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Aquatic animals and their threats to public health at human-animal-ecosystem interface: a review

Tristia Rinanda

Department of Microbiology, Faculty of Medicine, Syiah Kuala University, Aceh, Indonesia. Corresponding author: T. Rinanda, tristia.rinanda@unsyiah.ac.id

Abstract. The human-animal-ecosystem interface is the result of the complex interactions between humans, animals and the ecosystem since the existence of living organisms on earth. This interaction also takes place in aquatic environments. Aquatic animals help provide nutrition and other important substances for humans and also help balance the ecosystem. On the other hand, the increasing interface between humans and aquatic animals that may harbor or transmit infectious agents is a potential public health concern. This paper will discuss the threats to public health that can be caused by aquatic animals from the animal-human-ecosystem interface perspective. By identifying threats, we can better prepare preventative actions.
Keywords: aquatic, interface, zoonosis, antimicrobial resistance.

Introduction. The human-animal-ecosystem interface is increasingly appreciated nowadays due to the global initiative of the One Health concept. Continuous interaction between humans, animals and the environment has created a gateway for cross transmission of infectious agents through either direct (their own products) or indirect (their environments) ways (Reperant et al 2012).

Over the past 50 years, there has been a significant increase in the number of emerging infectious diseases originated from wildlife. These cases represent 72% of zoonosis cases all over the world (Newman & Reantaso 2010). The pathogens have invaded the human population which has led to sickness and death. They have also threatened the livestock industry as well as food safety and security. The diseases caused by these agents demonstrate several virulent characteristics including being highly infectious and potentially being spread in a rapid manner. They also show the link between human, animal and wildlife health. They emphasize the need for broader understanding of the ecological settings that play an important role in providing the opportunity for these pathogens to emerge, re-emerge and transmit to another host (Newman & Reantaso 2010).

The interface between humans, animals and ecosystems is continuously affected by increasing globalization, the growth and movement of human and livestock populations, rapid urbanization, expansion in the trade of animals and animal products, the increased sophistication of farming technologies and practices, closer and more frequent interactions between livestock and wildlife, increased changes in ecosystems, changes in vector and reservoir ecology, land-use changes including forest encroachment, and changes in patterns of hunting and consumption of wildlife. Zoonosis can therefore be said to emerge at the human-animal-ecosystem interface and poses a threat to human health (FAO/OIE/WHO 2011). Public health challenges arise from the complex multihost ecology of zoonotic infections, as well as from accelerating environmental and anthropogenic changes that are altering the rates and nature of contact between human and animal populations (Lloyd-Smith et al 2009). The human-animal-ecosystem interface also takes place in aquatic environments. Over 360 species of fish, invertebrates and plants are farmed around the world. This represents a wealth of genetic diversity both within and among species that helps make aquaculture one of the fastest growing food production sectors (FAO 2015). Aquatic animals have played an important role as a large component of the nutritional supplies for humans and other animals (such as poultry and mammalian meat animals). This fact indicates humans' dependency on aquatic food sources (Dawe 1990). On the other hand, aquatic animals can also cause threats to public health in relation to the human-animal-ecosystem interface, such as aquatic zoonoses, the transfer of antimicrobial resistance and other threats related to food safety (chemical agents and carcinogens derived from aquatic animals) (Dawe 1990; WHO 2015). These possible threats will be discussed below.

Aquatic zoonosis. Zoonosis is defined as a disease that can be transferred from animals (whether wild or domesticated) to humans. Aquatic zoonoses require special consideration due to the increasing volume of international trade of aquatic animals and their products and the worldwide growth of aquaculture (FAO 2012). There are several leading factors influencing the risk of infection associated with aquatic animals and their products such as the location of the farm, the species being farmed, water temperature, the husbandry system, post-harvest processing, and habits in food preparation and consumption. These factors are considered anthropogenic risk factors (WHO 2004; Graham et al 2008; Haenen et al 2013).

Climate change also plays an important role in the emergence of aquatic zoonoses (WHO and the Secretariat of the Convention of Biological Diversity 2015). The rise of sea level, increased incidence of storm surges and land- based run-offs as well as extreme weather events causefloods. This phenomenon leads to a condition where nutrients, pollutants and pathogens are flushed into the waterway and end up in coastal ecosystems, thus harming the invertebrates, fish, birds, mammals, and humans. The rise in temperature due to global warming leads to migration of tropical species of certain aquatic animals to subtropical regions. The migration may widen the range of infected hosts (Newman & Reantaso 2010).

