NOBANIS - Invasive Alien Species Fact Sheet

Aphanomyces astaci

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Species description

Scientific names: *Aphanomyces astaci* (Schikora 1906), Saprolegniaceae
Synonyms: None
Common names: crayfish plague (GB), krebsepest (DK), Krebspest, Wasserschimmel (DE), kräftpest (SE), krepsepest (NO), dżuma raków (PL), чума раков (RU), vēžu mēris (LV), vähikatk (EE), rapurutto (FI).

Fig. 1. Signal crayfish *(Pacifastacus leniusculus)* with a melanised spot (an immune system reaction), probably caused by an *Aphanomyces astaci*-infection, photo by Tomas Jansson.

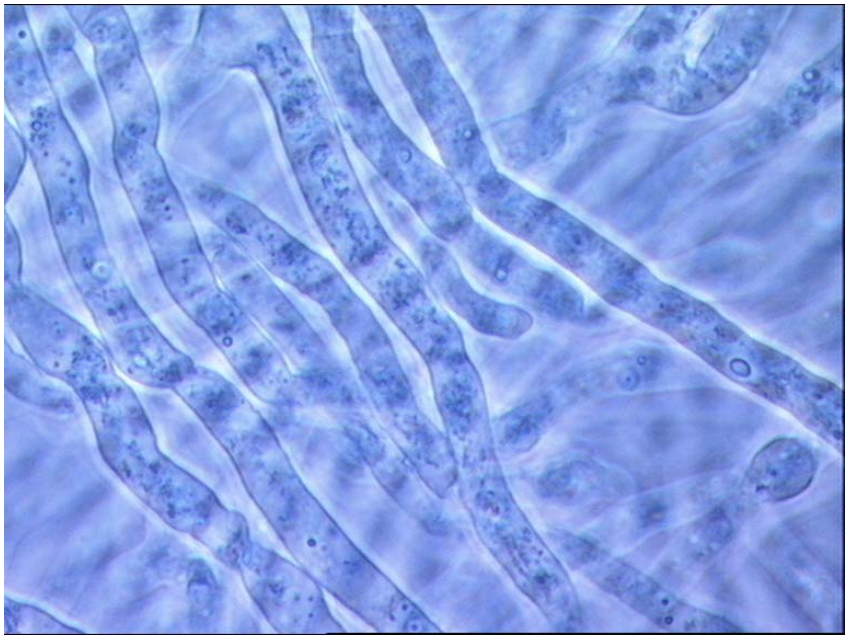

Fig. 2. Hyphae of the oomycete *Aphanomyces astaci*, photo by Trude Vrålstad.

Species identification
Aphanomyces astaci are not visible to eye. Non-septate, branching hyphae (*cf.* Fig. 2), ca. 7-10 µm in diameter with rounded hyphal tips can be seen in the cuticle of infected crayfish with light microscope (Evans & Edgerton 2002). It is impossible to identify the species only by viewing as many members of the Saprolegniaceae exhibit the same features. Confirmation of the species requires molecular methods (PCR and DNA-sequencing) or a more classical isolation and culture-technique (Vrålstad 2005, Cerenius *et al.* 1988).

Native range
The origin and native range of *Aphanomyces astaci* is assumed to be North America, based on the fact that North American crayfish species have developed defense mechanisms against the crayfish plague and display a normal host-parasite relationship, in contrast to European, Asian and Australian freshwater crayfish species which are highly susceptible (Unestam 1969, 1972, Evans & Edgerton 2002). This is evidence of co-evolution of the crayfish plague and the North American crayfish species on the North American continent.

