies *Poecilia reticulata*, sailfin mollies *Poecilia latipinna*, swordtails *Xiphophorus helleri*, and caudo *Phallocerus caudimaculatus*) are resident there or in northland (New Zealand Freshwater Fish Database, 2005). Global warming may also increase the likelihood of establishment of warm water fishes in temperate countries such as New Zealand (McDowall 2004).

The permitted lists do not contain many temperate species, and they exclude goldfish (*Carassius auratus*) and carp (*Carassius* spp., *Cyprinus* spp.). There are good reasons for these exclusions. Goldfish carry IPN-like (VR299) virus (Hedrick et al. 1985), goldfish virus 1 iridovirus and goldfish virus 2 iridovirus (Berry et al. 1983), herpesviral haematopoietic necrosis virus (Jung and Miyazaki 1995), infectious spleen and kidney necrosis virus (He et al. 2002), and *Rhabdovirus carpio* (spring viraemia of carp – SVC) (Alexandrino et al. 1998). They also carry atypical *Aeromonas*

[1] http://www.biosecurity.govt.nz/imports/animals/standards/fisornic.all.htm

salmonicida (see Yamada et al. 2000), *Yersinia ruckeri,* (see McArdle and Dooley-Martyn 1985), *Mycobacterium* spp. (see Anderson et al. 1987), *Rosculus ithacus* and *Vannella platypodia* (systemic amoebiases) (Dyková et al. 1996, Diggles et al. 2002), *Hoferellus carassii* (cystic kidney disease) (Molnar et al. 1989) and numerous helminths. Koi carp (*Cyprinus carpio*) may also harbour aquabirnaviruses (Humphrey 1995), herpesviruses (Hedrick et al. 2000), iridoviruses (Shchelkunov and Shchelkunov 1990), the zoonotic bacterium, *Edwardsiella tarda* (see Sai-Oui et al. 1984) and *Mitraspora cyprini* (kidney bloater disease) (Kovacs-Gayer et al. 1987). Interestingly, despite the importation of goldfish probably throughout the 20th century up to 1972, and of koi carp since the 1960s (McDowall 1990), relatively few of their parasites or disease agents have been recorded in New Zealand (Table 1.1). Several parasites arrived on and in 2,000 grass carp (*Ctenopharygodon idella*) imported from Hong Kong for weed control in 1972, but they were eradicated in quarantine (Edwards and Hine 1974). In contrast, many more disease agents have entered Australia and become established (Table 1.1). Australia permits the importation of goldfish, for which there is a 3 week quarantine period, whereas New Zealand has a ban on goldfish and carp, a 6 week quarantine for all other freshwater ornamental fish entering the country, and a 3 week quarantine period for all marine species on the permitted list.

It is widely recognised that ornamental fish have caused the spread of common parasites and diseases, such as ectoparasitic lice, anchor worms, white spot ("Ich"), *Cryptobia,* etc, that are well known to ornamental fish specialists (Thilakaratne et al. 2003). Their potential to spread more serious parasites and diseases, which should they be introduced may have a devastating impact on the native fishes of the importing country, is a more contentious issue. However there are many examples of disease transfer in the past (McCann et al. 1996, Langdon 1990, Humphrey and Ashburner 1993), and the evidence that ornamental fishes and the water used to transport them (Trust and Bartlett 1974) can act as vectors for viruses and other pathogens of national and international significance continues to increase.

For example, a 1977 survey of pet fishes in Florida, USA revealed 59% of all fishes carried pathogenic bacteria, 44% had ecologically related diseases, 35% carried protozoans, 28% carried trematodes, 13% carried nematodes, 2% carried dinoflagellates, 2% carried hirundineans, 2% carried crustaceans, 2% carried insects, and 2% had hereditary abnormalities (Meryman 1978). More than 95% of the new infectious fish diseases in Florida are found in newly imported shipments of fish (Meryman 1978). In Europe, populations of the endangered European cyprinid *Leucaspius delineatus* are being threatened by disease due to a rosette-like intracellular parasite introduced via apparently healthy specimens of the Asian cyprinid *Pseudorasbora parva* (see Gozlan et al. 2005).

In examples from Australia, atypical strains of the bacterial fish pathogen *Aeromonas salmonicida* were introduced through importation of infected goldfish *Carassius auratus* (see Humphrey and Ashburner 1993), and subsequently spread to other species including trout, carp and silver perch. The viral disease epizootic haematopoietic necrosis (EHN) is an OIE-listed disease that causes epizootics among redfin perch (*Perca fluviatilis*) (see Langdon et al. 1986), and to a lesser extent rainbow trout (*Oncorhynchus mykiss*) (see Langdon et al. 1988) and a range of other Australian native fishes (Langdon 1989). It was recognised as being unusual in causing the greatest mortalities to a fish species (*P. fluviatilis*) that had been introduced into Australia, and it was shown to belong to the frog iridovirus genus *Ranavirus* (see Hyatt et al. 2000). However, iridoviruses isolated from ornamental fish (*Poecilia reticulata, Labroides dimidatus*) entering Australia are closely related to the EHN virus, leading Hedrick and McDowell (1995) to speculate that EHN may have entered Australia in ornamental fish. *Edwardsiella ictaluri*, an OIE-listed bacterial pathogen that causes enteric septicaemia in catfish, and which is pathogenic to chinook salmon by immersion exposure for 30 seconds (Baxa et al. 1990), has been isolated from Siamese fighting fish (*Betta splendens*) entering Australia (Humphrey et al. 1986). *Edwardsiella tarda,* which can cause severe disease in humans and other vertebrates including fish, has been isolated from *Puntius conchonius* entering Australia (Humphrey et al. 1986). *Chilodonella hexasticha,* which is exotic to Australia, has been introduced, probably on exotic cyprinids, and it has subsequently caused epizootics in Australian native fishes (Langdon et al. 1985).

As recently as March 2005 Biosecurity Australia (2005) recognised that imported gouramis (subfamily Trichogastrinae of the family Osphronemidae), although having been imported into Australia over several decades without any known adverse consequences, harboured exotic strains of iridovirus (namely gourami iridovirus (GIV)). GIV was detected in several species of diseased ornamental gouramis sourced from a pet shop. In experimental cohabitation trials, the virus was transmitted to Murray cod (*Maccullochella peelii peelii*), a native fish, causing mortalities of 36.6% within 28 days (Go et al. 2005). Furthermore, intraperitoneal injection of organ filtrates from infected gouramis caused 96.6% mortality of Murray cod within 28 days (Go et al. 2005). This information has lead to Biosecurity Australia undertaking a re-assessment of the quarantine risk associated with imports of freshwater ornamental finfish with respect to iridoviruses (Biosecurity Australia 2005).

The non-host specific, pathogenic, Asian nematode *Camallanus cotti,* has spread in Southeast Asia, and been introduced into Europe, North America, Hawaii and Australia with the trade in ornamental fish, particularly guppies (*Poecilia reticulata*) (see Levsen and Berland 2002a, Levsen and Jakobsen 2002). Examination of guppies imported into Korea showed 14.4% prevalence (Kim et al. 2002b), and in those entering Australia the prevalence was 48% (Evans and Lester 2001). It caused 30% mortalities following introduction into an ornamental fish farm in Korea, where it infected 71% of the cultured fishes (Kim et al. 2002a). *Camallanus cotti* normally uses planktonic copepods as intermediate hosts, but if they are not present, it can infect directly, fish-to-fish (Levsen and Jakobsen 2002). After guppies were introduced into Hawaii for mosquito control, *C. cotti* jumped host into 5 native fish species, including an eleotrid (*Eleotris sandwicensis*) (see Font and Tate 1994, Font 1998), and New Zealand freshwater bullies (*Gobiomorphus* spp.) are eleotrids. It is so non-host specific that it has been reported from a marine stingray (Rigby et al. 1997).

The Asian tapeworm, *Bothriocephalus acheilognathi* (= *B. gowkongensis*) originated in China, but in the 20th century spread to Hawaii (Font and Tate 1994, Font 1998), North and Central America (Salgado-Maldonado et al. 1986, Hackmann et al. 1993, Clarkson et al. 1997), Australia (Evans and Lester 2001), Belorussia (Emel'yanov 1971), and Europe (Andrews et al. 1981, Denis et al. 1983). It originally infected Asian cyprinids, but it now infects a wide range of cyprinids globally, and like *C. cotti* in Hawaii it has jumped host into native gobiids and *E. sandwicensis* (see Font and

Tate 1994, Font 1998). It also infects Australian native eleotrids (*Hypseleotris klunzingeri, Phylipnodon grandiceps*) and *Retropinna semoni,* which is closely related to the New Zealand smelt, *Retropinna retropinna* (see Dove et al. 1997, Dove 1998, Dove and Fletcher 2000). In Arizona, U.S.A., it has jumped host into humpback chub (*Gila cypha*), an endangered cyprinid (Brouder and Hoffnagle 1997). It entered New Zealand in grass carp but was eradicated in quarantine (Edwards and Hine 1974).

Although some of the spread of *B. acheilognathi* may be due to movement of ornamental fish, some would have been moved with the movement of fish for aquaculture and human consumption. The movement of fish for aquaculture has played a significant part in the spread of fish diseases, but diseases and parasites are also spread by piscivorous birds, particularly herons (*Ardea, Egretta, Nycticorax*) (Table 1.2). Birds may also spread *Edwardsiella ictaluri* (see Taylor 1992), although the latter is not spread by herons (Waterstrat et al. 1999). Digenean flukes have been widely introduced globally throughout the tropics and sub-tropics by introduction of the snail intermediate host, *Melanoides tuberculata,* originally from east Africa (Pointier and Giboda 1999). While some of this spread may be due to international movements of ornamental fishes and aquatic plants (Madsen and Frandsen 1989), introductions have frequently been deliberate in order to control the serious human disease schistosomiasis (Pointier et al. 2000). *Melanoides tuberculata* out-competes other gastropods of the genus *Biomphalaria,* particularly *B. glabrata,* which acts as intermediate host of the digenean fluke *Schistosoma mansoni,* the cause of schistosomiasis. The use of *M. tuberculata* has not been entirely successful as it acts as intermediate host of several other digeneans that infect humans, such as *Clonorchis sinensis, Centrocestus formosanus,* and *Haplorchis pumilio* (see Scholz and Salgado-Maldonado 2000, Scholz et al. 2001, Wang et al 2002).

A summary of the introductions and transfers of parasites and other disease agents by finfish was completed by Ganzhorn et al. (1992). Not only fishes or eggs may be infected, but the water and the containers may also be contaminated and serve as vehicles for the introduction of pathogens. The risk of establishment of these parasites and disease agents depends on their biology, life cycle, the fate of the shipment, and the presence or absence of appropriate hosts in the receiving country (Ganzhorn et al. 1992).

The above examples show clearly there are risks of introduction of parasites and disease agents associated with the importation of live ornamental fishes into New Zealand. This risk analysis has been produced to assess these risks, and discuss the implementation of various risk mitigation methods to reduce risks associated with importation of diseases into New Zealand via ornamental finfish, in light of current knowledge of diseases of cultured and ornamental fishes worldwide.

1.1 Quarantine and stressors related to capture and transport

Currently the quarantine period for freshwater ornamental fish entering New Zealand is 6 weeks, while that for marine ornamental fish is 3 weeks. Both are relatively long time periods compared to other countries. For example, the quarantine period for goldfish entering Australia is only three weeks, for gouramis and cichlids its two weeks, and for all other species it is one week (AQIS 1999a). There are many variations in the handling and holding of ornamental fish between the time of capture and their arrival in the importing country. Fish may be captured from natural waters, held until there are sufficient numbers to take to a middleman, then they may be taken to an exporter, flown to an international trading centre, such as Singapore, and then exported to the recipient country (Ferraz and Araujo 1999). Alternatively fish may be taken from the wild and cultured under confinement, the fish for export going directly to the exporter. Most fish that are traded are tropical, and many of the countries from which they are taken are developing countries lacking a modern rapid-transport infrastructure. If the fisher takes a week to accumulate sufficient fish for export, it then takes 2 days transport overland to deliver them to the middleman, a further 2 days transport to the exporter, total 11 days. If they arrive at the international centre 2 days later, they are held 4 days during which fish are sorted and graded, and it takes a further 2 days before arrival in the recipient country, making a total of 19 days. If the fisher takes 1 day to catch the fish, 2 days to get them to the exporter, 2 days for sorting and grading, and 2 days to get to the importing country, that adds another 7 days. Adding 7-19 days to a 3 week quarantine period, gives 28-40 days between capture and release from quarantine. Adding 7-19 days to a 6 week quarantine period, gives 49-61 days.

During this period the fish will have been stressed by capture, handling, crowding, transport, and poor water quality. Capture stress causes elevation of plasma cortisol levels in coral trout (*Plectropomus leopardus*) (see Frisch and Anderson 2000) and coral reef fish (*Hemigymnus melapterus*) (see Grutter and Pankhurst 2000). Similarly, handling (Mazur and Iwama 1993, Frisch and Anderson 2000, Grutter and Pankhurst 2000, Georgiadis et al. 2001, Shrimpton et al. 2001), and crowding (Mazur and Iwama 1993, Yin et al. 1995, LaPatra et al. 1996), elevate plasma cortisol levels. Transport (Kodama et al. 1987, Frisch and Anderson 2000) and confinement (Wise et al. 1993, Ruane et al. 1999, Grutter and Pankhurst 2000, Kocan et al. 2001, Shrimpton et al. 2001), have the same effect. Disease may also cause elevation of plasma cortisol levels (Bowers et al. 2000, Ackerman and Iwama 2001). For some fish species close confinement that disturbs the hierarchy of ranking within the tank also stresses fish, raising cortisol levels (Iida and Kurogi 2001).

On perceiving the stress the brain stimulates the pituitary gland to release adrenocorticotropic hormone (ACTH), melanocyte stimulating hormone (MSH) and β-endorphin, which cause the interrenal cells in the kidney to produce cortisol. The cortisol mediates the inhibitory effects of stressors on the immune response, decreasing disease resistance (Houghton and Matthews 1990, Wendelaar Bonga 1997, Tully and Nolan 2002). There is a reduction in circulating lymphocytes (Ruane et al. 1999) and antibody production, proliferation of lymphoblastoid cells, and phagocytosis by mononuclear phagocytes (Pegg et al. 1995, Espelid et al. 1996, Tully and Nolan 2002). This not only makes the affected fish more susceptible to pathogens (Reddacliff et al. 1996, Davis et al. 2002), it discloses sub-clinical infections (Wise et al. 1993, Steinhagen et al. 1998, Taksdal et al. 1998, Antonio et al. 2000). Viral (Taksdal et al. 1998, Georgiadis et al. 2001), bacterial (Wise et al. 1993, Reddacliff et al. 1996), protozoan (Steinhagen et al. 1998, Davis et al. 2002), myxozoan (Schisler et al. 2000) and monogenean (Stoltze and Buchmann 2001) infections proliferate in fish under stress.

Just as elevated plasma cortisol due to stress makes fish more susceptible to disease, injecting cortisol has the same effect (Pegg et al. 1995, Harris et al. 2000, Iida and Kurogi 2001). Caution must, however, be exercised as under some circumstances cortisol may elevate phagocytosis (Pegg et al. 1995). Immunosuppression during a primary response may not affect susceptibility to a second challenge (Steinhagen et al. 1998), and one study found that stress improved blood clotting time and immune function (Ruis and Bayne 1997). Increases in plasma cortisol may increase susceptibility to one pathogen, but not another (Davis et al. 2002). Basal plasma cortisol may differ at times in the life cycle, such as in marine and freshwater stages, and the degree of cortisol elevation under stress may also differ (Shrimpton et al. 2001).

The time a disease may take to run its course depends on the host species and genotype, the disease agent and its genotype, environmental conditions, the presence of other infections, the initial general health of the fish, and the prevalence and intensity of the pathogen in the affected stocks. When Atlantic salmon (*Salmo salar*) stressed by water drainage were injected with IPNV and then co-habited with uninfected salmon, the injected salmon died after 5-6 days and the cohabitants after a further 5-6 days (Taksdal et al. 1998). Rohu (*Labeo rohita*) stressed by crowding may develop columnaris at 24 hours with mortalities at 36 hours, continuing for over 7 days (Kumar et al. 1986). Carp (*Cyprinus carpio*) stressed by crowding and challenged by *Aeromonas hydrophila* had elevated cortisol for over 30 days, but levels peaked at 7 days, and the carp appeared to adapt to the stress thereafter (Yin et al. 1995). Studies on plasma cortisol levels in stressed fish show they may be elevated for over 6 days in handling and confinement stressed gilthead sea bream (*Pagrus aurata*) (see Cubero and Molinero 1997), or for over 21 days after infection of Atlantic salmon (*Salmo salar*) with sea lice (*Lepeophtheirus salmonis*) (see Bowers et al. 2000).

Epizootics occurred in stressed white sturgeon (*Acipenser transmontanus*) 9-32 days after handling stress (Georgiadis et al. 2001). Rainbow trout (*Oncorhynchus mykiss*) mortalities peaked at 85%, 80 days after being introduced into seawater (Castric and de Kinkelin 1980). Confinement stress resulted in 43% prevalence in stressed channel catfish (*Ictalurus punctatus*) challenged with *Aeromonas hydrophila,* but only 7% infection among unstressed control groups (Walters and Plumb 1980). Similar results were obtained when *I. punctatus* were stressed by confinement, then challenged with *Edwardsiella ictaluri* (see Wise et al. 1993). Japanese flounder (*Paralichthys olivaceus*) experienced >80% mortalities two weeks after transport stress (Kodama et al. 1987), and tilapia (*Oreochromis niloticus*) stressed by poor water quality experienced 73.3% mortalities due to *Streptococcus iniae*, whereas 46.6% of unstressed fish died (Radwan 2002).

Over a period of 49-61 days, the length of time that passes between initial capture and final purchase is also important. Many diseases may run their course over that period, but other diseases may continue after the fish is introduced into the country. Time course will also depend on the type of exposure to the pathogen (immersion, feeding, vectors), the challenge dose, the degree of stress (capture, transport, handling, crowding), and temperature. In many cases the initial prevalence of the organism may equate to the challenge dose. If the initial prevalence of the organism is low, and the organism transmits directly and horizontally, it will take longer for the organism to build up to epizootic levels than if the initial prevalence is high.

Putting together the information on the stress response of different species of fish, and the time courses of diseases in the published literature, it appears very likely that many diseases would run their courses well before the end of the 6 week quarantine period. The frequent initial mortalities after capture (Ferraz and Araujo 1999), and improvements within the ornamental fish industry (Coles et al. 1999), such as improvements in water treatment (Teo et al. 1989), reduce the risk further.

1.2 Constraints

A number of problems were encountered when applying the standard animals risk analysis framework of the OIE to ornamental fish.

1. The taxonomy of ornamental fish species is in flux and therefore fish species may be placed in more than one genus.

2. The taxonomy of the parasites and pathogens of ornamental fish is also often uncertain, with species being lumped together one minute, and split the next.

3. Many ornamental fish species originate from developing countries, which lack scientific training and expertise on fish diseases.

4. When reports of fish parasites and diseases in developing countries are published, they are often in publications that are very difficult, usually impossible, to obtain, and they are written in the national language.

5. The only method available for access to the abstracts of obscure papers is to use computerised databases, which usually miss out several papers. The abstracts also often lack the details necessary to draw conclusions.

6. A large percentage of such papers are purely taxonomic.

7. Tropical fish are traded in such a way that batches from different sources are continually being mixed and it is therefore often impossible to know the origin of imported fish.

8. Relatively little is known about the endemic parasite fauna of New Zealand fishes, and therefore it is difficult to determine whether a parasite species, found for the first time, is exotic.

However, in the latter case, some parasites outside their normal geographical distribution, and some confirmed exotic introductions, can be recognised in the Australian and New Zealand freshwater fish faunas (Table 1.1).

The study used *Fishbase* (www.fishbase.org) to determine the taxonomy of many fish species. This database showed the chaotic, confusing, and ever changing taxonomy of tropical ornamental fishes. The permitted list for New Zealand is now very out-of-date, and needs major revision. Even though Fishbase can cope with minor mis-spellings, it was not possible to retrieve information on *Balanteocheilus* spp., *Ctneops* spp., *Dermogenyus* spp., *Poecilistes* spp., and *Stoniella* spp. on the freshwater list, and *Aspidontis* spp., *Eupornacentris* spp., and *Tetrachaetodon* spp. on the marine list. Furthermore, several names on the list are mis-spelt (*Jordanella* not *Jordinella, Nannacara* not *Nannocara, Amphiprion* not *Amphriprion, Histrio* not *Histro, Oxymonacanthus* not *Oxymoncanthus, Rhinomuraena* not *Rhinomaraena, Tetraodon,* not *Tetraodron*).

2. RISK ANALYSIS METHODOLOGY

The process of Risk Analysis comprises three components – Hazard Identification, Risk Assessment and Risk Management – related to one another as shown in Figure 1.

2.1 Hazard Identification

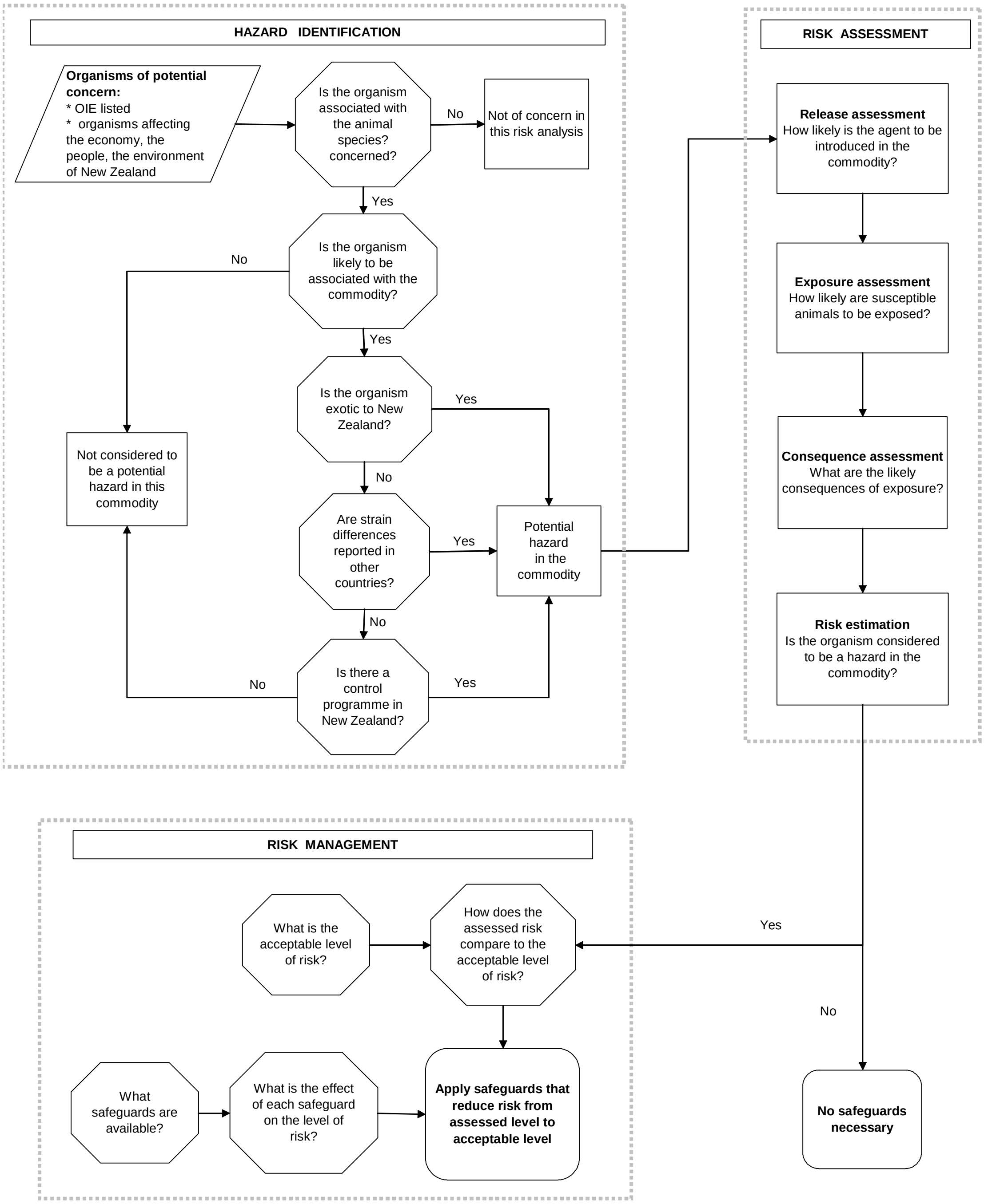
The initial step in a risk analysis is to identify the diseases and parasites of potential concern in the commodity under consideration. This process, hazard identification, must be relevant to the fish species that are permitted entry into a country, and to the fish species that occur in that country's waters. A disease agent was given detailed consideration if it was assessed to be:-

1. Carried by a fish species on the permitted list*; and
2. Infectious; and
3. Exotic to New Zealand; and
4. (a) OIE-listed**, and/or
   (b) likely to cause significant harm in New Zealand.

* This was considered as a host-based approach.
** This was considered a disease-based approach (after AQIS 1999b)

As mentioned previously (Section 1.2 above), there is relatively little information on the parasites (Hine et al. 2000) and diseases (Diggles et al. 2002) present in New Zealand fishes, and this might compromise identification of a particular pathogen as 'exotic'. However, serious parasites and diseases make their presence felt as they are by definition serious, and situations in which the presence of an organism in New Zealand is inconsistent with the global distribution of that organism, permit their identification as exotic (Table 1.1). For the purposes of this risk analysis, any parasite or disease that was identified under 'Hazard identification', that was unreported from New Zealand, was regarded as exotic. However, if a strain of an organism was different from a strain of the organism that was known to occur in New Zealand, this was also regarded as exotic. This risk analysis is qualitative rather than quantitative, because of the dearth of information on many of the diseases and parasites.

Figure 1. The risk analysis process.



An organism was regarded as likely to cause significant harm, and would therefore be a hazard, in New Zealand if it satisfied one or more of the following criteria:

1. it would be expected to cause a distinct pathological effect in a significant proportion of an infected population; and/or
2. it would be expected to cause significant economic harm (e.g. increased mortality, reduced growth rates, decreased product quality, loss of market access, increased management costs; and/or
3. it would be expected to cause significant damage to the environment and/or endemic species (an endemic species was defined as either a native species of fish that occurs in New Zealand waters naturally, or which was introduced into New Zealand, but which is now considered to be acclimatised).
4. it is known to cause a threat to human health.

2.2 Risk assessment

Once the diseases of concern had been identified, a risk assessment was carried out on each parasite or disease, and where parasites have very similar life cycles, a generic risk assessment was carried out. The risk analysis method used addressed both of these in a standardised manner to allow consistency in the overall approach to risk assessment, as follows:-
For each organism in the initial hazard list, the epidemiology is discussed, including a consideration of the following questions:

1. whether the various commodities could potentially act as a vehicle for the introduction of the organism,
2. whether it is exotic to New Zealand but likely to be present in exporting countries,
3. if it is present in New Zealand,
    a) whether it is "under official control", which could be by government departments, by national or regional pest management strategies or by a small-scale programme, or
    b) whether more virulent strains are known to exist in other countries.

For any organism, if the answers to questions one and either two or three are ‘yes’, it is classified as a potential hazard.

Following the OIE methodology, for each potential hazard, the risk assessment consists of the following steps:

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

Not every one of the above steps will be necessary in all risk assessments. The OIE risk analysis guidelines point out that if the likelihood of release is negligible for a certain potential hazard, then the risk estimate is automatically negligible and the remaining steps of the risk assessment need not be carried out. The same situation arises where the likelihood of release is non-negligible but the exposure assessment concludes that the probability of establishment in the importing country is negligible, or where both release and exposure are non-negligible but the consequences of introduction are concluded to be negligible.

These factors were considered for each parasite or disease of concern to allow a qualitative assessment of the probability of disease establishment (release and exposure assessments) and the consequences (consequence assessment) if that disease became established. For risk estimation, both the probability of disease establishment and the consequences of establishment were considered together to determine whether the risk posed by the disease agent was negligible or non-negligible. More details on the processes followed for each step are included in the following sections.

2.2.1 Release assessment

Release assessment consists of describing the biological pathways necessary for an importation activity to 'release' or introduce a *hazard* into a particular environment, and estimating the likelihood of that complete process occurring (OIE 2002).
The probability of a disease agent entering and becoming established depends on:

- the probability of the disease agent being present in the source country/region, and if present, its prevalence,
- the probability of the disease agent being present in an infective form in the fish entering New Zealand,
- the probability of the disease agent being detected in quarantine.

The release assessment may require information on:-

Biological factors

- the species, strain or genotype and age of the aquatic animal,
- the strain of the agent,
- epidemiology of the agent,
- tissue sites of infection or contamination,
- testing, treatment and quarantine.

Country factors

- prevalence of infection,
- the certifying authority, surveillance and control programmes of the exporting country.

2.2.2 Exposure assessment

Exposure assessment involves the likelihood of the disease agent, having entered the industry or New Zealand natural waters, establishing infection in susceptible hosts in New Zealand. This depends on the capacity of the disease agent to survive in its environment in an infective form, and the ease of infection of susceptible hosts and subsequent transmission of infection to others within a population.

Factors that may need to be considered for ornamental fish importations include:

Biological factors

- presence of potential vectors or intermediate hosts,
- properties of the agent (e.g. virulence, pathogenicity, and survival parameters).

Country factors

- aquatic animals (presence of known susceptible and carrier species, and their distribution),
- terrestrial animals (scavengers, piscivorous birds),
- geographical and environmental characteristics (current, temperature ranges, water courses).

Many of the disease agents likely to be associated with ornamental fish are parasites, which may have complex life-cycles. However, the more complicated the life cycle, the less likely it is that a parasite may become established, as each stage in the life cycle has a probability attached to it. For example, for a parasite with a 3-host life-cycle, the overall probability of the parasite being transmitted between the definitive hosts is the probability that it will establish in the first intermediate host, times the probability that it will establish in the second intermediate host, times the probability that it will establish in the definitive host. Some examples of parasite life cycles are shown in Figure 2.

For zoonotic organisms, direct contact with humans involved in the aquarium trade is of course possible.

2.2.3 Consequence assessment

Consequence assessment consists of identifying the potential biological, environmental and economic consequences of disease introduction. A causal process must exist by which exposures to a hazard results in adverse human health, environmental, or socio-economic consequences (OIE, 2005). Examples of consequences relevant to ornamental fish are as follows:

Direct consequences:

- aquatic animal infection, disease, production losses and facility closures,
- adverse, and possibly irreversible, consequences to fisheries, the environment and/or human health.

Indirect consequences:

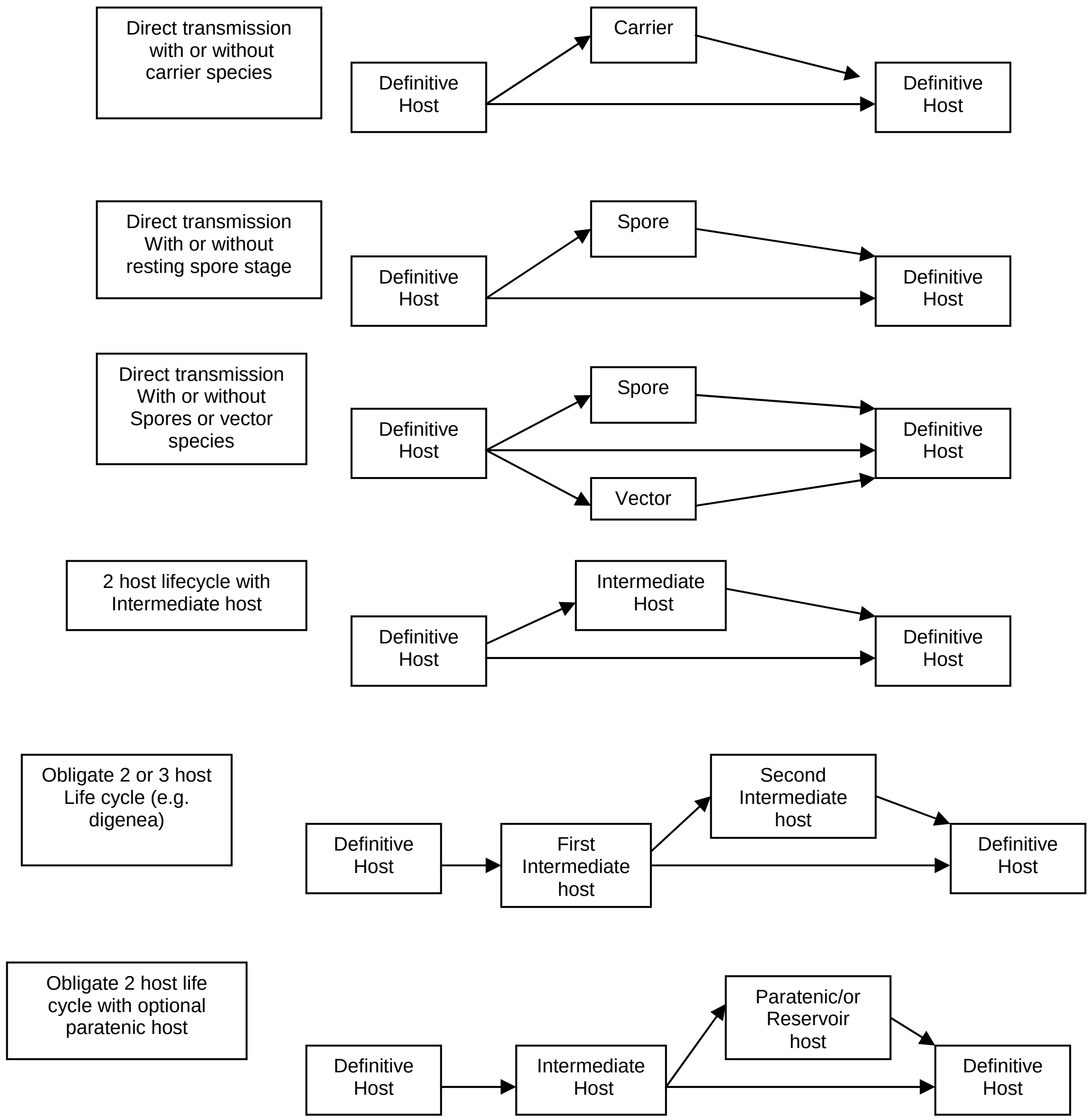
- surveillance and control costs,
- potential trade losses.

Where insufficient data were available on a parasite or disease agent, the precautionary approach was adopted, and evidence from similar disease agents was taken into account.

The key factors in classifying the significance of consequences of disease establishment were:-

1. The biological effects on aquatic species. The establishment of a new disease agent may have a biological effect and consequential effects on industry and the environment. The biological effect on establishment of disease is normally evaluated in terms of morbidity and mortality data reflecting epidemiological features of the disease. In general there is relatively little information on the parasites and diseases infecting ornamental fish and the epidemiology of those parasites or diseases. Therefore a qualitative approach was taken using the available information on similar pathogens, to determine a relative probability of an event occurring.
2. The availability, cost and effectiveness of methods for control/eradication.
3. The economic effects at an establishment/industry/national level, including effects on commerce and marketing.
4. The biological effects on endemic species of fish and other aquatic animals (e.g. amphibians), the environment (including any loss of social amenity) and human health.

Figure 2. Schematic examples of a variety of parasite life cycles.



2.2.4 Risk estimation

This final step involved with each assessment is to determine whether the extent of the risk presented by each disease agent to the New Zealand environment is sufficient to require additional risk management steps over and above those currently employed as the current status quo (which is essentially an extended period of quarantine). This iss done using a yes (non-negligible risk) or no (negligible risk) decision based on a combination of the qualitative answers given for the probability of establishment and the significance of the consequences of an introduction.

If the both the probability of establishment and the consequences of introduction were considered to be low or very low, it was considered the risk to New Zealand posed by the disease agent was negligible, and there was no need to implement any additional risk management steps over and above the status quo (Table 2.1). If the consequences of introduction were considered to be negligible, even a high probability of establishment was tolerated without the need for additional risk management. If the consequences of introduction were considered to be very low, a moderate probability of establishment was tolerated without the need for additional risk management. However if the consequences of introduction were considered to be low, a moderate probability of establishment was considered to represent a non-negligible risk requiring additional risk management. If the likelihood of establishment was considered to be high, or the consequences of introduction were considered moderate, high or catastrophic, then the risks of introduction of a parasite or disease agent were concluded to be non-negligible, requiring additional risk management steps.

2.3 Risk management

Section 5 of the risk analysis deals with management of the risks associated with introduction of parasites or disease agents identified in section 4 as requiring additional risk management. The risk management process had three main components, namely risk evaluation, option evaluation and recommended measures used to achieve a negligible likelihood of entry.

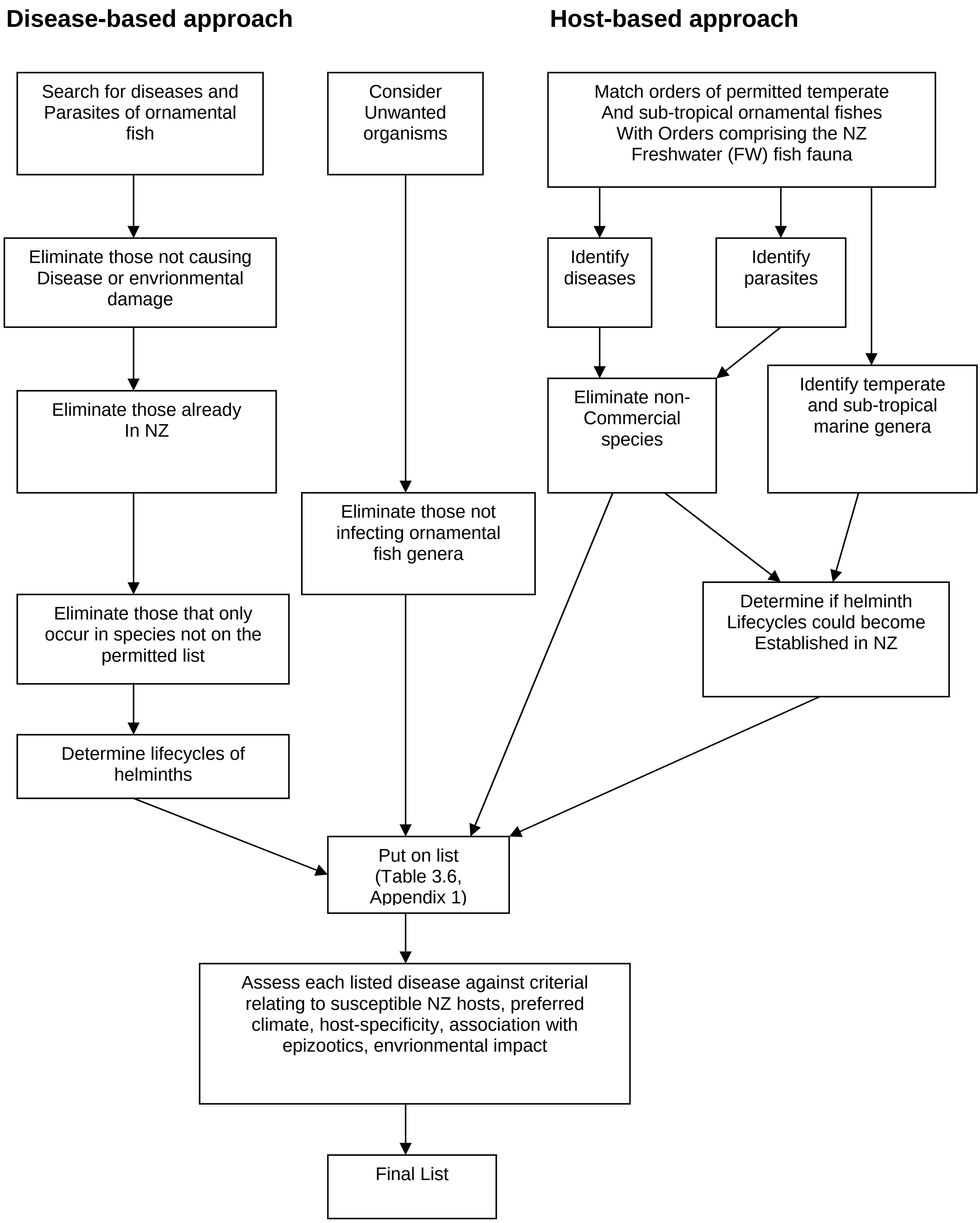
a) Risk evaluation	a determination is made as to whether sanitary measures are necessary.
b) Option evaluation	identify the options available for managing the risk, and consider risk reduction effects.
c) Recommended measures	the recommendation of the appropriate option or combination of options that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

3. HAZARD IDENTIFICATION

Hazard identification was carried out using two approaches; a host-based approach and a disease-based approach. In both cases literature searches were carried out using Commonwealth Agricultural Bureau (CAB) abstracts, Aquatic Sciences and Fisheries Abstracts (ASFA) of the Cambridge Scientific Abstracts (CSA) and the Scirius web search engine. To check on fish taxonomy and biology, Fishbase was used.

Hazard identification involved determining which, of all the diseases and parasites known from ornamental fishes, may be introduced into New Zealand, become established, and which may have an adverse effect on native biota. It was therefore necessary to establish which parasites and diseases may be introduced by ornamental fishes and from these identify those that should continue on to the risk assessment stage. Certain features of the ornamental fish trade and how it is managed determined the best way to go about hazard identification. Firstly it was necessary to consider the biota that may be at risk from such introductions. Superficially the New Zealand situation appears simple. The freshwater fishes are more at risk because of their confinement by lakes and catchments and their closer association with humans, than the marine fishes in open waters which have less contact with land-based humans. Secondly, New Zealand varies from a warm temperate to marginally sub-tropical climate in the north, to a cold temperate climate in the south, suggesting to the casual observer that diseases of tropical fish do not pose a risk. However, in the centre of the North Island, some geothermal streams and swamps can, and do, support introduced tropical fish, though their distributions are highly restricted. Another example of localised areas potentially capable of supporting populations of tropical ornamental fishes includes the artificially heated waters discharged from power station cooling towers into rivers (Cadwallader et al. 1980). Taking all these factors into consideration, it was decided to identify host species, parasites and diseases, by considering both the hosts entering the country (host-based approach), and the known diseases spread by international trade in ornamental fish (disease-based approach) (Figure 3).

