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# Contact-Zoonotic Bacteria of Warmwater Ornamental and Cultured Fish

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## Abstract

In this small review, the most important contact-zoonotic bacteria and the diseases they cause in fish and humans are described. Especially, warmwater ornamental and fish culture professionals, owners, and processors are at risk in acquiring infections by *Vibrio vulnificus*, *Photobacterium damsela* subsp. *damsela*, *Aeromonas hydrophila*, *Edwardsiella tarda*, *Mycobacterium marinum*, *Streptococcus iniae*, or *Streptococcus agalactiae*, transmitted from their fish and fish water, in freshwater to marine environments. The chance of acquiring such a zoonosis is low, unless humans are immuno-compromised, and in case their skin is injured. These zoonoses are under reported, as in most countries they are non-notifiable. Strict hygiene for humans having direct contact with these fish in various fish holding and rearing facilities, and regular screening and health checks of imported warmwater ornamental fish at airports are recommended to avoid zoonosis and spread of potentially zoonotic, and often multiresistant bacteria.

**Keywords:** fish health, zoonosis, disease, antibiotics, antimicrobial resistance

## Introduction

At a global scale, numerous warmwater fish species may be cultured as food or as ornamental fish in tropical countries, cultured indoors in warm water as food fish (FAO, 2018), or kept in warmwater aquaria as tropical ornamental fish; there are more than 800 ornamental species, mostly farmed in Asia (OFI, 2018). Warmwater fish may carry or be infected with zoonotic bacteria which may be harmful to humans via contact, i.e. potentially contact zoonotic (Lehane and Rawlin, 2000; Haenen et al., 2013). Moreover, as warmwater ornamental fish are often treated with various antibiotics before transport, and as multiresistant bacteria are proven to be present (Chanda et al., 2011; Weir et al., 2011), this implies a risk of transmission of multiresistant bacteria to humans.

Risks apply to fish handlers in the country of origin as well as in the importing country, in the transfer port in case water of the fish bags is refreshed, and in importing countries where live warmwater fish are

unpacked to enter the chain of ornamental fish trade as pets. Groups at risk are all individuals in direct skin contact with live fish, residues, and fish water. This includes professionals in all segments of the ornamental fish business (aquaculture and fisheries), inspections and, to a lesser extent, persons keeping an aquarium at home and recreational fish anglers. Most countries, including the European Union (EU), don't have legislation on prevention for these potential human health risks in place at international border inspections posts.

The principal pathogens causing contact zoonoses from either handling fish through spine puncture or open wounds are *Vibrio vulnificus*, *Photobacterium damsela* subsp. *damsela*, *Aeromonas hydrophila*, *Edwardsiella tarda*, *Mycobacterium marinum*, *Streptococcus iniae*, and *Streptococcus agalactiae* (Dryden et al., 1989; Lawler, 1994; Weinstein et al., 1997; Lehane and Rawlin, 2000; Chotmongkol et al., 2004; Oliver, 2005; Haenen et al., 2013). In exceptional cases, *Vibrio parahaemolyticus* may also cause contact

zoonosis (Ralph and Currie, 2007).

Most contact-zoonotic bacteria grow well at water temperatures above 25 °C, and these bacteria may, therefore, pose a risk in subtropical and tropical regions or indoor warmwater aquaculture systems. These pathogens are all indigenous to the aquatic environment and have also been associated with disease outbreaks in food fish. Although most fish-associated wound infections are self-limiting, more serious cases are mostly associated with an underlying immune deficiency or incompetence in the patient, infection with highly virulent strains, contact with a large inoculum, depth of penetration of the skin, or a combination of these factors. Patients may develop mild to severe infections that, in exceptional cases, may prove lethal, as in the case of *V. vulnificus* (Haenen et al., 2013).

## Fish Diseases Caused by Common Zoonotic Bacteria

*Vibrio vulnificus* may cause haemorrhagic disease in eels. Fish may show redness of the flanks of the body and tail (Austin and Austin, 1999). In advanced cases, pathological changes may be observed in the gills, heart, liver, spleen, and gastrointestinal tract (Miyazaki et al., 1977). Clinical signs in European eels (*Anguilla anguilla* (Linnaeus, 1758)) differed between the non-zoonotic ST 140 strain (Fig. 1), which showed open ulcers, and the zoonotic strain ST 112 (Fig. 2), which showed muscle boils that burst open (Haenen et al., 2014). In diseased tilapia, haemorrhages around the fin bases, exhaustion in swimming behaviour, and stiffness of muscles were observed as a chronic condition and resulted in a gradual death of 10 to 20 % of the pond fish (Sakata and Hattori, 1988). *Vibrio vulnificus* is found in warm coastal and estuarine environments and can be associated with even healthy aquatic animals. Infection by *V. vulnificus* may happen due to contact with seawater or estuarine water.

