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***Research Article** (Open Access)*

HOST SPECIFICITY OF GLOCHIDIA OF FRESHWATER MUSSELS AND IMPLICATIONS FOR THEIR CONSERVATION

***Sandhya Leeda D'Souza**
Department of Zoology, St. Joseph's University, Bangalore, Karnataka, India-560025.
**Author for Correspondence: sandhyadsouza1@gmail.com*

ABSTRACT
Glochidia, the larvae of freshwater mussels are known to parasitize the fishes for their transformation into adults. There exists a gap in knowledge about species specificity of a single mussel to particular fishes or to different host species. This review establishes the host specificity of glochidia to freshwater fishes, detailing on preference of mussel species to the host fishes for their dispersal. The mussels can be specialists or generalist in host selection depending on the availability of the host. Besides the glochidia show host limitation or metamorphose in different hosts based on the abundance of fish hosts. Further, the causes for the decline in mussel population are extrapolated. The understanding host specificity of Unionids would help to study their interactions aiding in effective implementation of conservation strategies.

Keywords: *Larvae, Freshwater ecosystems, Threats, Propagation, Parasitism*

INTRODUCTION
Freshwater mussels in the order Unionida are highly adapted to parasitize fish through their larvae for the primary purpose of dispersal. The parasitic larval stage known as glochidia affixes itself to the gills or fins of the host where it remains attached to the tissue, eventually develops into a free-living adult (Fig. 1). Thus they are keystone species and ecosystem engineers in freshwater habitats (Yeager and Sailor, 1995). Although glochidial infestation on gills reduces the blood flow, hampers gas exchange, alters the water flow over lamellar tissue, the parasitism is obligatory for their survival.

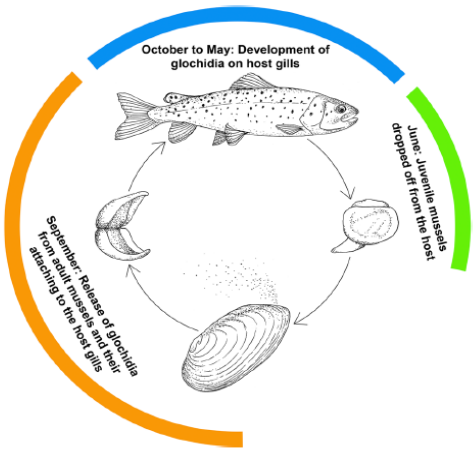

Fig. 1: Schematic representation showing life cycle of Unionids.
(Source: Vikhrev et al., 2019)

The freshwater mussels are filter feeders and help in nutrient deposition when burrowing through the sediments (Vikhrev *et al*., 2019). Research on host specificity of freshwater mussel larvae has gained the importance recently because of their ecological significance and vulnerability to extinction (Douda *et al.*, 2012; Vikhrev *et al*., 2019; Rock *et al.*, 2022).Thus the host fishes and glochidial relationship is needed for

their life cycle and population fluctuation. This article aims to understand the host fish species selection by freshwater mussels for their dispersal, the mechanism of host acquisition by the larvae, threats faced in aquatic environments, reasoning out their population decline. Moreover, it presents the information on host specificity of glochidia in global freshwater habitats, threats and implications on their sustainable conservation.

The host specificity of freshwater mussel larvae is a parasitic phenomenon leads to coevolution of species. The glochidia encounter host fishes by the attraction or because of dominance of particular host species in the habitat. Evolution of host specificity is associated with selective encounter of host taxa, because of host. However, this is evident from the studies of Reynolds *et al.*, (1997), wherein the congruent behaviour of European bitterlings on freshwater mussels is shown. There the larvae of fishes belonging to genera *Acheilognathus* and *Tanakia* found living in mussels with simple gills (Ableminae family), *Rhodeus* spp. preferred the mussels of family Anodontinae and Unioninae, having complex gill structures. Higher dispersal abilities of free-living larvae of *Anodonta* spp. could be partially attributed to their distribution worldwide (Douda *et al.*, 2012). Besides its introduction in different continents could be due to the presence of sympatric fish hosts. Among Unionid species, the host specificity varies from specialists that have the ability to parasitize one or few species of host and generalists that can complete the development in taxonomically broad range of species (Blazhekovikj-Dimovska *et al.*, 2023). The mussel *A. woodiana* is a generalist in host selection and known to complete its development on eight fish species that are either native or co-invasive (Douda *et al.*, 2012).