Figure 3. The hazard identification processes used in this risk assessment.



3.1 The host-based approach to hazard identification

The host-based approach is founded in two assumptions.

Assumption 1. It is assumed that a disease agent of a temperate or sub-tropical host is less likely to transmit to a tropical host, than is a disease agent of a tropical host and vice versa. This assumption is based on data on fish diseases in the scientific literature which indicates that the majority of obligate disease agents tend to transmit most effectively at temperatures within the thermal tolerances of their hosts.

Assumption 2. It is assumed that it is more likely that a disease agent will jump hosts between closely related hosts than between distantly related, or unrelated, hosts. This assumption is based on data (which is represented throughout the literature on fish diseases) which indicates that most obligate disease agents display some level of host specificity.

3.1.1 Freshwater fish species

Although New Zealand freshwaters are usually considered to be temperate, Fishbase lists some New Zealand native species, such as some *Galaxias* spp., some *Gobiomorphus* spp., and *Retropinna retropinna* (Table 3.1) as sub-tropical. Therefore, because of uncertainty about how *Fishbase* distinguishes temperate and sub-tropical habitats, New Zealand habitats are regarded here as covering a range from temperate to sub-tropical and both sub-tropical and temperate species are regarded as being possibly able to establish here. Tropical freshwater species were not considered in the host based approach, even though some may be able to survive in geothermal waters, as their diseases will be covered using the disease based approach. On the basis of assumption 1, the orders of temperate or sub-tropical species within the 178 genera and 99 species (total 277 taxa) comprising the list of freshwater species permitted to enter New Zealand were identified (Table 3.2). The orders into which they are classified were then compared with the orders comprising the New Zealand freshwater fish fauna (Table 3.1). Those orders listed in Table 3.2 that also occur in New Zealand were selected for further consideration (Table 3.2). *Aphanius fasciatus* and *Jordanella floridae* are both in the Order Cyprinodontiformes, the same order as the poeciliids that occur in New Zealand geothermal freshwater (Table 3.1), but they occur in a different family. *Barbodes* spp., *Barbus* spp., *Capoeta* spp., *Puntius* spp., *Pseudogastromyzon* and *Varicorhinus* spp. are temperate to tropical cyprinids (Table 3.2), and as the New Zealand freshwater fauna includes several introduced temperate cyprinids (Table 3.1), they have been included.

The genera *Callichthys, Corydoras, Hoplosternum, Loricaria* and *Platydoras* (Table 3.2), are almost exclusively tropical catfish of Central and tropical South America. However, these genera include species (*Callichthys callichthys, Corydoras barbatus, Hoposternum littorale, Loricaria cataphracta, Platydoras armulatus, Platydoras costatus*) listed by Fishbase as sub-tropical. The normal range of the brown bullhead (*Ameiurus* (=*Ictalurus*) *nebulosus*) (Table 3.1) is from southern Canada to the southern states of the United States. The ranges of *C. callichthys* and *H. littorale* extend down to north of Buenos Aires, and therefore they inhabit climatic regions similar to those of *A. nebulosus* in the southern states of the United States and to northern habitats in New Zealand. The siluriforms in Table 3.2 will therefore be considered further. As characiform and ophidiiform fish do not occur in New Zealand (Table 3.1), characiform and ophidiiform genera (*Aphyocharax, Astyanax, Cheirodon, Hasemania, Hyphessobrycon, Moenkhausia, Notopterus*) will not be considered further (Table 3.2).

3.1.2 Marine fish species

Of the 113 genera and 4 species (total 117 taxa) of marine ornamental fishes permitted into New Zealand, all but 9 genera (*Antennarius*, *Bodianus, Cantherhines, Chromis, Coris, Hemirhamphus, Hippocampus, Histrio,* and *Stethojulis*) are entirely tropical (Table 3.3). Even these few remaining genera are almost wholly tropical, with fewer sub-tropical species, and even fewer temperate species. *Bodianus* spp. have been reported from deep water around New Zealand (Gomon 2001), and other labrid genera (*Anampses* spp*., Coris* spp*., Suezichthys* spp., *Notolabrus* spp., *Pseudojuloides,*) occur in New Zealand coastal waters (Paul 2000). One labrid species, the spotty, *Notolabrus celidotus*, lives in shallow water and it has a close association with humans. Although New Zealand does not have filefishes of the genus *Cantherhines* spp., another monocanthid *Meuschenia scaber,* the leatherjacket, lives around reefs on the New Zealand coast. One member of the genus *Chromis* (*C.*

dispulus) and two members of the genus *Coris* (*C. picta* and *C. sandgeri*) are known from New Zealand waters (Paul 2000). Similarly, although New Zealand lacks *Hemirhamphus* spp., the closely related *Hyporhamphus ihi* lives in coastal waters around New Zealand, hence this genus will also be considered here. *Hippocampus abdominalis* is also common around New Zealand, and it is being experimentally farmed. *Histrio histrio*, and other antennarids (*Antennarius ocellatus, A. nummifer*) occur in northern New Zealand waters, although uncommon (Paul 2000). The parasites and diseases of these species of marine fish will be evaluated in this risk analysis. *Synchiropus*, and callionymid fishes do not occur around New Zealand, and the diseases of these fishes will not be further considered (Table 3.3).
The parasites and diseases of the freshwater genera *Barbodes, Barbus, Callichthys, Capoeta, Corydoras, Hoplosternum, Loricaria, Platydoras, Puntius* and *Varicorhinus,* are shown in Table 3.4. Literature searches did not find published reports of parasites or diseases from *Pseudogastromyzon,* nor the species *Aphanius fasciatus* and *Jordanella floridae* (Table 3.4).

The parasites and diseases of the marine genera *Antennarius*, *Bodianus*, *Cantherhines*, *Chromis*, *Coris*, *Hemirhamphus* (and *Hyporhamphus*), *Hippocampus*, *Histrio* and *Stethojulis* are shown in Table 3.5.

Those parasites and diseases identified from both freshwater and marine fishes using the host based approach were then reorganised into a list sorted by taxa. The species listed were reduced to genera when more than one congeneric species occurred in hosts from either list. The result of this process was considered to be the final list generated from the host based approach to hazard identification, as shown in Table 3.6.

3.2 The diseased based approach to hazard identification

CAB abstracts, ASFA and Scirius were searched for all the species and genera on the permitted list, combined with “disease*”, “mortalit*”, “parasit*” and “infect*”. These terms were also used against “ornamental” and “aquarium”. The list of diseases and parasites that were retrieved comprised a preliminary hazard list and considered for inclusion in the risk analysis. This list is included in Appendix 1.

3.3 Elimination of insignificant or irrelevant parasites and disease agents

The diseases and parasites in Table 3.6 and Appendix 1 identified using the very broad host and disease based approaches described in sections 3.1 and 3.2 above were then sorted and rationalised further, using the qualifying criteria outlined and discussed below, to eliminate many of the insignificant or irrelevant diseases and parasites to provide a more concise list of relevant disease agents and parasites to be considered in the risk assessment. In many cases the disease agents and parasites being discussed are known from taxonomic papers only. These have generally been excluded from the analysis because they are not known to be associated with disease or significant environmental perturbation. Furthermore, because there is little information to assess the risks these organisms represent to the New Zealand environment, no informed discussion can be provided on their potential impacts.

3.3.1 Viruses

The angelfish herpesvirus is excluded as the reported infection was stress-related, and the infection is rare and not fatal (Mellergaard and Bloch 1988). The taxonomy of aquabirnaviruses is still unclear (Blake et al. 2001), particularly regarding those reported from ornamental fishes (Adair and Ferguson 1981, Ahne 1982a, Hsu et al. 1993, Ortega et al. 1993a, 1993b, AQIS 1999b, Chew-Lim et al. 2002), however they will be included as infectious pancreatic necrosis (IPN), a disease identified from *Barbus* spp. using the host based approach, is caused by an aquabirnavirus, and is an OIE-listed disease.

As aquareoviruses are generally not associated with disease (Roberts 2001) and there is a lack of confamilial susceptible temperate hosts in the New Zealand fish fauna, the *Pomacanthus semicirculatus* aquareovirus (Lupiani et al. 1994) will be excluded. However the viral infection of *Apistogramma ramirezi* caused significant mortalities (Leibovitz and Riis 1980b), and it will be included in the risk analysis.

The iridoviral disease lymphocystis is excluded as it has been reported in New Zealand (Durham and Anderson 1981), and lymphocystis is a benign chronic disease.

Other iridoviruses must be included as they cause an emerging group of diseases that are OIE-listed. As can be seen in Appendix 1, they have been reported from species of ornamental fish that are permitted entry into New Zealand. There is now good evidence that some piscine iridoviruses and amphibian iridoviruses are ranaviruses (Ahne et al. 1997, Mao et al. 1997, 1999, Hyatt et al. 2000). It is now thought that global decline in amphibians is partly due to the spread of fish iridoviruses by the ornamental fish trade (Daszak et al. 1999). The iridovirus causing epizootic haematopoietic necrosis (EHN) in perch (*Perca fluviatilis*), rainbow trout (*Oncorhynchus mykiss*), and Australian native fishes, is the same as frog virus 3 (Eaton et al. 1991, Hyatt et al. 2000), the type *Ranavirus*. The EHN virus (EHNV) is also very closely related to iridoviruses in ornamental fish imported into Australia, leading Hedrick and McDowell (1995) to speculate that EHNV, an OIE-listed pathogen, was introduced into Australia in ornamental fishes. Not all fish iridoviruses are related to ranaviruses. In a recent molecular study, Sudthongkong et al. (2002b) showed that iridoviruses from sea bass in the South China Sea, red sea bream iridovirus in Japan, brown-spotted grouper with a grouper sleepy disease in Thailand, dwarf gourami from Malaysia and African lampeye from Sumatra Island, Indonesia, were not closely related to *Ranavirus, Lymphocystivirus* or *Iridovirus*, and suggested the name *Tropivirus* for tropical iridoviruses. Another strain of *Tropivirus* was detected in various species of diseased ornamental gouramis sourced from a pet shop in Australia (Go et al. 2005, Biosecurity Australia 2005). In experimental cohabitation trials, that virus was transmitted to and caused mortalities in Murray cod (*Maccullochella peelii peelii*), a native fish (Go et al. 2005).

The grouper (*Epinephelus* sp.) nervous necrosis virus will be included as it is OIE-listed, it infects fish that are sub-tropical to tropical, and members of the family Serranidae (*Lepidoperca* spp.) and other susceptible species occur in New Zealand coastal waters.

Various rhabdoviruses have been isolated from ornamental fish, including giant gourami (*Osphronemus gouramy*) suffering from epizootic ulcerative syndrome (EUS) in Thailand (Kanchanakhan et al. 1999a, 1999b). Although EUS is an OIE-listed disease, the aetiological agent is the fungus *Aphanomyces invadans* (see below), and the rhabdovirus isolation was co-incidental. Pike fry rhabdovirus causes serious disease and mortalities in larval pike (*Esox* sp.), and some cyprinids, and various strains exist (Stone et al. 2003), but none of the known susceptible species occur on the permitted list, hence they will not be included here.

The retroviral infections of *Xiphophorus* cause melanomas and neuroblastomas (Petry et al. 1992), but the disease is chronic and associated mortalities are low. Similarly, the retroviral infections of angelfishes (*Pterophyllum scalare*) cause benign lip fibromas (Francis-Floyd et al. 1993), and therefore they do not warrant further review. Rosy barb virus has not been associated with mortalities, has only been reported once, and hence does not appear a problematic disease agent and does not warrant inclusion.

Viral haematopoietic necrosis in angelfish (*Pterophyllum scalare*) has been associated with a virus (Schuh and Shirley 1990), but the disease was extremely rare, poorly characterised and did not cause significant mortalities, and hence will not be considered further.

Viral haemorrhagic septicaemia (VHS) virus was identified as a potential hazard as it has been isolated from *Barbus graellsii* in the carrier state. VHS is an OIE-listed disease, and therefore it will be included in the risk analysis.

3.3.2 Bacteria

Many of the bacteria isolated from ornamental fish (Table 3.6, Appendix 1) are ubiquitous opportunists (Love et al. 1981) of little significance. The following have been excluded from the risk assessment because of this, and the fact they already occur in New Zealand: *Aeromonas hydrophila, Aeromonas sobria, Citrobacter freundii, Photobacterium damselae damselae, Pseudomonas aeruginosa, Pseudomonas fluorescens, Vibrio anguillarum, Vibrio harveyi* and *Vibrio parahaemolyticus.*

Typical and atypical *Aeromonas salmonicida*, although considered serious and significant exotic pathogens in New Zealand, have not been reported from fish on the permitted list and are therefore excluded.

Epitheliocystis and the Rickettsia-like organisms that cause epitheliocystis are common in marine fish, they occur commonly in New Zealand coastal fish, and are very rarely associated with mortalities, and they are therefore excluded.

Edwardsiella ictaluri has been isolated from *Danio devario* and *Puntius conchonius* (see Blazer et al. 1985, Waltman et al. 1985, Humphrey et al. 1986), it is mildly zoonotic and causes enteric septicaemia in catfish which is an OIE-listed disease. Hosts include *Ameiurus* (=*Ictalurus*) *nebulosis*, which has been introduced into New Zealand, where it is a pest species. It has not been reported in New Zealand and will be further reviewed.

Edwardsiella tarda has been isolated from several ornamental fish species (Humphrey et al. 1986, Dixon and Contreras 1992, Shama et al. 2000, Ling et al. 2001), it is zoonotic, causing bacterial gastroenteritis, cellulitis, gas gangrene, septicaemia, meningitis, cholecystitis and osteomyelitis in humans (Vandepitte et al. 1983, Janda and Abbott 1993). It has not been reported in New Zealand and will be included in the risk analysis.

Although *Flavobacterium columnare* occurs in New Zealand (Hine and Boustead 1974), at least three genotypes exist (Triyanto and Wakabayashi 1999), and a particularly virulent strain has been reported from neon tetras (*Paracheirodon innesi*) (see Michel et al. 2002), and therefore *F. columnare* will be included in the risk analysis.

Lactococcus garvieae (formerly *Enterococcus seriolicida*), besides being zoonotic, is a significant pathogen of cultured yellowtail (*Seriola quinqueradiata*) in Japan as well as a number of other species including rainbow trout and freshwater prawns (*Macrobrachium rosenbergi*) (see Chen et al. 2001), both of which occur in New Zealand. Because *Coris* sp. are included in the permitted list, and *L. garvieae* was isolated from wild *Coris aygula* from the Red Sea (Colorni et al. 2003), and New Zealand has significant industries based on rainbow trout, freshwater prawns and yellowtail kingfish (*Seriola lalandi*), and since this bacteria has not been reported in New Zealand, it will be considered further.

Three *Mycobacterium* spp. (*M. marinum, M. fortuitum, M. chelone*) are common in ornamental fish and have been reported from ornamentals in New Zealand (Diggles et al. 2002). *Mycobacterium anabanti, M. abscessus, M. simiae,* and *M. scrofulaceum* have each only been isolated on one occasion (Santacana et al. 1982, Lansdell et al. 1993, Astrofsky et al. 2000). Since these bacteria are known to be present in NZ, they do not warrant further consideration here except to highlight their zoonotic significance. Infection with *Mycobacterium marinum* in humans is known as 'fish tank granuloma' and can lead to severe skin infections, whose treatment may last for over a year and frequently involves surgery (Aubry et al. 2002, Lahey 2003). Further discussion on the need for education on the public health aspects of aquarium keeping is made in section 5.2.5.

Nocardia spp. are opportunistic agents which may rarely cause light mortalities in stressed fish, and they are excluded.

Salmonella typhimurium has been isolated from *Pterophyllum scalare* and *Astronotus ocellatus* in Sweden (Lundborg and Robertsson 1978, Hongslo et al. 1987), and *Salmonella* spp. appear to be common in aquarium water (Manfrin et al. 2001), including serovars infecting humans (Trust et al. 1981). Salmonellae may also infect gastropods and amphibians (Trust et al. 1981), as well as fish (Lawton and Morse 1980), and in 1976 it was estimated that 280,000 cases of salmonellosis in the United States were attributable to pet turtles (Morse and Duncan 1976). *Vibrio cholerae* may also be isolated from aquarium water (Bassi et al. 1993, Manfrin et al. 1999, 2001). An assessment of risk suggested that salmonellae from aquaria do not pose a public health hazard (Morse and Duncan 1976), however in New Zealand, at least 10 cases of human salmonellosis due to *Salmonella* Paratyphi B var. Java were reported from contact with tropical aquariums between January 2004 and May 2005 (Boxhall et. al 2005). Disinfection of aquarium water during quarantine is specifically required in the current import health standard for ornamental fish to reduce the risk of introduction of zoonotic bacteria via aquarium water, yet clearly strains of *Salmonella* spp. are endemic throughout New Zealands aquarium industry, probably because fish and amphibians can act as asymptomatic carriers of these bacteria as commensal flora in their gut (Sanyal et al. 1997, Gaulin et al. 2002). Because of this, *Salmonella* spp. are excluded from further analysis.

Nevertheless, the requirement for disinfection of aquarium water and the need for education on the public health aspects of aquarium keeping are important safeguards for *Salmonella* and other bacteria of potential public health concern (see section 5.2.5).

Streptococcus iniae is a significant emerging disease agent of a wide variety of cultured and wild fish (Colorni et al. 2002), and will be included in the analysis. *Streptococcus* sp. isolated from *Brachydanio rerio* and *Brachydanio albolineatus* in Canada (Ferguson et al. 1994) caused acute necrotising lesions in both hosts, and in rainbow trout when exposed by bath immersion. This could make it a threat to the New Zealand salmonid industry, and it is included in the risk analysis.

3.3.3 Fungi

As with bacteria, most fungal infections are often caused by ubiquitous opportunistic saprophytes, such as *Achyla* spp. and *Saprolegnia* spp., which already occur in New Zealand (Hine and Diggles, unpublished data), and they are therefore excluded. *Pythium gracile, Fusarium moniliforme* and *Fusarium* sp. have been reported on the gills of fishes stressed by environmental conditions. They are weak opportunist pathogens and will not be included here.

Aphanomyces invadans is accepted as the aetiological agent of epizootic ulcerative syndrome (EUS), an OIE-listed disease, although several other organisms, notably *Aeromonas* spp., are frequently isolated from lesions. EUS was first reported from Japan in 1971, and it has now spread throughout Asia, as far west as Pakistan. It occurs down the coast of Australia as far as New South Wales. *A. invadans* has been isolated from ornamental fish species, such as *Etroplus suratensis* (see Pathiratne and Rajapakshe 1998) and *Trichogaster pectoralis* (see Pathiratne and Jayasinghe 2001) in Sri Lanka, *Trichogaster trichopterus* in the Philippines (Catap and Munday 1999) and Japan (Hanjavanit et al. 1997), *Colisa lalia* in Japan (Wada et al. 1994), *Osphronemus gouramy* in Thailand (Kanchanakhan et al. 1999a, 1999b) and kissing gouramis (*Helostoma* spp.) intercepted by authorities at the West Australian border (Animal Health Australia 2002). *A. invadans* also infects temperate fish species such as grey mullet, *Mugil cephalus,* in New South Wales (Fraser et al. 1992), and *M. cephalus* is a common and important food fish in coastal, estuarine and freshwater New Zealand waters. As EUS is an OIE listed disease and can infect endemic fish species, *A. invadans* will be examined further.

Aphanomyces pisci has been reported (Srivastava 1979) in association with high level (<90%) mortality among *Cirrhinus mrigala,* and experimentally it can infect fishes on the permitted list (*Colisa lalia, Puntius sophore*). However, it has not been reported in natural infections of ornamental species, it has not been reported in the literature since 1979, and it will therefore not be included. Similarly, *Aphanomyces laevis* has been reported in association with 100% mortality among *Aplocheilus panchax* (see Mondal and De 2002). In that case it appears to have been identified long after the fish became sick, it is an opportunist saprophyte that is usually a secondary or tertiary infection, and therefore it is excluded.

3.3.4 Protoza

The protozoans *Amyloodinium* spp., *Oodinium* spp., some *Chilodonella* spp., *Cryptobia* spp., *Hexamita* spp., *Ichthyophthirius multifiliis, Tetrahymena corlissi,* most *Trichodina* spp., and *Vorticella* spp. occur worldwide (Kuo et al. 1994, Thilakaratne et al. 2003), including New Zealand, and they are therefore excluded.

Brooklynella hostilis, Trichodina heterodentata, Trypanosoma danilewski, Trypanosoma trichogasteri, Goussia trichogasteri, Piscicryptosporidium reichenbachklinkei and systemic amoebiasis have not been associated with significant mortalities other than in aquaria, and confamilial hosts are absent from New Zealand, and therefore they are excluded.

Chilodonella hexasticha has been reported from the gills of tropical ornamental *Symphysodon discus* (see Imai et al. 1985, Ogawa et al. 1985), cichlids (*Oreochromis mossambicus, Oreochromis niloticus, Oreochromis aureus*), and coldwater cyprinids (*Abramis brama, Abramis ballerus, Blicca bjoerkna, Cyprinus carpio*). It also infects salmonids (*Oncorhynchus rhodurus, Salmo salar, Salmo trutta*), causing 2-10% mortalities among young fish (Rintamaki et al. 1994). It has been introduced into Australia, where it caused epizootic mortalities among native fishes (*Gadopsis marmoratus, Macculochella peeli, Nematalosa erebi*) (see Langdon et al. 1985, Humphrey 1995). Although treatable (van As et al. 1984), the ability to infect warm water ornamental fish and cold water salmonids, and its non-host specificity allowing it to jump hosts, warrants further consideration. The closely related *Chilodonella piscicola* has a similar host range, including warm water (*Paracheirodon innesi*), and cold water (*Oncorhynchus keta, Oncorhynchus gorbuscha, Oncorhynchus masou, Oncorhynchus mykiss, Salmo salar, Salmo trutta, Abramis brama, Abramis ballerus, Blicca bjoerkna*) fish, but is less pathogenic. It will be considered with *Chilodonella hexasticha.*

The ciliated protozoan *Coleps* sp. caused 20-90% mortalities among fry of *Corydoras schultzei, Barbus tetrazona* and *Carassius auratus,* held in densely populated aquaria (Szekely and Bereczky 1992). *Coleps* sp. has also been reported as a pathogen of rainbow trout, *Oncorhynchus mykiss,* held in recirculating systems (Wooster and Bowser 1994). The ornamental fish and rainbow trout infections were considered "unusual", it is uncertain whether these *Coleps* are the same species, and *Coleps* spp. are normally coprophagous or predatory on other protozoans. It is almost certain the hosts affected by *Coleps* sp. were immunocompromised, hence it appears *Coleps* spp. are opportunistic agents which only infect confined fish under exceptional circumstances. Because of this, they will not be considered further.

Cryptocaryon irritans has been reported from northern New Zealand in snapper (*Pagrus auratus*) and is commonly observed in marine ornamental fishes held at warm water temperatures throughout New Zealand (Hine and Diggles, personal observations, Diggles et al. 2002). It can cause serious disease in confined fish (Huff and Burns 1981), it transmits directly and is non-host specific (Giavenni 1982). Even though this parasite has been reported from New Zealand, there is considerable intraspecific variation (Diggles and Adlard 1997), and since ornamental fish may carry pathogenic exotic strains, it will be included in the risk analysis.

Eimeria spp. are apicomplexans (coccidian) parasites found in the intestine of marine and freshwater hosts including weedy sea dragon (*E. phyllopterycis* in *Phyllopteryx taeniolatus*) (see Upton et al. 2000), and a variety of cichlids (*E. vanasi*, see Lansberg and Paperna 1987). In these hosts it remains unclear whether these parasites cause disease, hence it appears extremely unlikely they are serious pathogens and therefore they will not be considered further.

Goussia carpelli causes problematic chronic mortalities among goldfish (*Carassius auratus*) in the United States, and severe enteritis and mortality in cultured carp (*Cyprinus carpio*) in Europe (Kent and Hedrick 1985). In the United States, fish became infected shortly after hatching and sporulated oocysts were found in 15-day old fish. At 6 weeks they stopped feeding, became lethargic and emaciated, and 50-75% cumulative mortalities occurred over the subsequent 2-3 weeks. Mortality was due to enteritis (Kent and Hedrick 1985, Jendrysek et al. 1994), although secondary *Aeromonas*-like infections occurred in the liver and spleen (Steinhagen et al. 1997) Transmission is direct (Steinhagen and Korting 1988), or through an oligochaete intermediate host, *Tubifex tubifex* or *Limnodrilus hoffmeisteri* (see Steinhagen and Korting 1990). *G. carpelli* infects *C. auratus* in Australia (Lom and Dykova 1995), and *Barbus barbus bocagei* in Spain (Alvarez-Pellitero and Gonzales-Lanza 1986). *Barbus barbus bocagei* is on the permitted list, and the disease may pose a threat to endemic goldfish stocks, therefore *G. carpelli* will be included in the risk analysis.

Among microsporidians, most *Glugea* spp., some *Heterosporis* spp., *Pleistophora* spp., *Microsporidium* sp. and *Pseudoloma neurophilia* cause chronic, disfiguring, but rarely epizootic disease. They are treatable and will not be considered further. Although *Heterosporis finki* causes significant mortalities among angelfish (Michel et al. 1989), the host is a tropical species with no confamilial species in New Zealand, and it will not be further considered in this risk analysis. However *Glugea heraldi* Blasiola, 1979 causes severe disease in seahorses (*Hippocampus erectus*), producing boil-like lesions (Blasiola 1981). Seahorses are abundant around ports and wharves, and therefore live close to humans. *Glugea heraldi* could threaten both wild seahorse populations, or the fledgling seahorse farming industry, and therefore it is included in the risk analysis.

Licnophora hippocampi is a ciliate reported on *Hippocampus trimaculatus* in China (Meng and Yu 1985). However since its description there have been no further reports of this parasite, hence due to its rarity and the fact that it apparently does not cause serious disease, it will not be considered further.

Piscinoodinium spp. will be considered because *Piscinoodinium pillulare* is highly pathogenic to *Puntius gonionotus*, but may also infect temperate to tropical fish species in many families, including temperate cyprinids, and tropical characids, anostomids, cichlids, and prochilodontids (Shaharom-Harrison et al. 1990, Martins et al. 2001).

Trichodina spheroidesi, was reported by Bunkley-Williams and Williams (1994) to cause mortalities among wild whitespotted filefish, *Cantherhines macrocercus*. However that paper is the only paper reporting *T. spheroidesi* in association with mortalities. This suggests that this ectoparasite is not an important pathogen in ornamental marine fish. *Trichodina arcuata* infects many species of many families of fishes, including salmonids, from temperate to tropical regions. It infects *Barbus brachycephalus*, which is on the permitted list, and therefore it could enter New Zealand. However, reports suggest that it is worldwide in distribution, and only in one case has it been reported in association with mortalities among salmonids, and that was in association with nine other trichodinid species (Migala 1993). There is no good evidence that *T. arcuata* is pathogenic, and therefore it will not be included. There is no evidence for primary pathogenicity amongst the other *Trichodina* spp. listed, and since these parasites are easily treatable, other *Trichodina* spp. will not be included.

Trypanosoma spp. and *Trypanoplasma cyprinoides* require a vector, greatly reducing the risk of establishment, hence they will not be considered further. *Spironucleus vortens* is an intestinal parasite (Poynton et al. 1995) that may cause hole-in-the-head disease and mortalities in cichlids (Paull and Matthews 2001). However, the disease is uncommon and treatable (Sangmaneedet and Smith 1999), and therefore *S. vortens* is excluded.

An unidentified dinoflagellate occurred on the skin, fins and gills of *Parauchenoglanis macrostoma, Synodontus punctatus, Synodontus flavitaeniatus,* *Acanthodoras cataphractus* and *Pterygoplichthys gibbiceps* imported into Germany from tropical Africa and South America (Steinhagen et al. 1999). Mortality rates were up to 100% in some consignments after 7-14 days, and the parasite was not treatable with malachite green, formalin or changes in salinity due to the formation of cysts. The dinoflagellate is a good example of importation of a previously unknown pathogen, which is likely to be the case in ornamental fish from time to time, and it will be included in the risk analysis.

3.3.5 Myxozoans

Myxosporeans have been reported from several tropical ornamental fish species (Appendix 1). They vary in site and host specificity, from very site and host specific (Molnar 2002), to non-host specific, such as *Enteromyxum* (=*Myxidium*) *leei* (see Padrós et al. 2001, Panzuela et al. 2002). The actinosporean stage of myxozoans may be less host specific, and many genera appear to use a few widely distributed oligochaete hosts, such as *Tubifex tubifex, Limnodrilus hoffmeisteri, Lumbriculus variegatus, Branchiura sowerbyi* and *Dero digitata.* Most myxozoans have multihost lifecycles, and hence do not pose a threat to ornamental fishes. However, *E. leei* is not only non-host specific to warm water fish (Padrós et al. 2001), there is evidence that it (Diamant 1997) and other marine fish myxosporeans (Redondo et al. 2002, Yasuda et al. 2002) can transmit directly, fish-to-fish. *Enteromyxum leei* has been isolated from aquarium-reared anemone fish, *Amphiprion frenatus* (see Kent 1999), *Coris julius*, *Chromis chromis*, *Thallasoma pavo* and blennids (Padrós et al. 2001) all which are on the permitted list. It also causes mortalities in warm-water sparids that are confamilial with New Zealand snapper (*Pagrus major*) which are now being cultured, and therefore it will be included in this risk assessment. Histozoic members of the genus *Myxobolus* have been associated with disease and other lesions such as skeletal deformities in a variety of marine and freshwater fish (Lom and Dykova 1992). However most have high host specificity and multihost lifecycles, and since no serious pathogens of the genus *Myxobolus* are widely reported in fish from the permitted host species list, this genus will not be considered further. None of the other myxosporeans genera listed in Appendix 1 or Table 3.6 have been associated with serious disease, and hence they also will not be considered further.

3.3.6 Monogeneans

Although the transmission of monogeneans is horizontal and direct, most species are very host and site specific (Poulin 1992, 2002, Cribb et al. 2002). When they enter a country on an exotic host, they generally stay confined to that host (Dove and Ernst 1998). In the Gyrodactylidae, 71% of 402 described species are host specific (Bakke et al. 2002). This appears also to be true of the many species in the Dactylogyridae. These two super-families are also treatable (Tojo and Santamarina 1998, Pretti et al. 2002), and since the only species of national interest, *Gyrodactylus salaris*, is specific to salmonids, neither superfamily will be further considered here. Hyperinfections of *Axine* spp. are reported to cause anaemia however this genus is host specific, the disease is treatable and not considered serious in ornamental fishes. Similarly, *Ancyrocephalus* spp., *Dactylogyroides longicirrus, Demiospermus anus, Dichodactylogyrus* spp., *Dicrodactylogyrus* spp., *Diplozoon* spp., *Dogielius* spp., *Gussevia* spp., *Indocotyle elegans*, *Lissemysia* spp., *Loxuroides fungiliformis*, *Markewitschiana triaxonis*, *Neodiplozoon polycotyleus*, *Oligapta hyporhamphi*, *Paradiplozoon* spp., *Paragyrodactylus superbus, Philocorydoras platensis, Sciadicleithrum* spp. and *Urocleidoides corydori* are only known from taxonomic studies, indicating they have high host specificity and generally do not cause disease, and hence will not be included here.

However, not all monogenean families are host specific, and some, such as capsalid monogeneans, may certainly cause disease. *Neobenedenia melleni* infects over 100 teleost species from more than 30 families and 5 orders (Whittington and Horton 1996), and *Benedenia epinepheli* infects 25 host species from the Perciformes, Scorpaeniformes, Pleuronectiformes, Tetraodontiformes and Anguilliformes (Ogawa et al. 1995). As *Epinephelus* spp. are a permitted importation into New Zealand, benedeniine capsalids may be pathogenic (Whittington 1996), and marine aquarium fishes are highly susceptible to *Benedenia epinepheli* (see Ogawa et al. 1995), it will be included in the risk analysis. *Benedenia lolo* from *Coris* sp. in Hawaii (Yamaguti 1968) is almost certainly specific to this host genus only, and will not be considered further. The record of *B. seriolae* from *Cantherines pardalis* is almost certainly a misidentification of an undescribed species of *Benedenia* (see Whittington et al.

2001), and in any case *B. seriolae* is already widely recorded from *Seriola lalandi* in New Zealand (Diggles et al. 2002), hence this parasite will not be considered further.

3.3.7 Crustaceans

Alitropus typus recorded from three *Puntius* spp. from the permitted list has caused disease in a wide range of tropical Asian freshwater fishes including snakehead, milkfish, eels, mullets and tarpon (Kabata 1985, McAndrew 2002). In Nile tilapia cultured in net cages in the Philippines this parasite was responsible for mortalities of up to 95% (Del Mundo et al. 1996). Clinical signs of infestation included swimming against the netting materials, lethargy and corkscrew swimming motion. Other noticeable signs included pale gills, sloughing of scales, haemorrhagic areas on the skin and ulcerations. Hyperinfections of this blood feeding parasite cause anaemia (Nair and Nair 1983). It thrives in water with high organic loading and in areas with high stocking densities, but appears to be a facultative pathogen and does not infest fish reared in high water quality conditions, hence this disease agent will not be considered further.

The *Anilocra*, *Ceratothoa* and *Nerocila* spp. recorded from ornamental fishes on the permitted list are all host specific parasites (Adlard and Lester 1994) which are not known to cause serious disease. Furthermore due to their host specificity these parasites are extremely unlikely to infect other hosts present in New Zealand, and hence neither genera will be considered further.

The ectoparasitic crustacean *Argulus foliaceus* is able to attach to and detach from hosts, it is non-host specific, and can cause epizootics in salmonids (Menezes et al. 1990). Also, it can act as a vector for spring viraemia of carp virus (SVCV) (Ahne 1985), and of nematodes (Molnar and Szekely 1998). *A. foliaceus* is a parasite of coldwater fishes, and it has been reported from *Barbus grypus* (see Hussein and Al-Hamdane 1992), which is a permitted species for entry to New Zealand, hence *A. foliaceus* will be considered further.

Caligus spp. occur on a wide range of freshwater and marine fishes worldwide in tropical and temperate areas. New Zealand already has a number of species of

Caligus parasitic on fishes (Hine et al. 2000), hence this genus will not be considered further.

Ergasilus sieboldi has been reported from *Barbus grypus* and *Barbus esocinus* in Iraq (Rashid et al. 1989), and it is very non-host specific in temperate and warm water fish species, but like other *Ergasilus* and *Paraergasilus* species, it is not associated with mortalities and hence this genus will not be included.

Chonopeltis victori, Colobomatus cresseyi, Dermoergasilus spp.*, Ergasilus ceylonensis, Ergasilus parvitergum, Ergasilus uniseratus,* and *Indopeniculus fryeri Ichthyoxenus fushanensis, Lamproglena* spp., *Lernanthropus eddiwarneri*, *Orbitacolax hepalogenyos*, *Pseudolamproglena* spp. and *Tracheliastes* spp. have only been reported in taxonomic studies (Ho et al. 1992, Ho and Kim 1997), there is no evidence that they cause mortalities, and they will not be considered further. Similarly, *Lernaea arcuata, Lernaea oryzophila* and *Lernaea minuta* have primarily been reported in taxonomic (Ho and Kim 1997) or new host:parasite (Kularatne et al. 1994a and 1994b) reports, and like the majority of other *Lernaea* spp. reported from fish on the permitted list they are not associated with significant mortalities and are excluded. *Lernaea polymorpha* infects silver carp, *Hypophthalmichthys molitrix*, an acclimatised fish in New Zealand, but it can be controlled (Jinpei et al. 1979), and is excluded. Penellid copepods of the genera *Lernaeenicus* and *Penella* are used as markers in fish stock discrimination studies, but generally do not cause disease or mortalities and hence are excluded from the analysis.

3.3.8 Complex life cycles

Most viruses, bacteria, protozoans, monogeneans and parasitic copepods have direct life cycles; i.e. they are transmitted directly fish-to-fish. However, most of the species of digeneans (flukes), cestodes (tapeworms), nematodes (roundworms) and acanthocephalans (spiny-headed worms), and probably also some of the myxozoans, utilise one or two intermediate hosts in their life cycles. If the intermediate or definitive hosts, or species closely related to them, do not exist in New Zealand (and for this risk assessment it has been assumed that they will continue not to do so), the parasite concerned cannot complete its life cycle, and therefore poses no risk.

Therefore, the life cycles of the genera of helminths in Table 3.6 and Appendix 1 were determined, where possible (Tables 3.7-3.9).

Three groups of life cycles were apparent; 1) digeneans that use *Melanoides tuberculata*, 2) digeneans that use lymnaeid gastropods, and 3) cestodes, nematodes and acanthocephalans that use copepods as first intermediate hosts (Table 3.8). The life cycles of the helminths in temperate and sub-tropical genera of the marine fishes were also considered (Table 3.9). Unfortunately, very little information was available on some genera, and closely related genera had to be researched (Table 3.9). For example, *Bianium rewa,* which infects *Cantherines pardalis*, is a lepocreadiid, and therefore the life cycles of other lepocreadiids (*Tetracerasta, Neopechona, Opechona*) are given. Similarly, the life cycle of *Haplosplanchus* is given as it is a haplosplanchnid-like *Scikhobalotrema,* and *Asymphylora, Monorchis, Parasymphylodora* and *Paratimonia* are all monorchids, like *Paraproctotrema,* while *Stephanostomum* and *Deropristis* are acanthocolpids, like *Cableia* (Table 3.9). From this information it was determined the temperate and subtropical marine species (Table 3.9) are very unlikely to have suitable intermediate hosts in New Zealand, and therefore they are not included in the risk analysis.

3.3.8.1 Digeneans

Most of the digeneans in Table 3.6 are either not associated with mortalities and/or their life cycles are unknown (*Acanthostomum* spp., *Allocreadium* spp., *Aspidogaster tigarai, Asymphyodora* spp., *Brahmputrotrema gwaliorensis, Bucephalopsis fusiformis, Neopodocotyle* spp. *Pseudoorientodiscus* spp., *Stephanoprora pandei, Tetracotyle lali, Transversotrema patialense*). Some could not establish a life cycle in New Zealand (*Isoparorchis hypselobagri, Opisthorchis viverrini, Petasiger grandivescularis*) due to the absence of suitable intermediate and/or definitive hosts (Table 3.7). They are excluded, but as digenean life cycles are similar, the assessment of those to be included (*Centrocestus formosanus, Clinostomum complanatum, Clinostomum piscidium, Diplostomum* spp., *Haplorchis* spp., *Haplorchoides mehrai,* see Tables 3.7 and 3.8 below) will indicate the risk of other digeneans establishing, if suitable hosts occur in New Zealand.

Centrocestus formosanus, occurs as metacercariae encysted in the gills of a wide range of teleost fish, including ornamental species (*Aplocheilus panchax, Aplocheilus melastigma, Poecilia reticulata, Puntius* spp., *Xiphophorus maculatus*) (Nath 1972, Madhavi 1980, Yanohara 1985, Evans and Lester 2001). It was identified as a potential pathogen in both the host-based and disease-based approaches. *C. formosanus* infects temperate to sub-tropical fishes, such as cyprinids (Velez-Hernandez et al. 1998), cichlids (Kalantan et al. 1999) and *Anguilla* (Yanohara and Kagei 1983), although it does not appear to have been reported from salmonids. The definitive hosts of *C. formosanus* are birds (Scholz and Salgado-Maldonado 2000) and a wide range of mammals, experimentally or naturally infected, including mice, rats, cats, rabbits and birds (Kalantan et al. 1999), and humans (Cheng 1991, Murrell and Bremner 2002) (Tables 3.7, 3.8). The first intermediate host, the gastropod *Melanoides tuberculata,* has recently been reported in New Zealand for the first time (Duggan 2002). *C. formosanus* has been spread to Texas (Mitchell et al. 2002), Mexico (Scholz and Salgado-Maldonado 2000, Scholz et al. 2001) and Australia (Evans and Lester 2001), with the spread of *M. tuberculata*, and movements of ornamental fishes. Movements of *M. tuberculata* have often been deliberate because it may compete with and displace *Biomphalaria glabrata,* the intermediate host of zoonotic schistosomes (Giovanelli et al. 2002). There is a risk of *C. formosanus* becoming established in New Zealand, and it will be included in the risk analysis.

Centrocestus formosanus and *Echinochasmus bagulai* (see below) use the heron *Ardeola grayii* (frequently called *Ardeola grayi,* or even *Ardea grayi*) as a definitive host in natural infections (Tables 1.2, 3.7, 3.8). *Clinostomum complanatum, Clinostomum piscidium* and *Haplorchis pumilio* (see below) use *Ardea* spp. as definitive hosts, in natural infections. *Ardea novaehollandiae*, *Ardea pacifica, Egretta alba, Egretta garzetta, Egretta sacra* and *Bubulcus ibis* occur in New Zealand (*Egretta* spp. are herons, and *Bubulcus* spp. are related). Thus *Clinostomum* spp. could establish in New Zealand (Tables 3.7, 3.8), but it is more difficult to determine whether *Centrocestus formosanus* could establish in hosts other than *Ardeola grayii.* The relationships of ardeid herons are not fully understood, but the world authority thinks that, although *Ardeola* is closer to other ardeid genera than it is to *Ardea*, there is little evolutionary distance between any of the genera (Dr Fred Sheldon: *pers. comm.*). It is therefore assumed that *Centrocestus formosanus* could establish in New

Zealand herons and it will be included in the risk analysis. *Clinostomum complanatum* uses freshwater gastropods (*Lymnaea* sp.) (see Aohagi et al. 1993b), and *Radix* spp., particularly *Radix auricularia* (see Chung et al. 1998), as first intermediate host, a variety of fish, including rainbow trout (Szalai and Dick 1988), as second intermediate hosts, and birds and mammals, including humans (Rim et al. 1996), as definitive hosts (Tables 3.7, 3.8). As *Lymnaea stagnalis* and *Radix auricularia* occur in New Zealand (Spencer and Willan 1995), *Clinostomum complanatum* could complete its life cycle and it will be included in the risk analysis.

