NOBANIS –Invasive Alien Species Fact Sheet

Dreissena polymorpha

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Species description

Scientific name: *Dreissena polymorpha* (Pallas,1771), Dreissenidae.
Synonyms: *Mytilus polymorphus* (Pallas), *Mytilus hagenii*, *Tichogonia chemnitzii* (Rossm.)
Common names: Zebra mussel, Wandering mussel (GB), slávička mnohotvárna (CZ), Zebramuschel, Wandermuschel, Dreikantmuschel, Dreiecksmuschel, Schafklaumuschel (DE), vandremusling (DK), tavaline ehk muutlik rändkarp (EE), Vaeltajasimpukka (FI), Svītrainā gliemene (LV), Dreisena (LT), Racicznica zmienna (PL), Vandringsmussla (SE).

Fig. 1. *Dreissena polymorpha,* photo by Viktoras Didziulis.

Fig. 2. *Dreissena polymorpha*, photo by Jonne Kotta, source: *D. polymorpha* fact-sheet, produced by Estonian Marine Institute.

Species identification
The shell of *D. polymorpha* is triangular (height makes 40-60 % of length) or triagonal with sharply pointed shell hinge ends (umbos). The maximum size of *D. polymorpha* can be 3-5 cm (Mackie *et al*. 1989). The prominent dark and light banding pattern on the shell is the most obvious characteristic of the *D. polymorpha*. Its specific name, "polymorpha", derives from the many variations in shell colour, pattern and shape depending on substrate, depth, and density of aggregation. Greenish, brownish-yellowish with clear dark and light coloured ("zebra") zig-zag banding. The outer covering of the shell (the periostracum) is generally well polished, light tan in colour with a distinct series of broad, dark, transverse colour bands which may be either smooth or zigzag in shape.

Native range
Dreissena polymorpha is native to the drainage basins of the Black, Caspian and Aral Seas (Gollasch and Leppäkoski 1999). *D. polymorpha* has been found as fossil in Central and Western Europe. Its recent reappearance is therefore regarded as a return migration. However, the return migration was only possible via shipping canals and therefore *D. polymorpha* is an alien species in the “new” habitats (Dr. Stefan Nehring, pers. comm.).

Alien distribution

History of introduction and geographical spread
Prior to the 19th century, *Dreissena polymorpha* was found in the Black, Caspian, and Azov Seas (Stanczykowska 1977). Between 1800 and 1900, *D. polymorpha* more than doubled its range in Europe (Schloesser 1995). *D. polymorpha* is now introduced to north-west Russia, central and western Europe, southern Scandinavia, Britain, Ireland and North-America (Gollasch *et al.* 1999,

Minchin *et al.* 2002). It is now found throughout most of Europe and extending east into the western Asia and south into Turkey and Ireland in west (Mackie *et al.* 1989).

It is largely unclear how the initial expansion from the Black Sea and Aralo-Caspian Sea took place. *D. polymorpha* may have penetrated from the Black Sea via Dnepr, the Oginskij Canal (completed in 1804) to the River Neman and further to the Curonian Lagoon, SE Baltic Sea. However, it may have come via canals from the Caspian region using the Volga and its tributaries and Lakes Onega and Ladoga. In 1990 it was reported from brackish water in the eastern part of the Gulf of Finland after being present for 150-years in the nearby freshwater Lake Ladoga (Gollasch and Leppäkoski 1999, Minchin *et al.* 2002).
D. polymorpha was presumably introduced into Germany in the course of the extension of the inland waterway network at the beginning of 1800s. It reached the Netherlands by 1826, being found in the Rhine at Rotterdam, most probably carried with timber imports from the Baltic (Kearney and Morton 1970, Minchin *et al.* 2002).
The first introduction of the species in Estonia was into the estuary of Põlula Brook in the Gulf of Finland and Pärnu Bay in the Gulf of Riga in the mid-1800s. A second introduction took place through Lake Peipsi to the easternmost part of the Gulf of Finland in the 1930s.
In Poland, *D. polymorpha* were first identified in the end of 1800s. The mussel is now found mainly in the northern half of the country territory but single sites are known from the upper drainage basins of the Odra and Vistula. (Dr. Katarzyna Zajac, pers. comm.). In Austria, the species was introduced in the 1860s or 1870s, presumably with diggers from excavation works of the Suez-channel (Suess 1916). The further spread was not documented, but a peak was observed in the 1960s, followed by a subsequent decrease. Recently, remote lakes and other standing waters were colonized, most likely due to translocation with sport boats (Reischütz 2005).
In the Czech Republic, it was discovered in the end of the 19th century in the river Labe. In Ireland, it was introduced to the Shannon-erne system in the early-mid 1990's.
In Denmark, the species was first recorded in 1843 in a channel in Copenhagen, where after it spread to spread to local lakes, and to Lake Fure (1915), Lakes Esrum (1922-23), and River Susaa system on the island of Zealand (1939). It has now spread to Jutland, occurring in Lakes Jels, Lake Faarup, and most recently in the River Guden system. In this system effects have been dramatic resulting in very transparent water, previously being very turbid due to phytoplankton growth favoured by eutrophication.

