Spring 2014

Water for Electricity in the Upper Savannah Basin: Impacts on Freshwater Mussels

Alan Johnson
Clemson University

Snehal Mhatre
Clemson University

Water for Electricity in the Upper Savannah Basin: Impacts on Freshwater Mussels

Alan Johnson and Snehal Mhatre
School of Agricultural, Forest and Environmental Sciences, Clemson University, South Carolina

INTRODUCTION

Freshwater mussels are among the most imperiled animals worldwide. These unionids tend to be most abundant in flowing streams and rivers. The distribution of unionids is often patchy, clumped, or otherwise irregular. Native freshwater bivalves particularly belonging to the family Unionidae are widely distributed in North America with 297 recognized taxa (William et al 1993). Of these 297 known taxa only 70 are considered to be stable. The greatest species diversity occurs in the southeastern US (Neves 1987) which has more freshwater mussel species than any other region of the world . All of South Carolina's freshwater mussel species belong to the family Unionidae. Of these, 26 species are in the SC DNR's CWCS priority species list (Kohlsaat et al. 2005), and several of these occur in the Savannah River Basin.

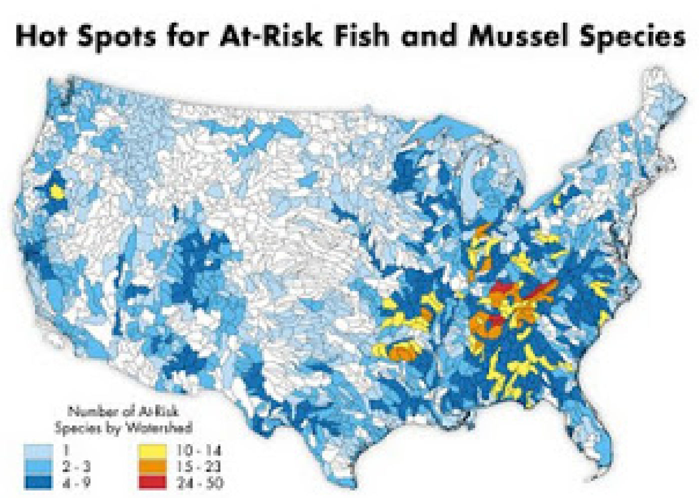


Fig. 1. Watersheds with 10 or more at-risk fish and mussel species. Concentration is highest in the Southeast, depicting the watersheds at risk of losing endemic biodiversity (Rivers of Life).

INTRODUCTION

The freshwater mussels populations have undergone dramatic historical declines, local extirpations, and extinctions. Many causal factors have been implicated, including the habitat degradation and altered hydrology associated with dams (Downing et al. 2010). Dams also fragment unionid metapopulations by acting as dispersal barriers for host fish. (Newton et al. 2008). Hydrologic alteration and low-temperature discharges associated with dam operations can affect unionid survival and reproduction (Peterson et al. 2011). The unionids have a long life span and a slow response time (Jackson et al 2005), hence the effects of human induced changes on regional unionid populations may only be fully expressed after a considerable lag time.

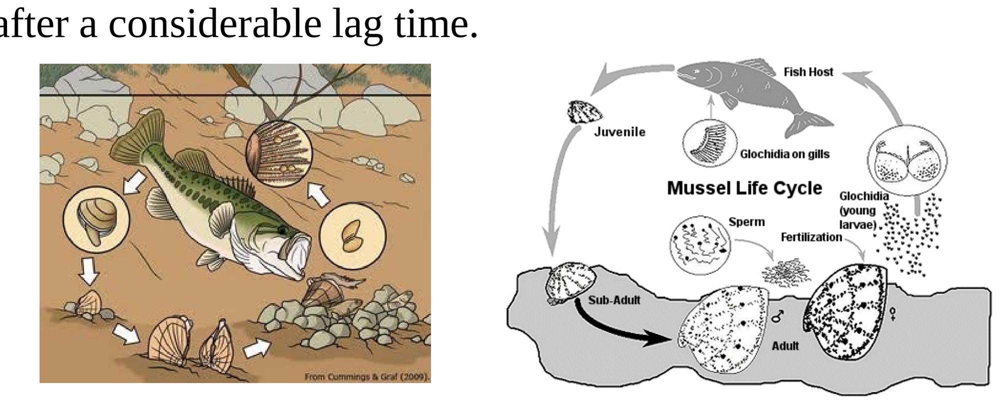


Fig. 2 & 3. Lifecycle of the unionid species

MATERIALS & METHODS

What factors limit the abundance of mussels in large rivers?