Clinostomum piscidium uses *Lymnaea* spp. as it first intermediate host, ornamental fish (*Trichopterus fasciatus*) as its second intermediate host, and herons as definitive hosts (Table 3.7) (Pandey 1973). However, it is very unlikely to establish itself in New Zealand, as wild piscivorous birds would have to come into contact with *Colisa fasciatus,* a tropical (22-28°C) fish kept in aquaria, hence it is therefore excluded.

Diplostomum (*=Diplostomulum*) *spathaceum* and *Diplostomum* (*=Diplostomulum*) *pseudospathaceum* live as metacercariae in the eyes of their hosts, causing blindness in heavy infections (Graczyk 1988). Both parasites use lymnaeid snails as first intermediate hosts, they are non-host specific in the second intermediate fish host, and are also non-host specific in the avian definitive host, particularly gulls (Tables 3.7, 3.8) (Niewiadomska 1986). They may readily establish in New Zealand and are therefore included.

The life cycle of *Echinochasmus bagulai,* a mildly zoonotic species, involves *Melanoides tuberculata* as first intermediate host, ornamental fish as second intermediate hosts, and herons (*Ardeola grayii*) as definitive hosts (Madhavi et al. 1989, Dhanumkumari et al. 1991). However, *E. bagulai* is not reported to cause disease in any of its hosts, and hence it is not included here.

Haplorchid digeneans (*Haplorchis pumilio, Haplorchis taichui, Haplorchis yokogawai, Haplorchoides mehrai*) also infect *M. tuberculata* (see Lo and Lee 1996). They occur as metacercariae in ornamental fishes, particularly *Puntius* spp. (see Velasquez 1973, Kliks and Tantachamrun 1974, Pande and Premvati 1977, Shameem and Madhavi 1988). *H. taichui* also occurs in the permitted *Aplocheilus* spp., and

Labeo bata (see Nath 1973, Madhavi 1980), and *H. pumilio* in wild or cultured fishes, including rainbow trout (Sommerville 1982). As adults they occur in reptiles, birds and mammals (Sommerville 1982), including humans (Murrell and Bremner 2002) (Tables 3.7, 3.8). They are non-host specific to the second intermediate and definitive hosts. *Haplorchis* spp. and *Haplorchoides* spp. will be considered generically with *Centrocestus formosanus.*

The human liver fluke, *Opisthorchis viverrini,* infects *Puntius* spp., including *P. gonionotus,* which is a permitted species in New Zealand. However, its first intermediate hosts are the gastropods, *Bithynia* spp. (see Adams et al. 1995), which do not occur in New Zealand, and therefore it is excluded from this risk analysis.

Transversotrema patialense is an ectoparasite on many species of warm water fish (Tables 3.7, 3.8) (Whitfield et al. 1986). The sole intermediate host, *Melanoides tuberculata,* occurs in New Zealand. However, it does not cause mortalities, infections become self-limiting (Mills et al. 1979), it is treatable, and therefore it will not be included in the risk analysis.

The other digenean trematodes listed in Tables 3.6 and Appendix 1 will not be included as they are either not associated with disease, or due to the absence of suitable intermediate hosts, they could not become established in New Zealand.

3.3.8.2 Cestodes

Cestodes also have a wide range of life cycles, and some can be excluded on the basis of those life cycles due to the lack of suitable intermediate and/or definitive hosts in New Zealand. Others, such as *Bathybothrium rectangulum*, *Caryophyllaeus* spp., *Diphyllobothrium* spp., *Khawia* spp., *Otobothrium penetrans*, *Proteocephalus* spp., *Ptychobothrium belones* and *Unicibilocularis* spp. have only been reported from ornamental fishes in taxonomic papers, and as such these species are not known to be associated with disease or significant ecological effects, and will therefore be excluded.

Bothriocephalus acheilognathi (=*B. aegyptiacus* and *B. gowkongensis*) is common in coldwater and tropical fishes, including species of ornamental fish (*Poecilia reticulata, Xiphophorus maculatus*) (Evans and Lester 2001). *B. acheilognathi* is very non-specific in the intermediate host and consequently it has become established in many countries including Poland (Pojmanska and Chabros 1993), South Africa (van As et al. 1981), Armenia (Grigoryan and Pogosyan 1983), Russia (Smirnova 1971), North America (Brouder and Hoffnagle 1997), the U.K. (Andrews et al. 1981), Hawaii (Font and Tait 1994) and Australia (Evans and Lester 2001). Samples from around the world fall into 3 genotypes (Luo et al. 2002), but the significance of this in relation to virulence and spread is unclear. In *Cyprinus carpio,* atrophy, catarrh, and degeneration of mucosa is thought to permit toxins from *B. acheilognathi* to be directly absorbed, leading to degeneration of the liver and kidney (Lozanov and Kolarova 1979). Lymphocytes, macrophages and eosinophils accumulate at the site of attachment, pass into the gut lumen and adhere to the parasite (Hoole and Nisan 1994). In *Ctenopharyngodon idella, Pimephales promelas* and *Notemigonus crysoleucas* excessive mucus production occurs, and there is lymphocyte infiltration into the gut wall (Scott and Grizzle 1979). Local spread is probably by piscivorous birds (Prigli 1975), but it entered Australia in ornamental fish (Evans and Lester 2001). It became established not only in introduced fish species (*Cyprinus carpio, Gambusia holbrooki*), but in native Australian fishes (*Hypseleotris klunzingeri, Hypseleotris* sp., *Phylipnodon grandiceps, Retropinna semoni*) (see Dove et al. 1997, Dove 1998, Dove and Fletcher 2000). Three of these native species are eleotrids, as are New Zealand bullies (*Gobiomorphus* spp.) and the other is congeneric with *Retropinna retropinna* in New Zealand. Were *B. acheilognathi* to become established in New Zealand, it would parasitise native fishes as well as the introduced cyprinids. It has entered New Zealand already, in grass carp (*Ctenopharyngodon idella*) in 1973, but it was eradicated in quarantine (Edwards and Hine 1974), and hence it will be considered in the risk analysis. *B. pearsei* and other *Bothriocephalus* spp. will also be covered in the risk analysis under the section for B. *acheilognathi*.

Ligula intestinalis has been reported in the wild in New Zealand (Weekes and Penlington 1986), and it is therefore not included in the risk analysis, as is *Ophiotaenia europaea*, which uses snakes as definitive hosts.

3.3.8.3 Nematodes

Camallanus cotti is a common parasite of guppies (*Poecilia reticulata*) that has a simple life cycle involving only a copepod intermediate host (Levsen and Berland 2002a, 2002b), or no intermediate host (Levsen 2001, Levsen and Jacobsen 2002). It has consequently spread with the international movements of guppies (Moravec and Nagasawa 1989, Font and Tate 1994, Rigby et al. 1997, Font 1998, Evans and Lester 2001, Kim et al. 2002a, 2002b, Levsen and Berland 2002a). Adult *C. cotti* feed on host blood (Stumpp 1975), causing significant mortalities (Kim et al. 2002a, 2002b), and are non-host specific in intermediate and definitive hosts (Moravec and Nagasawa 1989, Levsen 2001). *C. cotti* infects both teleosts and elasmobranchs (Rigby et al. 1997), and because of this, it will be included in the risk analysis.

Capillaria philippinensis is a pathogenic parasite of birds and mammals, including humans, that has a life cycle involving small fish as intermediate hosts (Cross et al. 1972), and mammals (Cross et al. 1978) or birds (Cross and Basaca-Sevilla 1983) as definitive hosts. Auto infection may occur in definitive hosts (Cross et al. 1972). It infects *Puntius gonionotus* which is on the permitted list and will be included here, along with *Capillaria pterophylli* which causes mortalities (Moravec 1983a), is non-host specific (Moravec and Gut 1982), and transmits directly fish-to-fish (Moravec 1983a).

Capillostrongyloides ancistri is highly pathogenic to its host (*Ancistrus dolichopterus*), it has been introduced into Europe from South America, but it is host specific, only one paper has reported it (Moravec et al. 1987a), suggesting it is not a major problem, and therefore it will not be considered further.

Camallanus praveeni, Contracaecum spp., *Cucullanus barbi*, *Cucullanus cyprini*, *Hysterothylacium* spp. and *Philometra karunensis* are only known from ornamental fishes in taxonomic studies (Rajyalakshmi and Vijaya-Lakshmi 1994, De and Maity 1996, Rajyalakshmi 1997), suggesting they are not a major problem, and therefore they will not be considered further. Likewise the genera, *Raphidascaroides*, *Rhabdochona* and *Spironoura* are reported from ornamental fishes only in taxonomic papers, there is little if any evidence they cause disease or ecological perturbations, and hence they will not be considered further.

Mexiconema cichlasomae requires ectoparasitic crustaceans (*Argulus* spp.), that are exotic to New Zealand, as vectors (Moravec et al. 1999), making its introduction and spread extremely unlikely, and hence it will not be considered in the risk assessment.

Pseudocapillaria brevispicula and *Pseudocapillaria tomentosa* infect temperate to tropical cyprinids by direct horizontal transmission (Moravec et al. 1987b, Kent et al. 2002). *P. brevispicula* infects both cold water and tropical cyprinids, and *P. tomentosa* causes severe disease in zebrafish (*Danio rerio*) (see Kent et al. 2002). New Zealand cyprinids would be susceptible to infection, and therefore *Pseudocapillaria* spp. are included here.

Procamallanus spiculogubernaculus uses cyclopoid copepods as intermediate hosts, including *Mesocyclops leukarti* (see Sinha 1988), which occurs in New Zealand. It causes damage to the intestinal mucosa and submucosa in fish hosts (Bose and Sinha 1984), including *Puntius conchonius.* However, it only matures in *Heteropneustes fossilis,* not *Puntius conchonius* (see Sinha 1988), and therefore it will not be included.

High numbers of larvae of *Raphidascaris acus* and their migration through liver tissue caused cyst- or granuloma-like formations in the liver parenchyma, resulting in mild to severe disease in stone loach, *Barbatula barbatula* in the Czech Republic (Koubkova et al. 2004). This parasite has been reported to cause pathology in a wide variety of hosts, including European eels, roach (*Rutilis rutilis*), salmonids and yellow perch *Perca flavescens* and some marine species (see Poole and Dick 1984, Valtonen et al. 1994, Moravec et al. 1990, Moravec 2003, Schabuss et al. 2005). As it also occurs on fishes on the permitted species list, and uses a variety of planktonic crustaceans such as cladocerans and amphipods as intermediate hosts (Moravec 1996, Moravec et al. 1998c), it is possible that it could complete its lifecycle and become established in many members of New Zealands native fish species, hence *R. acus* will be considered further in the risk analysis.

Spirocamallanus mysti utilises a copepod (*Mesocyclops leuckarti*), which occurs in New Zealand, as an intermediate host (De 1995). However it has rarely been reported (De et al. 1986), it has not been associated with disease, and it will not be included here. The life cycles of *Spirocamallanus pintoi* and *P. nilgiriensis* are unknown, however as these parasites are rarely reported, this suggests they do not cause major problems and therefore they will not be considered further.

Serpinema trispinosum uses turtles as definitive hosts and third stage larvae have been recorded from the intestine of cichlids, *Cichlasoma urophthalmus* in Mexico (Moravec et al. 1998b), which may act as paratenic hosts. Various *Cichlasoma* spp. are included in the permitted list, however *S. trispinosum* has only been recorded in taxonomic papers and does not appear to cause morbidity or mortality in any of its hosts. As turtles are rare in New Zealand marine waters, the chances of introduction and establishment of this parasite appear remote, and therefore it is not included.

3.3.8.4 Acanthocephalans

Acanthocephalans are specific to their intermediate hosts, and less so to their definitive hosts. *Acanthosentis dattai* utilises the copepod *Mesocyclops leuckarti* as its intermediate host (Sharma and Wattal 1976), and *M. leuckarti* occurs in New Zealand. It infects the ornamental cyprinids *Colisa fasciatus,* and *Puntius sophore,* but it has not been reported from sub-tropical or temperate hosts and will not be included. *Acanthosentis siamensis* is only known from its original description, and will not be included. *Acanthocephalus anguillae* and *A. clavula* infect eels and trout as well as a variety of other species. These parasites cause some pathology at the attachment site but no disease in affected hosts, and will not be included.

Neoechinorhynchus rutili and *Pomphorhynchus laevis* are reasonably well studied parasites of a variety of fish species, including brown and rainbow trout. This is due mainly to the fact that their larvae affect the behaviour of crustacean intermediate hosts (Mazzi and Bakker 2003), and that adult parasites tend to accumulate metals and hence are useful bioindicators of pollution (Sures 2004). Both species may be able to establish in New Zealand fish populations as they infect a range of crustaceans and other invertebrate intermediate hosts (Table 3.7), but they are not known to cause any significant disease in their final hosts (Dorucu et al. 1995) and hence they will not be considered further.

Juveniles of *Polyacanthorhynchus kenyensis* cause minor pathology in the liver of *Micropterus salmoides* and *Tilapia* spp. and hence they will not be considered further here This species was probably transferred from South America to North America (Schmidt and Canaris 1967). The following acanthocephalans are known only from taxonomic studies or host:parasite records: *Acanthocephalorhynchoides cholodkowskyi* (a synonym of *Quadrigyrus cholodkowskyi*), *Hanumantharaorhynchus hemirhamphi*, *Metechinorhynchus baeri*, *Micracanthorhyncha* spp., *Neoechinorhynchus chilkaensis*, *Pomphorhynchus yunnanensis*, *Pallisentis gaboes* and *Quadrigyrus* spp. This suggests they do not cause major problems and therefore they will not be considered further.

3.4 The parasites and disease agents to be considered

The process in section 3.3 considered each of the parasites and disease agents identified as potential hazards in Table 3.6 and Appendix 1 and eliminated those that appear insignificant or irrelevant to the disease status of fishes and other aquatic life in New Zealand. This process concludes the hazard identification section of this document and the remaining diseases and parasites will be considered further in the risk assessment section . The final list of parasites and disease agents that will be considered in this risk analysis is as follows:

Disease-based approach	**Host-based approach**
VIRUSES	**VIRUSES**
Aquabirnaviruses (including IPNV)	IPNV
Apistogramma viral disease	
Iridoviruses	
Grouper nervous necrosis virus	
Viral haemorrhagic septicaemia virus	Viral haemorrhagic septicaemia virus
BACTERIA	**BACTERIA**
Edwardsiella ictaluri	*Edwardsiella ictaluri*
Edwardsiella tarda	
Flavobacterium columnare	
	Lactococcus garvieae
Streptococcus spp.	
FUNGI	**FUNGI**
Aphanomyces invadans (EUS)	*Aphanomyces invadans* (EUS)
PROTOZOA	**PROTOZOA**
Piscinoodinium pillulare	*Piscinoodinium* spp.
Chilodonella hexasticha	
Chilodonella piscicola	
Cryptocaryon irritans	
	Glugea heraldi
	Goussia carpelli
Unidentified dinoflagellate	
MYXOZOA	
Enteromyxum leei	
MONOGENEA	
Benedenia epinepheli	

DIGENEA	**DIGENEA**
Centrocestus formosanus	*Centrocestus formosanus*
Clinostomum complanatum	
Diplostomum pseudospathaceum	
	Diplostomum spathaceum
	Haplorchis spp.
Haplorchis taichui	
	Haplorchoides mehrai
CESTODA	**CESTODA**
Bothriocephalus acheilognathi	*Bothriocephalus acheilognathi*
NEMATODA	**NEMATODA**
Camallanus cotti	
	Capillaria philippinensis
Capillaria pterophylli	
Pseudocapillaria brevispicula	*Pseudocapillaria brevispicula*
	Pseudocapillaria tomentosa
	Rhaphidascaris acus
CRUSTACEA	**CRUSTACEA**
Argulus foliaceus	*Argulus foliaceus*

4. RISK ASSESSMENT

For each disease considered, the risk assessment will first discuss the aetiology, the OIE listing and the status of the organism in New Zealand. Then the relevant epidemiology of the disease agent will be considered, particularly that concerning routes of transmission.

The release assessment will consider the likelihood that the organism will be introduced to New Zealand through the release of host fish from quarantine.This release assessment process may involve consideration of the initial prevalence and intensity of infection, the effect of stress from capture, transport and handling, the time course of the disease and how long the agent can survive outside the host. If the release assessment concludes that there is a negligible likelihood of release or the organism from quarantine, then the risk analysis will go no further for that particular organism.

However, if the release assessment concludes that the likelihood of release is non-negligible, then the exposure assessment will consider the likelihood that the infectious agent will come into contact with susceptible species and become established in New Zealand. The exposure assessment process considers prevalence and intensity of infection, transmission to susceptible species, spread by vectors, possible treatment, and temperature ranges of the introduced fish species.

If the exposure assessment concludes that the likelihood of exposure of New Zealands fishes and aquatic organisms to the disease agent is not negligible, then the likely consequences of the establishment of the disease in endemic populations will be examined in the consequence assessment.

Finally, the risk estimate summarises the preceding steps of the risk estimate, to arrive at an estimation of the risk involved in light of the risk management steps currently employed in New Zealand – which is essentially an extended period of post-arrival quarantine.

If the risk is estimated to be non-negligible then appropriate risk management measures will be considered in section 5 of this document.

VIRUSES

4.1 Aquabirnaviruses (including IPNV)

4.1.1 Aetiologic agent: Birnaviruses are double stranded RNA viruses, the ones of concern here being those of the genus *Aquabirnavirus* belonging to the family Birnaviridae.

4.1.2 OIE List: Yes (IPNV).

4.1.3 New Zealand's status: Aquatic birnaviruses have been recorded from Chinook salmon (*Oncorhynchus tschawyscha*) returning from the sea and from flatfish (*Colistium nudipinnis*) in a marine aquaculture facility. However the strains isolated from New Zealand are related to the relatively benign Ab strain of IPNV. More virulent strains have not been recorded.

4.1.4 Epidemiology

Aquabirnaviruses have been isolated from a wide range of marine and freshwater fish and shellfish. There are numerous strains (Zhang and Suzuki 2004), however one of the most significant to New Zealand is the highly contagious IPNV which causes infectious pancreatic necrosis (IPN), an OIE-listed disease. It has caused epizootics among salmonids held under culture conditions in Europe, the Americas, and Asia. Some strains of IPNV (Sp, VR-299) often cause overt disease, whereas others (Ab) seldom do. A molecular study has found that the Sp, VR299 and Ab strains are not closely related (Blake et al. 2001). It also found that the one tropical isolate examined, from snakeheads in Thailand, clustered with isolates from an English oyster, Danish trout, French trout and Norwegian salmon (Blake et al. 2001). Isolates from ornamental fish tend to be of the Ab strain (Adair and Ferguson 1981, Hsu et al. 1993) or other serotypes (Chew-Lim et al. 2002). Whether aquabirnavirus isolates from ornamental fish can infect salmonids is unknown, but a precautionary approach will be taken here and it will be assumed that they are able to.

Aquabirnaviruses persist in the aquatic environment without causing disease in wild fishes at variable prevalences, ranging from 0.06% (Amos et al. 2001) to 44.4% (Shankar and Yamamoto 1994) in feral salmonids. In contrast, these viruses can often cause disease when fish are crowded or stressed. For example, a survey of diseased fishes (*Plecoglossus, Scleropages, Epinephelus, Zanclus*) from fish farms in Taiwan, found 100% prevalence (Hsu et al. 1993). It is likely that the fish would appear healthy after capture and initial confinement, acting as asymptomatic carriers. Viral titres are usually low in carriers (Bootland et al. 1991, McAllister et al. (2000), and therefore it can be assumed that initially virus levels would be low.

4.1.5 Release assessment

Aquabirnaviruses such as IPNV can be transmitted horizontally (Bowden et al. 2002), or vertically by contaminated gametes (Seeley et al. 1977, Bootland et al. 1991). Virus would be easily transmitted in the crowded conditions of transport. The stress of handling and transport would probably reveal underlying infection in carriers (Stangeland et al. 1996, Taksdal et al. 1997, 1998, Chou et al. 1999). For IPNV the time course of the disease depends on the strain, the species, genotype and age of the fish, the method of exposure, and the temperature. Mortalities among salmonids that have been exposed by immersion in IPNV-laden water began between 6-21 days (Okamoto et al. 1984, Shankar and Yamamoto 1994, Taksdal et al. 1998, Bowden et al. 2002). The first signs of infection and viral shedding among rainbow trout occurred in < 2 days after immersion exposure, and uninfected fish cohabited with shedding trout showed the first signs of disease 2 days later (Bebak et al. 1998). Exposed rainbow trout experienced < 5% mortality at 5°C, but 70% mortality at 10-20°C (Okamoto et al. 1987). When infected at 15°C, mortalities peaked among rainbow trout after 4-6 days (Okamoto et al. 1987). Therefore, despite low initial titres, stress may cause immuno-suppression, allowing viral shedding under crowded conditions resulting in mortalities among IPN-infected consignments. The rapid time course of IPN makes it likely that the fish will die well before the end of quarantine. Therefore the time course in salmonids is much more rapid than the 28-40 days using even a 3-week quarantine period (marine fish). However, it is likely to be longer if cyprinid carriers are involved. In such a case, the time that the disease would be disclosed is unknown, and possibly would exceed a 6 week quarantine period (freshwater fish).

IPNV can survive > 231 days at 10°C in tap water and > 210 days in mud (pH 7.6, 4°C) (Ahne 1982b). It can survive 4-14 days at 20°C and 6-17 days at 15°C in seawater, and 3-14 days at 20 °C and 4-25 days at 15°C in freshwater (Barja et al. 1983). It is stable in estuarine water at 15°C (Toranzo and Hetrick 1982). Water in which fish have been transported therefore must be disposed of with care. Mortalities in salmonids due to IPN occur at 5-20°C, and the tropical ornamental fish from which aquabirnaviruses have been isolated have a combined temperature range of 18-30°C. The one exception to the latter is *Barbus graellsii*, which is a temperate cyprinid species on the permitted list, from which IPNV has been isolated (Ortega et al. 1993a, 1993b). It is likely that other temperate *Barbus* spp. and related cyprinids (*Barbodes, Puntius Varicorhinus, Capoeta*), which are on the permitted list, can act as carriers, and it is likely that aquabirnaviruses would be present in some carrier fish which survive quarantine.

4.1.6 Exposure assessment

It must be considered that due to the persistence of these viruses at temperatures typical of temperate regions, if carrier fish or contaminated water are subsequently released into the environment, there are many species of susceptible endemic fish which could be exposed to these viruses. Under these circumstances, it is considered there is a moderate chance exotic strains of aquabirnavirus could readily become established in New Zealand waters. There are several routes of transmission and herons (*Ardea cineria*) and other birds, which can spread the virus in their faeces, occur in New Zealand (Peters and Neukirch 1986, McAllister and Owens 1992). As infected invertebrates may act as reservoirs of IPNV infection (Mortensen 1993), care should be taken to prevent live invertebrates in the consignment being released from quarantine. If only tropical genera were imported, the risk might be low, but the importation of temperate cyprinids that may act as carriers puts the probability of establishment in the moderate category.

4.1.7 Consequence assessment

The establishment of virulent strains of aquabirnavirus in New Zealand would almost certainly have significant biological consequences with the potential to have adverse affects on aquaculture industries for both salmonids and marine species throughout the country. Considerable mortality and morbidity could be expected, hence the significance of the consequences of establishment of these disease agents is classed as high.

4.1.8 Risk Estimation

The likelihood of establishment of exotic strains of aquatic birnaviruses from ornamental fish is considered moderate, and the significance of the resulting consequences are considered high, hence the risks to the New Zealand environment are non-negligible, and additional risk management steps are required.

4.2 *Apistogramma* viral disease

4.2.1 Aetiologic agent: Apistogramma virus, an iridovirus composed of double stranded DNA with an icosahedral capsid.

4.2.2 OIE List: No.

4.2.3 New Zealand's status: Not recorded. Considered exotic.

4.2.4 Epidemiology

A viral disease which caused mortalities between 40 and 80% in five disease outbreaks among *Apistogramma ramirezi* imported into the U.S.A. (Leibovitz and Riis 1980b). Despite the high mortalities recorded during this outbreak, there have been no further reports of this disease in the literature. The virus appears to have been host specific, and *A. ramirezi* is a tropical species (27-30°C) which could not survive in New Zealand waters unless they were introduced into geothermal waters or the artificially heated waters discharged from power stations into some rivers.

4.2.5 Release assessment

Because this virus appears to be host specific and the host is a tropical species, the disease agent is likely to be adapted to water temperatures above those which occur naturally in New Zealand, except for in geothermal areas and discrete areas where heated waters are discharged from power stations. Because of this, these disease agents appear highly unlikely to cause disease in the vast majority of the country, and the probability of introduction is considered as extremely low. Considering the apparent host specificity of this virus, the probability of its establishment in wild fish populations in geothermal areas and power station outlets appears negligible, and hence the disease will not be considered further.

4.3 Iridoviruses

4.3.1 Aetiologic agent: Iridoviruses, large (130-300 nm) icosahedral double stranded DNA viruses of the genus *Ranavirus and Tropivirus*.

4.3.2 OIE List: The OIE lists 3 iridoviral diseases of fish, epizootic haematopoietic necrosis (EHN), red sea bream iridovirus (RSIV), and white sturgeon iridovirus (WSIV).

4.3.3 New Zealand's status: Not recorded. Considered exotic.

4.3.4 Epidemiology

Iridoviral infections of fish are divided into three groups. Viruses belonging to the genus *Lymphocystivirus* infect skin fibroblasts causing them to greatly hypertrophy so that they appear to be small tumours on the skin and fins (lymphocystis disease). The disease is usually benign, and in New Zealand it has been observed on parore (*Girella tricuspidata*), John Dory (*Zeus faber*), and imported gouramis (Durham and Anderson 1981). The second group comprises viruses of the genus *Ranavirus,* which cause severe systemic disease of fish, amphibians and reptiles. Some strains infect both fish and amphibians. They are an emerging group of diseases, and their apparent spread has been linked to the global decline in amphibians (Chinchar 2002). Ranaviruses have been reported from several species on the permitted list including *A. ramirezi, Colisa lalia, Trichogaster* spp.*, Etroplus maculatus, L. dimidatus, P. reticulata, Parapocryptes serperaster, Pterophyllum scalare,* and *Xiphophorus helleri* (see Leibovitz and Riis 1980a, Armstrong and Ferguson 1989, Anderson et al. 1993, Fraser et al. 1993, Martinez-Picado et al. 1993, Hedrick and McDowell 1995, Rodger et al. 1997, Paperna et al. 2001). The third group includes viruses of the genus *Tropivirus* and these cause iridoviral diseases of *Epinephelus* spp., *Colisa lalia, Aplocheilichthys normani*, *Helostoma* spp. and *Trichogaster* spp. (see Chua et al. 1994, Chou et al. 1998, Qin et al. 2001, Murali et al. 2002, Sudthongkong et al. 2002a, 2002b, Go et al. 2005). They differ from ranaviruses in amino acid sequences of their major capsid protein and ATPase, and occur in the Southeast Asian region.

Like ranaviruses they cause serious systemic disease. A molecular study found that isolates in a geographical region were more similar to each other, irrespective of host, than to isolates from other regions (Sudthonkong et al. 2002b).

4.3.5 Release assessment

It is difficult to obtain prevalence values for feral fish, as most cases of iridoviral infection in ornamental fish have been in consignments being traded internationally. Detection of virus is often from pooled samples, which prevents determination of prevalence. Mortality rates in such circumstances are often high, 40-100% (Leibovitz and Riis 1980a, Martinez-Picado et al. 1993, Ariel and Owens 1997, Rodger et al. 1997, Favero et al. 2001), but whether death is due to the primary viral infections or secondary infection is often unclear. Direct horizontal transmission appears common (Langdon 1989, Go et al. 2005). At least some strains transmit vertically (Georgiadis et al. 2001), and piscivorous birds may spread iridoviruses (Whittington et al. 1996).

Stress due to adverse environmental conditions (LaPatra et al. 1994) and stocking density (LaPatra et al. 1996) cause elevated cumulative mortalities in WSIV-infected sturgeon. Epizootics of WSIV occurred 9-32 days after stressing (Georgiadis et al. 2001). The time course of disease is relatively rapid under culture conditions, with WSIV having a 35 day replication cycle (Watson et al. 1998a). Peak mortalities of 3%/day occur at 23°C (Watson et al. 1998b). Red sea bream iridovirus (RSIV) shows first signs at 5-6 days, first mortalities at 6 days, and peak mortalities at 9 days after exposure (Oshima et al. 1998). Between 60% and 90% mortalities occurred 5-14 days after exposure to RSIV (Nakajima and Maeno 1998). Mortalities of 100% may occur 8 days after immersion exposure to sheatfish iridovirus, but at 11 days following co-habitation (Ahne et al. 1990). Mortalities of 100% have also been reported 8 days after immersion exposure to sheatfish iridovirus at 25°C (Ogawa et al. 1990). The time course of iridoviral infections in non-ornamental fish (WSIV, RSIV) is therefore faster than the time course of 28-40 days (3-week quarantine for marine fish), hence it appears likely that carrier fish would become clinically affected before or during quarantine if they were unduly stressed by transport. However, carriers held under ideal conditions may not show clinical signs of disease, even during a 6 week quarantine period (freshwater fish), hence it is possible that covertly infected fish may clear quarantine, and if released, find their way into the New Zealand environment.

4.3.6 Exposure assessment

Fish iridoviruses transmit directly, stressed fish have elevated susceptibility, the time course is rapid, and most reports from ornamental fish report epizootics before the fish are released from quarantine. Despite this, there is mounting evidence that iridoviruses are spreading, and that they are spread by ornamental fish trading, contributing to global decline of amphibians. Tropical ornamental fish released into the wild in New Zealand have remained confined to geothermal waters, without spread into temperate waters, and native temperate species do not co-habit geothermal waters. The combined temperature range of the iridovirus-infected fish on the permitted list is 18-30°C. EHN may have derived from imported tropical fish (Hedrick and McDowell 1995), the temperature range of which is 18-28°C (*P. reticulata* [18-28°C], *Labroides dimidatus* [24-28°C]), while that of the EHN-infected fishes, 10-24°C (*Perca fluviatilis* [10-22°C], *Oncorhynchus mykiss* [10-24°C]). There is, therefore, overlap in the temperature range of the ornamentals and the temperate species, making co-habitation possible. Little is known of the host specificity of iridoviruses, but the infection of fish and amphibians by one isolate (Moody and Owens 1994) and transfer to native fish by another isolate (Go et al. 2005), suggests ranaviruses and tropiviruses are non-host specific. Due to the likely availability of susceptible hosts throughout New Zealand, the probability of establishment after release from quarantine is considered to be moderate.

4.3.7 Consequence assessment

Ornamental fish iridoviruses appear non-host specific, so they may be a threat not only to the New Zealand fish fauna, but also to amphibians, and perhaps reptiles. The consequences of establishment of these disease agents in endemic fish populations are classed as high, and in threatened aquatic amphibians the results could be catastrophic.

4.3.8 Risk Estimation

The likelihood of establishment of iridoviruses from aquarium fish in New Zealand is considered moderate, and the significance of the resulting consequences are considered high to catastrophic, hence the risks to the New Zealand environment are non-negligible, and additional risk management steps are required.

4.4 Grouper nervous necrosis virus

4.4.1 Aetiologic agent: Grouper nervous necrosis virus, a betanodavirus consisting of small non-enveloped icosahedral virus particles (25-30nm) with an single stranded positive sense RNA genome.

4.4.2 OIE List: Yes (Viral Encephalopathy and Retinopathy, VER).

4.4.3 New Zealand's status: Not recorded, considered exotic.

4.4.4 Epidemiology

Grouper nervous necrosis virus is a betanodavirus that causes the disease viral encephalopathy and retinopathy (VER) in groupers (*Epinephelus* spp.) in China, Taiwan, Japan, Singapore, the Philippines and Indonesia (Fukuda et al. 1996, Chi et al. 1997, Zafran et al. 2000, Lin et al. 2001, Hegde et al. 2002, Maeno et al. 2002). VER is an OIE-listed disease which infects the central nervous system of larval and juvenile marine fish. Genomic classification has shown that there are at least four related groups of nodaviruses; striped jack nervous necrosis virus (SJNNV), tiger puffer nervous necrosis virus (TPNNV), barfin flounder nervous necrosis virus (BFNNV), and red-spotted grouper nervous necrosis virus (RGNNV) (Nishizawa et al. 1997, Valle et al. 2001, Tanaka et al. 2003). However, isolates of one group may also cause nervous necrosis in fish normally infected with nervous necrosis virus of another group (Tanaka et al. 2003). The disease is most severe in young fish, and pathogenicity may vary between different isolates infecting the same host (Breuil et al. 2001).

4.4.5 Release assessment

The prevalence of nodaviruses in wild fish varies but with development of sensitive molecular diagnostic techniques the virus has been shown to be widespread in many species of marine fish (Barker et al. 2002, Gagne et al. 2004). Transmission is horizontal and, in SJNNV and sea bass nervous necrosis, vertical (Nishizawa et al.

1996, Munday and Nakai 1997). The time course of the disease is relatively fast. Sea bass exposed by immersion develop brain lesions in 4-6 days (Breuil et al. 2001). In a study on sea bass, 6 days after immersion there were 32% mortalities, by co-habitation 43% mortalities, and orally 24% mortalities (Peducasse et al. 1999). Exposure by intra-muscular injection after 3 days with 100% mortalities, and by intra-peritoneal injection, after 3 days and 10% mortalities (Peducasse et al. 1999). Intra-peritoneal injection of *Epinephelus coioides* at 28°C resulted in mortalities after 1 day, and 100% mortalities after 50 hours (Chi et al. 1999). Nodavirus infections increase in severity and are earlier at onset at higher temperatures (Fukuda et al. 1996, Tanaka et al. 1998). Japanese flounder exposed to nodavirus on hatching showed first signs of disease at 17-18 mm length, with 100% mortality at 25 mm after two weeks (Nguyen et al. 1994). The time course is less than the 28-40 days of capture, transport, holding, and a 3-week quarantine (marine fish). The earliest onset of disease is 14 days post-hatch (OIE 2000), and therefore if the virus was present in juvenile fish, the disease would run its course before or during quarantine. However, once fish grow to larger sizes, they become carriers and may not show clinical signs of disease during the quarantine period, hence it is possible that covertly infected fish may clear quarantine, and if released, find their way into the environment.

4.4.6 Exposure assessment

Should grouper nodavirus enter New Zealand in ornamental fish, and should the infected hosts be introduced into coastal waters, it appears extremely unlikely they would survive for any period in temperate habitats, except in the height of summer in the northern parts of the country. Exposure of susceptible endemic species to infected fish also seems unlikely. *Epinephelus* spp. do not occur in New Zealand waters, and they are in a different sub-family (Epinephelinae) to New Zealand serranids, *Lepidoperca* spp. (Anthiinae), however local species of flatfish would be susceptible, as would other marine coastal species such as silver trevally and striped trumpeter. The probability of establishment therefore appears low.

4.4.7 Consequence assessment

Grouper nervous necrosis virus would probably infect New Zealand flatfish and possibly other susceptible marine coastal species such as silver trevally and striped trumpeter. All of these species have high economic value, and may be important aquaculture candidates in the future, especially in the northern parts of the country. If this virus became established, this disease may pose a significant threat to the aquaculture of these species. Nodaviruses are also listed by the OIE and their introduction may have adverse consequences to trade. The consequences of establishment are therefore considered moderate.

4.4.8 Risk Estimation

The combination of a low probability of establishment together with moderately significant consequences of an introduction, suggest that the risk of introduction of grouper nervous necrosis virus via imported *Epinephalus* spp. is non-negligible, and additional risk management steps are required.

4.5 Viral haemorrhagic septicaemia virus

4.5.1 Aetiologic agent: Viral haemorrhagic septicaemia virus (VHSV), a novirhabdovirus with an enveloped, bullet shaped virion approximately 70 x 180 nm and a single stranded negative sense RNA genome.

4.5.2 OIE List: Yes.

4.5.3 New Zealand's status: Not reported, considered exotic.

4.5.4 Epidemiology

Viral haemorrhagic septicaemia (VHS) disease is associated with epizootics among cultured rainbow trout (*Oncorhynchus mykiss*), turbot (*Scophthalmus maximus*) and Japanese flounder (*Paralichthys olivaceus*). The original epizootics in European trout farms occurred after fish were fed diets containing marine fishes, suggesting the virus originated from the marine environment (Snow et al. 2004). Subsequently, viral haemorrhagic septicaemia virus (VHSV) has been isolated from many species of marine fishes in the temperate seas of Europe (Dixon et al. 1997, Brudeseth and Evensen 2002), North America (Meyers et al. 1999) and Japan (Watanabe et al. 2002). Two genogroups of VHSV exist in Japanese waters, one being related to North American isolates, the other to European isolates (Nishizawa et al. 2002). VHSV has been isolated from *Barbus graellsii* in Spain (Basurco and Coll 1989), and *Barbus* spp. are on the permitted list.

4.5.5 Release assessment

Prevalence among wild fish is much lower than in cultured fishes. When wild herring with 1% prevalence of VHSV were held in captivity, prevalence reached 100% with 50% mortalities after 14 days (Kocan et al. 2001). Prevalence of VHSV in marine fishes in waters around Japan was reported as 6.6% (Takano et al. 2001). Transmission is horizontal and direct, but VHSV may be spread by herons (*Ardea cineria*), that occur in New Zealand (Peters and Neukirch 1986). Uninfected turbot

Scophthalmus maximus cohabited with infected turbot, and uninfected turbot exposed by immersion, had cumulative mortalities of 60% and 71%, respectively, after 60 days (Snow and Smail 1999). Rainbow trout stressed by transfer to seawater experienced heavy mortalities from VHSV with mortalities rising to 85% by 80 days post transfer (Castric and de Kinkelin 1980). The time course of infection depends on the dose to which the fish is exposed, and the method of exposure. Rainbow trout exposed by immersion had VHSV in the heart at 3-6 days, spleen at 5-17 days, pancreas at 5-11 days and kidney at 10-30 days (Ortega et al. 1994). Shedding via the faeces began 11 days after exposure. Rainbow trout exposed by immersion to low levels, moderate levels and high levels of VHSV had mortalities of 44% (low), 64% (moderate) and 96% (high) after 14 days (Evensen et al. 1994). The time course is faster than the 28-40 days involving a 3-week quarantine (marine fish), hence it is likely that sub clinical infections would be disclosed during quarantine after the stressors of transport and handling. However it would probably take much longer for disease to be disclosed in cyprinid carriers. How long is unknown, but it is possible that carrier fish could survive 6 weeks quarantine (freshwater fish) with subclinical infections.

4.5.6 Exposure assessment

The release assessment suggests that some species of carrier fish may survive quarantine with subclinical infections and thus VHSV could be introduced into the New Zealand environment if infected ornamental fish were released. Once introduced, the virus would most likely persist in many areas as VHS is a cold water disease. Fish exposed by immersion had the highest mortalities at 3.5-4.5°C, with lower mortalities at 11-12°C, and lowest mortalities at 19-20°C (Neukirch 1984). Similarly, the survival of VHSV outside the host is inversely correlated with water temperature (Parry and Dixon 1997). VHSV has been isolated from *Barbus graellsii* in Spain (Basurco and Coll 1989), which is a temperate cyprinid species on the permitted list. It is likely that other temperate *Barbus* spp. and related cyprinids (*Barbodes, Puntius Varicorhinus, Capoeta*), which are on the permitted list, can act as carriers. Many species in these genera may readily become established in New Zealand waters. The importation of temperate cyprinids that may act as carriers of VHSV is a threat that results in the probability of establishment being considered as moderate.

4.5.7 Consequence assessment

Should VHSV be introduced into New Zealand, where there are many susceptible species, the introduction would most likely have severe consequences, particularly for any future attempt to culture rainbow trout, and probably for marine species as well. There would possibly even be adverse effects on wild trout fisheries, as well as adverse consequences for trade in fish products. The significance of the consequences of introduction are therefore considered high.

4.5.8 Risk Estimation

A moderate likelihood of establishment combined with highly significant consequences of introduction, suggest the risk of introduction of VHSV via imported ornamental fish is non-negligible, and additional risk management is required.

BACTERIA

4.6 *Edwardsiella ictaluri*

4.6.1 Aetiologic agent: The bacterium *Edwardsiella ictaluri*, a gram negative rod shaped bacterium from the Enterocacteriaceae family.

4.6.2 OIE List: Yes.

4.6.3 New Zealand's status: Not recorded, considered exotic.

4.6.4 Epidemiology

Edwardsiella ictaluri causes enteric septicaemia primarily in channel catfish (*Ictalurus punctatus*), but also in several other catfish species, including *Ictalurus nebulosus,* which has been introduced into New Zealand. It infects or is carried by a wide range of fishes (OIE 2003). *E. ictaluri* has been reported from at least two species of freshwater ornamental fish. In *Danio devario,* no gross lesions occurred, but infection of the brain caused erratic swimming behaviour (Blazer et al. 1985). Forty percent mortalities occurred during quarantine in a consignment of *Puntius conchonius* imported into Australia, while a second consignment was clinically normal, but *E. ictaluri* could be cultured from both consignments (Humphrey et al. 1986). *I. nebulosus* may act as a carrier of *E. ictaluri*, but in chinook salmon exposed experimentally to the pathogen, it caused 92% mortalities in 14 days (Baxa et al. 1990).

