SDG 14: Life Below Water. Freshwater pearly mussels – fauna requiring conservation efforts locally and globally. Case study of *Margaritifera margaritifera* restoration in Europe.

Foreword

Sustainable Development Goal (SDG) 14 is dedicated to the sustainable use and conservation of the oceans, seas, and other marine habitats, which form the majority of the global water, covering almost ¾ of the Earth's surface. Although healthy oceans are essential to human survival (shaping the global climate and weather, hosting a vast biodiversity of living beings, providing food and water, and ensuring the income of a large population of people), no less necessary both for the global water cycle and for human existence are resources of freshwaters (these rivers and lakes account for only 0.036%[1] of the total world water volume; Duxbury, Duxbury & Sverdrup 2002). Freshwater bodies are an essential source of drinking water, making them significant to human culture and civilisations. They also serve as a resource for agriculture, industry, and energy today. Freshwater ecosystems – lakes, rivers, wetlands – are also among the planet's most impacted and threatened environments, and – at least in Europe – they have a history of human activity (and modifications) lasting for centuries. Inland waters are also bounded by the terrestrial ecosystems (e.g., rainfall feeds rivers but introduces organic and abiotic matter from the catchment area [drainage basin]), thus the land has a heavy impact on the quality and functioning of freshwater habitats (Vári et al. 2022).

Background

Freshwater mussels, known as unionoids (Phylum: Mollusca; Class: Bivalvia; Order: Unionida), are large, exclusively freshwater bivalves accepted as important environmental engineers in these habitats. Although they evolved and had already become globally distributed in the Triassic period, today, they are among the most imperilled freshwater species worldwide (Böhm et al. 2021; Lopes-Lima et al. 2025; Skawina & Dzik 2011). Freshwater mussels are important because they provide key ecological functions and keep the freshwater environments healthy: they play a role in structuring foodwebs, their burrowing behaviour oxygenates

[1] The estimates follow Duxbury, Duxbury & Sverdrup (2002); freshwater wetlands are not mentioned there.

deposits, and their shells provide a source of settlement space and calcium for other members of the ecosystem. They are filter-feeders that, together with their large biomass, shape their habitat. They provide the important function of keeping the water clear of suspended matter and converting filtered-out organic matter into the deposited fraction, available as food for other benthic fauna. They are long-lived (living for decades), and their life history includes a maternal care episode, where females brood offspring in their gills. Finally, their reproduction and ability to disperse are tightly connected with their association with their fish-host, as their larvae (usually the glochidium) must attach to the epithelium of the proper fish species to metamorphose into the juvenile bivalve properly. The duration of this process varies among species (see reviews and cited literature in Lopes-Lima et al. 2017; Patterson et al. 2018; Vaughn & Hakenkamp 2001).

The global diversity of Unionida reaches about 1000 known species. Still, in Europe, likely due to the effects of the last glaciation event, only a few tens of species are represented today (depending on classification or geographic range, e.g., IUCN SSC MSG/CPSG/CONFREMU 2024; Lopes-Lima et al. 2025). One of them, *Margaritifera margaritifera* (L., 1758), the freshwater pearl mussel (which has been exploited for pearls throughout Europe since pre-Roman times), is among those endangered – according to the IUCN Red List of Threatened Species – with the current population trend decreasing. It is already extinct in the wild in Lithuania, Luxembourg, and Poland (Moorkens 2024; Zając & Zając 2014). *M. margaritifera,* a Holarctic species, may live up to about 100 years, but requires cool, well-oxygenated, oligotrophic streams with pebbles and cobbles (thus, it can serve as an indicator and umbrella species, important for conservation strategies; Bauer 1988; Geist 2010). They also need salmonid fish to carry their larvae and proper deposit habitats for the survival of juvenile bivalves (their vulnerable juvenile period can extend for up to 15 years; Lavictoire & West 2024). Such streams, when recently searched in Poland, appeared as regulated and impacted by human settlement, industry, and pollution (Zając & Zając 2014). Freshwater pearly mussels are found in the wild in the western areas of the Atlantic and the Mediterranean; however, populations are fragmented, and they widely suffer from poor recruitment of juveniles, likely due to habitat pollution (e.g., summary in Geist 2010; Moorkens 2024).

Implementation

In an attempt to reverse the observed decline in populations, captive breeding and rearing programs have become the high-need answer, along with reintroduction for populations

that have already gone locally extinct, and/or reinforcement of existing populations (see Geist 2010; Geist et al. 2023; Lavictoire & West 2024). The successful program would establish a self-sustainable population in which mussels reproduce naturally in the wild: produce larvae that attach to suitable fish hosts, survive the early post-larval stage in deposits, and grow there to reach reproductive maturity. The challenge consists of many factors regarding the biology of the freshwater pearly mussel, and institutional support, e.g., ensuring the budget for long-lasting actions for this long-lived species (West & Lavictoire 2022). Still, the majority of ex-situ breeding techniques support the most critical juvenile stages (parasitic and post-parasitic), as their mortality appears to be highest here (e.g. Geist et al. 2023).