Host specificity freshwater pearl mussel *Margaritifera margaritifera* has been investigated in Austria (Jung *et al.*, 2013). The brook char fish *Salvelinus fontinal* and brown trout *Salmo trutta*, were found to be the suitable hosts for the larvae of these mussels. This specificity has been attributed to the increased resistance of the glochidia to these host fishes among other fish species. Yeager and Sailor (1995) identified host fishes for four mussel species (Table 1), inferring that these hosts occupy fast running waters and riffle habitats. Nevertheless, DNA barcoding has proved to be a useful tool in identification of fish hosts (Marshal *et al.*, 2018). Quantification of higher infestation and prevalence of glochidia in fishes would enhance the knowledge on the preferred host species.

Table 1: Suitable hosts of freshwater mussels

Mussel species	**Fish hosts**
Margaritifera margaritifera	*Salvelinus fontinal, Salmo trutta, Salvelinus fontinalis*
Margaritifera dahurica	*Brachymystax* spp. and *Thymallus tugarinae*
Margaritifera falcata	*Oncorhynchus tshawytscha, O. kisutch, Parasalmo clarki, P. mykiss, Gasterosteus aculeatus*
Margaritifera hembeli	Escosidae
Margaritifera marrianae	Esocidae
Lampsiline mussels	Percids: *Villosa nebulosa, Micropterus dolomieu, Ambloplites rupestris, Cottus carolinae, Medionidicus* spp, *Etheostoma rufilineatum, Etheostoma flabellare*
Epioblasma spp *Quadranula intermedia*	*Erimystax dissimilis* and *Erimystax insignis*
Cumberlandia monodonta	Hiodontidae: *Hiodon tergisus, H. alosoides.*
Pseudunio spp, *Gibbosula* spp.	Unknown but surely non-salmonids
Unio crassus	*Scardinius erythrophthalmus, Phoxinus phoxinus, Cottus gobio*
Utterbackia imbecillis	*Lepomis macrochirus*

Source: Zale and Neves, 1982; Yeager and Sailor, 1995; Vikhrev et al., 2019.

The global decline in freshwater mussel diversity is mainly because of anthropogenic habitat alterations. The most common threat to mussel population is construction of dams. It leads to habitat destruction and removal of dams takes many years for freshwater mussel population to recover in the same region (Liu *et al.*, 2019). Pearl exploitation from freshwater mussels has decreased mussel population drastically (Vikhrev *et al.*, 2019). The hosts of *Margaritifera dahurica* namely *Brachymystax* species have become endangered. This is due to overfishing, water pollution and environmental changes, in particular, and destruction of their natural habitats caused by channel improvement in China. Besides, illegal fishing, intensive in rivers of the Japan and other countries due to which the fish hosts are lost (Vikhrev *et al.*, 2019).Therefore, maintaining favourable habitat conditions, connectivity of rivers or lakes has been recommended. This is expected to strengthen study of life histories with host-test experiments to identify potential host fish species to promote freshwater mussel conservation.

The reports enlisting the host-glochidial relationship and their threats are scanty. However, few publications over the globe discuss the fish-mussel specificity. Modesto *et al.*, (2017) noted the percentage of mussel species that are under IUCN threat list are addressed in the literature. In North America and Europe, highest mussel species (40% and 52%) fall into Near Threatened or Least Concerned category. About 65% of the mussel species are Near Threatened or Least Concerned in Asia whereas, in other continents 76% are Data deficient and Not evaluated (Fig. 2). The data deficient status indicates that there is no much information available on the Unionid species from many continents and on their host fishes. The existing species are at a risk of becoming endangered in the future because of human interventions in their habitats.