4.6.5 Release assessment

E. ictaluri is transmitted horizontally (Shotts et al. 1986, Klesius 1994), and may be spread by herons (Taylor 1992). One study found 53% of 137 piscivorous birds shot at fish farms were positive for *E. ictaluri* (see Taylor 1992), but most isolates were not cultureable and hence may not have been viable (OIE 2003). In a temperature stress study, mortality was greatest among fish moved from 15°C to 25°C (77%), but less in *I. punctatus* moved from 15°C to 18°C (10%), and in fish moved from 15°C to 30°C

(23%) (Plumb and Shoemaker 1995). Acute outbreaks of disease in catfish tend to occur within a limited temperature range of 17-28°C (OIE 2003). Mortality rates after immersion exposure were 0% at 15°C, 46.6% at 20°C, 97.8% at 25°C, 25.0% at 30°C, and 4.0% at 35°C (Baxa-Antonio et al. 1992). In *I. punctatus,* following immersion challenge, bacteraemia occurred after 1 day, with 100% prevalence after 3 days (Wise et al. 1997). When infected and non-infected *I. punctatus* were cohabited, mortalities begin 12 days after co-habitation (Klesius 1994). *I. punctatus* infected by stomach tube show macroscopic lesions after 14 days (Shotts et al. 1986). The time course is faster than the 28-40 day period involving a 6-week quarantine period (freshwater fish). Furthermore, elevated mortalities occurred among *I. punctatus* fingerlings exposed to confinement stress (Wise et al. 1993). These disease characteristics suggest that fish stressed by capture and transport would be likely to show signs of clinical disease during quarantine, however it is also known that fish from a population that has recovered from this disease can be covertly infected carriers with high levels of *E. ictaluri* antibodies (OIE 2003). Viable bacteria can be detected in the kidney of carrier fish well over 4 months after exposure to the disease agent (Klesius 1992). It is possible, therefore, that some fish could survive quarantine without showing clinical signs of disease and may act as a reservoir of infection.

4.6.6 Exposure assessment

The release assessment suggests that some carrier fish may survive quarantine with subclinical infections and thus *E. ictaluri* could be introduced into the New Zealand environment if infected ornamental fish were released. Once introduced, the bacterium appears unlikely to cause disease in many areas of the country because in general, acute outbreaks of disease occur in waters between 17 and 28°C, and mortalities increase with temperature, being greatest at 22-28°C (Francis-Floyd et al. 1987). However water temperatures are within this range for at least some of the year in the northern parts of the country (where the largest populations of *I. nebulosus* occur), and within this range year round in some geothermal areas and the artificially heated waters discharged from power stations. Furthermore the bacterium can persist without causing clinical disease at temperatures below 10°C, and since the endemic species known to be susceptible include both catfish (*I. nebulosus*) and salmonids, there is a low probability that the bacterium could become established in endemic fish populations in most parts of the country with that probability increasing to moderate in the geothermal areas, power station outlets and in the warmer regions of the northern parts of the country.

4.6.7 Consequence assessment

It would appear unlikely that infected *D. devario* would be put in contact with chinook salmon under conditions that would favour infection, and a lack of reports of natural infection of chinook salmon from imported ornamentals, suggests that risk is low. However, the introduction of *E. ictaluri* may threaten populations of *I. nebulosus* and other susceptible fish species, including salmonids, in freshwater in the northern parts of New Zealand. This could have significant adverse affects on the health of fish populations in these areas, and as this disease agent is OIE listed, this would also impact the trading status of the salmon industry, hence the consequences of introduction are assessed as moderate.

4.6.8 Risk Estimation

A low to moderate probability of establishment combined with moderately significant consequences of introduction, suggest the risk of introduction of *E. ictaluri* via imported ornamental fish is non-negligible, and that additional risk management is required.

4.7 Edwardsiella tarda

4.7.1 Aetiologic agent: The bacterium *Edwardsiella tarda*, a gram negative rod shaped bacterium from the Enterobacteriaceae family.

4.7.2 OIE List: No.

4.7.3 New Zealand's status: Not recorded, considered exotic.

4.7.4 Epidemiology

Edwardsiella tarda is an enterobacterial organism that has been isolated from ornamental fish on the permitted list, such as *Betta splendens* and *Hyphessobrycon* sp. (see Humphrey et al. 1986), *Metynnis schreitmuelleri* and *Trichogaster trichopterus* (see Dixon and Contreras 1992, Ling et al. 2001), and *Rhamdia quelen* (syn. *Pimelodus quelen*) (see Shama et al. 2000). It infects all groups of vertebrates, including freshwater and marine fishes (Costa et al. 1998), amphibians including frogs, where it can be associated with redleg disease (Donnelly 2005) and humans, where it can cause gastroenteritis, cellulitis, gas gangrene, septicaemia, meningitis, cholecystitis and osteomyelitis (Vandepitte et al. 1983, Janda and Abbott 1993). It is mainly a pathogen of warm water fishes during the summer months, but natural infections occur in chinook salmon (Amandi et al. 1982), rainbow trout (Reddacliff et al. 1996), brook trout (Uhland et al. 2000) and eels (*Anguilla* sp.).

4.7.5 Release assessment

Transmission is direct and horizontal, with entry via the gastrointestinal tract, gills and body surface (Ling et al. 2001). When channel catfish were stressed by poor water quality (low dissolved oxygen, high ammonia, CO_2), similar to that in which fish have been transported for a long time, *E. tarda* prevalence was 43% in stressed fish, and 7% in unstressed fish (Walters and Plumb 1980). More than 80% of Japanese flounder died with *E. tarda* infections less than two weeks after transport stress (Kodama et al. 1987). The course of disease is relatively short. When Japanese flounder (*Paralichthys olivaceus*) were exposed to *E. tarda* by immersion or *per os*, fish were moribund after 7-10 days (Rashid et al. 1997). This is faster than the 28-40 days involving a 3-week quarantine period (marine fish). However it is also known that fish from a population that has recovered from this disease can be covertly infected carriers. It is possible, therefore, that subclinically infected fish could survive even 6 weeks quarantine (freshwater fish) and may act as a reservoir of infection.

4.7.6 Exposure assessment

The release assessment suggests that some carrier fish may survive quarantine with subclinical infections and thus *E. tarda* could be introduced into the New Zealand environment if infected ornamental fish were released. Almost all fish species and other aquatic organisms are susceptible to infection by *E. tarda*, but the usual prerequisites for development of disease include high water temperatures and organically polluted water. Because of this, the bacterium appears unlikely to cause disease in the vast majority of the southern parts of the country. However, suitable conditions for establishment may occur in isolated areas of northern New Zealand, such as in the artificially heated waters discharged from power station cooling towers into the Waikato River. Since this disease agent is known to infect a wide range of hosts, the probability of establishment is considered as low.

4.7.7 Consequence assessment

Although *E. tarda* is widespread globally, it is not problematic in fish culture to the same degree as *E. ictaluri*, which is considered to be a primary pathogen in many cases. In contrast, *E. tarda* is an opportunistic pathogen of a variety of animal groups and outbreaks of disease can be controlled by improving hygiene, water quality and reducing stocking densities. Hence the significance of the consequences of introduction to aquatic animals are considered to be low. However in humans, *E. tarda* is considered a potentially important pathogen. Infection, although rare, can have serious health implications and under exceptional circumstances can even cause death (Wang et al. 2005). Because of this, the significance of consequences of introduction of *E. tarda* are considered to be moderate.

4.7.8 Risk Estimation

A low probability of establishment combined with moderate significance of the consequences of introduction, suggest the risks involved with introduction of *E. tarda* via imported ornamental fish are non-negligible and require additional risk management.

4.8 *Flavobacterium columnare*

4.8.1 Aetiologic agent: Flavobacterium columnare, a filamentous gram negative slender motile rod shaped (0.5 x 4-12 µm) bacterium which causes columnaris disease in freshwater fishes.

4.8.2 OIE List: No.

4.8.3 New Zealand's status: Present in New Zealand.

4.8.4 Epidemiology

Flavobacterium columnare infects the gills and skin of freshwater fish, impeding respiration and damaging the skin leading to secondary infection and death. Severe mortalities may occur, especially in culture or crowded conditions (Morrison et al. 1981, Campbell and Buswell 1982, Kumar et al. 1986, Michel et al. 2002). *F. columnare* occurs worldwide, including New Zealand, and many strains of varying virulence exist (Decostere et al. 1998, Michel et al. 2002). Individual strains may be virulent in one host, but not another (Soltani et al. 1996). *F. columnare* was included in the risk assessment because of the report of a highly virulent strain (Michel et al. 2002).

4.8.5 Release assessment

Transmission is horizontal and direct, with the bacterium adhering to the gills (Decostere et al. 1999a, 1999b). When infected and uninfected fish were cohabited transmission occurred more readily at 20°C than at 15°C (Morrison et al. 1981). Elevated temperatures are thought to improve gill adhesion, increasing disease levels. Should ornamental fish infected with a virulent exotic strain of *F. columnare* enter the country, after the stress of handling, crowding and transport, such a virulent strain would be expected to cause mass mortalities in the first 3 weeks of the 6 week quarantine period, if not during transit. Not only is columnaris disease readily detectable in quarantine, it is also treatable (Bader et al. 2003). Surviving fish and untreated water may still contain viable bacteria (Trust and Bartlett 1974) however, and it is therefore possible that a virulent exotic strain of *F. columnare* could persist after quarantine and enter the New Zealand environment if sub clinically infected ornamental fish were released.

4.8.6 Exposure assessment

The release assessment suggests that some fish may survive quarantine with subclinical infections and thus *F. columnare* could be introduced into the New Zealand environment if infected ornamental fish were released. Most species of freshwater finfish are susceptible to *F. columnare*, however disease is caused only under conditions of adverse water quality, high stocking density and other stressors, and is promoted by higher water temperatures. Because of this, the bacterium appears unlikely to become established in the vast majority of the country, however since it is known to infect a wide range of hosts, the probability of establishment is considered as moderate.

4.8.7 Consequence assessment

F. columnare is an opportunistic pathogen and outbreaks can be controlled by improving hygiene, water quality and reducing stocking densities. It is already ubiquitous in New Zealand, hence the significance of the consequences of introduction of exotic strains of *F. columnare* are considered to be very low to negligible.

4.8.8 Risk Estimation

A moderate probability of establishment combined with very low to negligible significance of the consequences of introduction, suggest the risks involved with introduction of *F. columnare* via imported ornamental fish are negligible, and do not require additional risk management.

4.9 Lactococcus garvieae

4.9.1 Aetiologic agent: Lactococcus garvieae (formerly *Enterococcus seriolicida,* see Eldar et al. 1996), a gram positive non-motile bacterium with spherical or ovoid cells with a diameter of 0.6 – 0.9 µm.

4.9.2 OIE List: No.

4.9.3 New Zealand's status: Not recorded from fish in New Zealand, considered exotic.

4.9.4 Epidemiology

Lactococcus garvieae is an opportunistic pathogen of marine and freshwater fish worldwide, and has a wide host range which includes both aquatic and terrestrial vertebrates (including humans), and aquatic invertebrates (Eldar et al. 1999). Various strains exist in different geographic areas and there is evidence that some strains have been moved into different regions through importation of infected fish (Eldar et al. 1999). Under the right circumstances this bacterium causes disease and results in heavy mortalities in the culture of a very wide range of fish species, and also shellfish. It causes typical bacterial haemorrhagic septicaemia in susceptible fishes, usually under conditions of environmental stress such as high temperatures in summer, especially if this occurs together with high stocking densities. Infections are frequently associated with stressors such as concurrent infections (Kumon et al. 2002), and changes in feeding, handling or transportation, but sometimes primary outbreaks occur without any particular predisposing factor (Roberts 2001).

Lactococcosis caused by *L. garvieae* is the major bacterial disease of yellowtail (*S. quinqueradiata*) in Japan (Kusuda and Salati 1993, 1999). It has also been recorded to cause significant disease in the culture of eels and flatfish. One Australian strain was isolated from diseased rainbow trout (*Oncorhynchus mykiss*) in freshwater hatcheries in Tasmania and Victoria (Carson *et al.* 1993). In Tasmania, disease associated with *L. garvieae* infection was observed in rainbow trout soon after sea transfer of covertly infected fish from hatcheries with a known history of disease due to *L. garvieae*. In both cases, no transfer of disease to other species of marine fish was recorded. Transmission is direct and horizontal, with entry via the water or the rectal-oral route.

4.9.5 Release assessment

L. garvieae has been recorded from *Coris* spp. which are included in the permitted list, but it is an emerging disease agent with low host specificity, and hence could infect a wide range of species on the permitted list. Some covert carriers are likely to express disease if exposed to stressors associated with transport and quarantine, however if conditions remain favourable to the fish during the current 3 week quarantine period (marine fish), it is possible that subclinically infected fish could survive quarantine and may act as a reservoir of infection if they were released into the wild.

4.9.6 Exposure assessment

The most important route of infection is via the carcasses of infected fish, with other potential routes of infection including birds, faeces from infected fish, and directly through the water. If infected ornamental fishes were released and subsequently died and were eaten, many fish species in New Zealands freshwater and marine environments would be exposed to a chance of infection by *L. garvieae*. However its persistence in the environment would need to be facilitated by high stocking densities and high water temperatures, the combination of which are rarely encountered in the New Zealand marine environment outside fish farms in the northern parts of the country. In freshwater areas, suitable conditions for establishment may occur only in very localised areas in northern New Zealand, such as in the artificially heated waters discharged from power station cooling towers into the Waikato River. Hence the probability of establishment is considered to be low.

4.9.7 Consequence assessment

Lactococcus garvieae is a significant pathogen of cultured yellowtail (*Seriola quinqueradiata*) in Japan as well as a number of other species including rainbow trout and freshwater prawns (*Macrobrachium rosenbergi*) (see Chen et al. 2001). These or closely related species have significant commercial value in New Zealand, and hence the introduction of this bacterium could have deleterious impacts on industries associated with these species. However, vaccination and antibiotic therapy are generally effective in finfish and since the disease is associated with various stress factors, removal of these can greatly improve fish survival. Hence the significance of consequences of introduction are considered to be moderate.

4.9.8 Risk Estimation

A low probability of establishment combined with moderate significance of the consequences of introduction, suggest the risk of introduction of *Lactococcus garvieae* via imported ornamental fish is non-negligible, and additional risk management is required.

4.10 ***Streptococcus* spp.**

4.10.1 Aetiologic agent: Various members of the Streptococcaceae, including *Streptococcus iniae*, a gram positive, non motile spherical or ovoid bacteria occurring singly or in chains with a cell diameter of 0.6 – 0.9 µm.

4.10.2 OIE List: No.

4.10.3 New Zealand's status: Some species of *Streptococcus* known to be present, however *S. iniae* is considered exotic.

4.10.4 Epidemiology

Streptococcosis, caused by *Streptococcus iniae,* is an emerging disease of zoonotic importance. *S. iniae* infects tilapias (Perera et al. 1994, 1997, 1998, Press et al. 1998, Shoemaker et al. 2000, Mukhi et al. 2001), barramundi (Bromage et al. (1999), and striped bass (Evans et al. 2001). Other species of *Streptococcus*, including *S. shiloi* and *S. difficile* cause disease in various species of ornamental cyprinids and cichlids (see Eldar et al. 1995). Unidentified *Streptococcus* spp. infect ornamental fish *Brachydanio rerio, Brachydanio albolineatus, Tanichthys albonubes*, *Helostoma temminckii, Puntius conchonius, Puntius gelius, Rasbora* sp. and *Labeo* sp. (see Ferguson et al. 1994, Humphrey 1995). Whether the latter *Streptococcus* spp. are conspecific with *S. iniae,* is unclear.

Transmission is direct and horizontal (Evans et al. 2000, 2001). When *S. iniae* infected and uninfected tilapia were stressed by poor water conditions, mortalities of 73.3% among infected fish and 46.6% among uninfected fish, were reported (Radwan 2002). Tilapia kept at 24-26°C experienced mortalities at low stocking densities of 4.8%, medium stocking densities of 28.4%, and high stocking densities of 25.6%, suggesting the mortalities were mainly due to stress, rather than stocking density (Shoemaker et al. 2000). *S. iniae* has been reported to grow *in vitro* at 10-40°C with optimum growth at 25-35°C (Mukhi et al. 2001), and at 10-45°C with maximum mortalities at 20°C (Perera et al. 1997). For tilapia the range is 8-42°C, and for the ornamental fish from which *S. iniae* has been isolated 18-28°C. In general, disease caused by *S. iniae* usually occurs in high summer and is related to poor husbandry or excessive stocking levels (Roberts 2001).

4.10.5 Release assessment

The time course of disease is rapid. After inoculation of the nares of hybrid striped bass, infection was present in the cerebellum, blood of the gills, heart and kidney after, 4 hours, the olfactory lobe was positive at 12 hours, and the optic lobe at 18 hours (Evans et al. 2000, 2001). Barramundi infected by immersion experienced 40% mortalities in 2 days (Bromage et al. 1999). Tilapia injected intra-peritoneally experienced 100% mortalities in 7 days (Mukhi et al. 2001). The time course of the disease is much more rapid than the 28-40 days involving a 3-week quarantine period (marine fish) or 6 weeks used for freshwater fish.

The time course of *S. iniae* infections and the effects of stress on infected fish make it very likely that mortalities will occur long before the fish are released from quarantine. However any subclinically infected fish and untreated water may still contain viable bacteria (Trust and Bartlett, 1974), and it is therefore possible that exotic strains of *Streptococcus* could persist after quarantine and enter the New Zealand environment if covertly infected ornamental fish are released.

4.10.6 Exposure assessment

The release assessment suggests that some fish may survive quarantine with subclinical infections and thus exotic strains of *Streptococcus* could be introduced into the New Zealand environment if infected ornamental fish were released. Many species of freshwater finfish are susceptible to *Streptococcus* infection, however disease is caused only under conditions of adverse water quality, high stocking density and other stressors, and is promoted by higher water temperatures. Because of this, the bacterium appears unlikely to cause disease in the vast majority of the country, however since it is known to infect a wide range of hosts, the probability of establishment is considered as low.

4.10.7 Consequence assessment

Streptococcus spp. are opportunistic pathogens and outbreaks can be controlled by improving hygiene, water quality and reducing stocking densities. Hence the significance of the consequences of introduction are considered to be low.

4.10.8 Risk Estimation

A low probability of establishment combined with low significance of the consequences of introduction, suggest the risks involved with introduction of *Streptococcus* via imported ornamental fish are negligible and do not require additional risk management.

FUNGI

4.11 *Aphanomyces invadans*

4.11.1 Aetiologic agent: The fungus *Aphanomyces invadans*, a peronosporomycete member of the Saprolegniaceae with non septate hyphae (12-25 µm in diameter) which is the causative agent of Epizootic Ulcerative Syndrome (EUS).

4.11.2 OIE List: Yes.

4.11.3 New Zealand's status: Not recorded, considered exotic.

4.11.4 Epidemiology

Aphanomyces invadans is recognised as the primary disease agent responsible for epizootic ulcerative syndrome (EUS), although a rhabdovirus (Kanchanakhan et al. 1999a) and *Aeromonas* spp. (see Mastan and Qureshi 2001) have been implicated in the infection. The disease has been isolated from *Colisa lalia, Etroplus suratensis, Trichogaster* spp. and *Puntius sophore,* (see Srivastava 1980, Wada et al. 1994, Hanjavanit et al. 1997, Pathiratne and Rajapakshe 1998, Catap and Munday 1999, Kanchanakhan et al. 1999a, Pathiratne and Jayasinghe 2001), all of which are on the permitted list. EUS is seasonal and highly pathogenic. It was first reported in Japan in 1971 (Egusa and Masuda 1971), and then in eastern Australia in grey mullet (*Mugil cephalus*) in 1972 (McKenzie and Hall 1976). It has since been recorded throughout Papua New Guinea and Asia (OIE 2000).

Transmission is direct and horizontal, especially through open wounds (Mohan and Shankar 1999, Kiryu et al. 2002). Reported prevalence varies greatly, from 3.8-55.5% in brackish water ponds in one study (Mohan et al. 1999), from 16% in wild fish and 15.5% in farmed fish in another (Khan and Lilley 2002), and from 26-80% in another (Lilley et al. 2002). EUS is very non host-specific (Lio-Po 1999). Mortalities among fish exposed by immersion following net handling or trauma ranged from 94-100% with 70-79% showing characteristic lesions, while untraumatised controls experienced 24% mortalities with 32% showing lesions (Kiryu et al. 2002). Reduced salinity due to tropical storms may favour the fungus, or stress the fish hosts (Mohan et al. 1999). EUS epizootics occur when temperatures are low, but are more common in warm water fish than cold water fish (Catap and Munday 1999, Lio-Po 1999). This may be because at lower temperatures, the inflammatory response in warm water fish is slowed (Catap and Munday 1998).

4.11.5 Release assessment

EUS can be induced within 7-10 days by co-habitation (Mohan and Shankar 1999). In menhaden (*Brevoortia tyrannus*) injected with high or low doses of *A. invadans*, a granulomatous response was present after 5 days, and the first mortalities occurred at 7 days with the high dose and 9 days with the low dose (Kiryu et al. 2002). In sand whiting (*Sillago ciliata*) injected with *A. invadans* and subsequently held at 26°C or 17°C, peak leucocytic infiltration occurred after 14 days at 26°C, and 18 days at 17°C (Catap and Munday 1998). Snakeheads (*Channa striata*) exposed by immersion to *A. invadans* spores and held at 20°C developed EUS lesions after 30 days (Kanchanakhan et al. 1999b). The time course is more rapid than a 6 week quarantine period used for freshwater fish. This makes it likely that lesions would be observed and mortalities will occur before the fish are released from quarantine. However, more resistant fish species may not necessarily show clinical signs of disease during quarantine. Subclinically infected fish may still contain viable fungi, and it is therefore possible that *A. invadans* could persist after quarantine and enter the New Zealand environment if ornamental fish are released.

4.11.6 Exposure assessment

Some authorities consider that *Aphanomyces invadans* has spread rapidly and widely since the first record in 1971, largely by the natural or human movement of infected fishes. The release assessment suggests that some fish may survive quarantine with subclinical infections and thus *A. invadans* could be introduced into the New Zealand environment if infected ornamental fish were released. This fungus infects more than 100 fish species including some, like grey mullet (*Mugil cephalus*), that occur in New Zealand waters. Because of this, the fungus probably could infect a variety of estuarine species in the northern parts of the country. However, since *A. invadans* is restricted in distribution to salinities below 30 ppt, transmission is likely to occur only in brackish rivers and estuaries, hence the probability of establishment is considered as moderate.

4.11.7 Consequence assessment

Unlike other fungi, *A. invadans* is considered to be a primary pathogen. Should this disease agent arrive in New Zealand, it probably would infect many species which frequent rivers and estuarine areas. This could have significant adverse affects on the health of fish populations in these areas whenever conditions favour the pathogen, and as this disease agent is OIE listed, this would also impact New Zealand's trading status. For these reasons, the consequences of introduction are assessed as moderate.

4.11.8 Risk Estimation

A moderate probability of establishment combined with moderate significance of the consequences of introduction, suggest the risk of introduction of *Aphanomyces invadans* via imported ornamental fish is non-negligible, and additional risk management is required.

PROTOZOA

4.12 *Piscinoodinium pillulare*

4.12.1 Aetiologic agent: Fish invading dinoflagellates, including *Piscinoodinium pillulare* and other *Piscinoodinium* spp.

4.12.2 OIE List: No.

4.12.3 New Zealand's status: Some strains probably present in ornamental fish.

4.12.4 Epidemiology

Piscinoodinium pillulare and other *Piscinoodinium* spp. have been associated with severe disease and mortalities in tropical fish worldwide (Shaharom-Harrison et al. 1990, Ramesh et al. 2000, Martins et al. 2001). *Piscinoodinium* sp. was found on 22.5% of fish at a dealer's holding facility in Brazil, and on 14% of the same fish species from the same dealer on arrival in Britain (Ferraz and Sommerville 1998). Similarly, *Piscinoodinium pillulare* infected 14% of *Leporinus macrocephalus* and 8% of *Piaractus mesopotamicus* at a fish farm in Brazil (Tavares-Dias et al. 1999). However, *P. pillulare* was reported at only 0.2% prevalence on farmed goldfish in Italy (Marcer et al. 2001). Transmission is horizontal and direct. *Piscinoodinium pillulare* proliferated in matrinxa (*Brycon cephalus*) stressed by handling and transport (Carneiro et al. 2002a, 2002b**)**. The time course of disease is shortened when fish are crowded and held at higher temperatures. Epizootics occur at 24.5-31.5°C (Shaharom-Harrison et al. 1990). Large scale mortalities have been recorded at commercial farms.

4.12.5 Release assessment

Despite the translocation of the parasite to temperate developed countries, there have been no reports of it establishing in the wild or causing epizootics. However in the absence of active surveillance it is possible that some infected fish held at temperatures below those which favour the parasite may survive 6 weeks quarantine with subclinical infections, thus exotic *Piscinoodinium* spp. could be introduced into the New Zealand environment if infected ornamental fish were released.

4.12.6 Exposure assessment

These disease agents appear to be adapted to higher temperatures and disease tends to occur only when fish are crowded at high densities at water temperatures above those which occur naturally in New Zealand except for in geothermal areas and the artificially heated waters discharged from power stations. Because of this, these disease agents appear highly unlikely to become established in the vast majority of the country, and the probability of establishment is considered as low.

4.12.7 Consequence assessment

Piscinoodinium spp. tend to be opportunistic pathogens of captive fish and outbreaks can be treated and also controlled by improving hygiene, water quality and reducing stocking densities. Outbreaks of disease in wild fish restricted to geothermal and artificially heated waters would appear extremely unlikely, and would nevertheless be restricted by water temperature to specific localities, and hence the significance of the consequences of introduction are considered to be low.

4.12.8 Risk Estimation

A low probability of establishment combined with low significance of the consequences of introduction, suggest the risks involved with introduction of *Piscinoodinium* spp. via imported ornamental fish are negligible and do not require additional risk management.

4.13 *Chilodonella* spp.

4.13.1 Aetiologic agent: Exotic ectoparasitic histiophagous ciliates of the genus *Chilodonella*.

4.13.2 OIE List: No.

4.13.3 New Zealand's status: Some species present (Hine et al. 2000).

4.13.4 Epidemiology

Chilodonella cyprini and *C. hexasticha* have caused epizootic mortalities among native fishes in Australia (Langdon et al. 1985, Humphrey 1995). *Chilodonella* spp. are exotic to Australia and New Zealand, their presence being due to importation of live fish (Hine et al. 2000, Evans and Lester 2001). Signs of infection can include respiratory distress and excessive mucous production. *Chilodonella piscicola* may cause mortalities among cultured salmonids, but this has been rarely reported (Urawa 1992, Urawa and Yamao 1992). Prevalence varies greatly, being up to 100% by *Chilodonella piscicola* in a consignment of neon tetras (*Paracheirodon innesi*) (Evans and Lester 2001), to 0.001% by *C. piscicola* in Danish trout (*Oncorhynchus mykiss*) farms (Buchmann and Bresciani 1997). Transmission is horizontal and direct, with the gills being the main target organ. The time course of disease is likely to be rapid under stressful crowded conditions and at temperatures that are within the range for each *Chilodonella* species. Epizootics caused by *C. hexasticha* in Australia occurred during the winter months (Langdon et al. 1985), and the optimum temperature for *C. cyprini* is 5-10°C (Hoffman et al. 1979).

4.13.5 Release assessment

Chilodonella spp. have been spread worldwide by the international movement of live fish. They can occur in low numbers on fish which appear clinically healthy. It is possible, therefore, that infected fish may survive quarantine with subclinical infections and thus exotic *Chilodonella* spp. could be introduced into the New Zealand environment if infected ornamental fish were released.

4.13.6 Exposure assessment

These parasites have low host specificity, and their optimal temperatures are typical of those experienced by endemic fish in many parts of New Zealand. It is considered that the chances of establishment of exotic species in wild fish populations would be moderate.

4.13.7 Consequence assessment

Epizootics caused by these ciliates are relatively uncommon, unless hosts are stressed by poor conditions (Langdon et al. 1985) or crowding. In this respect, *Chilodonella* spp. are opportunistic pathogens comparable with *Ichthyophthirius multifiliis* the aetiological agent of white spot, which is widespread throughout New Zealand, and hence the significance of the consequences of their introduction are considered as very low.

4.13.8 Risk Estimation

A moderate probability of establishment combined with a very low significance of the consequences of introduction, suggest the risks involved with introduction of *Chilodonella* spp. via imported ornamental fish are negligible and do not require additional risk management.

4.14 *Cryptocaryon irritans*

4.14.1 Aetiologic agent: The ectoparasitic ciliate *Cryptocaryon irritans*, a member of the Prostomatea and the cause of white spot disease in marine fish.

4.14.2 OIE List: No.

4.14.3 New Zealand's status: Present.

4.14.4 Epidemiology

Cryptocaryon irritans is an ectoparasitic ciliate classified in the order Prorodontida within the Class Prostomatea (see Wright and Colorni 2002). This parasite commonly causes epizootic mortalities in marine aquarium fishes. Although not closely related, the gross signs and course of disease are similar to those caused by *Ichthyophthirius multifiliis,* the aetiological agent of white spot disease in freshwater fishes. It has been isolated from *Cantherhines macrocerus, Epinephelus fuscoguttatus, Epinephelus tauvina, Lutjanus johni*, and *Poecilia latipinna* traded internationally (Rasheed 1989, Tak-Seng and See-Yong 1989, Bunkley-Williams and Williams 1994, Yoshinaga and Dickerson 1994, Burgess and Matthews 1995, Afifi 2000), but can infect nearly all marine fishes. Strains exist that differ in virulence (Diggles and Adlard 1997, Young et al. 2000) and which vary in pattern of development (Diggles and Lester 1996b). Trophonts feed on the epidermis of the fish host. They leave the host and sink to the sediment where they form a cyst (tomont). Theronts leave the tomont and infect the fish host to become trophonts. A study in southeast Queensland showed that prevalence on wild fish at different sites and on different hosts ranged from 38-100% and mean intensity from 1.9-14.6 *C. irritans/*fish^{-1} (Diggles and Lester 1996a). In another study it infected 5.3% of grey mullet (*Mugil cephalus*) (see Wang et al. 2001). A local strain of *C. irritans* is present on coastal fish, including snapper (*Pagrus auratus*) in the north of the North Island of New Zealand (Hine, personal observation, Diggles et al. 2002), but due to its rarity has yet to be described. At 30°C, 25°C and 20°C, 70%, 77% and 64% of trophonts encysted in 16 hours, and at 30°C, 50% excysted in 5 days, and 100% in 7 days (Cheung et al. 1977, 1979). Trophonts completed their growth phase on the host in 3-7 days, and theront excystment occurred after 3-38 days. The theronts live for 23-48 hours (Colorni 1985). Excystment did not occur at 7°C and 37°C (Cheung et al. 1977, 1979). A strain of *C. irritans* from Southern Queensland poses a threat to mariculture where water temperatures are over 19°C (Diggles and Lester 1996c). Another strain grew well at 25-31°C, but was damaged at 34°C (Yoshinaga 2001). A cold water strain has been reported that causes disease in olive flounders (*Paralichthys olivaceus*) in Japan at 12-16°C (Jee-Bo et al. 2000).

4.14.5 Release assessment

The time course of infection is almost always shorter than the 28-40 days associated with a 3-week quarantine (marine fish), but if fish are transferred to different tanks on a regular basis during transport and quarantine, the lifecycle is interrupted and infections may not reach epizootic levels. *C. irritans* trophonts may occur in low numbers on lightly infected fish which appear clinically healthy, and in these circumstances there is virtually no way of detecting the infection without detailed microscopic examination. It is possible therefore that infected fish may survive quarantine with subclinical infections and thus exotic *Cryptocaryon irritans* strains could be introduced into the New Zealand environment if infected ornamental fish were released.

4.14.6 Exposure assessment

Cryptocaryon irritans is normally a warm water parasite, and if released most strains would only be a threat to the marine fishes of the north of the North Island during the summer months. However, a cold water strain (12-16°C) has been reported (Jee-Bo et al. 2000), which could affect fish throughout most of New Zealand at certain times of the year. *C. irritans* is non host-specific, and will experimentally infect hosts outside its geographic range (Burgess and Matthews 1995), however even so it seems unlikely that *C. irritans* in ornamental fishes would come into contact with susceptible fish in the wild. It would require infected ornamental fish to be released among susceptible hosts, and to stay among them until trophonts drop to the sediment, and theronts emerge from the tomonts a few days later. Given the short period of time the theronts are viable, the probability of establishment in the wild is considered to be low.

4.14.7 Consequence assessment

Most epizootics associated with *C. irritans* occur in aquaria or cage culture, rather than in the wild, even when *C. irritans* is common in the wild. Any adverse effects of introduction of cold water strains of this parasite would therefore be restricted to mariculture industries. There are several treatments for *C. irritans,* including caprylic acid (Hirazawa et al. 2001), benzalkonium chloride (Hirazawa et al. 2003), and changes in salinity (Pironet and Jones 2000). Should a virulent strain become established in New Zealand, the consequences, at most, would be low, for fish crowded in aquaria or sea cages, and negligible for wild fish.

4.14.8 Risk Estimation

A low probability of establishment combined with low to negligible significance of the consequences of introduction, suggest the risks involved with introduction of *C. irritans* via imported ornamental fish are negligible and do not require additional risk management.

4.15 *Glugea heraldi*

4.15.1 Aetiologic agent: Glugea heraldi, a microsporidian endoparasite of seahorses.

4.15.2 OIE List: No.

4.15.3 New Zealand's status: Not recorded, considered exotic.

4.15.4 Epidemiology

Infection by *Glugea heraldi* causes boil-like lesions and severe disease in seahorses (*Hippocampus erectus*) (see Blasiola 1981). The parasite infects the subcutaneous connective tissues, producing xenoma complexes 100 to 800 μm in diameter. Each cyst is encapsulated by an eosinophilic fibrous capsule and consists of a large number of tightly packed spores. Mature spores are released into the environment during rupture of the boils or upon the decay of the host (Blasiola 1979). One case study (Vincent and Clifton-Hadley 1989) reported infection of a captive population of seahorses (*Hippocampus erectus*) collected from Florida Bay, USA, with *G. heraldi*. Of 76 animals in the original population, only two survived (97.3% mortality). The prevalence of infection of wild seahorses was not determined. Infection is horizontal and direct after consumption of spores directly or indirectly through ingestion of live foods. The spore enters the gastrointestinal tract where it excysts to release a amoeboid sporoplasm which penetrates the intestinal epithelium and enters the bloodstream, through which it migrates to the subcutaneous connective tissue and begins dividing to form the xenoma. The parasite is thought to infect a variety of *Hippocampus* species, but appears specific to seahorses. Like other microsporidians, the lifecycle is probably temperature limited, and completed faster at higher temperatures.

4.15.5 Release assessment

Clinically affected fish exhibit multiple boil-like lesions which are visible to the naked eye, suggesting that heavily infected individuals would be detected during quarantine. The prepatent period of infection is not known, but based on the data of Blasiola (1981) and the development cycles of other microsporidians, is likely to be less than the time associated with 3 weeks quarantine used for marine fish. However the lesions are small and it may be possible that a lightly infected fish with a subclinical infection could escape detection during quarantine, after which there is a chance that *G. heraldi* could be introduced into the New Zealand environment if infected seahorses were released.

4.15.6 Exposure assessment

Even though endemic seahorses are relatively abundant around ports and wharves, infected ornamental seahorses would need to be released into areas where there were significant populations of endemic seahorses, and survive long enough to transfer infective spores to a significant number of seahorses in the endemic population. This combination of circumstances appears unlikely, and hence the risk of exposure of wild seahorses in New Zealand to *G. heraldi* introduced by ornamental seahorses appears low.

4.15.7 Consequence assessment

Glugea heraldi is not a threat to the vast majority of fishes in New Zealand, however its presence could possibly pose a very low threat to the health of wild seahorse populations, but would be more likely to pose a moderate threat to the fledgling seahorse farming industry.

4.15.8 Risk Estimation

A low probability of establishment combined with a moderate significance of the consequences of introduction to the seahorse farming industry, suggest the risk of introduction of *Glugea heraldi* via imported ornamental fish is non-negligible and requires additional risk management.

4.16 *Goussia carpelli*

4.16.1 Aetiologic agent: Goussia carpelli, an apicomplexan parasite classified in the subclass Coccidia, Order Eimeriida.

4.16.2 OIE List: No.

4.16.3 New Zealand's status: Not recorded, considered exotic.

4.16.4 Epidemiology

Goussia carpelli has been recorded from *Barbus barbus bocagei* on the permitted list, and causes problematic chronic mortalities among goldfish (*Carassius auratus*) in the United States (Kent and Hedrick 1985). It also causes severe enteritis and mortality in cultured carp (*Cyprinus carpio*) in Europe (Steinhagen et al. 1998). In the United States, fish became infected shortly after hatching and sporulated oocysts were found in 15-day old fish. At 6 weeks they stopped feeding, became lethargic and emaciated, and 50-75% cumulative mortalities occurred over the subsequent 2-3 weeks. Mortality was due to enteritis (Kent and Hedrick 1985, Jendrysek et al. 1994). The pathology associated with the lesion was characterized by regressive changes of the epithelial cells of the gut, including dystrophy, necrosis and desquamation. Diffuse enteritis eventually develops, with prevailing lymphocytic infiltration of subepithelial connective tissue, and sometimes even the lamina muscularis (Kent and Hedrick 1985). Transmission is direct (Steinhagen and Korting 1988), or through an oligochaete intermediate host, *Tubifex tubifex* or *Limnodrilus hoffmeisteri* (see Steinhagen and Korting 1990). Stress is an important mediator of initial infection, however surviving fish are often refractory to reinfection (Steinhagen et al. 1998). The development of the parasite was temperature dependent. At 20°C, oocysts were formed 2-3 wk post exposure (PE), at 15°C for 3-4 wk PE, and at 12°C for 5-6 wk PE (Steinhagen 1997).

4.16.5 Release assessment

This parasite causes disease and mortality in smaller fish, and milder signs in larger fish. Mortalities in small fish would occur within the quarantine period, however infected fish in larger size classes would not necessarily appear diseased. These parasites infect the gut, and hence would not be detected in quarantine unless fish were necropsied and examined microscopically. In the absence of active surveillance, it would be possible that lightly infected fish with subclinical infections could escape detection during quarantine, after which there is a chance that *G. carpelli* could be introduced into the New Zealand environment if infected ornamental fishes were released.

4.16.6 Exposure assessment

This parasite has a reasonably narrow host range and as carp and goldfish are not on the permitted list, the number of species of ornamental fishes which may exit quarantine harbouring sub clinical infections is small. These would then have to be released into waters containing feral populations of carp or goldfish, both of which occur throughout the country, but particularly in the North Island. This chain of events would appear unlikely to occur, however the oocysts are relatively long lived, and suitable intermediate hosts are already present in the country, hence the probability of establishment is considered to be low.

4.16.7 Consequence assessment

Because of the relatively restricted host range of this parasite, any adverse consequences of introduction are also likely to be restricted to feral populations of carp and goldfish. The parasite may also pose a threat to the goldfish culture industry in this country, however this threat could be circumvented in goldfish culture facilities by avoiding feral carp and goldfish and treatment of incoming water to remove any infective stages that may be present. Other species are not likely to be affected, hence the significance of consequences of introduction are considered as low.

4.16.8 Risk Estimation

An low probability of establishment combined with low significance of the consequences of introduction, suggest the risks involved with introduction of *Goussia carpelli* via imported ornamental fish are negligible and do not require additional risk management.

4.17 Unidentified dinoflagellate

4.17.1 Aetiologic agent: Unidentified protozoans, in this case a dinoflagellate.

4.17.2 OIE List: No.

4.17.3 New Zealand's status: Not recorded, considered exotic.

4.17.4 Epidemiology

The unidentified dinoflagellate associated with high mortalities among freshwater catfish occurred in only 1% of the catfish imported into Germany, but it spread rapidly in aquaria, causing up to 100% mortalities in some cases (Steinhagen et al. 1999). Although unidentified, the dinoflagellate was well illustrated in Steinhagen et al. (1999), permitting comparison with other suspect cases. As with many new fish diseases (Gaughan 2002), very little is known about the epidemiology of this disease agent, except that as the infected fish came from both South America (*Acanthodoras cataphractus, Glyptoperichthys* [=*Pterygoplichthys*] *gibbiceps*) and Africa (*Synodontis multipunctatus* [= *Synodontus punctatus*], *Anaspidoglanis* [= *Parauchenoglanis*] *macrostoma*), cross infection probably occurred during transit and holding. This suggests direct horizontal transmission in captive fish. However whether this disease agent would infect other fish families, including temperate species, remains unknown.

4.17.5 Release assessment

As this and other new protozoan disease agents are microscopic and undescribed, it is likely that they would not be immediately recognised in quarantine unless they were associated with epizootics. In the absence of active surveillance this suggests that infected fish with subclinical infections could survive quarantine, and therefore there is a chance that undescribed protozoan disease agents could be introduced into the New Zealand environment if infected ornamental fish were released.

4.17.6 Exposure assessment

As the hosts for this particular disease agent are tropical catfish, they would be unlikely to survive in New Zealand waters. Should they be able to, it would appear equally unlikely that they would infect the one, introduced, catfish in the country (*Ictalurus nebulosus*). Hence the probability of establishment of this particular parasite would appear extremely low or even negligible. However if this and other undescribed parasites had low host specificity, they would be more likely to be able to infect endemic fish hosts provided environmental conditions were favourable for survival and transmission of the disease agent. As most ornamental fishes are sourced from tropical areas, it would be reasonable to assume that most of their undescribed protozoan disease agents would require relatively high water temperatures, above those which occur naturally in New Zealand except for in geothermal areas and power station outlets. Because of this, previously undescribed protozoan disease agents on ornamental fishes appear highly unlikely to cause disease in the vast majority of the country, and in general their probability of establishment is considered as low.

4.17.7 Consequence assessment

The consequences of establishment would vary depending on the epidemiology of the disease agent. In the case of the unidentified dinoflagellate, the significance of the consequences of establishment would be considered as low if these parasites infected only introduced catfishes (*I. nebulosus*). However if the disease agent infected other fish species or aquatic animals, the significance could be moderate or high, depending on the species infected and the severity of disease.

4.17.8 Risk Estimation

A low probability of establishment combined with low to high significance of the consequences of introduction, suggest the risk of introduction of unidentified dinoflagellates and other undescribed protozoan disease agents via imported ornamental fish may require additional risk management in the case of disease agents with moderate to high significance of the consequences of their introduction.