One of the examples of a successful attempt at wildlife population support comes from the River Irt in North England, United Kingdom. The 22-km-long river was a habitat for a population of 300 individuals of *M. margaritifera*, affected by wildlife crime, pollution, and habitat loss, with no evidence of recruitment for the last 60 years, so it was at risk of extinction (Geist et al. 2023; West & Lavictoire 2022). The program of conservation work by the Freshwater Biological Association (FBA) in cooperation with the Environment Agency and Natural England started here in 2007 includes: (1) ex-situ rearing of juveniles; (2) improvement (restoration) of suitable habitat quality; (3) release of propagated juvenile bivalves, and (4) incorporation of monitoring techniques. The bivalves were treated with a high level of support: the broodstock mussels were transported to a facility to produce larvae, which were developed on salmon or trout (*Salmo trutta* or *S. salar*), which lasts about a year, and after this, juveniles were kept in an indoor culture to improve survival through the most vulnerable growth stage, up to 5 mm in length. When juvenile bivalves reached about >12 mm in length, they were individually tagged with super glue and Hallprint tags or Passive Integrated Transponder tags, then carefully released by hand placement into selected habitats in the river Irt bottom (when they were >15 mm and 6–9 years old). The tags made it possible to visually track the juveniles for further monitoring and revealed they were dispersed from the release location soon after the procedure; however, bivalves bury, making visual inspection difficult. Those observed lived in pockets of sandy gravel and continued to grow for the next three years (Geist et al. 2023; Lavictoire & West 2024; West & Lavictoire 2022).

Outcomes:

The project assumed reinforcement of the small population of *Margaritifera margaritifera* in the River Irt. The project was assessed as successful. West & Lavictoire (2022) explain that the proper choice of habitat for the release of propagated juveniles allowed the small freshwater pearl mussels to survive and grow for the next three years. Raising the

juveniles in the facility to release them when they reached up to 15 mm increased the costs, but improved their survival. The adequate age (size) of the released bivalves ensured they were resilient – strong enough to endure the translocation from the rearing facility into the wild, to adapt to natural conditions and to select their habitats within the river bottom. Tagging ensured future monitoring; however, due to their natural behaviour of burrowing, an alternative method, such as Passive Integrated Transponders, is more appreciated (inspections are less challenging and more successful). Finally, the project update underlines that the population of the initial 300 older pearly mussels in this river has currently increased thanks to the additional 2400 juveniles and sub-adults propagated within this program until 2024 (FBA.org.uk 2025; Lavictoire & West 2024). The project has yielded a deeper understanding of freshwater pearl mussel biology and ontogeny, with the results that being published in scientific journals (e.g., Geist et al. 2023; Lavictoire et al. 2016; Lavictoire et al. 2018; Lavictoire & West 2024). The survival of juveniles after 3 years has been confirmed in the River Irt; however, to ensure a self-sustainable population, successful reproduction in the wild (with larvae encysted on proper salmonid fish) and the survival of 'wild' juveniles are also required, which, according to the longevity of this species, may be a long-term project. Captive breeding, therefore, supports both the production of juvenile mussels and their survival through the most critical and vulnerable parts of their life cycle (e.g., Lavictoire & West 2024).

Questions

1) Why are freshwater habitats, although they make up only a small fraction of the world's water resources, essential for humans? *Consider the biological needs of humans as living beings, the cultural aspect, as well as the widely understood field of industry, with the impact of this neighbourhood on the quality of water environments.*
2) Why are large freshwater bivalves – pearly mussels – called environmental engineers? Why do they matter? *Consider their ecological functions – filter feeding, biomass, modifying the environment through their living activity, being a good indicator of environmental quality, and their decreasing diversity*.
3) *Margaritifera margaritifera* – freshwater pearl mussel – is a species that is endangered according to the IUCN Red List of Threatened Species, with a currently decreasing population trend. How can breeding facilities reverse this trend for this species (as well as for other unionoids)? *Consider the biology of unionoids, and based on this, determine the most vulnerable life stages for support. How can they be supported?*

4) What are the difficulties in conducting long-term supportive breeding projects? *Consider both the longevity of the mussels and the challenges in sustaining the living, growing mussels in an indoor facility, and selection (or restoration) of suitable habitats for release, as well as post-release monitoring, and ensuring long-term funding.*
5) How can experience with the reinforcement of the freshwater pearl mussel population relate to SDG 14 – life below water? *Reflect on the sustainable development goal's definition and ensuring the quality of global water resources, as well as on the role of such actions in sustaining the health of the aquatic ecosystem.*

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Author Aleksandra Skawina
a.skawina@uw.edu.pl