# Book of Abstracts

BUFFALO NY, USA, 4-8 OCTOBER 2015

2nd
INTERNATIONAL MEETING ON BIOLOGY AND
CONSERVATION OF FRESHWATER BIVALVES

**Title:** 2nd International Meeting on Biology and Conservation of Freshwater Bivalves: Book of Abstracts

**Editors:** Knut Mehler, Lyubov E. Burlakova, Alexander Y. Karatayev, Susan Dickinson

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**August 2015**

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# 2nd International Meeting on Biology and Conservation of Freshwater Bivalves:

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Buffalo, USA

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Knut Mehler

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Susan Dickinson

Great Lakes Center

Buffalo State College

The State University of New York

August 2015

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# Preface

Freshwater bivalves are a very important part of biodiversity, increasingly recognized as having key roles in the ecosystems they inhabit. Their global decline has been causing increasing concern. Although in recent decades there has been an increasing number of studies on the ecology and conservation of these animals, the integration of knowledge acquired by different research groups becomes urgent. This approach, in a comprehensive and integrative manner will also help policy makers to establish guidelines, which can then be applied in conservation management of these animals and their natural habitats.

It is under this perspective that we introduce the present event that brings together international experts in biology and conservation of freshwater bivalves which, through a cycle of conferences and debates, will be able to create a network of knowledge with the final goal of developing collaborative projects and eventually global directives for the protection and conservation of this important group of fauna. The conference will cover diverse topics in the field of biology and conservation of freshwater bivalves, such as:

- Anthropogenic impacts and climate change
- Biogeography
- Conservation and threats to species and ecosystems
- Experimental studies
- Genetics
- Invasive species
- Life history traits
- Physiology
- Systematics and taxonomy
- Taxonomy

In this context we would like to express our appreciation to our sponsors and organizing institutions, and our gratitude to our key note speakers, authors, session chair persons and all attendees whose contribution have made the meeting a success.

# Organization

Great Lakes Center at Buffalo State. The State University of New York.


BUFFALO STATE
The State University of New York

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Manuel Lopes-Lima - Mollusk Specialist Group (IUCN/SSC) and CIIMAR, Porto University, Portugal

# Keynote Speakers

## Caryn Vaughn

*Presidential Professor*
*Oklahoma Biological Survey and Department of Biology*
*University of Oklahoma*
*Oklahoma, United States*

Caryn Vaughn is the Presidential Professor of Biology in the Oklahoma Biological Survey and Department of Biology at the University of Oklahoma. Her research focuses on the ecology and conservation biology of streams, in particular the functional roles of freshwater mussels, and in quantifying the ecosystem services provided by stream organisms. For her outstanding research she received the "Lifetime Achievement Award" from the Freshwater Mollusk Conservation Society. She was also honored for "singular accomplishments and long-term contributions that have advanced the conservation and science of freshwater mollusks at a national and international level." This is the highest honor that this society gives, and Dr. Vaughn is the first woman to have received the award.

## Kevin Cummings

*Senior Research Scientist and Curator of Mollusks*
*Center for Biodiversity, Illinois Natural History Survey*
*Illinois, United States*

As the Senior Research Scientist and Curator of Mollusks at the Center for Biodiversity, Illinois Natural History Survey, Cummings is a renowned expert on mussels, and their protection and conservation. For decades, he has monitored mussels throughout Illinois, the Midwest, and around the world. Beyond his groundbreaking field work, Cummings has a special talent as an ambassador for these overlooked organisms, continuously engaging in public education regarding the value of mussels as sentinels and indicators of water quality and ecosystem health. His research interests are in the areas of conservation, systematics and ecology of freshwater mollusks and fishes, and the protection of freshwater habitats, primarily streams. Cummings received the Outstanding Public Servant award for a distinguished career spent researching and fostering critically important freshwater mussels, often called "the livers of the rivers."

## Alexander Y. Karatayev

*Director of the Great Lakes Center*
*SUNY Buffalo State*
*New York, United States*

Alexander Karatayev is the current Director of the Great Lakes Center at SUNY Buffalo State. He earned his Ph.D. and the Doctor of Science degrees in Hydrobiology in 1983 and in 1992. His current research focuses on spatial and temporal dynamics of benthic communities; the diversity, distribution, and conservation of native freshwater molluscs; and the ecology, biology, and patterns of spread of exotic species, as well as their role in aquatic ecosystems. The geography of his research activity includes Europe, Asia, and North and South Americas. Dr. Karatayev has published over 100 papers, presented over 100 talks at various meetings, and received over 30 research grants as principal investigator and/or co-investigator.

## Manuel Lopes-Lima


*Research Scientist*
*Mollusk Specialist Group (IUCN/SSC)*
*Aquatic Ecology and Evolution Laboratory*
*CIIMAR - Porto University, Portugal*

Manuel Lopes-Lima works at the Aquatic Ecology and Evolution Laboratory of CIIMAR - Interdisciplinary Centre of Marine and Environmental Research, University of Porto, Portugal. He is currently the (IUCN/SSC) Coordinator of the Red List Authority on Freshwater Bivalves within the Mollusk Specialist Group. His research interests are related with the global conservation of freshwater mussels including phylogeny, genetic diversity and ecophysiology. He is also an active promoter of international research efforts around this faunistic group, being one of the co-founders of these meetings among other actions. He is involved in international conservation projects in Portugal, Spain, Italy, Greece, Turkey, Morocco, and Malaysia.

# Venue - City

## Buffalo - The City of Good Neighbors

The conference will be held at the Hyatt Regency in downtown Buffalo, New York, USA. The city is located on the eastern shore of Lake Erie and the head of the Niagara River; a natural and historically rich environment. Founded in 1801 as a small trading community, it is nowadays the second largest city in New York State with its largest sector's being financial services, health care, technology, and education. As a melting pot of cultures, cuisine in the Buffalo area reflects a variety of influences. These include Italian, Irish, Jewish, German, Polish, African-American, Greek, Indian and American influences.

Buffalo is home to over 50 private and public art galleries, most notably the Albright-Knox Art Gallery, home to a world-class collection of modern and contemporary art. The local art scene is also enhanced by the Burchfield-Penney Art Center, Hallwalls Contemporary Arts Center, CEPA Gallery, Shea's Performing Arts Center, and the Buffalo Philharmonic Orchestra.

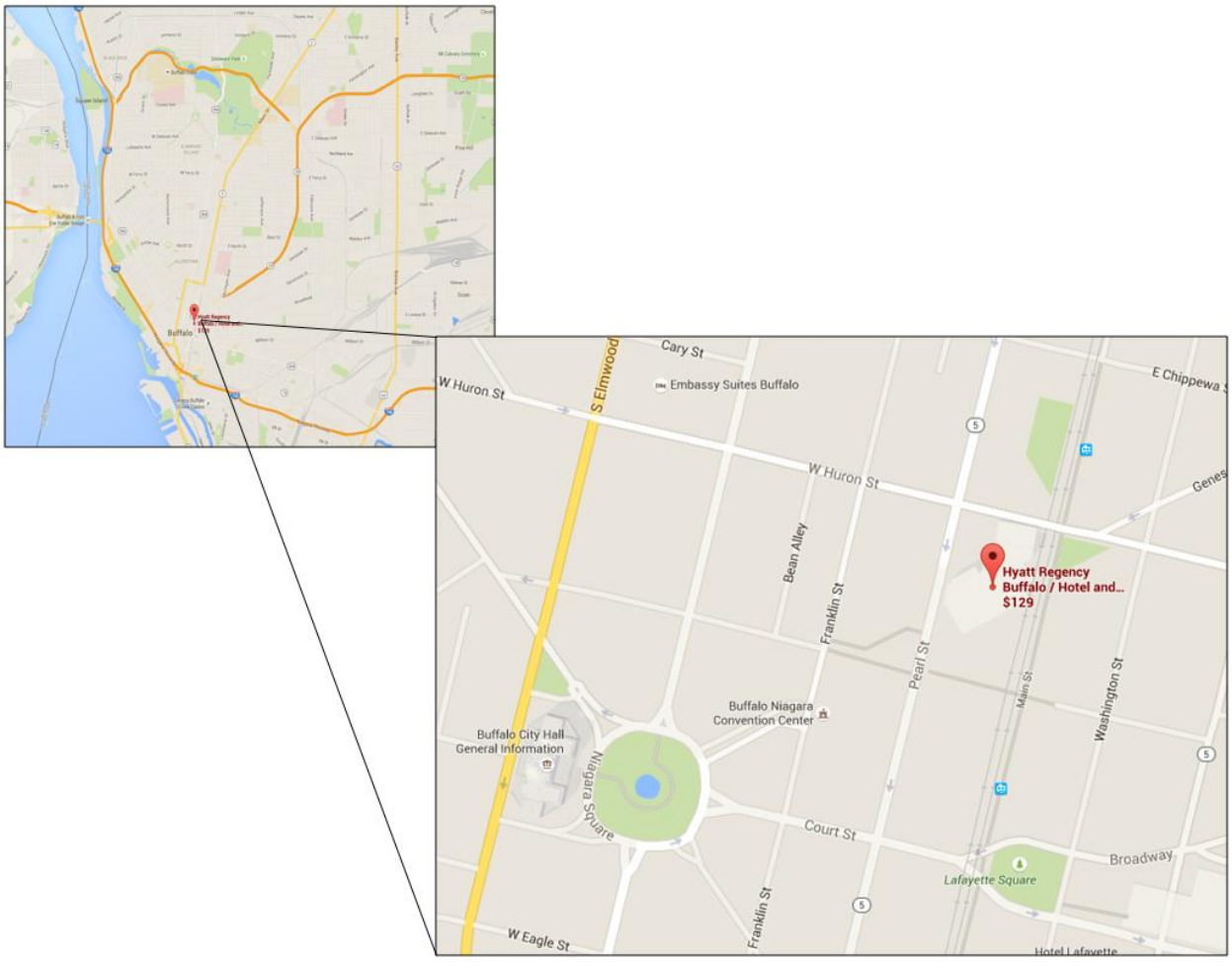
# Venue - Hotel

Hyatt Regency Buffalo

Two Fountain Plaza, Buffalo, NY 14202, USA

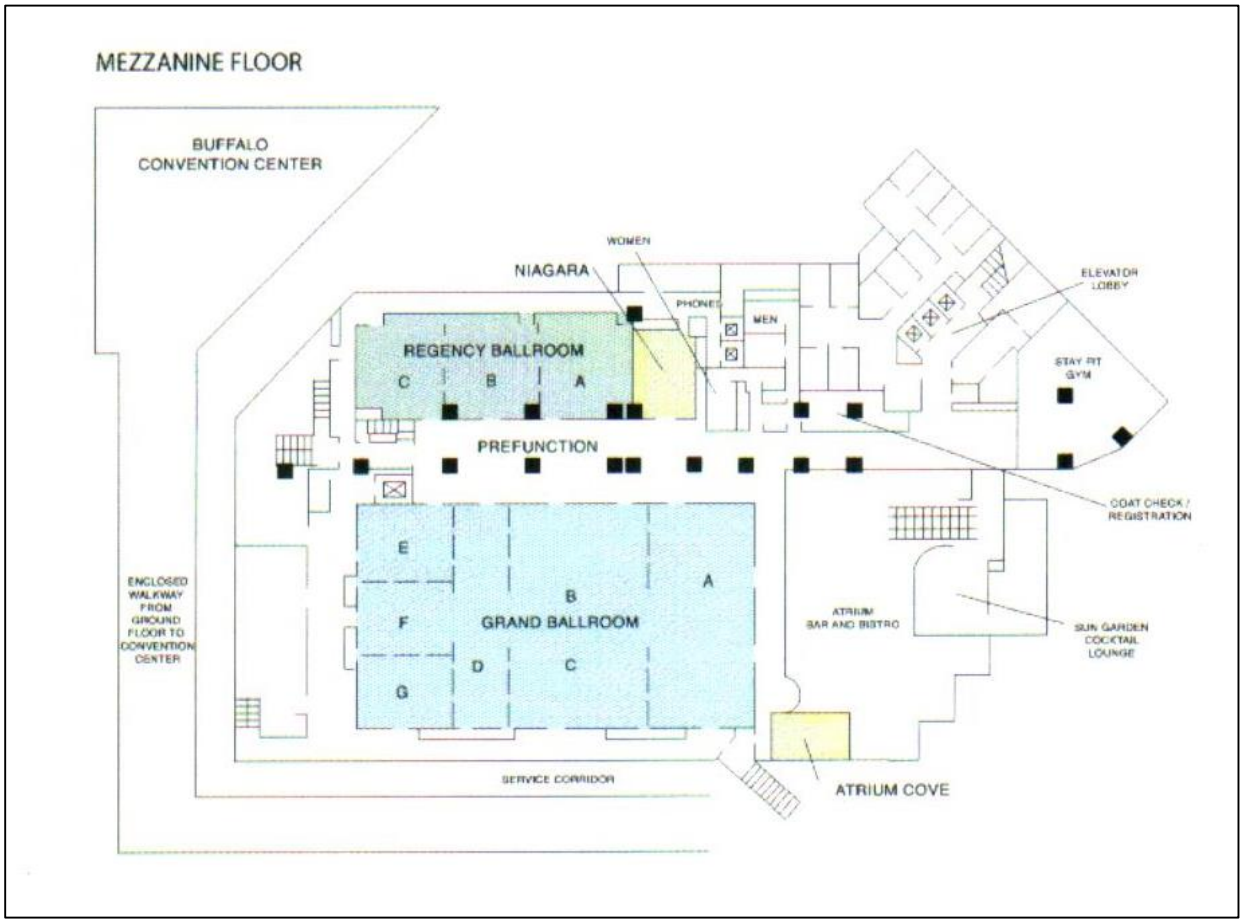
Web: www.Buffalo.hyatt.com

Phone: 716-856-1234



# Venue - Floor Plan

Oral presentations will be held in the Grand Ballroom (A). The poster reception will be held in the Ballroom Prefunction Area.




# Venue – Directions

## International flights

The nearest international airport is Buffalo/Niagara International Airport which is connected to several larger international airports such as New York's JFK, La Guardia and Newark; Detroit; Atlanta; Las Vegas; Philadelphia; and Charlotte.

## Train

Amtrak trains run daily between Buffalo Depew Train Station and larger cities in the United States and Canada, such as New York Penn Station, Detroit, and Toronto.

## Freeways

From East: Take I-90 West to Exit 51W (NY-33 West). Take the Goodell Street exit from NY-33 West, then bear left onto Pearl Street (NY-5 W). After three blocks, Hyatt Regency Buffalo will be on the left.

From West: Take I-90 East to I-190 North to Exit 8 (NY-266 Niagara Street). Turn right onto Niagara Street (south), then turn left onto West Huron Street. Turn right onto Pearl Street, and Hyatt Regency Buffalo will be immediately on your left.

# Schedule Overview

| Time | Sunday, Oct. 4, 2015 | Monday, Oct. 5, 2015 | Tuesday, Oct. 6, 2015 | Wednesday, Oct. 7, 2015 | Thursday, Oct. 8, 2015 |
|---|---|---|---|---|---|
| 9.00-9.20AM | | Conference Opening | Keynote Speaker Alexander Y. Karatayev | Keynote Speaker Manuel Lopes-Lima | Field Trips |
| 9.20-9.40AM | | | | | |
| 9.40-10.00AM | | Keynote Speaker Caryn Vaughn | Oral Presentations | Oral Presentations | |
| 10.00-10.20AM | | | | | |
| 10.20-10.40AM | | Coffee Break | Coffee Break | Coffee Break | |
| 10.40-11.00AM | | Oral Presentations | Oral Presentations | Oral Presentations | |
| 11.00-11.20AM | | | | | |
| 11.20-11.40AM | | | | | |
| 11.40-12.00AM | | | | | |
| 12.00-1.00PM | | Lunch Break | Lunch Break | Lunch Break | |
| 1.00-1.20PM | | Keynote Speaker Kevin Cummings | Oral Presentations | Oral Presentations | |
| 1.20-1.40PM | | | | | |
| 1.40-2.00PM | | Oral Presentations | | | |
| 2.00-2.20PM | | | | | |
| 2.20-2.40PM | | | | | |
| 2.40-3.00PM | | | | | |
| 3.00-3.20PM | Registration | | | | |
| 3.20-3.40PM | | Coffee Break | Coffee Break | Coffee Break | |
| 3.40-4.00PM | | Oral Presentations | Oral Presentations | Oral Presentations | |
| 4.00-4.20PM | | | | | |
| 4.20-4.40PM | | | | | |
| 4.40-5.00PM | | | | | |
| 5.00-5.20PM | | | | | |
| 5.20-5.40PM | | | | | |
| 5.40-6.00PM | | | | | |
| 6.00-9.00PM | Welcome Reception | Poster Reception | | Closing Dinner | |

# Oral Presentations Overview

## Monday, October 5th

| | | |
|---|---|---|
| 9.40-10.20AM | *Invited Speaker: Caryn Vaughn* | **Ecosystem services provided by freshwater bivalves** |
| 10.40-11.00AM | *Spooner, D., Hamilton, D.* | **Ecological services of a host-affiliate relationship across a gradient of nutrient loading** |
| 11.00-11.20AM | *Taskinen, J.* | **Trematode parasitism, an 'ecosystem service' provided by freshwater mussels** |
| 11.20-11.40AM | *Kreeger, D., Gatenby, C. Howard, J.* | **Comparison of particle filtration ecosystem services by North American freshwater mussels fed on natural seston** |
| 11.40-12:00PM | *Acharya, K., Ruhmann, E., Davis, C.J., Chandra, S.* | **A comparison of growth and survival of quagga mussel veligers in low and high calcium waters** |
| 1.00-1.40PM | *Invited Speaker: Kevin Cummings* | **The freshwater mussels (Bivalvia: Unionoida) of South America: A review** |
| 1.40-2.00PM | *Bespalaya, Y.V., Bolotov, I.N., Aksenova, O.V., Kondakov, A.V., Gofarov, M.Yu.* | **Biogeography, ecology and adaptive strategies of freshwater bivalves (Bivalvia: Sphaeriidae) in Arctic** |
| 2.00-2.20PM | *Konopleva, E., Kondakov, A., Vikhrev, I., Bespalaya, Y., Tumpeesuwan S., Bolotov, I.* | **Biogeography of freshwater mussels (Bivalvia: Unionoida) across the largest Southeast Asian riverbasins: Endemism and biodiversity assessment** |
| 2.20-2.40PM | *Sîrbu, I., Benedek, A.M.* | **The Naiads (Bivalvia: Unionidae) from Romania: Trends in knowledge, distribution, ecological requirements and human impacts** |
| 2.40-3.00PM | *Klunzinger, M.W., Lymbery, A.J., Walker, K.F.* | **A review of the life history of Australasian freshwater mussels with new information from Western Australia** |
| 3.00-3.20PM | *von Proschwitz, T., Falkner, G.* | **Nomenclatural remarks on some Western-Palearctic Najades (Bivalvia: Unionacea)** |
| 3.40-4.00PM | *Strayer, D.L., Malcom, H.M.* | **Twenty-five years of change in the Hudson River's bivalve populations** |

| | | |
|---|---|---|
| 4.00-4.20PM | Dittman, D., Johnson, J., Nack, C. | **Biology and habitat of *Sphaerium striatinum* in two streams in the upper Susquehanna River drainage** |
| 4.20-4.40PM | Sousa, R. | **From common to probably extinct: Tales about the peaclam *Pisidium amnicum* in the Minho River (Portugal)** |
| 4.40-5.00PM | Varandas, V., Assunção, T., Teixeira, A., Cortes, R., Lopes-Lima, M., Sousa, R., Froufe, E. | **Characterization and protection of native species of bivalves in two coastal lagoons** |
| 5.00-5.20PM | Bogan, A.E., Froufe, E., Ghamizi, M., Mock, K., Kebapci, U., Klishko, O., Kovitvadhi, S., Kovitvadhi, U., Paulo, O.S., Raley, M., Riccardi, N., Pfeiffer, J.M. III, Sereflisan, H., Sousa, R., Teixeira, A., Do, V.T., Varandas, S., Wu, X.P., Zanatta, D., Zieritz, A., Lopes-Lima, M. | **Unravelling the UNIONIDAE: Examination of subfamily relationships within Unionidae** |
| 5.20-5.40PM | Callil, C., Mateus, L., Leite, M., Jones, J. | **Life history trade-off of *Anodontites trapesialis* (Lamarck, 1819) (Bivalvia: Mycetopodidae) in a wetland: An evolutionary or environmental adaptation?** |