METAZOA

4.18 *Enteromyxum leei*

4.18.1 Aetiologic agent: Enteromyxum (=Myxidium) leei, a myxosporean parasite of marine fishes

4.18.2 OIE List: No.

4.18.3 New Zealand's status: Not recorded, considered exotic.

4.18.4 Epidemiology

Enteromyxum (=*Myxidium*) *leei* has been isolated from *Amphiprion* spp.*, Chromis* spp., *Coris* spp., and blennids (Kent 1999, Padrós et al. 2001), all of which are on the permitted list. It causes severe chronic enteritis (Padrós et al. 2001), often resulting in high mortalities (Rigos et al. 1999) among farmed and ornamental fish in the Mediterranean. It is non-host specific, and species in the Blenniidae and Labridae are particularly susceptible (Padrós et al. 2001). Prevalence can be as high as 80% among farmed *Diplodus* (=*Puntazzo*) *puntazzo* (see Athanassopoulou et al. 1999). Experimentally, 31.6% of previously uninfected *Sparus aurata* co-habited with infected *S. aurata*, and 33.3% of uninfected *S. aurata* exposed to contaminated water, were infected after 9 weeks (Diamant 1997). In a further study using red drum (*Sciaenops ocellatus*), the prevalences were 45.8% and 35.0%, respectively, after 43 days (Diamant 1998). Mortality rates may reach 30-70% (Rigos et al. 1999). *E. leei* is unusual for a myxosporean in that like other species in the genus (Redondo et al. 2002, 2004), it transmits directly and horizontally (Diamant 1997), whereas other myxozoans cycle through an invertebrate alternative host. It transmitted to one-third of cohabited gilthead sea bream (*Sparus aurata*) in 9 weeks (Diamant and Wajsbrot 1997), and in 43 days to 45.8% cohabited red drum (*Sciaenops ocellatus*) (see Diamant 1998). Mortalities are greatest in late summer when water temperatures reach 24-25°C (Rigos et al. 1999).

4.18.5 Release assessment

E. leei causes chronic disease, with trickling mortalities. It is unlikely that the parasite would be disclosed in a 3 week quarantine period (marine fish) if initial infection is light, nor for that matter even after a 6-week quarantine period. This suggests that there is a high chance that infected fish with subclinical infections could survive quarantine and that *E. leei* could be introduced into the New Zealand environment if infected ornamental fish were released.

4.18.6 Exposure assessment

The chronic course of this disease indicates that fish may be released from quarantine before clinical signs become apparent. If infected fish were subsequently released in to the New Zealand environment, the low host-specificity, and fish-to-fish transmission of *E. leei*, are factors that increase risk of its transfer to endemic fishes. Also, Labrids are particularly susceptible, and in New Zealand, the spotty (*Notolabrus celidotus*) is a labrid that has close contact with humans. However as the parasite favours warmer waters, it would be likely to be restricted to the northern parts of the North Island. Furthermore, compared to closed systems, the movements of hosts and water currents in the wild would not allow for prolonged contact with susceptible hosts. Because of this, the probability of establishment of *E. leei* is considered as low.

4.18.7 Consequence assessment

As *E. leei* is a parasite of warm water fish, it is likely that if it became established, it would be confined to the north of the North Island. More importantly, it causes disease only in the confined and crowded environments of mariculture and aquaria. However this disease agent is known to cause mortalities in a wide range of cultured fishes, and hence would likely pose significant problems for the mariculture of marine fishes in the northern parts of the country. Because of this, the significance of the consequences of establishment are considered as moderate.

4.18.8 Risk Estimation

A low probability of establishment combined with moderate significance of the consequences of introduction, suggest the risk of introduction of *E. leei* via imported ornamental fish is non-negligible, and additional risk management is required.

4.19 *Benedenia epinepheli*

4.19.1 Aetiologic agent: Benedenia epinepheli a monogenean ectoparasite with low host specificity.

4.19.2 OIE List: No.

4.19.3 New Zealand's status: Not recorded, considered exotic.

4.19.4 Epidemiology

Benedenia spp. are monogenean flukes that are ectoparasitic on the skin and fins of many marine fish species (Whittington et al. 2001). Some *Benedenia* spp. are host and site specific, but *B. epinepheli* is non host-specific (Ogawa et al. 1995), parasitising at least 25 fish species in the waters surrounding Japan (Whittington et al. 2001, Bondad-Reantaso et al. 1994). These include flounders, eels, tetraodontiform fishes (box fishes, porcupine fish, fugu), perciformes and scorpaeniforms (Ogawa et al. 1995). It has wide distribution, a direct lifecycle and high fecundity, and may cause mortalities under the crowded conditions of aquaria (Bondad-Reantaso et al. 1994). Like other monogeneans the time course of disease is inversely related to water temperature, but the lifecycle can be easily completed within 1 month at water temperatures above 20°C. These parasites are relatively small (2-2.5 mm long, Whittington et al. 2001) and are known to parasitise the gills as well as the body surface.

4.19.5 Release assessment

The time course of disease would be less than 30 days at water temperatures above 20°C, however usually with monogenean infections it takes 2 complete generations before the worms reach epizootic levels on confined hosts. This suggests that lightly infected fish may be subclinically infected during the course of 3 weeks quarantine (marine fish). Because these parasites are small, and the fact they are well camouflaged, it is possible that infected fish with subclinical infections could survive quarantine and that *B. epinepheli* could be introduced into the New Zealand environment if infected ornamental fish were released.

4.19.6 Exposure assessment

Most of the known host species for this parasite are sub-tropical, but some would probably survive in New Zealand coastal waters. However in the wild this parasite is considered unlikely to transmit from an introduced host species to a native host species, unlike if they were held together in confinement. This may be why there is no evidence that this parasite has been spread by movements of ornamental fish. For these reasons the probability of establishment is considered to be low.

4.19.7 Consequence assessment

This parasite only causes disease on marine fish in confinement, and thus there may be some increased risk of disease for cultured marine fish, especially in the northern parts of New Zealand. However, under conditions of confinement, *B. epinepheli* can be eradicated using praziquantel. Given that local species of marine fish are already parasitized by endemic species of *Benedenia*, such as *B. seriolae* and *B. sekii* (see Diggles et al. 2002), the consequences of introduction of *B. epinepheli* are considered as low.

4.19.8 Risk Estimation

A low probability of establishment combined with low significance of the consequences of introduction, suggest the risks involved with introduction of *Benedenia epinepheli* via imported ornamental fish are negligible and do not require additional risk management.

HELMINTH PARASITES WITH COMPLEX LIFE-CYCLES

As discussed in section 3.38, the life cycles of helminths can be divided into 3 groups; 1) digeneans that use *Melanoides tuberculata*, 2) digeneans that use lymnaeid gastropods, and 3) cestodes, nematodes and acanthocephalans that use copepods as first intermediate hosts (Tables 3.7, 3.8). The specific features of each parasite within the 3 groups will be given separately, but the similarity in life cycles makes it possible to consider the likelihood of transmission collectively for each group.

4.20 Helminths that cycle through *Melanoides tuberculata*

A number of the helminths listed in Table 3.7 utilise *Melanoides tuberculata* as their first intermediate host, and *M. tuberculata* has been introduced into the wild in New Zealand (Duggan 2002). They are *Centrocestus formosanus, Haplorchis pumilio, Haplorchis taichui, Haplorchis yokogawai* and *Haplorchoides mehrai.* All are zoonotic. *M. tuberculata* is native to sub-tropical and tropical areas of northern and eastern Africa, and southern Asia from Morocco and Madagascar to Saudi Arabia, Iran, Pakistan, India, southern China, and Indonesia (www.gsmfc.org/nis/nis/Melanoides_tuberculata.html). It has since been spread by human agency to sub-tropical and tropical countries throughout the world. *M. tuberculata* acts as a host to other parasites that also infect humans (*Clonorchis sinensis, Paragonimus westermani*). *M. tuberculata* has a wide salinity tolerance and can survive in waters from 0 to 34 ppt salinity, i.e. from freshwater to full strength seawater (Englund et al. 2000).

4.20.1 *Centrocestus formosanus,* and *Haplorchis* spp.

4.20.1.1 Aetiologic agent: *Centrocestus formosanus* and *Haplochis* spp., digenean worms that utilise *Melanoides tuberculata* as their first intermediate host.

4.20.1.2 OIE List: No.

4.20.1.3 New Zealand's status: Not recorded, considered exotic.

4.20.1.4 Epidemiology

Centrocestus formosanus: The prevalence of *C. formosanus* infection in *M. tuberculata* is related to the size of the host. Prevalence in *M. tuberculata* was 15% in 18-21mm long snails, and > 50% in snails > 30 mm long (Yanohara 1985). Prevalence of *C. formosanus* may also vary with season, being lower in the hot season (18%), and higher in the cold season (52%), due to migration patterns of the piscivorous avian definitive host (Yanohara 1985). *C. formosanus* is specific to thiarid gastropods as first intermediate host, but non host-specific to piscine second intermediate hosts and avian and mammalian definitive hosts. Among the fish species that can act as hosts are *Poecilia reticulata, Xiphophorus maculatus* and *Gambusia affinis* (see Dhanumkumari et al. 1993, Evans and Lester 2001). *M. tuberculata* inhabits streams with a temperature range of 18-25°C in the United States, and 16-18°C during the cold season in Japan (Yanohara and Kagei 1983). In New Zealand it has been found at 29-30.4°C in geothermal waters (Duggan 2002). However, Lo and Lee (1996) kept *M. tuberculata* at 10°C while determining the effect of temperature on cercarial shedding, which occurred at 15-35°C. The optimum temperature for survival of *C. formosanus* cercariae was 15°C, at which cercariae survived up to 160 hours.

Haplorchis spp. : Relatively little information is available on *Haplorchis* spp., except for numerous studies to experimentally verify the life cycle. *M. tuberculata* is the first intermediate host of *Haplorchis pumilio*, and a variety of fishes, such as *Puntius* spp., *Gambusia affinis*, rainbow trout and grass carp, may act as second intermediate hosts. Birds and mammals, including cormorants (*Phalacrocorax carbo*), herons (*Ardea cinerea*) and humans, are the definitive hosts (Sommerville 1982, Saad et al. 1995, Wang et al. 2002). *Gambusia affinis* also acts as second intermediate host for *H. yokogawai* (see Fahmy et al. 1986). Peak cercarial shedding of *H. pumilio* occurs at 30-35°C (Umadevi and Madhavi 1997).

4.20.1.5 Release assessment

These worms are both endoparasitic and hence would not be detected in quarantine unless fish were necropsied and examined microscopically. In the absence of active surveillance it is therefore likely that infected fish could survive quarantine and that infective stages of *Centrocestus formosanus* and *Haplochis* spp. could be introduced into the New Zealand environment if infected ornamental fish or snails were released.

4.20.1.6 Exposure assessment

If *M. tuberculata* infected with these flukes were released into the geothermal areas of New Zealand, and if they were released very soon after arriving in the country, there is a possibility that the flukes might infect one or more susceptible host (*Poecilia, Xiphophorus, Gambusia*) in those waters. Alternatively, if ornamental fish infected with either *Centrocestus formosanus* or *Haplochis* spp. were released into areas where *M. tuberculata* also was present, there is a chance that the lifecycle could be promoted if suitable bird or mammalian hosts were present. However, in both cases the two "ifs" make the probability of establishment low. The fish have to be infected, then eaten by one or more definitive hosts (mammals or piscivorous birds), the latter of which, cormorants or herons, is the more likely. Eggs of the adult fluke in the bird or mammal must then be passed out into the water in which susceptible hosts live. This involves two steps (ingestion of the second intermediate host by the definitive host, and eggs passing back into the water), reducing the low risk to very low. For the parasite to spread, it is necessary that *M. tuberculata* be moved to other bodies of water in which susceptible hosts live, and that either the *M. tuberculata* are infected with the flukes, or that one or more infected definitive hosts arrive at the scene. These further two steps reduce the probability to extremely low. Known hosts *Poecilia reticulata* and *Poecilia latipinna* occur in the geothermal waters into which *M. tuberculata* has been released, as does *Xiphophorus helleri. Gambusia affinis* occurs from the Waikato northwards, around the Bay of Plenty and Hawke Bay, in streams where *M. tuberculata* could survive. Therefore under suitable host and environmental circumstances, the probability of establishment is considered to be low.

4.20.1.7 Consequence assessment

The significance of consequences of introduction of these worms into the New Zealand environment would probably be negligible when fish health is being considered. However there may be some effects on the health of heavily infected birds, and/or mammals. The final necessity is that the definitive hosts have to eat infected fish hosts frequently and then infect *M. tuberculata,* otherwise the life cycle will be broken. Should all these requirements be fulfilled, the significance of the consequences would be low, unless humans start eating raw fish hosts. Hence the significance of any ecological consequences are considered as low.

4.20.1.8 Risk Estimation

A low probability of establishment combined with negligible to low significance of the consequences of introduction, suggest the risks involved with introduction of *Centrocestus formosanus* and *Haplochis* spp via imported ornamental fish are negligible and do not require additional risk management.

4.21 Helminths that cycle through lymnaeid gastropods

Three digenean flukes use lymnaeid gastropods as their first intermediate hosts, they are *Clinostomum complanatum, Diplostomum pseudospathaceum,* and *Diplostomum spathaceum.*

4.21.1 *Clinostomum complanatum*

4.21.1.1 Aetiologic agent: *Clinostomum complanatum*, a digenean trematode endoparasite which utilises *Lymnaea auricularia* as first intermediate host.

4.21.1.2 OIE List: No.

4.21.1.3 New Zealand's status: Not recorded, considered exotic.

4.21.1.4 Epidemiology

Clinostomum complanatum utilises *Lymnaea auricularia* as first intermediate host, a wide range of temperate to tropical fishes and amphibians (McAllister 1990) as second intermediate host, and piscivorous birds (herons, cormorants, pelicans gulls, kingfishers) (Aohagi et al. 1992b), as definitive host. In the definitive hosts *C. complanatum* infects the upper respiratory and alimentary tracts. Humans may also become infected. The cercariae burrow into the skin and underlying muscle in which they encyst. They are progenetic (they produce viable eggs, even though they are immature), and they can therefore complete their life cycle without utilising a definitive host. Rainbow trout may become heavily infected, making them unmarketable, or causing mortality (Szalai and Dick 1988). A prevalence of 55.2% in *Aphanius dispar* was reported, with 4-41 metacercariae per fish of which 47.3% were in the trunk region (Kalantan et al. 1987). Larger fish had higher burdens, and prevalence remained 66-100% throughout the year (Kalantan et al. 1987). In an Indian reservoir, between 1 and 218 metacercariae per fish were recorded (Jha et al. 1992). Prevalences vary with species of host. In a pond in Japan, prevalences were 30.2% in *Carassius gibelio*, 43.9% in *Carassius cuvieri,* 28.2% in *Cyprinus carpio*, 6.7% in *Pseudorasbora parva,* 0.9% in *Rhodeus ocellatus,* and 10.0% in *Rhodeus* *lanceolatus* (see Aohagi et al. 1992a). Adult worms usually live for 10-15 days, but may survive up to 50 days, in their avian hosts. The first larval stage, the miracidium, hatches in 15 days at 20-22°C, 9-10 days at 27°C, and 30 days at 16-18°C, it lives for 6-8 hours, during which it must find the snail host, *Lymnaea auricularia*, in which it develops to a cercaria in 25-28 days (Galieva 1973). Therefore the life cycle may vary from 44-108 days, probably longer than the 49-61 days involving a 6-week quarantine period.

4.21.1.5 Release assessment

This worm is endoparasitic and hence would not be detected in quarantine unless fish were necropsied and examined microscopically. This, and the longevity of the metacercarial stage in fish, means it is therefore likely that infected fish could survive quarantine and that infective stages of *Clinostomum complanatum* could be introduced into the New Zealand environment if infected ornamental fish were released.

4.21.1.6 Exposure assessment

C. complanatum is host specific to *L. auricularia,* but *L. auricularia* is rare in New Zealand, not being reported until 1979, and then from a pond in a farm paddock near Palmerston North (Charleston and Climo 1979). The snails have subsequently been virtually wiped out by pollution, hence the probability of *C. complanatum* becoming established is negligible.

4.21.1.7 Risk Estimation

A negligible probability of establishment suggests no additional risk management is required for *Clinostomum complanatum* in imported ornamental fish.

4.21.2. *Diplostomum pseudospathaceum* and *Diplostomum spathaceum*

4.21.2.1 Aetiologic agent: Diplostomum pseudospathaceum and *Diplostomum spathaceum*, two species of digenean trematode endoparasites which utilise *Lymnaea* spp. and other gastropods as first intermediate hosts.

4.21.2.2 OIE List: No.

4.21.2.3 New Zealand's status: Not recorded, considered exotic.

4.21.2.4 Epidemiology

Diplostomum pseudospathaceum infects *Lymnaea* spp. and other gastropods as first intermediate host, *Poecilia reticulata, Xiphophorus xiphophorus* and many cyprinids as second intermediate hosts, and gulls (*Larus* spp.) as definitive hosts (Niewiadomska 1986, Graczyk 1991a, Niewiadomska and Szymanski 1992). *D. pseudospathaceum* infects the eyes of its fish hosts, causing cataracts (Graczyk 1988, 1991a, 1991b, 1992). Roach (*Rutilus rutilus*) and brown trout (*Salmo trutta*) exposed to *D. pseudospathaceum* cercariae showed increased swimming activity which lasted for 36 hours in roach and 5-6 hours in brown trout (Laitinen et al. 1996).

Diplostomum spathaceum utilises *Lymnaea stagnalis* as first intermediate host, a wide range of temperate (*Oncorhynchus, Salmo, Salvelinus, Perca, Cyprinus*) to tropical (*Poecilia, Xiphophorus*) fishes as second intermediate hosts, and birds (gulls) as definitive hosts (Buchmann 1989, Graczyk 1991a, Brassard et al. 1992, Hoglund 1995, Al-Sadi et al. 1996, Buchmann and Bresciani 1997). *D. spathaceum* infects the eyes, causing cataracts, blindness and, in severe cases, death. Prevalence ranged from 5.8-100% in 7 fish species (Palmieri et al. 1976). Seasonally, prevalence ranged from 4.1% in May-June to 18.6% in August-September in *L. stagnalis* in a pond system in Germany (Loy and Haas 2001). Miracidia survive 24 hours at 20°C (Waadu 1991). *L. stagnalis* may become infected between 6-25°C, and cercariae are shed 8 weeks later (Waadu and Chappell (1991). Therefore it is unlikely to complete its life cycle, even with a 6-week quarantine period. Shedding of cercariae from *L.*

stagnalis is temperature dependent, with shedding between 4°C and >20°C, the rate of shedding increasing with temperature. Cercariae are infective at 7°C, but 4-5 times less infective than at 15°C (Lyholt and Buchmann 1996).

4.21.2.5 Release assessment

These worms are endoparasitic and hence would not be detected in quarantine unless fish were necropsied and examined microscopically, or showed clinical signs such as cataract. This, and the longevity of the metacercarial stage in fish, means it is likely that subclinically infected fish could survive quarantine and that infective stages of *Diplostomum pseudospathaceum* and *D. spathaceum* could be introduced into the New Zealand environment if infected ornamental fish were released.

4.21.2.6 Exposure assessment

L. stagnalis occurs widely in New Zealand, and it has a wide temperature tolerance range. It is found not only in still water bodies, but streams and backwaters. Three other species that might be utilised by *D. pseudospathaceum,* namely *Lymnaea tomentosa, Lymnaea columella* and *Lymnaea truncatula* are also common. For *Diplostomum* spp. to become established in New Zealand, and to complete their life cycles, imported infected tropical poeciliids would have to be eaten by gulls. The eggs of the flukes in the faeces of the gulls would then have to be deposited in a habitat with the appropriate *Lymnaea* spp. and susceptible fish hosts. This is slightly more likely to occur with *D. spathaceum,* than with *D. pseudospathaceum,* as the former infects temperate fish hosts, several of which occur in New Zealand. However due to the multiple steps required to ensure transmission, and the fact that to keep the life cycle going, *Lymnaea* spp., susceptible fish and gulls would have to have regular contact, the probability of establishment is considered to be low.

4.21.2.7 Consequence assessment

Should the flukes be introduced into New Zealand, the chronic effects of stress of infection and blindness would cause minor on-going problems for freshwater fish aquaculture, and may even affect the health of freshwater fish populations in some localised areas. However closure of the lifecycle is unlikely to occur frequently, especially in aquaculture establishments, therefore the significance of the consequences of introduction is considered low.

4.21.2.8 Risk Estimation

A low probability of establishment combined with a low significance of the consequences of introduction, suggest the risks involved with introduction of *Diplostomum pseudospathaceum* and *D. spathaceum* via imported ornamental fish are negligible and do not require additional risk management.

4.22 Helminths that cycle through cyclopoid copepods

This group includes a cestode (*Bothriocephalus acheilognathi*), and a nematode (*Camallanus cotti*).

4.22.1. *B. acheilognathi* (syn. *Bothriocephalus gowkongensis*)

4.22.1.1 Aetiologic agent: The cestode *Bothriocephalus acheilognathi*.

4.22.1.2 OIE List: No.

4.22.1.3 New Zealand's status: Not recorded, considered exotic.

4.22.1.4 Epidemiology

Bothriocephalus acheilognathi has been spread throughout Asia, Europe, South Africa, North and Central America, and Australia from its origin in China, by movements of live tropical (Font and Tate 1994) to temperate (Dove et al. 1997, Dove and Fletcher 2000) fishes. It entered New Zealand in grass carp (*Ctenopharyngodon idella*), but it was eradicated in quarantine (Edwards and Hine 1974). Its life cycle utilises common cyclopoid copepods, several of which live in New Zealand (*Cyclops* spp., *Acanthocyclops robustus, Mesocyclops leuckarti*), as the only intermediate host. *B. acheilognathi* infects cyprinids, including *Barbus, Puntius* and *Varicorhinus,* which are on the permitted list. It does not infect salmonids, but it infects *Poecilia* spp., *Gambusia* spp. and *Xiphophorus* spp., which in New Zealand live in geothermal waters. In the U.S.A., it jumped host into native fishes, and in Australia, it infected native fishes (*Hypseleotris* spp., *Retropinna semoni*) (see Dove and Fletcher 2000), which are closely related to New Zealand native fishes. Mean prevalence was 28% (range 0-78%) in *Gila cypha* and 8% (range 0-16%) in *Rhinichthys osculus*, with intensities of infection of 46 and 28 worms, respectively (Clarkson et al. 1997), in the U.S.A.. In another study, prevalences were 22.5% in *Gila cypha*, 10.3% in *Fundulus zebrinus*, 3.8% in *Rhinichthys osculus,* 2.2% in *Pimephales promelas* (Brouder and Hoffnagle 1997). In an Australian study, 34.2% (13/38) of *Cyprinus carpio,* 50% (2/4) of *Gambusia affinis,* and 16.7% (2/12) of *Hypseleotris klunzingeri* from New

South Wales were infected (Dove et al. 1997). Lower prevalences have been reported from a Bulgarian reservoir; 3.28% in *Cyprinus carpio,* 1.44% in *Leuciscus cephalus,* 1.20% in *Carassius carassius,* 3.03% in *Lepomis gibbosus,* 6.89% in *Chondrostoma nasus*, 0.94% in *Alburnus alburnus* (see Nedeva 1988). In consignments of ornamental fish imported into Australia, 36% of *Poecilia reticulata* and 10% of *Xiphophorus maculatus* were infected with *B. acheilognathi* (see Evans and Lester 2001). In *Gambusia affinis,* mortalities were 15% at 20°C, 27% at 25°C, and 50% at 30°C (Granath and Esch 1983a). *B. acheilognathi* can survive at 5-40°C (Strazhnik and Davydov 1975). At above 25°C, growth and development of the parasite were stimulated, but also above 25°C, the immune system of *Gambusia affinis* causes parasite rejection (Granath and Esch 1983b). In the copepods, plerocercoids develop to the infective stage in 11 and 12 days at 28.0°C and 21.2°C, respectively (Nedeva 1988). *B. acheilognathi* develops to maturity in 12-14 days at 22-25°C, and in 22-25 days at 15-18°C (Davydov 1978). The life cycle can therefore be completed in 23-37 days, which is within the 28-40 days involving a 3-week quarantine. However, it is likely that the cestode can survive longer than that in the fish host.

4.22.1.5 Release assessment

These worms are endoparasitic and hence would not be detected in quarantine unless fish were necropsied and examined microscopically. This means it is therefore likely that subclinically infected fish could survive quarantine and that infective stages of *Bothriocephalus acheilognathi* could be introduced into the New Zealand environment if infected ornamental fish were released.

4.22.1.6 Exposure assessment

The importation of *B. acheilognathi* may occur with the importation of temperate to sub-tropical cyprinid species, such as *Barbus* spp., *Puntius* spp., *Varicorhinus* spp., *Barbodes* spp., and *Capoeta* spp., or tropical and subtropical poeciliids (*Poecilia, Gambusia, Xiphophorus*), all of which are on the permitted list. The temperate cyprinid species could almost certainly establish in New Zealand waters, and the poeciliids are already established in geothermal waters, while *Gambusia* are established throughout the northern half of the North Island, and in areas around

Nelson. The intermediate hosts are already present in New Zealand, therefore the probability of establishment is rated as high.

4.22.1.7 Consequence assessment

As *B. acheilognathi* is non host-specific, and in Australia it has jumped host into native species that are closely related to New Zealand native species, it appears likely that if this parasite was released into the New Zealand environment, it would infect a range of endemic fish hosts and cause significant disease. The significance of the consequences of its introduction is therefore also rated as high.

4.22.1.8 Risk Estimation

A high probability of establishment combined with high significance of the consequences of introduction, suggest the risk of introduction of *Bothriocephalus acheilognathi* via imported ornamental fish is non-negligible, and additional risk management is required.

4.22.2 *Camallanus cotti*

4.22.2.1 Aetiologic agent: The Asian fish nematode *Camallanus cotti*.

4.22.2.2 OIE List: No.

4.22.2.3 New Zealand's status: Not recorded, considered exotic.

4.22.2.4 Epidemiology

Camallanus cotti originates from East, South, and Southeast Asia, but with the movement of guppies (*Poecilia reticulata*) in the ornamental fish trade, it has spread to Europe, North America, Australia and Hawaii (Font and Tate 1994, Font 1998, Evans and Lester 2001, Kim et al. 2002a, Levsen and Berland 2002a). It is non host-specific in temperate to tropical species within the Cypriniformes, Cyprinodontiformes, Siluriformes, Scorpaeniformes and Perciformes (Levsen 2001, Levsen and Berland 2002a). It has also been reported from a freshwater elasmobranch (Rigby et al. 1997). It has a flexible life cycle, either using the cyclopoid copepod *Macrocyclops albidus,* which occurs in New Zealand, as the sole intermediate host, or transmitting directly and horizontally from fish to fish (Levsen and Jakobsen 2002). In Hawaii it has transmitted from guppies to a native sleeper (Font and Tate 1994), of the family Eleotridae, the family to which New Zealand bullies belong. It can occur at high prevalences. For example, in 3 consignments of guppies imported into Australia, 48% were infected with *C. cotti* (Evans and Lester 2001). At 22°C, development within the copepod host takes 11 days. At 23°C, development to adults takes 33 days in male guppies and 34-42 days in female guppies (Levsen and Berland 2002a).

4.22.2.5 Release assessment

These worms are endoparasitic and hence would generally not be detected in quarantine unless fish were necropsied and examined microscopically. However adult parasites do occasionally protrude from the anus of the fish while laying eggs, hence in some circumstances infection might be detected by close examination of the fish.

However in the absence of active surveillance, in most cases subclinically infected fish would survive quarantine and that infective stages of *Camallanus cotti* could be introduced into the New Zealand environment if infected ornamental fish were released.

4.22.2.6 Exposure assessment

The rapid spread of *C. cotti*, and the known cases where it has infected native hosts, suggest that the probability of establishment is high in sub-tropical to tropical countries, and in warm water culture. Also, it can be assumed that guppies imported into New Zealand have similar prevalences of infection by *C. cotti* to those imported into Australia (Evans and Lester 2001), and yet to date there are no reports of *C. cotti* in New Zealand's freshwater fish fauna in either poeciliids or bullies (Hine et al. 2000). It appears from the evidence at hand that *C. cotti,* like its host, is a warm water organism that is unlikely to become established outside of the geothermal region of the North Island and localised areas surrounding power station outlets. The probability of establishment therefore appears to be low.

4.22.2.7 Consequence assessment

C. cotti appears to be a problem primarily in confinement situations, and it appears unlikely that even if it jumped host, it would result in disease in the wild. The impact on ecosystems in Hawaii is probably greater from the environmental impact of the host having established in the wild, than from the nematode establishing in other hosts. The consequences are therefore considered to be low.

4.22.2.8 Risk Estimation

A low probability of establishment combined with low significance of the consequences of introduction, suggest the risks involved with introduction of *Camallanus cotti* via imported ornamental fish are negligible and do not require additional risk management.

4.23 *Capillaria philippinensis*

4.23..1 Aetiologic agent: Capillaria philippinensis, a zoonotic nematode which causes human intestinal capillariasis.

4.23.2 OIE List: No.

4.23.3 New Zealand's status: Not recorded, considered exotic.

4.23.4 Epidemiology

Capillaria philippinensis infects a wide range of homoeothermic vertebrates, including humans (Bhaibulaya and Indra-Ngarm 1979, Nice 1994). It uses small fishes, including an ornamental species on the permitted list *Puntius gonionotus* (see Bhaibulaya et al. 1979), as intermediate hosts, although auto-infection may occur in definitive hosts (Cross et al. 1978). White-breasted water hens (*Amaurornis phoenicurus*) fed infected *Gambusia holbrookii* passed *C. philippinensis* eggs in their faeces 22-30 days after the last fish meal. Herons (*Ardeola bacchus*) passed eggs at 16 days after the last fish meal (Bhaibulaya and Indra-Ngarm 1979). Larval *C. philippinensis* fed to gerbils (*Meriones unguiculatus*) developed into adults after 10-11 days, and produced larvae after 13-14 days. The larvae developed to second generation adults after 22-24 days, and the highest number of worms were recovered at 36-46 days (Cross et al. 1978). Development from eggs to larvae takes about 3 weeks in tropical intermediate hosts. Eggs appeared in the faeces of experimentally infected monkeys 22-96 days after infection, patent infections lasted for more than a year (Cross et al. 1972). The alternative hosts necessary for the life cycle to be completed are terrestrial.

4.23.5 Release assessment

Infective larvae of these worms are endoparasitic in the fillet and hence would not be detected in quarantine unless fish were necropsied and examined microscopically. In the absence of active surveillance, this means it is likely that subclinically infected fish could survive quarantine and that infective stages of *Capillaria philippinensis* could be introduced into the New Zealand environment if infected ornamental fish were released and eaten by suitable definitive hosts.

4.23.6 Exposure assessment

Despite being able to infect a wide range of birds and mammals without the necessity of an intermediate host, the fish species that might introduce the parasite are tropical, except carp (*Cyprinus carpio*), which can survive over a wide temperature range (3-32°C). As the parasite naturally occurs only in tropical fish hosts, it may not be able to survive in temperate environments. It is unlikely that piscivorous birds or mammals would come into contact with tropical fish, except for in geothermal areas and power station outlets. The most likely route that may result in introduction would appear to be for the parasite to transmit from imported tropical fish into carp that are in the wild. These wild carp would then have to be eaten by birds or mammals, for the infection to become established in definitive hosts. Such scenarios seem highly unlikely, therefore the probability of establishment is considered to be very low.

4.23.7 Consequence assessment

The consequences are only likely to be significant if humans become infected, as the parasite can cause severe diarrhoea and sometimes death if undiagnosed in sub-tropical and tropical developing countries (El-Karasky et al. 2004). Infection of humans would require them to eat uncooked infected birds, mammals or fish. Given the increasing number of immigrants from Asia becoming resident in New Zealand, the likelihood of people consuming raw carp infected with *C. phillipinensis* may be increasing. Hence while establishment of the parasite in the New Zealand environment appears unlikely, the consequences of establishment would be considered high if the human health aspects of the introduction are considered.

4.23.8 Risk Estimation

An very low probability of establishment combined with high significance of the consequences, suggest the risks involved with introduction of *Capillaria philippinensis* via imported ornamental fish are non-negligible, and additional risk management is required.

4.24 *Capillaria pterophylli*

4.24.1 Aetiologic agent: The nematode *Capillaria pterophylli*.

4.24.2 OIE List: No.

4.24.3 New Zealand's status: Not recorded, considered exotic.

4.24.4 Epidemiology

Capillaria pterophylli was included because it causes mortalities in fishes (Moravec 1983a), it is non-host specific (Moravec and Gut 1982), and it transmits directly fish-to-fish (Moravec 1983a). *Capillaria pterophylii* has been recognized for many years as a common pathogen of captive angelfish and discus fish (Richenbach-Klinke 1952) and the closely related *Capillostrogyloides ancistri* is highly pathogenic to the bushymouth catfish *Ancistrus dolichopterus* (see Moravec et al. 1987a).

4.24.5 Release assessment

These worms are endoparasitic and hence would not be detected in quarantine unless fish were necropsied and examined microscopically. In the absence of active surveillance this means it is therefore likely that subclinically infected fish could survive quarantine and that infective stages of *Capillaria pterophylli* could be introduced into the New Zealand environment if infected ornamental fish were released.

4.24.6 Exposure assessment

This parasite species has only been reported to cause disease in aquaria, and only in tropical fish species. This is because fish in aquaria are confined, often at high densities, and the parasite can transmit directly from fish to fish causing hyperinfections which may lead to mortality if untreated. However the host range of the parasite is relatively restricted. Hence the probability of establishment in wild temperate species at water temperatures typical of the New Zealand environment appears negligible, except in geothermal areas and power station outlets where the chances of establishment would be low.

4.24.8 Consequence assessment

The restricted host range of this species would indicate that if it did become established, its effects would most likely be limited to infection of introduced ornamental fishes which have become established in geothermal areas and could become established in power station outlets. In the wild the parasite would be very unlikely to cause disease as wild fish are not confined like fish in aquaria, and hence are not as susceptible to development of hyperinfections. The consequences of establishment are therefore considered as low.

4.24.8 Risk Estimation

A low probability of establishment combined with low significance of the consequences suggests the risks involved with introduction of *Capillaria pterophylli* via imported ornamental fish are negligible and do not require additional risk management.

4.25 ***Pseudocapillaria brevispicula*** **and** ***Pseudocapillaria tomentosa***

4.25.1 Aetiologic agent: The nematodes *Pseudocapillaria brevispicula* and *Pseudocapillaria tomentosa*

4.25.2 OIE List: No.

4.25.3 New Zealand's status: Not recorded, considered exotic.

4.25.4 Epidemiology

Pseudocapillaria brevispicula and *Pseudocapillaria tomentosa* occur in temperate to tropical cyprinids (de Liberato et al. 2002) and other families (Koeie 1988, Moravec and Nagasawa 1989, Moravec et al. 1999), including cyprinid species on the permitted list (de Liberato et al. 2002). They are not host specific, infecting some 25 fishes in the family Cyprinidae and members of other orders such as Anguilliformes (eels), Gadiformes (cod fishes), Salmoniformes (salmon) and Siluriformes (catfishes) (Moravec 1987). *Pseudocapillaria tomentosa* was associated with mortality in captive tiger barbs (*Puntius tetrazona*) (see Moravec et al. 1984) and related parasites cause disease in other aquarium fishes. Lomankin and Trofimeko (1982) showed that oligochaetes (e.g. *Tubifex tubifex*) can serve as paratenic hosts for *P. tomentosa* in laboratory transmission studies. In the same study, they demonstrated that direct transmission in the absence of worms is also a route of infection.

4.25.5 Release assessment

These worms are endoparasitic and hence would not be detected in quarantine unless fish were necropsied and examined microscopically. In the absence of active surveillance this means it is likely that subclinically infected fish could survive quarantine and that infective stages of *Pseudocapillaria brevispicula* and *Pseudocapillaria tomentosa* could be introduced into the New Zealand environment if infected ornamental fish were released.

4.25.6 Exposure assessment

Cyprinus carpio and *Tinca tinca,* which occur in New Zealand waters are susceptible to infection (Moravec 1983b). These parasites occur in temperate cyprinid species on the permitted list (de Liberato et al. 2002), which could become established in the wild if imported and released. Since the lifecycle is direct and tubifex worms can be paratenic hosts and therefore could act as reservoirs of infection, this increases the chances of transfer of infection and hence the probability of establishment is considered to be moderate.

4.25.7 Consequence assessment

These parasites have not proven to be pathogenic in wild fish, but may cause disease and mortalities in aquaria (Moravec et al. 1984). Should they become established in natural waters, the consequences are likely to be negligible.

4.25.8 Risk Estimation

A moderate probability of establishment combined with negligible significance of the consequences of introduction, suggest the risks involved with introduction of *Pseudocapillaria brevispicula* and *Pseudocapillaria tomentosa* via imported ornamental fish are negligible and do not require additional risk management.

4.26 *Rhaphidascaris acus*

4.26.1 Aetiologic agent: An ascaridoid nematode *Raphidascaris acus* which uses fishes as intermediate, paratenic and final hosts.

4.26.2 OIE List: No.

4.26.3 New Zealand's status: Not recorded, considered exotic.

4.26.4 Epidemiology

Larvae of this parasite has been reported to cause pathology in a wide variety of hosts, including European eels, roach (*Rutilis rutilis*), salmonids and yellow perch *Perca flavescens* and some marine species (see Poole and Dick 1984, Valtonen et al. 1994, Moravec 2003, Schabuss et al. 2005). High numbers of larvae of *Raphidascaris acus* and their migration through liver tissue caused cyst- or granuloma-like formations in the liver parenchyma, causing mild to severe disease in stone loach, *Barbatula barbatula* in the Czech Republic (Koubkova et al. 2004). *R. acus* uses a variety of planktonic crustaceans such as cladocerans and amphipods as intermediate hosts (Moravec 1996, Moravec et al. 1998c) and adults occur in the intestines of predatory fishes such as trout, which are the final hosts. The lifecycle may also be completed directly by the faecal oral route. The prevalence of infection of *R. acus* larvae in *B. barbatula* from the River Haná ranged throughout the year from 73.3 to 100%. The abundance and the mean intensity of infection also varied throughout the year with a peak in September (Kubkova et al. 2004). In another study, the internal organs of roach were most heavily infected with *R. acus* in the eutrophic, polluted Lake Vatia (63% of fish infected with 4.0 nematodes/fish) and in the two eutrophic lakes, compared to the oligotrophic Lake Peurunka (23%, 0.8) (Valtonen et al. 1994). The prevalence of infection had significantly higher values in autumn in most cases, and larvae accumulated in the inner organs and intestine of older roach (Valtonen et al. 1994).

4.26.5 Release assessment

These worms are endoparasitic and hence would not be detected in quarantine unless fish were necropsied and examined microscopically. In the absence of active surveillance this means it is likely that subclinically infected fish could survive quarantine and that infective stages of *Raphidascaris acus* could be introduced into the New Zealand environment if infected ornamental fish were released.

4.26.6 Exposure assessment

As eels and both brown and rainbow trout are known to be definitive hosts for *R. acus* (see Dorucu et al. 1995, Kubkova et al. 2004), it is possible that infected ornamental fishes released into the New Zealand environment could be eaten by predators, thus leading to liberation of eggs by adult worms. A variety of planktonic crustaceans such as cladocerans and amphipods are known to act as intermediate hosts for *R. acus*, hence due to its relatively low specificity for both intermediate and final hosts, and the longevity of the larval stages in fish intermediate hosts, it is possible that the parasite could complete its lifecycle and become established in many endemic fish species in New Zealands. As there are a number of compounding circumstances which would need to be met before this occurred, the probability of establishment of this parasite is considered to be low.

4.26.7 Consequence assessment

Under certain circumstances hyperinfections of larvae in the internal organs, particularly the liver, can cause disease in small fish which act as intermediate hosts for the parasite. This suggests that individuals of some smaller endemic fishes in New Zealand, such as bullies, galaxids and smelt, may experience adverse effects due to parasitism by *R. acus* larvae. However based on overseas data, in the natural environment it is very unlikely that adverse effects would extend to the population level in these prey fishes, and there is no evidence that infections of adult worms in trout or other predatory species cause any significant morbidity or disease (Dorucu et al. 1995). Because of these reasons, the significance of the consequences of introduction are considered to be low.

4.26.8 Risk Estimation

A low probability of establishment combined with low significance of the consequences of introduction, suggest the risks involved with introduction of *Raphidascaris acus* via imported ornamental fish are negligible and do not require additional risk management.

4.27 *Argulus foliaceus*

4.27.1 Aetiologic agent: Argulus foliaceus, a branchiuran crustacean ectoparasite (freshwater fish louse).

4.27.2 OIE List: No.

4.27.3 New Zealand's status: Not recorded, considered exotic.

4.27.4 Epidemiology

The crustacean *Argulus foliaceus* is a large (6-7 mm) ectoparasite which is able to attach and detach from freshwater hosts, it is non-host specific, and can cause epizootics in salmonids (Menezes et al. 1990). Also, heavy infections predispose fish to secondary bacterial infection, and it can act as a vector for spring viraemia of carp virus (SVCV) (Ahne 1985), and of nematodes (Molnar and Szekely 1998). Adults are obligate fish ectoparasites, feeding on fish blood and body fluids (Bower–Shore 1940), but large individuals may live free from the host for up to 15 days at lower water temperatures.

A minimum temperature of 10° C is required for egg laying, which in the northern hemisphere occurs continuously during the spring, summer and early autumn months in a broadly synchronous manner (Gault et al. 2002). Mature females leave the host and lay several hundred eggs on vegetation and various objects in the water, then return to the host. After 2-4 days they may detach again and lay more eggs (Pasternak et al. 2000). Eggs are ovoid in shape and are covered by a gelatinous capsule. Eggs do not hatch unless water temperatures are above 10°C, and juveniles, adults and eggs undergo anabiosis after winter (Gault et al. 2002). However, even at 20°C, eggs hatch asynchronously in 20 to 240 days (Pasternak et al. 2000). Under favourable environmental conditions, this produces between 2 and 3 parasite generations each year.

A. foliaceus can search for its hosts in both light and dark conditions and uses vision in the light. The mean swimming speed and the area explored were 3-4 times higher in the dark, when the parasite employed a cruising search strategy. This changed to an ambush (hover-and-wait) strategy in the light (Mikheev et al. 2000). The population density of fish hosts appears the main factors influencing the survival and reproductive success of the parasite (Mikheev et al. 1998).