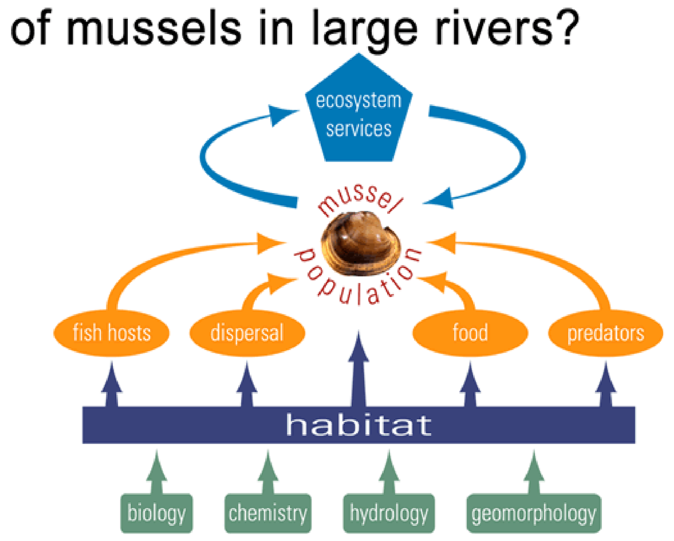


Fig. 4. Generalized Population Model for Freshwater mussels Source:4http://www.umesc.usgs.gov/native_mussels_team.html .

For this study we implemented a stage structured – Lefkovitch matrix population model in RAMAS GIS (Akçakaya 1998). The demographic parameters used in the simulations were chosen to match the dynamics of a age-classified model developed by Jones et al. (2012) for *Epioblasma capsaeformis.*

The Stage-classified matrix model has four stages a) recruits (juveniles) b) sub-adults c) small adults d) large adults. The demographic parameters represent "typical" unionid: long-lived (high adult survival), delayed maturity, low fecundity and variable recruitment. Demographic and environmental stochasticity were included in the model because both the factors can seriously affect small population sizes and expose them to the risk of extinction. Population projections were stochastic (1000 iterations). Dispersal distance function represents host fish mobility assuming host fish exist both upstream and downstream.

The model derived from Jones et al (2012) was run to consider three different scenarios with 1000 replications and 10 metapopulations:

1) Only barrier effect (B model) : Considers dispersal and correlation matrices.
2) Only habitat degradation (H model) : Considers dispersal as a function of barrier effect and correlation matrix
3) Both barrier effect and habitat degradation (BH model)

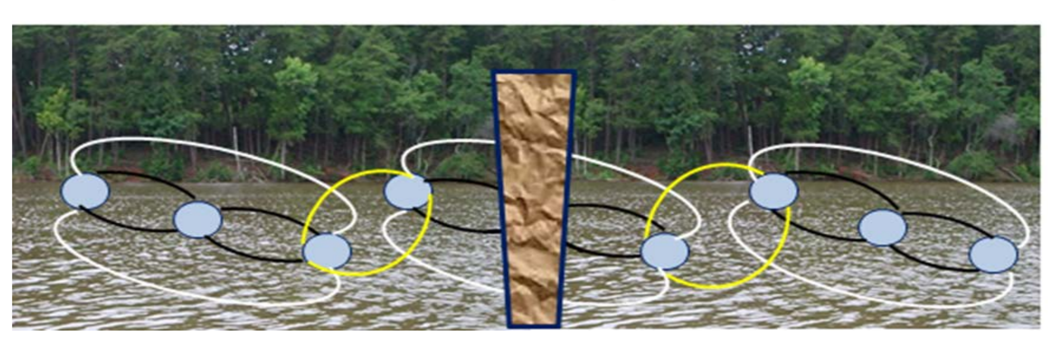


Fig. 5. Metapopulations of unionids interacting in a stretch of free-flowing stream