## Tuesday, October 6th

| | | |
|---|---|---|
| 9.00-9.40 AM | *Invited Speaker: Alexander Y. Karatayev* | **Endangered or invaders? Molluscs - the most imperiled group of freshwater invertebrates includes the highest number of invaders** |
| 9.40-10.00AM | Lucy, F.E., Sullivan, M.R., Moran, H. | **Invasion history of *Dreissena polymorpha*, the zebra mussel in Lough Key, an Irish lake** |
| 10.00-10.20AM | Bergengren, J., Svensson, J.-E., von Proschwitz, T., Lundberg, S. | **A recent *Dreissena* invasion in an old canal system in northern Europe** |
| 11.00-11.20AM | Mehler, K., Karatayev, A.Y., Burlakova, L.E. | **Estimation of exotic bivalve distribution and abundance in a large river using traditional sampling, remote sensing, and GIS-derived benthic habitat maps** |

| | | |
|---|---|---|
| 11.20-11.40AM | *Collas, F.P.L., Buijse, A.D., Hendriks, A.J., Leuven, R.S.E.W.* | **Using species sensitivity distributions for assessing effects of river management measures on native and non-native mollusc assemblages** |
| 11.40-12:00PM | *King, T.* | **Enhanced phylogeography, demography, and life history resolution in unionid species: Transitioning from population genetics to population genomics** |
| 1.00-1.20PM | *Breton, S., Stewart, D.* | **Sex determination in freshwater mussels: A mitochondrial story** |
| 1.20-1.40PM | *Krebs, R.A., Zanatta, D.T.* | **Dispersal and gene flow in unionid mussels and the boundaries defining Great Lakes assemblages** |
| 1.40-2.00PM | *Zanatta, D., Hewitt, T.L., Mathias, P* | **Varied patterns of post-glacial dispersal by freshwater mussels species into the North American Great Lakes with implications for conservation and management of imperiled taxa** |
| 2.00-2.20PM | *Porto-Hannes, I., Burlakova, L., Lasker, H.* | **Species boundaries and levels of intermixing between two freshwater mussel species (Family: Unionidae)** |
| 2.20-2.40PM | *Vikhrev, I., Bespalaya, Y., Gofarov, M., Konopleva, E., Tumpeesuwan, S., Minn, M., Bolotov, I.* | **Morphological variability of Indochinese pearl mussels: Environmental signal or chance for species identification?** |
| 2.40-3.00PM | *McElwain, A., Bullard, S.* | **Cellular changes associated with nematode infections in the foot of the Alabama rainbow (*Villosa nebulosa*)** |
| 3.00-3.20PM | *Springall, B., Fleming, R., Gulkarov, A., Kyaw, W., Lajoie, M., Lima Da Silveira Jr., L., Lovell, J., Maney, C., McElwain, A.* | **Pathological changes associated with a co-infection of metacercaria (Digenea) and eggs of *Unionicola* sp. (Acari, Uninonicolidae) in the mantle of *Elliptio complanata* (Bivalvia, Unionidae)** |
| 3.40-4.00PM | *Cole, J.C., Galbraith, H.S., White, B. St. J., Lellis, W.A., Blakeslee, C.J., Weaver, S., Wicklow, B.J.* | **Variation in growth and survival in *Alasmidonta heterodon* across locations in the Northeast United States** |
| 4.00-4.20PM | *Chowdhury, M.M.R., Salonen, J.K., Taskinen, J.* | **Does exposure to duck mussel (*Anodonta anatina*) immunize brown trout (*Salmo trutta*) against the endangered freshwater pearl mussel (*Margaritifera margaritifera*)?** |
| 4.20-4.40PM | *Collas, F.P.L., Karatayev, A.Y., Burlakova, L.E., Leuven, R.S.E.W.* | **Boat hull mediated overland dispersal chance of dreissenid mussels** |

| | | |
|---|---|---|
| 4.40-5.00PM | *Stoeckl, K., Denic, M., Geist, J.* | **Mussel monitoring in the context of the European Habitats Directive: New information on the ecological requirements of *U. crassus*** |
| 5.00-5.20PM | *Riccardi, N., Froufe, E., Lopes-Lima, M., Mazzoli, C.* | **Recovery of mussels in Lake Orta revealed by social networks ninety years after their extirpation** |
| 5.20-5.40PM | *Protasov, A., Sylaieva, A.* | **Bivalves in human-modified and natural ecosystems of Ukraine** |

## Wednesday, October 7th

| | | |
|---|---|---|
| 9.00-9.40 AM | *Invited Speaker: Manuel Lopes-Lima* | **Addressing global conservation issues on freshwater bivalves: Challenges and opportunities** |
| 9.40-10.00AM | *Geist, J.* | **Seven steps towards improving mussel conservation success** |
| 10.00-10.20AM | *Soler, J., Wantzen, K.M., Araujo, R.* | **Project Grande Mulette: Conservation of the giant pearl mussel (*Margaritifera auricularia*) in Europe** |
| 10.40-11.00AM | *Kebapçı, Ü.* | **Unionid biodiversity and conservation problems in Turkey** |
| 11.00-11.20AM | *Wengström, N., Lundberg, S.* | **Conservations efforts with focus on the thick shelled river mussel (*Unio crassus* Philipsson, 1788) and its host fish fauna in Svennevadsån, Sweden** |
| 11.20-11.40AM | *Cheng, K., Kreeger, D., Padeletti, A., Thomas, R.* | **A comprehensive freshwater mussel restoration program: Progress in the Delaware River Basin** |
| 11.40-12:00PM | *Capoulade, M., Pasco, P.-Y., Dury, P., Ribeiro, M., Beaufils, B., Rostagnat, L.* | **Saving six freshwater pearl mussel *Margaritifera margaritifera* populations in the Armorican Massif (France)** |
| 1.00-1.20PM | *Burlakova, L.E., Karatayev, A.Y., Karatayev, V.A., Miller, T., Perrelli, M.F.* | **Conservation of endangered unionids in high-flowing fragmented rivers: Historical changes and metapopulation dynamics of the Rio Grande endangered endemic *Popenaias popeii*** |
| 1.20-1.40PM | *Choo, J.M., Taskinen, J.* | **Latitudinal distribution of the unionid mussel *Anodonta anatina* and its trematode parasites in Finland** |

| | | |
|---|---|---|
| 1.40-2.00PM | *Österling, M.E.* | **Parasitic freshwater pearl mussel larvae reduce the drift-feeding rate of juvenile brown trout** |
| 2.00-2.20PM | *Wengström, N., Wahlqvist, F., Näslund, J., Aldvén, D., Zaworka, L., Höjesjö, J.* | **Fast swimming brown trout receives a higher parasitic load of freshwater pearl mussel (*Margaritifera margaritifera*) larvae** |
| 2.20-2.40PM | *Woolnough, D.A., Timmers, R.B., Ross, M.J.* | **Are all glochidia equal? Evidence of variation within and among individual unionids** |
| 2.40-3.00PM | *Teixeira, A., Varandas, S., Sousa, R., Froufe, E., Lopes-Lima, M.* | **Host fish biotic homogenization. A major threat to Iberian freshwater mussel (Unionoida) species** |
| 3.00-3.20PM | *Dascher, E., Olson, J., Burlakova, L.E., Karatayev, A.Y., Bonner, T., Schwalb, A.N.* | **How does the distribution of unionid freshwater mussels in Texas relate to the distribution of fishes?** |
| 3.40-4.00PM | *Galbraith, H.S., Blakeslee, C.J., Devers, J.L., Minkkinen, S.* | **Recovering from co-extirpation: The challenge of restoring an ecologically relevant host-affiliate relationship** |
| 4.00-4.20PM | *Antelo, J., Suarez-Abelenda, M., Pastoriza, C., Barral, J., Ondina, P., Outeiro, S., Lois, S., Antelo, J.M.* | **Does the accumulation of trace elements in riverine sediments affect the populations of *Margaritifera margaritifera*?** |
| 4.20-4.40PM | *Santos, R., Callil, C., Mansur, M., Michiura, A., Colle, A.* | **Environmental influences on the community composition of freshwater mussels as a baseline to spatial conservation prioritization: A case study in the Cuiabá River Basin, Midwest of Brazil** |
| 4.40-5.00PM | *Blakeslee, C.J., Galbraith, H.S.* | **Physiological and behavioral response of native freshwater mussels to environmental variables** |
| 5.00-5.20PM | *Choy, S.J., Buttermore, E.N., Moore, J.N.* | **Investigating the impacts of water quality on freshwater mussels** |

# Field Trips

1. Niagara Falls (half day), with optional late afternoon meal at the Great Lakes Center Field Station

Only a 30 minute drive from Buffalo, the world famous Niagara Falls are located between the U.S. and Canada. From largest to smallest, the three waterfalls are the Horseshoe Falls, the American Falls and the Bridal Veil Falls. The Horseshoe Falls lie on the Canadian side, while the American Falls and the Bridal Veil Falls are on the American side, separated by Goat Island. Using the Rainbow Bridge offers a great opportunity for viewing The Falls. It connects the cities of Niagara Falls, New York, United States (to the east), and Niagara Falls, Ontario, Canada (west). It is named for the fact that you can often see a rainbow over The Falls, which are just upstream from the bridge. For more information please visit:
http://www.niagarafallsstatepark.com
After visiting the falls, we will return to Buffalo in the afternoon and stop at the Great Lakes Center Field Station for Buffalo's favorite meal: Chicken wings and pizza.

## 2. Letchworth State Park (full day) with late afternoon meal at the Great Lakes Center Field Station

Located 60 miles (95 km) southeast of Buffalo, Letchworth State Park is one of the most famous of New York's state parks. Letchworth State Park, renowned as the "Grand Canyon of the East," is one of the most scenically magnificent areas in the eastern U.S. The Genesee River roars through the gorge over three major waterfalls between cliffs - as high as 600 feet (200m) in some places - surrounded by lush forests. The highest waterfall in New York is located in the park. Known as Inspiration Falls, it is a spectacular ribbon waterfall that is located on a tributary creek a short distance east of the Inspiration Point Overlook, 0.4 mile (640 m) west of the park visitor center. It has a total drop of 350 feet (107 m). Hikers can choose among 66 miles of hiking trails in Letchworth State Park, which are wide, lined with stone or sufficiently cleared. Steps are generally stonework and well-kept. Some trails are even paved. The less beaten pathways are narrow, lined with dirt, rocks and branches. For more information, please visit: http://nyfalls.com/waterfalls/letchworth

After visiting the park, we will return to Buffalo in the afternoon and stop at the Great Lakes Center Field Station for Buffalo's favorite meal: Chicken wings and pizza.

# Abstracts

# Oral Presentations

# Ecosystem services provided by freshwater bivalves

*Vaughn, C.C.*[1]

[1]*Oklahoma Biological Survey, Department of Biology, and Ecology and Evolutionary Biology Graduate Program, University of Oklahoma, Norman, OK 33019, USA.*

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Ecosystem services are the benefits that humans derive from healthy ecosystems. Biologically complex freshwater ecosystems provide important ecosystem services such as provisioning of freshwater, nutrient processing and water filtration, and recreation and ecotourism. Freshwater mussels (Bivalvia: Unionidae) are a guild of benthic, burrowing, filter feeding bivalves. Mussels provide many important ecosystem services in rivers. Mussels often occur as dense, speciose aggregations called mussel beds. Recent work has shown that mussel beds create biogeochemical hotspots in rivers. While mussels remove seston through filter-feeding creating top down effects in streams, they also have strong bottom up effects in streams via nitrogen excretion leading to increases in benthic algae, macroinvertebrates fish, and even riparian spiders. Mussel tissue (soft and shell) provides long-term nutrient storage, which in turn alters nutrient limitation and decreases movement of nutrients downstream. Mussel shells also provide biogenic habitat for other organisms and mussel shells and activity can influence sediment stability. Recent work experimentally tracking mussel-derived nitrogen through a stream food web with $^{15}N$ showed that mussel excretion can account for 40 – 74% of the total N demand in small streams where mussels are abundant. Effects of mussel-provided nutrients and biofiltration are spatially patchy because of the patchy distribution of beds and temporally variable due to seasonal changes in hydrology and water temperature.

# Ecological services of a host-affiliate relationship across a gradient of nutrient loading

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The freshwater mussel-American eel (affiliate-host) relationship is a promising system to evaluate the role of natural capital in mitigating and restoring ecological services. Eels facilitate ecosystem level nitrogen removal via their migration activities; they colonize upper watersheds as small juveniles and leave for the open ocean as grown adults. They also serve as primary hosts for freshwater mussels, who have experienced dramatic losses in areas experiencing eel extirpation. Through their filtration activities, mussels intercept materials that otherwise would be flushed to the estuaries and coasts. This process of benthic-pelagic coupling facilitates biodiversity (bacteria, algae, and consumers), nutrient storage, and promotes healthy ecosystems. Here we address 3 key issues associated with natural capital and nutrient abatement in the Chesapeake and Delaware watersheds: (1) What is the ultimate fate of intercepted nutrients (storage, capacitance, removal)? (2) To what extent are nutrients mitigated along gradients of nutrient loading? (3) What is the ecological and economic significance of removal in terms of other abatement strategies and watershed goals? This study highlights the utility of ecosystem service economics as a framework for decision support protocols.

# Trematode parasitism, an 'ecosystem service' provided by freshwater mussels

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Freshwater mussels are important part of aquatic ecosystems. Increasing amount of evidence has recently suggested that filtering and burrowing activities by freshwater mussels may influence ecosystem functions and biological diversity, for example, by linking different trophic levels. However, an interesting, potentially significant, but less known ecosystem service provided by mussels may be connected to parasitism. Freshwater mussels act as hosts of trematodes (e.g., family Bucephalidae), and thereby, as a factor connecting mussels to small fishes (2nd intermediate hosts) and predatory fishes (definitive hosts). In this presentation, I summarize results on our studies performed in Finland and Canada, on life cycles, occurrence and abundance of trematode parasites in freshwater mussels, and mussel host relationship, including effects on reproduction, growth and survival of mussels. Moreover, I present results on the occurrence and abundance of bucephalid trematodes in fish 2nd intermediate hosts, to which they are transmitted from mussels. These results show that in freshwater ecosystems, unionid mussels may be linked to fishes – in addition to their own glochidia larvae – via trematode parasites.

# Comparison of particle filtration ecosystem services by North American freshwater mussels fed on natural seston

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Similar to other suspension-feeding bivalves, freshwater mussels possess numerous adaptations for optimal foraging, including modulation of particle filtration rates and absorption efficiencies as environmental and dietary conditions change. Since optimal foraging strategies can vary widely with temperature, food quality, and food quantity, physiologically-based estimates of ecosystem services should be determined with natural diets and conditions. Clearance rates (CR), filtration rates (FR), and absorption efficiencies (AE) were assessed using natural diets and consistent methods for 7 representative mussel species of the Atlantic (*Elliptio complanata*), Mississippi (*Actinonaias ligamentina, Elliptio dilitata, Lasmigona costata*) and Pacific (*Anodonta californianus, Margaratifera falcatus, Gonidea* sp.) slopes. Mussels and water were collected from natal streams, and physiology studies were then conducted within 12 hours at ambient temperatures. The disappearance of seston over time was used to calculate CR (volume per time), which was multiplied by dry diet weights to estimate FR (mass per time). The Conover method was used to determine AE. "Optimal foraging" was represented as the net absorption rate (NAR) of dietary seston, determined by multiplying FR by AE. Physiological rate functions were adjusted for mussel dry tissue weights (DTW) using allometric relationships, and then contrasted among seasons and mussel species. To test the effect of mussel source (and associated food quantity/quality), in some experiments rate functions were assessed for the same species taken from different rivers. Clearance rates were generally comparable among mussel species during the growing season, averaging between 0.3-1.1 L $hr^{-1}$ [g DTW]$^{-1}$, except for *E. complanata* (3.4 L $hr^{-1}$ [g DTW]$^{-1}$). Other interspecific differences were minor, such as a comparatively greater CR by *M. falcatus* during only the coldest season. Absorption efficiencies for all species averaged between 40-60% during summer, but they were lower (<25%) during spring and fall. Seston quantity was inversely related to AE, and seston organic content was positively correlated with AE. Taken together, these findings suggest that physiological rate functions of freshwater mussels vary more with seasonal temperature and food conditions than among mussel species. Physiologically based models of ecosystem services can therefore be parameterized with data for temperature, seston quantity and quality, and mussel population biomass.

# A comparison of growth and survival of quagga mussel veligers in low and high calcium waters

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Calcium is considered the defining factor for determining if a lake or river is suitable for quagga mussel establishment. The minimum calcium threshold for invasion was developed in prior studies using the calcium requirements of zebra mussels, a close relative to the quagga mussels. However, research has shown that there are many differences between the two species and the risk of quagga mussel survival in low calcium waters might be underestimated. This study sought to fill the gaps in quagga mussel veliger research. Lake Tahoe, CA-NV was chosen as the system to represent naturally low calcium levels (approximately 12 ppm Ca). Quagga mussels have yet to establish in the lake. To represent a system of high calcium, water from Lake Mead, NV-AZ (approximately 70 ppm Ca) was used. Additional calcium was added to Lake Tahoe water for conditions of additional comparison (20, 25, and 32 ppm dissolved Calcium). Survival after 28 days was lowest for Lake Tahoe (30% versus 95% for Lake Mead) while the added calcium in the Lake Tahoe water helped to increase survival. On the other hand, those veligers which survived the 28 day assay grew at a similar rate no matter the calcium level of the treatment water.

# The freshwater mussels (Bivalvia: Unionoida) of South America: A review

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We conducted a systematic re-evaluation of the genera and species of South American freshwater mussels (Bivalvia: Unionoida) based on fieldwork, collections-based research in 23 major collections, and a literature review. Digital photographs of specimens and geo-referenced localities were integrated into a comprehensive database of freshwater mussel taxonomy, literature records, and museum specimens. To-date, we have captured data on over 8300 lots from South America. These data are publicly available via the MUSSEL Project Web Site (http://www.mussel-project.net/). The continent is inhabited by three families of freshwater mussels: Etheriidae, Hyriidae, and Mycetopodidae. We currently recognize approximately 130 species in 20 genera, all but 4 of which are endemic. We divided the continent into 5 regions corresponding to major drainages: 1. Northern South America (including the Magdalena, Orinoco and other tributaries to the Carribean); 2. Amazon (including the Tocantins); 3. Rio de la Plata; 4. São Francisco and Atlantic tributaries; and 5. Pacific drainages. The most speciose region is the Rio de la Plata with 64 species and 21 endemics followed by the Rio São Francisco and Atlantic tribs. (40 species, 8 endemics), Amazon basin (43 species, 21 endemics), Northern South America (36 species, 22 endemics) and the Pacific drainages with 3 species (1 endemic?). The freshwater mussel fauna of South America is poorly understood, particularly the basins outside of the Rio de la Plata and Atlantic drainages. We will present our results on patterns of species richness and taxonomic diversity in the Amazon basin and summarize the known deficiencies in our understanding of the biogeography and evolution of these taxa.

