

Previous Projects:

Long-term changes in *Dreissena* spp. populations in Lake Erie

Lake Erie has the longest history of colonization by both *Dreissena polymorpha* and *D. rostriformis bugensis* in North America and is therefore optimal for the study of long-term dynamics of dreissenid species. Distribution of dreissenid species in Lake Erie varied depending on the time since the initial invasion, depth, and lake basin. During 2014, quagga mussels were found at various depths and in all basins, while zebra mussels were common in the western basin only and were limited in the central and eastern basins to a very few spots in shallow depths, resulting in almost complete replacement of *D. polymorpha* with *D. r. bugensis*. In the shallowest western basin of Lake Erie, zebra mussels distributed as widely as quagga mussels, but represented <15% of the combined dreissenids density and wet biomass. In addition, to further elucidate the relationship between hypoxia and dreissenid abundance, an exploratory dreissenid abundance/habitat mapping approach was conducted with both underwater cameras mounted on a Ponar grab and on a benthic sled towed by U.S. EPA Great Lakes National Program Office R/V Lake Guardian. Preliminary video footage analysis verified by Ponar grab samples revealed that *Dreissena* spp. avoid the central basin hypoxic zone and that monitoring dreissenid distribution and size structure can be an effective tool in mapping of the extent and frequency of hypoxia in a large waterbody.

Round goby impacts on tributary stream leaf litter decomposition

The round goby has been implicated in the alteration of both macroinvertebrate and fish communities in tributary streams to the Great Lakes. This project assessed whether this invasive invertivorous, benthic fish impacted crayfish foraging, leading to a change in leaf litter decomposition. We used a field mesocosm manipulation to assess whether round gobies or crayfish had different impacts on the benthic macroinvertebrate community and then, indirectly, on leaf mass loss. Graduate student Stephen Tentinger quantified the results for his Master's thesis in Biology.

Stream restoration effects on fish and macroinvertebrate communities

This project compared fish and macroinvertebrate communities in Elton Creek before and after an in-stream and riparian zone restoration project. The original restoration work was intended to improve trout habitat along a 1 km reach. We sampled fish and invertebrates several months prior to the project onset, and six and 12 months post-project. Sculpins did not respond to the restoration, but trout numbers in the restoration section improved slightly. Macroinvertebrate community response is still being assessed.

Conservation of native freshwater mussel refuges in Great Lakes coastal zones

Since the introduction of dreissenid mussels into the Laurentian Great Lakes in the late 1980s, the diverse native mussel communities of the region have declined sharply. However, there have been several locales identified as refuges in coastal and nearshore areas. During the last three years within this large collaborative project funded by the U.S. Fish and Wildlife Service we surveyed over a total of 198 sites at 88 locations in bays, coastal wetlands, and drowned river mouths in the lower Great Lakes region and collected 4,329 individual unionids of 26 species. This information will help managers develop conservation strategies to sustain existing populations in these refuges. This expansive project also trained multiple undergraduate and graduate students, creating a cadre of future scientists and

managers who will work to protect this imperiled resource, including graduate student Isabel Hannes (University at Buffalo) studying the phylogenetic relationship between *Lampsilis radiata* and *L. siliquoidea*, the levels of intermixing, and gene flow at different spatial scales. While species assemblages in the lakes have shown major shifts, these findings are especially encouraging given that surveys shortly after the dreissenid invasion pointed toward total extirpation of the unionid fauna. The number and weight of dreissenids attached to unionid shells was found to be tenfold fewer than in the early stages of invasion, indicating that the adverse impact of dreissenids on unionids has declined. We also found that the rate of infestation depends on the dominant *Dreissena* species in the lake: zebra mussels infested unionids much more often and in greater numbers. Consequently, the proportion of infested unionids, as well as the number and weight of attached dreissenids were lower in waterbodies dominated by quagga mussels. This was the first large-scale systematic study that revealed how minor differences between two taxonomically and functionally related invaders may have large consequences for native communities they invade (Burlakova et al. 2014 <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0114926>). Results of the study were published in seven papers and presented at multiple meetings in the US and abroad. For more information please check the project webpage (<http://people.cst.cmich.edu/zanat1d/unionidrefuges.html>).

Long-term changes in the distribution range and population size of endangered Rio Grande endemic mollusk *Popenaias popeii*

The Texas Hornshell (*Popenaias popeii*) is listed as a Species of Greatest Conservation Need in Texas and New Mexico, as Endangered in both states, and is a candidate for listing in both states under the federal Endangered Species Act. Using an opportunity provided by U.S. FWS for bilateral species conservation effort in New Mexico and Texas, we studied the current distribution and population densities of the unionid *Popenaias popeii* endemic to the Rio Grande in Texas and developed a method to reconstruct the historical range and population size of species to evaluate changes in the population's size and distribution range over the last 100 years. Sampling over 250 sites in four rivers, constituting the entire historical range of *P. popeii*, we found that the species has been extirpated from two rivers, a 76% decrease in the combined total length of the rivers populated by the mussel, and an 85% overall decline in the population size of *P. popeii*. The results of this project are published in one paper and presented at national and international scientific meetings.

Invasion risk assessment for Ponto-Caspian fishes to the Great Lakes

A majority of invasive species discovered in the Great Lakes since 1994 are native to the Ponto-Caspian region, including species that have had strong negative impacts in the Great Lakes (for example, dreissenid mussels and the round goby). The rich biota of the Ponto-Caspian region coupled with a high volume of commercial shipping traffic strongly suggests that this region will continue to be a major source of invasive species to the Great Lakes. To assess invasion risk in Ponto-Caspian fishes that had not been included in previous studies, we reviewed English-language publications and untranslated European literature (published primarily in Russian), and used discriminant analysis to identify five additional fish species that have a high probability of becoming established, spreading, and having significant negative impacts in the Great Lakes. In a continuation of the study, within the project "Enhanced Early Detection of Invasive Ponto-Caspian Fishes in the Great Lakes" we use a variety of sources of information (primarily European literature available in English and Russian) to more accurately assess fine-scale geographic distributions and "propagule pressure" in European shipping ports associated with high-risk Ponto-Caspian fishes to identify spatial and seasonal "hot spots" in and

around Great Lakes ports that should be the focus of future surveillance and early detection efforts. This project will provide surveillance and early response teams with more accurate information for their monitoring and control activities.

