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Freshwater Mussels *(Margaritifera margaritifera)*: Bio-filter Against Water Pollution

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Abstract: Currently, the biological control of water pollution by using microorganisms or aquatic animal is practiced frequently. Freshwater mussels *(Margaritifera margaritifera)* are the dominant filter feeders in many of the world's lakes and rivers, which strain out suspended particles and pollutants from the water column and help to improve water quality. Some mussels can filter up to 10 gallons of water per day. Unfortunately, freshwater mussel is one of the most vulnerable animals in Holarctic running waters. Captive breeding would be a valuable tool for conservation of *M. margaritifera*, as it has great ecological, environmental and economic value all over the world. This review article summarizes the potency of freshwater muscles against water pollution, their current population status, conservation strategies and future prospects as a tool for bioremediation.

Key words: *Margaritifera margaritifera* · Bio-filter · Water pollution · Conservation

INTRODUCTION

Environmental changes are the universal features of natural environments and malignant indicators of population dynamics. At present, the world environment is being destroyed day by day and we the human being, are responsible for deteriorating our climate and biodiversity. Among all natural resources, water is the most vital part of natural environment. Almost two third portion of the world is water. Sometimes this vast quantity of water may be scarce for pollution. Water resources are disturbed by human interference, especially in developing nations to perverse financial incentives for development and exploitation and inadequate or no institutions and infrastructure [1]. The water may also be polluted by industries, urban wastes, pesticides, accidental discharges by ships. The effect is very lethal and serious for human life [2].

The pollutants at low concentrations to the environment create chronic poisoning of animals. As for example, some birds are prone to contamination by dioxins, or pesticides that inhibit to lay eggs, form weak shell [3]. The organic and inorganic poisons discharge into the sea and rivers that affect the whole food chain of plants and animals. If people eat those affected animals captured by fishermen or hunters, they will get health hazardous problems. The lead, mercury, cadmium, chromium, arsenic, nickel, etc. heavy metals causing damage and death in many animal and vegetable species that form food chain living in water [2].

Water may be polluted in different ways, mostly affected by human activities. To avoid this pollution, the natural recycling process within the ecosystem should be followed. Biological process is the perfect for maintaining ecosystem balance. In a lake or a river, fresh water is the habitat of aquatic organisms like fishes, crabs, snails, pearl mussels, insects, etc. All these animals maintain a food cycle in freshwater ecosystem as well as they naturally purify the water. They have some organs that work as anti-pollutants [4]. By avoiding the use of chemicals for water purification, the application of these micro organisms or animals in water can be encouraged considering its economic importance as well.

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Several legislations have been implemented in Europe to protect water status within river basins, taking into consideration the vulnerability and equilibrium of aquatic ecosystems [e.g. Directive 2000/60/EC of the European Parliament and of the Council (23 October 2000), set up a framework for Community action in the field of water policy; Council Directive 98/83/EC (3 November 1998) on the quality of water intended for human consumption] [3]. For man-made water bodies, these directives advised the use and evaluation of quality elements applicable to other natural surface water categories, which include biological elements, chemical and physicochemical elements, supporting the biological elements among others. To fulfill these, biomonitorization processes should be implemented and applied to natural and artificial aquatic ecosystems with the aim of maintaining better water quality and sustainability. The use of freshwater mussels has recently been regarded as an environmental remediation tool in rivers, lakes and other freshwater ecosystems.

Freshwater Mussels: as a Tool for Water Pollution Remediation Freshwater mussels *(Margaritifera margaritifera*) are the main filter feeders in lakes and rivers, so they are called 'keystone taxon'. They can burrow through sediments and their body shells create habitat for epiphytic and epizoic organisms [5]. A single mussel can filter about 40 L of water per day [6]. This filtering process clarifies water and encourages the development of macrophytes, which help to deposit the nitrogen, phosphorus and heavy metals in the tissue and shell of freshwater pearl mussels. In a study, it was found that each ton of freshwater pearl oyster material harvested resulted in approximately 703 g metals, 7452 g nitrogen and 545 g phosphorus being removed from the waters of Port Stephens [7]. Thus pearl aquaculture may be used to assist in the removal of pollutants from coastal waters while producing a commercially profitable commodity.

