Return of the Thick-shelled River Mussel

Restoring floodplains, habitats and connectivity by using mussels and brains

UNIO CRASSUS *for* LIFE

The thick-shelled river mussel (*Unio crassus*) was previously widespread and very abundant in the streams and rivers of Central Europe and Sweden. Under favourable conditions, this freshwater species could grow on stream beds in dense populations of up to several hundred individuals per square metre.

Today, the thick-shelled river mussel is under severe threat in several European countries. Due to drastic population losses within its entire range, preservation of the species has become a conservation priority. The species is classified as endangered on the IUCN Red List of Threatened Species. (Photo: Jakob Bergengren)

This is UC4LIFE

The objective of the project entitled "Return of the Thick-shelled River Mussel" is to improve water quality and habitats in twelve rivers of southern Sweden, and thereby in the Baltic Sea, for the benefit of biodiversity and human welfare. The endangered thick-shelled river mussel is sensitive to environmental disturbances and is the emblematic species of the project.

Return of the Thick-shelled River Mussel Project makes ripples on the water

One component of "Return of the Thick-shelled River Mussel" Project was the restoration of over 200 kilometres of flowing rivers and 300 hectares of floodplain. Carried out over a period of five years, the measures taken had positive effects on the water quality and biodiversity of twelve rivers that empty into the Baltic Sea. In addition, the project has significantly improved our knowledge of Sweden's most endangered freshwater bivalve, the thick-shelled river mussel. For the first time ever, the species has been cultivated and reintroduced to Swedish waters!

The project

should be seen as a cost-efficient and sustainable investment in the environment, with positive effects on water purification, biodiversity, fish production and recreation. The societal benefits of the project are indisputably large.

Freshwater mussels – ecosystem engineers

Due to their direct and indirect effects on freshwater ecosystems, mussels are often referred to as "ecosystem engineers". As they filter particles from the water, mussels transfer substances and the energy from the free-flowing water to the benthos. This has a strong influence on primary and secondary biological production, biogeochemical cycles, sedimentation rates and turbidity. In addition, their shells are an important source of substrates and habitats for many other organisms.

Freshwater mussels

contribute to ecosystem services to humans, such as water purification. They are also an important source of protein for several commercial fish species, and some species even produce valuable materials such as pearls and mother-of-pearl.

Photo: Jakob Bergengren

The thick-shelled river mussel has a fascinating life cycle

Sweden

has seven native species of large freshwater mussel. The thick-shelled river mussel (*Unio crassus*) and the freshwater pearl mussel (*Magaritifera margaritifera*) live only in streams and rivers, while the other species also live in lakes. When streams and rivers are straightened and cleared, and when reservoirs block the migration of fish, the thick-shelled river mussel and many other species are negatively affected.

Female mussels rear their young and also keep their eggs and maturing larvae in a modified gill (marsupium) inside their shells. Fertilization occurs when male sperm enters a female's mantle cavity via its intake siphon. The fertilized eggs develop into specialised larvae called glochidia. When the larvae are ripe, they are released into the water, where they attach themselves as parasites to host fish and continue to develop within cysts on the gills of the fish.

After roughly one month, the larvae detach themselves from the fish. They have now transformed into young juvenile mussels, only about one millimetre in length. Then comes the next critical phase. The tiny mussels must find a suitable stream bed with coarse sand or fine gravel where they can bury themselves and live among the bottom particles for a few years. When the mussel has grown to 10 – 12 millimetres in length, it crawls up to the bottom surface, ready to begin living — like other mature mussels — by filtering small food particles from the surrounding water.

The life cycle of the thick-shelled river mussel can be described in four steps. Each step must be successful in order for reproduction to succeed.