4.27.5 Release assessment

Adult *A. foliaceus* are relatively large ectoparasites which would be easily detected during quarantine. However early larvae (metanauplius stages, < 0.8 mm) and juveniles are much smaller and the asynchronous development of eggs means that cohorts of parasites in each year class may range significantly in size. This means that low numbers of small parasites may escape detection in clinically healthy fish, even after 6 weeks quarantine. It is possible, therefore, that subclinically infected fish could survive quarantine and that *A. foliaceus* could be introduced into the New Zealand environment if infected ornamental fish were released.

4.27.6 Exposure assessment

The lifecycle is direct and *A. foliaceus* has high life cycle flexibility which facilitates its survival even when fish hosts are rare (Pasternak et al. 2000). At ambient water temperatures typical of New Zealand this parasite would be able to survive wherever there were sufficient populations of fish hosts. The parasite could infect salmonids and a range of other endemic fish species and female parasites could lay eggs year round in most parts of the country. Because of these reasons, the probability of establishment if introduced is considered to be moderate.

4.27.7 Consequence assessment

This population dynamics of this parasite are most heavily influenced by host population densities. Hence in any situations were fish numbers are high, such as in healthy fisheries and aquaculture facilities, heavy infections of this parasite may result in disease. In freshwater fish farms, epizootics in salmonids, goldfish and other species held at high densities may occur. The significance of the consequences of introduction of this parasite are therefore considered moderate.

4.27.8 Risk Estimation

A moderate probability of establishment combined with moderate significance of the consequences of introduction, suggest the risk of introduction of *Argulus foliaceus* via imported ornamental fish is non-negligible, and additional risk management is required.

5. RISK MANAGEMENT

5.1 Risk evaluation

From the risk assessment, the following disease agents require additional risk management; aquabirnaviruses (including IPNV), iridoviruses, grouper nervous necrosis virus, viral haemorrhagic septicaemia, *Edwardsiella ictaluri, Edwardsiellatarda, Lactococcus garvieae*, *Aphanomyces invadans, Enteromyxum leei, Glugea heraldi*, *Bothriocephalus acheilognathi*, *Capillaria philippinensis* and *Argulus foliaceus.* The species of permitted hosts reported for these pathogens are given in Table 5.1. In addition, there is an undetermined risk associated with the potential for introduction of previously unidentified protozoans and/or other new disease agents which may have moderate to high significance of consequences of their introduction.

It is noticeable that nearly all the host fish species are tropical or sub-tropical except for *Barbus graellsii*, and that *B. graellsii* from Spain have been reported as being infected with IPNV (Ortega et al. 1993a, 1993b) and as a carrier of VHSV (Basurco and Coll 1989). Furthermore, the temperate to tropical cyprinid genera *Barbus,* and *Puntius,* including the temperate *Barbus barbus* (see Grabda-Kazubska and Pilecka-Rapacz 1987), are hosts of *Bothriocephalus acheilognathi*, while *Puntius gonionotus* is host for the zoonotic nematode *Capillaria philippinensis.* Perhaps the easiest way to manage the risk of introduction of these serious pathogens in temperate cyprinids would be to take all temperate and sub-tropical species of *Barbus, Puntius, Varicorhinus, Barbodes* and *Capoeta* off the permitted list.

This would not reduce the risk of introduction of IPNV by carriers, but the time course of IPN is short with mortalities among susceptible species 6-12 days after exposure, and although carriers do not show signs of infection, the stress of confinement, transport and handling may disclose an underlying infection during quarantine.

The management of other aquabirnaviruses is more difficult. Certainly, passive surveillance should be particularly targeted at the species reported to carry aquabirnaviruses. These are, *Apistogramma ramirezi, Brachydanio rario, Colisa lalia, Epinephelus* spp., *Pterophyllum scalare, Scleropages formosus, Symphysodon discus, Xiphophorus xiphidium* and *Zanclus cornutus*. However it may be that alternative measures, such as health certification of consignments of these known carrier species, are required to ensure the risk of introduction of these unwanted viruses is negligible. Iridoviruses are emerging as a serious cause of disease in poikilothermic vertebrates (fish, amphibians and reptiles), and there is accumulating evidence that iridoviruses are being moved around the world by the international trade in live aquatic animals. For example, various different species of diseased gouramis examined from pet shops in Sydney were shown to be carrying an exotic strain of gourami iridovirus, which are related to tropiviruses (Go et al. 2005).

In another example from Australia, epizootic haematopoietic necrosis (EHN) emerged in Australia in 1986, where it causes epizootic mortalities in redfin perch (*Perca fluviatilis*), and mortalities in rainbow trout (*Oncorhynchus mykiss*) (Langdon and Humphrey 1987, Langdon et al. 1988, Langdon 1989). It is very similar to European sheatfish virus in Germany and European catfish virus in France (Hedrick et al. 1992) and it is also very similar to iridoviruses isolated from ornamental fish (Hedrick and McDowell 1995). All these viruses in turn are similar to frog virus 3, and may therefore be put into the *Ranavirus* genus, a genus that is pathogenic to frogs. New Zealand has a small primitive and rare frog fauna that is already endangered, and it is likely that the arrival of such viruses in New Zealand would be catastrophic to these species. The high risk hosts which should be targeted for passive surveillance in quarantine, as well as considered for pre export certification and/or other risk mitigation options discussed below, include *Apistogramma ramirezi, Aplocheilichthys normani, Colisa lalia, Epinephelus* spp., *Etroplus maculatus, Helostoma* spp., *Labroides dimidiatus, Parapocryptes serperaster, Poecilia reticulata, Pterophyllum scalare, Trichogaster leeri, Trichogaster trichopterus* and *Xiphophorus helleri*. Some fish species should be examined for both aquabirnavirus and iridovirus, while *Epinephelus* spp., *Cephalopholis* spp. and *Cromileptes* spp. should be examined for these and also grouper nervous necrosis virus and other nodaviruses during passive surveillance and/or pre export certification.

Although the it was concluded that there is a low risk of introduction of *Edwardsiella ictaluri* and *Lactococcus garvieae*, it is more likely that infections would be disclosed during confinement, transport and handling, given that these diseases have a rapid time course from exposure to mortality. It would be time consuming, expensive and unjustified, to put in place active surveillance for *E. ictaluri* and *E. tarda.* Passive surveillance targeting ornamental species previously found to be infected with these bacteria would be more appropriate. The time course of *Aphanomyces invadans* infection, 7-30 days, makes it likely that mortalities will occur during confinement, handling and transport. Also, the clinical signs of congested lesions in the skin, make it relatively easy to make a presumptive diagnosis. Passive surveillance of target species (*Colisa lalia, Etroplus suratensis, Helostoma* spp.*, Osphronemus gouramy, Trichogaster* spp.) in quarantine would most likely be effective. However, as *A. invadans* is very non host-specific, any fish showing congested skin lesions should be thoroughly investigated for *A. invadans* during passive surveillance, with consideration of pre-export certification for fish exported from areas where EUS has been previously recorded.

Enteromyxum leei is known from a variety of cultured and ornamental marine fishes from Europe and is a significant emerging pathogen with broad host specificity. For this parasite the main prerequisites for infection appears to be availability of fish hosts at high densities and/or in confinement at water temperatures above 18°C. It almost certainly can infect a wider range of marine fishes than currently recorded, and could easily be passed onto new hosts wherever fish are held together in confinement during the capture, wholesale, transport and quarantine process. Disease caused by *E. leei* usually results in chronic trickling mortalities due to massive enteritis. Even a quarantine period of 6 weeks (twice the current 3 week period required for marine fish) may not be sufficient to detect recent infections of this parasite, especially as infected fish may not show clinical signs of disease (Padrós et al. 2001). Preventing movements of this parasite with ornamental marine fishes is therefore very difficult. The currently restricted distribution of the parasite to the Mediterranean would suggest that marine fishes imported from these areas should be afforded particular scrutiny. However detection of similar, if not the same species of parasite in fishes from the USA (Kent 1999) may indicate either the parasite has already been translocated with movements of ornamental fishes, or that closely related species, such as *E. scophthalmi*, which is also known to occur in marine fishes in Europe (Redondo et al. 2002, 2004), may also pose a similar threat. Passive surveillance of marine fishes, with particular attention being paid to those from areas where *Enteromyxum* spp. have been previously recorded, is the suggested risk management measure, as is extending the current quarantine period for marine fish to 6 weeks and consideration of pre-export certification of fish from areas where this parasite is known to be endemic.

Detection of seahorses (*Hippocampus* spp.) infected with the microsporidian *Glugea heraldi* should be relatively straightforward in quarantine if clinically affected fish are present, due to the large size of the xenoma complexes (100 to 800 µm in diameter). However these xenomas could be easily mistaken for other disease agents (e.g. *Cryptocaryon irritans*), hence detection of this parasite would be facilitated by extending the current 3 week quarantine period for marine fish to 6 weeks, and educating industry about the existence of this parasite and the importance of containing any incursions in order to minimise any potential threats to both wild seahorse populations and the seahorse aquaculture industry.

Bothriocephalus acheilognathi may be encountered in *Poecilia reticulata* during targeted passive surveillance for iridoviral disease. Removal of *Barbus* spp., *Varicorhinus* spp. and *Puntius* spp. from the permitted list would significantly lower the risk of *B. acheilognathi* entering the country and becoming established. If *B. acheilognathi* entered the country in *Xiphophorus maculatus,* and infected *X. maculatus* were released into the wild in geothermal areas or power station outlets, it would be possible that temperate native fishes would come into contact with *B. acheilognathi.* Again, targeted passive surveillance of *Xiphophorus* spp. is the the most practical and least costly risk management measure, however pre-export certification of fish from areas where this parasite is known to be endemic may also be considered to further reduce risk.

Argulus foliaceus poses a threat due to its direct lifecycle, low host specificity, and the fact that it can cause mortalities in salmonids. New Zealand's trout fisheries are very important to the tourist economy and the native galaxids are important for their conservation significance and because certain galaxid species support significant whitebait fisheries. Introduction of *A. foliaceus* would likely have a detrimental impact on the health of both trout and galaxids in at least some parts of their range. This parasite could be present on a variety of species of ornamental fish taken from areas where *A. foliaceus* is endemic (Europe, Asia) and could easily jump from host to host if fish from different areas were mixed during the process of capture, transport, wholesaling and quarantine. Diligent passive surveillance of fish during quarantine and education of fish wholesalers and aquarists of the importance of eradicating this parasite is likely to be the best way of managing the risks posed by *A. foliaceus*.

There is always an undetermined risk associated with the potential for introduction of new disease agents, such as the unidentified dinoflagellate (see section 4.17). Some of these may have moderate to highly significant consequences of their introduction. In the absence of information on their identity and epidemiology, however, it is difficult to determine an appropriate course of action to mitigate the risks involved with every possible scenario, hence the reason why unidentified parasites have not been included in Table 5.1. However it must be realised that these risks do exist (Gaughan 2002). As with many of the other diseases discussed above, however, the most practical and cost effective approach appears to be targeted passive surveillance of fishes in quarantine with prompt review of the risk management methods employed for ornamental fish whenever information becomes available on the emergence of significant new diseases of ornamental fishes overseas, and also within New Zealand.

5.2 Option evaluation

5.2.1 Rationalisation of the permitted species list

As discussed in section 5.1, to eliminate the risk of introduction of several significant diseases, temperate and sub-tropical cyprinids (*Barbus, Puntius, Varicorhinus, Barbodes* and *Capoeta*) could all be removed from the permitted list. However, it must be recognised that the present permitted list contains so many species and genera that it is not practical or realistic to expect identification of all the species on arrival at the border. This inability to identify the host presents a significant risk, as it is impossible to perform targeted surveillance on a shortlist of high risk species if it is not known whether those species are present in a shipment of fish. If it could be ensured that all imported fish were mature enough to be identified to species, minimum lengths might be used to ensure accurate identification. The Federation of New Zealand Aquatic Societies (FNZAS) lists ornamental fish that are already in New Zealand[2]. The FNZAS list is basically an annotated version of the MAF list of approved aquarium imports, and also includes a number of species not on the permitted list. Unfortunately, the great majority of fish on the FNZAS list are only identified to genera, and the FNZAS admits that the list may not be accurate. Despite this, and obvious taxonomic chaos, at least 65 genera and 53 species listed have not been reported in New Zealand. These are probably best removed from the permitted list in order to reduce uncertainties surrounding fish identification and to minimise any unknown disease threats these species may pose to endemic aquatic animals.

If passive targeted surveillance were to be carried out on the high risk species identified in Table 5.1, Biosecurity New Zealand border staff could be given visual guides to the identification of those species as being of top priority based on their disease risk. If possible, one or two Biosecurity New Zealand officers at Auckland and Christchurch airports should be trained to recognise many other species on the permitted list. This might be done in co-operation with the FNZAS, as it would be of benefit to all concerned.

5.2.2 Pre export measures

Risks of importation of diseased fish into quarantine can be reduced by a number of pre export measures. One of these is a requirement that all ornamental fish undergo a period of pre-export isolation for a period of 2 weeks, as is required for imports into Australia. This step effectively increases the period of time the fish are quarantined. A second pre export measure worthy of consideration is zoosanitary certification. The majority of live animals imported into New Zealand are accompanied by health certification, however fish are currently imported without certification. To be consistent with the recommendations of the OIE Aquatic Animal Health Code (OIE, 2005), ornamental fish should be accompanied by an international aquatic animal health certificate for live fish, signed out by the exporting countries competent authority, which indicates the fish are free from specified disease agents and are sourced from populations or zones free from specified disease agents. If a blanket

[2] This list is available on the internet at http://www.fnzas.org.nz/tropical-fish.0.html

approach to health certification is simply too onerous and costly for industry, perhaps this form of risk management could be applied only to high risk species known to carry unwanted disease agents, such as those fish species listed in Table 5.1, and/or applied only to maintain a level of protection at least equal to that currently enjoyed if a reduction in quarantine period is sought (see 5.2.4).

5.2.3 Mortality rate cutoff in quarantine

Many of the risks associated with introduction of disease with imported ornamental fish can be managed cost-effectively by conducting targeted passive surveillance while the fish are in quarantine. This would involve taking samples of fish showing signs of disease or mortality in quarantine and sending them to the Investigation and Diagnostic Centre (IDC) of Biosecurity New Zealand, or a laboratory recognised by them as competent. That laboratory would then send their results to the IDC. It is necessary to identify a level of mortality in quarantine at which fish would be submitted. If the level is too high, 30% for example, there is a greater risk than if it were decided to put the level of significant mortality at 2%. Conversely, if the level is too low, too many samples will be submitted, revealing many trivial infections, and making surveillance less effective given the limited resources available. It is suggested that the mortality level at which it is necessary to submit samples be set at 20% cumulative mortality for any fish species during the 6 week quarantine period (including deaths on arrival).

5.2.4 Quarantine period

New Zealand operates much longer quarantine periods than other countries, the 6 weeks for freshwater fish being twice the period the Australian authorities demand for their highest risk imports, goldfish. Marine fish in New Zealand are subject to 3 weeks quarantine, in line with recommendations by authorities in other countries, which have determined from previous records that if mortalities are to occur in quarantine, they will mostly occur within the first 3 weeks. Many of the organisms considered under risk management have disease time courses that would be completed between the time of capture, and release after a 3 week quarantine period, but a significant proportion of the disease agents of concern would not be disclosed during that period. New Zealand has relatively few reported fish disease incursions compared to, say, Australia, which uses up to 3 weeks quarantine (Table 1.1) together with a period of pre-export isolation . While the increased incursion rate in Australia may be, at least in part, due to differences in climate, increased volumes of ornamental fish imports, and/or more intense surveillance, it is also possible that a 6 week quarantine period provides additional protection against those disease agents which would not be disclosed during a 3 week quarantine period. Indeed, as a precautionary measure it could reasonably be argued that the current 3 week quarantine period for marine fish should be extended to match the 6 weeks for freshwater fish, particularly when considering the low probability of severe pathogens such as *Enteromyxum leei* being detected in 3 weeks in the absence of an active surveillance programme. However, while there may be some evidence that a longer quarantine period provides additional protection aginst incursion of some disease agents, if a blanket 6 week quarantine period for both freshwater and marine fish were too onerous for industry to maintain, consideration could be made to reduce it to 4 weeks for both freshwater and marine fish. However, to maintain a level of protection at least equal to that currently achieved, any decrease in duration of the quarantine period should be traded off against a period of pre-export isolation and/or disease certification, and/or a reduced mortality rate cut off for compulsory disease investigations. For example, the currently proposed cut-off for compulsory disease investigations of 20% mortality should be reduced to 10% mortality if the quarantine period was reduced from 6 to 4 weeks.

5.2.5 Education

One of the key underlying assumptions inherent in how each disease agent was assessed during this risk analysis was that aquarists will inevitably release ornamental fish into the wild either deliberately or inadvertently. Clearly the risk to New Zealand's endemic fishes and aquatic fauna posed by diseases carried by ornamental fishes would be greatly reduced if aquarists were better educated to consider these risks and cease to liberate unwanted aquarium fish into the wild or allow them to escape from outdoor ponds. The likelihood of compliance would also increase if mechanisms were put in place at the retail level to accept and dispose of unwanted ornamental fishes.

Development and distribution of educational materials for display in retail outlets selling ornamental fish must be considered as an extremely cost effective method of potentially reducing the number of aquarium fish liberated into the wild. A cost benefit analysis of this approach would almost certainly be favourable, particularly in comparison to the costs involved with surveillance and control/eradication of exotic introductions. It would also appear very useful to develop and distribute at the retail level educational materials which highlight the potential for contracting zoonotic diseases from aquarium fishes and aquarium water, and how to avoid them. If more people knew of the potential to contract salmonellosis, mycobacteriosis, edwardsiellosis and other zoonotic diseases from aquariums, it would be very likely that more people would undertake some of the simple precautionary measures required to prevent these infections from occurring.

5.3 Recommended measures

1. That temperate and sub-tropical cyprinids (the genera *Barbus, Puntius, Varicorhinus, Barbodes* and *Capoeta*) should no longer be eligible for import.

2. That Biosecurity New Zealand and ERMA determine which species of ornamental fish were in New Zealand before July 1998. Those not present before July 1998 should not be eligible for import unless approved by ERMA as a new organism.

3. That the post-arrival quarantine period should be consistent for both freshwater and marine species.

4. That Biosecurity New Zealand develop appropriate training resources about the identification of fish species and the diagnosis of key diseases for MAF Quarantine Services Biosecurity Officers, supervisors and operators of Transitional Facilities.

5. That Biosecurity New Zealand work with the Department of Conservation to inform the Federation of New Zealand Aquatic Societies of the need to actively discourage their members from releasing unwanted fish into the wild.

6. That Biosecurity New Zealand work with the Ministry of Health to inform retail outlets selling ornamental fish of potential public health issues.

7. That targeted passive surveillance be conducted for the following disease agents: aquabirnaviruses, iridoviruses, grouper nervous necrosis virus, viral haemorrhagic septicaemia, *Edwardsiella ictaluri, Edwardsiella tarda, Lactococcus garvieae*, *Aphanomyces invadans, Enteromyxum leei, Glugea heraldi*, *Bothriocephalus acheilognathi*, *Capillaria philippinensis* and *Argulus foliaceus*.

8. That when cumulative mortalities of 20% or greater occur among any species of imported ornamental fishes during quarantine, suitable samples (moribund, freshly dead, or 10% formalin-fixed) must be sent to the Investigation and Diagnostic Centre (IDC) of Biosecurity New Zealand, or a laboratory regarded by them as competent.

9. That the post-arrival quarantine period may be reduced for both freshwater and marine fish from 6 weeks to 4 weeks, provided that consignments are accompanied by an international aquatic animal health certificate for live fish, signed by the competent authority in the exporting country, stating that the fish are free from specified disease agents or are sourced from populations or zones free from specified disease agents.

10. That for consignments where the post arrival quarantine period is reduced to 4 weeks, the cutoff cumulative mortality rate for the taking of samples be reduced to 10%.

11. That aquarium water from the quarantine period must be disinfected prior to disposal.

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Table 1.1 Parasites and disease agents introduced into Australian and New Zealand fish populations.

The following pathogens, presumably introduced, have been found to infect introduced and native fish in Australia and New Zealand.
* infecting native fish
** detected in quarantine and eradicated

AUSTRALIA

Disease agent	Hosts	Reference
VIRUSES		
Gourami iridovirus (GIV)	F. Osphronemidae	Biosecurity Australia (2005), Go et al. (2005)
Iridoviruses	*Poecilia reticulata*, *Labroides dimidatus*	Hedrick and McDowell (1995)
Iridoviruses	*Colisa lalia*	Anderson et al. (1993)
Iridoviruses	*Oreochromis mossambicus*	Ariel and Owens (1997)
Lymphocystis	*Macropodus opercularis*	Humphrey (1995)
BACTERIA		
Edwardsiella ictaluri	*Puntius conchonius*	Humphrey et al. (1986)
Edwardsiella tarda	*Betta splendens*, *Cyprinus carpio*, *Paracheirodon innesi*	Humphrey et al. (1986)
Photobacterium damselae damselae	*Chromis punctipinnis*, *Anguilla reinhardtii**	Ketterer and Eaves (1992)
PROTOZOANS		
Amoebae	*Colisa lalia*	Anderson et al. (1993)
Chilodonella cyprini	*Nematalosa erebi**, *Gadopsis marmoratus**, *Maccullochella ikei**, *Maccullochella peelii**	Humphrey (1995)
Chilodonella hexasticha	*Amniataba percoides**, *Gadopsis marmoratus**, *Leiopotherapon unicolor**, *Maccullochella peelii**, *Melanotaenia splendida**, *Nematalosa erebi**, *Neosilurus* sp.*	Langdon et al. (1985), Rowland et al. (1991), Humphrey (1995)
Chilodonella piscicola	*Paracheirodon innesi*	Evans and Lester (2001)
Cryptobia sp.	*Gyrinocheilus aymonieri*	Evans and Lester (2001)

Goussia carpelli	*Carassius auratus*	Lom and Dykova (1995)
Goussia piekarskii	*Gambusia holbrooki*	Lom and Dykova (1995)
Hexamita sp.	*Paracheirodon innesi, P. axelrodi*	Evans and Lester (2001)
Tetrahymena corlissi	*Poecilia reticulata*	Evans and Lester (2001)
MYXOZOANS		
Chloromyxum sp.	*Gyrinocheilus aymonieri*	Evans and Lester (2001)
Australia (con't)		
Disease agent	**Hosts**	**Reference**
MONOGENEANS		
Dactylogyrus extensus	*Cyprinus carpio*	Dove and Ernst (1998)
Dactylogyrus anchoratus	*Carassius auratus*	Dove and Ernst (1998)
Gyrodactylus bullatarudis	*Poecilia reticulata, Xiphophorus helleri*	Dove and Ernst (1998)
Gyrodactylus macracanthus	*Misgurnus anguillicaudatus*	Dove and Ernst (1998)
Urocleidoides reticulatus	*Poecilia reticulata, Xiphophorus maculatus*	Evans and Lester (2001)
DIGENEANS		
Centrocestus formosanus	*Poecilia reticulata, Xiphophorus maculatus*	Evans and Lester (2001)
CESTODES		
Bothriocephalus acheilognathi	*Carassius auratus, Cyprinus carpio, Gambusia holbrooki, Hypseleotris klunzingeri*, Hypseleotris* sp.*, *Phylipnodon grandiceps*, Poecilia reticulata, Retropinna semoni*, Xiphophorus maculatus*	Dove (1998), Dove and Fletcher (2000), Dove et al. (1997), Evans and Lester (2001)
NEMATODES		
Camallanus cotti	*Poecilia reticulata*	Evans and Lester (2001)

NEW ZEALAND

Disease agent	Hosts	Reference
VIRUSES		
Herpesvirus	*Carassius auratus*	Hine 2005, unpublished data
PROTOZOANS		
Ichthyophthirius multifiliis	*Anguilla australis**, *Carassius auratus*, *Cyprinus carpio*, *Ctenopharyngodon idella*, *Galaxias brevipinnis**, *Gobiomorphus cotidianus**, *Oncorhynchus mykiss*, *Oncorhynchus tshawytscha*	Boustead (1982), Edwards and Hine (1974), Hine et al. (2000)
Chilodonella sp.	*Anguilla australis**, *Carassius auratus*	Boustead (1982), Hine and Boustead (1974), Hine (1978), Hine et al. (2000)
Tripartiella sp.**	*Ctenopharyngodon idella*	Edwards and Hine (1974), Hine et al. (2000)
MYXOZOANS		
Myxobolus cerebralis	*Oncorhynchus mykiss*, *Oncorhynchus tshawytscha*, *Salmo trutta*, *Salvelinus fontinalis*	Hewitt (1972), Boustead (1993), Hine et al. (2000)
MONOGENEANS		
*Dactylogyrus ctenopharyngodonis***	*Ctenopharyngodon idella*	Edwards and Hine (1974), Hine et al. (2000)
*Gyrodactylus ctenopharyngodonis***	*Ctenopharyngodon idella*	Edwards and Hine (1974), Hine et al. (2000)
CESTODES		
*Bothriocephalus acheilognathi***	*Ctenopharyngodon idella*	Edwards and Hine (1974), Hine et al. (2000)
CRUSTACEANS		
*Lernaea cyprinacea***	*Ctenopharyngodon idella*	Edwards and Hine (1974), Hine et al. (2000)
Lernaea cyprinacea	*Carassius auratus*	Boustead (1982), Hine et al. (2000)
Lernaea sp.	*Aldrichetta forsteri**	Boustead (1982), Hine et al. (2000)
Argulus japonicus	*Carassius auratus*	Boustead (1982), Hine et al. (2000)

Table 1.2 Piscivorous birds as vectors of fish pathogens and parasites.

Host	Pathogen	Pathogenesis and/or prevalence	Reference
Ardea cineria	Infectious Pancreatic Necrosis virus (IPNV)	Shed in faeces for 7 days after feeding	Peters and Neukirch (1986), McAllister and Owens (1992)
Ardea cineria	Spring Viraemia of carp Virus (SVCV)	Shed in faeces for 7 days after feeding	Peters and Neukirch (1986)
Ardea cineria	Viral Haemorrhagic Septicaemia virus (VHSV)	Shed in faeces for 7 days after feeding	Peters and Neukirch (1986)
Larus novaehollandiae *Phalacrocorax carbo,*	Epizootic Haematopoietic Necrosis virus (EHNV)	*L. novaehollandiae* 3/9, *P. carbo* 1/1	Whittington et al. (1996)
Ardea, Casmerodius, Egretta	*Clinostomum complanatum*	53% prevalence	Taylor (1992)
Ardea cinerea *Egretta garzetta* *Egretta intermedia* *Nycticorax nycticorax*	*Clinostomum complanatum*	*A. cinerea* 5/5, *E. garzetta* 2/5, *E. intermedia* 1/2, *N. nycticorax* 5/9	Aohagi et al. (1992b)
Egretta alba	*Clinostomum complanatum*	*E. alba* 2/2	Aohagi et al. (1993a)
Ardea cocoi, Egretta alba, Egretta thula, *Nycticorax nycticorax* *Phalacrocorax carbo*	*Clinostomum complanatum*	A. *cocoi* 19/20, *E. alba* 1/7, *E. thula* 1/18, B. *N. nycticorax* 0/10, *P. carbo* 14/24	Dias et al. (2003)

Table 3.1 Classification of New Zealand's endemic freshwater and estuarine fish species.

After McDowall 1990, New Zealand Freshwater Fish Database 2005

Species or genus	**Family**	**Order**	**Status**
Aldrichetta forsteri	Mugilidae	Perciformes	Native
Ameiurus nebulosus	Ictaluridae	Siluriformes	Introduced
Anguilla spp.	Anguillidae	Anguilliformes	Native
Arripis trutta	Arripidae	Perciformes	Native
Carassius auratus	Cyprinidae	Cypriniformes	Introduced
Cheimarrichthys fosteri	Pinguipedidae	Perciformes	Native
Ctenopharyngodon idella	Cyprinidae	Cypriniformes	Introduced
Cyprinus carpio	Cyprinidae	Cypriniformes	Introduced
Galaxias spp.	Galaxiidae	Osmeriformes	Native
Gambusia affinis	Poeciliidae	Cyprinodontiformes	Introduced
Geotria australis	Geotriidae	Petromyzontiformes	Native
Gobiomorphus spp.	Eleotridae	Perciformes	Native
Grahamnia sp.	Trypterigiidae	Perciformes	Native
Hypophthalmichthys molitrix	Cyprinidae	Cypriniformes	Introduced
Leptoscopus macropygus	Leptoscopidae	Perciformes	Native
Leuciscus idus	Cyprinidae	Cypriniformes	Introduced
Mugil cephalus	Mugilidae	Perciformes	Native
Neochanna spp.	Galaxiidae	Osmeriformes	Native
Oncorhynchus spp.	Salmonidae	Salmoniformes	Introduced
Parioglossus marginalis	Microdesmidae	Perciformes	Introduced
Perca fluviatils	Percidae	Perciformes	Introduced
Phallocerus caudimaculatus	Poeciliidae	Cyprinodontiformes	Introduced
Poecilia spp.	Poeciliidae	Cyprinodontiformes	Introduced
Retropinna retropinna	Retropinnidae	Osmeriformes	Native
Rhombosolea retiaria	Pleuronectidae	Pleuronectiformes	Native

Salmo spp.	Salmonidae	Salmoniformes	Introduced
Salvelinus spp.	Salmonidae	Salmoniformes	Introduced
Scardinius erythrophthalmus	Cyprinidae	Cypriniformes	Introduced
Stokellia anisodon	Retropinnidae	Osmeriformes	Native
Tinca tinca	Cyprinidae	Cypriniformes	Introduced
Xiphophorus helleri	Poeciliidae	Cyprinodontiformes	Introduced

Table 3.1 Classification of New Zealand's endemic freshwater and estuarine fish species

Table 3.2 Permitted genera of sub-tropical and temperate freshwater fish.

Genera preceded by an asterisk (*) were not considered further for reasons explained in the text.

Genus	**Family**	**Order**	**Temperature range**
* *Aphyocharax* (=*Phoxinopsis*)	Characidae	Characiformes	Sub-tropical
* *Astyanax*	Characidae	Characiformes	Sub-tropical
* *Cheirodon*	Characidae	Characiformes	Sub-tropical
* *Hasemania*	Characidae	Characiformes	Sub-tropical
* *Hyphessobrycon*	Characidae	Characiformes	Sub-tropical
* *Moenkhausia*	Characidae	Characiformes	Sub-tropical
* *Notopterus*	Carapidae	Ophidiiformes	Sub-tropical
Aphanius fasciatus	Cyprinodontidae	Cyprinodontiformes	Temperate
Barbodes	Cyprinidae	Cypriniformes	Temperate to tropical
Barbus	Cyprinidae	Cypriniformes	Temperate to tropical
Callichthys	Callichthyidae	Siluriformes	Sub-tropical
Capoeta	Cyprinidae	Cypriniformes	Temperate to tropical
Corydoras	Callichthyidae	Siluriformes	Sub-tropical
Hoplosternum	Callichthyidae	Siluriformes	Sub-tropical to tropical
Jordanella (=*Jordinella*) *floridae*	Cyprinodontidae	Cyprinodontiformes	Sub-tropical
Loricaria	Loricariidae	Siluriformes	Temperate
Platydoras	Doradidae	Siluriformes	Sub-tropical
Pseudogastromyzon	Balitoridae	Cypriniformes	Temperate
Puntius	Cyprinidae	Cypriniformes	Temperate to tropical
Varicorhinus	Cyprinidae	Cypriniformes	Temperate to tropical

Table 3.3 Permitted genera of sub-tropical and temperate marine fish.

Genera preceded by an asterisk (*) were not considered further for reasons explained in the text.

Genus	**Family**	**Order**	**Climate range**
* *Synchiropus*	Callionymidae	Perciformes	Temperate to tropical
Antennarius	Antennariidae	Lophiiformes	Sub-tropical
Bodianus	Labridae	Perciformes	Sub-tropical to tropical
Cantherhines	Monacanthidae	Tetraodontiformes	Sub-tropical to tropical
Chromis	Pomacentridae	Perciformes	Sub-tropical to tropical
Coris	Labridae	Perciformes	Sub-tropical to tropical
Hemirhamphus	Hemirhamphidae	Beloniformes	Temperate to tropical
Hippocampus	Syngnathidae	Syngnathiformes	Temperate to tropical
Histrio	Antennariidae	Lophiiformes	Sub-tropical
Stethojulis	Labridae	Perciformes	Temperate to tropical

Table 3.4 Diseases and geographical distribution of shortlisted freshwater fish species.

The "shortlisted species" are : Barbodes spp., Barbus spp., Callichthys spp., Capoeta/Varicorhinus spp., Corydoras spp., Hoplosternum littorale, Loricaria spp., Platydoras spp., and Puntius spp., and their geographical distribution.

Literature searches could not find published records of specific parasites or diseases in *Aphanius fasciatus*, *Jordanella floridae* or *Pseudogastromyzon* spp.

***Barbodes* spp.**		
Disease agent	**Host species**	**Distribution**
FUNGI		
Aphanomyces invadans	*B. gonionotus*	Asia
MONOGENEA		
Dactylogyrus aciculus	*B. caldwelli*	China
Dactylogyrus remicirrus	*B. sinensis*	China
Dactylogyrus paradinosaurinus	*B. denticulatus yunnanensis*	China
Dicrodactylogyrus hastatus	*B. lacustris*	China
DIGENEA		
Allocreadium ovaliformae	*B. sinensis*	China
ACANTHOCEPHALA		
Pomphorhynchus yunnanensis	*B. exigua*	China
***Barbus* spp.**		
Disease agent	**Host species**	**Distribution**
VIRUS		
Infectious pancreatic necrosis	*B. graellsii*	Spain
Viral haemorrhagic septicaemia	*B. graellsii*	Spain
FUNGI		
Fusarium moniliforme	*B. rana*	India
Fusarium udum	*B. rana*	India

PROTOZOA		
Trypanosoma neinavana	*B. grypus*	Iraq
Trypanosoma percae	*B. barbus*	Czech Republic
Goussia carpelli	*B. b. bocagei*	Spain
Goussia koertingi	*B. barbus*	Hungary
Eimeria barbi	*B. capito*	Uzbekistan
Eimeria leucisci	*B. b. bocagei*	Spain
Ichthyophthirius multifiliis	*B. grypus*	Iraq
Trichodina acuta	*B. brachycephalus*	Aral Sea
Trichodina kalinibeza	*B. fasciolaticus*	Namibia
Trichodina minuta	*B. trimaculatus, B. fasciolaticus*	South Africa, Namibia
Trichodina pediculus	*B. chola, B. sarana, B. stigma*	India
Trichodina uretra	*B. trimaculatus*	South Africa
Coleps sp.	*B. tetrazona*	Unknown
MYXOZOA		
Chloromyxum complicatum	*B. b. bocagei*	Spain
Chloromyxum cyprini	*B. b. bocagei*	Spain
Myxidium carinae	*B. b. bocagei*	Spain
Myxidium nyongensis	*B. aspilus, B. martorelli, B. guerali, B. jae*	Cameroon
Myxobolus azerbajdzanicus	*B. lacerta cyri*	Azerbaidzhan
Myxobolus barbi	*B. aspilus, B. martorelli, B. camptacanthus, B. jae*	Cameroon
Myxobolus bulbocordis	*B. sharpeyi*	Iran
Myxobolus cutanei	*B. b. bocagei*	Spain
Myxobolus iranicus	*B. luteus, B. grypus, B. sharpeyi*	Iran
Myxobolus karuni	*B. grypus*	Iran
Myxobolus koli	*B. koli*	India
Myxobolus lobatus	*B. b. bocagei*	Spain
Myxobolus mesopotamiae	*B. rajanorum, B. grypus, B. luteus*	Iran
Myxobolus muelleri	*B. b. bocagei*	Spain
Myxobolus njinei	*B. martorelli, B. guerali, B. camptacanthus*	Cameroon
Myxobolus nodulointestinalis	*B. sharpeyi*	Iran

Myxobolus persicus	*B. grypus*	Iran
Myxobolus pfeifferi	*B. esocinus, B. grypus, B. luteus*	Iraq
Myxobolus pinnaurati	*B. pinnauratus*	India
Myxobolus shadgani	*B. rajanorum*	Iran
Myxobolus sharpeyi	*B. sharpeyi*	Iran
Myxobolus tauricus	*B. b. bocagei, B. tauricus*	Spain, Russia
Myxobolus varicorhinii	*B. capito*	Tadzhikistan
Myxosoma karnatakae	*B. chola*	India
Thelohnellus valeti	*B. jae*	Cameroon
Unicauda lumae	*B. grypus*	Iraq
MONOGENEA		
Dactylogyrus aferoides	*B. bynni, B. bynni waldroni, B. bynni occidentalis, B. waldroni, B. petitjeani, B. occidentalis*	Niger, West Africa, Mali
Dactylogyrus affinis	*B. lacerta cyri, B. brachycephalus*	Russia, Iran
Dactylogyrus afrolongicornis	*B. trimaculatus*	South Africa
Dactylogyrus afrosclerovaginus	*B. paludinosus*	South Africa
Dactylogyrus allongionchus	*B. trimaculatus*	South Africa
Dactylogyrus andalousiensis	*B. microcephalus, B. sclateri*	Spain
Dactylogyrus archeopenis	*B. sacratus, B. parawaldroni, B. petitjeani*	West Africa, Gulf of Guinea
Dactylogyrus atlasensis	*B. b. pallaryi*	Morocco
Dactylogyrus balistae	*B. b. bocagei*	Spain
Dactylogyrus balkanicus	*B. cyclolepis prespensis*	Greece
Dactylogyrus barbioides	*B. grypus*	Iraq
Dactylogyrus barbuli	*B. barbulus*	Iraq
Dactylogyrus bocageii	*B. b. bocagei*	Spain
Dactylogyrus borjensis	*B. b. nasus*	Morocco
Dactylogyrus carpathicus	*B. barbus, B. b. meridionalis, B. plebeius*	Bulgaria, Spain, Iran
Dactylogyrus clani	*B. petitjeani*	Senegal
Dactylogyrus comizae	*B. comiza*	Spain
Dactylogyrus cornu	*B. grypus, B. xanthopterus*	Iraq
Dactylogyrus crivellius	*B. cyclolepis prespensis*	Greece

Dactylogyrus deziensis	*B. kersin*	Iran
Dactylogyrus deziensoides	*B. kersin*	Iran
Dactylogyrus djolibaensis	*B. bynni waldroni, B. bynni occidentalis, B. waldroni, B. petitjeani, B. occidentalis*	West Africa, Niger
Dactylogyrus doadrioi	*B. microcephalus, B. comiza*	Spain
Dactylogyrus dominici	*B. paludinosus*	South Africa
Dactylogyrus draaensis	*B. b. pallaryi*	Morocco
Dactylogyrus dyki	*B. b. meridionalis, B. cyclolepis prespensis*	Spain, Greece
Dactylogyrus enidae	*B. neefi*	South Africa
Dactylogyrus extensus	*B. capito*	Armenia
Dactylogyrus fimbriphallus	*B. b. pallaryi, B. b. figuiensis, B. b. lepinayi, B. b. massaensis, B. b. moulouyensis, B. b. issinensis*	Morocco
Dactylogyrus gracilis	*B. lacerta cyri*	Russia
Dactylogyrus guadiensis	*B. microcephalus, B. comiza*	Spain
Dactylogyrus guirensis	*B. b. pallaryi*	Morocco
Dactylogyrus heteromorphus	*B. b. callensis*	Morocco
Dactylogyrus inutilis	*B. xanthopterus*	Iraq
Dactylogyrus jamansajensis	*B. lacerta cyri, B. capito*	Russia, Armenia
Dactylogyrus kersini	*B. kersin*	Iran
Dactylogyrus ksibii	*B. setivimensis, B. ksibi, B. b. magniatlantis*	Morocco
Dactylogyrus ksibioides	*B. setivimensis, B. b. moulouyensis*	Morocco
Dactylogyrus kulindrii	*B. labeobarbus fritschii, B. labeobarbus reinii*	Morocco
Dactylogyrus kulwieci	*B. lacerta cyri*	Russia
Dactylogyrus lamellatus	*B. brachycephalus*	Russia
Dactylogyrus legionensis	*B. b. bocagei*	Spain
Dactylogyrus lenkoranoides	*B. guiraonis, B. haasi*	Spain
Dactylogyrus linstowi	*B. plebeius, B. capito*	Iran
Dactylogyrus linstowoides	*B. graellsii, B. guiraonis*	Spain
Dactylogyrus markewitschi	*B. b. meridionalis*	Bulgaria
Dactylogyrus marocanus	*B. setivimensis, B. b. nasus, B. ksibi, B. labeobarbus fritschii, B. labeobarbus reinii, B. labeobarbus harteti,*	Morocco

	B. labeobarbus paytonii	
Dactylogyrus mascomai	*B. graellsii, B. guiraonis, B. haasi*	Spain
Dactylogyrus orbus	*B. lacerta cyri*	Iraq
Dactylogyrus oumiensis	*B. labeobarbus reinii, B. labeobarbus harteti, B. labeobarbus paytonii*	Morocco
Dactylogyrus parawaldronii	*B. parawaldroni*	Gulf of Guinea
Dactylogyrus pavlovskyi	*B. grypus, B. sharpeyi*	Iraq, Iran
Dactylogyrus petitjeanii	*B. petitjeani*	Senegal
Dactylogyrus prespensis	*B. cyclolepis prespensis*	Greece
Dactylogyrus pseudanchoratus	*B. bynni, B. bynni waldroni, B. bynni occidentalis, B. sacratus, B. waldroni, B. parawaldroni, B. petitjeani, B. occidentalis*	West Africa, Nile Basin, Gulf of Guinea, Gabon
Dactylogyrus reinii	*B. labeobarbus reinii*	Morocco
Dactylogyrus ruahae	*B. sacratus, B. parawaldroni, B. petitjeani, B. wurtzi*	West Africa
Dactylogyrus sacrati	*B. sacratus*	Gulf of Guinea
Dactylogyrus sahalensis	*B. bynni, B. bynni waldroni, B. bynni occidentalis, B. waldroni, B. petitjeani, B. occidentalis*	West Africa, Niger, Mali
Dactylogyrus sphyrna	*B. cyclolepis prespensis*	Greece
Dactylogyrus terese	*B. paludinosus*	South Africa
Dactylogyrus tunisiensis	*B. b. callensis*	Tunisia
Dactylogyrus volutus	*B. labeobarbus fritschii*	Morocco
Dactylogyrus wurtzii	*B. parawaldroni*	Gulf of Guinea
Dactylogyrus zatensis	*B. labeobarbus fritschii*	Morocco
Dactylogyrus spp. (2)	*B. altianalis radcliffi, B. oxyrhynchus*	Kenya
Diplozoon barbi	*B. luteus*	Iraq
Diplozoon gracile	*B. b. meridionalis*	Spain
Diplozoon homoion	*B. tauricus cyclolepis*	Bulgaria
Diplozoon sp.	*B. b. meridionalis*	France
Dogielius junorstrema	*B. altianalis radcliffi*	Kenya
Dogielius pedaloe	*B. parawaldroni*	Gulf of Guinea
Dogelius persicus	*B. grypus, B. sharpeyi*	Iran