The mussels exhibit a highly contagious, non-random spatial distribution pattern. Adult and juvenile *M. margaritifera* are found to have broadly similar habitat preferences, although adults are found over a wider range of physical conditions. River bed substratum characteristics appear to be the best physical parameters for describing *M. margaritifera* habitat. Boulder-stabilized refugia, which contain enough sand for burrowing, are ideal microhabitats for juvenile mussels. Adults are able to tolerate silty or muddy conditions for unknown lengths of time, but juveniles are never found in this type of habitat [8]. *M. margaritifera* mussels purify water by removing suspended clay, silt, bacteria, phytoplankton and small zooplankton. They also remove particulate organic matter from water column and sediment by deposit feeding [5,9]. The filtration rate depends on various points like bivalve species and size, temperature, particle size and concentration and flow regime also. Bivalve's species excrete nutrients in freshwater systems that also increase sediment water and oxygen content. The physical presence of bivalve shells create habitat for epiphytic and epizoic organisms [5,10]. In the River Thames, UK, unionid mussels comprise >90% of the benthic biomass, which can directly affect nutrient dynamics in freshwater systems through excretion as well as biodeposition of feces [10]. Furthermore, the presence of zebra mussels on artificial substrates locally increased macroinvertebrate abundance. Some mussels can filter up to 10 gallons of water per day, which helps to improve the water quality for other animals, including humans. Local biota can benefit from the mussels' filtration, excretion, biodeposition and physical presence [11-12].

Mussels can be used as a tool warning system to increase the possibility of identifying toxic events [13]. They are commonly used as indicators or biological monitors of past and present water quality in rivers and lakes. A sudden increase in mortality of freshwater mussels is a reliable indicator of toxic contamination. The disappearance of freshwater mussels usually indicates chronic water pollution problems. Biologists can measure the amount of pollutants found in mussel shells and tissue to determine the type, extent and even timing of water pollution events in streams and lakes [14]. Use of mussel abundance as a surrogate, provides a rapid and straightforward alternative to conventional methods of assessing freshwater biodiversity. No deep knowledge is required and any standardized sampling technique can be used [11].

Current Population of *M. Margaritifera:* *M. margaritifera* is one of the most vulnerable animals in Holarctic running waters [15]. Their populations are under serious threat of extinction throughout their geographical range and only a few remnant populations are recruiting to adulthood. Outeiro *et al.* [16] assessed population density and age structure of *M. margaritifera* in two Galician rivers (Eo and Masma in north-west Spain). They found that mussels occur at low densities and are highly aggregated in these rivers. *M. margaritifera* showed a preference for the strip of river bed within 1.5 m from the river bank and avoided sites at greater distances. The species also showed a preference for sites with more than

80% tree cover and avoided sites with <50% cover. Iberian populations exhibit the highest growth rate, together with the lowest maximum age and maximum length known for *M. margaritifera*. Although distributed over large parts of Europe and North America, with good populations still existing in Scotland, Scandinavia and Russia, the species has shown a serious decline in most of its range. At the moment, the freshwater mussel is threatened in at least 15 European countries. In Ireland, *M. margaritifera* population is declining despite legislation designed to protect freshwater pearl mussels and their habitat [17]. In portugal, six rivers with *M. margaritifera* had been considered extinct. The previous distribution of the freshwater pearl mussel in Portugal included suitable habitats in river basins located north and the Vouga river basin. A severe decline, caused by pollution and river channel alteration, seems evident [18]. A census of the population of *M. margaritifera* in a 1.6-km stretch of Lowland River in south-west Ireland was taken as part of an environmental impact study for a proposed flood relief scheme. Ninety-four cross-sections (2-3m wide) were taken and various habitat parameters were recorded. The total population was estimated to be only 14,194. High mussel densities were associated with shaded channels and low channel depths [19].

A survey of freshwater pearl mussels was carried out on rivers in County Donegal, northwest Ireland, to determine the current distribution, size and density of *M. margaritifera* populations, as well as to identify potential threats to mussels there [17]. The survey revealed that the freshwater pearl mussel is widespread, particularly in the western half of the county. However, densities of mussels at most sites are low, with just two sites having mussel densities of over 5 m^{-2}. Furthermore, the species appears to be absent from a number of sites from which it had been previously recorded. It is therefore included in IUCN's Red Data Book. *M. margaritifera* is globally endangered and is threatened by commercial exploitation, pollution and habitat loss throughout its range [4]. Other threats considered were hydropower regulations, excavations and constructional work in the watercourse, fishing for pearls, acidification and natural droughts or floods [15].

