Securing the future of the Freshwater Pearl Mussel

Diane O'Leary, Jackie Webley and Iain Sime

Freshwater Pearl Mussels in the River Ehen.
Diane O'Leary

The River Ehen, in Cumbria, holds the last breeding population of Freshwater Pearl Mussels Margaritifera margaritifera in England. The river is designated as a Special Area of Conservation (SAC) for Freshwater Pearl Mussel and Atlantic Salmon Salmo salar. Species monitoring reveals that the mussel is struggling to survive, with juveniles failing to reach adulthood. Over the past five years, the 'Pearls in Peril' LIFE project (www.pearlsinperil.org.uk) has completed extensive conservation work to improve the river habitat and increase the population.

The Freshwater Pearl Mussel

This is an ancient species belonging to the family Margaritiferidae, which is believed to be 200 million years old, making these the most primitive of the large freshwater mussels (Degerman et al. 2009). The mussel is a filter-feeder and thus is intrinsic to the healthy functioning of a river with low nutrients and high levels of dissolved oxygen (an oligotrophic watercourse). An adult mussel, which may grow up to 15cm, can filter as much as 50 litres of water a day (Ziuganov et al. 1994). Meanwhile, the excreted waste products are enriched food for other invertebrates and plant life. Freshwater Pearl Mussels are considered an excellent indicator of aquatic-ecosystem health (Aldridge et al. 2007), and as an umbrella and keystone species their conservation will provide benefits to the entire riverine ecosystem (Vaughn & Hakenkamp 2001).

Once widespread across the Northern Hemisphere, the Freshwater Pearl Mussel has in the last 90 years declined globally by 61.5% and in Europe by 87%, making it endangered (Moorkens 2011) and listed on the IUCN Red List of Threatened Species. It is estimated that the Freshwater Pearl Mussel is now present in just 5% of its former range compared with known localities at the beginning of the 20th century (Mollusc Specialist Group 1996). This decline is reflected in Britain, where the distribution of Freshwater Pearl Mussels is now restricted to just a handful of rivers in England and Wales and 125 rivers in Scotland (Watt et al. 2015).

The species has declined owing to a range of factors. These include pearl-fishing, siltation, pollution, river engineering works, and changes to river morphology, water quality, temperature and chemistry from land-management practices and climate change.

Life cycle

The Freshwater Pearl Mussel has a fascinating life cycle. It is dioecious (has male and female individuals), but it can become hermaphroditic if

conditions dictate (Mollusc Specialist Group 1996), such as in small populations with too few males to fertilise eggs. The mussels remain fecund for most of their adult lives, which can exceed 100 years, providing the potential for large viable populations if juveniles survive well. The oldest mussel recorded is 280 years old, and comes from Görjeån (the Görje river) in north Sweden (Degerman et al. 2009). Both sexes mature at the age of 12–20 years (Skinner et al. 2003).

The life cycle begins in May, when males start to release sperm into the water column. The sperm is ingested by females downstream and fertilises the eggs which they are carrying. Fertilised eggs develop into glochidia (microscopic larval mussels) in a pouch attached to the female's gills (Hastie & Young 2003a). There can be several million glochidia per female mussel that develop over the summer period. Female mussels release glochidia as a synchronised event over a period of a few days between July and September, indicating that this act is triggered by an environmental cue such as water temperature (Hastie & Young 2003a). It has also been suggested that the underlying release mechanism may be respiratory, whereby the uptake of oxygen is reduced owing to the pressure of developing glochidia on females' gills and competition with the glochidia for oxygen (Hastie & Young 2003a,b).

When the glochidia are released they resemble miniature mussels, measuring 0.06–0.08mm across. At this stage, their tiny shells can be seen snapping and they have to encounter and be inhaled by a juvenile salmonid, typically Atlantic Salmon or Brown Trout Salmo trutta. Once inhaled, the tiny shells clamp shut on to the fish's gill filaments and are encased (encysted) there, living and growing in this oxygen-rich environment for several months. This part of the life cycle is termed 'encystment'. A healthy population of juvenile salmonids is thus essential for mussel survival, as the chances of a glochidium attaching itself to a salmonid are very low; almost all glochidia are swept away downriver and die.