# Biogeography, ecology and adaptive strategies of freshwater bivalves (Bivalvia: Sphaeriidae) in Arctic

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Arctic ecosystems are considered to be particularly valuable in research that focuses on factors affecting a communities' functioning and the forms of adaptations and adaptive strategies in extreme conditions of high latitudes. The objective of this study was to estimate the biodiversity, abundance and distributional pattern of bivalves in relation to environmental factors in lakes Talatinskoe and Yangoto, northern Vaigach Island in the Arctic Sea. We aimed to investigate the brooding of *P. casertanum* (Poli 1791). We found six bivalve species belonging to the family Sphaeriidae with *Pisidium casertanum* (Poli 1791) being the dominant species (91.9%). Our results indicate that substrate type, vegetation composition and hydrochemical parameters being important factors in affecting the distribution of freshwater bivalves. We found that *P. casertanum* has a specific brooding mechanism, accompanied by asynchronous development and embryos released by the parent, which is atypical for species in the genus *Pisidium*. We suggest that such a mechanism could presumably result in an increase of the populations breeding success in the Arctic lakes harsh environment. We found five specimens of an undescribed *Sphaerium* species (Bivalvia: Sphaeriidae), which is closest related to Nearctic species (particularly *Sphaerium rhomboideum*), with most of them occurring in the Great Lakes region of North America. Our finding suggests a Nearctic rather than Palearctic origin of this lineage. Genetic evidence demonstrates the existence of freshwater refugia in the European Arctic during the last glacial maximum. The Nearctic origin of the Vaigach lineage would suggest the existence of a phylogeographic element distinct from other bivalve molluscs of Northern and Alpine Europe origin inhabiting the European Arctic. This study has been supported by the President of the Russian Federation (grant no. MD-6465.2014.5), the Russian Foundation for Basic Research (project nos 14-04-98801, 15-04-05638) and the Ural Branch of the Russian Academy of Sciences.

# Biogeography of freshwater mussels (Bivalvia: Unionoida) across the largest Southeast Asian riverbasins: Endemism and biodiversity assessment

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Indo-China represents a great scientific interest as a region with many freshwater biodiversity hotspots. Large river basins of the South-East Asia are inhabited by numerous Unionoida species but our knowledge about mussel distribution and taxonomy is mainly based on few past studies that required reexamination. Mussel samples were collected from 21 different sites of Mekong, Irrawaddy and Salween river basins and molecular data for 106 specimens were obtained. Based on combined sequences for fragments of mitochondrial (COI) and nuclear (28S) genes a phylogenetic tree was produced. The analysis of phylogenetic tree has demonstrated the absence of species which inhabit more than one river basin. The distribution of sister taxa across Mekong, Salween and Irrawaddy river systems is registered for various genera: Trapezoideus, Lamellidens and Radiatula. Our data shows that each river basin represents a separate evolutionary hotspot with a high level of endemism in freshwater bivalve fauna. The analysis of phylogenetic tree topology has shown that species of Mekong basin are the most divergent from species of Salween and Irrawaddy. The obtained results highlight the existence of multiple evolutionary hotspots for freshwater fauna across Indo-China, an ancient connection between the greatest Southeast Asian rivers, and high conservation value for each studied river basin.
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# The Naiads (Bivalvia: Unionidae) from Romania: Trends in knowledge, distribution, ecological requirements and human impacts

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As part of Eastern Europe, over the last three decades, Romania experienced major historical as well as environmental changes that are highly complex in causes, expression and consequences. These changes were reflected in the quality of freshwater ecosystems and their communities. In this paper the authors establish links between the economic trends, and the naiads' distribution, species' replacement and community structure, dynamics and other ecological features. The current distribution of Unionidae species in Romania is explained mainly by the anthropic effects, but also by the heterogeneity of geomorphological conditions. At present, it is impossible to establish a clear and complete picture of their distribution at national level, because of the extremely uneven knowledge concerning these organisms. The lack of specialists was and still is an impediment, to which subjective and modern requirements in science have to be added. Since research on invasive species seems to have higher academic interest we experience the odd state of knowing more about the invasive species *Sinanodonta woodiana*, than the native, imperiled and endangered species. Even *Unio crassus*, largely considered as a "flagship" species that is highly abundant in the flowing waters of Romania, is not evaluated in several regions despite the legal requirements. The authors' data, gathered during the last 20 years, in addition to information available from the past two centuries were used to document some of the local and regional extinctions, to model the changes in distribution, population structure and dynamics, communities' responses to human pressure, and to analyse the ecological requirements of the naiads as well as some of their ecological indicator value. A variety of research methods and models were used, such as comparing past and present-day distribution of species and local and regional analysis in relation to the habitat conditions. Multivariate community structure and spatial dynamics were analysed by means of hierarchical clustering, gradient analysis, ordination models and other methods.

# A review of the life history of Australasian freshwater mussels with new information from Western Australia

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"The succession of individuals, connected by reproduction and belonging to a species, makes it possible for the specific form itself to last for ages." — Ernst Haeckel

Broadly speaking, the reproductive cycle of freshwater mussels (Unionida) is generally well known…reproduction is sexual; larvae are brooded in the gills of females; larvae are released and undergo a period of metamorphosis whilst attached to fishes/amphibians, followed by a post-parasitic juvenile maturation phase and adulthood. Gametogenesis is variable and occurs annually or seasonally, but appears to be independent of geography or taxonomy, although larval morphology has shown taxonomic merit. Here we review the present knowledge of life history in the Australasian Hyriidae and provide new information on the life history of *Westralunio carteri*, a threatened species from south-western Australia. In general, larval release is seasonal or opportunistic in temperate climates, but gametogenesis generally is continuous. In tropical areas, however, reproduction may occur year-round, with multiple broods. Histological examination of gonads in *W. carteri* over two years showed that spawning, brooding and glochidia release are synchronous and seasonal, in keeping with the regional Mediterranean climate. Gametogenesis occurs year-round, but oogenesis and spermatogenesis peak during winter. The species is tachytictic, brooding in late winter to early spring. With increasing water temperatures from late spring through early summer, the female mussels release mature glochidia at a time when spawning migrations of host fishes occur. We hope this presentation will stimulate further research on the life history of the Australasian freshwater mussels.

# Nomenclatural remarks on some Western-Palearctic Najades (Bivalvia: Unionacea)

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1. The correct name and publication date of the type species of Microcondylea Vest 1866.

We try to give a complete nomenclatural history of *Unio bonellii*. Discussed names are: *Anodonta uniopsis* Lamarck 1819, *Unio depressa* C. Pfeiffer 1825, *Unio (Alasmodonta) bonellii* A. Férussac 1827, *Unio bonelli* Menke 1828, *Alasmodonta compressa* Menke 1830. The controversy in this case is due to uncritical citation of errors made by later authors (e. g. Haas 1940, Zilch 1967). *Unio bonellii* was first introduced in a publication by A. Férussac 1827. In this publication the availability of the name does not depend on the interpretation whether it is considered (1) a replacement name for the preoccupied *Unio depressa* C. Pfeiffer 1825, or (2) published as a junior synonym, as it simultaneously fulfils the ICZN Arts. 12.2.1 and 12.2.3. If the second alternative is chosen, the availability according to ICZN Art 11.6.1 is based on the almost continuous use of the name since Menke 1828. If *Unio bonellii* would not have been made available by Férussac himself, the name would be available only one year later as *U. bonelli* in Menke 1828, which name is available with the same kind of indication (replacement name) as *Alasmodonta compressa* Menke 1830.

2. Again on the type species of Potomida Swainson 1840.

We consider the genus-group name Potomida as established in generic rank. As it is introduced by Swainson (1840), it is mentioned 7 times as genus, 4 times as subgenus, and 4 times in uncertain or problematic rank. In the latter part of the paper it is always used as a generic name, and in the Index it is listed with the explicit addition "genus". One could also argue, that if the independent descriptions of Potomida as subgenus (p. 268) and as genus (p. 281) are regarded as simultaneous nomenclatural acts, ICZN Art. 24.1 (Automatic determination of precedence of names) can be applied, which gives the name proposed at higher rank precedence. The description as a genus is consistent and the indication of the type species is unequivocal and valid. Consequently, the epithet corrugata is published in combination with Potomida and not with Unio and thus not preoccupied by secondary homonymy (the combination *Unio corrugatus* was then in use for *Mya corrugata* O. F. Müller 1774). Ellis (1946) has identified Swainson's *Potomida corrugata* with a najad from Lake Tiberias which he named *Potomida littoralis semirugata* (Lamarck 1819). A careful re-examination of the holotype of *Unio semirugata* in the Geneva Museum showed that it stems with high probability from northern France and that the name cannot be applied to a form from Near East. The subspecies of *Potomida littoralis* in the valley of the Jordan must therefore be named *Potomida littoralis corrugata* Swainson 1840.

3. On the authorship of the genus Unio 1788 and the pertaining species-group taxa.

Although in most cases attributed to Philipsson, sometimes Retzius, or even Philipsson in Retzius is cited as author. The problem arises from the peculiar examination system in practice at Swedish universities at that time: The professor wrote the thesis to be defended by the student. According to this, the author of the thesis defended by Philipsson should most probably be Retzius, but in this case the authorship of Retzius is in no way evident from the content and publication circumstances and there exists no external proof. Hence the attempts and efforts to prove and establish Retzius as author are in vain, as it is the procedure prescribed by the Code (ICZN Art. 50.1.1) for the recognition of the responsible author that leads inevitably to acceptance of Philipsson as nomenclatural author. Furthermore, both the genus Unio and the pertaining species-group taxa are placed on the Official Lists of Generic respectively Specific Names in Zoology with Philipsson as author (Opinions 335 and 336). Consequently, we have to write: *Unio* Philipsson 1788; *U. crassus* Philipsson 1788 and *U. tumidus* Philipsson 1788.

# Twenty-five years of change in the Hudson River's bivalve populations

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Annual quantitative samples taken since 1990 from the freshwater, tidal Hudson River in eastern New York show that its bivalve populations have been very dynamic, chiefly as a result of the appearance of zebra mussels in 1991. Zebra mussels (and now, quagga mussels) have been very abundant in the Hudson since late 1992, and have caused large, pervasive changes to the ecosystem. Dynamics of the dreissenids have been governed by (i) strong, persistent cycling, probably resulting from interactions between adults and larvae; (ii) large increases in adult mortality since the early 1990s; and (iii) appearance of quagga mussels in 2008. At this writing, quagga mussels still constitute a small fraction of the dreissenids in the river. Three species of unionids (*Elliptio complanata, Anodonta implicata, Leptodea ochracea*) were abundant in the Hudson before the zebra mussel invasion. After 1992, all three suffered from large declines in recruitment, adult survival, body condition, and population size. Recruitment of juvenile unionids recovered to pre-invasion levels by about the year 2005, but these juveniles are failing to survive to adulthood, and it now appears that unionids may disappear from the river. Exploitative competition and apparent competition, rather than fouling, appear to be the main mechanisms by which dreissenids have affected unionids in the Hudson. Our data on sphaeriids are less complete, but show that the populations (chiefly small-bodied *Pisidium*) fell steeply after zebra mussels arrived, then recovered after the year 2000. Finally, *Corbicula* appeared in the tidal Hudson in 2008; although abundant in some tributaries, it remains scarce in the river itself. The zebra mussel invasion of the early 1990s set off dynamics that have not yet stabilized, showing that an invasion may take decades to play out.

# Biology and habitat of *Sphaerium striatinum* in two streams in the upper Susquehanna River drainage

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In many lotic systems drastic declines in freshwater bivalve populations, including Sphaeriidae, have created concerns associated with future biodiversity and ecosystem services. The habitat distribution and biology of the Fingernail Clam *Sphaerium striatinum* was measured in Labrador and Tioughnioga Creeks, New York, in the upper Susquehanna River drainage. Labrador Creek is associated with the protected Labrador Hollow Unique Area, but both creeks are influenced by agriculture. We used core sampling in equally spaced transects to investigate the densities and distribution of *S. striatinum* associated with river substrate, water quality, water flow, and the co-occurring macroinvertebrate community. Size distributions, brooding pattern and feeding periodicity were measured as possible population status indicators. Stream water quality, measured with the Hilsenhoff Biotic Index, was slightly impaired. The local populations *S. striatinum* in these streams had positive biological indicators. Understanding the biology and habitat use by freshwater bivalves in relatively pristine headwater streams is fundamental to developing overall conservation goals.

# From common to probably extinct: Tales about the peaclam *Pisidium amnicum* in the Minho River (Portugal)

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Extirpation or even extinction of freshwater invertebrate species is a neglected conservation problem and a far less documented issue than for vertebrate species. One of the faunal groups more threatened in freshwater ecosystems are bivalves. In this study, we used a long data set (from 2004 to 2014), with samples collected annually over a large area (comprising 16 different sites), to document the rapid decline of the bivalve *Pisidium amnicum* in the Minho River tidal freshwater wetlands (Portugal). A rapid decline in density, biomass and spatial distribution was recorded without any sign of a potential recovery. Mean density values reached more than 80 ind./$m^2$ in 2004, but decline to 0 ind./$m^2$ in the last two years; an identical declining trend was also observed for biomass. The abiotic changes resulting from the 2005 drought and possibly the negative interactions with the invasive bivalve *Corbicula fluminea* were the main factors responsible for the declining trends. Given the very low density and the apparent very low resilience to the recent environmental changes, *P. amnicum* is facing a serious risk of extinction in this ecosystem (and in the entire Iberian Peninsula) and conservational measures are urgently needed.

# Characterization and protection of native species of bivalves in two coastal lagoons

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The Coastal lagoons of Barrinha de Mira and Mira are highly productive and sensitive natural wetlands, and form part of the Natura 2000 Network known as the Dunas de Mira, Gandara and Gafanhas. The ecological integrity of these lagoons depends on the environmental sustainability of the surrounding area and intrinsically related to the intensity level of both natural and anthropogenic pressures. Bioindicators through reference seeks to recognize the resilience of these ecosystems, and develop plans and measures to rehabilitate or preserve these systems. Communities of bivalves (also called naiads), elements with great functional and ecological importance in these humid ecosystems, were used as bioindicators. Once abundant in epicontinental aquatic ecosystems, they are currently among the most threatened groups of organisms at risk of extinction. This project sought to characterize and quantify the populations of native freshwater bivalve species, and contribute to the knowledge of these species in lentic systems, thereby promoting the Natural Heritage of these ecosystems. In both lagoons studied (Barrinha de Mira and Mira) two species of native freshwater bivalves are present: *Anodonta cygnea* and *Unio delphinus*. A special attention should be given to *A. cygnea* since this species is possibly restricted to only three sites (these two lagoons plus Pateira de Fermentelos) in the Iberian Peninsula. The main threats to these native bivalve species in both lagoons are: water eutrophication, presence of invasive species (e.g. *Corbicula fluminea*, *Eichhornia crassipes*, *Carassius auratus*), lack of native hosts, dredging, overfishing, etc. Eutrophication poses perhaps the greatest long-term threat to the ecological integrity of these lagoons characterized by restricted water circulation, shallow depths, and heavily populated surroundings. This situation is usually intensified by the overgrowth of *Eichhornia crassipes* that needs constant control. Finally, in order to increase environmental awareness, we produced information on the preservation of the lagoons in the form of a guide, leaflets and informative panels, providing knowledge to the public on the intrinsic natural values of the lagoons, promoting the importance of the invasive species control, and the conservation of freshwater bivalves, their habitats and their hosts.

# Unravelling the UNIONIDAE: Examination of subfamily relationships within Unionidae

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Malacologists have been organizing the genera assigned to the Unionidae into subgroups for over 200 years. We are still working toward a consensus on which genera to recognize - currently between 131 and 142 genera. A total of 56 subfamily and tribe level names have been described under Unionidae. Three names are unavailable and one is for a fossil group, leaving 52 family group names available. Various schemes to group unionid genera have been developed based on shell-shape, shape of anterior shell margin, umbo sculpture, and marsupial and larval characteristics. In the last several decades, molecular phylogenetic studies of mitochondrial and nuclear gene sequences have helped clarify the family group-level relationships and morphological evolution of the Unionidae. We are presenting our analyses based on sequences of cytochrome oxidase c subunit 1 (COI) and 28S for 66 species and analyzed with Bayesian inference and maximum likelihood. Our analyses resolved 17 major well supported clades. These clades are interpreted as representing six subfamilies: Unioninae, Anodontinae, Ambleminae, Gonideinae, Parreysiinae and Rectidentinae. The validity and position of *Modellnaia*, assigned to a monotypic subfamily, remains unresolved due to lack of recent tissue samples. Some genera with multiple included species are not monophyletic. We discuss our results in the context of all available subfamily and tribe-level names and the developing higher-level classification of the Unionidae.

# Life history trade-off of *Anodontites trapesialis* (Lamarck, 1819) (Bivalvia: Mycetopodidae) in a wetland: An evolutionary or environmental adaptation?

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Determining how, when and why energy allocation occurs based on different life history traits among species, provides core knowledge for understanding evolution, ecology and conservation of populations. Using an energy allocation and life history trait approach, we studied maturation of gametes, incubation period of larvae, and marginal increment of growth rings of *Anodontites trapesialis* (Lamarck, 1829), an abundant and widely distributed freshwater mussel in the Pantanal wetland of Mato Grosso, Brazil. Our study was conducted in an oxbow lake of the Cuiaba River, Midwest Brazil. We determined for the first time, asymptotic maximum size ($L_\infty$ =274.11 mm), longevity (11 years) and *K* (*k*=0.072) for this mussel. This species is a functional hermaphrodite and the production of gametes is continuous. Maturation and spawning occurs at the end of the flood period and when the waters start to set back, the fishes come back to the main river channel and the larvae, *lasidiun* in this case, hitch a ride. Our prediction that shell growth lines are formed during the reproductive period, when the Pantanal is experiencing its seasonal flood pulse, was confirmed. We discuss how evolutionary factors such as fast growth, short life and high reproductive effort drive the fitness of a population for rapid colonization and persistence in disturbed and unstable but productive habitats like Pantanal.