*Photobacterium damsela* spp. *damsela* is a normal inhabitant of the marine environment (Hawke, 2014), and causes a chronic bacterial infection characterised by skin ulceration that may progress to haemorrhagic septicaemia. This occurs in a wide variety of marine fish including Japanese amberjack (*Seriola quinqueradiata* Temmnick and Schlegel, 1845), gilthead seabream (*Sparus aurata* Linnaeus, 1758), European seabass (*Dicentrarchus labrax* (Linnaeus, 1758)), Senegalese sole (*Solea senegalensis* Kaup, 1858) common sole (*Solea solea* (Linnaeus, 1758)), striped bass (*Morone saxatilis* (Walbaum, 1792)), hybrid striped bass (*M. saxatilis* x *M. chrysops* (Rafinesque, 1820)), and white perch (*Morone americana* (Gmelin, 1789)) (Romalde, 2002; Rivas et al., 2013). Fish affected by systemic infection show fatty liver with petechiae, abdominal swelling caused by splenomegaly, and ascites (Labella et al., 2011).



Fig. 1. *Vibrio vulnificus* infection in eel by the non-zoonotic ST 140 strain (Haenen et al., 2014).



Fig. 2. *Vibrio vulnificus* infection in eel by the zoonotic ST 112 strain (Haenen et al., 2014).

*Aeromonas hydrophila* is considered ubiquitous in fresh and brackish water and is a facultative pathogen of various cold- and warm-blooded animals. It may cause motile aeromonad septicaemia, haemorrhagic septicaemia, motile aeromonad infection, red pest, red sore ulcerative disease, and furunculosis, especially in intensively cultured warmwater fish such as Indian major carps, catfish, cyprinids, goldfish, etc. (Austin and Adams, 1996; Camus et al., 1998; Austin and Austin, 2007). A highly virulent pathotype of *A. hydrophila* (vAh) is emerging in the United States of America, causing high losses in the channel catfish industry (Hossain et al., 2014).

*Edwardsiella tarda* is considered one of the most important bacterial pathogens in aquaculture worldwide (Kodama et al., 1987; Castro et al., 2006; Xu and Zhang, 2014). It has been reported as a causative agent of edwardsiellosis from over 20 fish species across five continents (Plumb, 1999; Mohanty and Sahoo, 2007). It has also been isolated from reptiles, birds, and mammals (Sharma et al., 1974; Tan and Lim, 1977; Leotta et al., 2009; Wang et al., 2012). Its major economic impact is in disease outbreaks in both freshwater and brackish water cultured fish. The disease includes small cutaneous ulcerations on the sides and caudal peduncle that can progress into deep abscesses in the musculature with gas (Meyer and Bullock, 1973).

*Streptococcus iniae* may cause haemorrhagic disease in various freshwater and marine warmwater fish species, like channel catfish (*Ictalurus punctatus* (Rafinesque, 1818)), Nile tilapia (*Oreochromis niloticus* (Linnaeus, 1758)), barramundi (*Lates calcarifer* (Bloch, 1790)), European seabass, gilthead seabream, bastard

halibut (*Paralichthys olivaceus* (Temminck and Schlegel, 1846)), white-spotted spinefoot (*Siganus canaliculatus* (Park, 1797)) and red porgy (*Pagrus pagrus* Linnaeus, 1758)), but also in rainbow trout (*Oncorhynchus mykiss* (Walbaum, 1792)) and some ornamental fish (Kitao et al., 1981; Kusuda, 1992; Perera et al., 1994; Eldar et al., 1995). Haemorrhagic meningoencephalitis often accompanied by blindness is typical for this disease. At necropsy, pale and/or haemorrhagic liver and kidney, swollen spleen, and occasionally ascites are seen (Soltani et al., 2005; Salati, 2011).

*Streptococcus agalactiae* is an important fish pathogen and causes warmwater streptococcosis. It has been isolated from humans, various warm-blooded animals, and various freshwater, brackish, and marine farmed, wild and ornamental fish species (Evans et al., 2008; Amal and Zamri-Saad, 2011; Bowater et al., 2012; Delannoy et al., 2013). The disease affects fish species like Nile tilapia, hybrid striped bass, gilthead seabream, golden shiner (*Notemigonus crysoleucas* (Mitchill, 1814)), hardhead sea catfish (*Aropius felis*), squeteague (*Cynoscion regalis* (Bloch and Schneider, 1801)), and flathead grey mullet (*Mugil cephalus* Linnaeus, 1758), among others (Evans et al., 2002; Garcia, 2007). However, *S. agalactiae* may be a member of the normal bacterial flora for common carp (*Cyprinus carpio* Linnaeus, 1758) (Buller, 2014) and North African catfish (*Clarias gariepinus* (Burchell, 1822)) (O.L.M. Haenen, unpublished).