Observing Systems and Monitoring in Lake Erie

This project is an EPA Great Lakes Restoration Initiative funded project that aims at deploying three buoys in the Western and Eastern parts of Lake Erie. The project PI and co-PIs from the GLC, Buffalo State, and CILER University of Michigan have worked closely with engineering firms and other Buffalo groups to create a set of custom specific buoys. The near-real time data collected by the buoys is being complemented by the use of an Automated Underwater Vehicle (AUV) that increases the spatial resolution of mapping along the nearshore regions of Lake Erie. A website detailing the equipment and the data will allow stakeholders to access data concerning the state of health of the lake and help improve management decisions.

Diversity, distribution and long-term changes in freshwater Unionidae in Texas

Freshwater Unionidae is the most rapidly declining faunal group in the U.S. Among the 52 species known in Texas, there are at least 26 species that require special attention, including six endemic and one federally listed endangered species. Currently we are funded by the U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department (State Wildlife Grants, 2004-2012) to conduct statewide surveys of the rare and the most valuable Unionidae populations in Texas.

As a result of our surveys, of the 46 Unionidae species currently present in Texas, 65 percent were classified as rare and very rare, including all state and regional endemics (Burlakova et al. 2011). In July 2011 using State Wildlife Grants funding we surveyed sites on the Colorado, Frio, Guadalupe, Llano, Neches, Nueces, San Marcos, San Saba, Rio Grande and Trinity rivers to update the status of unionid species of greatest conservation need threatened False spike (*Quincuncina mitchelli*), Texas fatmucket (*Lampsilis bracteata*), Texas pimpleback (*Quadrula petrina*), smooth pimpleback (*Quadrula houstonensis*) and Mexican fawnsfoot (*Truncilla cognata*). We found abundant and diverse unionid assemblages, including rare endemic species, in lower San Saba River, in the Nueces, San Marcos, Neches and Trinity rivers. All collected data soon will be a part of the Texas Natural Diversity Database, making the data readily available for conservation, monitoring and decision making. Fifteen rare freshwater mussel species were recently added to the state's list of threatened species (Texas Register 35, 2010), and 11 of those are currently under consideration for federal listing by the U. S. Fish and Wildlife Service (74 FR 66261; 74 FR 66866). Taxonomic identification of species based on shell morphology is challenging and complicates conservation efforts, therefore we are currently working on molecular taxonomic identification of the most problematic Texas endemic species.

The results of this research was published in the following papers:

Burlakova, L. E., Karatayev, A. Y. Karatayev, V. A., M. E. May, Bennett, D. L., and Cook, M. J. 2011. Endemic species: contribution to community uniqueness, effect of habitat alteration, and conservation priorities. *Biological Conservation* 144: 155–165. [Request a copy.](#)

Burlakova, L. E., A. Y. Karatayev, V. A. Karatayev, M. E. May, D. L. Bennett, and M. J. Cook. 2011. Biogeography and conservation of freshwater mussels (Bivalvia: Unionidae) in Texas: Patterns of diversity and threats. *Diversity and Distributions* 17: 393-407. [Request a copy.](#)

For more images, [see this photo album](#).

Surveys of freshwater mussel refuges in Lake Ontario

This summer we worked on project "Conservation of native freshwater mussel refuges in Great Lakes coastal zones" funded by Great Lakes Fish and Wildlife Restoration Act. The main goal of the project was to determine if native unionids survived dreissenid invasion, and to locate possible mussel refuges in the lower Great Lakes. This project is a large collaborative study that includes scientists from 12 universities, federal and state agencies in Michigan, Ohio, Pennsylvania and New York ([project webpage](#)).

In 2011, we surveyed Lake Erie and Lake St. Clair and found that despite a sharp decline in the diversity and density of unionids in the Great Lakes associated with *Dreissena* invasion, native clams survived in many refuges including bays, river mouths, and coastal wetlands. Based on the data, Dr. Jon Bossenbroek (University of Toledo) produced a predictive model for unionid refuges in Lake Ontario. So our goal for 2012 summer season was to check if this model works. In July and August 2012, together with faculty and students from Central Michigan University, Cleveland State University and Kent State University, we surveyed Lake Ontario bays, river mouths, and coastal wetlands to locate the possible refuges. This survey was a lot of hard work, but also a lot of fun and adventure, thanks to our jovial and dedicated students. It was also a very productive study that helped to reveal freshwater mussel diversity in places that have not been surveyed for a long time, or have never been surveyed before. During four weeks of surveys, we sampled 56 sites in Lake Ontario and found 1,802 live unionids belonging to 10 species. The most mussel-rich sites we found in Black River Bay, Johnson Creek, and the mouth of the Salmon River.

Preliminary data analysis indicated that infested unionids had fewer attached dreissenid mussels (median = 4) than in the early 1990s, and much lower than the threshold number causing unionid mortality (100 per host unionid). Despite the quagga mussel's lake-wide dominance, zebra mussels were more often found on unionids, and their number and weight per host unionid were significantly higher than those of quagga mussels.

These results were presented at the 55th Annual Conference on Great Lakes Research (Canada), at the Cornell Biological Field Station Summer Seminar Series, and at the International Meeting on Biology and Conservation of Freshwater Bivalves in Portugal.

Survey of Texas Hornshell populations in Texas

The Texas Hornshell (*Popenaias popeii*) is listed as a Species of Greatest Conservation Need in Texas and New Mexico, as Endangered in both states, and is a candidate for listing (priority 8) in both states under the federal Endangered Species Act (Federal Register 2008). Using an opportunity provided by US FWS for bilateral species conservation effort in New Mexico and Texas, we are assessing the current distribution and habitat requirements of *P. popeii* in Texas, evaluating existing populations and their trends, and studying species' biology to develop the recovery plan and management options for *P. popeii* in Texas.