# Endangered or invaders? Molluscs - the most imperiled group of freshwater invertebrates includes the highest number of invaders

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The diversity and species composition observed in biological communities is the dynamic result of two continuous ecological processes: immigration and extinction or extirpation of species already established in the system. The impacts of humans on natural communities has dramatically accelerated both processes. Nonnative species are being introduced to communities at an ever increasing rate, and human alterations to ecosystems, as well as direct harvesting, has resulted in the extirpation of local native species. Estimated extinction rates are higher than at any other time in history. We examined several questions about North American freshwater macroinvertebrate species categorized as endangered and those that are considered invaders, including: whether these two group include members of the same major taxa, or whether they represent phylogenetically distinct groups, and whether invaders and endangered species are ecologically similar in terms of habitat use. We found that freshwater exotic invertebrates (introduced from a different continent or major biogeographic region) and native transplant invertebrates (introduced to another region on the same continent) and endangered invertebrates are not a random selection of species, and largely overrepresented by molluscs. Both exotic and native transplant molluscs were phylogenetically different from extinct and endangered species (belong to different families). More freshwater molluscs have recently gone extinct (79 species) than the number of exotic species that have been introduced to new regions (36 species). In addition, these two groups of species occupied different waterbody types. For both gastropods and bivalves, the number of waterbody types inhabited was lowest for extinct and endangered species, and greatest for invaders. While most of the extinct and endangered species were primarily in lotic environments, transplant and exotic species preferentially colonize lakes and reservoirs.

# Invasion history of *Dreissena polymorpha*, the zebra mussel in Lough Key, an Irish lake

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The zebra mussel (*Dreissena polymorpha*) arrived in Ireland circa 1993 and spread to Lough Key, Co. Roscommon, from the interconnected River Shannon in the late 1990s. The mussels were monitored annually in this 9km$^2$ lake between 1998 and 2003. The zebra mussel population (density and biomass) in Lough Key was assessed using a combination of snorkel and dive techniques along lake transects. In 2003, the population estimate was six billion ($6x10^9$) with high cover of zebra mussels on stones in near-shore areas of the lake. This invasion resulted in the extirpation of the only native unionid present (*Anodonta*), with no live specimens recorded in this study after 2000. In summer 2015, the transect survey was repeated to assess changes in the zebra mussel population after a twelve year gap in monitoring. The survey also assessed whether *Anodonta* had managed to recolonize the lake. This presentation on the invasion history of the zebra mussel in an Irish lake will indicate whether this invader has exhibited a boom-bust cycle or is undergoing annual oscillations in population dynamics.

# A recent *Dreissena* invasion in an old canal system in northern Europe

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The Göta Canal was opened in 1832 and connects the Baltic and the Atlantic Sea via the large lakes Vänern and Vättern in south Sweden. Originally used for commercial transport, the canal is today one of the most popular tourist attractions in Sweden with canal cruises, pleasure boating and canoeing. Inventories in 2013 showed that *Dreissena* mussels recently have invaded lakes, streams and canals in the Motala River drainage basin, i.e. the eastern part of the Göta Canal. According to interviews with local people, the mussels may have been there since 2012. During the late summer in 2013 and in 2014, we monitored mussels by scuba diving and we sampled planktonic larval populations in locks and the canal. *Dreissena* has not dispersed to the western part of the canal system, i.e. west of lake Vättern, where most lakes are oligotrophic with low Ca- and Mg-levels. In the eastern part, where several lakes are eutrophic and Ca- and Mg-levels higher, populations have increased very fast. The inventories showed local densities of 10,000 adults $m^{-2}$ in some eutrophic lakes and larval densities of up to 70 individuals $L^{-1}$ in the canal water. In Europe, the large range expansion of *Dreissena* occurred during the late 19th and early 20th century. Why have they dispersed so late into the Göta Canal, i.e. some 170 years after the canal was constructed and some 80 years after they had dispersed to other lakes in Sweden north of Göta Canal? We cannot dismiss dispersal as a limiting factor, but given the historically sustained boat traffic in the region it seems likely that ecological factors may have been important. Freshwaters in Scandinavia are usually low in Ca and Mg and many lakes are characterized by oligotrophic conditions poor in food for filter-feeding Dreissena. In the Göta Canal, changes in biological factors affecting relationships between *Dreissena* and the regional biota needs to be studied, however. Although we cannot explain the delayed invasion, we conclude that *Dreissena* is now established in the largest canal system in northern Europe.

# Estimation of exotic bivalve distribution and coverage in a large river using traditional sampling, remote sensing, and GIS-derived benthic habitat maps

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The invasive mussel *Dreissena* spp. (*Dreissena rostriformis bugensis* and *Dreissena polymorpha*) has invaded many freshwater bodies both in the Old and New World, and numerous efforts have been made to describe and predict its distribution and coverage on the ecosystem scale. Benthic habitat mapping has become an important tool to increase our understanding of the link between the spatial distribution of substrate and *Dreissena* spp. Here, we tested the feasibility of using remote sensing and GIS-generated benthic habitat maps to describe the abundance and coverage of *Dreissena* in the lower Niagara River. A side scan sonar survey was carried out in 2011 and a benthic map was created in ArcMap 10.1 to delineate major substrate classes in the river. The map was used to link the distribution of physical habitat characteristics with biological information obtained from direct benthic sampling to predict the abundance and coverage of *Dreissena* in the river. More than 150 sites along a 10 km stretch of the lower Niagara River were surveyed, and *Dreissena* abundance and coverage from Ponar grab samples was determined. Concomitantly, 80 underwater videos were taken to describe *Dreissena* coverage in areas which could not be sampled due to strong currents and/or bedrock. The subsrate map, in combination with abiotic data and underwater video images, can be used to determine which factor(s) effect *Dreissena* presence/absence and *Dreissena* distribution and coverage in the river. Our preliminary results show that *Dreissena* prefers nearshore-areas in the river with low flow velocity independent from substrate.

# Using species sensitivity distributions for assessing effects of river management measures on native and non-native mollusc assemblages

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There is an increasing demand for self-sustaining rivers that allow better utilization of their natural processes to reduce maintenance costs. Currently, several riverine projects are carried out that aim at improving natural processes. In order to acquire more knowledge on the natural response of river systems to these interventions the RiverCare program was initiated in the Netherlands. One of the goals of this program is to derive species sensitivity distributions (SSDs) for various environmental stressors, including physical factors. SSDs are statistical distributions that describe the variation between species in their sensitivity to an environmental stressor. The SSDs can be used to determine the potentially not occurring fraction of a species assemblage. This makes the SSD approach useful for determining ecological risks and predicting effects of interventions on riverine biodiversity. Here, we present SSDs based on the desiccation, temperature and salinity tolerance of mollusc species occurring in the River Rhine. Additionally, a comparison was made between SSDs of native or non-native species. Desiccation resulting from low flow events was found to be the primary limitation that influences species assemblages in the littoral zones of the River Rhine. No difference in desiccation and salinity tolerance was found between native and non-native mollusc species. On the contrary, temperature tolerance of non-native species was higher than the tolerance of native species. Based on the combined effect of the three stressors, 62 and 80% of the actually not occurring native and non-native species could be explained, respectively. In order to increase the applicability of SSDs as a tool to evaluate management measures SSDs ought to be constructed for additional physical environmental factors (e.g., flow velocity, wave tolerance and minimum required dissolved oxygen levels).

# Enhanced phylogeography, demography, and life history resolution in unionid species: Transitioning from population genetics to population genomics

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Unionids present major challenges to conservation biologists, as relatively little information is available on the amount or distribution of genetic diversity present in and differentiation among populations. Moreover, little is known about unionid physiology, particularly the genes responsible for mediating adaptation and conferring resiliency to ecological change. Developing a clear understanding of spatial population structure and its relationship to host fish spatial structure, gene flow at drift-driven and natural selected loci, phenotypic plasticity, and adaptability is critical for unionid conservation in the presence of unprecedented environmental change. This information is necessary to highlight the evolutionary processes affecting/controlling observed patterns of genetic variation and to identify populations that should be prioritized for management. Massively parallel sequencing presents great promise for addressing many intractable conservation questions, including exploring the mechanistic basis of adaptive evolution. Genotype-by-sequencing (GBS) provides a time- and cost-effective means of identifying the genes associated with parallel evolutionary changes among recently diverged lineages. We are using GBS to delineate the phylogeographic structure among collections of *Elliptio complanata*, a widely distributed species in eastern North America collections. GBS allows us to transition from population genetics (11 microsatellite markers screened across ~88 chromosomes) to population genomics (screen thousands of single nucleotide polymorphism markers across the genome). In a preliminary survey of unionids from the Susquehanna, Delaware, and Androscoggin Atlantic slope drainages, we are identifying and contrasting large numbers of neutral and non-neutral markers among populations of *E. complanata*. This population genomics assessment will provide an assessment of functional (meta) population assemblages, elucidate cryptic migratory corridors or landscape barrier (demarcated and cryptic) effects, identify evolutionarily significant lineages, and model adaptive resiliency. We believe this study provides an important resource for future studies of unionid physiological and immunological processes, and helps delineate adaptive differentiation which ultimately could promote resiliency in the context of environmental change.

# Sex determination in freshwater mussels: A mitochondrial story

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Among the greatest challenges facing biologists today are the conservation and effective management of biodiversity in the face of climate change and environmental degradation. This requires a proper understanding of the distribution/abundance of species, their assembly into ecosystems and the genetic variation within species. This, in turn, depends on our knowledge of the processes generating diversity, i.e. how new species form and how they are adapting to global changes. This is called speciation; the process that splits a group of interbreeding individuals into two reproductively isolated groups. Despite the well-known importance of reproductive isolation in speciation, its molecular/cellular bases still remain obscures. My research focuses on mitochondria and their genomes (mtDNA), which have recently been identified as a key factor in shaping the tolerance of organisms towards environmental change, and a possible key driver of speciation. To address my research questions in new and creative ways, I use an integrative approach (omics & physiology) to investigate the only known exception to the rule of maternal inheritance of mtDNA in animals; the system of Doubly Uniparental Inheritance of mtDNA in bivalves. According to my recent findings, my model system would provide the first mtDNA-based sex determination in animals, supporting the hypothesis that mtDNA is a candidate genetic mechanism to be involved in the genesis of reproductive barriers and speciation events.

# Dispersal and gene flow in unionid mussels and the boundaries defining Great Lakes assemblages

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The unionid fauna of the Laurentian Great Lakes is recent, yet also diverse. The distribution and composition of this entire community is now greatly reduced following invasion of dreissenid mussels, but understanding their origin and opportunities for dispersal back into the lakes are critical steps in an evaluation of possible recovery. The traditional hypothesis, since negated by Graf, is that all the Ohio Basin mussels present in Lake Erie migrated through Glacial Lake Maumee. Many did, but the historical patterns of community composition throughout the Great Lakes, which in total may compose 50 species, and evidence of gene flow and stream capture within surrounding streams, paint a complex picture. As glaciers receded, mussels entered the watershed through multiple, although not necessarily defined, points all along the southern borders of the Great Lakes, including the Illinois, Wabash, and Ohio River watersheds, as well as the Kirkfield outlet connecting Lakes Ontario and Huron. Thus dispersal spanned modern boundaries. Genetic analyses using both male and female inherited forms of mtDNA and microsatellite markers suggest that species varied in where and how often they entered the lakes. The present review therefore characterizes identified points of exchange between adjacent watersheds, and sets directions for focusing new work on genetic diversity of common species as a means to identify existing opportunities for dispersal and gene flow across watershed boundaries.

# Varied patterns of post-glacial dispersal by freshwater mussels species into the North American Great Lakes with implications for conservation and management of imperiled taxa

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Freshwater mussels (Bivalvia: Unionidae) are among the most endangered animals in North America. Understanding the genetic diversity of imperiled species across a large spatial scale is necessary for developing appropriate conservation strategies. Mitochondrial sequences and/or microsatellite loci were used to analyze the population genetics of three common and widespread unionid species (*Lampsilis cardium*, *Lasmigona costata*, and *Quadrula quadrula*) from the Great Lakes and the historically connected Wabash, Illinois, and Wisconsin river drainages; hypothesized conduits for mussels from refugia south of the Pleistocene glacial maximum. Using standard methods, a fragment of the mitochondrial gene CO1 was sequenced and suites of microsatellite loci were genotyped. Mitochondrial DNA sequences resulted in 26 haplotypes for *L. cardium* and 18 haplotypes for *L. costata*. Ten of the putative *L. cardium* haplotypes found in the Maumee (Great Lakes) and Wabash (Ohio River) drainages were revealed to be more similar to *L. ovata* sequences available on GenBank rather than *L. cardium*. *Lampsilis cardium* and *L. ovata* may be interbreeding in the drainage where they co-occur; analysis of microsatellite DNA genotypes may help to reveal if this is the case. Our findings using microsatellite markers suggest that both *L. cardium/ovata* and *L. costata* entered the Great Lakes via multiple routes of entry, while *Q. quadrula* likely entered the Great Lakes via a connection with the Illinois River. This study will provide greater understanding of large-scale genetic structure linked to the complex redistribution of mussels into new habitats following the dramatic climactic shift at the end of the Pleistocene.

# Species boundaries and levels of intermixing between two freshwater mussel species (Family: Unionidae)

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After the last glaciation, freshwater mussel species (Family Unionidae) range expansion led to secondary contact between species that were isolated in the past, and if these species had incomplete reproductive barriers, gene flow could have occurred (hybridization with or without introgression). There is some evidence that two closely related species, *Lampsilis radiata* and *L. siliquoidea* can potentially hybridize; however the prevalence, direction and geographic extent of the potential hybrid zone is not well known. Hybridization was suggested due to the presence of morphological and genetic intermediate forms where their geographic range overlap in the lower Great Lakes, St. Lawrence River and Lake Champlain watersheds in the United States and Canada. The presence of intermediate forms has also led to a long history of name confusion and debate on their phylogenetic relationship. The goal of this study was to determine the phylogenetic relationship and levels of intermixing (e.g., non vs. limited hybridization vs. introgression) between *L. siliquoidea* and *L. radiata*. Species boundaries and potential hybridization were determined using mitochondrial cytochrome oxidase subunit I gene (COI) and 9 microsatellite loci. Maternally (m)- and paternally (p)- inherited COI haplotypes of these two species are distinct, indicating that these species are different. Incongruences between m- and p-inherited COI haplotype assignments were also found suggesting restricted hybridization in eastern Lake Ontario and St. Lawrence River tributaries. Preliminary microsatellite data analysis supports hybridization, however further testing is needed. This project contributes to determining the phylogenetic relationship of these two species and sheds light on the speciation process in unionids. Furthermore, correct identification of species, potential hybridization and description of hybrid zones is fundamental in developing and implementing measures to conserve and restore unionid species and populations.

# Morphological variability of Indochinese pearl mussels: Environmental signal or chance for species identification?

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According to the current taxonomy, *Margaritifera laosensis* (Lea, 1863) is a unique Margaritiferidae species distributed in Southeast Asia. Recently, *M. laosensis* has been rediscovered from some tributaries of the Nam Ou River, Mekong basin. Here we represent two more localities from the Sittaung River drainage, central Myanmar. Comparative conchological and morphometric study of almost all available specimens of *M. laosensis* from museum collections and field surveys assigned all these specimens to one cluster on the PCA plot based on three main conchological indexes, in spite of high conchological variability. The only exceptions are two shells of *M. woodthorpi* (Godwin-Austen, 1919) from the collection of National History Museum of UK. These specimens significantly differed in morphology from other Margaritiferidae and were situated outside of 95% ellipses on the PCA plot. Morphological distance between *M. woodthorpi* and *M. laosensis* was significantly larger than between *M. laosensis* and other pearl mussel species from Eurasia, namely *M. margaritifera*, *M. dahurica*, *M. middendorffi* and *M. laevis*. Intraspecific variability in *M. laosensis* from different habitats is lower than differences with *M. woodthorpi*. While DNA is not available for the latter species, we hypothesize that morphological difference between *M. woodthorpi* and *M. laosensis* may indicate taxonomical difference. Our findings confirm the great conservation priority of a few viable *M. laosensis* populations. Restricted distribution of these populations highlights the existence of multiple mountain refugia for oligotrophic freshwater fauna in tropical Asia. The study has been partly supported by the grant from the President of Russia (МК-4735.2015.4).

# Cellular changes associated with nematode infections in the foot of the Alabama rainbow (*Villosa nebulosa*)

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A recent review regarding the parasites and diseases of freshwater bivalves has indicated that the biodiversity and pathogenicity of metazoan parasites of freshwater mussels (Unionoida) is poorly understood. While studying the cellular anatomy of the Alabama rainbow (*Villosa nebulosa*) towards the development of a histological atlas for freshwater mussels, we observed filiform nematodes infecting the foot. Although free-living nematodes are common inhabitants of aquatic environments, and although there are many records of histozoic nematodes from marine bivalves, there are scant observations of parasitic nematodes from freshwater bivalves. From a sample of 43 *V. nebulosa* (24–51 mm shell length) sampled from Terrapin Creek, Alabama in May 2010, August 2011, July 2012, May 2013, and July 2014, nematodes were observed in the tissues of 32 individuals (prevalence = 74%). This sample comprises 14 mussels that were sampled for histology, and 29 mussels that were sampled to obtain worms for a diagnosis. Uninfected foot consists of bundles of myofibers that become branched and appear interwoven in the ventral tip of the foot. Infections ranged from a small number of isolated worms threaded through somatic musculature, to a larger, irregular mass consisting of 100 or more individuals. Infections characterized by a seemingly low number of worms exhibited a small, localized gap surrounding each worm. Foot infected with a larger mass of worms exhibited severed or compressed myofibers. However, a cellular response to these infections was not observed. Since these nematodes damage pedal musculature, we speculate that these parasites may limit pedal extension and retraction such that mussels may be more vulnerable to predation or to scouring water currents.

# Pathological changes associated with a co-infection of metacercaria (Digenea) and eggs of *Unionicola* sp. (Acari, Uninonicolidae) in the mantle of *Elliptio complanata* (Bivalvia, Unionidae)

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Declines of North American freshwater mussel (Unionidae and Margaritiferidae) populations are largely attributed to structural changes to aquatic habitats and contaminants while the role of etiological agents as contributing factors remains unclear. To that end, we are utilizing stereomicroscopy, histology, and scanning electron microscopy to investigate metazoan parasite infections in the eastern elliptio (*Elliptio complanata*). In July 2014 we collected 28 mussels from Oquaga Creek (Delaware River Basin, Broome County), New York. Of the sampled mussels, 25 (prevalence = 0.89) were infected with metacercaria and/or mite eggs; Mite eggs alone were present in seven mussels (prevalence = 0.25), while metacercaria alone infected three individuals (prevalence = 0.10). Metacercaria typically infected connective tissue and musculature of mantle edge while clusters of mite eggs were deposited in middle mantle connective tissue. Uninfected mantle edge had a pleated surface in comparison to the smooth middle mantle; infected tissue sometimes exhibited nodules. Metacercaria and mite eggs were associated with localized compression of fibrous tissue and a thin layer of emarginated hemocytes sometimes surrounded an infection. However, the irregular composition and eosinophilic staining characteristics of fibrous tissues precluded us from determining if a host response was always present in hematoxylin and eosin stained tissues. We intend to shed light on these cryptic host responses using specialized staining techniques such as a Giemsa stain. Additionally, we plan to use scanning electron microscopy to analyze external signs of infection such as hypersecretion of mucous.

# Variation in growth and survival in *Alasmidonta heterodon* across locations in the Northeast United States

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Freshwater mussels are known to be long lived organism having life spans of up to 100 years, although growth and age vary among species and populations. Variation in age and growth demographics among populations may indicate differences in population health and viability. We assessed age and growth of the federally endangered dwarf wedgemussels (*Alasmidonta heterodon*) from six streams in the Northeast in both the Delaware and Connecticut River watersheds. These six rivers incorporate a range of land-use and flow management schemes that are typical throughout this species range. Site specific length-at-age curves and a unified growth curve were created to evaluate differences in population age structure. Mussels showed varying growth curves depending upon location. Delaware River mainstem dwarf wedgemussels were smaller and reached their maximum length faster than mussels in other sites which were more similar in their maximum length and growth rates. Our findings indicate the mainstem population may have different growth relationships compared to other locations in the Northeast which may have consequences for their conservation and restoration.