1. In the spring, the males release their sperm into the water.

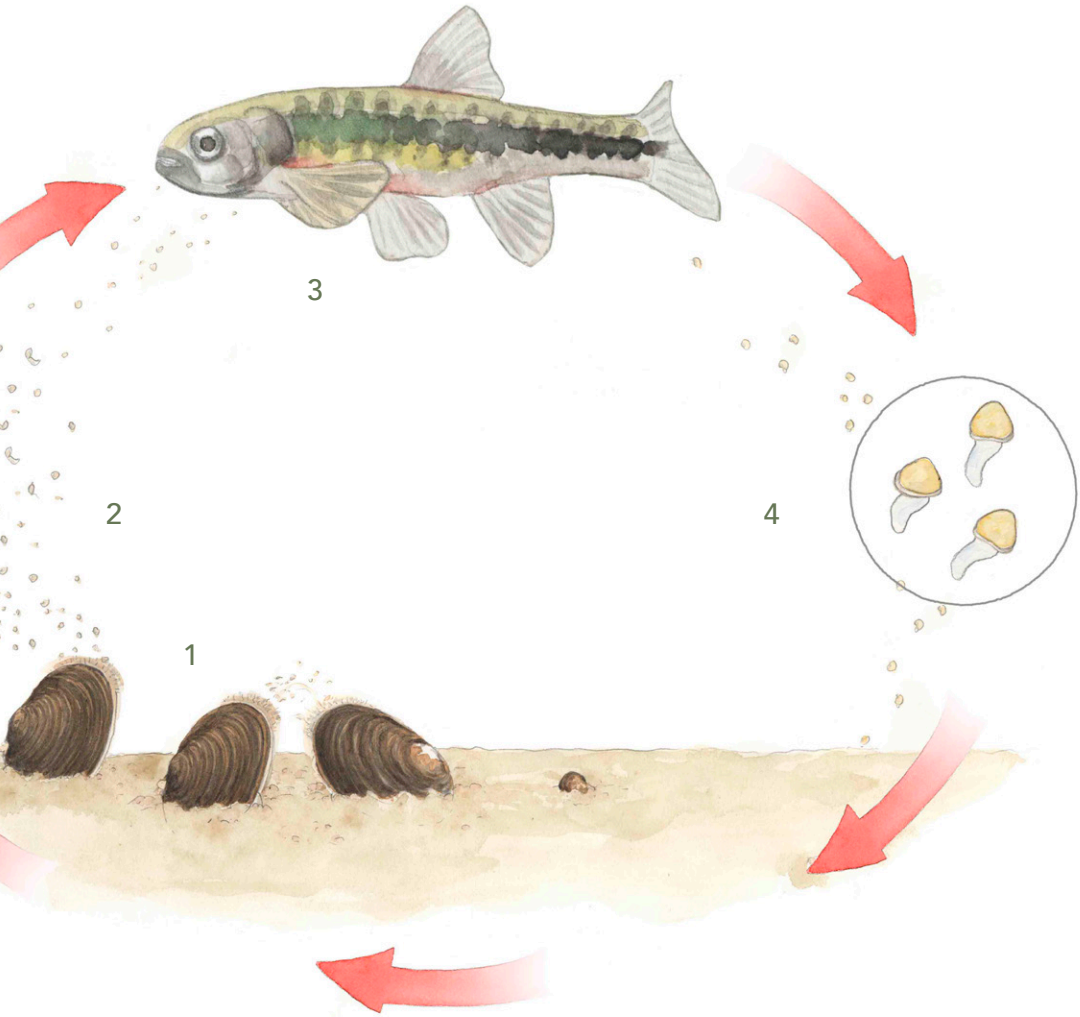
2. The sperm reach the female mussels via the water they filter. Inside a female, the sperm fertilizes the eggs it is carrying.

3. The fertilised eggs remain inside the female for a few weeks, developing into small larvae called glochidia which are released into the water. Now the larvae must quickly find a host fish! The larvae attach themselves to the gills of the fish and live there as parasites for about a month. During that time, the larvae metamorphose and develop into fully formed mussels. Carrying the mussel larvae causes no injury to the fish.

4. When the tiny young mussels have completed their development on the host fish, they detach themselves from the gills and fall to the stream bed. There, they bury themselves completely in the sand or gravel, and remain there until they have grown to about one centimetre in length. Then they crawl up to the surface of the stream bed, where they remain stationary and begin to filter the passing water.

As their host fish

move about in the river, the mussel larvae hitch a ride and are thus able to establish themselves in new areas. Since adult mussels can only move short distances by themselves, this is a necessary and effective means for the species to widen its distribution in the aquatic environment.



Unique restoration measures in twelve rivers

One aspect of the UC4LIFE project

"Return of the Thick-shelled River Mussel" involved restoration of over 200 kilometres of rivers and 300 hectares of floodplain along twelve rivers that empty into the Baltic Sea. The results have been positive for both water quality and biodiversity.

