How can algae infect farmed fish?

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Aquaculture. Over the past years, worldwide fish farm production has increased year on year. As a result, aquaculture is the fastest growing food sector in the world. Production has increased from 13 million tonnes of fish in 1990 to 73.8 million tonnes in 2014 (FAO Fishery Information). Fish farming has now overtaken beef (68 million tonnes in 2014) as a food source. With wild fish production stagnating, the growth in overall fish production has come almost entirely from the global boom in aquaculture, especially in developing countries (**Figure 1**). Fish farming now represents more than 44% of total fish production. The majority of global production comes from freshwater aquaculture (47.1 million tonnes), followed by marine culture (26.7 million tonnes). In the foreseeable future, it is highly likely that aquaculture will remain the greatest source of increased fish production.

Figure 1. Carp farming in India (Uttar Pradesh)

To allow continued sustainable growth of the sector, we need to tackle a few problems that the industry is facing. For example, a large part of the food that we feed the fish in aquaculture is fish meal made from wild fish caught at sea. Obviously, this is not ideal because we would really like to catch less fish in the wild to keep our biodiversity and fish stock levels high enough to sustain a healthy population of whales, seals, fish and birds that also feed on wild fish. Another problem that is affecting fish farms around the world are emerging fish diseases. Indeed, the largest cause of economic losses in aquaculture is from diseased fish. Fish infections can be caused by several groups of pathogens including viruses, bacteria, fungi, parasites and oomycetes.

Water moulds. Some of the most devastating diseases of plants and animals, are caused by oomycetes, also known as water moulds. They can inflict enormous economic and environmental damage in both natural and cultured ecosystems. Although these organisms look like fungi, they are in fact more closely related to some algae, such as diatoms and kelp. *Phytophthora infestans* is the best-known water mould. It is one of the most destructive plant pathogens in human history and caused tremendous human suffering in the mid1840s when potato crops failed in Ireland and Scotland, resulting in widespread famine. Other *Phytophthoras* can infect soybean, cocoa trees, various fruits, rhododendron and numerous trees. Almost every plant species is susceptible to one or more species of *Phytophthora*. Other oomycetes are responsible for serious infections in animals. For example, *Lagenidium* species infect mosquito larvae, *Halioticida* infects abalone (shellfish) and lobster eggs, *Saprolegnia* species can infect insects, amphibians and fish, whereas *Aphanomyces* species can infect crayfish and also fish. Two very destructive oomycete pathogens on fish are *Saprolegnia parasitica* and *Aphanomyces invadans*. *S. parasitica* can kill up to 10% of salmon, trout, tilapia, catfish and many other fish species, whereas *A. invadans* infects pre-dominantly carp species.

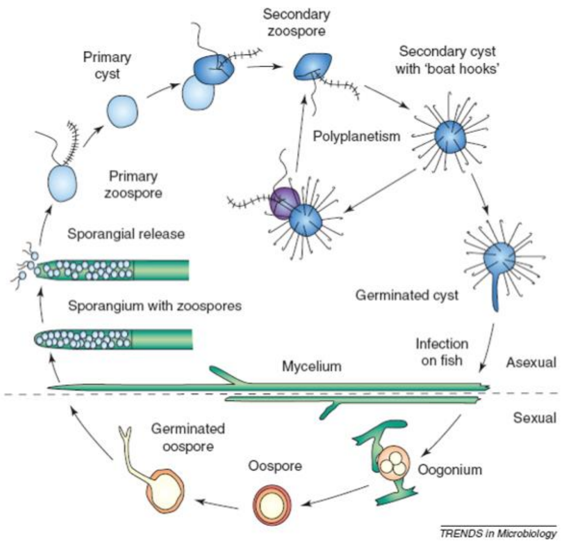

Figure 2. Lifecycle of *Saprolegnia* (adapted from Phillips *et al*., 2008 Trends in Microbiology).

Infections of fish by *Saprolegnia parasitica*. Several clearly defined developmental stages are found in the life cycle of oomycetes that are not found in true fungal pathogens (**Figure 2**). Infections can take place on both eggs and fish. On eggs the disease is manifested by abundant mycelial growth on the cells resulting in death. On fish, *Saprolegnia* invades epidermal tissues, often beginning behind the head or on the fins and spreading over the entire surface of the body in cotton-like radiating patterns. *Saprolegnia* can also cause cellular necrosis whereby hyphae penetrate into the muscle and blood vessels of fish. In some cases, infection takes place very rapidly and inflammatory responses in the fish appear to be completely absent. This has led many researchers to believe that *S. parasitica* is able to suppress the immune response in fish by expressing several effector proteins that are likely to be critical to achieve an infection. Effector proteins are secreted by the pathogen and help with the infection process. If untreated, *Saprolegnia* leads to death by osmoregulatory failure.

Molecular studies of *Saprolegnia parasitica*. *Saprolegnia parasitica,* like plant-pathogenic oomycetes, employs highly specialised infection structures and is able to secrete effector proteins, which can translocate into host cells to manipulate the host. Recently our research group showed that a particular effector protein, SpHtp3, can enter fish cells. We found a sequence motif at the end of SpHtp3 which is responsible for uptake into host cells; when this sequence was mutated, SpHtp3 was unable to enter the cells. The uptake process is helped by a receptor located in the fish cell membrane. SpHtp3 is translocated into the cell *via* small vesicles that seem to bud off from the membrane and is subsequently released from these vesicles into the cytoplasm of the fish cell with help of another effector. Once in the cytoplasm, SpHtp3 is able to fulfil its function in the infection process, which is to degrade mRNA in the fish cell, ultimately resulting in cell death.

Conclusion. A thorough understanding of the basic molecular processes in *Saprolegnia*, the nature of the interactions with its hosts, and the functional characterisation of proteins involved in the infection processes, could lead to novel control strategies that boost fish health, reduce disease losses and benefit the economy of regions dependent on fish farming.

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Further reading

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AUTHOR PROFILE

Professor Pieter van West obtained his BSc (1992), MSC (1993) and PhD (1998) in plant pathology from Wageningen University, the Netherlands. In 1998 he became a post - doctoral researcher at the University of Aberdeen and in 2000 was awarded a Royal Society University Research Fellowship to investigate oomycete pathogens. In 2012 he was awarded a Chair in Mycology and in 2015 became Director of the International Centre for Aquaculture Research and Development at Aberdeen. He was President of the British Mycological Society from 2017-18.