# Does exposure to duck mussel (*Anodonta anatina*) immunize brown trout (*Salmo trutta*) against the endangered freshwater pearl mussel (Margaritifera margaritifera)?

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Freshwater pearl mussel (*Margaritifera margaritifera*) is endangered throughout its range of distribution in Europe. In some rivers, *M. margaritifera* co-occurs with the duck mussel (*Anodonta anatina*) where brown trout (*Salmo trutta*) is a suitable fish host for both mussel species. Previous studies suggest that cross immunization between unionid species can take place in their shared fish host. We tested this by exposing juvenile brown trout to *A. anatina* glochidium in late May 2012, while a control group was kept unexposed. In August, when the *A. anatina* glochidium had detached, fish were marked with fin cutting and both groups of fish were infected by *M. margaritifera* glochidium two weeks after marking. Number and size of *M. margaritifera* glochidium in fish gills were studied throughout the parasitic period in September, December, May and June. Fish length had statistically significant positive effect on abundance of *M. margaritifera* in every time point. Fish-length-adjusted differences in the mean number or size of *M. margaritifera* glochidium between *A. anatina* exposed and control fish were inconsistent, and statistically not significant. Thus, no indication of cross immunization was observed. Surprisingly, *M. margaritifera* abundance was lower in fin cut fish in all time points regardless of the exposure to *A. anatina*, and this situation was statistically significant in May and June. Results suggest that sharing fish host with *A. anatina* may not be a threat for the endangered *M. margaritifera* populations. However, fin cut may decrease success of *M. margaritifera* glochidium during the parasitic period in fish, possibly due to nonspecific immunity.

# Boat hull mediated overland dispersal chance of dreissenid mussels

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Dreissenid mussel invasions have been contributed to a wide range of pathways and vectors. These vectors either enable continuous dispersal in interconnected water systems from native or introduced source populations or overland introductions into isolated water bodies. Recreational boats and various types of equipment (e.g. buoys, pontoons and suction dredgers) have been reported to be important vectors that facilitate dreissenid introductions into isolated water bodies. Boats provide several introduction pathways, one of them being attachment to their hull. For successful boat hull mediated introductions dreissenids have to attach and to survive air exposure during overland transport. After arrival at a new site, mussels have to detach after boat launching and have to establish a viable population. Though numerous studies on separate parts of the boat hull mediated introduction chain of events, until now no experiments have been performed that chronologically incorporate all pathway steps. Therefore, the objective of this study is to experimentally evaluate the entire ship hull mediated introduction pathway of dreissenids. Quagga and zebra mussels were allowed to attach for seven days at either 15 or 20°C to two common boat hull materials (aluminum and fiberglass). The proportion of zebra mussel attachment (range: 48.0 – 81.7%) was significantly higher than quagga mussel attachment (range: 18.3 – 58.7%) under all experimental conditions. Attached individuals were subsequently exposed to desiccation, mimicking overland transport of a boat. After either 24 or 48 hours of air exposure, the plates were rewetted and detachment of both species was assessed. Alive detachment ranged between 5.6% and 22.7% depending on the experimental condition and was on average 14.6% and 12.4% for quagga and zebra mussels, respectively. The average chance of introduction to a water body after overland transport was calculated by combining the fraction of 1) mussel attachment, 2) alive detachment of mussels during rewetting, and 3) boating data of Lake St. Clair. Boating data parameters were derived based on their similarity to the experimental conditions: boats that remained in water for at least seven days and boats that travelled either 24 or 48 hours overland to not infested sites. The average overland introduction chance of one quagga or zebra mussel on a boat hull was estimated to be 0.0054% and 0.0077%, respectively. However, these calculations did not include mitigating measures to prevent the attachment and spread of dreissenids resulting in an overestimation of the introduction chance.

# Mussel monitoring in the context of the European Habitats Directive: New information on the ecological requirements of *U. crassus*

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The European Habitats Directive has the objective of protecting vulnerable species, as well as habitat types across their natural range within the EU. This contribution exemplarily illustrates the population and habitat monitoring approach for the thick-shelled river mussel (*Unio crassus*) – a species that is highly endangered and listed in annexes II and IV of the Directive. Based on survey work in 15 streams in Germany considering population distribution and status, water and stream bed quality, availability and status of host fish populations, information on the ecological requirements of the species was obtained. In contrast to the current perception of the autecology of the species, the results of this survey show that densely colonized stream patches were characterized by low flow velocities (< 0.3 $ms^{-1}$), low mean penetration resistances (0.36 ± 0.52 kg $cm^{-2}$), as well as by low bottom shear stress. At sites with juvenile recruitment, fine sediment deposition was high, with 19.4 kg $m^{-2}$*$month^{-1}$. Results of chemical water analyses indicated high nitrate loads in a range of 4.1 to 6.5 mg NO3-N/l. Several species of host fish are suitable for glochidia attachment and metamorphosis, with highly different fish communities observed in different streams. Functional streams with recent recruitment had higher densities of host fishes compared to non-functional ones. Our results indicate that, despite its conservation status, *U.crassus* has a broader niche width for habitat concerning hydrological and substrate characteristics than expected. The greater tolerance of *U. crassus* to adverse substratum and water chemical conditions, and the links between functional mussel and host fish populations, all suggest that conservation management should more strongly consider appropriate fisheries management.

# Recovery of mussels in Lake Orta revealed by social networks ninety years after their extirpation

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Live mussels of *Unio elongatulus* have been found in Lake Orta (Italy), over one century after the last (and only) record (Pini 1886). Industrial pollution caused mussels´ extirpation in the lake in 1926; acidification and increase of metal concentrations likely prevented their recovery over the following decades. Once extirpated from a water body, recolonization is difficult, particularly if access to restocking populations is hindered and/or if mussel dispersal/recruitment is limited by host specificity and host abundance. In Lake Orta, a fish community reappeared just before liming, but either host-fish species/numbers were insufficient to support mussel recovery, or mussel juveniles died after they were released. After liming, the increased sediment toxicity likely hindered re-colonization in spite of water quality improvement. The questions of how and when Lake Orta recolonization has started were raised by the discovery of the current population. To address the "how" we compared the haplotype/s of Lake Orta specimens of *Unio elongatulus* (the only species present) with those of Northern Italian populations. An answer to the "when" was searched by estimating the age of the larger and seemingly older individuals. Since Lake Orta lacks a direct connectivity with putative source populations, colonizing mussels were almost certainly transported by fish infected with glochidia used for lake restocking after liming. The mussel population currently present in the lake is composed of multiple age classes, suggesting that recruitment likely occurs. Therefore, though limited in numbers and spatial extension, this population may represent the first nucleus for the natural recolonization of the lake.

# Bivalves in human-modified and natural ecosystems of Ukraine

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Many species of freshwater mussels are considered among the most threatened animal groups in Ukraine. Knowledge of their current status is imperative for their protection, especially in human-modified ecosystems (techno-ecosystems) like cooling ponds and channels of nuclear and thermal power plants. Seven species of freshwater bivalves were found during 16 years of study in the cooling pond and channels of Khmelnitsky Nuclear Power Plant (northwestern Ukraine). We found that abundance of Unionidae in this system was reduced, likely due to elevated temperatures of discharge waters. The introduction of bivalves belonging to oriental faunistic complexes (e.g., Sinanodonta woodiana Lea) with higher temperature tolerance could perhaps be recommended for such aquatic techno-ecosystems (S. woodiana maintained high abundance after accidental introduction in Konin lakes used it as a cooling system for two thermal power plants in Poland). Invasion of two species of Dreissenidae to the Khmelnitsky cooling pond occurred sequentially, starting with Dreissena polymorpha Pall. in 2002-2003, followed by D. bugensis Andr. in 2009-2010. One of the most common substrate for Zebra mussel attachment was Unionidae shells. At the first stage of invasion, almost 60% of Unionidae had Zebra mussel druses, with biomass more than twice of the host unionid weight, attached to their shells. However, no negative effects of Dreissenidae on the Unionidae populations were recorded.The population of D. polymorpha evolved according to "standard" scenario, with a sharp increase in density in the first 2-3 years after invasion. D. polymorpha biomass in benthos was up to 30 kg/m², and in periphyton on the channels' concrete walls it was up to 37 kg/m². Five to six years after invasion, D. polymorpha population declined. In contrast, D. bugensis populations evolved without the initial sharp increase in densities. The high abundance of zebra mussels has led to "bentification" or "countourization" of the ecosystem, accompanied by significant changes in its structure and functioning. Compared to the cooling pond, a much higher biomass of Cycladidae was found in rivers Goryn and Vilia, where the biomass of Sphaeriastrum rivicola (Lam.) reached 1.7-3.8 kg/m² at a depth of 1.5 m. This enormous density and biomass in massive mussel settlements (mostly Unio pictorum L.) was found in the river Gnily Rig, a small left-bank tributary of River Vilia on the Pripyat basin, and water source of the cooling system (pond) of Khmelnitsky NPP. The large accumulation of mussels was found in the form of a multilayered settlement with a minimum thickness of 25 cm; the maximum biomass per sample (square 0.0225 m²), in five years of investigation, was 112.2 kg/m² (the average was near 90 kg/m² in 2013). In all, depressed populations of native bivalves, with the exception of invasive Dreissenidae, were found in the cooling pond of Khmelnitsky Nuclear Power Plant. The unique Unionidae congregation in river Gnily Rig requires further study and protection.

# Addressing global conservation issues on freshwater bivalves: Challenges and opportunities

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The preservation and management of freshwaters are highly important because they constitute valuable resources. On the other hand, freshwaters are one of the most fragile ecosystems in the world and are experiencing biodiversity declines far greater than those on marine and terrestrial habitats. These biodiversity losses are very high in freshwater molluscs, being one of the most threatened groups assessed to date, by the International Union for Conservation of Nature (IUCN), with many species facing extinction. This is especially true for freshwater bivalves which are among the most threatened faunistic groups at a global scale. Since the late 1970s, there has been an exponential growth on freshwater bivalves' research, both in the field of basic biology, ecology and physiology, but also on applied conservation such as habitats, rehabilitation and propagation. However, there is a need to further integrate and make this knowledge available to ecologists, conservation biologists and freshwater malacologists at a global scale. The Freshwater Mollusk Conservation Society has played this role in North America, promoting research and awareness, but also by organizing periodic meetings and workshops. In other parts of the world, research efforts vary and integration and knowledge exchange are needed, mainly in undeveloped countries of the Southern Hemisphere. The IUCN Species Survival Commission has been successfully promoting conservation efforts worldwide. Over the last 20 years, IUCN SSC Mollusc specialist group have accomplished this role for all Molluscs, and since 2013, a new Red List Authority Group is aiming to address conservation issues on these particular molluscan taxa. In the present lecture, the global conservation status and needs for Freshwater Bivalves will be presented as well as future pathways for addressing the major conservation issues on our beloved species.

# Seven steps towards improving mussel conservation success

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The key roles of freshwater mussels in the functioning of freshwater ecosystems are increasingly recognized and there is a large number of projects addressing their conservation. However, restoration of mussel habitats and populations is often based on gut feeling rather than on scientific evidence. Consequently, there are many cases in which conservation and restoration efforts have failed. This contribution analyses successful and unsuccessful European examples of mussel conservation and stream habitat restoration, and delineates the factors which seem to determine conservation success. Based upon these analyses, seven steps towards improving the success of such projects are proposed: (1) Decisions on conservation objectives, (2) Determination of status quo, (3) Identification of bottlenecks and problems, (4) Prioritization and decisions on conservation action, (5) Conservation action, (6) Evaluation and adaptive management, and (7) Exchange and publication of results. As illustrated in the context of two species, the thick-shelled river mussel (*Unio crassus*) and the freshwater pearl mussel (*Margaritifera margaritifera*), these planning guidelines are valid both for scientists as well as for conservation practitioners. Ideally, each of these steps should involve transdisciplinary planning, distinguish systematic and aggregated processes, and include a before-after-control-impact (BACI) design. Moreover, the importance of unsuccessful projects for avoiding similar errors in other areas and occasions is currently underestimated. Using the example of a systematic comparison of four different methods of stream bed restoration in German streams, it is illustrated that the result of restoration and conservation actions can be more negative than before the action. With many pressures on mussel populations ahead, the importance of evidence-based conservation approaches is emphasized.

# Project grande mulette: Conservation of the giant pearl mussel (*Margaritifera auricularia*) in Europe

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Thanks to the project LIFE13/FR/BIO/001162, since July 2014, the University of Tours and the Conseil Général de Charente Maritime, France, cooperate with partners in France, Spain and Germany to preserve and reinforce the last populations of the critically endangered Giant Pearl Mussel *Margaritifera auricularia* in France and more widely in Europe. The Giant Pearl Mussel, previously widespread in Western Europe, remains in a few relict populations in certain rivers in France and the Ebro basin in Spain; however, the recruitment of young individuals is not probable. Causes of this decline are multiple: the near extinction of its best-known host fish (European sturgeon), hydromorphological degradation of rivers, overfishing during the last century, and fragmentation of populations. Here, we present the main objectives of the project and the principal results obtained the first year of our study, which focused on the artificial rearing of mussels and the reproduction biology of the French populations.

# Unionid biodiversity and conservation problems in Turkey

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A total of 13 species belonging to 5 genera from Unionidae have been recorded from Turkey. The fauna represents a mixture of elements from different zoogeographic origins and 8 out of 12 native species (66%) have their origins in the Eastern Mediterranean, hence the greatest diversity is seen in south and southeastern regions, while the remaining 4 are widespread European taxa. Although distributed in the adjacent areas to Turkey, several species are absent from the country: *Unio tumidus* and *Pseudanodonta complanata* both recorded from Bulgaria, *Pseudodontopsis euphraticus* from Tigris-Euphrates System (Iraq), *Margaritifera homsensis* from Lake Homs (Syria). Eastern Palearctic invasive alien species *Sinanodonta woodiana* has recently been recorded from northwestern Turkey. Distributional data of the unionid taxa are often incomplete, however it is apparent that the distributions of widespread taxa are discontinuous, and large distributional gaps among isolated populations suggest presumable subspecific or specific differentiation yet to be uncovered. There is also a strong need for implementation of molecular methods, in combination with other methods, to resolve taxonomic relationships, as correct species identification may be obstructed by the phenotypic plasticity, and evaluation of the existing records based on the conchological characters may be problematic. The major threat for the Unionidae species is habitat destruction which can be observed in many forms (dam construction, water abstraction, alteration of water courses and pollution), often perceived together at once especially in larger rivers. Drought may be considered in southern parts a primary threat factor for the survival of the species directly, or indirectly, and the coastal Mediterranean streams previously known to house unionid populations are heavily stressed and many are likely to have gone according to recently conducted surveys.

# Conservations efforts with focus on the thick shelled river mussel (*Unio crassus* Philipsson, 1788) and its host fish fauna in Svennevadsån, Sweden

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Conservation efforts for the endangered species thick shelled river mussel (*Unio crassus*) was conducted in November 2008 and July 2009 in one stretch of the Svennevadsån-Skogaån River, Örebro County, Sweden. The dominated bottom substrate of this stretch was soft and anoxic mud. Coarse substrate, gravel, stones and rocks were supplied to create a heterogeneous stretch and to improve the habitat. The measures were combined with test fishing in July 2009 in order to investigate the presence and density (abundance) of suitable host fishes of the mussel. In addition, a supply of bullhead (*Cottus gobio*), a definite host to *U. crassus*, was stocked in the restored stretch together with 100 adult *U. crassus* taken from a downstream stretch of the river. Mussels were marked with individual numbers for long term survey purposes. In 2013 and 2014, the stretch was surveyed and length of the mussels was measured; an additional electrofishing survey was carried out to investigate glochidia prevalence and infection intensity on suitable hosts. The length of the marked mussels increased between 2009 and 2013, and we conclude that introduction was a success. Host fish fauna changed between 2013 and 2014 at the restoration site from 3 to 5 species. Glochidia prevalence on different suitable host fishes changed from 100% to 80% between the years. In 2013, ruffe (*Gymnocephalus cernuus*) was the most common species in the stretch with a 100% prevalence of glochidia and a mean infection intensity of 2.8 glochidia per infected fish (n=6, S.E ± 0, 6). In 2014, ruffe was still the most common species at the stretch with a glochidia prevalence of 31% and a mean infection intensity of 1.5 glochidia per infected ruffe (n=4, S.E ± 0.3). Ruffe has been identified as a definite host in earlier studies and we suggest that it may be an important host to *U. crassus* in Svennevadsån.

# A comprehensive freshwater mussel restoration program: Progress in the Delaware River Basin

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Freshwater mussels are the most imperiled of all animals in the United States despite their ecosystem services and importance as natural heritage. In most streams of the Delaware River Basin, few or no mussels remain, whereas historical data suggest that most streams surveyed had once supported robust numbers of up to 12 mussel species. In 2007, a multi-pronged Freshwater Mussel Recovery Program (FMRP) was designed and implemented with diverse partners. The FMRP consists of nine complementary activities aimed at conserving and restoring native species of freshwater mussels throughout the watershed, which is viewed as a driver for ecosystem-based restoration and one facet of a water quality enhancement strategy. As part of the FMRP, streams are being comparatively assessed for their ability to support mussel populations by tracking the survival and growth of >1000 sentinel mussels that were electronically tagged (passive integrated transponders) and reintroduced to nine stream reaches throughout southeast Pennsylvania and northern Delaware. A combination of *Elliptio complanata* and *Pyganodon cataracta* were used to also contrast restoration outcomes between species. Despite severe storms and flooding (e.g. Hurricanes Irene and Sandy), mussels have persisted and exhibited positive shell growth in multiple streams. Streams with reduced success were typically either located in urban landscapes, had little riparian cover, or suffered from stormwater scouring. Comparative rankings of restoration readiness are being used to prioritize FMRP next steps, such as potential reseeding of adult mussels salvaged from development activities or juvenile mussels propagated in hatcheries.

# Saving six freshwater pearl mussel *Margaritifera margaritifera* populations in the Armorican Massif (France)

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The freshwater pearl mussel populations of the Armorican Massif are old and their numbers are declining at an alarming rate. Without proper protection they will likely to go extinct within the next 10 years. Therefore, the conservation of this species using rearing stations is essential to preserve and support their population in the wild. The Fédération de pêche du Finistère [local fishing federation] is actively involved in the conservation research for the pearl mussel on the Favot fish-farming site at Brasparts, where a rearing station was established as part of the LIFE Mulette programme (LIFE09NATFR000583) and specifically dedicated to this species. The rearing protocol is constantly being improved based on communications with other projects, their feedback from their research and our own observations. Proper predictions of how each strain will behave under artificial rearing conditions are difficult to make, which in turn makes it difficult to develop a standard 'turnkey' protocol. In order to restore the habitat quality in rivers, local authorities and associations making every effort and mobilize all possible means for action. We hope that these rivers regain their original potential to host dynamic freshwater pearl mussel populations that evolved naturally with their host fish, such as the salmonids in the rivers of the Armorican Massif.