Dogielius phrygieus	*B. sacratus*	Gulf of Guinea
Gyrodactylus barbi	*B. polyponesius*	Romania
Gyrodactylus elegans	*B. grypus, B. xanthopterus*	Iraq
Gyrodactylus katharineri	*B. barbus, B. b. meridionalis, B. polyponesius*	Poland, Romania
Gyrodactylus malmbergi	*B. b. meridionalis, B. polyponesius*	Bulgaria, Romania
Gyrodactylus markwitschi	*B. barbus*	Bosnia and Herzegovina, Moravia
Neodiplozoon polycotyleus	*B. marequensis, B. neumayeri*	South Africa, Uganda
Paradiplozoon homojon homojon	*B. barbus, B. b. meridionalis*	Bulgaria, Poland
Paradiplozoon sp.	*B. lacerta cyri*	Azerbaijan
DIGENEA		
Allocreadium isoporum	*B. b. meridionalis, B. lacerta cyri, B. tyberinus*	Spain, Armenia, Italy
Allocreadium saranai	*B. sarana*	India
Allocreadium sp.	*B. b. bocagei*	Spain
Aspidogaster africanus	*B. bynni*	Sudan
Asymphyodora kedari	*B. sarana*	India
Asymphyodora tincae,	*B. tyberinus*	Italy
Clinostomum complanatum	*B. lacerta cyri, B. plebeius*	Russia, Turkey
Diplostomum pseudospathaceum	*B. barbus*	Poland
Diplostomum spathaceum	*B. brachycephalus*	Russia
Diplostomum sp. larvae	*B. barbus*	Austria, Hungary
Diplostomum spp. metacercariae	*B. barbus*	Poland
Hysteromorpha triloba	*B. lacerta cyri*	Russia
Neodiplostomum sp.	*B. luteus*	Iraq
Plagioporus sp.	*B. b. bocagei*	Spain
Pseudochaetosoma salmonicola	*B. luteus*	Iraq
Transversotrema chackai	*B. puntius*	India
CESTODA		
Bathybothrium rectangulum	*B. barbus, B. b. meridionalis*	Austria, Hungary, Czech Republic, Spain
Bothriocephalus acheilognathi	*B. brachycephalus, B. barbus, B. bynni, B. capito, B. trimaculatus, B. sharpeyi, B. luteus, B. esocinus*	Russia, Transvaal, South Africa, Iraq, Armenia
Bothriocephalus barbus	*B. bynni*	Egypt

Bothriocephalus rectangulus	*B. brachycephalus*	Caspian Sea
Caryophyllaeus brachycollis	*B. meridionalis, B. tyberinus*	France, Italy
Caryophyllaeus laticeps	*B. bynni, B. tyberinus*	Egypt, Italy
Diphyllobothrium sp.	*B. b. bocagei*	Spain
Khawia armeniaca	*B. grypus, B. luteus*	Iraq
Khawia baltica	*B. b. bocagei*	Portugal
Khawia sp.	*B. b. bocagei*	Spain
Ligula intestinalis	*B. lacerta cyri, B. plebeius*	Russia, Turkey
Proteocephalus torulosus	*B. barbus, B. grypus*	Austria, Hungary, Czech Republic, Iraq
NEMATODA		
Camallanus praveeni	*B. ticto*	India
Camallanus sp.	*B. paludinosus*	South Africa
Contracaecum sp.	*B. trimaculatus, B. paludinosus, B. marequensis, B. unitaeniatus*	South Africa
Contracaecum spp. larvae	*B. marequensis, B. mattozi*	Transvaal, South Africa
Cucullanus barbi	*B. bynni, B. perince*	Egypt
Cucullanus cyprini	*B. luteus*	Iraq
Hysterothylacium narayanensis	*B. ticto*	India
Philometra karunensis	*B. sharpeyi*	Iran
Philometra sp.	*B. luteus*	Iraq
Pseudocapillaria tomentosa	*B. tyberinus*	Italy
Raphidascaris acus	*B. tyberinus*	Italy
Raphidascaris sp.	*B. b. bocagei*	Spain
Rhabdochona denudata denudata	*B. luteus, B. tyberinus*	Iraq, Italy
Rhabdochona esseniae	*B. trimaculatus, B. paludinosus, B. marequensis, B. lineomaculatus*	South Africa
Rhabdochona gnedini	*B. b. bocagei*	Spain, Portugal
Rhabdochona hellichi	*B. barbus, B. b. meridionalis*	Czech Republic, Spain
Rhabdochona similis	*B. luteus*	Iraq
ACANTHOCEPHALA		
Acanthocephalus anguillae	*B. barbus, B. tyberinus*	Poland, Italy

Acanthocephalus clavula	*B. tyberinus*	Italy
Acanthocephalus sp.	*B. b. bocagei*	Spain
Acanthosentis tilapae	*B. bynni*	Egypt
Neoechinorhynchus chilkaensis	*B. ticto*	India
Neoechinorhynchus rutili	*B. barbus, B. esocinus*	Czech Republic, Austria, Hungary, Iraq
Polyacanthorhynchus kenyensis	*B. amphigrama*	Kenya
Pomphorhynchus laevis	*B. barbus, B. tyberinus*	Bulgaria, England, Austria, Hungary, Italy
CRUSTACEA		
Argulus foliaceus	*B. grypus, B. esocinus*	Iraq
Argulus japonicus	*B. marequensis*	South Africa
Caligus lacustris	*B. brachycephalus*	Aral Sea
Chonopeltis victori	*B. marequensis*	South Africa
Ergasilus sieboldi	*B. esocinus, B. grypus*	Iraq
Lernaea cyprinacea	*B. sclateri*	Spain
Pseudolamproglena annulata	*B. luteus*	Iraq

***Callichthys* spp.**

Disease agent	**Host species**	**Distribution**
NEOPLASIA		
Nodular epidermal neoplasia	*C. callichthys*	South America

***Capoeta/Varicorhinus* spp.**

Parasite species	**Host species**	**Distribution**
PROTOZOA		
Eimeria varicorhini	*V. capoeta heratensis*	Uzbekistan
MYXOZOA		
Myxidium ningnanense	*V. simus*	China
Myxidium onychostomatis	*V. simus*	China
Myxobolus mokhayeri	*C. trutta*	Iran
Myxobolus molnari	*C. trutta*	Iran
Myxobolus varicorhinii	*V. heratensis stendachneri*	Tadzhikistan

MONOGENEA		
Dactylogyrus araxicum	*V. capoeta gracilis, V. capoeta sevangi*	Azerbaidzhan
Dactylogyrus araxius	*V. capoeta gracilis*	Azerbaidzhan
Dactylogyrus capoetae	*C. damascina*	Iran
Dactylogyrus chramulii	*V. capoeta gracilis*	Georgia
Dactylogyrus cincinnatus	*C. semifasciolata*	China
Dactylogyrus falcilocus	*V. wurtzi*	Guinea
Dactylogyrus gracilis	*V. capoeta gracilis, V. capoeta sevangi*	Azerbaidzhan, Georgia
Dactylogyrus hirunoides	*V. lepturus*	China
Dactylogyrus kendalanicus	*V. capoeta sevangi*	Azerbaidzhan, Georgia
Dactylogyrus lencorani	*V. capoeta gracilis*	Azerbaidzhan
Dactylogyrus lenkorani	*C. capoeta*	Iran
Dactylogyrus lineatus	*C. semifasciolata*	China
Dactylogyrus microcirrus	*C. trutta*	Iran
Dactylogyrus narzikulovi	*V. capoeta heratensis*	Russia
Dactylogyrus parahirudinus	*V. lepturus*	China
Dactylogyrus parawaldroni	*V. wurtzi*	Guinea
Dactylogyrus placentiformis	*V. gerlachi*	China
Dactylogyrus pulcher	*C. capoeta, C. trutta, V. capoeta gracilis*	Azerbaidzhan, Iran
Dactylogyrus ramosus	*C. semifasciolata*	China
Dactylogyrus rohdeianus	*C. damascina*	Iran
Dactylogyrus varicorhini	*V. capoeta gracilis*	Azerbaidzhan
Dactylogyrus volfi	*C. tetrazona*	Czechoslovakia
Dichodactylogyrus campoformis	*V. gerlachi*	China
Diplozoon varicorhini	*V. capoeta sevangi*	Azerbaidzhan
Dogielius pedaloe	*V. wurtzi*	Guinea
Dogielius vexillus	*V. wurtzi*	Ivory Coast
Gyrodactylus capoetai	*V. capoeta gracilis*	Azerbaidzhan
Gyrodactylus ibragimovi	*V. capoeta gracilis*	Azerbaidzhan
Gyrodactylus mikailovi	*V. capoeta gracilis*	Azerbaidzhan
Gyrodactylus varicorhini	*V. capoeta gracilis*	Azerbaidzhan

Markewitschiana triaxonis	*V. capoeta*	Georgia
DIGENEA		
Allocreadium isoporum	*V. capoeta*	Armenia
Allocreadium varicorhini	*V. barbotulus*	China
Clinostomum complanatum	*C. capoeta, C. tinca*	Iran, Turkey
Diplostomum spathaceum	*V. capoeta sevangi*	Armenia
Tetracotyle sp.	*V. capoeta sevangi*	Armenia
CESTODA		
Khawia armeniaca	*V. capoeta sevangi, C. bushei, C. capoeta*	Armenia, Iran
Ligula intestinalis	*C. capoeta umbla, V. capoeta sevangi*	Turkey, Armenia
NEMATODA		
Contracaecum sp. larvae	*V. trutta*	Turkey
Rhabdochona tigrae	*V. trutta*	Iraq
ACANTHOCEPHALA		
Acanthocephalorhynchoides cholodkowskyi	*C. bushei, C. capoeta gracilis*	Iran
Metechinorhynchus baeri	*V. capoeta sevangi*	Armenia
Neoechinorhynchus rutili	*C. trutta*	Turkey
Quadrigyrus cholodkowskyi	*V. capoeta sevangi*	Armenia
Quadrigyrus sp.	*V. capoeta sevangi*	Armenia
COPEPODA		
Ichthyoxenus fushanensis	*V. barbatulus*	Taiwan
Lamproglena pulchella	*C. trutta*	Turkey
Tracheliastes polycolpus	*C. capoeta gracilis*	Iran
***Corydoras* spp.**		
Disease agent	**Host species**	**Distribution**
PROTOZOA		
Coleps sp.	*C. schultzei*	Hungary
Piscinoodinium spp.	*C.* sp.	U.K. from Columbia and Brazil
MONOGENEA		
Gyrodactylus anisopharynx	*C. paleatus*	Brazil

Gyrodactylus samirae	*C. ehrhardti*	Brazil
Paragyrodactylus superbus	*C. paleatus*	Argentina
Philocorydoras platensis	*C. paleatus*	Argentina
Urocleidoides corydori	*C. aeneus*	Trinidad
NEMATODA		
Spirocamallanus pintoi	*C. paleatus*	Brazil
ACANTHOCEPHALA		
Neoechinorhynchus sp.	*C. paleatus*	Argentina
Hoplosternum littorale		
Disease agent	**Host species**	**Distribution**
MYXOZOA		
Henneguya amazonica	*H. littorale*	Brazil
DIGENEA		
Crassicutis intermedius	*H. littorale*	Paraguay
***Loricaria* spp.**		
Disease agent	**Host species**	**Distribution**
PROTOZOA		
Trypanosoma britskii	*L. lentiginosa*	Brazil
MONOGENEA		
Demidospermus anus	*L. anus*	Argentina
DIGENEA		
Procaudotestis uruguayensis	*L.* sp.	Uruguay
NEMATODA		
Raphidascaris (*Sprentascaris*) *mahnerti*	*L.* sp.	Paraguay
Spirocamallanus cervicalatus	*L.* sp.	Paraguay
***Platydoras* spp.**		
Disease agent	**Host species**	**Distribution**
CESTODA		

Proteocephalus sp.	*P. costatus*	Paraguay
***Puntius* spp.**		
Disease agent	**Host species**	**Distribution**
BACTERIA		
Edwardsiella ictaluri	*P. conchonius*	Australia from Singapore
FUNGI		
Achlya americana	*P. conchonius*	Not known
Achlya caroliniana	*P. conchonius, P. sophore, P. ticto*	India
Achlya klebsiana	*P. sophore*	India
Achlya orion	*P. sophore*	India
Achlya prolifera	*P. sarana, P. sophore*	India
Aphanomyces invadans	*P. conchonius, P. gonionotus, P. sarana, P. schwanenfeldii, P. sophore, P. ticto*	Bangladesh, India, Sri Lanka, Thailand
Fusarium moniliforme	*P. sophore*	India
Pythium gracile	*P. ticto*	India
Saprolegnia ferax	*P. sophore*	India
Saprolegnia parasitica	*P. conchonius, P. ticto*	India
PROTOZOA		
Cryptobia indica	*P. sarana*	India
Piscinoodinium pillulare	*P. gonionotus*	Malaysia
Trypanoplasma cyprinoides	*P. ticto*	India
Trypanosoma lomi	*P. hexastichus*	India
Trypanosoma marathwadensis	*P. hexastichus*	India
Trypanosoma puntii	*P. kolus*	India
Trypanosoma rayi	*P. sarana*	India
Trypanosoma saranae	*P. sarana*	India
Trypanosoma seenghali	*P. sophore*	India
Trypanosoma solapurensis	*P. jerdoni*	India
Trypanosoma stigmai	*P. stigma*	India
Trypanosoma ticti	*P. ticto*	India

Vorticella sp.	*P. conchonius* eggs	India
MYXOZOA		
Myxobolus aravalae	*P. sophore*	India
Myxobolus bhaduria	*P. sarana*	India
Myxobolus curmucae	*P. curmuca*	India
Myxobolus saranae	*P. sarana*	India
Myxobolus sophorae	*P. sophore*	India
Myxosoma filamentosa	*P. filamentosus*	India
Myxosoma mathurii	*P. sarana*	India
Thelohanellus sp.	*P. gonionotus*	Malaysia
MONOGENEA		
Dactylogyroides longicirrus	*P. sophore*	India
Dactylogyrus angularis	*P. stigma*	India
Dactylogyrus barbusi	*P. sarana*	Pakistan
Dactylogyrus binotati	*P. binotatus*	Malaysia
Dactylogyrus brevitignus	*P. stigma*	India
Dactylogyrus bului	*P. bulu*	Malaysia
Dactylogyrus cauveryi	*P. ticto*	India
Dactylogyrus crescenticleithrium	*P. binotatus*	Malaysia
Dactylogyrus cristatocleithrium	*P. orphoides*	Thailand
Dactylogyrus fasciati	*P. fasciatus*	Malaysia
Dactylogyrus fasciculi	*P. bulu*	Malaysia
Dactylogyrus helicoidus	*P. fasciatus*	Malaysia
Dactylogyrus iskanderensis	*P. fasciatus*	Malaysia
Dactylogyrus kanchanaburiensis	*P. gonionotus*	Thailand
Dactylogyrus kwainensis	*P. daruphani*	Thailand
Dactylogyrus lampam	*P. altus, P. gonionotus, P. schwanenfeldii*	Thailand
Dactylogyrus longiacus	*P. stigma*	India
Dactylogyrus magnicystocirrus	*P. semifasciolatus*	China
Dactylogyrus megavesicularis	*P. schwanenfeldii*	Malaysia
Dactylogyrus orphoidis	*P. orphoides*	Malaysia

Dactylogyrus pahangensis	*P. bulu*	Malaysia
Dactylogyrus partipentazonae	*P. partipentazona*	Malaysia
Dactylogyrus pentabrachiatus	*P. bulu*	Malaysia
Dactylogyrus pentabrachicleithrium	*P. partipentazona*	Malaysia
Dactylogyrus perakensis	*P. orphoides*	Thailand
Dactylogyrus pseudosphyrna	*P. gonionotus, P. schwanenfeldii*	Thailand
Dactylogyrus puntii	*P. gonionotus, P. schwanenfeldii*	Malaysia
Dactylogyrus siamensis	*P. daruphani, P. gonionotus*	Thailand
Dactylogyrus sclerovaginalis	*P. binotatus*	Malaysia
Dactylogyrus sekerai	*P. schuberti*	India
Dactylogyrus tapiensis	*P. altus, P. gonionotus, P. schwanenfeldii*	Thailand
Dactylogyrus tonguthaii	*P. gonionotus*	Thailand
Dactylogyrus viticulus	*P. altus, P. gonionotus, P. schwanenfeldii*	Malaysia, Thailand
Dactylogyrus sp.	*P. binotatus*	Malaysia
Lissemysia agrawali	*P. ticto*	India
Lissemysis pandei	*P. sarana*	India
Paradiplozoon magnum	*P. bulu*	Malaysia
DIGENEA		
Acanthostomum burminis	*P. parrah*	India
Allocreadium mahaseri	*P. ticto*	India
Allocreadium schizothoracis	*P. ticto*	India
Aspidogaster tigarai	*P. sophore*	India
Asymphylodora longicaeca	*P. sarana*	India
Asymphylodora puntiusii	*P. puntius*	India
Asymphylodora sp.	*P. sophore*	India
Brahmputrotrema gwaliorensis	*P. sophore*	India
Bucephalopsis fusiformis	*P. ticto*	India
Centrocestus formosanus	*P*. spp.	Not known
Diplostomulum ellipticus	*P. ticto*	India
Diplostomulum minutum	*P*. spp.	India
Echinochasmus bagulai	*P. sophore*	India

Haplorchis pumilio	*P. binotatus, P. gonionotus, P. leicanthus, P. orphoides*	Philippines, Thailand
Haplorchis taichui	*P. gonionotus, P. leicanthus, P. orphoides, P. sarana*	India, Thailand
Haplorchis yokogawai	*P. gonionotus, P. leicanthus, P. orphoides*	Thailand
Haplorchis sp.	*P. gonionotus, P. leicanthus, P. orphoides, P. stolickkae*	Thailand
Haplorchoides mehrai	*P. sophore*	India
Isoparorchis hypselobagri	*P. conchonius*	India
Neopodocotyle dayali	*P. sarana*	India
Neopodocotyle lucknowensis	*P. sarana*	India
Opisthorchis viverrini	*P. gonionotus, P. leicanthus, P. orphoides*	Thailand
Petasiger grandivesicularis	*P. tetrazona*	Bulgaria
Phyllodistomum sp.	*P. sarana*	India
Podocotyle mehrai	*P. sarana, P. sophore*	India
Prosorhynchus sp.	*P. sophore*	India
Pseudoorientodiscus laxmibaii	*P. sarana*	India
Pseudoorientodiscus sengurai	*P. sarana*	India
Stephanoprora pandei	*P. sophore*	India
Tetracotyle lali	*P. ticto*	India
Transversotrema patialense	*P. binotatus*	India
Transversotrema soparkari	*P. chola, P. sophore*	India
CESTODA		
Bothriocephalus aceilognathi	*P. binotatus*	Malaysia
Ligula intestinalis	*P. dorsalis*	India
Ophiotaenia europaea	*P. tetrazona*	Russia
Proteocephalus sp.	*P. binotatus*	Malaysia
NEMATODA		
Camallanus praveeni	*P. ticto*	India
Capillaria philippinensis	*P. gonionotus*	Thailand
Hysterothylacium longicaecum	*P. dorsalis*	India

Hysterothylacium narayanensis	*P. ticto*	India
Procamallanus spiculogubernaculus	*P. conchonius*	Not known
Pseudocapillaria brevispicula	*P. tetrazona*	Czechoslovakia
Pseudocapillaria margolisi	*P. conchonius, P. sophore*	India
Rhabdochona charsaddiensis	*P.* sp.	Pakistan
Rhabdochona penengensis	*P. binotatus*	Malaysia
Spironoura nilgiriensis	*P. cornaticus*	India
ACANTHOCEPHALA		
Acanthosentis dattai	*P. sophore*	Thailand
Acanthosentis siamensis	*P. gonionotus*	Thailand
Pallisentis gaboes	*P. binotatus*	Malaysia
COPEPODA		
Alitropus typus	*P. gonionotus, P. sarana subnasutus*	India
Ergasilus ceylonensis	*P. dorsalis, P. sarana*	Sri Lanka
Lamproglena minuta	*P. binotatus*	Malaysia
Lernaea arcuata	*P. gonionotus*	Thailand
Lernaea cyprinacea	*P. binotatus, P. javanicus, P. partipentazona*	Java, Thailand
Lernaea minuta	*P. gonionotus*	Malaysia
Lernaea oryzophila	*P. gonionotus*	Thailand
Lernaea sp.	*P. ticto*	India
Lernaea sp.	*P. stigma*	India

Table 3.5 Diseases and geographical distribution of ‘shortlisted’ marine fish species.

The ‘shortlisted’ marine species are : Antennarius spp., Bodianus spp., Cantherhines spp., Chromis spp., Coris spp., Hemirhamphus spp., Hippocampus spp., Histrio spp., Hyporhamphus spp. and Stethojulius spp.

Antennarius **spp.**		
Disease agent	**Host species**	**Distribution**
BACTERIA		
Mycobacterium marinum	*A. striatis*	Brazil
FUNGI		
Unidentified systemic mycosis	*A. striatis*	Brazil
PROTOZOA		
Cryptocaryon irritans	*A. commerson*	Hawaii
Bodianus **spp.**		
Disease agent	**Host species**	**Distribution**
PROTOZOA		
Eimeria catalana	*B. speciosus*	Senegal
CRUSTACEA		
Nerocila benrosei	*B. rufus*	Puerto Rico
Cantherhines **spp.**		
Disease agent	**Host species**	**Distribution**
PROTOZOA		
Trichodina spheroidesi	*C. macrocerus*	Puerto Rico
MONOGENEA		
Benedenia seriolae	*C. pardalis*	Okinawa, Japan
DIGENEA		
Bianium rewa	*C. pardalis*	Australia, Japan

Cableia pudica	*C. dumerili*	Australia
Schistorchis seychellesiensis	*C. pardalis*	Seychelles
***Chromis* spp.**		
Disease agent	**Host species**	**Distribution**
BACTERIA		
Photobacterium (*Vibrio*) *damsela*	*C. punctipinnis*	USA
Mycobacterium marinum	*C. cyanea*	Europe
MYXOZOA		
Ceratomyxa chromis	*Chromis sp.*	Mediterranean
Enteromyxum leei	*C. chromis*	Spain
Kudoa amamiensis	*Chromis sp.*	Japan
Leptotheca chromis	*Chromis sp.*	Mediterranean
Sinuolinea sp.	*C. atripectoralis*	GBR, Australia
CRUSTACEA		
Anilocra pomacentri	*C. nitida*	GBR, Australia
Anilocra chromis	*C. multilineatus, C. cyanea*	Caribbean
Lernanthropus eddiwarneri	*C. lineatus*	Senegal
***Coris* spp.**		
Disease agent	**Host species**	**Distribution**
BACTERIA		
Lactococcus garvieae	*C. aygula*	Red Sea
PROTOZOA		
Amyloodinium ocellatum	*C. gaimard*	USA
Cryptocaryon irritans	*C. gaimard*	USA
Eimeria banyulensis	*C. julis*	Mediterannean
MYXOZOA		
Ceratomyxa coris	*C. julius*	Mediterranean
Enteromyxum leei	*C. julius*	Spain
Myxidium oviforme	*C. julius*	Mediterranean

MONOGENEA		
Benedenia lolo	*C. gaimard, C. flavovittata, Coris* sp.	Hawaii
CESTODA		
Unicibilocularis sp.	*C. batuensis*	GBR, Australia
***Hemirhamphus* spp.**		
Disease agent	**Host species**	**Distribution**
MONOGENEA		
Ancyrocephalus flexuosus	*H. sajori*	China
Axine sp.	*H. far*	Israel
Indocotyle elegans	*H. georgii*	India
Loxuroides fungilliformis	*H. quoyi*	South China Sea
DIGENEA		
Bucephalopsis hemirhamphi	*H. brasiliensis*	Venezuela
Chauhanotrema indica	*H. far*	India
Galactosomum angelae	*H. melanochir*	South Australia
Koseiria manteri	*H. leucopterus*	Goa
Neogonapodasmius hemirhamphi	*H. xanthopterus*	India
Paraproctotrema spinoacetabulum	*H. brasiliensis*	Venezuela
Schikhobalotrema acutum	*H. marginatus*	Bay of Bengal
CESTODA		
Otobothrium penetrans	*H.* sp.	Philippines
ACANTHOCEPHALA		
Hanumantharaorhynchus hemirhamphi	*H. marginatus*	Bay of Bengal
Micracanthorhyncha hemirhamphi	*H. melanochir*	South Australia
Micracanthorhyncha indica	*H. xanthopterus*	India
COPEPODA		
Lernaeenicus hemirhamphi	*H. xanthopterus*	India
Orbitacolax hepalogenyos	*H. marginatus*	Kuwait

***Hippocampus* spp.**		
Disease agent	**Host species**	**Distribution**
BACTERIA		
Vibrio harveyi	*H. kuda, H.* sp.	Spain
PROTOZOA		
Amyloodinium sp.	*H.* spp.	USA
Brooklynella hostalis	*H.* spp.	USA
Cryptocaryon irritans	*H.* spp.	USA,
Licnophora hippocampi	*H. trimaculatus*	China
MICROSPORIDIA		
Glugea heraldi	*H. erectus*	Florida, U.S.A.
MYXOSPOREA		
Sphaeromyxa sp.	*H. erectus*	Florida, U.S.A
DIGENEA		
Opegaster hippocampi	*H. trimaculatus*	China
Opegaster tamori	*H. trimaculatus*	China
Telorhynchus hippocampi	*H. trimaculatus*	China
***Histrio* spp.**		
Disease agent	**Host species**	**Distribution**
COPEPODA		
Pennella sagitta	*H. histrio*	NW Atlantic Ocean
***Hyporhamphus* spp.**		
Disease agent	**Host species**	**Distribution**
MYXOZOA		
Ceratomyxa aggregata	*H. unifasciatus*	Florida, U.S.A.
MONOGENEA		
Anyrocephalus spirae	*H. unifasciatus*	Gulf of Mexico
Oligapta hyporhamphi	*H. quoyi*	Papua New Guinea

CESTODA		
Ptychobothrium belones	*H. capensis = H. knysnaensis*	Zululand
CRUSTACEA		
Cerathoa angulata	*H. dussumieri*	Guam
Colobomatus cresseyi	*H. regularis*	South Africa
***Stethojulis* spp.**		
Disease agent	**Host species**	**Distribution**
DIGENEA		
Callohelmis pichelinae	*S. bandanensis*	GBR, Australia
CESTODA		
Anthobothrium spp.	*S. strigiventer*	GBR, Australia

Table 3.6 Parasites and diseases identified as potential hazards through the host-based hazard identification process.

Those parasites or diseases that already occur in New Zealand are listed in bold.
Diseases of unknown aetiology and neoplastic diseases listed in Tables 3.4 and 3.5 are excluded.

Host-based approach	
VIRUSES	**MONOGENEA**
Infectious pancreatic necrosis virus	*Ancyrocephalus* spp.
Viral haemorrhagic septicaemia virus	*Axine* spp.
BACTERIA	***Benedenia seriolae***
Edwardsiella ictaluri	*Dactylogyroides longicirrus*
Lactococcus garvieae	***Dactylogyrus* spp.**
Mycobacterium marinum	*Demidospermus anus*
Photobacterium (*Vibrio*) *damsela*	*Dichodactylogyrus campoformis*
Vibrio harveyi	*Dicrodactylogyrus hastatus*
FUNGI	*Diplozoon* spp.
Achyla spp.	*Dogielius* spp.
Aphanomyces invadans (EUS)	***Gyrodactylus* spp.**
Fusarium moniliforme	*Indocotyle elegans*
Fusarium spp.	*Lissemysia agrawali*
Pythium gracile	*Lissemysia pandei*
Saprolegnia ferax	*Loxuroides fungiliformis*
Saprolegnia parasitica	*Markewitschiana triaxonis*
PROTOZOA	*Neodiplozoon polycotyleus*
Amyloodinium ocellatum	*Oligapta hyporhamphi*
Coleps spp.	*Paradiplozoon* spp.
Cryptobia indica	*Paragyrodactylus superbus*
Cryptocaryon irritans	*Philocorydoras platensis*
***Eimeria* spp.**	*Urocleidoides corydori*
***Goussia* spp.**	**DIGENEA**

Ichthyophthirius multifiliis	*Acanthostomum* spp.
Licnophora hippocampi	*Allocreadium* spp.
Piscinoodinium spp.	*Aspidogaster* spp.
Trichodina **spp**.	*Asymphyodora* spp.
Trypanoplasma cyprinoides	*Bianium rewa*
Trypanosoma spp	*Brahmputrotrema gwaliorensis*
Vorticella **spp.**	*Bucephalopsis* spp.
MYXOZOA	*Cableia pudica*
Ceratomyxa **spp.**	*Callohelmis pichelinae*
Chloromyxum **spp.**	*Centrocestus formosanus*
Enteromyxum leei	*Chauhanotrema indica*
Henneguya amazonica	*Clinostomum* spp.
Leptotheca **spp.**	*Crassicutis intermedius*
Myxidium **spp.**	*Diplostomulum* spp.
Myxobolus **spp.**	*Diplostomum* spp.
Myxosoma filamentosa	*Echinochasmus bagulai*
Myxosoma mathurii	*Galactosomum angelae*
Sinuolinea spp.	*Haplorchis* spp.
Thelohanellus **spp**	*Haplorchoides mehrai*
Unicauda lumae	**DIGENEA (con't)**
CESTODA	*Hysteromorpha triloba*
Anthobothrium **spp.**	*Isoparorchis hypselobagri*
Bathybothrium rectangulum	*Koseiria manteri*
Bothriocephalus acheilognathi	*Neodiplostomum* spp.
Bothriocephalus **spp.**	*Neogonapodasmius hemirhamphi*
Caryophyllaeus spp.	*Neopodocotyle* spp.
Diphyllobothrium spp.	*Opisthorchis viverrini*
Khawia spp.	*Paraproctotrema spinoacetabulum*
Lingula intestinalis	*Petasiger grandivesicularis*
Ophiotaenia europaea	***Phyllodistomum*** **spp.**
Otobothrium penetrans	***Plagioporus*** **spp.**

Proteocephalus spp.	*Podocotyle mehrai*
Ptychobothrium belones	*Procaudotestis uruguayensis*
Unicibilocularis spp.	*Prosorhynchus* spp.
NEMATODA	*Pseudochaetosoma salmonicola*
Camallanus spp.	*Pseudoorientodiscus* spp.
Capillaria philippinensis	*Schokhobalotrema acutum*
***Contracaecum* spp.**	*Schistorchis seychellesiensis*
***Cucullanus* spp.**	*Stephanoprora pandei*
***Hysterothylacium* spp.**	*Tetracotyle* spp.
***Philometra* spp.**	*Transversotrema patialense*
Procamallanus spiculogubernaculus	*Transversotrema* spp.
Pseudocapillaria spp.	**CRUSTACEA**
Raphidascaris spp.	*Alitropus typus*
Raphidascaroides sp.	*Anilocra* spp.
Rhabdochona spp.	***Argulus* spp.**
Spirocamallanus spp.	***Caligus* spp.**
Spironoura nilgiriensis	*Ceratothoa angulata*
ACANTHOCEPHALA	*Chonopeltis victori*
***Acanthocephalus* spp.**	*Colobomatus cresseyi*
Acanthocephalorhynchoides cholodkowskyi	*Ergasilus* spp.
Acanthosentis spp.	*Ichthyoxenus fushanensis*
Hanumantharaorhynchus hemirhamphi	*Lamproglena* spp.
Metechinorhynchus baeri	***Lernaea* spp.**
***Micracanthorhyncha* spp.**	*Lernaeenicus hemirhamphi*
***Neoechinorhynchus* spp.**	*Lernanthropus eddiwarneri*
Polyacanthorhynchus kenyensis	*Nerocila benrosei*
Pomphorhynchus spp.	*Orbitacolax hepalogenyos*
Pallisentis gaboes	*Penella sagitta*
Quadrigyrus spp.	*Pseudolamproglena annulata*
	Tracheliastes polycolpus

Table 3.6 Parasites and diseases identified as potential hazards through the host-based hazard identification process

Table 3.7 Life histories of helminths with complex life cycles.

The helminths with complex life cycles include the genera of digeneans, cestodes, nematodes and acanthocephalans.
* = based on experimental exposure.

Digeneans	**1st intermediate hosts (gastropods)**	**2nd intermediate hosts**	**Definitive hosts**
Centrocestus formosanus	*Melanoides tuberculata*	*Amblypharyngodon, Anguilla, Aplocheilus* spp., *Aristchthys,, Carassius, Channa,, Cirrhina, Ctenopharyngodon, Cyprinus, Etheostoma, Gambusia, Ictalurus**, *Labeo, Morone* spp.*, *Mugil, Mylopharyngodon, Notemigonus**, *Oreochromis, Pimephales**, *Puntius, Xiphophorus*, Atherinidae, Characidae, Cichlidae, Cyprinidae, Eleotridae, Gobiidae, Ictaluridae, Mugilidae, Poeciliidae	Humans, *Ardeola grayi, Nycticorax* (herons), *Tatera indica** (gerbil), *Rattus** (rats), *Canis** (dogs)
Clinostomum complanatum	*Lymnaea auricularia, Lymnaea japonica, Lymnaea ollula, Lymnaea swinhoe*	*Acheilognathus spp., Barbus plebejus, Capoeta tinca, Cichlasoma urophthalmus, Colisa lalia, Lateolabrax japonicus, Oncorhynchus mykiss, Perca spp., Pseudorasbora parva*, Rutilus rutilus*, Texas salamander *(Eurycea neotenes)*	*Ajaiai ajaja* (spoonbills), *Ardea albus, A. cinerea, A. goliath, A. novaehollandiae* (herons), *Egretta alba, E. garzetta, E. intermedia* (egrets), *Nycticorax nycticorax* (cormorants), pelicans and gulls, and many others.
Diplostomum pseudospathaceum	*Lymnaea peregra, Lymnaea stagnalis, Lymnaea turricula*	*Alburnus alburnus, Cyprinus carpio, Leucaspius delineatus, Poecilia reticulata**, *Xiphophorus xiphophorus*	*Gavia stellata* (loons), *Gallus** (chicken), *Larus** (sea gulls)
Diplostomum spathaceum	*Lymnaea elodes, Lymnaea palustris, Lymnaea peregra, Lymnaea stagnalis, Lymnaea turricula Physa gyrina*	*Alburnus, Barbus, Catostomus, Cyprinus, Gila, Hybognathus, Leucaspius, Oncorhynchus, Poecilia*, Richardsonius, Rutilus, Salvelinus, Salmo, Xiphophorus**	*Gallus** (chickens), *Mergus merganser, Larus* spp. (sea gulls), *Sterna forsteri* (tern)
Echinochasmus bagulai	*Melanoides tuberculata*	*Aplocheilus panchax, Puntius sophore*	*Ardeola grayii* (heron)

Digeneans	**1st intermediate hosts (gastropods)**	**2nd intermediate hosts**	**Definitive hosts**
Haplorchis pumilio	*Melanoides tuberculata, Bithynia striatulus*	*Gambusia affinis, Oreochromys niloticus, Pseudorasbora parva, Puntius binotatus, Puntius leiacanthus, Puntius gonionotus, Puntius orphoides, Puntius sophore, Sarotherodon* spp.*, *Tilapia zilli**, *Oncorhynchus mykiss**	Humans, *Canis familiaris* (dogs), *Rattus** (rats), *Columba* (pigeons), *Anas** (ducklings), *Ardea cinerea* (herons), *Phalocrocorax* sp. (shag), *Varanus* (monitor lizard)
Haplorchis taichui	*Melanoides tuberculata*	*Cirrhina reba, Amblypharyngodon mola, Aplocheilus* spp., *Labeo bata, Puntius leiacanthus, Puntius gonionotus, Puntius orphoides, Puntius sarana*	*Columba* (pigeons)*, *Canis* (dogs)*
Haplorchis yokogawai	*Melanoides tuberculata*	*Gambusia affinis, Puntius leicanthus, Puntius gonionotus, Puntius orphoides, Tilapia nilotica*	Birds, including chickens, and mammals, including rats and humans
Haplorchoides mehrai	*Melanoides tuberculata*	*Puntius sophore*	*Mystus* spp., *Nangra robusta*
Isoparorchis hypselobagri	*Indoplanorbis exustus, Juga* spp.	*Ecdyonurus aurarius, Gammarus lacustris* (amphipods)*. Nandus nandus, Pseudorasbora, Gobio, Rhodeus, Phoxinus* (small fishes)	*Channa punctatus, Mystus* spp., *Tandanus tandanus, Wallago attu,* predatory catfishes
Petasiger grandivescicularis	*Planorbis planorbis*	***Carassius, Poecilia, Puntius, Xiphophorus***	Canaries*
Transversotrema patialense	*Melanoides tuberculata*	None	*Ambassis, Aplocheilus, Barbus, Betta, Brachydanio Cheirodon, Danio, Jordanella, Lates calcarifer, Melanotaenia, Nanostomus, Poecilia, Pterophyllum, Puntius, Rasbora, Tanichthys, Trichogaster, Xiphophorus*

Cestodes	**1st intermediate hosts**	**2nd intermediate hosts**	**Definitive hosts**
Bothriocephalus acheilognathi, (syn.*B. aegyptiacus*)	Many *Cyclops* spp., *Acanthocyclops robustus, A. vernalis, A. viridis*, Diacyclops thomasi, Ectocyclops phaleratus, Eucyclops agilis, E. serrulatus, Mesocyclops edax, M. leuckarti, M. oithonoides, Microcyclops bicolor, Paracyclops fimbriatus, Tropocyclops prasinus, Phyllodiaptomus blanci*	None	*Awaous guamensis, Barbus bynni, Ctenopharyngodon idella, Cultrichthys erythropterus, Cyprinus carpio, Eleotris sandwicensis, Esox lucius* (pike), *Fundulus zebrinus, Gambusia* spp., *Gila cypha, Hemiculter leucisculus, Hypseleotris* spp., *Phylipnodon grandiceps, Pimephales promelas, Potamotrygon* sp. (stingray), *Puntius binotatus, Retropinna semoni, Rhinichthys osculus, Xiphophorus* and many other cyprinids
Caryophyllaeus brachycollis	*Tubifex*	None	*Abrama, Barbus meridionalis, Leuciscus cephalus*
Caryophyllaeus laticeps	*Tubifex tubifex*	None	*Barbus, Cyprinus, Leuciscus, Rutilus, Scardinius, Tinca*
Ophiotaenia europaea	*Acanthocyclops robustus, Cyclops vicinus, Eudiaptomus vulgaris*	*Puntius terazona, Rana ridibunda*	Snakes

Nematodes	**1st intermediate hosts**	**2nd intermediate hosts**	**Definitive hosts**
Camallanus cotti	*Macrocyclops albidus*	None	Very common in, and spread by, guppies (*Poecilia reticulata*). It also infects many freshwater teleosts and can transmit directly fish-to-fish
Capillaria philippinensis	None	Small fishes - *Ambassis commersoni, Apogon* sp., *Eleotris melanosoma*	A wide range of birds and mammals, including humans
Capillaria pterophylli	None	None	*Cichlasoma octofasciatum, Pterophyllum scalare, Symphysodon aequifasciatus,*
Procamallanus spiculogubernaculus	*Cyclops vicinus, Mesocyclops hyalinus, Mesocyclops leukarti*	None	*Clarias batrachus, Heteropneustes fossilis, Lepidocephalichthyes guntea, Puntius conchonius*
Pseudocapillaria brevispicula	None	None	*Puntius tetrazona* and other cyprinids
Pseudocapillaria tomentosa	None	None	*Barbus tyberinus, Danio rerio*
Spirocamallanus mysti	*Mesocyclops crassus, Mesocyclops leuckarti*	None	*Aorichthys seenghala, Mystus spp., Ompok bimaculatus, Ompok pabda, Wallago attu*

Acanthocephala	**Intermediate host**		**Definitive host**
Acanthocephalus anguillae	*Asellus aquaticus* (isopod)		*Anguilla anguilla*, *Salmo trutta*, *Esox lucius* (pike), and others
Acanthocephalus clavula	*Echinogammarus stammeri* (amphipod)		*Anguilla anguilla*, *Salmo trutta* and others
Acanthosentis dattai	*Mesocyclops leuckarti*		*Colisa fasciatus*, *Puntius sophore*
Neoechinorhynchus rutili	*Cypria reptans* (ostracod) *Sialis lutaria* (mayfly)		*Barbus barbus*, *Cyprinus carpio*, *Gasterosteus aculeatus*, *Oncorhynchus mykiss*, *Salmo salar*, *Salmo trutta* and others
Neochinorhynchus cristatus	*Cypridopsis helvetica* (ostracod)		*Catastomus macrocheilus*
Pomphorhynchus laevis	*Gammarus* spp. , *Echinogammarus* spp. (Amphipods)		*Cottus gobio*, *Gasterosteus aculeatus*, *Gobio gobio*, *Noemachelius barbatulus*, *Oncorhynchus mykiss*, *Phoxinus phoxinus*, *Leuciscus cephalus*, *Leuciscus leuciscus*, *Salmo trutta* and others

Table 3.7 Life histories of helminths with complex life cycles

Table 3.8 Life histories of helminths with complex life cycles where key intermediate hosts occur in NZ.

