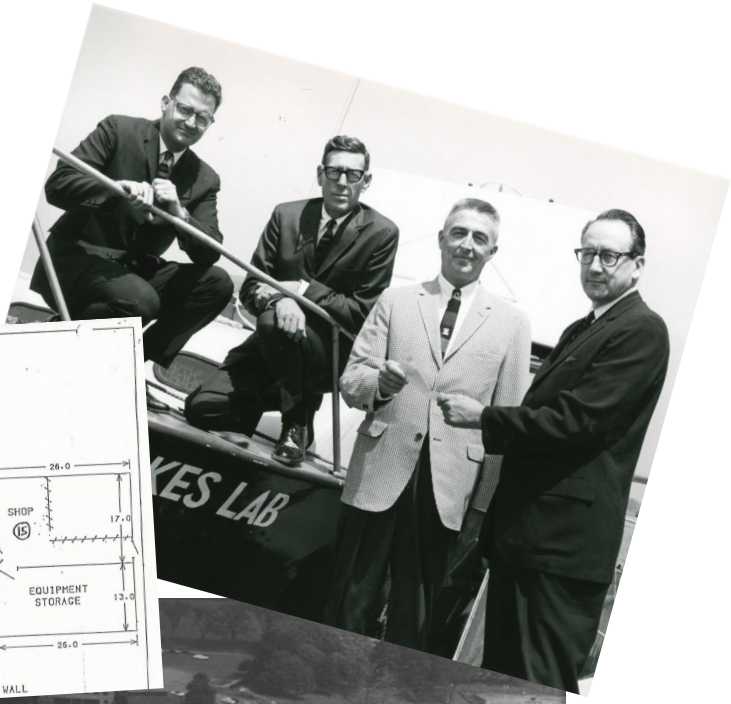

CELEBRATING 50 YEARS OF RESEARCH
1871
DEDICATED TO EXCELLENCE
Buffalo State
Great Lakes Center
1966–2016


KES LAB

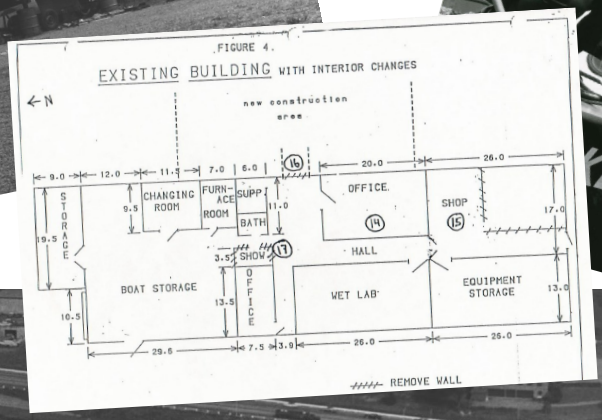


FIGURE 4.
EXISTING BUILDING WITH INTERIOR CHANGES
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new construction area
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BATH
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OFFICE
SHOP
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HALL
BOAT STORAGE
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WET LAB
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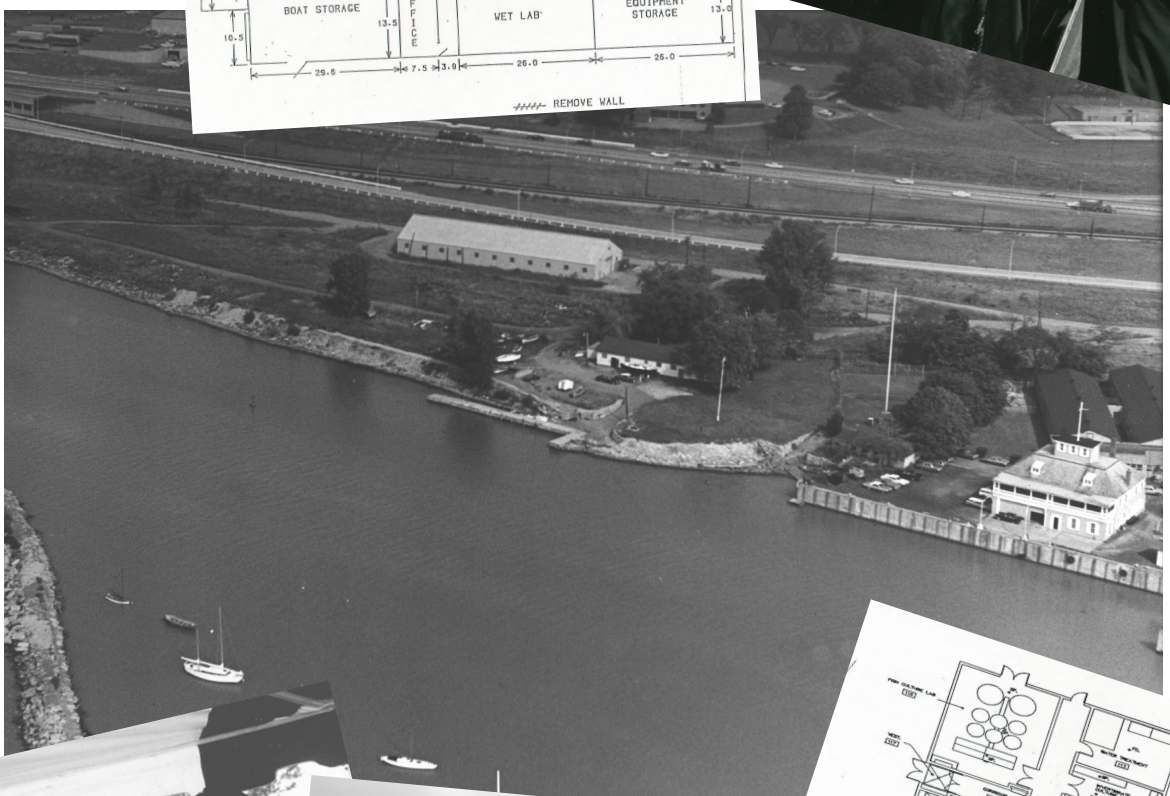
REMOVE WALL




