Ornamental Fish as Trans-Boundary Vectors of Viral Diseases

ELLEN ARIEL
European Community Reference Laboratory for Fish Diseases, Denmark
Danish Institute for Food and Veterinary Research

ABSTRACT

The ornamental fish industry transfers large quantities of fish between countries. Due to the largely unregulated nature of this trade, it presents considerable potential for trans-boundary transfer of disease agents. Although tropical ornamental fish are usually kept in indoor aquaria and are unlikely to survive for long if released into the environment of temperate regions, they are capable of carrying viruses that pose a threat to temperate fish species. Of particular concern are ranaviruses, which have been reported in several tropical ornamental fish. Some of these ranaviruses are highly pathogenic to certain temperate fish species, both farmed and wild. The so-called 'cold-water ornamentals' are fancy varieties of common species, mostly cyprinids, which do survive and breed in temperate waters, as well as in tropical countries. The most widely traded of these species internationally are goldfish (*Carassius auratus*) and koi carp (*Cyprinus carpio koi*) and both species have been implicated in trans-boundary transfer of viral diseases. Most recently, koi herpes, which is capable of causing large-scale mortalities not only in koi carp, but also in common carp varieties farmed for consumption, has been spread to several countries via this trade. The ornamental fish trade is also suspected in the first introduction of the OIE notifiable disease: spring viraemia of carp (SVC) to the USA. Such events are likely to lead to increased demands for health certification for ornamental fish, which may in the short term cause restrictions on the trade; however, in the long term it is likely to aid the sustained development of the ornamental fish industry.

INTRODUCTION

As the name indicates, ornamental fish are usually fish of striking colours or unusual shape and those kept in fish tanks are generally small, tropical species that are exotic to the importing country. Approximately 90% of the freshwater ornamental species are bred in captivity (Dawes, 1998) and thus exposed to farming procedures not unlike those for fish bred for consumption.

Ornamental fish may be found in many private homes and gardens of the western world, thus 16% of Australian, 13% of UK and 10% of USA households harbour ornamental fish (FAO, 1998). The major exporting countries are Singapore, Hong Kong, the Netherlands, Germany, and the USA, although some of these may act as hubs for neighbouring and other countries. The big importers consist of the USA, Japan, Germany, UK, and France, all of which are temperate climate areas. According to the 1996 FAO global statistics the international trade in ornamental fish exceeded US$ 200 million in export value, an amount which certainly reflects the trade of a great number of live ornamental fish worldwide.

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Whenever live animals are moved, there is potential to transfer the pathogens they host as well. In order to prevent the spread of diseases across boundaries without unjustified trade restrictions, international regulations regarding the health state of livestock have been produced (World Trade Organization, 1994) as an agreement on the application of Sanitary and Phyto-Sanitary Measures (the SPS agreement). The agreement is based on the standards, guidelines, and recommendations of the *Office International des Epizooties* (OIE) for animal health and zoonoses. The animal health control measures are adjusted according to the status of the importing and exporting country with respect to the presence of the OIE listed pathogens, which are considered of high risk if imported into a pathogen free zone. This paper illustrates the potential of ornamental fish to act as trans-boundary vectors of significant diseases and describes how the current health regulations apply to the trade.

TRADITIONAL VIEW OF ORNAMENTAL FISH IN LEGISLATIVE CONTEXT

Ornamental fish are pets not destined for human consumption and therefore exempt from regulations for livestock. They are supposed to be kept in closed systems and any disease outbreaks are therefore not directly a national concern, because in theory the outbreak is limited both in economic and epidemiological terms (Davenport, 2000). In reality, however, ornamental fish do occasionally escape to the wild and some are deliberately released.