Bacteria, viruses, parasites and biotoxins are several potential biological contaminations of aquaculture products. The pathogens may be indigenous to the aquatic environment or the result of environmental contamination. Fish farms'close proximity to animal farms and human settlements (faecal effluents) and the use of excreta as fertilizer are common examples of environmental contamination (Haenen et al 2013). The interaction between humans and aquatic species pathogens is very complex because many zoonotic pathogens do not cause diseases in aquatic animals. The unaffected carriers (healthy fish) can potentially transfer the pathogens to humans. The commensal pathogens of aquatic animals can also be pathogens of humans (Lowry & Smith 2007).

Zoonoses from aquatic animals occur through two major exposures, namely ingestion (infected animals or water harboring infected animals) and topical contact with infected animals or water through open wounds or skin abrasions. The type of exposure determines the species of pathogens (Novotny et al 2004) (Table 1).

There have been a significant number of reported cases involving these pathogens. The infection of *Streptococcus iniae* in humans, initially reported in 1995, caused acute meningitis, cellulitis, septic arthritis and endocarditis all over the world (Weistein et al 1997). *Vibrio vulnificus* has been reported as a zoonotic invasive pathogen which causes fasciitis necroticans, sepsis and even death when a skin injury comes into contact with infected seawater, fish or shellfish (Bock et al 1994). *Mycobacterium marinum* causes granulomatous skin lesions in humans which develop progressively into invasive septic arthritis and osteomyelitis in immuno compromised persons (Haenen et al 2013). The trematodes parasites, such as *Clonorchis sinensis* and *Opisthorchis viverrini*, have infected over 18 million people and about half a billion of the world population is at risk (Chai et al 2005). There are also potential risks of viral (calicivirus) and fungal (*Candida*) infections, but there have not been any reported cases in humans (http://iacuc.al.umces.edu/zoonotic-diseases.html).

Some bacteria cause human sickness by means of poisoning, such as histamine fish poisoning. The fish are not toxic when caught, but later, due to the presence of certain bacteria (*Escherichia* spp., *Salmonella* spp., *Shigella* spp., *Clostridium* spp., *Morganella morganii, Vibrio parahemolyticus* and *V. alginolyticus*), the amino acid histidines are processed (decarboxylated) and changed into histamines. The histamines cause anaphylactic reactions in humans (Novotny et al 2004).

Table 1

Types of pathogens related to exposures

Pathogens	*Type of exposure*	
	Ingestion	*Topical contact*
Bacteria		
Streptococcus	√	√
Staphylococcus	√	
Clostridium	√	
Vibrio	√	√
Plesiomonas	√	
Shigelloides	√	
Aeromonas	√	
Pseudomonas	*	*
Salmonella	√	
Escherichia	√	
Campylobacter	√	
Listeria	√	
Edwarsiella	√	√
Erysipelothrix		√
Mycobacterium		√
Nocardia		√
Klebsiella		√
Parasites		
Anasakiasis	√	
Eustrongyloides	√	
Cestodes	√	
Trematodes	√	
Protozoa	√	√

√ - reported case in humans; * - no report cases in the humans, but the potential risk exists.
Source: http://iacuc.al.umces.edu/zoonotic-diseases.html; Nemetz & Shotts (1993); Greger (2007); Novotny et al (2004); Haenen et al (2013).

Antimicrobial resistance (transference of resistance). Antimicrobial resistance in aquatic environments is the result of the use of several antibiotics in aquaculture in order to enhance the production. The use of antibiotics in the fish industry is complicated because the compounds are administered directly into the water where the organisms live. The antibiotics used in aquaculture are also effective in human medicine, and the pathogens in fish also infect humans. Therefore, transference of antibiotic resistance is highly probable. The resistance can still be transmitted even if the treatment is discontinued or suspended before the fish is harvested and sold (Serrano 2005).

Resistance is determined by the bacterial genomes. This can be changed through mutation or acquisition of a new genetic material. Bacterial resistance genes are not encoded in chromosomes only, but also transferred through a variety of mechanisms. The transfer can occur horizontally, i.e. from resistant to susceptible bacteria. At the same time, a microorganism that has developed resistance to one antibiotic tends to be resistant to other antibiotics (IOM 1998).