In twelve project areas, measures were carried out and selected on the basis of the types and extent of environmental disturbances to which the twelve areas were exposed. Three main categories of restoration measures were performed:

- Removing barriers: focus on migration and the disperasal of species
- River restoration: focus on habitats and increased biodiversity
- Floodplain restoration: focus on improved water quality and habitats

An important component of the project is the cultivation and reintroduction of the thick-shelled river mussel in streams and rivers where the species has either died out, or is still present but only in low densities and without satisfactory juvenile recruitment. The objective is to have healthy mussel populations within ten years.

Continuous studies are being conducted to determine whether the measures taken in the twelve project areas have the desired effects on water quality and habitats.

Minnow (*Phoxinus phoxinus)*

Measures that are beneficial for mussels and fish have positive effects on animal life in general, even above the water surface. Seen here is a kingfisher with a newly caught minnow (*Phoxinus phoxinus*) in its beak. Minnows serve as hosts to the thick-shelled river mussel. (Photo: Göran Gustafsson)

"Return of the Thick-shelled River Mussel" project includes 12 areas that are distributed fairly evenly within the historical range of the species.

Removing barriers to benefit migration and the dispersal of species

One of Sweden's longest fauna passages (2.4 kilometres) has been built in the Lillån River. No fewer than eight migratory barriers have been removed or eliminated. In addition, water flow conditions have been ensured with a new discharge regime and a revision of water regulations. One thousand square metres of production area for fish and invertebrates have been re-established. (Photo: Peter Johansson)

In order to create better conditions for fish and mussels, and for the interplay between the thick-shelled river mussel and its host fishes, eight migratory barriers have been removed and then replaced with fauna passages in six rivers — the Klingavälsån, Bräkneån, Emån, Brusaån, Storån and Kisaån. This has resulted in dramatic increases in opportunities for fish and invertebrates to disperse and colonize new areas in the rivers. Free migration routes in our streams and rivers are a precondition for healthy ecosystems and biodiversity.

Example of an advanced fauna passage in the Bräkneån River. The main difficulty in its construction was that the available space for the passage was limited.

Before restoration. (Photo: Thomas Nydén)

After restoration. (Photo: Andreas Nilsson)

River restoration: focus on habitats and increased biodiversity

In order to create more varied environments in the rivers included in the project and in nearby ecosystems, river restoration measures have been carried out in all twelve. Among the most common measures have been tree-planting along the banks and the addition of bottom substrate — a mixture of sand, stones, boulders and woody debris. In addition, new flowing-water environments have been created in dried-out side channels by opening them up to the waters of the main channel. This has resulted in larger areas under water and more dynamic habitats, along with levels of production and biodiversity that are much greater than before the measures were taken. That has been clearly confirmed by electrofishing surveys. Examples include the Fyleån and Kisaån rivers, where both the density and the diversity of fish species have increased dramatically since the river restoration measures were carried out.

Helicopters were used to add new bottom substrate to sections of the Mörrumsån River that are difficult to access. (Photo: Andreas Nilsson)

The restoration measures resulted in more varied environments and, consequently, to increased biodiversity.

Before restoration. (Photo: Ursula Zinko)

After restoration. (Photo: Helena Herngren)

Just one year after the stream was re-meandered, electrofishing surveys found six fish species in the Fyleån river. Most of them serve as hosts to the thick-shelled river mussel. That result indicates a significant improvement compared with the situation prior to the conservation measures. (Photo: Johan Hammar)

Floodplain restoration – focus on improved water quality and habitats

In order to reduce the transport of nutrients and improve water quality in the Klingavälsån and Fyleån rivers, and thus eventually in the Baltic Sea, re-meandering has been carried out along the two rivers. That has involved extensive excavations to restore previously straight channels to their original meandering forms. As a result both valleys been enriched with new wetlands. Tributaries which previously ran through culverts have been restored. The channels of both rivers have doubled in length and become more winding, and their habitats have become more diverse.