Conservation of *M. Margaritifera* for Water Safety: Freshwater mussels were once an important natural resource for Native Americans, particularly the mound-building tribes of the Midwest. While it seems that they were gathered primarily for use as a food source, their shells were also valued and used for tempering pottery and making tools, utensils and jewelry. It was not until the late 1800s, however, that the commercial value of freshwater mussels was recognized by the newly born American button industry. Mussels are, in turn, consumed by muskrats, otters and raccoons and young mussels are often eaten by ducks, herons and fishes, as well as other invertebrates [20]. There is a long history of pearl fishing in Ireland and neighboring counties. Evidence from heaps of shells found on the riverbed and banks at several sites and recent anecdotal reports from local people suggest pearl fishing is being established [1]. Decline of water quality has been implicated as the primary reason for the international decline of *M. margaritifera* [21-22]. The main conservation requirements for *M. margaritifera* populations are to maintain water quality at its present high standard and, as pearl fishing appears to be a widespread and immediate threat to the remaining mussel populations, to enforce existing legislation designed to protect *M. margaritifera* [21]. Eutrophication is subsequently noted as the main problem and more recently, the impact of eutrophication on the quality of the substratum in which *Margaritifera* lives was highlighted [23]. Several institutions across many countries have set up Ark sites at hatcheries to culture and rear young *M. margaritifera* from population remnants, with the intention of stocking these juveniles into rivers [24].

Presently, the awareness is increasing among population about freshwater mussels declination, however these aquatic organisms and their habitats are going to be threatened day by day [14]. Conservation efforts should focus on restoration and pollution management at the watershed scale. The restoration of stream, dam removal and control of invasive and pollution are some of the options under consideration to protect native freshwater mussels [25]. To effectively carry out such a large scale recovery, lot of effort will be required for cooperation and coordination between State and Federal agencies. It is very hard to the success of ecosystem and watershed conservation is the involvement of the general public, land users, conservation organizations and private corporations. Good news is action plans have been made for well distribution of *M. margaritifera* in Sweden and Norway. Captive breeding would be a valuable tool in enhancing the status of *M. margaritifera* in the world [25]. Captive breeding could help safeguard critically endangered populations, but current rearing methods need to be optimized. As with other conservation projects, captive breeding of the freshwater pearl mussel cannot

compensate for loss of critical habitats and is likely to be most efficient in combination with *in situ* conservation [26]. Reduction of micro-algal blooms and maintenance of improved water quality has been suggested as a function of bivalve suspension feeding [27].

The development of conservation strategies for freshwater pearl mussels and for other bivalve species faces many challenges, including the selection of priority populations for conservation and strategic decisions on habitat restoration and/or captive breeding [28]. The availability of high resolution genetic markers and the knowledge of the critical stages in the life cycle are important prerequisites for conservation. For effective conservation management also requires an evaluation of previous actions and management decisions. An integrative conservation approach is urgently needed to protect and manage freshwater pearl mussel diversity [28].

Prospects of *M. Margaritifera* as Water Pollution Control Tool: The freshwater pearl mussel, which is completely protected in most European countries, has been the focus of a significant amount of conservation efforts [29]. Several attempts have been taken including the transfer of adult mussels to areas where it had gone extinct, the culture of juvenile mussels and the release of juvenile trout, which have been infected with glochidia, into small rivers, but mainly the freshwater pearl mussel has benefited from habitat restoration projects in some areas [30]. Because of the important role of salmon fish in the life of the freshwater pearl mussel, the conservation of salmon also crucial for the survival of this endangered freshwater mussel [27].

It can be expected that the Water Framework Directive may help to develop policies, legislation and management strategies that could work towards managing damaged land uses and improving water and habitat quality [30]. It is imperative that recoverable pearl mussel populations are given the highest priority and that everyone involved in the implementation of this Directive understands. Action Plan has been written in order to identify and monitor milestones toward improved conditions [31]. The overall improved monitoring regime for the pearl mussel is a positive step. The situation of the freshwater pearl mussel in Austria has changed catastrophically in the past years, as it has in large parts of Western and Central Europe [31]. At the beginning of the 19th century, the mussel inhabitant rivers and brooks in enormous densities in upper and lower Austria. Nowadays, there are only some isolated scattered populations left, the largest one in the river Waldaist, not exceeding 1.000 individuals. Recent investigations have pointed out that in most of the Inhabitant Rivers; no recruitment has taken place over the last 20 years [31]. In order to conserve the few remaining populations, a protection program has been carried out for a decade, dealing mainly with the support of natural reproduction by releasing juvenile autochthonous brown trout that have been infected with glochidia.