The convenient, and as of yet prevailing tendency in veterinary circles, to view ornamental fish as pets with pathogens of no importance to local species, is slowly turning as evidence to the opposite emerges (Humphrey *et al*., 1986; Goodwin, 2002). Should governments eventually decide to lay down rules for pet fish, the major obstacle to implementation of any such legislation will be the difficulty associated with surveying hobbyists. People are not required to register their pet fish in the same way, as livestock is registered - and even cats and dogs in some countries. Once the fish is carried out the pet shop door, there is no official knowledge of its health state or whereabouts. Therefore, health requirements for ornamental fish can only be effectively implemented at border crossings, and perhaps by health inspections at the point of sale.

PARTIES AT RISK

If one were to consider the possible impact the ornamental fish trade could have with respect to disease transfer, who would be the implicated parties? The local and private populations of both tropical and coldwater ornamental fish would obviously be at risk in terms of likelihood of exposure when the imported population is merged with the existing one, but also in terms of susceptibility to the pathogens carried by the same species.

Other potential parties could be the food fish industry, should any pet fish be released or escape from captivity with a disease that affect the cultured fish. This scenario would implicate the food industry, which is of public concern. The same would hold true should the endemic, aquatic wildlife be exposed to detrimental diseases from ornamental fish (Laurance, 1995). It is also of public concern, if pet fish owners or handlers contract zoonotic diseases from the fish. Last, but not least: The trade in ornamental fish itself would ultimately suffer economic losses and credibility should diseases impact on the health and survival of the fish.

Any rules and regulations established to protect the above mentioned parties must comply with the requirements of the World Trade Organization (WTO), which states: "Restrictions on animal movements should be based on scientific evidence." (WTO, 1994). The following will explore any such evidence to support the justification for health requirements for ornamental fish.

COLD-WATER ORNAMENTAL FISH - CYPRINIDS

Although cyprinids are considered pets, they often inhabit the same environments as wild or cultured fish and therefore pose a particular risk in terms of disease transfer, assuming they are capable of carrying diseases that are a threat to temperate fish species - cultured and / or wild. There is evidence to support this assumption for 2 very serious viral diseases of fish: spring viraemia of carp (SVC) and koi herpes (KH).

Spring viraemia of carp (SVC)

The virus causing SVC is a rhabdovirus, which affects cyprinid fishes with acute haemorrhagic viraemia in susceptible species (Fijan *et al*., 1971). The disease has a serious economic impact on carp culture due to the mortalities associated with outbreaks and it is therefore listed as notifiable to the OIE (OIE Diagnostic Manual for Aquatic Animal Diseases, 2001). Until recently, this disease was only known to occur on the European continent.

United Kingdom. Since 1996 SVCV has on occasions been imported into the UK with shipments of cold-water ornamentals from Asia (Stone *et al*., 2002). The consignments were intercepted in the airport and the virus discovered during routine screenings. Genetic analysis of SVCV isolates has revealed one Western European type and 2 Eastern European types. The isolates from shipments originating in Asia were of a 4th type, tentatively termed the 'Asian' type.

United States of America. SVC has never been known to occur in the USA until April 2002, where a koi carp farm in Eastern USA experienced an outbreak with clinical signs consistent with SVC (Goodwin, 2002). A virus was isolated and identified as SVC virus; 15,000 koi died during the outbreak and another 135,000 fish were destroyed upon diagnosis of SVC. The farm was a wholesale distributor of koi carp and goldfish to customers throughout the USA. Control and eradication appeared difficult because customers were spread over such a large area and because the koi carp farm drained into a river system. In May and June a second outbreak occurred in a population of wild carp in Lake Cedar, 2000 km from the first site; 10,000 kg of carp died. Genetic analysis of the SVCV isolates from these 2 outbreaks showed 99% similarity between the two and 98% similarity to the isolates termed the 'Asian' type and only 88% similar to the European types. Speculations are that the virus entered the country with imports of ornamental fish from Asia.

Denmark. Till June 2002, Denmark was considered free of SVC, when a pet shop owner submitted samples of koi carp for diagnosis at the Danish Veterinary Institute. He was experiencing mortality in the remainder of a batch of koi bought from a German wholesale distributor with many sources. SVCV was isolated from the samples and since SVC is common in Germany, the virus could have originated from anywhere along the line of trade. There are no records of the buyers, so SVC is now presumably present in private Danish garden ponds of unknown location.