These excavations have contributed to an increase in the two valleys' "flow equalization capacity" — i.e. the extent and effects of flooding have been reduced, while improving the ability of the valleys to retain water during lengthy drought and periods of low river levels. In addition to improved water flow dynamics (slower currents) these measures have helped to increase the retention of nutrients so that more of them remain in the river water instead of being transported out to the Baltic Sea, which is already suffering from severe eutrophication problems such as anoxia. The measures have also contributed to a multiple increase in the number of diverse habitats.

Since 2013, thick-shelled river mussels have been reintroduced in both rivers, on newly excavated bottoms to which has been added substrate that is suitable for both the mussels and their host fish.

In contrast to the formerly straight channel (right), the winding channel (left) contributes to natural flow dynamics, improved water quality and greater biodiversity in the entire valley. (Photo: Johan Hammar)

Activities for schools, landowners, and other stakeholders

In connection with the UC4LIFE project, over 200 information events have been held and nearly 11,000 citizens have participated in them. An important aspect of the project has been to address young schoolchildren. Around 800 children have participated along the 12 project sites. Showing and explaining project activities to children in the field have been very successful and, in addition to the schools that have already participated, several others have shown great interest in taking part. A book about life in the project rivers has been produced; its title is *Musse målarmussla ("Mickey Mussel")* and it has been very positively received.

Nearly 800 children have played, sung and done theatre about the thick-shelled river mussel's fascinating life in Swedish streams and rivers. The children have participated in everything from fish surveys to mussel explorations. They have also used a microscope to see how tiny mussels have been cultivated at Hemmestorps Mölla. It can thus be said that the thick-shelled river mussel is an excellent teacher! (Photo: Ivan Olsson)

Host-fish studies and mussel cultivation

The life cycle of the thick-shelled river mussel is complex, and insufficient knowledge about its ecological relationships is an important cause of its disappearance from many rivers in Sweden and Europe. Knowledge about its host fish is especially inadequate. An important objective of the project has therefore been to find out which fish species host the mussel in the various rivers. The method used was to study the mussel larvae encystment on the gills of wild fish, combined with tests of various species' suitability as host fish in nine of the twelve rivers (project sites).

Tests of various fish species' suitability as hosts were conducted in an aquarium facility at Hemmestorps Mölla. Those tests were also used to cultivate juvenile mussels for reintroduction of the species in the Fyleån and Klingavälsån rivers in Skåne County.

Host fish studies

The objective of the studies were to determine which fish species serve as hosts to the mussel larvae, and whether their suitability as hosts is to any extent dependent on which river they live in. If no host fish are available, the affected population is doomed to eventual extinction.

Various methods have been used to catch fish for analysis, and electrofishing has turned out to be the most effective. Fish of 16 species have been caught. Mussel larvae on their gills have been removed and analysed with innovative DNA techniques which make it possible to identify the origin of larvae species.

Taking a sample with electrofishing (Photo: Stefan Berthold)

These studies

have found that the bullhead (*Cottus gobio*), three-spined stickleback (*Gasterosteus aculeatus*) minnow (*Phoxinus phoxinus*) and brown trout (*Salmo trutta*) are functional hosts for the thick-shelled river mussel in the Klingavälsån River, and that the bullhead and three-spined stickleback are host fish in the Fyleån River. Both rivers are in Skåne County.

In general it can be stated that the common bleak (*Alburnus alburnus*), minnow and bullhead made the best hosts for the thick-shelled river mussel, because they were suitable hosts and often present in large numbers. It is interesting to note that the suitability of some species as hosts appears to vary between rivers; examples include the minnow, bullhead and brown trout.

The main purpose of modern water conservation and river restoration is to improve water quality and habitats which benefit biodiversity. One way to determine if improvements actually take place is to make use of indicator species. Such a species is sensitive to environmental disturbances and, if it thrives, many other species in and near the same body of water often thrive as well. The thick-shelled river mussel is a good example of an indicator species because of its complex interactions with several fish species that are also sensitive to environmental disturbances in varying degree.

The host fish studies lay the groundwork for future restoration measures and reintroductions of the thick-shelled river mussel, because we have tested new methods for identifying the mussel's host fish; and with that newly won knowledge we have succeeded in cultivating mussels for the first time in Sweden.

The project's

major achievement has been to cultivate the thick-shelled river mussel. Also, mussels have been successfully reintroduced for the first time in Sweden.