Results of the study will soon be published in journal Aquatic Conservation: Marine and Freshwater Ecosystems (Karatajev, A. Y., Miller, T. D., and L. E. Burlakova "Long-term changes in unionid assemblages in Rio Grande, one of the World's top 10 Rivers at Risk.")

[Read the 2012 update.](#)

Invasion paradox: who is the better invader – *Dreissena rostriformis bugensis* or *Dreissena polymorpha*?

Dreissena polymorpha (zebra mussel) and *D. r. bugensis* (quagga mussel) are both invaders, co-occur in their native habitat, and have very different histories of invasion. We compared the rates of spread of *D. polymorpha* and *D. r. bugensis* at different spatial scales and contrasted differences in their ecological and population characteristics to determine the relative importance of these traits on the success and patterns of invasion for these two species. In recent years, *Dreissena r. bugensis* has become the dominant species of dreissenids in the lower Great Lakes. However, we found that in glaring contrast to the ratios of the dreissenid species in the Great Lakes, *D. polymorpha* was found to obtain similar or larger sizes and density than *D. r. bugensis* on examined boats - the main vectors of spread for the two species. Therefore, lakes Erie and Ontario are still important sources for *D. polymorpha* secondary spread in North America.

Role of exotic invertebrates in Lake Erie

This project examines the role of exotic invertebrates in Lake Erie benthos that increased dramatically during last decades. Our 2009, 2011, and 2012 benthic survey of Lake Erie has shown that benthic invaders currently constitute 40% of total benthic density, and over 95% of the total wet biomass. Benthic community structure and dominance has changed significantly since 1979, and the community is currently dominated by exotic species, resulting in dramatic changes in the food web dynamics of the whole lake.

Parasites of aquatic exotic invertebrates: identification of potential risks posed to the Great Lakes

Exotic species typically lose most of their associated parasites during long-distance spread. However, the few parasites that are co-introduced may have considerable adverse impacts on their novel hosts, including mass mortalities. We conducted a comprehensive inventory of parasites known to infect 38 species of exotic invertebrates established in the Great Lakes, as well as 16 invertebrate species predicted to arrive in the near future, all of them crustaceans. Based on a literature analysis, we identified a total of 277 parasite taxa associated with the examined invertebrates in their native ranges and/or invaded areas. Of these parasites, 56 species have been documented to cause various pathologies in their intermediate or final hosts, with humans and fishes being the most frequently affected host categories. Potentially harmful parasites were identified in 61% of the invaders, with molluscs and crustaceans hosting the highest numbers of such parasites. The results of our study provide a baseline for further assessment and management of the parasitological risks posed by exotic species to the Great Lakes.

Evaluate Ponto-Caspian fishes for risk of Great Lakes invasion

In our previous GLRI project we used multivariate statistical techniques and new physiological and ecological data from European literature to identify Ponto-Caspian fishes possessing characteristics that correlate strongly with harmful invasions of the Great Lakes. In the current project, we studied the geographic distributions, habitat use, and reproductive biology of high-risk Ponto-Caspian fishes identified in our earlier project and the work of others (e.g. Kolar and Lodge 2002), with a particular focus on areas in and around key European ports. The results of the project will improve our estimates of invasion risk by examining not only species characteristics, but also the likelihood of successful

introductions based on current geographical distributions and seasonal variation in occurrences in Europe. As a part of the project, we will also integrate species identification information and other outreach products in development from our previous GLRI project that target fisheries managers, recreational water users and coastal educators, and make this information easily available.

Among the fish with the highest risk for invading the Great Lakes were black-striped pipefish (*Syngnathus abaster*, above), Caspian tyulka (*Clupeonella caspia*), Volga dwarf goby (*Hyracanogobius bergi*), and Caspian bighead goby (*Ponticola gorlap*).

[See the article in the spring 2013 newsletter.](#)

Effects of Calcium decline and food levels on *Daphnia* development and reproduction

The common cladoceran zooplankter *Daphnia* takes calcium to form their carapace from the surrounding water. They also are an important link at the base of many aquatic food webs. Declining levels of calcium in the Canadian Shield lakes threaten to disrupt trophic interactions and lead to significant changes in ecosystem functioning. We are investigating the interaction between food availability and calcium on growth, reproduction, and survivorship of *Daphnia*.

Botulism type E in the Great Lakes

We have 10 years of research experience in the new and ongoing botulism outbreaks in the Great Lakes basin. Our current role in this topic is to act as a resource for information for federal (EPA) and state agencies (DEC, NY-FWS) as well as the Great Lakes Research Consortium and to the greater research community. Our expertise includes sources of type E botulism in the Great Lakes and food web transmission.

Food web-mediated transport and bioaccumulation of flame retardants (PBDE) in sport fish from eastern Lake Erie

We sampled sport fish (walleye, lake trout, steelhead trout, smallmouth bass) and their forage fish (gobies, emerald shiners, yellow perch, smelt), and forage invertebrates (dreissenids, amphipods and zooplankton), water and sediment, to determine PBDE congener load at all these trophic levels. Stable isotopic determination of organisms will help us determine their position in the food web and bioaccumulation coefficients for these chemicals of concern.

The Lake Erie Nearshore and Offshore Nutrient Study (LENONS)

Even though nutrient input target levels in Lake Erie have been reached, significant issues like the central basin "dead-zone," extensive *Cladophora* growth in the eastern basin and *Lyngbya* in the west, and repeated outbreaks of nuisance algae continue to occur. The role of nearshore and offshore dreissenid mussel populations and the flux and sequestration of nutrients within mussel beds and sediments remain a priority consideration to understanding the nearshore shunt hypothesis, and to explaining the Lake Erie trophic paradox.

The work conducted in 2011 and 2012 quantified all the major biotic and abiotic nutrient pools, flux rates, and trophic pathways in the nearshore and offshore regions of Lake Erie.

We directly measured nutrient levels in these compartments and flux rates in the most rapidly cycling pools. Additionally, we will couple our data with hydrodynamic models of particle transport and phosphate source tracking using $\delta^{18}\text{O}_p$ to assess whether the pools of nutrients in the nearshore and offshore regions follow the predicted patterns of lake mixing models and the nearshore shunt hypothesis.