Alien distribution

History of introduction and geographical spread
The introduction of crayfish plague into Europe occurred most likely via the importation of infected North American crayfish. The crayfish plague was probably first observed on the European continent in the Po valley of Northern Italy in 1859, with mass crayfish mortalities over the ensuing years. The first authentic record of *Aphanomyces astaci* in Germany appeared in 1864, where the pestilence evidently had spread from Italy through France (Arnold 1900). From here it spread throughout the European continent and Russia (Evans & Edgerton 2002). Lithuania was hit by the plague in 1886, Finland in 1893, Estonia in 1896 and Latvia in 1909 (Mazitis 1955, Skurdal *et al.* 1999). The plague arrived in Sweden with a shipment of infected crayfish from Finland in 1907. Norway was for a long time not affected by the crayfish plague, but in 1971 mass mortality of crayfish caused by the plague was observed in a border river, moving upstream from Sweden into Norway. There is some uncertainty about when the plague arrived to Denmark, but probably the

first outbreaks were in the period 1907-10 (Larsen 1990). In all countries were the crayfish plague has been recorded it has remained viable, and new outbreaks, in new or earlier affected water bodies, have been reported in different time periods, until the present date.

Pathways of introduction

The initial introduction of the crayfish plague to a new watercourse mostly result from human activities, first and foremost by the spread of non-indigenous, plague-carrying crayfish species like the signal crayfish (Alderman *et al.* 1990, Oidtmann *et al.* 1999, Skurdal *et al.* 1999, Söderhäll & Cerenius 1999). It can also be introduced through the transmission of viable zoospores in contaminated water (moist fishing gear, water in boats, containers, etc.) (Alderman *et al.* 1987, Taugbøl *et al.* 1993). Crayfish predators like mink, otter, herons and other birds also have the ability to bring infected crayfish from one water body to another (Evans & Edgerton 2002).

Alien status in region

Aphanomyces astaci has been introduced to all countries in the region where freshwater crayfish exist (i.e. not to Iceland, Greenland and the Faroe Islands which have no freshwater crayfish species) (see also table 1.). There are a large number of populations of suitable hosts, i.e. the signal crayfish (*Pacifastacus leniusculus*) in Sweden, Finland, Denmark and Latvia, and in addition, the spiny-cheek crayfish (*Orconectes limosus*) in Germany, Poland and Lithuania. Thus the crayfish plague is permanently established in these countries through a chronic infection of these populations. In Norway, with only one known population of signal crayfish (Johnsen *et al.* 2007) and, Estonia and NW Russia where only susceptible crayfish occur, the appearance of the crayfish plague (as mass mortality of crayfish) is more incidental with more or less frequent outbreaks recorded. It is not known whether the crayfish plague is permanently present in these countries between the outbreaks, surviving at a minimum level in low-density crayfish populations (Fürst 1995) or if it is repeatedly brought into the countries by infected water or equipment (or by illegally stocked signal crayfish not yet detected).

Country	Not found	Not established	Rare	Local	Common	Very common	Not known
Denmark				X			
Estonia		X					
European part of Russia		X					
Finland						X	
Faroe Islands*	X						
Germany					X		
Greenland*	X						
Iceland*	X						
Latvia			X				
Lithuania					X		
Norway			X				
Poland					X		
Sweden						X	

Table 1. The frequency and establishment of *Aphanomyces astaci*, please refer also to the information provided for this species at www.nobanis.org/search.asp. The frequency and establishment are directly linked to the presence of alien crayfish species suitable as hosts/carriers for *Aphanomyces astaci*. Legend for this table: **Not found** – *A. astaci* is not found in the country (*No freshwater crayfish species (hosts) are present); **Not established** - *A. astaci* is regarded as not established, because no suitable hosts are present, only the susceptible native crayfish species; **Rare** - Few sites with alien *A. astaci*-carrying crayfish species; **Local** - Locally abundant, due to populations of alien *A. astaci*-carrying crayfish species in some areas of the

country; **Common** - Due to populations of alien *A. astaci*-carrying crayfish species in many parts of the country; **Very common** - Due to many populations of alien *A. astaci*-carrying crayfish species in large parts of the country; **Not known** – No information available.

Ecology

Habitat description

A. astaci is an obligate parasite of freshwater crayfish with no secondary hosts or resting structures, and thus occupies the same aquatic habitats as their hosts. Several North American crayfish species inhabiting almost all kind of water bodies, from ditches to clear-water lakes, have been shown to harbour *A. astaci* (Evans & Edgerton 2002). The European crayfish species are highly susceptible to the crayfish plague and cannot act as a permanent host. If there is only European crayfish in a water body where *A. astaci* is being introduced, this will not be a suitable habitat as the crayfish plague itself will also die out after killing all the crayfish.