Around ten months later, usually in May or early June, the glochidia, now measuring approximately 0.4mm across, drop off the fish gills. They must land and bury themselves 5–10cm into sandy, gravelly substrate to continue to grow and mature to adult mussels. These sandy gravels must be clean in order to allow the exchange of oxygen with the main water column, otherwise the young mussels will suffocate.

River Ehen

The River Ehen supports the largest Freshwater Pearl Mussel population in England, with high densities found at some locations and population estimates for the entire river exceeding 100,000 (JNCC 2017). The conservation importance of the site is further enhanced by the presence of juveniles, indicating successful recruitment within the last five to ten years (Pearls in Peril unpublished survey data).

River Ehen case study

One of the main reasons for the decline in the River Ehen mussel population is considered to be habitat degradation from an excess of fine sediments entering the river. This sediment blocks the interstitial spaces between the coarse sands and gravels, compacting the riverbed and reducing the oxygen available for juvenile mussels. The Pearls in Peril project has implemented habitat-improvement measures (e.g. stock-fencing of river banks, creating tree-lined buffer strips; repairing bank erosion by using willow, brash and woody debris) and developed a protocol for undertaking bankside artificial encystment.

Artificial encystment is a method that ensures that glochidia have a greater opportunity to become attached to host fish, thus increasing the number of juvenile mussels surviving the first stage of the life cycle and subsequently improving the chance for them to excyst (drop off) in areas of the river where suitable habitat is found. The method was initially developed in continental Europe (Altmüller & Dettmer 2000) and was successfully adapted and trialled on the Ehen.

Bankside artificial encystment method

Guidelines for this work were prepared by Scottish Natural Heritage, with input from West Cumbria Rivers Trust, the Environment Agency and Malacological Services.

The first step of the process was to determine the timing of glochidial release. Starting in late July, under a protected-species licence issued by Natural England, we examined a small number of mussels in the field to ascertain their reproductive

Inspection of gills by means of an otoscope.
Diane O'Leary

condition. The mussels were carefully opened by means of specially designed tongs. An otoscope (an instrument with magnification and a light, similar to that used to look inside ears) can then be safely inserted near the top of the shell and the tongs removed. The mussel then clamps on to the otoscope and for the most part the shell will be closed (see photo above). The otoscope can then be used to inspect the mussel's gills (Moorkens 2005). Existence of glochidia is evidenced by the presence of a pale brown, creamy colour on the gills.

To ascertain further when the glochidia may be released, another technique, developed in Austria by Scheder et al. (2011), was applied. Once the shells were opened with the tongs, a syringe was used to take a small sample of glochidia from inside the swollen gills. Done carefully, this should not harm the mussels. The sample was examined under a ×35 field microscope to check glochidial development, five stages of which have been identified by Scheder et al. (2011). This information then assists in estimating the date on which bankside artificial encystment should be undertaken.

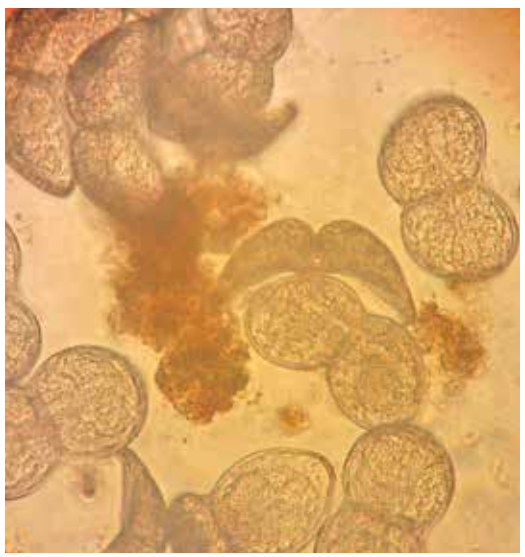
Well-developed glochidia are shown on the right. Only a small, representative number was checked, as all the mussels tend to release their glochidia around the same time. In 2015, however, different parts of the river seemed to have different rates of development, which may have been due to small differences in temperature through depth or shading. Hastie & Young (2003b) found that glochidial release occurred mainly within a few days at two different sites over one kilometre apart, but some mussels did not release glochidia until up to six weeks later.