Read the [article](#) about our June 2012 sampling trip, or view pictures or video from our gallery.

Lake Erie Intensive Study

Researchers from the Great Lakes Center, the US Geological Survey, and the US EPA Great Lakes National Program Office are participating in this year's Lake Erie Intensive Study, a project that will evaluate the lake's benthic community and compare its diversity and abundance to historical data.

Following a 5-year rotation schedule, each year one of the Great Lakes is the focus of a multi-agency assessment made possible through the Cooperative Science and Monitoring Initiative (CSMI), a binational effort started by the US EPA and Environment Canada in 2001. The goal of the studies is to facilitate research into specific questions facing Great Lakes managers. Lake Erie has been studied in 2004, 2009, and now in 2014. Our goal this year is to provide estimates of lake-wide and habitat-specific benthic invertebrate abundance and biomass of Lake Erie to compare to previous studies.

Lake Erie is perhaps the most severely impacted of all the Great Lakes, and phosphorus loading and the introduction of non-indigenous species continue to drive large-scale trophic changes today. Comparing benthic communities among the Great Lakes can help our understanding of how these and other factors alter energy pathways. It also permits quantitative estimation of the benthic-pelagic flux of energy and nutrients in each basin.

The 2014 survey of benthos also continues long-term benthic assessments initiated in 1929 to assess ecosystem changes in the western basin. The historic data sets of benthic communities, assembled by the USGS Great Lakes Science Center, will help explain ecosystem changes that have occurred as a result of dreissenid mussels and pollution-abatement programs. These data will help us examine the causes of major increases in algae blooms that have occurred in western Lake Erie over the past two decades.

We will collect over 300 samples from all 3 basins of Lake Erie using the U.S. EPA Great Lakes National Program Office R/V Lake Guardian and GLC and USGS small vessels. We will also employ an exploratory habitat mapping approach using an underwater camera mounted on a towed benthic sled along 6 transects in the Central Basin. Video footage will be analyzed to map dreissenid abundance in relation to the hypoxic zone, confirmed with ponar grabs to assess mussel presence and absence.

Diversity, distribution and long-term changes in freshwater Unionidae in Texas.

Freshwater Unionidae is the most rapidly declining faunal group in the U.S. Among the 52 species known in Texas, there are at least 26 species that require special attention, including six endemic and one federally listed endangered species. Currently we are funded by the U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department (State Wildlife Grants, 2004-2012) to conduct statewide surveys of the rare and the most valuable Unionidae populations in Texas. As a result of our surveys, of the 46 Unionidae species currently present in Texas, 65 percent were classified as rare and very rare, including all state and regional endemics (Burlakova et al. 2011). In July 2011 using State Wildlife Grants funding

we surveyed sites on the Colorado, Frio, Guadalupe, Llano, Neches, Nueces, San Marcos, San Saba, Rio Grande and Trinity rivers to update the status of unionid species of greatest conservation need threatened False spike (*Quincuncina mitchelli*), Texas fatmucket (*Lampsilis bracteata*), Texas pimpleback (*Quadrula petrina*), smooth pimpleback (*Quadrula houstonensis*) and Mexican fawnsfoot (*Truncilla cognata*). We found abundant and diverse unionid assemblages, including rare endemic species, in lower San Saba River, in the Nueces, San Marcos, Neches and Trinity rivers. All collected data soon will be a part of the Texas Natural Diversity Database, making the data readily available for conservation, monitoring and decision making. Fifteen rare freshwater mussel species were recently added to the state's list of threatened species (Texas Register 35, 2010), and 11 of those are currently under consideration for federal listing by the U. S. Fish and Wildlife Service (74 FR 66261; 74 FR 66866). Taxonomic identification of species based on shell morphology is challenging and complicates conservation efforts, therefore we are currently working on molecular taxonomic identification of the most problematic Texas endemic species. (2012)

Comparison of growth and condition of invasive round gobies in Lake Erie and Ellicott Creek, a tributary stream.

The round goby has invaded tributary streams of Lake Erie. As a result, goby diets have adapted to the foods available in the stream. We investigate how this change in diet affects their development and whether the ontogenetic shift observed in gobies with lake diets also occurs in stream gobies. (2012)

Feeding ecology of the new Great Lakes invader *Hemimysis anomala*.

A new invasive species in Lake Erie and other Great Lakes that is also making its way into the Finger Lakes region, *Hemimysis anomala* is the first mysid to become established in Lake Erie. *H. anomala*'s feeding selectivity carries the potential for trophic cascade effects as their predation may limit the number of important grazer species. However, their adaptive omnivorous diet may allow them to shift their diet to include a larger portion of algae, occupying an intermediate feeding niche. We are examining diet selectivity of this species in laboratory and field experiments. (2012)

Exotic molluscs host epizootically important parasites.

Exotic species may serve as vectors of introduction for their specific parasites, including highly pathogenic ones, and may also become hosts for aboriginal disease agents. This can result in catastrophic outbreaks of parasitic diseases that would otherwise not have existed in the introduced areas. We found that many exotic molluscs that were believed to be free of parasites have already acquired trematodes native to North America. Some of the exotic molluscs hosted exotic trematodes that are highly pathogenic to their vertebrate hosts. In six of the 12 waterbodies studied, exotic molluscs had a prevalence of trematode infection high enough to pose medium to high risk of parasite transmission to their subsequent vertebrate hosts. We suggest that parasitological assessment should be an integral part of the assessment of the ecological and economic risks these species pose. (2012)

Round goby-steelhead trout interactions in stream mesocosms.

This project will examine the interactions between invasive round gobies and stream-form steelhead trout. As gobies invade further inland in tributary rivers and streams, their aggressive behavior coupled with their wide diet breadth may result in direct and indirect impacts to other fishes with similar niches. (2012)

Molluscan community survey of Oneida Lake.