In the past few years, the successful breeding was impeded and previous efforts were destroyed by unforeseen circumstances [30]. These circumstances were mainly the activities in the catchment area, which defied any controllability, e.g. the flushing of an impoundment or the release of a toxic substance into the river. In spite of the current conservation efforts the number of population as well as the number of individuals in the mussel beds are still declining. According to this fact, the simple continuation of the previous conservation measures cannot expect to be sufficient.

CONCLUSIONS

The freshwater pearl mussel (*M. margaritifera*) has declined dramatically throughout its range. Considering ecology, environment, economy and biodiversity perspectives, fresh water pearl mussel has great importance all over the world. More than half of the world's recruiting population exists in Scotland and Ireland, Continental Europe, including Austria, Belgium, Germany, Denmark, Sweden, Norway etc. Research works for conserving *M. margaritifera* and their utilization to control water pollution are mainly conducted in these areas of the world. Water pollution problem is a major environmental problem especially for the third world including some Asian, African or Latin American countries. As the use of modern technologies to recover this problem is tough to these countries, biological control through freshwater mussels may be a valuable and effective way to control pollution for these and other countries. Without application of any chemical for water treatment, *M. margaritifera* acts as a natural water purifier and at the same time creates good habitat for other aquatic organisms that is very important for water environment.

REFERENCES

1. Pirot, J.Y., P.J. Meynell and D. Elder, 2000. Ecosystem management: lessons from around the world. International Union for Conservation of Nature. Cambridge, UK. pp: 370-382.

2. Bonincontro, A., 2009. How water pollution affects the environment? (http://www. helium. com/items /70046-how- water - pollution - affects - the - environment). Retrieved on 2010-03-04.
3. Pérez, J.R., S. Loureiro, S. Menezes, P. Palma, R.M. Fernandes, I.R. Barbosa and A.M.V.M. Soares, 2010. Assessment of water quality in the Alqueva Reservoir (Portugal) using bioassays. Environmental Science Pollution Res., 17: 688-702.
4. Preston, S.J., A. Keys and D. Roberts, 2006. Culturing freshwater pearl mussel *Margaritifera margaritifera*: a breakthrough in the conservation of an endangered species, UK. Aquatic Conservation: Marine and Freshwater Ecosystems, 17: 539-549.
5. Vaughn, C.C. and C.C. Hakenkamp, 2001. The functional role of burrowing bivalves in freshwater ecosystems. Freshwater Biol., 46: 1431-1446.
6. Tankersley, R.A. and R.V. Dimock, 1993. The effect of larval brooding on the filtration rate and particle retention efficiency of Pyganodon cataracta (Bivalvia: Unionidae). Canadian J. Zool., 71: 1934-1944.
7. Gifford, S., H. Dunstan, W. Connor and G.R. Macfarlane, 2005. Quantification of in situ nutrient and heavy metal remediation by a small pearl oyster (*Pinctada imbricata*) farm at Port Stephens, Australia. Marine Pollution Bulletin, 50: 417-422.
8. Hastie, L.C., P.J. Boon and M.R. Young, 2000. Physical microhabitat requirements of freshwater pearl mussels, *Margaritifera margaritifera* (L.). Hydrobiologia, 429: 59-71.
9. MacIsaac, H.J., 1996. Potential abiotic and biotic impacts of zebra mussels on the inland waters of North America. American Zoologist, 36: 287-299.
10. Negus, C.L., 1966. A quantitative study of growth and reproduction of unionid mussels in the River Thames at Reading. J. Animal Ecol., 35: 513-532.
11. Horvath, T.G., K.M. Martin and G.A. Lamberti, 1999. Effect of zebra mussels, Dreissena polymorpha, on macroinvertebrates in a lake-outlet stream. American Midland Naturalist, 142: 340-347.
12. Mayer, C.M., R.M. Keats, L.G. Rudstam and E.L. Mills, 2002. Scale-dependent effects of zebra mussels on benthic invertebrates in a large eutrophic lake. Journal of the North American Benthological Society, 21: 616-633.
13. Allen, H., J.W.T. Waller, M.F. Acevedo, E.L. Morgan, K.L. Dickson and J.H. Kennedy, 1996. A Minimally Invasive Technique to Monitor Valve-Movement Behavior in Bivalves. Environmental Technol., 17: 501-507.
14. Fish and Wildlife Habitat Management Leaflet on Native Freshwater Mussels, 2007. Number 46. Virginia Department of Game and Inland Fisheries, Ireland.
15. Dolmen, D. and E. Kleiven, 2008. Distribution, status and threats of the freshwater pearl mussel *Margaritifera margaritifera* (Linnaeus) (Bivalvia, Margaritiferidae) in Norway. Fauna Norvegica, 26: 3-14.
16. Outeiro, A., P. Ondina, C. Fernandez, R. Amaro and E.S. Miguel, 2007. Population density and age structure of the freshwater pearl mussel, *Margaritifera margaritifera,* in two Iberian rivers. Freshwater Biol., 53: 485-496.
17. Beasley, C.R. and D. Roberts, 1996. The current distribution and status of the freshwater pearl mussel *Margaritifera margaritifera* in north-west Ireland. Aquatic Conservation: Marine and Freshwater Ecosystems, 6: 169-177.
18. Reis, J., 2003. The freshwater pearl mussel [*Margaritifera margaritifera* (L.)] (Bivalvia, Unionoida) rediscovered in Portugal and threats to its survival. Biological Conservation, 114: 447-452.
19. Gittings, T., D. O'Keefe, F. Gallagher, J. Finn and T. O'Mahon, 1998. Longitudinal Variation in Abundance of a Freshwater Pearl Mussel *Margaritifera margaritifera* Population in Relation to Riverine Habitats. Biology and Environment: Proceedings of the Royal Irish Academy, 98: 171-178.
20. Bauer, G., 1988. Threats to the freshwater pearl mussel *Margaritifera margaritifera* L in Central Europe. Biological Conservation, 45: 239-253.
21. David, C., A. Tom, M. Fayle and N. Jackson, 2007. Freshwater mussel abundance predicts biodiversity in UK lowland rivers. Aquatic Conservation: Marine and Freshwater Ecosystems, 17: 554-564.
22. Peters, N. and M. Meybeck, 2000. Water quality degradation effects on freshwater availability: impacts of human activities. Water International, 25: 185-193.
23. Araujo, R. and M.A. Ramos, 2000. Action Plan for *Margaritifera margaritifera* in Europe. Convention on the conservation of european wildlife and natural habitats council of Europe, Strasbourg. Museo Nacional de Ciencias Naturales (CSIC) José Gutiérrez Abascal, 2. 28006-Madrid, Spain.
24. Bolland, J.D., L.J. Braceen, R. Martin and M.C. Lucas, 2010. A protocol for stocking hatchery reared freshwater pearl mussel *Margaritifera margaritifera*. Conservation: Marine and Freshwater Ecosystems, 20: 695-704.