Reproduction and life cycle

A. astaci is, as mentioned, a parasite of freshwater crayfish and reproduces asexually through formation of mobile zoospores. Infection of the host commences with the encystment of the zoospore in the cuticle of the crayfish. Both susceptible and more resistant crayfish are infected this way, but the subsequent host defence response determines whether the host is killed or a stable host-parasite relationship is established. After settling on the crayfish cuticle the zoospore discards the flagellae and encysts. Germination proceeds, a germ tube penetrates the cuticle and hyphae ramify the cuticle. In resistant species, encapsulation/melanisation of the growing tip of the hyphae inhibits further invasion. In susceptible species, hyphae penetrate into deeper tissues and organs. This may also happen in individuals of resistant species weakened by other infections, injuries or stress. The final phase of the infection is sporulation and release of zoospores, which occurs just prior to or soon after death, when hyphae grow outwards and give rise to sporangia. The primary spores are extruded through the hyphal tip and cluster around the sporangial orifice to form a typical "spore ball". These primary spores then discharge as secondary zoospores, develop flagella and swim off in the hunt for a new host. The zoospores remain viable only for a few days, after which they either encyst in a favourable site and germinate, or, if the encystment site is not suitable, develop into a new zoospore. This process of repeated zoospore emergence can occur up to three times before the zoospore finally dies (Evans & Edgerton 2002 and references herein)

Dispersal and spread

Humans are the overall most important vector for the dispersal and spread, by the illegal/uncontrolled spread of plague-carrying crayfish species, first and foremost the signal crayfish (see also above).

Once introduced to a water body the crayfish plague will spread downstream through water transport of spores, while upstream spread mainly occurs through movement of infected crayfish. Fish is not a suitable host for the crayfish plague, but zoospores encysted on a fish can be transported quite a distance before they develop into new swimming zoospores hunting for another host (Häll & Unestam 1980). The rate of spread depends on factors such as crayfish density, flow rates and the presence of barriers to crayfish movements (weirs, waterfalls, etc.) (Taugbøl *et al.* 1993).

Impact

Affected habitats and indigenous organisms
Aphanomyces astaci is a fatal disease of the European freshwater crayfish species (OIE 2003) and the major reason why three of these species (only one in the Nordic/Baltic region, the noble crayfish *Astacus astacus*) are recognized as threatened and included in the international and national red lists, the Bern Convention and EU's Habitat Directive.

The crayfish plague does not directly affect other biota than the crayfish. But by killing the crayfish, a key species in the food web structure, it may indirectly have a great affect on the abundance of different animal and plant species (Nyström 2002). When the crayfish disappear the sedimentation of dead organic material will increase because the crayfish as a detritus feeder plays an important role in the degradation of organic matter. This might have a negative effect on the water quality (Hessen & Skurdal 1989).

Genetic effects
No genetic effects have been reported.

Human health effects
No human health effects have been reported.

Economic and societal effects (positive/negative)
There are no positive effects of the introduction of *Aphanomyces astaci*. Being a fatal disease of European freshwater crayfish, the negative effects have been enormous. Among the broader mass of people in Europe, crayfish eating traditions started to develop first in the nineteenth century. In the period between 1853 and 1879 more than 5 million crayfish were annually consumed in Paris alone, and most of this trade came from Germany and Russia (Ackefors & Lindqvist 1994). The demand for crayfish increased and commercial harvesting became a big industry in the nineteenth century in many European countries, including the Nordic/Baltic region. The crayfish plague, after being introduced from North America, ruined most of this commercial and recreational fishery. Only in Sweden and Finland, and to some extent in the other countries in the region, there are remains of a fishery on the indigenous noble crayfish. Current harvests in the region are less than 5% compared to the situation before the crayfish plague was introduced (Skurdal *et al.* 1999). Also this remaining fishery is at risk due to the continuous spread of the crayfish plague associated with the plague-carrying North American crayfish species.