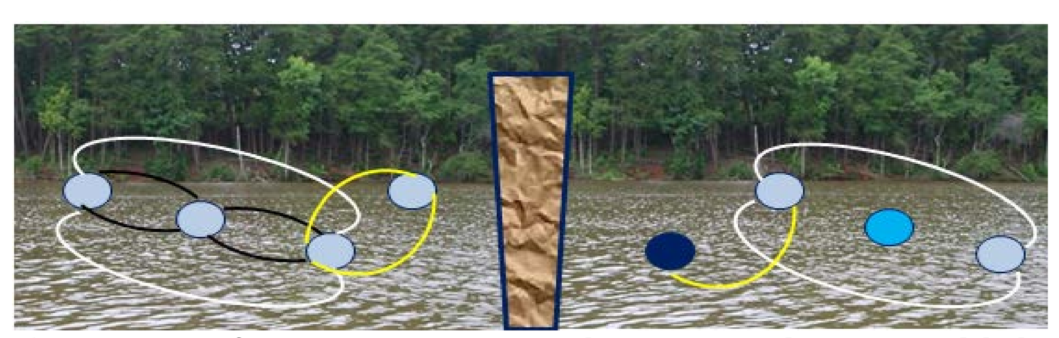


Fig. 6. Loss of connectivity among the metapopulations and habitat degradation due to barrier effect of dams/reservoirs