Pathways of introduction
The main pathways of the expansion in the range of *D. polymorpha* are through inland navigation, particularly since the opening of new waterways between eastern and central Europe at the beginning of the 1800s (Martens 1865, Rebhan 1984, Kinzelbach 1992, Dreyer 1995, Reinhold and Tittizer 1997, Nehring and Leuchs 1999, Gollasch 1996, Orlova 2002, Nehring 2002), the transfer of animals (including crayfish) for stocking in farms (*e.g.* Thienemann 1950) and the introduction into lakes of mussels attached to boat hulls (*e.g.* Jungbluth 1996), also due to the increase of recreational boating during the post-war period.

Alien status in region
The numbers of *Dreissena* have started to decrease in the Baltic Sea due to the high water salinity and cold winters. Still generally the spread of *Dreissena* is increasing, especially in the warmer Liivi Bay and Peipsi Lake. The massive dispersal could be also caused by global climate changes (Kull 2005).
The species has been established in a few localities of the easternmost Gulf of Finland (Valovirta and Porkka 1996, Kotta *et al.* 1998) and in less saline parts of the Gulf of Riga (Kotta *et al.* 1998). *D. polymorpha* has not been found in the Väinameri.

In German freshwater, the most important molluscan invader is *D. polymorpha* (see also table 1). This invasive species lives in lakes, dam reservoirs and large rivers, as well as in brackish water bodies connected to the North and Baltic Sea. Increasing water pollution in the mid-20th century strongly reduced *Dreissena* populations. The continuous improvement of water quality since the 1980s has allowed the populations to recover. Today they have again attained densities of up to 40,000 individuals per m² (Böhmer *et al.* 2001, Nehring 2005).
During 1900-1925 *D. polymorpha* was rather seldom recorded in water bodies of Poland. During the subsequent 25 years, *D. polymorpha* records started to increase rapidly. Since 1975 the increase in number of new records has decreased, and at the same time in some of the species sites, the population number has also decreased (Katarzyna Zajac, pers. comm.).
In Denmark, the species is still a locally distributed species, but the recent spread in the River Gudenaa system is very dramatic, and the populations are now extremely large no doubt affecting native unionids.
It is not found in Iceland (Mandahl-Barth 1938).