*Mycobacterium marinum* may cause chronic mild to severe disease in many freshwater and marine fish species, especially in warmwater (ornamental and edible) fish culture (DeCostere et al., 2004; Gauthier and Rhodes, 2009). Mycobacteriosis should be suspected when a typically chronic and progressive condition resulting in weight loss is seen. The external clinical signs in affected fish include scale loss and dermal ulceration, exophthalmos, abnormal behaviour, pigment changes, spinal defects, emaciation, and ascites (Gauthier and Rhodes, 2009). Some infected fish may develop fin and tail rot. Internal clinical signs of mycobacteriosis include enlargement of kidney, liver, and spleen, nodular skin lesions, abdominal distension, and haemorrhages (Chinabut, 1999). Some infected fish do not show clinical signs. *Mycobacterium fortuitum* and *M. chelonae* are also considered as causing fish tuberculosis in various species (Thoen and Schliesser, 1984; Stoskopf, 1993; Noga, 1995; Sanders and Swaim, 2001). *Mycobacterium fortuitum* is also considered a zoonotic pathogen (Nigrelli and Vogel, 1963).

## Diseases Common Zoonotic Bacteria May Cause in Predominantly Immuno-Compromised Humans

*Vibrio vulnificus* may cause wound infections when a

person with skin injury comes into contact with infected seawater, fish, or shellfish. This human skin infection may develop into *fasciitis necroticans* and, in exceptional cases, even full sepsis and death (Oliver, 2005; Ralph and Currie, 2007; Jones and Oliver, 2009; Austin, 2010). Immuno-compromised patients suffering from liver diseases are at risk. Mortality after wound infection may reach up to 25 %. After sepsis, mortality may reach up to 55 %, mostly within 48 hours of the first appearance of clinical signs (Haenen et al., 2013). Diagnostics, including ribotyping and genotyping of *V. vulnificus* can discriminate potential zoonotic strains from others (Arias et al., 1995, 1997; Rosche et al., 2005; Cohen et al., 2007; Sanjuán et al., 2009; Haenen et al., 2014).

*Photobacterium damsela* subsp. *damsela* may cause wound infections in humans (Dryden et al., 1989) and in exceptional cases necrotic fasciitis (Barber and Swygert, 2000), especially when humans are severely immunocompromised. An extreme variant of a highly severe necrotising fasciitis where antibiotic administration proved unable to control the progression of fatal infections was reported in some cases (Rivas et al., 2014). Few extremely serious infections with fatal outcome where patients infected by *Ph. damsela* subsp. *damsela* developed multiple organ failure very soon after occurrence of initial symptoms despite therapy and surgical debridement of infected tissues were reported (Yamane et al., 1993)

*Aeromonas hydrophila* may cause local skin infections and occasionally, diarrheal disease (Lehane and Rawlin, 2000). Several large-scale retrospectives or prospective investigations on bacterial diarrhoea indicate that aeromonads are associated with stools of 0.5 to 16.9 % of ill persons and 0 to 10 % of controls (Janda and Abbot, 2010), but the role of *A. hydrophila* in causing diarrheal diseases is still debated.

*Edwardsiella tarda* may cause extra-intestinal infections through puncture wounds in adults with underlying disorders such as hepatobiliary disease, diabetes, malignancies, and other immune-compromising conditions (Lehane and Rawlin, 2000). It also causes gastrointestinal infections in children. *Edwardsiella tarda* is an important zoonotic pathogen, and is one of the principal causes of human infections acquired from fish, including from ornamental fish (Vandepitte et al., 1983; Javier, 2012; Haenen et al., 2013). Clinical disease in humans may include necrotic skin lesions, gastroenteritis, and in severe cases, septicaemia leading to osteomyelitis, meningitis, or cholecystitis (Gilman et al., 1971). At present, the zoonotic potential of *E. anguillarum* and *E. piscicida* is unknown.

As a consequence of fish handling, *S. iniae* may cause severe disease, including septicaemia, endocarditis, arthritis, meningitis, fever, and abdominal distension and pneumonia, especially in elderly humans with underlying conditions such as chronic rheumatic

heart disease, osteoarthritis, duodenal ulcer, gallstones, diabetes mellitus, hepatitis, liver cirrhosis, alcoholism, hypertension, and hypothyroidism (Evans et al., 2009a). Soft-tissue infections and acute discitis have been reported by Fuller et al. (2001), and Koh et al. (2004). In humans, infection is clearly opportunistic, usually associated with direct infection of puncture wounds during the preparation of contaminated fish, and generally seen in immunocompromised individuals (Haenen et al., 2013). In 1995, an epidemic occurred in Toronto, Canada in patients handling live or freshly killed tilapia (Weinstein et al., 1997).

