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Editorial: Fish and Shellfish Pathology

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Editorial on the Research Topic

Fish and Shellfish Pathology

The study of the pathology of aquatic animal species has received global attention over time, and increased in the last 25 years along with the intensification of aquatic production system and global climate change. One of the first descriptions is reported in 1939 in the sponge (*Tethya lyncurium*) due to fungal infection, named "wasting disease" (Galtsoff et al., 1939). Since then, a considerable amount of publications has been produced, concerning different taxonomic groups including ecologically and economically important species (fish, shellfish, corals, seals, sea stars, sea urchins, etc.) affected by large-scale epidemics resulted in dramatic shifts in community structure (Harvell et al., 1999; Ward and Lafferty, 2004). The prevention, control, and eradication of animal diseases depend on a good understanding of the diseases and their distribution (Mohan et al., 2008). For that reason, the study of aquatic pathology can be considered an important multidisciplinary instrument, useful in many aquatic scientific fields like marine ecology, aquaculture, and ecotoxicology, and can also be used in monitoring programmes to evaluate the condition of environment. As such, the identification of fish and shellfish diseases and pathologies, with a related broad range of possible aetiological agents, are progressively being used as indicators of environmental stress since they also provide an ecologically relevant end-point of chemical exposure and can be used as biological models (Matthiessen et al., 1993; Stentiford et al., 2009; Brundo et al.; Salvaggio et al.).

Aquaculture is one of the fastest growing food-producing sectors. In terms of global production volume, that of farmed fish and aquatic plants combined surpassed that of capture fisheries in 2013. In terms of food supply, in 2014 aquaculture provided more fish than capture fisheries for the first time (FAO, 2016) and is expected to dominate production by the year 2030 (Brugère and Ridler, 2004). By 2014, a total of 580 farmed species around the world, including those once farmed in the past, have been registered with production data by FAO. These species include 362 finfishes (including hybrids), 104 molluscs, 62 crustaceans, and other aquatic organisms (FAO, 2016). The most farmed species are, e.g., *Ruditapes philippinarum* and *Crassostrea gigas* for bivalve molluscs and carps (*Ctenopharyngodon idella*, *Hypophthalmichthys molitrix,* and *Cyprinus carpio*) among finfish (FAO, 2014). Despite past and current efforts to prevent the spread of infectious diseases of fish and molluscs, new outbreaks continue to be recorded and, in endemic zones, diseases continue to be a major constraint to the industry. The World Bank in 2006 reported a global loss of about US $3 billion per year to aquaculture production and trade due to disease.

The key event in the emergence of those diseases is a change in host–pathogen interaction resulting from ecological changes. Such modifications act on pathogen to allow increased transmission between individual hosts, increased contact with new host populations or species, and selection pressure leading to the dominance of pathogen strains adapted to these new environmental conditions (Daszak et al., 2001; Marcogliese, 2008; Chiaramonte et al., 2016). To date, numerous disease outbreaks, especially in marine organisms, have been associated to