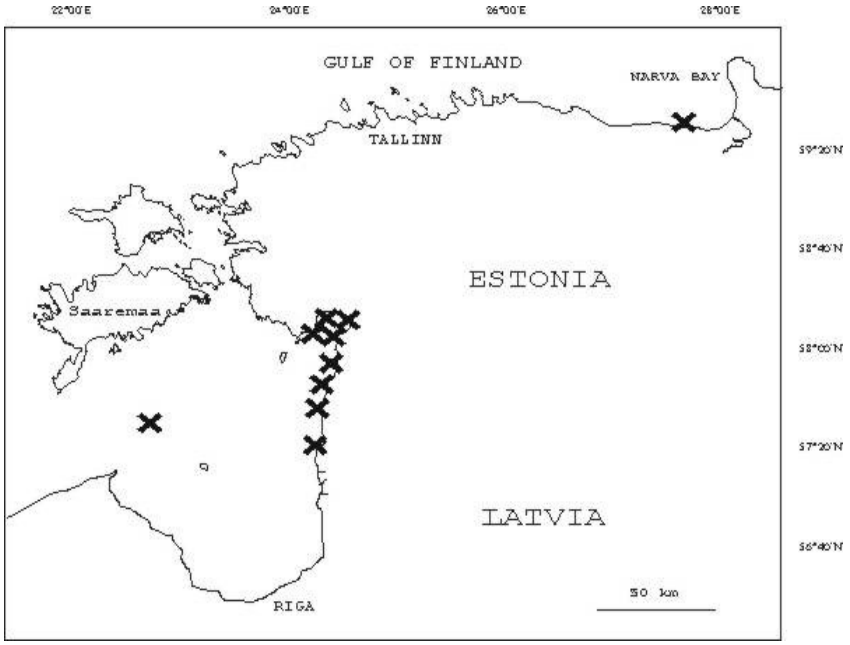

Fig. 3. Crosses show the recent distribution area of *D. polymorpha* in the Estonian coastal sea. Map by Jonne Kotta, Source: *D. polymorpha* fact-sheet, produced by Estonian Marine Institute.

Country	Not found	Not established	Rare	Local	Common	Very common	Not known
Austria						X	
Czech republic				X			
Denmark				X			
Estonia					X		
European part of Russia					X		
Finland				X			
Faroe Islands	X						
Germany						X	
Greenland	X						
Iceland	X						
Ireland				X			

Latvia		X
Lithuania		X
Norway	X	
Poland		X
Sweden		X

Table 1. The frequency and establishment of *Dreissena polymorpha*, please refer also to the information provided for this species at www.nobanis.org/search.asp. Legend for this table: **Not found** –The species is not found in the country; **Not established** - The species has not formed self-reproducing populations (but is found as a casual or incidental species); **Rare** - Few sites where it is found in the country; **Local** - Locally abundant, many individuals in some areas of the country; **Common** - Many sites in the country; **Very common** - Many sites and many individuals; **Not known** – No information was available.

Ecology

Habitat description

D. polymorpha colonizes lakes, rivers and brackish lagoons. Their preferred habitats include the calm waters upstream of dams *e.g.* on the central section of the Weser River (Busch *et al.* 1995). The mussels require suitable substrate for attachment. They are most abundant on hard surfaces, particularly rocky surfaces, and on macrophytes. (Dr. Katarzyna Zajac comm.) According to Kinzelbach (unpubl.), the mass occurrences of the species show that it is a typical r-strategist, i.e. short-lived but with great reproductive capacity.

Reproduction and life cycle

D. polymorpha usually spawns in May-July, and the fertilized egg give rise to a veliger larva up to 100 µm in size. The larva lives planktonically for 2 to 4 weeks and is capable of swimming rapidly by means of its velum (Einsle and Walz 1972, Einsle 1973, Orlova 2002). The final larval stage lasts for about one week, after which the mussel attaches to hard substrates by secreting byssal threads (termed "spatfall"; cf. Jantz 1996). According to Jantz and Schöll (1998), spatfall usually occurs in early summer, but it may also continue through the summer and into September. The spat settle on stones, deadwood, walls of embankments, the hulls of ships, and on buoys, and they may also attach themselves to crustaceans, snails and the shells of other bivalves (epoecious commensalisms, Kinzelbach 1969, cf. Wagner 1936), often forming dense clusters on these substrates. They are also capable of releasing old byssus threads and forming new ones.

In contrast to lake populations, the recruitment of *D. polymorpha* in rivers depends on populations located further upstream, because the larvae invariably drift downstream during their 2 to 4 week pelagic phase. The age and size composition of river populations vary greatly (Jantz *et al.* 1998, Jantz and Schöll 1998).

Dispersal and spread

The high reproductive output and ability to extend their planktonic stage enables *D. polymorpha* to disperse rapidly. Larvae and adults may be distributed in ballast water or as fouling on ship and boat hulls, navigation buoys, fishing vessel wells, as well as by transport of timber or river gravel, fish stocking water and fishing equipment. The overland transport of *D. polymorpha* by small trailed boats has been repeatedly implicated in inner-lake dispersal (Gollasch and Leppäkoski 1999).

Impact

Affected habitats and indigenous organisms
Owing to its large filtration capacity and mass occurrence, *D. polymorpha* out-competes the native species of similar feeding type. The species slows down the eutrophication processes, indirectly favours the blooms of blue green algae, increases water transparency and ameliorate the conditions for benthic macro-vegetation. Through biodeposition *D. polymorpha* increases the density of benthic deposit feeders. *Dreissena* consumes a lot of plankton in the water. In Lake Esrum, Denmark, 18 % of the phytoplankton production was consumed by *D. polymorpha* (Hamburger *et al.* 1990). This may therefore also cause a decline in the populations of some fish.