Life histories of the genera of digeneans, cestodes, nematodes and acanthocephalans of fishes permitted entry into New Zealand, for which intermediate and definitive hosts already occur in New Zealand, and where the life cycle involves species being imported in ornamental fish.

Digeneans	**1st intermediate hosts (gastropods)**	**2nd intermediate hosts**	**Definitive hosts**
Centrocestus formosanus	*Melanoides tuberculata*	*Anguilla, Aplocheilus* spp., *Carassius, Ctenopharyngodon, Cyprinus, Gambusia, Ictalurus, Mugil, Puntius, Xiphophorus,* Cichlidae, Cyprinidae, Eleotridae, Ictaluridae, Mugilidae, Poeciliidae	Humans, *Ardeola, Rattus, Canis*
Echinochasmus bagulai	*Melanoides tuberculata*	*Aplocheilus panchax, Puntius sophore*	*Ardeola*
Haplorchis pumilio	*Melanoides tuberculata,*	*Puntius binotatus, Puntius gonionotus, Puntius sophore*	Humans, *Canis, Rattus, Columba,* Anas, *Ardea cinerea, Phalocrocorax* carbo
Haplorchis taichui	*Melanoides tuberculata*	*Aplocheilus spp., Labeo bata, Puntius gonionotus, Puntius sarana*	*Canis, Columba*
Haplorchis yokogawai	*Melanoides tuberculata*	*Puntius gonionotus,*	Birds and mammals
Haplorchoides mehrai	*Melanoides tuberculata*	*Puntius sophore*	*Mystus* spp.
Transversotrema patialense	*Melanoides tuberculata*	None	*Ambassis, Aplocheilus, Betta, Brachydanio Cheirodon, Danio, Jordanella, Melanotaenia, Nanostomus, Poecilia, Pterophyllum, Rasbora, Tanichthys, Trichogaster, Xiphophorus*
Clinostomum complanatum	*Lymnaea auricularia*	*Colisa lalia, Oncorhynchus mykiss, Perca*	*Ardea albus, A. novaehollandiae, Egretta alba, E. garzetta*
Diplostomum pseudospathaceum	*Lymnaea stagnalis*	*Poecilia reticulata, Xiphophorus xiphophorus*	*Gallus, Larus*
Diplostomum spathaceum	*Lymnaea stagnalis*	*Barbus, Cyprinus, Oncorhynchus, Poecilia, Salvelinus, Salmo, Xiphophorus*	*Gallus, Larus*

Cestodes	**1st intermediate hosts**	**2nd intermediate host**	**Definitive hosts**
Bothriocephalus acheilognathi	*Cyclops , Acanthocyclops robustus, M. leuckarti,*	None	*Ctenopharyngodon idella, Cyprinus carpio, Gambusia, Puntius binotatus, Retropinna, Xiphophorus*
Bothriocephalus claviceps	*Macrocyclops albidus*	*Gambusia, Poecilia*	*Anguilla* spp.
Nematodes	**1st intermediate hosts**	**2nd intermediate host**	**Definitive hosts**
Camallanus cotti	*Macrocyclops albidus*	None	*Poecilia reticulata*, and many freshwater teleosts
Spirocamallanus mysti	*Mesocyclops leuckarti*	None	*Mystus spp., Ompok bimaculatus, Ompok pabda*
Pseudocapillaria brevispicula	None	None	*Puntius tetrazona*, other cyprinids
Pseudocapillaria tomentosa	None	None	*Danio rerio*
Acanthocephala	**1st intermediate hosts**	**2nd intermediate host**	**Definitive hosts**
Acanthosentis dattai	*Mesocyclops leuckarti*	None	*Colisa fasciatus, Puntius sophore, Trichopterus fasciatus*

Table 3.8 Life histories of helminths with complex life cycles where key intermediate hosts occur in NZ

Table 3.9 Life histories of helminths with complex life cycles where intermediate hosts are not present in NZ.

The life cycles of the genera of digeneans infecting temperate and sub-tropical marine fishes permitted entry into New Zealand, based on computerised databases. These and related parasites are not considered further in the risk analysis as they are unlikely to have suitable intermediate hosts here.

Digeneans	**1st intermediate hosts (gastropods)**	**2nd intermediate hosts**	**Definitive hosts**
Tetracerasta blepta (Lepocreadiidae)	*Posticobia brazieri*	Small fishes	*Anguilla reinhardtii*
Neopechona cablei (Lepocreadiidae)	*Mitrella lunata*	Cnidarian medusae, ctenophores	*Stenotomus chrysops*
Opechona bacillaris (Lepocreadiidae)	*Nassarius pygmaeus*	Cnidarian medusae, ctenophores, chaetognaths	*Cyclopterus lumpus*
Bucephalus baeri	*Tapes aureus*	*Pomatoschistus microps*	*Dicentrarchus labrax*
Galactosomum bearupi	*Clypeomorus batillariaeformis*	*Pomacentrus* spp.	Not given
Galactosomum timondavidi	*Cerithium mediterraneum*	Small fish (e.g. *Mugil*)	*Larus argentatus*
Galactosomum ussuriense	*Cerithium coralium*	*Therapon jarbua*	*Larus brunnicephalus*, *Sterna hirundo*
Haplosplanchnus pachysomus (Haplosplanchidae)	*Hydrobia ventrosa*	None	Mugilids
Asymphylodora tincae (Monorchiidae)	*Bythinia tentaculata*	*Bythinia tentaculata*	*Tinca tinca*
Monorchis parvus (Monorchiidae)	*Cerastoderma edule*	None	*Diplodus* spp.
Parasymphylodora markewitschi (Monorchiidae)	*Bythinia tentaculata*	*Bythinia tentaculata*, *Limnaea limosa*	*Leuciscus cephalus*
Paratimonia gobii (Monorchiidae)	*Abra ovata*	*Abra* spp. (siphon)	*Pomatoschistus microps*
Stephanostomum baccatum (Acanthocolpidae)	*Buccinum undatum*, *Neptunea antiqua*	None	*Pleuronectes platessa* (0+)
Deropristis inflata (Acanthocolpidae)	*Hydrobia stagnorum*	*Nereis diversicolor*	*Anguilla anguilla*

Table 5.1 Disease agents requiring additional risk management measures, and their hosts.

Disease agent	**Host species**	**Distribution**	**OIE List**
VIRUSES			
Aquabirnaviruses (including IPNV)	*Apistogramma ramirezi, Barbus graellsii, Brachydanio rerio,Colisa lalia, Epinephelus* spp., *Pterophyllum scalare, Scleropages formosus, Symphosydon discus, Xiphophorus xiphidium, Zanclus cornutus*	Germany, Ireland, Spain , Singapore, Taiwan, unknown.	Yes
Iridoviruses	*Apistogramma ramirezi, Aplocheilichthys normani, Colisa lalia, Epinephelus* spp., *Etroplus maculates, Helostoma* spp., *Labroides dimidiatus, Parapocryptes serperaster, Poecilia reticulata, Pterophyllum scalare, Trichogaster* spp., *Xiphophorus helleri*	Hong Kong, Indonesia, Israel, Malaysia, South America , Singapore, Taiwan, UK, USA, Australia	Yes
Grouper nervous necrosis virus	*Epinephalus* spp., *Cephalopholis* spp., *Cromileptes* spp.	China, Japan, Taiwan	Yes
Viral haemorrhagic septicaemia virus	*Barbus graellsii*	Spain	Yes
BACTERIA			
Edwardsiella ictaluri	*Danio devario, Puntius conchonius*	Singapore, USA	Yes
Edwardsiella tarda	*Betta splendens, Hyphessobrycon spp., Metynnis schreitmuelleri, Pterophyllum spp., Rhamdia (Pimelodus) quelen, Trichogaster spp.*	Brazil, amongst other countries	No
Lactococcus garvieae	*Coris aygula*	Red Sea	No
FUNGI			
Aphanomyces invadans	*Barbodes gonionotus, Colisa lalia, Etroplus suratensis, Osphronemus gouramy, Puntius conchonius, P. gonionotus, P. sarana, P. schwanenfeldii, P. sophore, P. ticto, Trichogaster* spp.	Asia, Bangladesh, India, Philippines, Japan, Singapore, Sri Lanka, Thailand	Yes
MYXOZOA			
Enteromyxum leei	*Amphiprion frenatus, Coris julius, Chromis chromis*, other members of the Labridae, Blennidae, and Sparidae	Spain, USA	No
MICROSPORIDIA			
Glugea heraldi	*Hippocampus* spp.	USA, amongst other countries	No
NEMATODA			
Capillaria philippinensis	*Puntius gonionotus*	Thailand, Philippines, Asia	No
CESTODA			
Bothriocephalus acheilognathi	*Barbus brachycephalus, B. barbus, B. bynni, B. capito, B. trimaculatus, B. sharpeyi, B. luteus, B. esocinus, Puntius binotatus*	Russia, Transvaal, South Africa, Iraq, Armenia, Malaysia	No
CRUSTACEA			
Argulus foliaceus	*Barbus grypus, B. esocinus*, Acipenserids,Cyprinids,Gobiids Gasterosteids, Salmonids	Asia, Europe, Iraq	No

APPENDIX 1 Preliminary Hazard List

The following table lists the diseases and parasites that were initially considered in the disease-based approach.

Agent	**Host**	**Country**	**Reference**
VIRUSES			
Angelfish *Herpesvirus*	*Pterophyllum altum*	From Amazon Basin	Mellergaard and Bloch (1988)
Aquabirnavirus	*Apistogramma ramirezi* *Colisa lalia* *Ophicephalus micropeltes* *Oxyeleotris marmoratus* *Plectropomus maculatus* *Pterophyllum scalare*	Singapore	Chew-Lim et al. (2002)
Aquabirnavirus (IPNV)	*Barbus graellsii*	Spain	Ortega et al. (1993a,1993b)
Aquabirnavirus (IPNV)	*Brachydanio rerio*	Unknown	Ahne (1982a)
Aquabirnavirus (IPNV)	*Carassius auratus* *Symphosydon discus*	Ireland	Adair and Ferguson (1981)
Aquabirnavirus (IPNV)	*Epinephelus* sp. *Scleropages formosus* *Zanclus cornutus*	Taiwan	Hsu et al. (1993)
Aquabirnavirus	*Xiphophorus xiphidium*	Germany	AQIS (1999b)
Aquareovirus (pathogenic)	*Pomacanthus semicirculatus*	U.S.A.	Lupiani et al. (1994)
Apistogramma viral disease	*Apistogramma ramirezi*	U.S.A. from South America	Leibovitz and Riis (1980b)
Iridovirus	*Apistogramma ramirezi*	From South America to U.S.A.	Leibovitz and Riis (1980a)
Iridovirus	*Colisa lalia, Aplocheilichthys normani*	Singapore (previously cultured in Sumatra, Indonesia)	Sudthongkong et al. (2002a)
Iridovirus	*Colisa lalia* *Trichogaster trichopterus*	Singapore to Australia	Anderson et al. (1993)
Iridovirus	*Epinephelus awoara*	Taiwan	Murali et al. (2002)
Iridovirus	*Epinephelus tauvina*	Singapore	Chua et al. (1994), Qin et al. (2001)

Iridovirus	*Epinephelus* sp.	Taiwan	Chou et al. (1998)
Iridovirus	*Etroplus maculatus*	Singapore	Armstrong and Ferguson (1989)
Tropivirus	*Helostoma* sp.	Australia	Go et al. 2005
Iridovirus	*Ictalurus melas*	France	Pozet et al. (1992)
Iridovirus	*Ictalurus melas*	Italy	Favero et al. (2001)
Iridovirus (EHNV-like)	*Labroides dimidiatus* *Poecilia reticulata*	U.S.A.	Hedrick and McDowell (1995)
Iridovirus	*Oreochromis mossambicus*	Australia	Ariel and Owens (1997)
Iridovirus	*Oreochromis niloticus*	Canada in fish from Florida	McGrogan et al. (1998)
Iridovirus	*Parapocryptes serperaster*	Malaysia	Martinez-Picado et al. (1993)
Iridovirus	*Pterophyllum scalare*	U.K.	Rodger et al. (1997)
Iridovirus	*Siniperca chuatsi*	China	He et al. (2000)
Iridovirus	*Trichogaster leeri* *Trichogaster trichopterus* *Xiphophorus helleri*	Israel	Paperna et al. (2001)
Iridovirus	*Trichogaster trichopterus*	U.S.A.	Fraser et al. (1993)
Lymphocystis	*Trichogaster trichopterus* *Trichogaster pectoralis*	Imported into New Zealand from Singapore and Hong Kong	Durham and Anderson (1981)
Lymphocystis	*Trichogaster leeri* *Pterophyllum scalarae*	Israel	Paperna et al. (2001)
Lymphocystis	*Pomacanthus semicirculatus* *Zanclus canescens* *Chaetodon capistratus* *Platax orbicularis* *Holacanthus cilaris* *Zebrasoma veliferum*	U.S.A.	Lawler et al. (1978)
Lymphocystis	*Chanda ranga*	Imported into Puerto Rico from Thailand	Williams et al. (1996)
Lymphocystis	*Macropodus opercularis*	? Imported into Australia	Humphrey (1995)
Lymphocystis	*Trichogaster pectoralis*	Israel	Paperna et al. (1987)
Grouper nervous necrosis virus	*Epinephalus akaara* *Epinephalus fuscogutatus*	Taiwan	Chi et al. (1997)

Grouper nervous necrosis virus	*Epinephalus septemfasciatus*	Japan	Fukuda et al. (1996)
Grouper nervous necrosis virus	*Epinephalus* spp.	China	Lin et al. (2001)
Grouper nervous necrosis virus	*Cromileptes* spp.	Asia	OIE (2003)
Pike fry rhabdovirus	*Pseudorasbora parva*	Germany	Ahne and Thomsen (1986)
Rhabdovirus	*Channa striata* *Osphronemus gouramy* *Anabas testudineus*	Thailand	Kanchanakhan et al. (1999b)
Retrovirus	*Xiphophorus*	Germany	Petry et al. (1992)
Retroviral lip fibromas	*Pterophyllum scalare*	U.S.A.	Francis-Floyd et al. (1993)
Rosy barb virus	*Puntius conchonius*	Australia	Humphrey (1995)
Viral haematopoietic necrosis	*Pterophyllum scalare*	?	Schuh and Shirley (1990)
Viral haemorrhagic septicaemia virus	*Barbus graellsii*	Spain	Basurco and Coll (1989)
BACTERIA			
Epitheliocystis	*Morulius chrysophekadion*	Not given	Humphrey (1995)
Rickettsia-like organisms	*Panaque suttoni*	Colombia to Canada	Khoo et al. (1995)
Aeromonas hydrophila *Vibrio anguillarum* *Vibrio parahaemolyticus* Eye infections	*Balistrapus undulatus* *Canthigaster margaritata* *Caranx* spp. *Chaetodon vagabundus* *Epinephelus* spp. *Lutjanus* spp. *Naso* spp. *Platax undulata* *Pterois* spp. *Triacanthus* spp.	From Andaman Islands to India	Shome et al. (1999)
Aeromonas hydrophila	*Carassius auratus* *Marble sailfish* *Xiphophorus helleri*	?	Humphrey (1995)

Aeromonas hydrophila	*Channa punctatus* *Macrognathus aculeatus* *Mystus vittatus* *Puntius conchonius*	India	Devashish et al. (1999).
Aeromonas hydrophila *Aeromonas sobria*	*Danio rerio*	?	Pullium et al. (1999)
Aeromonas hydrophila *Aeromonas sobria* *Pseudomonas aeruginosa* *Staphylococcus epidermidis*	*Pterophyllum scalare*	?	Ahmed et al. (1990)
Aeromonas hydrophila *Vibrio anguillarum*	*Trichogaster trichopterus*	Singapore	Fang et al. (2000)
Atypical *Aeromonas salmonicida*	*Anarhichas lupus*	UK	Rodger et al. (1997)
Typical *Aeromonas salmonicida*	*Labrus bimaculatus*	?	AQIS (1999b)
Aeromonas sp.	*Astronotus ocellatus*	Iran	Soltani et al. (1998)
Clostridium difficile	*Nimbochromis venustus*	USA	Dixon et al. (1997)
Citrobacter freundii	*Poecilia reticulata* *Pterophyllum altum* Symphosydon aequifasciatus	Taiwan	Kuo and Chung (1994)
Edwardsiella ictaluri	*Danio devario*	U.S.A.	Waltman et al. (1985) Blazer et al. (1985)
Edwardsiella ictaluri	*Puntius conchonius*	Imported into Australia	Humphrey et al (1986)
Edwardsiella tarda	*Betta splendens* *Cyprinus carpio,* *Hyphessobrycon sp.*	Australia	Humphrey et al (1986)
Edwardsiella tarda	*Metynnis schreitmuelleri* *Trichogaster trichopterus*	?	Dixon and Contreras (1992)
Edwardsiella tarda	*Pterophyllum scalare*	Zoonotic infant infection	Humphrey (1995), Vandepitte et al. (1983)
Edwardsiella tarda	*Rhamdia quelen*	Brazil	Shama et al. (2000)
Edwardsiella tarda	*Trichogaster trichopterus*	Singapore	Ling et al. (2001)

Flavobacterium columnare	*Paracheirodon innesi*	France	Michel et al. (2002)
Flavobacterium columnare	*Poecilia sphenops, Xiphophorus maculates*	U.S.A.	Decostere et al. (1998, 1999a)
Flavobacterium columnare	*Chiclasoma severum* *Misgurnus anguillicaudatus* *Poecilia reticulata* *Pterophyllum altum* *Symphosydon aequifasciatus*	?	AQIS (1999b)
Flavobacterium columnare	*Poecilia reticulata* *Poecilia sphenops* *Xiphophorus helleri* *Xiphophorus maculatus*	Thailand	Decostere et al. (1999a)
Flavobacterium sp. (pseudotuberculosis)	*Carassius auratus* *Colisa labiosa* *Hyphessobrycon* sp. *Pterophyllum* sp.	U.K.	Majeed et al. (1981)
Mycobacterium anabanti	*Macropodus opercularis*	France	Besse (1949) in Santacana et al. (1982)
Mycobacterium abscessus *Mycobacterium chelonae* *Mycobacterium fortuitum*	*Brachydanio rerio*	?	Astrofsky et al. (2000)
Mycobacterium simiae	*Cichlasoma bimaculatum*	U.S.A.	Lansdell et al. (1993)
Mycobacterium scrofulaceum	*Leptocottus armatus*	U.S.A	Lansdell et al. (1993)
Mycobacterium sp.	*Barbodes everetti* Blue ram *Carassius auratus* *Gourami*	Not given	Humphrey (1995).
Mycobacterium sp.	*Betta splendens* *Trichogaster leeri*	South America	Santacana et al. (1982)
Mycobacterium sp.	*Carassius auratus* *Moenkhausia santaefilomenae*	Malaysia	Shamsudin et al. (1990)
Mycobacterium sp.	*Carassius auratus* *Moenkhausia santaefilomenae*	Malaysia	Anderson et al. (1987)

Mycobacterium sp.	*Hyphessobrycon innesi* *Symphysodon* sp.	?	Mbuthia et al. (1996)
Mycobacterium sp.	*Poecilia reticulata*	Venezuela	Conroy and Conroy (1999)
Mycobacterium sp.	*Trichogaster trichopterus*	Imported into Venezuela from Colombia	Santacana et al. (1982)
Mycobacterium sp.	*Xiphophorus helleri*	?	Gomez et al. (1996)
Nocardia sp.	*Danio* sp. Penguin tetra	U.S.A.	Humphrey (1995)
Photobacterium damselae damselae	*Chromis punctipinnis* *Anguilla reinhardtii*	Australia	Ketterer and Eaves (1992)
Pseudomonas fluorescens	*Astronotus ocellatus*	U.S.A.	Humphrey (1995)
Salmonella typhimurium	*Pterophyllum scalare*	Sweden	Hongslo et al. (1987)
Salmonella sp.	*Astronotus ocellatus*	Sweden	Lundborg and Robertsson (1978)
Streptococcus iniae	*Oreochromis niloticus*	U.S.A.	Shoemaker et al. (2000)
Streptococcus iniae	*Oreochromis niloticus*	Canada	Press et al. (1998)
Streptococcus iniae	*Tilapia nilotica x aurea*	U.S.A.	Perera et al. (1994) (1997)(1998)
Streptococcus sp.	*Brachydanio rerio* *Brachydanio albolineatus* *Tanichthys albonubes*	Canada	Ferguson et al. (1994)
Streptococcus sp.	*Helostoma temminckii* *Puntius conchonius* *Puntius gelius* *Rasbora* sp. *Labeo* sp.	U.S.A.	Humphrey (1995)
Vibrio parahaemolyticus	*Aphanius iberus*	Spain	Alcaide et al. (1998a)
FUNGI			
Achyla flagellata, Saprolegnia ferax, Saprolegnia declina	*Puntius sophore* *Colisia lalia*	Germany	Srivastava (1980)
Achlya sp. *Saprolegnia declina*	*Pterophyllum scalare*	?	Ahmed et al. (1990)

Aphanomyces invadans (EUS)	*Channa striata* *Osphronemus gouramy* *Anabas testudineus*	Thailand	Kanchanakhan et al. (1999a)
Aphanomyces invadans (EUS)	*Colisa lalia*	To Japan from Singapore	Wada et al. (1994)
Aphanomyces invadans (EUS)	*Etroplus suratensis*	Sri Lanka	Pathiratne and Rajapakshe (1998)
Aphanomyces invadans (EUS)	*Trichogaster pectoralis*	Sri Lanka	Pathiratne and Jayasinghe (2001)
Aphanomyces invadans (EUS)	*Trichogaster trichopterus*	Philippines	Catap and Munday (1999)
Aphanomyces invadans (EUS)	*Trichogaster trichopterus*	Japan	Hanjavanit et al. (1997)
Aphanomyces laevis	*Colisa lalia* *Puntius sophore*	Germany	Srivastava (1980)
Aphanomyces pisci	*Colisa lalia* *Cirrhinus mrigala* *Puntius sophore*	India	Srivastava (1979)
Aphanomyces sp.	*Colisa lalia*	Japan from Singapore	Wada et al. (1994)
Aphanomyces sp.	*Channa pleurophthalmus* *Trichogaster trichopterus*	Japan	Hanjavanit et al. (1997)
Glugea anomala	*Cynolebias nigripinnis* *Fundulopanchax filamentosus* *Nothobranchius eggersi* *Nothobranchius korthausae*	U.S.A.	Lom et al. (1995)
Glugea heraldi	*Hippocampus erectus*	?	AQIS (1999b)
Heterosporis finki	*Pterophyllum scalare*	France	Michel et al. (1989).
Heterosporis schuberti	*Ancistrus cirrhosus* *Pseudocrenilabrus multicolor*	Czech Republic	Lom et al. (1989)
Heterosporis sp.	*Betta splendens*	Czech Republic	Lom et al. (1993)
Microsporidium sp.	*Brachydanio rerio*	France	De Kinkelin (1980)
Pleistophora hyphessobryconis	*Paracheirodon innesi*	France	Michel et al. (2002)
Pseudoloma neurophilia	*Brachydanio rerio*	U.S.A.	Matthews et al. (2001)

PROTOZOA			
Oodinium cyprinodontum	Cyprinodontids	U.S.A.	Lawler (1977)
Oodinium sp.	*Pangio kuhlii*, Shark	U.S.A.	Gratzek et al. (1978)
Piscinoodinium pillulare	*Puntius gonionotus*	Malaysia	Shaharom-Harrison et al. (1990).
Piscinoodinium sp.	*Brochis splendens* *Corydoras* spp.	U.K. from Brazil	Ferraz and Sommerville (1998)
Brooklynella hostilis	*Pomacanthus arcuatus* *Pomacanthus paru*	U.S.A.	Landsberg and Blakesley (1995)
Chilodonella cyprini	Epizootic mortalities in *Gadopsis marmoratus, Macculochella peeli, Nematalosa erebi*	Australia.	Humphrey (1995)
Chilodonella hexasticha	Epizootic mortalities in *Gadopsis marmoratus, Macculochella peeli, Nematalosa erebi*	Australia.	Langdon et al. (1985), Humphrey (1995)
Chilodonella hexasticha	*Oreochromis mossambicus, Satherodon aurea X nilotica, Tilapia rendelli, Tilapia zillii*	Israel and South Africa	Paperna and van As (1983)
Chilodonella hexasticha	*Symphysodon discus*	Japan	Imai et al. (1985)
Chilodonella piscicola	*Paracheirodon innesi*	Imported into Australia	Evans and Lester (2001)
Chilodonella sp.	*Trichogaster* sp. *Cyprinus carpio*	Russia	Vanyatinskii (1978)
Coleps sp.	*Barbus tetrazona* *Carassius auratus* *Corydoras schultzei*	Hungary	Szekely and Bereczky (1992)
Cryptocaryon irritans	*Cantherhines macrocerus*	Puerto Rico	Bunkley-Williams and Williams (1994)
Cryptocaryon irritans	*Epinephelus fuscoguttatus*	Saudi Arabia	Afifi (2000)
Cryptocaryon irritans	*Epinephelus tauvina*	Kuwait	Rasheed (1989)
Cryptocaryon irritans	*Lutjanus johni*	Malaysia	Tak-Seng and See-Yong (1989)
Cryptocaryon irritans	*Poecilia latipinna*	UK	Burgess and Matthews (1995)
Cryptocaryon irritans	*Poecilia latipinna*	USA	Yoshinaga and Dickerson (1994)

Ichthyophthirius multifiliis	*Brachydanio rerio* *Capoeta tetrazona* *Carassius auratus*	Singapore	Ling et al. (1991)
Ichthyophthirius multifiliis	*Capoeta tetrazona* *Carassius auratus* *Poecilia reticulata* *Xiphophorus helleri* *Xiphophorus maculatus*	Singapore	Ling et al. (1995)
Ichthyophthirius multifiliis	*Carassius auratus* *Cyprinus carpio* *Rasbora kalachroma* *Xiphophorus maculatus* *Xiphophorus* sp.	Philippines	Lumenlan et al. (1992)
Ichthyophthirius multifiliis	*Carassius auratus* *Pterophyllum scalare* *Xiphophorus helleri*	Singapore	Ling et al (1992)
Ichthyophthirius multifiliis	*Gasteropelecus sternicola*	Brazil	De Sao Clemente et al. (2000)
Ichthyophthirius multifiliis	*Pterophyllum scalare*	?	Ahmed et al. (1990)
Ichthyophthirius multifiliis	*Puntius tetrazona*	Korea	Kim et al. (2002b)
Ichthyophthirius multifiliis	*Trichogaster trichopterus*	Isolates from Malaysia, Singapore, Indonesia	Leung et al. (1995)
Ichthyophthirius sp.	*Etroplus suratensis*	Sri Lanka	Vinobaba (1999)
Tetrahymena corlissi	*Gyrinocheilus aymonieri* *Paracheirodon innesi* *Paracheirodon axelrodi* *Poecilia reticulata* *Xiphophorus maculatus*	Imported into Australia	Evans and Lester (2001)
Tetrahymena corlissi	*Poecilia reticulata*	Korea	Kim et al. (2002b)
Trichodina heterodentata	*Trichogaster trichopterus*	Philippines	Duncan (1977)
Trichodina spheroidesi	*Cantherhines macrocerus*	Puerto Rico	Bunkley-Williams and Williams (1994)

Trichodina sp.	*Carassius auratus* *Epalzeorhynchus frenatus* *Paracheirodon simulans* *Rasbora kalochroma* *Tanichthys albonubes*	Philippines	Lumenlan et al. (1992)
Trichodina sp.	*Etroplus suratensis* *Tachysurus* sp.	Sri Lanka	Vinobaba (1999)
Trichodina sp.	*Puntius tetrazona*	Korea	Kim et al. (2002b)
Cryptobia borreli	Coldwater cyprinids	Europe	AQIS (1999b)
Cryptobia sp.	*Gyrinocheilus aymonieri*	Imported into Australia	Evans and Lester (2001)
Hexamita sp.	*Leiocassus siamensis*	Philippines	Lumenlan et al. (1992), Gratzek et al. (1978)
Hexamita sp.	*Paracheirodon axelrodi* *Paracheirodon innesi*	Imported into Australia	Evans and Lester (2001)
Hexamita sp.	*Pterophyllum* sp.	Singapore	Ling and Khoo (1997)
Spironucleus vortens	*Amphiprion* sp.	U.S.A.	Francis-Floyd and Reed (2001)
Spironucleus vortens	*Pterophyllum scalare*	Canada	O'Brien et al. (1993)
Spironucleus vortens	*Pterophyllum scalare*	U.S.A.	Poynton et al. (1995)
Spironucleus vortens	*Pterophyllum scalare,* *Symphysodon discus*	U.K.	Paull and Matthews (2001)
Trypanosoma danilewskyi (carassii)	Coldwater cyprinids	Europe	AQIS (1999b)
Trypanosoma danilewskyi (carassii)	*Danio malabaricus*	?	Woo and Black (1984)
Trypanosoma trichogasteri	*Trichogaster fasciata*	India	Gupta and Jairajpuri (1981)
Eimeria phyllopterycis	*Phyllopteryx taeniolatus*	USA	Upton et al. (2000)
Eimeria vanasi	*Oreochromis aurea x nilotica*	Israel	Kim and Paperna (1993)
Goussia carpelli	*Carassius auratus, Cyprinus carpio*	U.S.A. and Europe	Kent and Hedrick (1985), Jendrysek et al. (1994)
Goussia trichogasteri	*Trichogaster trichopterus*	Imported into Hungary, Israel	Szekely and Molnar (1992), Kim and Paperna (1993)
Piscicryptosporidium reichenbachklinkei	*Trichogaster leeri*	Israel	Paperna and Vilenkin (1996)

Systemic amoebiasis	*Colisa lalia*	Singapore to Australia	Anderson et al. (1993)
Unidentified dinoflagellate	*Parauchenoglanis macrostoma* *Synodontus punctatus* *Synodontus flavitaeniatus* *Acanthodoras cataphractus* *Pterygoplichthys gibbiceps* *Pelvicachromis taeniatus*	Imported into Germany	Steinhagen et al. (1999)
MYXOZOA			
Chloromyxum sp.	*Gyrinocheilus aymonieri*	Imported into Australia	Evans and Lester (2001)
Enteromyxum leei	25 species	Spain	Padrós et al. (2001)
Henneguya amazonica	*Hoplosternum littorale*	Brazil	Torres et al. (1994)
Henneguya sp.	*Pterophyllum scalare*	?	Ahmed et al. (1990)
Hoferellus cyprini	Cyprinids	Eurasia	Humphrey (1995)
Myxidium fasciatum *Myxosoma trichogasteri*	*Trichogaster fasciatus*	India	Sarkar (1985)
Myxidium sp.	*Pantadon buchholzi*	Philippines	Lumenlan et al. (1992)
Myxobolus etropli	*Etroplus suratensis*	India	Rajendran et al. (1998)
Myxobolus mokhayeri *Myxobolus molnari*	*Capoeta trutta*	Mesopotamia	Baska and Masoumian (1996)
Myxobolus nuevoleonensis	*Poecilia mexicana* *Poecilia reticulata*	Mexico	Segovia-Salinas et al. (1995)
Myxosoma dermitis	*Labeo rohita*	India	Haldar et al. (1981)
Myxosoma filamentosa	*Puntius filamentosus*	India	Haldar et al. (1981).
Myxosoma magauddi	*Trichogaster fasciatus*	India	Bajpai et al. (1981)
MONOGENEA			
Benedenia epinepheli	25 host species	Japan	Ogawa et al. (1995)
Dactylogyrus megavesicularis	*Puntius schwanenfeldii*	Malaysia	Bu and Seng (1995)
Dactylogyrus sp.	Not given	Imported into Australia	Humphrey (1995)
Dactylogyrus sp.	*Carassius auratus* *Cyprinus carpio* *Labeo frenatus*	Philippines	Lumenlan et al. (1992)

Gussevia asota	*Astronotus ocellatus*	Korea	Kim et al. (2002b)
Gussevia asota *Gussevia astronoti* *Gussevia rogersi*	*Astronotus ocellatus*	Brazil	Kritsky et al. (1989)
Gussevia herotilapiae	*Herotilapia multispinosa*	Nicaragua	Vidal-Martinez et al. (2001)
Gyrodactylus bullatarudis	*Poecilia reticulata*	?	Cone and Odense (1984)
Gyrodactylus bullatarudis	*Poecilia reticulata* *Xiphophorus helleri*	Australia	Dove and Ernst (1998)
Gyrodactylus bullatarudis	*Xiphophorus maculatus*	Korea	Kim et al. (2002b)
Gyrodactylus macracanthus	*Misgurnus anguillicaudatus*	Australia	Dove and Ernst (1998)
Gyrodactylus sp.	*Pterophyllum scalare*	?	Ahmed et al. (1990)
Gyrodactylus sp.	Calico goldfish *Carassius auratus* *Helostoma temmincki* *Macrognathus* sp *Paracheirodon innessi* *Puntius conchonius*	Philippines	Lumenlan et al. (1992)
Sciadicleithrum bicuense	*Archocentrus nigrofasciatus*	Nicaragua	Vidal-Martinez et al. (2001)
Sciadicleithrum bravohollisae	*Cichlasoma geddesi* *Cichlasoma lentiginosum* *Cichalosoma malaguense* *Cichlasoma pearsei* *Cichalosoma salvini* *Cichlasoma synspilum*	Mexico	Mendoza-Franco et al. (2000)
Sciadicleithrum bravohollisae	*Cichlasoma pearsei* *Cichlasoma synspilum* *Petenia splendida*	Mexico	Kritsky et al. (1994)
Sciadicleithrum ergensi *Sciadicleithrum uncinatum* *Sciadicleithrum umbilicum*	*Cichla ocellaris*	Brazil	Kritsky et al. (1989)

Sciadicleithrum geophagi	*Geophagus surinamensis*	Brazil	Kritsky et al. (1989)
Sciadicleithrum iphthimum	*Pterophyllum scalare*	Brazil	Kritsky et al. (1989)
Sciadicleithrum maculicaudae	*Cichlasoma malicauda*	Nicaragua	Vidal-Martinez et al. (2001)
Sciadicleithrum meekii	*Cichlasoma meeki* *Cichlasoma callolepis* *Cichlasoma helleri* *Cichlasoma managuense*	Mexico	Mendoza-Franco et al. (2000)
Sciadicleithrum mexicanum	*Cichlasoma urophthalmus*	Mexico	Kritsky et al. (1994)
Sciadicleithrum mexicanum	*Cichlasoma trimaculatum*	Guatamala	Mendoza-Franco et al. (2000)
Sciadicleithrum mexicanum	*Cichlasoma urophthalmus* *Cichalosoma aureum* *Cichalosoma friedrichstahli* *Cichalosoma octofasciatum* *Petenia splendida*	Mexico	Mendoza-Franco et al. (2000)
Sciadicleithrum nicaraguense	*Amphilophus alfari*	Nicaragua	Vidal-Martinez et al. (2001)
Sciadicleithrum (=Urocleidoides) reticulatus	*Poecilia reticulata* *Xiphophorus maculatus*	Imported into Australia	Evans and Lester (2001)
Sciadicleithrum splendidae	*Cichlasoma friedrichstahli* *Cichasoma managuense*	Mexico	Mendoza-Franco et al. (2000)
Sciadicleithrum splendidae	*Petenia splendida*	Mexico	Kritsky et al. (1994)
Sciadicleithrum tortrix	*Uaru amphiacanthoides*	Brazil	Kritsky et al. (1989)
DIGENEA			
Centrocestus formosanus	*Aplocheilus panchax* *Aplocheilus melastigma*	India	Madhavi (1980)
Centrocestus formosanus	*Poecilia reticulata* *Xiphophorus maculatus*	Imported into Australia	Evans and Lester (2001)
Centrocestus formosanus	*Puntius* spp.	Thailand	Srisawangwong et al. (1997)
Clinostomum complanatum	*Barbus plebejus, Capoeta tinca*	Turkey	Oge and Sarimehmetoglu (1996)
Clinostomum complanatum	*Capoeta capoeta*	Iran	Malek (1993)
Clinostomum complanatum	*Cichlasoma urophthalmus*	Mexico	Ramos (1995)
Clinostomum complanatum	*Colisa lalia*	India	Agarwal et al. (1986)

Clinostomum piscidium	*Trichogaster fasciatus*	India	Pandey (1973)
Diplostomum pseudospathaceum	*Carassius auratus, Poecilia reticulata, Xiphophorus xiphophorus*	Poland	Graczyk (1992)
Haplorchis taichui	*Labeo bata*	India	Nath (1973)
Transversotrema patialense	*Aplocheilus panchax, Puntius binotatus, Rasbora sumatrana, Trichogaster trichopterus*	Malaysia	Seng (1988)
CESTODA			
Bothriocephalus acheilognathi	*Cyprinus carpio* *Gambusia holbrooki* Australian native fishes: *Hypseleotris klunzingeri* *Hypseleotris* sp. *Phylipnodon grandiceps* *Retropinna semoni*	Australia	Dove and Fletcher (2000)
Bothriocephalus acheilognathi	*Poecilia reticulates* *Xiphophorus maculatus*	Imported into Australia	Evans and Lester (2001)
Bothriocephalus pearsei	*Cichlasoma urophthalmus*	Mexico	Scholz et al. (1996)
Ligula intestinalis	*Puntius dorsalis*	India	Rahman (1989)
NEMATODA			
Camallanus cotti	*Poecilia reticulata*	Imported into Australia	Evans and Lester (2001)
Camallanus cotti	*Poecilia reticulata*	Korea	Kim et al. (2002a, 2002b)
Capillaria pterophylli	*Cichlasoma octofasciatum, Pterophyllum scalare, Symphosodon aequifasciatus* *Symphosodon* sp.	Czech Republic	Moravec and Gut (1982), Moravec (1983a)
Capillostrongyloides ancistri	*Ancistrus dolichopterus*	Czech Republic	Moravec et al. (1987)
Mexiconema cichlasomae	*Cichlasoma spp.* *Ginglystoma cirratum*	Mexico	Moravec et al. (1998a)
Pseudocapillaria brevispicula	*Hyphessobrycon innesi*	Czech Republic	Moravec et al. (1984)

	Puntius tetrazona		
Pseudocapillaria brevispicula	*Cyprinus carpio, Tinca tinca*	Czech Republic	Moravec (1983b)
Pseudocapillaria margolisi	*Puntius conchonius, Puntius sophore*	India	De and Maity (1996)
Rhabdochona spp.	*Alestes imberi, Astyanax fasciatus, Astyanax mexicanus, Barbus barbus, Barbus bocagei, Barbus luteus, Barbus marequensis, Barbus meridionalis, Barilius* sp., *Cichlasoma nigrifasciatum, Holocentrus ittodai, Mystus vittatus, Synodontis schall, Synodontis zambezensis, Xiphophorus* sp. and many others	Worldwide	Very many papers, most of them taxonomic
Serpinema trispinosum	*Cichlasoma urophthalmus*	Mexico	Moravec et al. (1998b)
CRUSTACEA			
Argulus foliaceus	Acipenserids Cyprinids Gobiids Gasterosteids Salmonids	Europe, Asia	AQIS (1999b)
Caligus sp.	*Leognathus* sp. *Tachysurus* sp. *Tilapia* sp.	Sri Lanka	Vinobaba (1999)
Dermoergasilus amplectens *Dermoergasilus varicoleus* *Ergasilus parvitergum*	*Chanos chanos* *Etroplus maculatus* *Gerres setifer* *Hyporamphus xanthopterus* *Megalops cyprinoides* *Valamugil seheli* *Liza tade* *Caranx malabaricus*	India	Ho et al. (1992)

 Ergasilus rostralis *Ergasilus uniseriatus* *Paraergasilus dentatus*	*Etroplus suratensis* *Liza macrolepis* *Liza tade* *Valamugil seheli* *Glossogobius giuris* *Xenentodon cancila* *Glossogobius giuris*		
Dermoergasilus amplectans *Ergasilus parvitergum* *Ergasilus sieboldi*	*Etroplus suratensis* *Etroplus suratensis* *Siganus* sp. *Siganus* sp.	Sri Lanka	Vinobaba (1999)
Indopeniculus fryeri	*Notopterus notopterus*	Thailand	Ho and Kim (1997)
Lamproglena chinensis	*Anabas testudineus*	Thailand	Ho and Kim (1997)
Lamproglena cirrhinae	*Cirrhinus jullieni*	Thailand	Ho and Kim (1997)
Lamproglena forficata	*Ophiocephalus striatus*	Thailand	Ho and Kim (1997)
Lernaea arcuata	*Puntius gonionotus*	Thailand	Ho and Kim (1997)
Lernaea cyprinacea	*Puntius partipentazona*	Thailand	Ho and Kim (1997)
Lernaea cyprinacea	Not given	Imported into Australia	Humphrey (1995)
Lernaea cyprinacea	*Helostoma temmincki*	Canada	Woo and Shariff (1990)
Lernaea cyprinacea	*Aristichthys nobilis* *Carassius auratus* *Helostoma temmincki*	Malaysia	Shariff and Sommerville (1986)
Lernaea minuta	*Puntius gonionotus*	Malaysia	Kularatane et al. (1994a, 1994b)
Lernaea oryzophila	*Puntius gonionotus* *Cyprinus carpio*	Thailand	Ho and Kim (1997)
Lernaea polymorpha	*Aristichthys nobilis*	Malaysia	Shariff and Sommerville (1986)
Lernaea polymorpha	*Cyprinus carpio*	Thailand	Ho and Kim (1997)
Lernaea polymorpha	*Labeo rohita*	India	Zahida et al. (1999)
Lernaea taipila	*Oreochromis mossambicus*	Thailand	Ho and Kim (1997)
Lernaea sp.	*Brachydanio rerio*	?	Paria and Manna (1999)
Lernaea sp.	*Ctenopharyngodon idella* *Esomus danrica*	India	Nandeesha et al. (1985)

	Mollienesia latipinna *Puntius stigma* *Rasbora daniconius* *Xiphophorus helleri*		
Lernaea sp.	*Puntius ticto*	India	Manna (1990)