25. Young, M.R., 1991. Conserving the freshwater pearl mussel (*Margaritifera margaritifera* L.) in the British Isles and Continental Europe. Aquatic Conservation: Marine and Freshwater Ecosystems, 1: 73-77.
26. Thomas, G.R., J. Taylor and C.G. de Leaniz, 2010. Captive breeding of the endangered freshwater pearl mussel *Margaritifera margaritifera*. Endangered Species Res., 12: 1-9.
27. Herman, P.M.J. and H. Scholten, 1990. Can suspension feeders stabilize estuarine ecosystems? In M. Barnes and R.N. Gibson (eds): Trophic Relationships in the Marine Environment. Aberdeen University Press, Aberdeen, UK, pp: 104-116.
28. Geist, J., 2010. Strategies for the conservation of endangered freshwater pearl mussels (*Margaritifera margaritifera* L.): a synthesis of Conservation Genetics and Ecology. Hydrobiologia, 644: 69-88.
29. Moorkens, E.A., I.J. Killeen and E. Ross, 2007. Freshwater pearl mussel (*Margaritifera margaritifera* (L) (1029) Conservation Status Assessment Report. A Report to: The National Parks and Wildlife Service, Department of Environment Heritage and Local Government, 7 Ely Place, Dublin 2, Ireland.
30. Lundberg, S., 2009. A survey of freshwater mussel monitoring efforts in Sweden. International Conference: "Aquatic Conservation with Focus on the Freshwater Pearl Mussel *Margaritifera margaritifera*, Sundsvall, 12-14 August, 2009" Sweden.
31. Csar, D., 2009. The Freshwater Pearl Mussel in Austria - current status and prospects for the future. International Conference: "Aquatic Conservation with Focus on the Freshwater Pearl Mussel *Margaritifera margaritifera*, Sundsvall, 12-14 August, 2009" Sweden.