# Conservation of endangered unionids in high-flowing fragmented rivers: Historical changes and metapopulation dynamics of the Rio Grande endangered endemic *Popenaias popeii*

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Although freshwater molluscs in the order Unionoida are considered one of the most endangered groups of animals in the world, sufficient data on their status are lacking for the majority of species, and a species may become endangered and even extinct before the first population assessment is conducted. This is especially true for endemic species, particularly those limited to remote regions with difficult access. We studied the current distribution, population dynamics, survival and downstream movement of endemic Rio Grande unionid *Popenaias popeii* in Texas, and developed a method to evaluate changes in the population's size and distributional range over the last 100 years. Sampling over 250 sites in four rivers that constitute the entire historical range of *P. popeii* in Texas, we found that this species has likely been extirpated from two rivers. The total length of the rivers populated by this mussel has declined by 75%, and the total *P. popeii* population size has declined by 72%. The remaining population of this species in the Rio Grande is fragmented, with only one 190 km stretch still supporting high densities. Using mark-recapture data collected in 2011-2014, we estimated *P. popeii* annual survival rates and downstream movement. While nearly all studies and conservation efforts assume negligible rates of unionid immigration and emigration, we observed large changes in local abundance concomitant with interannual variation in discharge that can only be explained by high rates of downstream emigration and immigration of adult mussels from upstream sites. Our study was the first to quantify the dominant effect of flow dispersal on population dynamics, suggesting that it can be an important source of connectivity between available unionid habitats. Species conservation must aim to preserve both occupied and unoccupied suitable habitats, as well as the connectivity among these habitats to allow recolonization of extinct patches following local disturbances.

# Latitudinal distribution of the unionid mussel *Anodonta anatina* and its trematode parasites in Finland

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Geographic ranges of distribution of species are expected to shift or expand due to climate change. In order to better anticipate changes that will take place among unionid mussels and in their trematode parasites in north Europe, we mapped the current distribution and abundance of the common freshwater mussel, *Anodonta anatina*, by examining host fishes (Eurasian perch *Perca fluviatilis* and roach *Rutilus rutilus*) for *A. anatina* glochidia – and by studying the occurrence and prevalence of two bucephalid trematodes in their 1st and 2nd intermediate hosts, *A. anatina* and roach *Rutilus rutilus*, respectively. Materials were collected from southern (61-63°N), northern (Posio-Kuusamo: 65-66°N) and northernmost (Enontekiö: >68°N) Finland. *A. anatina* occurred in perch and roach collected from the southern (12 out of 14 sites) and from the northern regions (6 out of 7 sites), but did not occur in the 6 populations from the northernmost region. Whereas the trematode *Rhipidocotyle fennica* occurred in 10/13 *A. anatina* populations and in 9/11 roach populations from the south, it only occurred in 2/7 *A. anatina* populations and in 0/6 roach populations from the north. *R. campanula* was found in 7/13 *A. anatina* populations and in 6/6 roach populations from the south, and in 5/7 *A. anatina* populations and in 4/6 roach populations from the northern region. Like *A. anatina*, the trematode parasites also did not occur in the 6 northernmost populations studied. However, the 2-7 °C increase in air temperature predicted for Finland by 2080 may drastically change the situation in future.

# Parasitic freshwater pearl mussel larvae reduce the drift-feeding rate of juvenile brown trout.

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I will describe the effects of freshwater pearl mussel (*Margaritifera margaritifera* L.) encystment on the drift-feeding behavior of juvenile brown trout (*Salmo trutta* L.). Because both mussel and salmonid populations are often threatened, this study not only adds knowledge to the understanding of host-parasite systems, but it is also of conservation value. Individual trout, mussel-encysted (25.1±5.7 larvae·g−1 body weight) or non-encysted, were fed with chironomid larvae in a flow-through stream aquarium. Feeding trials were filmed and analyzed by counting the numbers of chironomid larvae each individual ate, and by estimating the prey-capture distance. Non-encysted trout had a significantly higher drift-foraging rate than did encysted trout, and they captured significantly more prey further away from their focal point. The reduced foraging success of encysted trout was mainly due to their failure to catch prey relatively further from their focal point. This suggests that reduced foraging success of encysted trout may be due to poorer energetic status, but the physical effects of mussel larvae on prey handling time cannot be ruled out. Encysted trout caught approximately 20% fewer prey, which would result in a reduction in growth potential during the period of mussel encystment. Reduced energetic status might also result in reduced competitive ability or in increased exposure to predation risk.

# Fast swimming brown trout receives a higher parasitic load of freshwater pearl mussel (Margaritifera margaritifera) larvae

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The aim of this experiment was to investigate if specific behavior or attributes in brown trout can explain the prevalence of freshwater pearl mussel larvae (glochidia) in a population of host fish (brown trout). Individual differences in boldness and/or activity patterns are well known in trout and may alter the exposure from larvae of freshwater pearl mussel (glochidia larvae) which could explain the difference in glochidial load that has been observed. The experiment was performed in the river Kvarnabäcken on the west coast of Sweden where a reintroduction program for freshwater pearl mussel is in action by using artificial infested brown trout and reallocation of adult gravid mussels. Here, one hundred 1+ brown trout were caught in June, brought into a lab for behavioral scoring, marked with a passive integrated transponder (PIT-tag) and released back into the stream in July. Prior to release of the fish, fifty gravid mussels was also relocated to the stream. In October, 44 fish were recaptured and brought back to lab for a second behavioral scoring. Seventeen percent of these fish were now infested with glochidia larvae with a range between 1 and 10. Our results suggest that individuals with higher mean swimming speed were exposed to more glochidia larvae causing a larger prevalence of infection for these fish. Possibly, an increased swimming speed corresponds with a higher ventilation rate and thereby an increasing amount of water with infectious gill parasites that passes over the gill arches. Behavior was constant between the trials indicating that a low amount of glochidia does not affect the behavior of the fish. This study shows novel data that host fish behavior can have an effect on glochidia infection and that it is not just a random event caused by free drifting larvae.

# Are all glochidia equal? Evidence of variation within and among individual unionids

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Glochidia, larval stage of unionids, are often used in toxicity and host fish testing. Most conclusions from these tests do not consider potential variation of microstructures of the glochidium, potentially misinterpreting the mechanisms driving variation. Scanning Electron Microscopy (SEM) was used to quantify varation in two unionid species. Glochidia from gravid *Ligumia recta* from the Flat River, Lake Michigan Drainage, MI, USA (n=82) were analyzed to describe within and between mother variation in shell measurements, pithing characteristics, and micropoints. For the first time, glochidia from the federally endangered *Epioblasma triquetra* (n=292) from two Great Lakes basins were studied at different stages of host fish infestation with *Percina caprodes* (2 stages, 6 treatments). Significant differences in measurements and descriptions of glochidia reveal multiple morphotypes of glochidia being produced by a single mother and among individuals within a species. Also, variation is documented among different treatments during host tests. Comparison of shell measurements to past studies were made to determine variation among different watersheds. Possible explanations for variation in traits and morphotypes of glochidia and their impacts on the literature are discussed. For example, documented variation could provide insight on how to improve transformation success, toxicological tests, and host fish specificity experiments which currently could be misrepresenting results by not accounting for glochidial variation.

# Host fish biotic homogenization. A major threat to Iberian freshwater mussel (Unionoida) species

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Many Iberian freshwater mussel (Bivalvia, Unionoida) populations are threatened by habitat loss and fragmentation, degradation of riparian and aquatic ecosystems, water abstraction and mainly by river regulation. The introduction of Invasive Alien Species is also accepted by scientists as well as conservationists, as a major threat. However, in some cases, available evidences showing that invasions and extinctions are correlated, are subjective, speculative and based upon limited observation. Mediterranean fresh waters are also among the most heavily invaded ecosystems in the world. In particular, the increasing abundance of invasive fish species (e.g. *Micropterus salmoides*, *Esox lucius*, *Gambusia holbrooki*, *Oncorhynchus mykiss*) lead to biotic homogenisation of the fish communities in most of the Iberian freshwater ecosystems. It is known that mussels have a complex reproductive behaviour where their larvae (glochidia) parasitize and depend on specific fish species as hosts for metamorphosis and upstream dispersion. In the present work we successfully reproduce and determine the host fish species for *Anodonta anatina*, *Potomida litorallis* and *Unio delphinus*. The fish species that successfully transformed glochidia in juveniles were considered valid hosts. The results of host fish experiments showed that, with two exceptions, all effective hosts were native. Additionally previous host fish trials revealed that most alien fish species are not suitable for the other Iberian mussels. For this reason, the status of the freshwater mussel fauna in Iberia may suffer a major decline in the near future. Conservation measures are needed and must consider monitoring and adequate legislation programs for the protection of mussel populations based on the conservation and/or the rehabilitation of ecological integrity of aquatic ecosystems.

# How does the distribution of unionid freshwater mussels in Texas relate to the distribution of fishes?

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Current distributions of fishes in Texas were shaped by Pleistocene glacial dispersion and interglacial isolation events resulting in predictable species distributions along a climate gradient from the humid east to the arid west regions of Texas. It is likely that the present-day distributions of unionid mussels are similarly related to these processes as early life stages of unionid mussels are known to be parasitic on freshwater fishes. The objectives of our study are to: (1) Examine broad-scale spatial patterns of diversity of mussels in Texas in relation to diversity of fish; (2) Compare patterns of endemism of mussels and fish; (3) Examine smaller scale within drainage patterns of mussels and fish. The current distribution of fish show a gradient from high diversity in the east to lower diversity in the west-Texas, with hotspots of endemism in Central Texas and Rio Grande. Preliminary results suggest that a similar pattern exists for unionid mussels with the exception of a lower proportion of endemism in the Rio Grande where fishes have a high rate of endemism largely related to karst spring refugia. Mussels are more abundant in higher order streams and tend to be absent from springs. Water scarcity resulting from increased water demand by a growing population is a major threat for stream fishes in Central Texas, the area with the highest endemism of mussels. This could also lead to further declines in mussels more directly by processes such as decreases in water quality, but also indirectly through a decline of their host fish.

# Recovering from co-extirpation: The challenge of restoring an ecologically relevant host-affiliate relationship

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American eels (*Anguilla rostrata*) have declined dramatically throughout their range, partially due to the stream barriers blocking migration pathways. Evidence suggests that the historically abundant and common eastern elliptio mussel (*Elliptio complanata*) has also declined in parts of its range. Freshwater mussels are obligate ectoparasites on one or more host fish species to complete their metamorphosis from larvae to juveniles. Results of host fish studies indicate that American eels are good hosts for *E. complanata*, which may partially explain data suggesting limited recruitment of *E. complanata*. Because eels were historically of economic importance, and both eels and freshwater mussels contribute essential functions to stream ecosystems, efforts have been made to restore eel populations, particularly around native mussel beds. Effects of experimental stocking on eel and mussel population dynamics are being assessed, but preliminarily show increased recruitment in *E. complanata*. Alternative methods for restoring eel populations, and thereby *E. complanata* recruitment, are being assessed.

# Does the accumulation of trace elements in riverine sediments affect the populations of *Margaritifera margaritifera*?

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The freshwater pearl mussel (*Margaritifera margaritifera*) populations have experienced a large recession or even disappeared during the last decades. The existing populations are highly vulnerable to natural and anthropogenic impacts, such as climatic change, introduction of invasive species, eutrophication or habitat alteration. Moreover, the freshwater mussels are considered susceptible to increases in the basal-content of trace metals in sediments due to their longevity within the substrate. The accumulation and bioavailability of trace metals in riverine sediments could directly affect the flora and fauna present in these ecosystems. The objective of the present study was to analyze the relationship between the content of trace metal and metalloids in the riverine sediments and the abundance of freshwater pearl mussel populations. The effect of water and sediment quality on the populations along a riverine basin was also assessed. Finally, geochemical indexes were obtained to evaluate the anthropogenic influence on the presence of trace elements in the sediments. Initial results indicated that trace elements accumulated in the lower reaches of the river basin and larger concentrations were found at sites affected by anthropogenic activities. A negative correlation was found between the distribution of trace elements on the basin and the abundance of M. *margaritifera*. Populations of *M. margaritifera* were absent, or in its lowest abundance when the riverine sediments contained relevant concentrations of Cu, Zn, Ni and As, which may negatively affect the survival of the individuals.

# Environmental influences on the community composition of freshwater mussels as a baseline to spatial conservation prioritization: A case study in the Cuiabá River Basin, Midwest of Brazil

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The effective maintenance of species depends on the conservation planning which addresses their distributions, relationships with the environment and the main population decline factors. In the center of South America, aquatic organisms undergo anthropogenic alterations like an expansion of hydropower matrix and agribusiness. As consequence, the structure and functioning of aquatic ecosystems are modified. In this context, we propose a conservation plan using a combined analysis of the freshwater mussels' distribution and the main environmental factors related to that. To understand the relationship between environment and mussel composition we used a multivariate approach. To identify mussel conservation prioritization areas, we applied a systematic conservation planning (SCP) wherein looked at five attributes: mining, hydropower plants, invasive species, limestone lands and protected areas. Over 70 collection sites across the hydrological gradient of the Cuiabá River Basin (upland and lowland ≈ 192.626km$^2$), we collected 7499 mussels belonging to 27 different species of Mycetopodidae (15sp.; 2700ind.), Hyriidae (3; 1811), Sphaeriidae (2; 148), Pisidiidae (5; 636) and Corbiculidae (3; 2205). The MNDS applied to biological data identified five different groups. The environmental variables explained 87.33% of the total variation, conductivity being the main factor that explained the community variation. Our results show a clear ordination of mussels' community composition according hydrological gradient and limestone. These preliminary results should be seen as a first assay to plan priority areas for mussel conservation in this region, being a useful tool for both scientists and managers to allocate future efforts on restoration and conservation.

# Physiological and behavioral response of native freshwater mussels to environmental variables

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Native freshwater mussel populations are declining across the United States due to a variety of environmental and anthropogenic variables. The U. S. Geological Survey Northern Appalachian Research Laboratory (NARL) has been assessing the response of several Atlantic slope species (*Alasmidonta heterodon*, *A. marginata*, *A. varicosa*, *Elliptio complanata*, *Strophitus undulatus*, and *Pyganodon cataracta*) to a range of environmental variables: temperature, stream velocity, water removal, dissolved oxygen, salinity, and sedimentation. Understanding how multiple, and sometimes interacting, stressors impact freshwater mussel physiology and behavior, and how these responses vary between species aids management and conservation of this imperiled group of organisms. The results of our studies suggest that mussels can be grouped into guilds based on their tolerance to individual, and potentially combined, stressors. A database of mussel physiology and behavior will be developed for use in identifying species susceptibility to environmental stressors, determining which will be most impacted by changes to water management strategies, and highlighting areas for remediation and mussel restoration.

# Investigating the impacts of water quality on freshwater mussels

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Freshwater mussels (family: Unionidae) are among the most endangered organisms in North America, with over 70% of native unionid species listed as endangered, threatened or as a species of special concern. Pollution is cited as one of the major factors in the decline of unionids. Recent laboratory toxicity tests indicate that freshwater mussels, particularly in the juvenile life-stage, are among the most sensitive aquatic organisms to ammonia, copper and major ions. In addition, studies have also shown that concentrations of contaminants (including ammonia) can be elevated in pore water (i.e. the interstitial water between particles of sediment) relative to overlying surface water. With juvenile mussels constantly being exposed to pore water via direct contact and feeding, resource managers may be missing a key piece of information with regard to limiting factors by focusing on concentrations of contaminants in surface water. In 2013 and 2014, U.S. Fish and Wildlife Service biologists collected pore water and overlying surface water at sites in Michigan, Wisconsin and Minnesota to examine any potential correlations between surface water quality and pore water quality, and water quality and mussel abundance. The overarching objectives of the project were to aid decision-making and provide resource managers with additional data and tools (e.g., by enhancing a Mussel Threats Geospatial Database) with respect to mussel reintroduction and restoration efforts. We will present a summary of our methods, results, conclusions and any relevant recommendations that may contribute to future management and conservation of freshwater mussels.

# Abstracts

# Poster Presentations

# The Project LIFE Potamo Fauna: An initiative for the recovery of naiad populations from the Northeast of the Iberian Peninsula

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In the Fluvià and Ter rivers, in the northeast of the Iberian Peninsula, live 4 of the 10 Spanish native naiad species: *Unio mancus, Unio ravoisieri, Anodonta anatina* and *Potomida littoralis*, all legally protected. With some exceptions, their populations are very fragmented. Modification of the hydraulic system, proliferation of exotic fish species and water pollution have caused a strong naiad decline. In 2010 a laboratory for naiad recovery was developed by the Consorci de l'Estany. In this facility, we successfully reproduced three of these species to repopulate Lake Banyoles, part of the Natura Web 2000 from the European Union. In 2014, we initiated the project LIFE Fauna Potamo (LIFE12 NAT / ES / 0001091) with the ultimate objective being the recovery and long-term preservation of several endangered species of river fauna of European interest (Habitats Directive): the naiads *U. mancus* and *U. ravoisieri*, the snails *Vertigo moulinsiana* and *V. angustior*, the European crayfish *Austropotamobius pallipes* and the European pond turtle *Emys orbicularis*. Regarding naiads, we hope to sample and monitor the Unio populations in the selected basins, study their ecology, population status and repopulate different river sections with individuals reproduced in captivity. Here we present the results of the first two years of the project LIFE Potamo Fauna.

# *Castalia ambigua, C. inflata,* or both? New data about geographical distribution and population genetics in central South America

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Although freshwater mussels have become imperiled in recent years, they remain largely under-investigated. The genus *Castalia* Lamarck, 1919 (UNIONOIDA, Hyriidae) is distributed in many major basins of South America; however, baseline data on species' distributions are lacking. Here, data on the occurrence of *C. ambigua* Lamarck, 1819 and *C. inflata* Orbgny, 1835 in the upper Paraguay River basin are provided based on a study of distribution around 70 sample sites, validated historical records and a study of population genetics. The distribution of *C. ambigua* is found in four of the eight major Brazilian basins: the Amazon, Paraguay and Paraná, with a restricted distribution in the Uruguay River basin. *C. inflata* is distributed in the Paraguay River basin and the middle-lower Parana basin. This study focusses upon the area of overlapping occurrence of the two species, the watershed between the Paraguay and Amazon basins. The upper Paraguay River basin (BAP) has distinct regions, the highlands and lowlands, that include the Pantanal, the biggest continuous wetland in the world. The distribution map for these species shows that *C. inflata* occurs in both regions and *C. ambigua* occurs in the highlands, predominantly in karstic waters. On the basis of the mitochondrial *COI* gene sequence, *C. inflata* is a cohesive species, with but a few single-nucleotide polymorphisms. Variation within *C. ambigua* is under investigation. *COI* sequences of C. *inflata* are distinct from those of other members of the genus.

# Urban effects on the structure and composition of freshwater mussels assemblages in shallow lakes

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We studied the effect of physical and chemical factors, mainly a conservation prioritization nutrient concentration, on the structure and composition of freshwater mussels assemblages present in urban and no urban shallow lakes. Our aim is to know a set of variables that can be used to resume the structure and composition of this faunal group. The assumption is: the richness and density of mussels are a function of nutrient availability and so the structure and composition of assemblages are determined by the water quality. During the dry season of 2012/13, we sampled 18 water bodies around Cuiabá town (Brazil). From each, the main environmental variables were measured, including water and sediment features. Mussels were: sampled by active search, biometrics taken, tags placed, and returned to same place. Regarding the effect of water on mussel, we considered a multivariate approach. We sampled 1364 alive mussels belonging to 8 species. Environmental variables explained 55.27% of variation in the composition of species between the sites studied, wherein nitrate ($r^2$=0.3769; p=0.028) and organic matter ($r^2$=0.3970, p=0.019) showed a significant relationship with the community structure. Different models described the influence of the environment on the population structure, represented by total length (Lt), *A. trapesialis* was adjusted by DO and total P, while *A. elongatus* by pH, DO, OM and $NO_3$. Overall, the data supports that nutrient and organic matter are important for maintenance of freshwater mussels. However, release of wastewater immediately upstream of the Pantanal will negatively affect these species.