RESULTS

Fig 7. Trajectory summary of the combined BH model over 1000 simulations

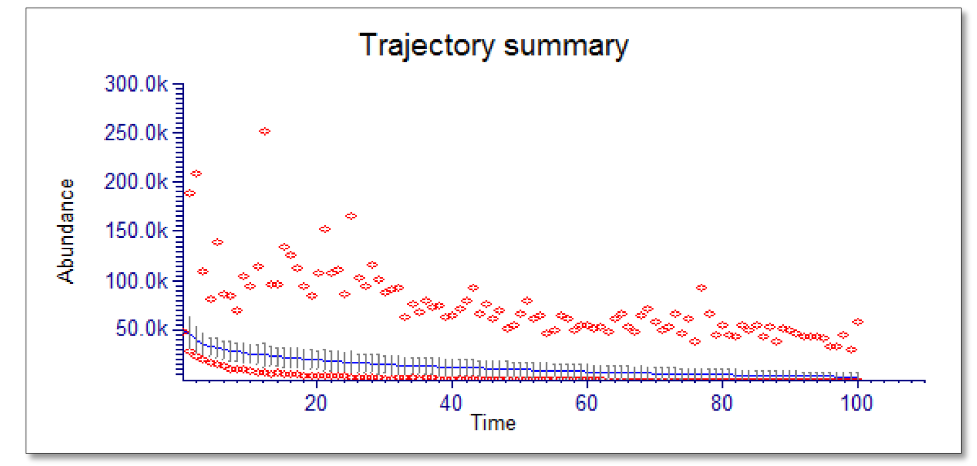


Fig. 8. Extinction probability of the BH model over 1000 simulations

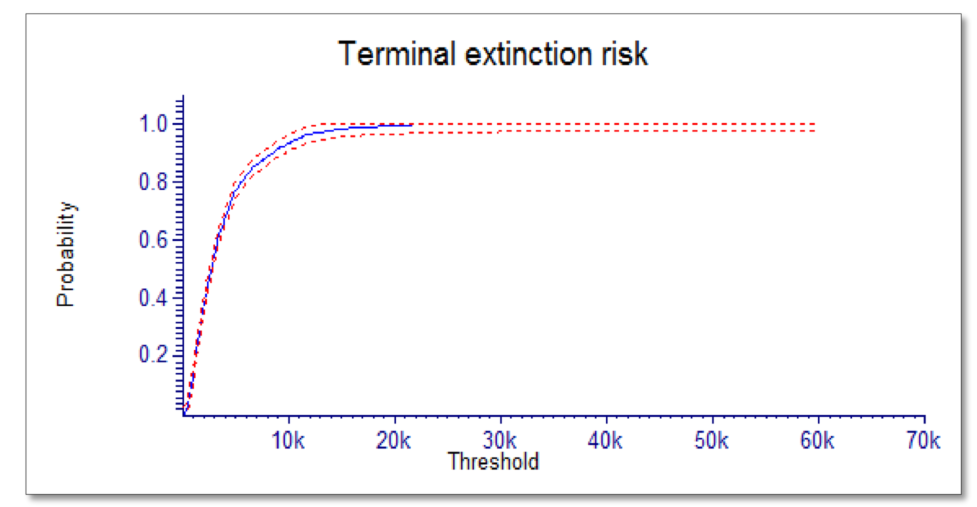


Fig. 9. Metapopulation Trajectory – Effects of Dam

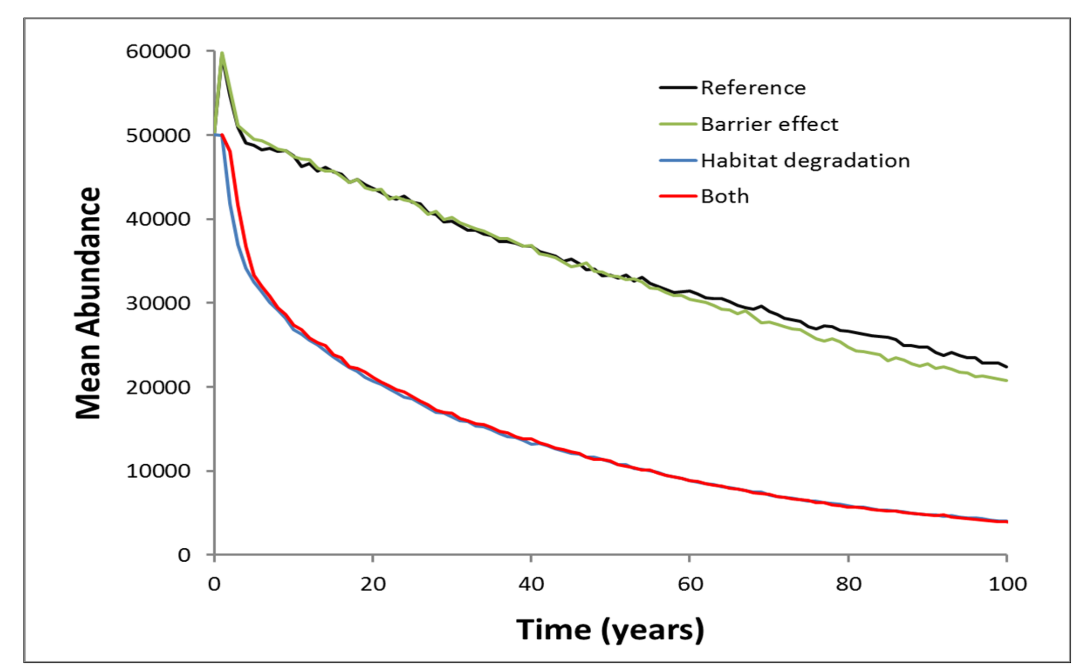
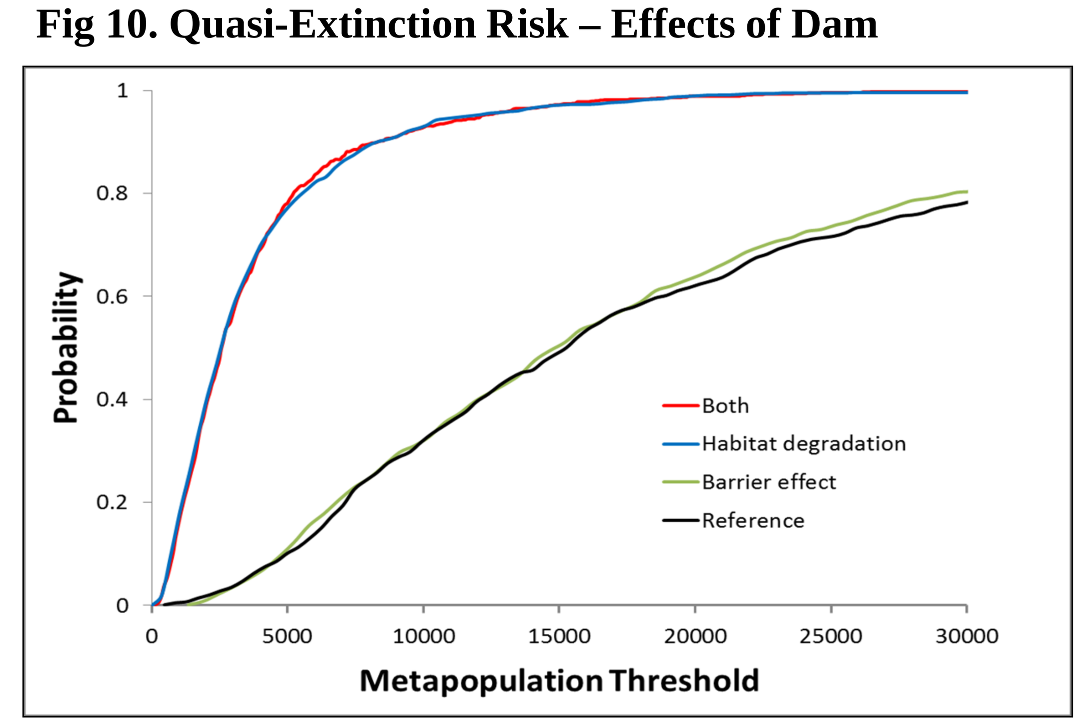


