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Epidemiology of crayfish plague

Crayfish plague is a severe disease of European crayfish species and has rendered the indigenous crayfish populations vulnerable, endangered or even extinct in the most of Europe. Crayfish plague is caused by an oomycete *Aphanomyces astaci*, a fungal-like water mould that lives its vegetative life in the cuticle of crayfish and infects other crayfish by producing zoospores. Zoospores swim around for a few days in search of crayfish, and when they find one they attach onto its surface, encyst and germinate to start a new growth cycle as new growing hyphae penetrate the crayfish tissues. Unrestricted growth of *A. astaci* leads to the death of the infected animal in just a few weeks.

Crayfish plague induced mortalities started in Italy around 1860. Although the disease was known about since 1860 its cause remained unknown for several decades. Little was done to prevent the spread of the disease. A lively crayfish trade probably facilitated the spread of the crayfish plague, which reached Finland in 1893. The crayfish plague has remained the most important disease problem of the Finnish noble crayfish *Astacus astacus*, since then. The consensus was that the disease killed all infected animals in a short time, and it appeared almost impossible to restore the flourishing crayfish populations to the levels that existed before. Following the example of neighbouring Sweden, a North American crayfish species, the signal crayfish *Pacifastacus leniusculus* that appeared resistant to crayfish plague was introduced to Finland in 1960s. As expected, the signal crayfish slowly started to replace the lost populations of the noble crayfish to become an important part of the crayfish fisheries.

The introduction of the signal crayfish significantly added to the management problems of the noble crayfish stocks left. Signal crayfish appeared to be a chronic carrier of the crayfish plague agent, and spread the disease to the dwindling vulnerable noble crayfish populations. Later research showed that the crayfish plague agent is a parasite of North American crayfish that in normal circumstances does not harm the host animal. Intriguingly, the crayfish plague agent carried by the signal crayfish, genotype Ps1, is different from the pathogen originally introduced into Europe, genotype As.

The diagnosis of crayfish plague especially when based on the isolation of the pathogen is challenging and accordingly the genotype difference was mostly unrecognized until recently. In this study we determined the genotype of the causative agent from most of the detected Finnish crayfish plague cases between 1996 - 2006. It appeared that most of the epidemics in the immediate vicinity of signal crayfish populations were caused by genotype Ps1, whereas genotype As was more prevalent in the noble crayfish areas. Interestingly, a difference was seen in the outcome of the infection. The Ps1 infection was always associated with acute mortalities, while As infections were also frequently found in existing but weak populations. The persistent nature of an As infection could be verified in noble crayfish from a small lake in southern Finland. This finding explained why many of the efforts to introduce a new noble crayfish population into a water body after a crayfish plague induced mortality were futile.

The main conclusion from the field study data of this research was the difference in virulence between the Ps1 and As genotype strains. This was also verified in a challenge trial with noble crayfish. While the Ps1 strains did not show much variation in their growth behaviour or virulence, there was much more variation in the As strains. The As genotype arrived in Finland more than 100 years ago, and since that date it seems to have adapted to the novel host, the noble crayfish, to some extent. In order to gain insight into a possible vector of this genotype, we studied another North American crayfish species present in Europe, the spiny-cheek crayfish *Orconectes limosus* from a Czech pond. This crayfish species appeared to carry a novel genotype of *A. astaci*, named Orconectes genotype, designated "Or". It seems possible that many of the North American crayfish species carry their own type of crayfish plague agent, with variable features such as virulence. These differences should be further tested in the future.



The results of this study alleviate the necessity to study the noble crayfish mortalities for the verification of crayfish plague, including the study for the genotype of the *A. astaci* strain. Crayfish fisheries and conservation management decisions should not be made without a prior control of the donating population and the receiving water body for the eventual presence of a low-virulent *A. astaci*.