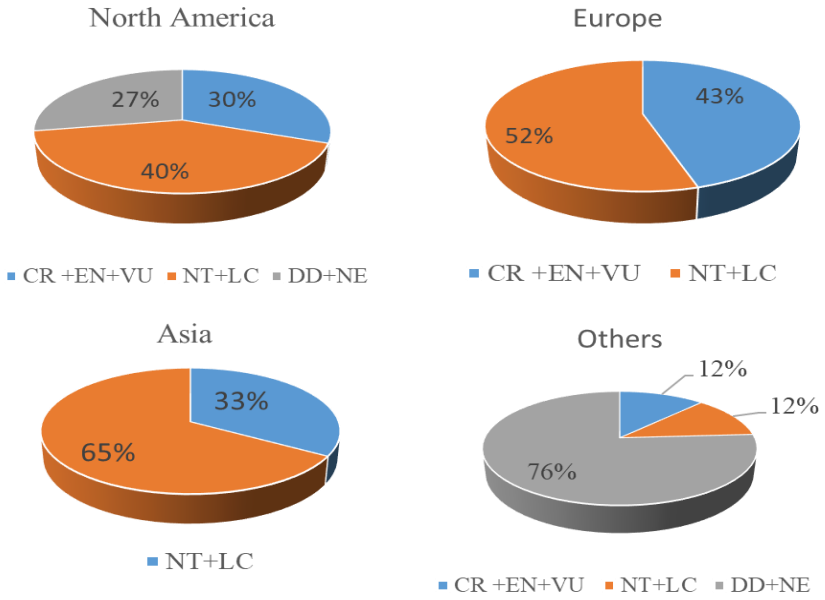

Fig. 2: **Percentage of freshwater mussel species in IUCN categories that were reported in publications related to fish–mussel relationship** *(CR: Critically endangered; EN: Endangered: VU; Vulnerable, NT: Near Threatened; LC: Least concerned, DD: Data deficient, NE: Not evaluated) (Source: Modesto et al., 2017).*

Douda *et al.*, (2012) opined that the threats to mussels result from host unavailability or rare availability of fishes needs to be incorporated into conservation. Their experiments indicated that the glochidia of *Unio crassus* metamorphosed only in three species of host fishes among the other fish hosts (Table 1). Conversely, Reis *et al.*, (2014) showed that the parasitism is more host specific, because glochidia of *Unio tumidiformis* successfully metamorphosed exclusively on cyprinids of the genus *Squalius.* More data is

needed on the fish availability and host limitation, their abundance to identify potential threats to this mussel species.

The population of host fishes and glochidia decline due to anthropogenic disturbances in freshwater ecosystem such as temperature changes, habitat degradation, siltation, and pollution (Vikhrev *et al.*, 2019). The specific host fishes that are infested with glochidia may not transform in the same hosts. The non-host embryos parasitize the gills of mussels causing biological threat to mussel population (Eg: Fish *Rhodeus sericeaus* in gills of *M. dahurica*). Literature suggests incorporation of host limitation or specificity issues into conservation if the glochidial limitation of Unionids to fish hosts is previously known (Douda *et al.*, 2012). The host specificity data would be useful in conservation of threatened freshwater mussels or rare mussel species. Artificial breeding of mussels in fish hatcheries with their host fishes would be helpful in expansion of mussel and host population (Vikhrev *et al.*, 2019). Mussel culture or propagation programs may be beneficial in restoring declined or lost mussel population (Marshal *et al.*, 2018).

CONCLUSION

The host mussel relationship is obligatory, for the freshwater mussels to complete the life cycle in their habitats. Glochidial preference for attachment to the host is improperly known, can be attributed to the availability and abundance of particular species or different fish species belonging to the same group. The review infers that the host-parasite relationship of freshwater mussels is more ecologically driven. Host specificity data would be beneficial for conservation of rare mussel species and to lessen their population decline. Identification of threats to Unionids in future is required for the management of glochidial population. Artificial breeding of mussels and host fishes is suggested for their conservation.

Conflict of interest: *The author has no conflicts of interests.*

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