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climatic events such as the El Niño-Southern Oscillation. At the same time, both climate and human activities may have also accelerated global transport of species, bringing together pathogens, and previously unexposed populations. The evidence of the spread of two protozoan parasites (*Perkinsus marinus* and *Haplosporidium nelsoni*) northwards from the Gulf of Mexico to Delaware Bay has resulted, for example, in mass mortalities in the Eastern oyster (*Crassostrea virginica*) (De Silva and Soto, 2009). In shellfish aquaculture, in 2002, seed loss of Pacific oysters *C. gigas* has been associated with the *Malacaherpesviridae* ostreid herpesvirus-1 (OsHV-1) in Europe, and in the same year, a similar OsHV was detected in California (USA) where in 1993 a 90% of losses of oysters occurred (Burge et al., 2011). Nowadays the OsHV-1 is recorded in many areas from Europe to New Zealand and Australia. In France, in 2008 oysters started to die massively and ubiquitously around the coast (Dégremont et al.). Since then, massive mortalities have occurred every year, with mortality averaging 80% of the stock, and French production has fallen from about 130,000 tonnes (2008) to 80,000 tonnes (2011), with South Brittany and Normandy as the most impacted areas (www.agrobiosciences.org). Among aspects influencing the development of this viral disease, a rapid increase in the sea water temperature seems to be a critical stressful factor (Prado-Alvarez et al.), but husbandry practice can also contribute to a reduction of pathogen impact (Carrasco et al.). Viruses are probably the most destructive pathogens in aquaculture since no specific chemotherapies are available. Among the 10 notifiable fish diseases (diseases with great social and economic and/or public health repercussion) appearing in the 2017 Aquatic Animal Health Code of the OIE (Office International des Epizooties), eight are caused by viruses (http://www.oie.int/en/animal-health-in-the-world/oie-listed-diseases-2017/). Viral Hemorrhagic Septicemia Virus (VHSV), a virus affecting *Scophtalmus maximus* production, is included in this OIE list (Pereiro et al.). Besides viral diseases, parasites are increasingly affecting aquaculture production. Amoebic gill disease (AGD) caused by *Neoparamoeba perurans*, has emerged in Europe as a significant problem for the Atlantic salmon farming industry. AGD has affected the marine Atlantic salmon industry in Tasmania since the 1980's and has since been described in farmed salmon in Ireland, Norway, Chile as well as France, Scotland, and the Faroe Islands. In addition to Atlantic salmon, AGD has also been described in a number of other marine fish species (Oldham et al., 2016) including cleaner fish species used as a biological control of sea lice in Atlantic salmon farms (Downes et al.). Despite no bacterial diseases are encountered in the OIE list, many of them are of economic importance in aquaculture industry. The most threatening bacterial diseases occurring worldwide are vibriosis, photobacteriosis, furunculosis, flexibacteriosis, streptococcosis, lactococcosis, BKD, mycobacteriosis, and piscirickettsiosis. Some diseases classically considered as typical of fresh water aquaculture, such as furunculosis (*Aeromonas salmonicida*), bacterial kidney disease (BKD) (*Renibacterium salmoninarum*), and some types of streptococcosis, are today important problems also in marine culture (Toranzo et al., 2005; Lafferty et al., 2015). At the same time, in bivalves, vibriosis, rickettsiosis (RLO), and nocardiosis can cause important economic losses (Travers et al., 2015). Currently, vaccines are available for many economically important bacterial and viral diseases, that have proven to be efficacious in fish (Sommerset et al., 2005; Muktar et al., 2016).

By focusing on the research in aquatic pathology and related areas, this Frontiers Research Topic presents new visions into the comparative pathology of aquatic vertebrates and invertebrates and demonstrates how this field is now reaching important objectives. In this line of thought, this Frontiers Research Topic brings together contributions from researchers with different backgrounds and preparations (biologists, veterinarians, immunologists, epidemiologists) that is an important prerequisite for consolidating the body of knowledge emerging on life in oceans, coastal and inland waters, for determining safe limits of stress endurance, and for developing rigorous measures for controlling and correcting growing human impact on the aquatic environment. There are a number of emerging patterns forming important foundations of the general pathology, like disease diagnosis and pathogenesis (Aranguren and Figueras; Guevara Soto et al.), practical farm management to reduce disease spreading (Domnik et al.; Carrasco et al.), use of alternative medicine like phytotherapy (Marino et al.), and new insights into functional biological organization and responses to environmental factors of the different aquatic organisms (Calduch-Giner et al.; Carella et al.; Di Cosmo and Polese).

Compared to disease investigations in humans, the study of fish and shellfish pathology is in its infancy. In particular, investigations related to pathogenesis of disease in molluscs are few compared to human disease (Carnegie et al., 2016) and the terminology is in some case still under construction (Carella et al., 2015). This increasing intensive culture and use of aquatic species has underlined the importance of maintaining a refined understanding of pathology of various organ systems of these diverse species (Spitsbergen et al., 2009; Adams et al.) and educating the scientific community about the value of pathology. Nowadays, histopathology is still a fundamental tool for investigating the patho-morphological features of diseases, along with the new emerging technologies in diagnosis. Because aquatic pathology is critical for the best basic research, environmental monitoring, and aquaculture disease research, it is essential that aquatic pathology is considered equally to other disciplines such as genetics, cell biology, molecular biology, and immunology (Spitsbergen et al., 2009).

This special focus can also give the readers ideas for future research in this field, about the work that has been accomplished up to the present and provides insight into the future pathways and directions of this discipline.

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FC contributed to the design of the manuscript and drafted the manuscript. RS contributed to the design of the manuscript and revised it.

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