Native mussels belonging to the genera *Unio* and *Anodonta*, of which some are listed in national Red Lists in the region, are co-opted by zebra mussels as hard substrate for successful settlement. Those mussels that serve as "hosts" for *Dreissena* are effectively starved, because undisturbed filter feeding is no longer possible (Böhmer *et al.* 2001).

Due mainly to predation by aquatic birds, well-established *Dreissena* populations are nowadays a "non-problematic element of the ecosystem" (Siessegger, pers. comm.), while expanding stocks seem to repeatedly cause severe impacts, both ecological and economic, in their new areas (see below).

Genetic effects
There might be a risk of hybridization between *D. polymorpha* and *D. bugensis*. *D. polymorpha* and *D. bugensis* mussel hybrids were created by pooling gametes collected after exposure to serotonin in the laboratory, indicating that interspecies fertilization may be feasible (Mills *et al*., 1996). There is, however, evidence for species-specific sperm attractants suggesting that interspecific fertilization may be rare in nature (hybrids are very rare both in North America and in the Volga River basin (M. Orlova, pers. comm.). If hybridization does occur; these hybrids will constitute a very small proportion of the dreissenid community (Mills *et al*. 1996). *D. bugensis* must have arrived more recently than *D. polymorpha* based on differences in size classes, and therefore it seems plausible that *D. bugensis* is still in the process of expanding its non-indigenous range (May and Marsden 1992, MacIsaac 1994). The absence of *D. bugensis* from areas where *D. polymorpha* are present may be related to the timing and location of introduction rather than physiological tolerances (MacIsaac 1994).
The genus Dreissena is highly polymorphic and has a high potential for rapid adaptation to extreme environmental conditions by the evolution of allelic frequencies and combinations, possibly leading to significant long-term impacts on North American waters (Mills *et al*. 1996).

Human health effects
Injuries to bathers, resulting from the sharp edges of the shells have been documented (Siessegger 1970, Minchin *et al.* 2002).

Economic and societal effects (positive/negative)
Negative economic impacts caused by *D. polymorpha* are fouling of intake pipes, ship hulls, navigational constructions, cages of aquaculture and reduced angling catches (Gollasch and Leppäkoski 1999, Minchin *et al.* 2002, Table 1).

When the mussels die, their decay causes accelerated corrosion. This problem has also affected supplies of drinking water taken from Lake Constance, and - until recently - the cooling water systems of power plants throughout Germany (Sipplingen, Siessegger, pers. comm., see also Bernauer *et al.* 1996).

Another negative effect is the high cost of cleaning the shores from the sharp *Dreissena* shells (when they are massively spread across the shore, it is practically impossible to walk).
On the other hand *Dreissena* is an important food component for some fish, crayfish and some birds. Crushed shells could also be used as a fertilizers and poultry feed.
In conclusion, the impacts of *Dreissena* are many-sided, as summarized in Table 2.

Changes to environment	Changes to industry and leisure
Fouling of firm substrata	Pipe blockages
Increased water clarity	Fouling of craft
Increase of submerged macrophytes	Maintenance of navigation marks
Changes to benthos	Lacerations to bathers
Reduction of unionid populations	Municipal water supply
Changes to food-web dynamics	Disturbance from feeding birds
Fouling of marginal aquatic plants	Fouling of lock gate systems
Changes to phosphorus cycling	Water abstraction

Table 2. Impacts in Ireland following the introduction of zebra mussels (from Minchin *et al.* 2002).

Management approaches

Prevention methods

Prevention is only possible if the repeated introduction via the above mentioned pathways are reduced.

Eradication, control and monitoring efforts

Due to its sensitivity to anthropogenic influences, *Dreissena* is important as a bioindicator and biomonitoring organism (Franz 1992), and quantitative assessments have been conducted regularly since the 1960s in the context of water quality surveys *e.g.* in the Rhine (Schiller 1990).

D. polymorpha is one of the indicator species of the German Federal Government's Environmental Specimen Bank (UBA 1999). Jantz and Schöll (1998) name various monitoring systems that employ *Dreissena* as test organism (cf. ARGE Elbe 1991, Borcherding 1992, 1994, Borcherding and Volpers 1994, Busch *et al.* 1995, 1998, Franz 1992).