Koi herpes (KH)

The disease is characterized by acute or per acute mortality, skin lesions, loss of mucus and severe gill necrosis and is caused by a herpes virus koi herpes virus (KHV) (Hedrick *et al*., 2000). The disease manifests at water temperatures between 18 and 29°C and affects all ages of fish (Gilad *et al*., 2002). Survivors may act as carriers. Cell culture has proven extremely difficult and only possible on the cell line KF-1 developed for the purpose (Hedrick *et al*., 2000).

Europe. The first case of koi herpes was diagnosed in the UK in 1996 (Way *et al*., 2001), the next year in Germany (Hoffmann, 2000), then Israel (Hedrick *et al*., 2000), and following on from there in the Netherlands (Haenen, CIDC-Lelystad, the Netherlands, pers. commun., unpublished results), USA (Hedrick *et al*., 2000), Belgium (Body *et al*., 2000), Italy (Bovo, Istituto Zooprofilattico Sperimentale delle Venezie, Italy, pers. commun.) and most recently in Indonesia (Sunato *et al*., 2002) and Denmark, where the batch of koi carp imported into Denmark with SVCV referred to above, also harboured KHV. In effect, one batch of ornamental fish succeeded in importing 2 exotic diseases into Denmark. The impact of the disease in affected populations in Europe seems to have increased between 2000 and 2002 (Haenen, CIDC-Lelystad, the Netherlands, pers. commun.; unpublished results).

Recently, the European Commission proposed KH as a listed disease. The basis for this was the severe consequences this disease can cause in the ornamental fish trade and the high risk it poses to common carp that are also susceptible. The proposal has not been accepted, however, because there are no records of movements of these pet fish and laboratory diagnosis is currently not sufficient to identify carriers. With the new evidence that wild carp populations in Germany have been infected (Hoffmann, Institut für Zoologie, Fishereibiologie und Fischkrankheiten, Munich, pers. commun.) it seems that KHV could be endemic in certain parts of Europe and that any measures employed to contain this disease may have been too little and too late. To further complicate the situation, one of the exporting countries has instigated an immunization scheme, whereby a batch is deliberately infected at temperatures beyond the preferred range of the virus (Haimi and Ariav, 2000). The fish of batches thus exposed will not develop clinical disease and associated mortality and they do much better when exported, because they are immune to KHV. The downside of this is that these fish are likely carriers and are thus able to carry the infection into new populations. In the short term the exporter gains, but in terms of disease control, it is a very irresponsible act.

Indonesia. In 2002, a serious disease outbreak affecting koi and common carp occurred in Indonesia (Sunarto, 2002). The clinical signs were consistent with KH and this diagnosis was confirmed by PCR. Virus isolation has as of yet not been successful, which is a situation often experienced by laboratories attempting to culture the virus. The route of entry of this pathogen into Indonesia is suspected to be via trade with koi carp. The spread of KH into South-East Asia could have great socio-economic consequences and Indonesia has acted responsibly by closing its borders to the carp trade.

TROPICAL ORNAMENTAL FISH

For tropical ornamental fish to act as vectors of diseases across boundaries, they must harbour diseases that are a threat to fish or aquatic wildlife in the importing country. Such diseases may be well known and even listed, or they may be an exotic introduction for which the associated hazard cannot be predicted. The following will present evidence for the hazard associated with importation of ranavirus into a naïve population of susceptible species.