Bullhead *(Cottus gobio)*

Minnow *(Phoxinus phoxinus)*

Brown trout (*Salmo trutta*)

Mussel cultivation and reintroduction

To enable the reintroduction of the thick-shelled river mussel to streams and rivers from which it has disappeared, unique methods for cultivating mussels have been developed at the Hemmestorps Mölla facility in Skåne County. Thousands of juvenile mussels have been reintroduced in two county rivers, the Klingavälsån and Fyleån.

One method of reintroduction was to contain host fish in cages until the mussel larvae detached themselves from the fish. Another method was applied in the Klingavälån and Fyleån rivers; there, juvenile mussels were carefully planted on the river beds.

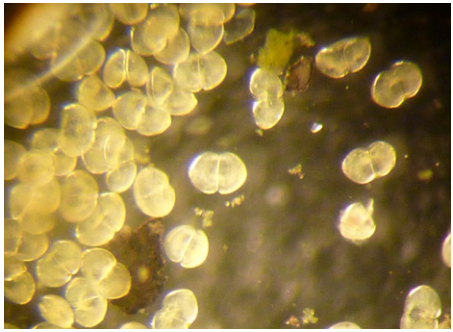
A third method was to transplant mature mussels from the Bråån and Tommarpsån rivers to the Klingavälsån and Fyleån. In order to monitor the mussels over a lengthy period, each individual was tagged with a transmitter from which data could be received without touching the animals. The results showed that most of them were still alive two years following the transplantation after being moved to their new locations.

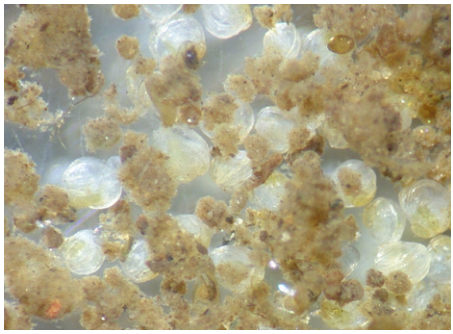
Moreover, transplantations of mature mussels have been conducted in four additional project rivers (Emån, Brusaån, Vretaån and Vedaån).

Mussel hatching tanks in the laboratory at Hemmestorps Mölla. The tanks are covered with netting to prevent the fish from leaping out. Water is pumped continuously between the aquarium and a storage tank on the floor beneath the aquarium. When the juvenile mussels detach themselves from their host fish, they are carried via a system of pipes to the storage tank, where they are caught in a sieve (fine-mesh net) inside the tank. The captured juveniles are removed from the sieve daily, and are then kept in small containers until planted in streams and rivers.
(Photo: Marius Heiss)

Juvenile mussels are especially sensitive during their first year of life in the stream beds. To study that phase, a test was conducted which involved placing them in various kinds of boxes when reintroduced. A new method which turned out to be effective was to place the juveniles in small pipes in boxes through which the river water could flow. The method was tested during the summer and autumn of 2016 and is promising — a large proportion of the juvenile mussels survived.

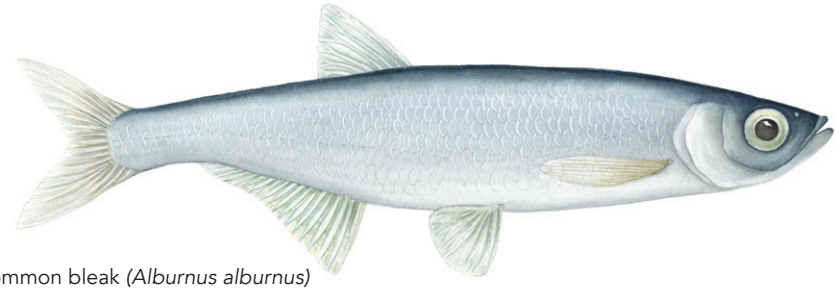
To summarize, the project has demonstrated that juvenile mussels can be successfully cultivated and reintroduced with several methods, and that their survival rate can be measured. The transplanting of mature mussels was also successful. There is thus good reason to hope that the future will bring growing and recruiting populations of thick-shelled river mussels in the restored rivers.





Top: Thick-shelled river mussel larvae before they attach themselves to host fish. Photo: Lea D. Schneider. *Bottom*: Juvenile mussels, two weeks after detachment from their host fish. (Photo: Valentina Zülsdorff)

European perch (*Perca fluviatilis*)



Common bleak *(Alburnus alburnus)*

What happens when the project concludes?