# The Asian clam *Corbicula fluminea*: Seasonal filtration rates of representative populations in two tributaries of the Delaware River

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The Asian clam, Corbicula fluminea, is an exotic freshwater bivalve that was first introduced to the United States in the early 1930s. Populations of *C. fluminea* have rapidly spread over the country due to its high reproductive output and short life cycle. Due to its numerical abundance and filter feeding behavior, *C. fluminea* has the potential to impact water quality through a reduction of turbidity, as well as possibly removing particulate pollutants such as nutrients. In the Delaware River system where *C. fluminea* was first documented over 40 years ago, the clams have assumed a dominant position in the benthic community of many streams, often representing a majority of benthic faunal biomass. Despite its high population abundance and potential to alter stream ecology, there have been few studies regarding the clam's feeding behavior on natural seston diets and seasonal changes in population demographics and feeding processes. Seasonal changes in natural seston, clam filtration rates, and clam population demographics were contrasted between two representative tributaries of the Delaware River Basin: the Cooper River, New Jersey, and Red Clay Creek, Deleware. Clam filtration rates significantly differed by season in both streams ($p<0.001$). Filtration rates of clams in Cooper River were more than twice that of clams in Red Clay Creek over all seasons. Clams from Cooper River were larger on average ($p<0.005$) than clams from Red Clay. Data from physiology studies, population surveys, and seston analyses were coupled to estimate the importance of clam-mediated particle filtration in removing suspended matter flowing through each study stream.

# The effects of glochidia infection intensity and stress levels on the metamorphic success and lipid reserves of *Lampsilis siliquoidea*

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An increasing number of studies demonstrate the critical role of the host–parasite relationship for the persistence and distribution of unionid populations. Laboratory experimental methods are a powerful tool for quantifying the physiological compatibility between the mussel and the fish host and are clearly applicable to species conservation. Recent findings however, indicate potential need for more thorough approaches to control for biases caused by overinfestation and increased stress levels during experimental procedures. In this study, we verified the robustness of freshwater mussel-fish compatibility, testing against stress stimuli in laboratory experiments. Glochidia metamorphic success of *Lampsilis siliquoidea* on *Lepomis macrochirus* were quantified in a laboratory environment together with the quantification of lipid reserves in juvenile mussels and Cortisol level quantification in host fish plasma. The main aims were to investigate the relationship between the levels of glochidia infection and the success of metamorphosis, and to quantify the differences in the observed mussel-fish compatibility between traditional and stress-free infection approach. Our results indicate non-significant effect of glochidia bath density (1000-4000-8000 glochidia per litre) on transformation success of *Lampsilis siliquoidea* glochidia on *Lepomis macrochirus*, and only weak differences between both approaches used for the infestation. Overall, standard host compatibility testing approaches likely represent relatively robust methods for the evaluation of host compatibility, but more emphasis on laboratory settings may help to further improve infestation protocols for glochidia of freshwater mussels to provide more repeatable data. Implications for the strategies of host evaluation in laboratory experiments are discussed.

# Distribution of adult pearl mussel (*Margaritifera margaritifera*) individuals and location suitability bioindicitively assessed in the longitudinal stream profile on the border of a natural area

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The river basin of the Vltava River in the trans-border national parks Šumava/Bayerischer Wald (Czech Republic - Germany) hosts one of the important residual populations of the pearl mussel (*Margaritifera margaritifera*) in Central Europe. Less than 1000 adult individuals inhabit an oligotrophic meandering stream at an elevation of about 800 meters above sea level, which is close to the upper tolerance limit for this species. Two genetically different populations were identified, dispersed along a 20km stretch of the stream. Sub-adult individuals were rarely found in the same locations where individuals from the rescue programme were released.
Biotope suitability was assessed bioindicatively in-situ by using one-year-old juveniles. The individuals were placed into the breeding plates described by Budensiek and evaluated separately. The plates were placed in microhabitats above, on and in the sediment.
The detritus was tested analogously ex-situ. Noticeable mortality was only observed in the hyporheic zone, where the mortality was negatively correlated with the microhabitat oxygen concentration. Water temperature was a significant factor influencing the juveniles' growth in the river's longitudinal profile. Favourable conditions for juveniles were bioindicatively found in some of the tributaries and the upper part of the stream.

# Taxonomic examination of the Unio species (Bivalvia, Unionidae) from Russia and Ukraine based upon morphological and molecular data

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Identification of mussel species of the genus Unio (Bivalvia, Unionidae) in Eastern Europe, Russia and Ukraine is difficult because there is no correspondence between existent classifications. According to V.I. Zhadin (1938, 1952), the genus Unio Philipsson in Retzius, 1788 consists of three species: *U. pictorum, U. tumidus* and *U. crassus*. In contrast, Y.I. Starobogatov and co-authors (2004) developed a specific systematics system that lead to the separation of Unio in three distinct genera: *Unio* (4 sp.), *Tumidiana* Cervain, 1882 (3 sp.), and *Crassiana* Cervain, 1882 (6 sp.). This last genus was reassigned to the subfamily Psilunioninae with subgenera *Crassiana* s.str. and *Batavusiana* Cervain, 1882. The disagreement between these classifications raises a fundamental question: what is the system that better reveals the phylogenetic relationships among these taxa and therefore should be considered as valid? Molecular genetics research based upon analysis of the mtDNA CO1 gene sequences revealed the existence of only three Unio species – *U. pictorum*, *U. tumidus* and *U. crassus* in Russia, Ukraine, and Eastern Europe. The analysis of morphological characters of mussels collected from different regions of Russia and Ukraine also confirm the existence of three highly polymorphic widespread species. The hypothetic species within each genus using the Starobogatov system, have statistically insignificant discreteness (λ 0.563–0.969) and belong to three polymorphic species of Unio. This integrated molecular and morphological data confirms the validity of the classification by Zhadin (1938, 1952), and therefore does not support the complex classification of Starobogatov et al. (2004).

# Conservation status and threats of existence for species *Unio* (Bivalvia Unionidae) in the refuge of the Transbaikalia, Russia

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European species of the genus *Unio* in the lake-refuge Kenon (Transbaikalia, Russia) are most likely the relict of a larger population during the Pleistocene and its conservation status indicates the population is being threatened and endangered. Populations are declining due to predation by the muskrat (*Ondatra zibethicus*) which largely reduced the number of mussels to critical state during the last 10 years. Freshwater mussels have an obligate parasitic larvae stage (glochidia) on gills or fins of host fish as part of their lifecycle. In the lake- refuge mutual reproduction relationships between mussels and fish-hosts (e.g. bitterlings *Rhodeus cericeus*) were shaped in the process of coevolution and the lack of either species makes reproduction of the other one impossible. Although, the condition of the mussels can be negatively affected by bitterling fry hatching in their gills (e.g. increase in respiration, deformations and perforation of the septum and gill walls) the nominal restoration success of the Unio populations in the lake-refuge is related to a declining number of fish-hosts necessary for glochidia development.

Mussels are also threatened by anthropogenic activities such as degradation of habitats due to dredging, thermal and toxic inflow of wastewater from a thermal power plant, and surface drainage of heavy metals from ash-disposal area. Being active filter feeders, freshwater mussels accumulate considerable concentrations of heavy metals in their tissues. Some heavy metals, such as cadmium, lead, mercury and arsenic are carcinogenic and mutagenic even in small concentrations and may reduce or even suppress vital functions. The data of biogeochemical diagnostics on accumulation of heavy metals in the mussels from different lake zones shown higher concentration of toxic heavy metals in *Unio* species collected from the thermal lake zone. In addition in mussels from this lake zone was revealed the different pathology in soft tissues and shells. The heightened values of bioaccumulation of toxic metals and pathology in mussels indicate their unfavorable ecological condition. Since freshwater bivalve mussels are an ecologically significant component of any ecosystem, their conservation in the lake-refuge requires the special attention and immediate action, such as a decrease in the muskrat population and anthropogenic impacts.

# Environmental DNA next-generation sequencing assays for biological and population genetic inferences in a mollusk community

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The Great Lakes are one of the most invaded aquatic habitats, numbering 186 invasive species, including the notorious dreissenid mussels (zebra and quagga). Detecting invasive species prior to establishment greatly increases chances of eradication and control. Environmental DNA (i.e., genetic material shed from living organisms via urine, mucus, tissues, filter feeding, etc.) is a powerful technique to assess the presence/absence of invasive and/or rare species, which is especially effective at low population levels compared to traditional sampling. However, most eDNA assays just reveal single species presence/absence, lacking information about relative abundance and genetic diversity. We are developing rapid high-resolution diagnostic assays to identify and quantify invasive and rare mollusk species. These assays simultaneously provide information on species identities and their relative abundances, along with related species and potentially entire communities. This design also provides population genetic data from haplotypic variation and relative frequencies in the populations, allowing in depth genetic comparisons that can elucidate patterns of spread throughout the course of an invasion. We developed primers to amplify regions of the cytochrome *b*, COI, and 16S mitochondrial genes, as well as the 28S nuclear gene that targets dreissenid mussels and their relatives, at various taxonomic levels. This design can be readily adjusted to target other species, communities, and geographic regions for quick, effective species diversity and population genetic studies from a single assay. The power of such assays can also be implemented for rare and endangered species that are difficult to sample, such as unionid communities.

# Can ecological niche models predict potential fish hosts? A case study with East Texas threatened unionids

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Unionids exhibit an unusual life cycle in which their larvae, called glochidia, are obligate ectoparasites on fish gills or fins. Knowledge of host fish species is lacking for many unionids, as hosts are unverified or still unknown. Natural history data is critical for successful propagation and conservation of this group. Ecological niche modeling has been proven to be a useful tool in predicting habitat for many threatened unionids. By improving upon these models, we intend to explore their effectiveness at predicting potential hosts. These models can be useful for rare mussel species that are scarcely abundant in high numbers; therefore, natural infestations of glochidia for such species increase in difficulty to sample and identify. Also, a single unionid species is capable of using many host fishes, niche models might be able to discern which fish species is most ecologically important. Niche models were constructed in Maxent using seven environmental variables (soil type, geology, vegetation type, landform, groundwater recharge, land cover type, cumulative drainage area) found to be important for six state-threatened unionids species (*Fusconaia askewi, F. lananensis*, *Lampsilis satura, Obovaria jacksoniana*, *Pleurobema riddellii*, and *Potamilus amphichaenus*) in East Texas rivers. These models will be reexamined with the addition of fish species layers to ascertain potential hosts. If the model increases in fitness, that fish species will be considered a natural host. To determine the accuracy of these niche models, they will be compared with previous reported hosts and with results from encysted glochidia on wild caught fish in East Texas.

# Hydrodynamic impacts of freshwater mussels: Measurement of turbulence generation in a laboratory flume

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Hydrodynamics of aquatic ecosystems encompass both the physical interaction between flow and organisms, as well as ecologically relevant mass-transfer-uptake processes. As benthic filter feeders, mussels contribute to near bed flow hydrodynamics in two ways. First, mussel shells act as a physical roughness feature at the water-sediment interface, and second, mussel-filtering activity generates mass and momentum transfer processes with the surrounding water. Here, we look at turbulence generation due to mussel filtering activity in a laboratory flume. To control the experimental inputs, we used mussel shells (*Lampsilis siliquoidea*) with a model siphon pair connected to a peristaltic pump to enable variable filtration rates. We used three filtration rates representing a range of naturally occurring filtration ability. For each filtration rate, we introduced a range of ambient flow velocities in the flume and characterized the hydrodynamic flow conditions using two-dimensional particle image velocimetry. We are in the process of analyzing the results and will estimate the effect of filtering on downstream turbulence for each filter and flow scenario. These results will be used to make conclusions on how the filtering activity of mussels contribute to near-bed hydrodynamics and how this information can provide insight to nutrient mixing and feeding efficiency within mussel beds.

# Investigating the potential effects of Black Carp (*Mylopharyngodon piceus*) invasion on native freshwater mussels (Unionidae) in the Laurentian Great Lakes

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Black Carp (*Mylopharyngodon piceus*) is a large (up to 1.5m and 70 kg) molluscivorous cyprinid, native to eastern Asia including China, eastern Russia and possibly northern Vietnam. It was first introduced to North America accidentally in the 1970s as a contaminant in Grass Carp (*Ctenopharyngodon idella*) shipments arriving in Arkansas. Subsequent deliberate introductions occurred during the 1980s when the fish was used as a food fish and as a biological control for yellow grub (*Clinostomum margaritum*). The first known escape of Black Carp into the wild occurred in 1994 when as many as 30 escaped during a flood event from an aquaculture facility into the Osage River in Missouri. Black Carp are now known in the wild from Arkansas, Illinois, Louisiana, Mississippi and Missouri and are within 1000 km of the Great Lakes Basin. Black Carp are voracious predators with the potential to have strong negative impacts on native freshwater mussels (Unionidae) should they become established within the Great Lakes basin. We have identified 51 species of Unionidae, including 15 federally listed (Canada or U.S.) and 34 provincial or state listed species occurring within the region of the Great Lakes basin likely to be impacted by a Black Carp invasion. Through an analysis of gape limitation, unionid size distribution, and growth patterns, we will attempt to evaluate the potential impact on these imperiled freshwater mussel stocks.

# Status of *Margaritifera margaritifera* (L., 1758) in the Ulla basin (Galicia, NW of Spain): Preliminary steps to initiate recovery actions

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The endangered naiad *Margaritifer*a *margaritifera* reaches its southern European distribution limit in NW Iberian Peninsula, where Galician basins host 80% of Iberian populations of this species. The severe decline of these populations indicates a risk of extinction if corrective actions are not taken to ensure successful breeding and recruitment. The Ulla basin (2,764 km² catchment area) summarizes the environmental pressures on Galician rivers, some of which are implicated in freshwater pearl mussel decline: water eutrophication and river structure damage by bad management agriculture practices and livestock farming intensification; pollution due to, industry and mining, river flows disruption and host stocks decreasing by river regulation schemes. We suggest this basin as an example of integral approach, deeply involving habitat and species, in order to identify the problems underlying species declines. The results of this study will support management decision making to design and implement corrective measures. The first results of this study are presented, focusing on remnant naiad populations, to know its distribution, age structure, population size and genetic diversity in the basin. The combination of ecological and genetic data is essential to identify critical populations and to define conservation units, thus establishing the basis for captive breeding and measures leading to facilitate the natural recruitment of populations in the wild. Sampling results allow estimating a census of 30,000 individuals. The age profiles reveal that the species still preserves some reproductive ability, but not enough to maintain the long-term viability of populations. The results of the genetic analysis using microsatellite loci showed very low and structured genetic variation. So, two management unit (MUs) were proposed to maximize the genetic diversity representativeness in the breeding program to preserve the evolutionary potential for supplementation actions to reduce the risk of extinction. This work was developed within the Life + 09NAT/ES/00514 Margal Ulla Project.

# Experiments on reinforcement and in-situ rearing systems of the pearl mussel (*Margaritifera margaritifera*) in the Armorican Massif (France)

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The objective of the LIFE Mulette programme (LIFE09NATFR000583) is the conservation of the six major pearl mussel populations in the Armorican Massif. One of the problems identified here is the lack of juvenile recruitment. A rearing station has been built and habitat restoration activities started on rivers. The first population reinforcements began in 2012. We used cylindrical tubes of stainless steel mesh to test the survival and growth of some of the young mussels released in 2014. In each stream, 12 mesh tubes (with a mesh size of 0.42 or 0.8 mm) each containing five one-year-old mussels were installed for 3 months (60 mussels / stream). The survival rate varied from 6.67% to 95%. The size of the mesh of the tubes could have an influence on mussel survival. The average growth was about 0.5 mm for the rivers in Brittany. For rivers in Lower Normandy, very few measurements could be made because of the low survival rates.

It is possible that these results could have been skewed because: the tube installation method was not the same in Brittany and Normandy, and the mussels used on rivers in Lower Normandy came from a Breton stock whereas, in Brittany, we were able to use young mussels issued from the mussel populations of the very same rivers in which the releases were made. However, the use of this technique seems to be of interest in the context of a population reinforcement program to measure the survival and growth of young mussels.

# How relocation affects freshwater mussel metabolism

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Freshwater mussel conservation often requires the animals to be relocated to other habitats or brought into captive research facilities. The objective of this study was to assess the effects of stress in captive and relocated mussels using metabolomics techniques. A total of 66 freshwater mussels of the species *Amblema plicata* were collected from the Muskingum River in Washington County, Ohio, in June 2012. Half of the mussels were brought into captivity inside the Freshwater Mussel Conservation and Research Center in Powell, Ohio and half were transported to Big Darby Creek in Franklin County, Ohio. Hemolymph samples from the anterior adductor muscle were taken in the wild immediately upon collection in June 2012 and subsequently in August and October 2012 and May and August 2013. Samples were analyzed using gas and liquid chromatography-mass spectrometry. Biochemicals involved in glucose metabolism and the Krebs cycle showed similar seasonal variation among all groups of mussels regardless of habitat. The stress of relocation was evidenced in changes in polyamine and nucleic acid metabolism. While levels of metabolites involved in polyamine synthesis were elevated in the wild mussels later in the year, these same metabolites decreased or remained unchanged in both groups of relocated mussels. Similarly, metabolites indicative of nucleic acid turnover and degradation tended to increase in the wild mussels and decrease in the relocated mussels. The significantly lower levels of polyamine and nucleic acid metabolites suggests decreased cell growth and proliferation, which in the long-term may impair tissue maintenance and cause decreased growth rates.

# American invader, brook trout (*Salvelinus fontinalis*) is a potential threat to freshwater pearl mussel (*Margaritifera margaritifera*) in Europe

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Brook trout, originally an American salmonid fish and a suggested host of the freshwater pearl mussel there, was introduced to Europe and has replaced native salmonids, the hosts of *Margaritifera* in Europe, in many rivers. Therefore, there is an urgent need to assess the suitability of this invader as a host for European *Margaritifera*. The study was conducted in a Finnish catchment by exposing brook trout and native salmonids to *Margaritifera* infection. Natural infection in wild fish and occurrence of brook trout in the region was also investigated. In all experiments, brook trout was less often infected and harboured fewer *Margaritifera* glochidium larvae than brown trout or salmon. The size of larvae was smallest in brook trout, and the laboratory results indicated premature drop of larvae from brook trout. The field observations were in line with the experimental results, except in one river where some *Margaritifera* larvae had remained in brook trout for at least 9 months. Moreover, occurrence of brook trout was more frequent in brown trout rivers with *Margaritifera* than without *Margaritifera*, supporting the enemy release hypothesis; since glochidiosis is costly to the host, the poor infectivity in brook trout offers a competition advantage for this alien over the native salmonids in mussel rivers. Overall, brook trout is an unsuitable host for *Margaritifera* in Europe, and therefore the dispersion of this fish should be considered a potential threat not only to the original, native salmonids, but also to the *Margaritifera* populations by substituting for their necessary host fish.