Chemical control of *D. polymorpha* can be achieved by applying chlorine, sodium hydroxide or potassium dichromate (Schalekamp 1971). The larvae suffer total mortality after exposure to ultrasonic vibration (22 to 800 kHz) for 3 minutes (Schalekamp 1971), but the technical effort involved is prohibitive. Exposure to radiation appears equally unfeasible because of the high dosage required (Jungen 1972). Other possible control methods are poisoning with a molluscicide, such as Bayer 73, air exposure, burning, and electrocution.

Fouled pipes for non-potable water and cooling water are cleaned with chemical agents, usually by exposing the mussels to sodium hydroxide (pH 11 to 12) for 24 to 36 h. This dissolves the byssal threads, thus detaching the mussels from the substrate (Siessegger 1971). In cooling water systems, *Dreissena* can be controlled by recirculating the water to raise its temperature to 35 or 40°C for a few hours. This also leads to the detachment of the byssal threads and to gaping of the shells, and the animals fall off after a few days (Siessegger 1971). In those sections of the cooling water system where thermal treatment is impossible, control may be achieved by temporary chlorination during the summer. In drinking water systems, chlorination (at high dosage, 2-10 mg C12 per litre must be conducted at the intake filter, and it must subsequently be neutralized with activated charcoal (Siessegger 1971, 1973).

The timing of the control measures is also important. Ideally, control in non-potable water systems should take place in late fall, because larvae may be present until late October. Control of the larvae is the key, because they are small enough to pass through the sieves. The biomass of the juveniles subsequently increases 20 times in the course of the next two years.

The mussels die after 7 to 14 days of air exposure, but they do not detach themselves from the substrate, so that they need to be scraped off mechanically (Schalekamp 1971).
A combination of chemical and thermal procedures has proved particularly successful. Larvae are killed in a few minutes, and adult mussels in a few hours, at pH 12 and 30°C (Lentz 1993).
Other methods of control include: oxygen deprivation, thermal treatment, exposure and desiccation, radiation, manual scraping, high-pressure jetting, mechanical filtration, removable substrates, molluscicides, ozone, antifouling coatings, electric currents, and sonic vibration. Some industries even build their intake structures and piping at depths too low for zebra mussel colonization.
Biological control so far has proven to be ineffective in controlling *Dreissena* species. Predation by migrating diving ducks, fish species, and crayfish may reduce mussel abundance, though the effects are short-lived (Bially and MacIsaac 2000).

Other biological controls being researched are selectively toxic microbes and parasites that may play a role in management of *Dreissena* populations (Molloy 1998). Another prospective approach is to control *Dreissena* populations by disrupting the reproductive process, by interfering with the synchronization of spawning by males and females in their release of gametes (Snyder *et al*. 1997).
A further approach would be to inhibit the planktonic veliger from settling, since this is the most vulnerable stage in the life cycle (Kennedy 2002).

Information and awareness
In Estonia a booklet has been published which introduces invasive species of local importance including *Dreissena* ("Invasiived võõrliigid Eestis" 2005). The purpose of this booklet is to make the wider range of people aware of the problems going hand-in-hand with the spread of invasive species. Another purpose of the booklet is to explain and show how the species look and give some simple hints how the spread of species could be controlled. The species has also been included into the Baltic Sea Alien Species Database.
Today the occurrence of *Dreissena polymoprha* in German waters is not well known by the general public, since a purposeful information platform is not yet established. Education and increased public awareness is therefore highly needed (Stefan Nehring, pers. comm.).

Knowledge and research
The problems related to *Dreissena* are mainly well known and a lot of control and eradication methods have been worked out (see above). The distribution of the species is partly mapped and described several times (especially in the Baltic region, *e.g.* Gulf of Finland, Gulf of Riga).

Recommendations or comments from experts and local communities
A monitoring program for *D. polymorpha* is recommended. There are no known prevention methods against the further spread of *Dreissena* in Estonia, but the Estonian Marine Institute maps for dispersal of the species provides a basis for future prevention actions.

References and other resources

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Links

D. polymorpha fact-sheet, produced by Estonian Marine Institute

D. polymorpha fact-sheet developed by the University of Southern Mississippi/College of Marine Sciences/Gulf Coast Research Laboratory

Electronical version of booklet "Invasive species in Estonia" – in estonian, published by Estonian Ministry of Environment.

Information about zebra mussel, provided by Great Lakes Information Network (*e.g.* maps, news)

Baltic Sea Alien Species Database

Aquatic alien species in German inland and coastal waters (database) – in english

Central Fisheries Board – Ireland – General information on Zebra Mussel

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