Management approaches

Prevention methods
The crayfish plague cannot live without a suitable host and only the North American crayfish species have been shown to be naturally adapted hosts. The European crayfish species are susceptible and will eventually die after being infected with the crayfish plague. Thus, if there are no American crayfish species present in an infected watercourse, it is supposed that the crayfish plague will disappear after killing all the susceptible native crayfish, and the crayfish population can be re-established (Smith & Söderhäll 1986, Taugbøl *et al.* 1993). However, there are also examples indicating that the crayfish plague may remain as a chronic infection for decades also in watercourses with only native crayfish (Svärdson 1965, Fürst 1995). If North American crayfish species are present in the watercourse the crayfish plague is also permanently established. The only way to get rid of the crayfish plague is by eradicating the crayfish, and there is no practical way of doing this (except perhaps for small, isolated water bodies) (Holdich *et al.* 1999, Hiley 2003, Peay *et al.* 2006).

The only effective way of preventing further spread and maintenance of the crayfish plague is to stop the spread of American, plague-carrying crayfish species. In all countries in the region it is forbidden to stock crayfish in natural waters (permission needed), and in most of the countries there is a strict ban on the import of live crayfish.

Viable crayfish plague spores can also be spread from an infected watercourse to new water bodies by contaminated water, boats or equipment. Not taking water from one locality to another and disinfection or drying of the gear are effective methods to avoid such spread (Häll & Unestam 1980, Fiskeriverket/Naturvårdsverket 2005, Direktoratet for naturforvaltning/Matttilsynet 2005). This requires good and targeted information which can be a great challenge.

Eradication, control and monitoring efforts
These topics are partly dealt with above. As mentioned, there is no practical way of eradicating plague-hosting crayfish, and thus the crayfish plague, from a watercourse. The key element in controlling further spread of the crayfish plague is to control spread of the plague-carrying crayfish. Mapping and monitoring the distribution of these crayfish species is important in a management and control strategy.

Conservation of the native, red-listed crayfish species, the noble crayfish, is a main objective of all countries in the region, and to prevent further spread of the crayfish plague and plague-carrying crayfish species is the most important effort. In many countries, management plans for the noble crayfish address this problem (Taugbøl & Skurdal 1998, Taugbøl *et al.* 1998, Tuusti *et al.* 1998, Fiskeriverket/ Naturvårdsverket 1998, Taugbøl *et al.* 2004).

Information and awareness
The key factor in order to prevent further spread of the crayfish plague and plague-carrying crayfish species is information about the negative effects. With live signal crayfish easily accessible from natural waters not far away, it is impossible to prevent (illegal) stocking if local people want to do so. Local people must be convinced that the noble crayfish is the best alternative for crayfish harvest, and they must know the disastrous effects of spreading the plague-carrying crayfish. The right knowledge, attitude and enhanced awareness of local people is a key factor regarding the prevention of further spread of the crayfish plague and this can only be achieved through information (folders/brochures (Fiskeriverket/Naturvårdsverket 2005, Direktoratet for naturforvaltning/Matttilsynet 2005), media contact, education in schools, concrete projects involving relevant interest groups, see for example www.astacus.org).

Knowledge and research
Aphanomyces astaci has been the the subject of many studies during the last hundred years. There is detailed knowledge of life cycle and host defense reactions. Improved diagnostic methods have been developed in recent years (Oidtmann et al 2004, Vrålstad 2005). Four different genotypes of the crayfish plague have been identified so far (Söderhäll & Cerenius 1999). There are still many questions related to the epidemiology the crayfish plague, for example on the survival of the crayfish plague after it strikes a susceptible population (Fürst 1995).

Recommendations or comments from experts and local communities
It is imperative to convince landowners/fishermen that the indigenous noble crayfish is a great, harvestable resource and that spread of the crayfish plague and plague-carrying crayfish species to noble crayfish localities is a tragedy for nature and to the socioeconomic/ -cultural values the noble crayfish represents. In addition, it is an environmental crime. Information is the key factor.

References and other resources

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Links

The Astacus-project (Interreg collaboration Norway-Sweden)
CRAYNET (EU Thematic Network)
The International Association of Astacology (IAA)
Global Invasive Species Data Base - *Aphanomyces astaci* (ISSG - Invasive Species Specialist Group)

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