In the summer of 2012, we spent three wonderful weeks at the Cornell University Biological Field Station on Lake Oneida doing extensive molluscs survey and enjoying the warm hospitality of its faculty, staff, and especially the Station's Director, Lars Rudstam. This trip was a result of several discussions with Lars in the preceding years about a potential collaboration between the Great Lakes Center and the Cornell Biological field station at Shackelton Point to understand the possible reasons for the decline in the molluscan diversity in Lake Oneida. This lake was a subject of multiple studies at the beginning of the 20th century conducted by a prominent malacologist Frank Baker, who published several detailed descriptions of its molluscan fauna, including quantitative data. According to Baker, in the early 20th century this lake hosted an abundant and diverse molluscan community of 41 species, including 12 unionid bivalves. However, later studies conducted by Willard Harman and John Forney in 1967, and later in 1992-1995, stated that due to habitat loss, introduction of invasive species, and other aspects of human activity, the diversity of molluscs has dramatically declined. By the mid-1990s, 20 species of molluscs found in the lake in 1918 had disappeared, indicating a 50% decline in diversity. At the same time, at least 11 species of molluscs were introduced, including the zebra mussels and quagga mussels, which have had a devastating effect on the native unionid mussels. During our preliminary study of molluscs of Lake Oneida in 2010, we found 19 species, including 6 species that were previously listed as lost, suggesting at least a partial recovery in the molluscan community. In 2012 we collected 272 samples, paying special attention to historical sites that were previously sampled by Baker and other scientists. Identification of these historical sites from literature wasn't easy after 100 years of development, and required a lot of "detective" work. Preliminary analysis of the collected samples indicated that at least 32 species of molluscs are currently present in Oneida Lake. Two species were found for the first time, including a very rare native snail *Armiger crista* (Photo 2) and the exotic snail *Cipangopaludina chinensis* (Chinese mystery snail) (Photo 3). Only dead shells of native *Unionidae* were found during our study, suggesting complete extirpation of these bivalves from the lake, most likely due to the impact of zebra mussels. The overall mollusc assemblage of Oneida Lake is currently dominated by invasive species, especially zebra and quagga mussels. These two dreissenid species comprise over 90% of the wet total mass of all molluscs in the lake (Photo 4). Results of this study will be presented at the next meeting of the International Association for Great Lakes Research in 2013. (2012)

Seasonal stoichiometric changes in river seston and *Dreissena* populations.

This project will determine the seasonal changes in the C:N:P ratios of river seston and the invasive quagga mussel, *Dreissena bugensis rostriformis*. Understanding the plasticity of body tissue elemental composition can shed light on a species ability to survive under varying food quality regimes, which might aid invasion of new habitats. (2012)

The Nearshore and Offshore Lake Erie Nutrient Study (NOLENS).

Although the nutrient abatement strategies implemented in the Lake Erie watershed have reduced nutrient inputs to target levels, not all of the anticipated responses have been realized. The central basin hypoxia event (the "dead-zone"), extensive *Cladophora* growth in the eastern basin, and repeated outbreaks of nuisance algae in the western basin have all occurred since the reduction in nutrient inputs. This project documented the quantity of nutrients present in all biotic and abiotic compartments of the nearshore and offshore pelagic and benthic habitats and pathways for trophic transfer. We measured directly flux rates in the most rapidly cycling pools and use published, scientifically peer-reviewed nutrient flux rates for the remaining biota in the system, coupled with published

hydrodynamic models of particle transport, to assess whether the pools of nutrients in the nearshore and offshore regions follow the predicted patterns of early lake mixing models. This project is in collaboration with National Center for Water Quality Research in Heidelberg University, Kent State University, Ohio State University, and Case Western Reserve University. (2009)

Goby Larval Drift and Recruitment

This project will determine the density, seasonal timing, and diel patterns in the drift of larval round gobies in a tributary stream to Lake Erie. These samples will be coupled with lake plankton trawls to estimate the relative contribution of tributary streams/rivers to lake round goby recruitment. (2010)

Round Goby Effects on Stream Processes

This project will examine the effect of invasive round gobies on stream primary production and leaf litter decomposition by combining field measurements of periphyton standing stock and leaf litter breakdown rates at locations with and without round gobies present. It will also use replicate experimental streams to test the impact of fish communities (either round gobies only, darters only, both, or none) on the same stream processes as the field study (i.e., periphyton production and leaf litter decomposition). (2010)

Do lake and stream round gobies (*Neogobius melanostomus*, Palls 1814) occupy the same trophic position?

This project examines the different trophic niches that the round goby occupies in Lake Erie and in the tributaries that it has invaded. Through examination of the diet of different size/age gobies and their trophic status (determined by stable isotope analyses) we seek to determine differences among the goby populations that inhabit these very different environments and their impact in invaded streams. (2009)

Parasites of aquatic invasive species: an underestimated threat to invaded ecosystems

Exotic species may serve as vectors of introduction for their specific parasites, including highly pathogenic ones, and may also become hosts for aboriginal disease agents. This can result in catastrophic outbreaks of the parasitic diseases that would otherwise not have existed in the introduced areas. A clear understanding of the mechanisms and patterns of the spread of exotic species and their associated parasites is therefore required to predict and prevent such outbreaks. We are assembling a database of parasites of aquatic invaders and conducting field study to determine the prevalence and intensity of infection of aquatic exotic invertebrates by parasites in their native and invaded ranges. (2008-2009)

Endocrine-disrupting effects of persistent organic pollutants in fish populations from eastern Lake Erie

We are studying the effects of the endocrine disrupting pollutants PCB and PBDE on steelhead trout, common carp, and largemouth bass from eastern Lake Erie. To assess the impacts to reproduction of these chemicals we are measuring the levels of a unique female protein synthesized for egg production in male fish. The effects of these pollutants on fish include the alteration of their sexual characteristics and reproductive fitness. (2009)

The role of the zooplankton *Bosmina freyi* in acidifying lake ecosystems

This organism plays a vital role in the future of lakes that are exposed to acid rain and deforestation and, therefore, have declining calcium levels. *Bosmina* is small zooplankton species that has low Ca requirements and, therefore, can potentially replace the common grazer *Daphnia* in many of the thousands of lakes that are part of the Canadian Granitic Shield, altering permanently the structure of the food webs. We are working with researchers at York University, Ontario, to compare in a highly replicated experiment the competitive and environmental advantages of *Bosmina* in lakes suffering from decalcification and Climate Change. (2010)

Effects of transgenerational Calcium decrease in freshwater cladocerans

We are studying how Ca requirements through several generations of *Daphnia pulex* can impact populations in low Ca aquatic environments. Effects of low Ca include decreased survivorship and reproduction and possibly a vulnerability to impacts of additional stressors. (2010)

Lake Ontario Nearshore Nutrient Assessment.