Cleaner water and increased biodiversity?

The effects of the restoration measures and the reintroduction of mussels are being studied by measuring water quality and the presence of various organisms, both before and after the measures were carried out. With regard to the thick-shelled river mussel, it will be interesting to monitor changes in the number of individuals, size range, regeneration and the presence of potential host fish. If we eventually end up with sizable populations of thick-shelled river mussels and improvements in both habitats and water quality, that will constitute important evidence that the project has been successful.

Improved ecosystem services?

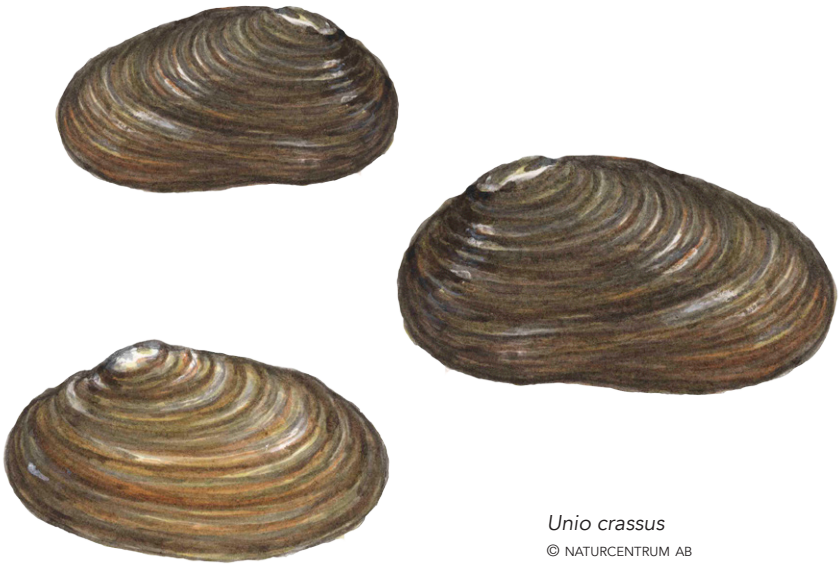
Included in the project is a pilot study designed to test a method for assigning monetary values to improvements in ecosystem services resulting from restoration measures in the Fyleån River. Improved water quality, and increases in fish production, biodiversity and recreation value all contribute to societal benefits that can be evaluated in terms of money. Preliminary results suggests that the financial value of the societal benefits of the project's restoration measures will exceed their total cost within six years of completion.

Photo: Lennart Johansson

Mussels ecology

Mussels comprise an important component of freshwater ecosystems. Changes in their diversity and population structures are influenced by loss and fragmentation of habitats, excessive exploitation, pollution, loss of host fish, introduction of alien species, water consumption, and climate changes. The resulting declines of mussel populations can in turn have important repercussions for ecosystem functions and services to which mussels contribute and from which humans benefit.

Despite dramatic population declines and the threat of extinction experienced by European species of freshwater mussels, there are grounds for optimism. For example, the water quality of many European streams and rivers has significantly improved in recent decades, making it possible for mussels to return to a number of streams, rivers, lakes and ponds. Media have reported on the preservation status of mussels, and as a result many more people have become aware of that fauna group. Such media coverage is vital to the work of preservation. In recent decades there has also been an increase in the number of European scientists studying freshwater mussels, resulting in greater knowledge about ecological aspects and new methods of preserving them. The work of preserving freshwater mussels on a large scale in both Sweden and Europe would benefit from a Europe-wide action plan or a strategy for increasing collaboration among scientists, nature conservation authorities and, not least, the general public.



Unio crassus

The thick-shelled river mussel has a fascinating life cycle and is an excellent "teacher". (Photo Ivan Olsson)

Return of the Thick-shelled River Mussel

The project was conducted by the Skåne County Administrative Board in partnership with Karlstad University and the administrative boards of Blekinge, Jönköping, Östergötland and Södermanland counties. The project ran from 2012-2016, with a budget of circa SEK 50 million. Half of that sum was provided by the EU Commission's LIFE Fund, and the other half by the participating county administrative boards, Karlstad University and the Swedish Water Authorities.

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