Fig 10. Quasi-Extinction Risk – Effects of Dam



CONCLUSIONS

1) As seen in the Fig.9 the primary effect of a dam on unionid metapopulation dynamics is expected to occur due to habitat degradation rather than barrier effect.
2) The mean abundance in the metapopulation trajectory is same for the reference model and the barrier effect model but the mean abundance value for the habitat degradation and the combined effect model plummet sharply to almost half of the original mean abundance value.
3) The combined effect of habitat degradation and barrier effect leads to a drastic increase in the probability of local extinctions.

DISCUSSION

- Turbidity and sedimentation caused due to degraded habitat have been documented of causing low recruitment and juvenile mortality thus dwindling mussel populations.
- In South-eastern US, natural drought and changing hydrologic regime due to dams has led to the creation of isolated pools, resulting in high summer water temperatures and subsequent mortality of these thermally sensitive species (Galbraith et al 2010).

Limitations:

- This assumes that host fish persist both upstream and downstream of the dam.
- Only direct demographic effects were modeled (not genetic consequences such as disease or bottlenecks)
- Fragmented metapopulations may be more vulnerable to localized catastrophes.

LITERATURE CITED

- Graf, D.L. & K.S. Cummings. 2009. Actual and alleged freshwater mussels (Mollusca: Bivalvia: Unionoida) from Madagascar and the Mascarenes, with description of a new genus, Germainaia. Proceedings of the Academy of Natural Sciences of Philadelphia 158: 221-238.
- Williams, J. D, M. L. Warren, K. S. Cummings, J. L. Harris, and R. J. Neves (1993). "Conservation Status of Freshwater Mussels of the United States and Canada". *Fisheries* **18** (9):6.22
- Neves, R. J., & Widlak, J. C. (1987). Habitat ecology of juvenile freshwater mussels (Bivalvia: Unionidae) in a headwater stream in Virginia. American Malacological Bulletin, 5(1), 1-7.
- Kohlsaat, T., L. Quattro, and J. Rinehart. 2005. *South Carolina Comprehensive Wildlife Conservation Strategy, 2005-2010.* South Carolina Department of Natural Resources.
- Downing, J.A., P. Van Meter, and D.A. Woolnough. 2010. Suspects and evidence: a review of the causes of extirpation and decline in freshwater mussels. *Animal Biodiversity and Conservation* 33(2): 151-185.
- Newton, T.J., D.A. Woolnough, and D.L. Strayer. 2008. Using landscape ecology to understand and manage freshwater mussel populations. *Journal of the North American Benthological Society* 27: 424-439.
- Jackson, C., J. Martin, D. Leigh, and L. West. 2005. A southeastern piedmont watershed sediment budget: evidence for a multi-millennial agricultural legacy. *Journal of Soil and Water Conservation* **60**: 298-310.
- Master, Lawrence L., Stephanie R. Flack and Bruce A. Stein, eds. 1998. Rivers of Life: Critical Watersheds for Protecting Freshwater Biodiversity. The Nature Conservancy,
- Jones, J.W., R.J. Neves, and E.M. Hallerman. 2012. Population performance criteria to evaluate reintroduction and recovery of two endangered mussel species, *Epioblasma brevidens* and *Epioblasm capsaeformis* (Bivalvia: Unionidae). *Walkerana* **35**: 27-44.
- Galbraith,et al (2010). Synergistic effects of regional climate patterns and local water management on freshwater mussel communities. *Biological Conservation, 143*(5)