This is a multi-institutional, binational effort that is aimed at understanding the dynamics of a lake changing in response to impacts of climate change, non-indigenous species, and anthropogenic factors. This project is in collaboration with SUNY Brockport, SUNY Buffalo, SUNY ESF, Niagara University, and University of Rochester. (2008)

Senes.

This project will determine the biomass and coverage of benthic algae to field-verify satellite imagery on color spectra from nearshore Lake Ontario near the FitzPatrick nuclear power facility. (2008)

Goby barriers.

This project will determine the interaction between water velocity, substrate composition, and streambed slope on round goby swimming performance. Ultimately, these data may assist in barrier design to reduce upstream passage or allow us to predict which streams are most at risk to further invasion. (2008)

Amphipod intraguild predation.

This project will assess intraguild predation as a mechanism promoting successful invasion of non-native benthic amphipod species. (2008)

Crayfish predator avoidance.

This project will assess the importance of learning in predator avoidance by native and invasive crayfish. (2008)

Predict the characteristics and spread of aquatic invertebrate invaders.

Long-term experience of studying the exotic species has allowed us to bring together an international team currently working on a project. For 98 freshwater, marine, and brackish species, we collected data on a wide range of biological and ecological parameters. Using this database, we will be able to employ a quantitative approach to address many important problems in invasion biology, and to predict a set of future scenarios that determine invasion success. (2008)

Predict the potential effects of zebra mussels on benthic community and lake ecosystems of Madison lakes.

The objectives of this 3-year study are to: provide pre-invasion information on the community composition, density, biomass and production of benthic habitats in the Madison lakes; predict the effect of zebra mussel invasion on benthic communities in the Madison lakes through comparisons with data to be obtained in southeastern Wisconsin lakes and an extensive long-term database from Eastern European lakes; and to estimate the potential effect of zebra mussels on benthic and pelagic communities and associated fisheries in the Madison Lakes.

Results to date:

Benthic samples collected from Lake Mendota in 2003, 2004, and 2006 were identified during fall 2006 and winter and spring 2007. Eighty macroinvertebrate taxa were identified to the lowest possible taxonomic level in benthic samples from Lake Mendota, including 25 taxa to species level.

Dreissena polymorpha density was sampled in Delavan Lake and Upper Nemahbin Lake. In total, 107 samples were collected from various substrata throughout the lake. The average density of *D. polymorpha* in Delavan Lake was $21,141 \pm 6,785$ mussel m^{-2} ; biomass: $1,077 \pm 268$ g m^{-2} . Maximum densities were found on macrophytes and maximum biomass was found on dead shells. These densities are higher than those reported from European lakes (Karatayev et al. 1998). The average density of *D. polymorpha* in the Upper Nemahbin Lake was much lower: $3,009 \pm 971$ mussel m^{-2} ; biomass: 71 ± 19 g m^{-2} (n = 38). Maximum density (and biomass) were found on macrophytes. (2008)

South American channeled applesnail (*Pomacea insularum*).

South American channeled applesnail (*Pomacea canaliculata*) has been introduced at locations throughout the Indo-Pacific Region where it has become a major threat to rice and taro crops. First reproducing population of channeled-type applesnails was first discovered in Texas in 1989. This invader is of special concern for the Texas coastal ecosystems and Texas rice belt that supports a billion dollar industry annually. The goals of this research are to determine its current distribution and reproductive potential, to define its physiological limits and to predict the potential spread of channeled applesnails in Texas. Thus far the data from this project has been used to produce three M.Sc. theses (by David Hollas and Leah Cartwright, 2006, and Kevin Nichol, 2008) and are currently in preparation for several publications. The first paper will be published in 2008 in *Journal of Wetland Restoration*.

Objectives and Brief Results:

Determine current distribution in southeastern Texas. The distribution surveys are conducted annually; in 2005 and 2006 the presence of *Pomacea insularum* was confirmed in seven southeast Texas counties (Austin, Brazoria, Chambers, Fort Bend, Harris, Galveston, and Waller). Of 394 total sites surveyed in 13

counties, snails were found in 53. Snails were found in 18 waterways including canals, bayous and streams (Brazos River, Horspen, Sims, Bessie's, Armand, Buffalo, Mustang, Chocolate, Disckinson, New, Whites Bayou, American Canal), and 2 reservoirs (Barker and Addicks). In 2005 snails were first found in four new waterbodies (Sims, Bessie's, Horsepen Bayous, and Bear Creek), all outside of the region of previous distribution.

Determine current densities at selected locations. Population densities in Texas have never been defined before the beginning of our study although these estimates could provide an indication of the potential extent of possible environmental impact and serve as benchmarks to determinations of future increases or declines in numbers. 20 infested sites in 13 waterways in 5 counties (Brazoria, Galveston, Harris, Waller, and Ford Bend) were sampled in August 2005. Average densities were from <0.1 to 4 snails/m². The highest densities found were up to 24 snails /m²; biomass up to >800 g/m² (Mustang Bayou, Fort Bend). In October 2005 much higher densities (in average 826 snails/m²; 6,689 g/m²) were found in a rice irrigation canal in Brazoria County.

Study monthly population dynamics of snail populations in several permanent lotic and lentic waterbodies. Changes in densities, size structure, growth rate, and reproduction were monitored at permanent sites (3 ponds in Chambers Co Golf Course, and a ditch near Alvin) from November 2004 to January 2005. Snail densities in ponds were up to 44 m⁻², biomass: up to $>1,700$ g m⁻² (wet total live mass). Average densities in ponds were from 0.2 ± 0.03 to 2.4 ± 0.3 snails m⁻². In the ditch, densities were lower (average 0.7 ± 0.2 m⁻², max 8 m⁻², biomass 400 g m⁻²).