The transfer of resistance can occur through several mechanisms such as conjugation, transformation, transduction, resistance cassette gene transfer and the expression of virulence factors. Antibiotic resistance spreads both as a result of resistance gene dissemination (infectious drug resistance) and, to a major extent, as a result of resistant bacteria dissemination (Serrano 2005). Several reported cases have shown the bacterial transfer of resistance from aquatic animals to humans. Furushita et al (2003) reported a 92-100% sequence identity on tetracycline-resistance genes between farmed fish and hospital and clinical bacteria, suggesting that there was an interaction between aquaculture and hospital isolates. Comparative DNA analysis of *Yersinia pestis* IP275 plasmids showed identical backbones to multidrug resistance plasmids isolated from fish pathogens, *Y. ruckreri.* This plasmid was isolated widely suggesting that the use of antibiotics may have broader biomedical, public health and biodefense implications than previously measured (Welch et al 2007). Human outbreaks have been linked to the consumption of fish (Heinitz et al 2000) and the increasing number of isolates is likely associated with rapid dissemination of multidrug resistant strains (CDC 2002). A study by Hofacre et al (2001) showed that from 165 animal protein products originating from fish, poultry, and cattle, 85% of isolated samples were antibiotic resistant bacteria.

Other threats related to food safety. In Japan and China, there were several cases of illness and death related to exposure to a fish neurotoxin that is present in puffer fish (Tetraodontidae). The toxin, called tetrodotoxin, is located in the skin, viscera and roe of the fish. The fish muscles do not contain the toxin, but diffusion or contact with the viscera and skin can contaminate the muscles. Humans who consume the muscles can become paralyzed or even die (Dawe 1990; http://iacuc.al.umces.edu/zoonotic-diseases.html).

Certain dinoflagellates also contain the neurotoxin. Mollusks, particularly mussels, scallops, clams, cockles, and oysters are consumed by humans, other mammals, birds, and fish and can cause severe acute muscle paralysis or death (Dawe 1990; Nemetz & Shotts 1993).

As a source of food, aquatic animals can also potentially harm public health through contained substances that can induce the neoplasm. This fact strongly correlates to the use of feral fish and mollusks as carcinogenic chemical indicators in the environment. Most of the reported cases were related to hepatic neoplasms and cholangio carcinoma resulting from chronic fish and trematodiases infections (Chai et al 2005). It is very challenging to determine whether the carcinogenic substances are produced by the aquatic animals or simply exist in the environment and are absorbed by the organisms. There have been a number of increasing reports on enzootic neoplasia in fishes (Rafferty 2003). These findings have triggered public concern about the safety of consuming fish taken from habitats where fish neoplasms are highly prevalent. Whether it is safe or not is still unknown, but there are several factors that should be considered including the number of carcinogens in a particular fish, the amount a particular fish is eaten, and the method of fish preparation (Dawe 1990).

Aquatic animals can serve as indicators of xenobiotic toxic chemicals contaminating the environment. Animals that contain the chemicals can harm their predators and humans, although there are no visible morphological changes due to the pathological effects of chemical exposures. The most dramatic illustration was the Minamata disease (mercury poisoning) and itai-itai disease (cadmium poisoning) in Japan in 1950s (Baby et al 2010). Until today, trace metal contamination in fish and shellfish is constantly supervised (Dawe 1990).

Conclusions. The interaction between humans, aquatic animals and ecosystem provides a symbiotic relationship which has offered enormous advantages for the human's lives. However, it poses a threat to humans' health by allowing the cross transmission of infectious agents which results in the emergence of zoonotic diseases. Human farming activities and climate changes are the major contributing factors. Antimicrobial resistance transferred from aquatic animals to humans is another challenging threat. This issue is strongly correlated to the use of antibiotics in fish industry which are also effective in human medicines. In relation to its interaction with humans and ecosystem, aquatic animals can also pose other threats in terms of food safety by producing toxins and preserving xenobiotic chemicals and carcinogenic substances which can danger the humans' health.

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Author:
Tristia Rinanda, Department of Microbiology, Faculty of Medicine, University of Syiah Kuala, Banda Aceh, Indonesia, Jl. Tanoh Abee, Darussalam, Banda Aceh, 23111, e-mail: tristia.rinanda@unsyiah.ac.id

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