Ranaviruses

While ranaviruses are sometimes isolated in the absence of mortality, they are also increasingly being mentioned in the context of disease outbreaks. Whether this is because an increase in intensive culture of a local host provides suitable conditions for local strains to attain virulence - or whether it is an introduced strain in a local host or a local strain in an introduced host - is not always possible to determine. It is however certain, that under specific conditions, these ranaviruses can be extremely virulent and this is why the OIE has made the disease epizootic haematopoietic necrosis (EHN) notifiable (OIE International Aquatic Animal Code, 2001). Three of the better-known viruses that are listed are: epizootic haematopoietic necrosis virus (EHNV), European catfish iridovirus (ECV) and European sheatfish iridovirus (ESV). Differentiating strains

It is possible to separate one strain from the other using molecular techniques (Marsh *et al*., 2002) and it certainly is interesting from a taxonomic point of view, but in practical terms, on pond level, it doesn't really matter whether a ranavirus belongs to the EHNV, ECV, ESV, largemouth bass iridovirus type or any of the other ranaviruses that cause mass mortality in infected populations. So long as we do not have a molecular marker for virulence, we cannot use molecular techniques to differentiate strains in terms of risk/virulence and for legislation purposes, they will all have to be considered as a group. The European Community is experiencing precisely the same problem for viral haemorragic septicaemia (VHS), where highly pathogenic 'freshwater' strains are notifiable, whereas the low-virulent marine strains are considered harmless. However, a scheme for differentiating the two types on the basis of molecular techniques is still lacking.

Where to expect ranaviruses

Ranaviruses have been isolated from a range of different hosts spanning from fish over reptiles into amphibians. For many years Australia enjoyed a virus free status, until EHN virus caused a massive outbreak in free-living redfin perch (Perca fluviatilis) in Victorian lakes (Langdon and Humphrey, 1987). In 1988, mass mortalities were reported in sheatfish culture in Germany due to an iridovirus (Ahne *et al*., 1989). European catfish iridovirus was identified as the etiological agent in an epizootic of wild catfish (Ictalurus melas) in a French lake in 1990 (Pozet *et al*., 1992). The following year, a similar virus totally devastated the catfish (Ictalurus melas) culture in northern Italy (Bovo *et al*., 1993). All 4 isolates were shown to belong to the genus Ranavirus of the Iridoviridae (Hedrick *et al*., 1992; Ahne *et al*., 1998). Such examples show how devastating these viruses can be under the right conditions, both in the wild and in culture. However, genetically very similar viruses have also been reported from apparently healthy hosts (Jensen, Bloch and Larsen, 1979; Tapiovaara *et al*., 1998).

In addition to sporadic reports of isolations of ranavirus from individual chameleons (Drury *et al*., 2002) and turtles over the years (Westhouse *et al*., 1996; Marchang *et al*., 1999), a ranavirus is claimed to be responsible for disease in farmed soft-shelled turtles in China (Chen *et al*., 1999). A ranavirus has also been isolated from specimens of green python (Chondropython viridis) recently imported into Australia from Irian Jaya (Hyatt *et al*., 2002).

Epizootics in the endangered species of tiger salamanders (*Ambystoma tigrinum stebbensi*) in Arizona, USA, and in juvenile and adult salamanders (*Ambystoma tigrinum diaboli*) in Canadian ponds, have all been attributed to ranaviral aetiology (Jancovich *et al*., 1997; Bollinger *et al*., 1999). Outbreaks in Chinese and Thai frog farms (Zhang *et al*., 2001; Weng *et al*., 2002; Kanchanakhan, 1998) and wild frog declines worldwide have also been attributed to ranavirus infections (Daszak *et al*., 2000). In the well-recorded declines of the common frog (*Rana temporaria*) in the UK (Cunningham *et al*., 1996), the most frequently recorded factor in association with frog deaths was concurrent fish death in garden ponds (OIE Fish Diseases Commission report, June 2002).

With this plasticity in host range, it comes as no surprise that many ranaviruses have been isolated from ornamental fish (Armstrong and Ferguson, 1989; Fraser *et al*., 1993; Hedrick and McDowell, 1995; Rodger *et al*., 1997; Anderson *et al*., 1993). It has also been suggested that outbreaks of systemic iridoviruses (ranaviruses included) around the globe, may be attributed to the transcontinental movements of ornamental fish (Hedrick, 1996).