Determine reproduction potential (number of eggs per egg mass; number of egg masses/female/unit of time; reproductive temperature range in Texas). The number of eggs per clutch and annual clutches per female can help predict population growth as it relates to possible future environmental impacts. Reproduction in Texas starts in March and finishes at the end of October – beginning of November. Number of egg masses was proportional to the size of the population and increased through the season from 8 to 426 in August. The average number of eggs per egg clutch was app. 1,000; max: app. 2,500 eggs.

Define selected physiological limits to some abiotic parameters. Understanding tolerance limits to temperature, pH, salinity, calcium levels and emersion are critical to understanding which areas may be most at risk from applesnail invasions. These studies are currently ongoing in the University of Texas in Arlington (Dr. Robert McMahon and his students).

Determine potential food items in southeastern Texas. Feeding laboratory trials were conducted in summer 2005 to determine the willingness of snails to consume plant taxa present in and near the Galveston Bay drainage area. Over 15 native and exotic plant species were tested up to date. Non-choice laboratory feeding experiments revealed that palatability of aquatic plants to the snails varies depend on plant species.

Objectives for 2006-2009:

Determine the rate of applesnail spread in southeastern Texas. Surveys of *P. insularum* distribution conducted in 2005 and 2006 provided us with a unique opportunity to determine the rate of *P. insularum* spread in Texas. David Hollas and Leach Cartwright are going to continue the survey in summer 2008.

GIS analysis of the current distribution of applesnails. Data on the current distribution and densities of applesnails combined with abiotic data will allow us to determine the speed, vectors and factors affecting snail spread and distribution in Texas. (2009)

Limnoperna research in South America.

Limnoperna fortunei, a bivalve mollusc native to China, is now rapidly spreading in South America. As with *Dreissena* (the zebra mussels), *Limnoperna* has rapidly become a major nuisance for many industries and power plants, and its impact on the environment may be even stronger than that of *Dreissena*. Together with colleagues from Argentina, we conducted the first quantitative survey of *Limnoperna* in Rio Tercero Reservoir, analyzed mussel coverage on different substrate types, estimated the overall population size, and studied their effect on the benthic community. Our data will help us to predict the potential effect of *Limnoperna* on aquatic ecosystems in the US. (2008)

Exotic goby effects.

Round gobies (*Neogobius melanostomus*) invaded the Great Lakes via ballast water transfer in the early 1990's. Since that time they have colonized all of the Great Lakes, with significant impacts on benthic fish and invertebrate communities. Recently, researchers documented the migration of these aggressive benthic fish into tributary streams of some of the lakes. Researchers within the GLC are investigating the impact of goby invasion on stream macroinvertebrate communities.

Most identified stream populations of round gobies are composed of relatively small fish compared to lake populations. Since small gobies tend to consume a diverse array of invertebrates, before switching to a diet high in molluscs when older, there is concern they might reduce the prey base for other stream species. Of particular concern is their possible effects on stream-spawning salmonid species since gobies readily consume fish eggs.

The invasive round goby has had clear documented effects on native benthic fishes and recent studies have shown they could have significant effects on recruitment of nest-guarding species like smallmouth bass via egg consumption. Male round gobies locate and defend nests during reproduction, and then guard the eggs laid by females. Native crayfish make use of similar nest cavities during egg incubation, and egg-brooding dates in the two species overlap. These observations set the stage for potential competition for nest cavities between the invasive goby and resident crayfish. GLC researchers are investigating nest cavity competition between the species to understand the possible effects of this fish invader on the benthic community of the Lakes.

Predator-avoidance behavior of native and invasive amphipods.

Amphipods are important littoral benthic invertebrates in the Great Lakes, being used as food by almost every fish species at some point in their life cycle. Recently, an amphipod invader, *Echinogammarus ischnus*, has become numerically dominant in several locations throughout the lakes. The native amphipod has life history characteristics that should enable it to outnumber the invasive species; it reproduces earlier, has larger broods, and grows larger. Yet, in some habitats and locations, the invasive species far outnumbers the native. It is possible that the invasive species simply does better in certain habitat conditions, like mussels beds, than the native. Other researchers have shown that both species

prefer mussel bed habitats over other habitat types, and these habitats likely provide excellent refuge from fish predators.

Researchers at the GLC have been investigating amphipod behavioral responses to fish and crayfish predators to determine if differences in predator-avoidance behavior might explain why the invasive species is out competing the native species in mussel beds. Both species seem able to identify fish predators, avoiding fish that prey on invertebrates, but not avoiding fish that do not prey on invertebrates. Both species respond more when more fish are present, but the invasive species responds more to round gobies than the native species. The invasive amphipod is from the Ponto-Caspian region, just like the round goby is. Thus, these two species share an evolutionary history that is not shared by the native amphipod. Possibly, the high density of round gobies in the Lakes, coupled with the prevalence of mussel beds, is enhancing the success of invasive amphipods. Counteracting this finding is the response of these amphipod species to crayfish predators.

Crayfish are omnivorous, benthic organisms that seem to shift their diet preferences with age; eating more animal matter as juveniles and more plant matter as adults (though there is certainly some controversy on this). Different sized crayfish (and presumable different ages) differ in their ability to capture and consume amphipods and the amphipod species appear to have differences in their ability to avoid crayfish predators. In studies performed at the Field Station, the invasive amphipod was able to avoid large crayfish predators better than the native amphipod, but there was no difference in their ability to avoid small crayfish. Thus, changes in the size distribution, or population age structure of crayfish in the lakes may have implications for amphipod invasion success.

Status of invasive freshwater mollusks in Texas.