Once lively snapping glochidia are seen, the release of these is imminent. A specialist team of people was mobilised to undertake bankside artificial encystment at a previously selected reach of the river. This was chosen because of the presence there of large numbers of mussels, potential juvenile habitat in good condition, and ease of access to undertake the work.

Salmonids were electrofished from the selected reach of river and placed in an aerated holding tank. A small number of mussels were removed from the river and placed in a sample of river water. In order to induce glochidial release, the water temperature was gradually warmed by 2°C to replicate a natural environmental trigger. The increased temperature and the resulting reduction in dissolved oxygen caused the desired release within minutes. The mussels were then returned unharmed to their original location.

The glochidia were then added to the aerated tank holding the juvenile salmonids. The controlled environment maximises the potential for glochidia to attach themselves to the fish gills. After a few

Glochidia under microscope. Freshwater Biological Association



Electrofishing team, and team monitoring the tank with glochidia and salmonids. Aaron Watson

minutes, the fish were counted, measured and returned to the river, carrying the next generation of mussels. The fish were left with the glochidia for only a few minutes in order to ensure that they did not receive too high a glochidial load, which might compromise their health. Studies have shown that very high glochidial loads can cause slower swimming speeds and even mortality in trout (Ieshko et al. 2016). The water in the tank was emptied into the river to allow any remaining glochidia the opportunity to encyst naturally.

Project findings

Monitoring work undertaken by West Cumbria Rivers Trust and the Environment Agency has shown that Freshwater Pearl Mussels in the River Ehen favour Atlantic Salmon fry as their glochidial host (Environment Agency unpublished studies).

Determining the timing of glochidia release was the most challenging and critical part of the bankside encystment process. If induced too early, the glochidia would not be developed sufficiently to be able to attach themselves to the gill filaments; if left for too long, the adult mussels would have released glochidia naturally into the river and the opportunity would be missed.

Approximately ten months after encystment, fish were safely collected and their gills checked for glochidia, which had grown big enough to be seen with the naked eye (see photo below). It is hoped that artificial encystment will ultimately contribute to an increase in the number of glochidia surviving to this stage, dropping off into the riverbed and developing into adult mussels.

The future

Given that the mussels grow very slowly and spend 12–20 years completely buried in the riverbed, it will take decades to demonstrate improvement in their numbers in the River Ehen from both catchment-management projects and bankside artificial encystment. Should there be an increase, there is currently no known method available to determine whether it would be from natural encystment, from artificial encystment or from a combination of the two. Nevertheless, it is essential to try as many strategies as possible so as to ensure that juvenile mussels have the best chance of surviving to adulthood.

Glochidia (white spots) on salmonid gills. Diane O' Leary

Pearls in Peril is just one of many projects underway across Europe which are attempting to reverse the decline of this critically endangered species. The experience and knowledge gained as part of the River Ehen trial may contribute to similar ongoing projects, such as United Utilities' Compensatory Measures Project for the River Ehen and the Biffa Award Project run by the Freshwater Biological Association (FBA 2015). The Biffa Project is attempting reintroductions of juvenile mussels raised in their Ark facility to native rivers throughout England.

Bankside artificial encystment is a proven approach where there are suitable riverbed conditions that can support juvenile Freshwater Pearl Mussels. Altmüller & Dettmer (2000) had no successful juvenile survival for many years until catchment-management efforts resulted in riverbed improvements. The River Ehen contains areas of suitable riverbed substrate which should help to improve Freshwater Pearl Mussel survival rates. Encystment projects should not be undertaken in isolation; it is essential to continue with habitat-improvement measures, such as stock-exclusion fencing and tree-planting, that will support habitat for fish and give juvenile mussels the best chance of survival when they drop off and burrow into the riverbed. This can be achieved only through collaboration, with funding and by the efforts of individuals who are determined to see the benefits to our river ecosystem and save this hidden treasure from extinction.

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Diane O'Leary was the Pearls in Peril Project Officer for West Cumbria Rivers Trust, Jackie Webley was the Pearls in Peril Project Manager for Scottish Natural Heritage, and Iain Sime is the Freshwater & Wetlands Group Manager for Scottish Natural Heritage. E-mail address for correspondence: diane@westcumbriariverstrust.org.