Ornamental fish can evidently carry serious diseases as indicated above and these clearly present a risk to other populations of fish with which they come into contact. Given the wide host range, ranaviruses from ornamental fish could theoretically also infect wild reptiles and amphibians as indicated in the UK study (Cunningham *et al*., 1996), which would be detrimental to the environment (Laurance, 1995). Other zoonotic diseases, not discussed here could also potentially be transferred with ornamental fish or the water they are contained in. This was shown for *Vibrio* and *Salmonella* spp. in a study commissioned by the Italian Ministry of Health out of concern for human and aquatic animal pathogens arriving into the country via the ornamental fish trade (Manfrin *et al*., 2000).

CURRENT REGULATIONS

The evidence presented above indicates a clear risk associated with unchecked trade of ornamental fish, which raises the question of any existing regulations that could prevent the trans-boundary movements of pathogens with ornamental fish. In general, ornamental fish are often overlooked in terms of disease vectors in trade, but there are a few instances where they are referred to in international guidelines or national legislations.

OIE

The OIE guidelines on international trade in aquatic animals and their products do not make any distinctions between wild or cultured fish, nor between fish that are destined for consumption or decoration (OIE International Aquatic Animal Code, 2001). So the trade in ornamental fish is covered by the OIE guidelines for the diseases listed. For any other disease, the importing country may be asked to prove absence of the disease, as well as the risk involved with importing this disease, before it can ask for health certification from the exporting country.

European Community

The legislation laid down for the EC regarding animal health conditions in relation to trade is based on Council Directive 91/67/EEC, which mainly concerns salmonid diseases, and specifically viral haemorrhagic septicaemia (VHS) and infectious haematopoietic necrosis (IHN). The regulations are therefore aimed primarily at those species known to be susceptible to the listed diseases, except for article 14, which deals with non-susceptible species. All fish species should thus be covered, however, in article 14 there is an exemption, which states: "This article shall not apply to ornamental tropical fish kept permanently in aquariums." Consequently, the trade in tropical ornamental fish in the EC is completely unregulated at present. Although coldwater ornamentals are covered by the legislation, they are still not considered of public concern and appear to be overlooked by the veterinary administration in many countries.

National Legislations

China and Singapore. The Department of Primary Industry in Singapore and China has developed hygiene accreditation procedures for the exporters of ornamental fish and these procedures are apparently being extended to cover producers as well (Cheong, 1996; Jiang Yu-Lin, Shenzhen Animal and Plant Quarantine Bureau, China, pers. commun.).

United Kingdom. The UK has a national control program for SVC and may therefore ask for health guarantees from countries or areas known to be infected with SVC when importing susceptible species such as cyprinids (Commission Decision 93/44/EEC).

Australia and New Zealand. In the absence of historical evidence, Australia has claimed freedom from a number of diseases, including some not listed by the OIE. An elaborate and comprehensive import risk analysis (IRA) on live ornamental fin fish has been produced for 10 diseases known to occur in ornamental fish (AQUIS, 1999). The IRA has identified hazards, assessed the risk and recommended risk management strategies for each of these diseases. It is a daunting piece of work, but necessary if a country wishes to comply with the rules of the world trade organization for diseases not covered by the OIE. New Zealand is currently in the process of producing a similar IRA for ornamental fin fish (Mike Hine, Ministry of Agriculture and Forestry, New Zealand, pers. commun.).

SUMMARY

The accounts above provide the circumstantial scientific evidence for restricting trade in ornamental fish. Two of the diseases (EHN and SVC) are listed by the OIE and the third disease (KH) has already caused great socio-economic detriment in a developing country, and all 3 diseases were apparently imported into naïve populations via the ornamental fish trade.

Such events are causing growing concern and lead to reconsideration of the status of ornamental fish in an international trade context. It is likely that many countries will follow in the footsteps of Australia in terms of import risk analysis on live ornamental fish and subsequently make health certification a requirement. This may in the short term complicate the trade. However, in the long term, it will protect the wildlife and aquaculture industry in importing countries as well as the ornamental fish trade in those countries that are able to provide meaningful health certification.

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