# Simulating mussel impacts on near-bed hydrodynamics using a computational fluid dynamic model

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The interaction between flow and organisms is a major contributor to the structure and function of stream communities. As filter feeders, mussels actively interact with flow for feeding purposes. Furthermore, mussel shells passively contribute to flow hydrodynamics by acting as a roughness feature on streambeds. This mussel-flow interaction has potential to influence both the structure and function of stream ecosystems at multiple scales. In this study, we construct a computation fluid dynamic (CFD) model to examine the physical interactions between flow and freshwater mussels. CFD models provide an invaluable resource to test complex fluid dynamic problems and are used to simulate and visualize various flow situations to establish a detailed understanding of a system's underlying physical processes. Using Flow3D, we simulated various flow conditions around a single mussel to examine the downstream three-dimensional turbulence structure. In addition, we analyzed the influence of the mussel filtration activity on the near-bed hydrodynamics. This model will be calibrated with an ongoing flume experiment. Once our model is calibrated, it can be used to investigate a number of flow and transport processes across a wide range of scales and relevant flow conditions. Potential examples include describing and quantifying bed shear stress around mussels to better understand the forces that dislocate mussels from the bed or describing mass-transfer processes between filtering mussels and surrounding water to better understand nutrient transport.

# Utilizing Environmental Protection Agency rapid water quality assessment protocols to predict unionid abundance and diversity

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Predicting the presence, abundance, and diversity of freshwater mussels (Bivalvia, unionoida) has important implications for the conservation of imperiled species. This study tested the correlations between qualitative and quantitative habitat parameters, diversity and abundance of freshwater mussels among five streams in the Lake Ontario watershed. Thirty-six study sites were examined according to Environmental Protection Agency habitat assessment protocols along with a qualitative in-situ sampling of mussel diversity and density. Thirteen different species were found, primarily along two streams with historical records of high diversity, with only two individuals found in the other three streams. Simple linear regressions showed no significant correlations between any single habitat parameter and either diversity or abundance. Multivariate and spatial statistical analyses may reveal more significant patterns of mussel species and assemblages related to habitat characteristics, although factors we did not measure or legacy effects of past disturbance in the streams may also be influencing current distribution. If a habitat assessment protocol is related to current or historical mussel distribution, it can help inform managers' conservation efforts. Quantifying mussel habitat requirements and preferences would allow aquatic ecosystem maintenance, restoration, and conservation to be focused towards (or at least incorporate) freshwater mussels.

# Threatened fish and mussel populations of northern Portugal (Douro Basin): Developing conservation measures

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The Mediterranean areas are globally identified as ecosystems with higher biodiversity. Among them, aquatic ecosystems are reported to be particularly fragile and several autochthonous species are threatened and in extinction risk due to negative human activities. In three northeastern watercourses of Portugal, Sabor, Tua and Tâmega rivers (Douro Basin), large areas are suffering a substantial reduction in the natural lotic habitats, namely after the construction of three large dams. For this reason it is crucial to include mitigation measures on the areas outside the influence of those dams. This would include the rehabilitation of the disturbed lotic reaches of these rivers and the protection of habitats and ecosystems with good ecological integrity, as well as the development of monitoring and applied conservation programs for those taxa. The national Project "SOS (Save Our Species): threatened fish and bivalve populations of northeastern Portugal" was designed to: 1) promote in-situ conservation plans for mussel and fish species; 2) define the adequate methodologies to the ex-situ reproduction of the target species, and 3) develop environmental education in an Aquaculture Station, belonging to the Forest and Environmental National Services (Posto Aquícola de Castrelos - ICNF). The selected target species of this project were two Iberian endemic fish, *Squalius alburnoides* and *Achondrostoma arcasii*, and four autochthonous mussel species (Unionoida) *Margaritifera margaritifera*, *Potomida littoralis*, *Unio delphinus* and *Anodonta anatina*.

# River specific genetic diversity of *Margaritifera margaritifera* is affected by host fish and population size

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Effective conservation approaches for endangered species such as the freshwater pearl mussel (*Margaritifera margaritifera*) require integration of ecological and genetic information. Low genetic diversity is a matter of concern, as it may reduce the ability of the species to adapt to environmental changes. Therefore, maintaining genetic diversity has been identified as one of the key elements in successful conservation programs. We examined the genetic structure and diversity of 21 freshwater pearl mussel populations located in Finland, Sweden and Norway. We used mitochondrial DNA COI sequences and microsatellites to generate genetic information. Eighteen COI haplotypes and an average of 5.2 alleles were observed for the 9 microsatellite loci used in this study. Hierarchical analysis of molecular variance (AMOVA) revealed that 0% of the genetic variation was among drainage systems, 31% among populations within drainages, and 69% within populations. The results of the Mantel test ($r = -0.041$ $P = 0.662$) confirmed that there was no isolation by distance between the populations. A regression model was fitted to the four response variables, mean observed and expected haplotype (H) and allelic (A) richness, using the host species and the mussel population size (N) as predictor variables, assuming asymptotic increase in the response variable with the increase in N. Atlantic salmon rivers had higher asymptotic H and A than brown trout rivers (all $p < 0.1$). The A was at its asymptotic level already in the smallest observed N of < 10.000 and the H reached its asymptote with N around 50.000 mussels.

# Future impacts of global climate change and local anthropogenic pressures in Beça River *Margaritifera margaritifera* population

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Climate change is one of the most important causes of biodiversity loss in freshwater ecosystems and it is expected to cause extinctions of many species in the future. Freshwater ecosystems are also highly affected by anthropogenic pressures such as land use/land cover changes, water abstractions and impoundments. The aim of this study is to assess the impacts of future climate and land-use changes in the Beça River (northern Portugal), namely on the conservation status of the endangered pearl mussel *Margaritifera margaritifera* (Linnaeus, 1758). This species is currently present in several stretches of the Beça River that still hold adequate ecological conditions. However, the species is threatened by projected declines in precipitation for the 21st century, with implication on the river flows and water depths that might decrease below the species requisites. This situation could be especially critical during summer conditions since the ecological flows may not be assured and several river stretches may be converted into stagnant isolated pools. The habitat connectivity will also be affected with reverberating effects on the mobility of *Salmo trutta*, the host of *M. margaritifera*, with consequences in the reproduction and recruitment of pearl mussels. In addition, human-related threats mostly associated with the presence of dams and wildfires are expected to increase in the future. In view of future climate and land-use change scenarios, conservation strategies are proposed, including the negotiation of ecological flows with the dam promoters, the replanting of riparian vegetation along the water course and the reintroduction of native tree species throughout the catchment.

# The development of *Margaritifera margaritifera* (L., 1758) up to 1 mm length, does it depend on the host? Atlantic salmon *vs*. brown trout

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*Margaritifera margaritifera* (Unionoida) is distributed along the Atlantic rivers in Europe and Northeast America. It exhibits a complex life-cycle including an obligate parasitic stage on a suitable host fish, the Atlantic salmon (*Salmo salar*, L.) and the brown trout (*Salmo trutta*, L.). *M. margaritifera* is a protected species under the Habitats Directive, the Bern Convention, and is catalogued as an endangered species by the IUCN. The alarming absence of recruitment in many European populations of the freshwater pearl mussel promoted the development of breeding programs in captivity aiming for the reinforcement of those populations, or their reintroduction in formerly occupied river systems. The larval phase and the first juvenile stages are especially relevant in the cited programs, because they represent the critical spots in the mollusc life cycle, and where the mortality rates are higher. One of the main goals of breeding programs in captivity is the search for a suitable host, either Atlantic salmon or brown trout. The aptitude of both host species is compared in this work, regarding their suitability in a good development of the mussel in the parasitic phase and first juvenile stages. 500 individuals of each host species were tested, following the same protocols. The study shows salmon and trout infestation rates, comparative data on cyst growth in the gills, and juvenile survival rates in laboratory conditions until a maximum shell diameter of 1 mm was reached.

This work was developed within the Life + 09NAT/ES/00514 Margal Ulla Project.

# Habitat stochasticity and metapopulation structure as a problem for freshwater mussels conservation - the case of the *Unio crassus* in the Biała River

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The Biała River harbors one of the most important populations of *Unio crassus* in Poland. The distribution of the species within the river is related to the channel slope - the highest density and continuous distribution of population overlap with the river section of the smallest slope, whereas the reaches of higher slope contain fragmented mussels' sub-populations, which frequently disappear. *U. crassus* has been extirpated from the upper part of the river isolated in the past by dams likely due to water pollution. In 2012, we restored the species occurrence there, in a series of stepping stones, in order to speed up re-colonization of the upper reach after rebuilding of the dams. For the next years we observed the process of young dispersal and dynamics of adults populations introduced into the stepping stones. Almost all initial stepping stones has been destroyed by lateral erosion during the course of study (2012-2015), whereas the species persisted due to juveniles, which settle in new sites.

# Habitat requirements of *Unio crassus* in the Biała River: Hydrology, substrate, chemistry and fish

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The Biała River flows in south Poland, from the Beskid Niski Mts. to their forehills (N Carpathians). It harbors the largest estimated population of *U. crassus* in Poland (200 000 ind.). In the past it occupied a much larger river section, but almost half of the population has been extirpated due to water pollution and river fragmentation by dams. In a longitudinal hydrological profile, the present population occupies the flattest part of the channel, where the clean tributaries join the river. The population density number correlates with occurrence of fine sediments, and high pH values. It occurs outside the range of the most suitable fish hosts. In a cross sectional profile, individual mussels inhabit only water margins. The young recruitment varies between years, showing no correlation with local population density number. Numerous individuals also occupy the regulated reaches of the river, although are sensitive to water level changes.

# The quagga mussel (*Dreissena rostriformis bugensis*) in the southern Baltic coastal lagoon: A visitor or an invader?

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*Dreissena rostriformis bugensis*, a bivalve native to the mouth areas of the Bug and Dnieper in Ukraine, has colonised inland waters of eastern and western Europe and North America. In 2014, the species was first recorded in the Szczecin Lagoon (River Odra estuary, southern Baltic Sea). That was also the first record of the species in the Baltic catchment, a next stage of the quagga mussel's dispersal in Europe. The quagga mussels were extracted from samples containing also the zebra mussel (*D. polymorpha*). Genetic analyses based on the DNA sequences of two mitochondrial genes confirmed the newcomer's identity. In 2014, the Szczecin Lagoon quagga mussel population consisted of individuals 1.56-31.76 mm in shell length, 52.5% being contributed by small (<7 mm) individuals. The size distribution analysis indicates the bivalve to have first appeared in the area, undetected, at least three years previously. At present, *D. rostriformis bugensis* is common and abundant throughout the Lagoon. It has established an independent, reproducing, strong population co-occurring with that of *D. polymorpha*, abundant in the area for years. In 2014, the zebra:quagga mussel ratio was 6:4, mean abundances being about 6000 and 4000 inds/$m^2$, respectively. The high relative abundance of *D. rostriformis bugensis* with respect to *D. polymorpha* may evidence its successful invasion and efficient competitive ability. Monitoring of the quagga mussel progress in the Lagoon is planned, with a focus on interspecific relationships with *D. polymorpha*.

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# The freshwater mussels (Bivalvia, Unionida) of Malaysia: Diversity, distribution and threats

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In comparison to Europe and North America, the freshwater mussel fauna of Southeast Asia is notoriously understudied. For Malaysia, this is particularly unfortunate, as pollution and changes in land-use, including the immense increase in deforestation and oil palm-plantations, are likely to heavily impact this imperilled faunal group with consequences for important ecosystem functions and services. This project, funded by the Mohamed bin Zayed Species Conservation Fund, aims to develop a National Red-list of freshwater mussels of Malaysia, as well as Action Plans towards the protection of the most vulnerable species. This is being achieved by collecting data on species diversity and distribution, population health, reproductive status and habitat requirements across all provinces of Peninsular Malaysia and Malaysian Borneo. In the first phase of the project, conducted over two weeks in February 2015, 61 sites across 8 of the 11 Peninsular Malaysian States were surveyed for mussels and physico-chemical characterization. In total, 19 sites produced 8 species of Unionida, as confirmed by COI sequencing. Mussel absence was clearly related to pollution (particularly of ammonium) and low pH. The effect of pollution and land-use will subsequently be analysed using Species Distribution Modelling. Particularly dense and diverse mussel assemblages were found in the Sungai Pahang, Sungai Perak and Sungai Muar catchments. Further expeditions into remaining areas of Peninsular Malaysia are planned for summer 2015, and to Malaysian Borneo in 2016.

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A comparison of growth and survival of quagga mussel veligers in low and high calcium waters.

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Does the accumulation of trace elements in riverine sediments affect the populations of *Margaritifera margaritifera*?

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A recent *Dreissena* invasion in an old canal system in northern Europe.

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Biogeography, ecology and adaptive strategies of freshwater bivalves (Bivalvia: Sphaeriidae) in Arctic.

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Physiological and behavioral response of native freshwater mussels to environmental variables.

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Unravelling the UNIONIDAE: Examination of subfamily relationships within Unionidae.

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Sex determination in freshwater mussels: A mitochondrial story.

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Conservation of endangered unionids in high-flowing fragmented rivers: Historical changes and metapopulation dynamics of the Rio Grande endangered endemic *Popenaias popeii.*

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Life history trade-off of *Anodontites trapesialis* (Lamarck, 1819) (Bivalvia: Mycetopodidae) in a wetland: An evolutionary or environmental adaptation?
**Castalia ambigua*, *C. inflata*, or both? New data about geographical distribution and population genetics in central South America.
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*The Project LIFE Potamo Fauna: An initiative for the recovery of naiad populations from the Northeast of the Iberian Peninsula.
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Saving six freshwater pearl mussel *Margaritifera margaritifera* populations in the Armorican Massif (France).

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A comprehensive freshwater mussel restoration program: Progress in the Delaware River Basin.
*The Asian clam *Corbicula fluminea*: Seasonal filtration rates of representative populations in two tributaries of the Delaware River.

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Latitudinal distribution of the unionid mussel *Anodonta anatina* and its trematode parasites in Finland.

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Does exposure to duck mussel (*Anodonta anatina*) immunize brown trout (*Salmo trutta*) against the endangered freshwater pearl mussel (Margaritifera margaritifera)?

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Investigating the impacts of water quality on freshwater mussels.

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Variation in growth and survival in *Alasmidonta heterodon* across locations in the Northeast United States.

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The freshwater mussels (Bivalvia: Unionoida) of South America: A review.

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How does the distribution of unionid freshwater mussels in Texas relate to the distribution of fishes?

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Biology and habitat of *Sphaerium striatinum* in two streams in the upper Susquehanna River drainage.

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*The effects of glochidia infection intensity and stress levels on the metamorphic success and lipid reserves of *Lampsilis siliquoidea.*

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Recovering from co-extirpation: The challenge of restoring an ecologically relevant host-affiliate relationship.

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*Distribution of adult pearl mussel (*Margaritifera margaritifera*) individuals and location suitability bioindicitively assessed in the longitudinal stream profile on the border of a natural area.

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Endangered or invaders? Molluscs - the most imperiled group of freshwater invertebrates includes the highest number of invaders.

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Unionid biodiversity and conservation problems in Turkey.

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*Taxonomic examination of the Unio species (Bivalvia, Unionidae) from Russia and Ukraine based upon morphological and molecular data.
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A review of the life history of Australasian freshwater mussels with new information from Western Australia.

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Biogeography of freshwater mussels (Bivalvia: Unionoida) across the largest Southeast Asian riverbasins: Endemism and biodiversity assessment.

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Dispersal and gene flow in unionid mussels and the boundaries defining Great Lakes assemblages.

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Comparison of particle filtration ecosystem services by North American freshwater mussels fed on natural seston.

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Addressing global conservation issues on freshwater bivalves: Challenges and opportunities.
*The freshwater mussels (Bivalvia, Unionida) of Malaysia: Diversity, distribution and threats.

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Invasion history of *Dreissena polymorpha*, the zebra mussel in Lough Key, an Irish lake.

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*Environmental DNA next-generation sequencing assays for biological and population genetic inferences in a mollusk community.
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Cellular changes associated with nematode infections in the foot of the Alabama rainbow (*Villosa nebulosa*).

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Estimation of exotic bivalve distribution and coverage in a large river using traditional sampling, remote sensing, and GIS-derived benthic habitat maps.

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*Investigating the potential effects of Black Carp (*Mylopharyngodon piceus*) invasion on native freshwater mussels (Unionidae) in the Laurentian Great Lakes.

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*Status of Margaritifera margaritifera (L., 1758) in the Ulla basin (Galicia, NW of Spain): Preliminary steps to initiate recovery actions.

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Bivalves in human-modified and natural ecosystems of Ukraine.

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*How relocation affects freshwater mussel metabolism.

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*American invader, brook trout (*Salvelinus fontinalis*) is a potential threat to freshwater pearl mussel (*Margaritifera margaritifera*) in Europe.

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*Simulating mussel impacts on near-bed hydrodynamics using a computational fluid dynamic model.

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Environmental influences on the community composition of freshwater mussels as a baseline to spatial conservation prioritization: A case study in the Cuiabá River Basin, Midwest of Brazil.

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The Naiads (Bivalvia: Unionidae) from Romania: Trends in knowledge, distribution, ecological requirements and human impacts.

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Project grande mulette: Conservation of the giant pearl mussel (*Margaritifera* auricularia) in Europe.

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From common to probably extinct: Tales about the peaclam *Pisidium amnicum* in the Minho River (Portugal).

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Ecological services of a host-affiliate relationship across a gradient of nutrient loading.

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Pathological changes associated with a co-infection of metacercaria (Digenea) and eggs of *Unionicola* sp. (Acari, Uninonicolidae) in the mantle of *Elliptio complanata* (Bivalvia, Unionidae).

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Mussel monitoring in the context of the European Habitats Directive: New information on the ecological requirements of *U. crassus.*

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Twenty-five years of change in the Hudson River's bivalve populations.

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*Utilizing Environmental Protection Agency rapid water quality assessment protocols to predict unionid abundance and diversity.

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Trematode parasitism, an 'ecosystem service' provided by freshwater mussels.
*River specific genetic diversity of *Margaritifera margaritifera* is affected by host fish and population size.

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Host fish biotic homogenization. A major threat to Iberian freshwater mussel (Unionoida) species.
*Threatened fish and mussel populations of northern Portugal (Douro Basin): Developing conservation measures.

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Characterization and protection of native species of bivalves in two coastal lagoons.
*Future impacts of global climate change and local anthropogenic pressures in Beça River Margaritifera margaritifera population.

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*The development of *Margaritifera margaritifera* (L., 1758) up to 1 mm length, does it depend on the host? Atlantic salmon vs. brown trout.

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*The quagga mussel (*Dreissena rostriformis bugensis*) in the southern Baltic coastal lagoon: A visitor or an invader?

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Conservations efforts with focus on the thick shelled river mussel (*Unio crassus* Philipsson, 1788) and its host fish fauna in Svennevadsån, Sweden.
Fast swimming brown trout receives a higher parasitic load of freshwater pearl mussel (Margaritifera margaritifera) larvae.

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Are all glochidia equal? Evidence of variation within and among individual unionids.

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*Habitat stochasticity and metapopulation structure as a problem for freshwater mussels conservation - the case of the *Unio crassus* in the Biała River.
*Habitat requirements of *Unio crassus* in the Biała River: Hydrology, substrate, chemistry and fish.

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Varied patterns of post-glacial dispersal by freshwater mussels species into the North American Great Lakes with implications for conservation and management of imperiled taxa.

# Notes

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