*Streptococcus agalactiae* may cause bacteraemia, septicæmia, meningitis, pneumonia, endophthalmitis (Chotmongkol et al., 2004), endocarditis (Kannan et al., 2001), spondylodiscitis (Sijpkens et al., 1997), and osteomyelitis (Bauer et al., 1997) in immune-compromised patients. In these cases, however, there were no links with fish as the source of infection. Infections in humans related to fish bacterial strains are scarce and were mostly opportunistic, associated with direct infection of puncture wounds during the preparation of contaminated fish, and generally in immunocompromised individuals (Haenen et al., 2013). The infection may be transmitted from a pregnant woman to her newborn child (Glaser et al., 2002). A link was proven between a fish strain and human neonatal meningitis infections in Japan (Evans et al., 2008, 2009b). Additionally, Liu et al. (2013) showed that a sequence type 7 (ST 7) strain from diseased cultured tilapia in the People's Republic of China showed a close genomic relationship with the human strain A909, although no related zoonosis was published. Verner-Jeffreys et al. (2012) isolated *S. agalactiae* from diseased warmwater red garra (*Garra rufa* (Heckel, 1843)) used for pedicure immediately after importation from Indonesia. This means that we need to be aware of the potential of *S. agalactiae* from fish to cause contact-zoonotic infections in humans.

*Mycobacterium marinum* may cause granulomatous inflammation and nodular or diffuse granulomas of the skin, subcutaneous tissues, and tendon sheaths of fingers and hands, and is referred to as "swimming pool granuloma", "fish tank granuloma", "fish handlers disease", "fish fanciers disease" or "fish TB" of man (Lawler, 1994; Lewis et al., 2003; Petrini, 2006; Haenen et al., 2013). *Mycobacterium marinum* and *M. fortuitum* are a potential occupational hazard for workers in the aquaculture and subtropical aquarium fish industries, as well as for private tropical pet fish owners who have direct contact with their fish when cleaning their aquaria. Piscine mycobacteria may cause morbidity and mortality in fish, but also have documented zoonotic potential for humans, especially for immunocompromised individuals. Occasionally, piscine mycobacteria can also spread to internal organs of the human body and have been isolated from pulmonary lesions, synovial fluid, and

muscles (Blacklock and Dawson, 1979; Chinabut, 1999). Diagnosis in humans is set up by examining a biopsy of the suspected lesion. A history of any aquatic-related activities should be informed to the doctor. A Ziehl Neelsen stain of the biopsy is made and isolation should be done at 30 °C (and not at 37 °C, as is often done at hospitals, because at this temperature no colonies of *M. marinum* will appear) (Haenen et al., 2013). For quick results, polymerase chain reaction (PCR) based techniques should be performed from the biopsy sample. Corticosteroids should never be given to patients infected with mycobacteriosis, as it is contraindicated. Precautionary principles such as education about the health risks, with hygiene and care to prevent contracting the disease must be applied to personnel involved in this industry and private aquarium owners, since mycobacteria may be serious zoonotic organisms. *Mycobacterium fortuitum* and *M. chelonae* may cause local skin infections, but also pulmonary inflammation (Tanaka et al., 1992).

In general, fish-related contact zoonoses are under reported, as in most countries they are non-notifiable (Haenen et al., 2013). In the United States of America, however, for instance, *Mycobacterium marinum* zoonosis is notifiable (Lahey, 2003), apart from *Vibrio* zoonosis (CDC, 2020).

## Conclusion

Warmwater live fish culture, tropical fish, and their trade may pose a risk to professionals and fish hobbyists because of direct contact with potential contact-zoonotic bacteria in the infected fish or the transport water. Current border inspections for import control do not consider these risks, nor do import centres, or retail shops selling tropical fish. Awareness-raising about these risks among warmwater fish culturists, slaughter professionals, ornamental fish traders, warmwater fish hobbyists, veterinarians, medical practitioners, and governmental authorities is important.

To prevent contact zoonosis, good hygiene is a must. Hand and skin washing with soap after contact with warmwater fish and their holding water at fish farms, zoos, ornamental import sites, tropical aquaria, or warmwater fish processing facilities are a must. Regular screening for potential zoonotic bacteria in warmwater fish and their water is of utmost importance. Besides, monitoring of the health status of ornamental fish should be implemented on a global level, as its transboundary movement may act as a source of zoonotic infection and antimicrobial resistance for aquatic animals and humans.

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