Six species of exotic molluscs known to be established in Texas are: Asian clam (*Corbicula fluminea*), applesnail (*Pomacea insularum*), red-rim melania (*Melanoides tuberculatus*), quilted melania (*Tarebia granifera*), giant rams-horn snail (*Marisa cornuarietis*), and Chinese mysterysnail (*Cipangopaludina chinensis*). Because the current status of *C. fluminea*, and *P. insularum* in Texas was recently reviewed (Karatayev et al., 2005; Howells et al., 2006), in this report we concentrated on the analysis of the history of spread, current distribution and potential impact of other exotic gastropods established in Texas. Over 20 waterbodies, most of them known to have populations of exotic gastropods, were sampled in 2006-2007. We found that *M. tuberculatus* continue to spread in Texas and are already present in at least 27 waterbodies and 18 counties. In contrast to *M. tuberculatus*, other exotic gastropods are limited to thermally stable spring-fed ponds and streams and did not expand their distribution during the last 30 years. *Tarebia granifera* was found in the San Antonio River, San Marcos River, and Comal Springs, *M. cornuarietis* was found only in San Marcos River and Comal Springs. The single well established population of *C. chinensis* was found in Kidd Springs (spring-fed city park pond) in Dallas, Tarrant County. The main vector of spread of exotic gastropods in Texas is aquarium release. In addition, these snails might be spread with scientific equipment that was not adequately disinfected.

The results of the survey are in preparation for publication.

The role of the zooplankton grazer *Holopedium gibberum* in acidifying lake ecosystems.

This organism plays a vital role in the future of lakes that are exposed to acid rain and deforestation and, therefore, have declining calcium levels. *Holopedium* is an acid tolerant species that has low Ca

requirements and, therefore, can potentially replace the common grazer *Daphnia* in many of the thousands of lakes that are part of the Canadian Granitic Shield, altering permanently the structure of the food webs. We are working with researchers at York University, Ontario, to compare in a highly replicated experiment the competitive and environmental advantages of *Holopedium* in lakes suffering from decalcification and global warming.

Crayfish populations.

To better understand the role of crayfish in nutrient dynamics in tributary streams of Lake Erie, researchers at the GLC are studying crayfish populations in Ellicott Creek. Three species of crayfish occur in the stream, and they appear to partition the habitat based on size and morphology. Since different stream sections have different hydraulic patterns (e.g., riffles are fast-flowing whereas pools are slow-flowing), they hold different amounts and qualities of organic matter and sediment. The processing characteristics of the different species, coupled with their habitat partitioning, may have implications for nutrient quality and quantity exported from tributary streams.

Mercury in crayfish.

Crayfishes are an extremely important group of freshwater organisms moving nutrient from the benthic zone to the water column. One of their many roles is processing organic matter; taking coarse organic matter and converting it into fine organic matter which is then available to a large suite of detritus-feeding organisms. This organic matter conversion is important in regulating nutrient cycles and availability as well. When consumed by top aquatic predators, crayfish represent movement of benthic-acquired nutrients to the water column. They also have been shown to bioaccumulate mercury in their muscle tissue. Researchers at the GLC have studied the mercury levels in crayfish throughout New England to correlate mercury levels in these important benthic omnivores with mercury levels in other compartments of lakes and rivers.

Mercury in riparian zone spiders.

Mercury is a potent neurotoxin with no physiological function in organisms. Biomagnification (an increase in contaminant concentration observed with increasing trophic level) of mercury has been documented for many systems, and often top piscivores in aquatic systems contain the highest mercury levels. All the Great Lake states have issued fish consumption advisories related to mercury contamination in top predator fish species. Researchers affiliated with the GLC are trying to further understand the dynamics of mercury movement through ecosystems by examining the movement of mercury from aquatic to terrestrial habitats.

Riparian zone spiders (*Larinioides sclopetarius*) build their webs on structures adjacent to aquatic habitats and feed on emerged aquatic insects. This study examined the mercury content of riparian spiders and their midge prey from areas within the Buffalo River Area of Concern (AOC) and from an upstream area. Spiders contained significantly more mercury than their midge prey, and surprisingly, spiders upstream from the AOC held more mercury than those within the AOC. Researchers are continuing to investigate why the upstream area had higher mercury levels.

Winter macroinvertebrates.

Coupled with studies on land use impacts on benthic macroinvertebrate communities and the use of benthic indices for water quality assessment, studies have been conducted to determine how indices vary with season. Big and Little Sister Creeks, tributaries to Lake Erie, were studied in summer and winter to compare the range of variability in benthic indices and macroinvertebrate community composition. If water quality managers seek to identify small changes in surface water quality, they need to have data with low variability. Understanding the seasonal variability in macroinvertebrate community metrics might assist water quality managers in collecting benthic data able to show smaller changes in water quality.

Stream macroinvertebrates.

Streams draining into Lake Erie flow through catchments with varied land uses, from forested to agricultural to urban. Water quality condition is affected by the landscape through which a stream flows. Studies have been conducted, and are on-going, as to the effects of various land uses on water quality, and the efficacy of different macroinvertebrate indices in documenting water quality changes.

Dobsonfly oviposition behavior in Lake Ontario tributary streams.

Dobsonflies are aquatic insects belonging to the Order Megaloptera. They are long-lived insect predators (often a 3-year life cycle), living their larval stages in streams and the adult stage terrestrially. They are dependent on riparian trees or other structures overhanging a stream to complete their life cycle. GLC scientists are investigating whether females show a tree species preference for oviposition. Understanding the role of the riparian corridor tree community composition for these important aquatic insects may provide land-use managers with information on near-stream habitat management.

Diet of steelhead trout.

Steelhead are an important predator in the lake and the most stocked salmonine with stocking rates of around 2 million fish/year. Previous data on steelhead diet are limited, and do not encompass the entire range of these fish in Lake Erie. The goal of this project is to continue to collect information that is fundamental to understanding the food web dynamics of lake Erie. A better understanding of the role steelhead play in food web dynamics will help fishery managers make effective management decisions.

Freshwater unionids.

This project has been examining the freshwater mussel community of Cassadaga Creek in Chautauqua County NY. Results so far have included evidence of 15 species of mussels in the creek. Among these mussels were the first living specimens of the Rayed Bean (*Villosa fabalis*), listed as a NYS endangered species, to be found in Cassadaga Creek. In addition, a recently dead specimen of a federally listed species the Clubshell (*Pleurobema clava*) was collected. This was the first evidence of a recently living Clubshell in NY since 1919. Plans for future work include an extended survey of Cassadaga Creek targeted at identifying areas of high mussel densities. Also, because fishes are essential hosts for the parasitic lifestage of many unionids mussels, we hope to examine the composition of the fish community in creek.