State of New York
OCT - 2002
GREAT LAKES LAB
$100,000 00

DEDICATION

GREAT LAKES LABORATORY

STATE UNIVERSITY COLLEGE AT BUFFALO

SATURDAY, OCTOBER 8, 1966

NEW SCIENCE AUDITORIUM

DR. SIGMUND A. SMITH
Director of Mathematics and Science Division
Presiding

3:00 p.m.	Welcome	DR. PAUL G. BULGER *President*
	Introduction of Guests	
	Acceptance of Gift	
	Remarks	DR. HOWARD G. SENGBUSCH *Director, Great Lakes Laboratory* *Dean, Arts and Science*
		HON. EARL W. BRYDGES *President pro tem and* *Majority Leader* *New York State Senate*
		HON. RICHARD D. MCCARTHY *House of Representatives* *Washington, D.C.*

4:00 p.m. Dedication Ceremony at Site

4:30 p.m. Reception
President's Home
152 Lincoln Parkway

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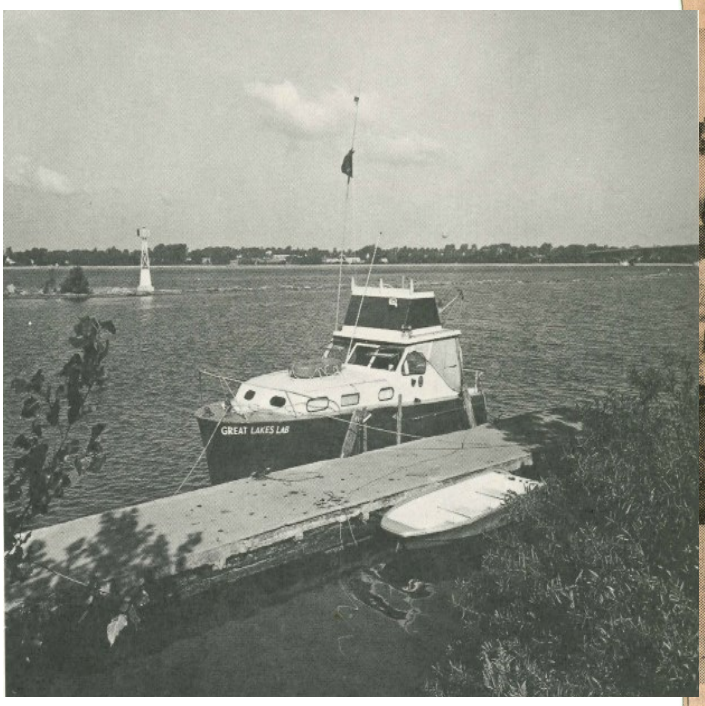
GREAT LAKES CENTER

BUFFALO STATE • The State University of New York

Mission

The Great Lakes Center (GLC) mission is to improve the quality of the environment by providing the best possible science to decision-makers concerned with the health and sustainability of resources, with a primary focus within the Great Lakes and their watersheds. This is accomplished through high quality research, informed and current graduate and undergraduate education, and dissemination of information to the public through outreach. The Center is committed to improving human-environment interactions in the Great Lakes ecosystem guided, in part, by an understanding of the evolutionary and ecological processes and patterns acting on the system. Although the main focus of the research in the GLC concentrates on the Great Lakes basin, nation-wide and international projects are also considered of high priority as they expose GLC scientists to the cutting edge of modern science, facilitate collaboration, and greatly increase visibility of the Center's activity in the scientific community.

The Field Station sports one of its amphibious vehicles, circa 1967.



The first vessel used at the Great Lakes Lab.

Ready to Start Study of Lake Erie

Two sciences, biology and geology, dived into Lake Erie off Sturgeon Pt., marking the start of an underwater study at this end of the lake. The venture, financed by a federal grant, was made possible by the co-operation of State University of Buffalo and State University College at Buffalo.

Diving gear and scientific equipment were loaded aboard the college's Great Lakes Laboratory cruiser near the Buffalo Yacht Club. Lake bottom geology will be studied and plotted—the 9 miles between Sturgeon Pt. and Pt. Abino, Canada. The biologists concurrently will study and set up reference stations while examining floc, a botton mass of organic matter related to lake pollution.

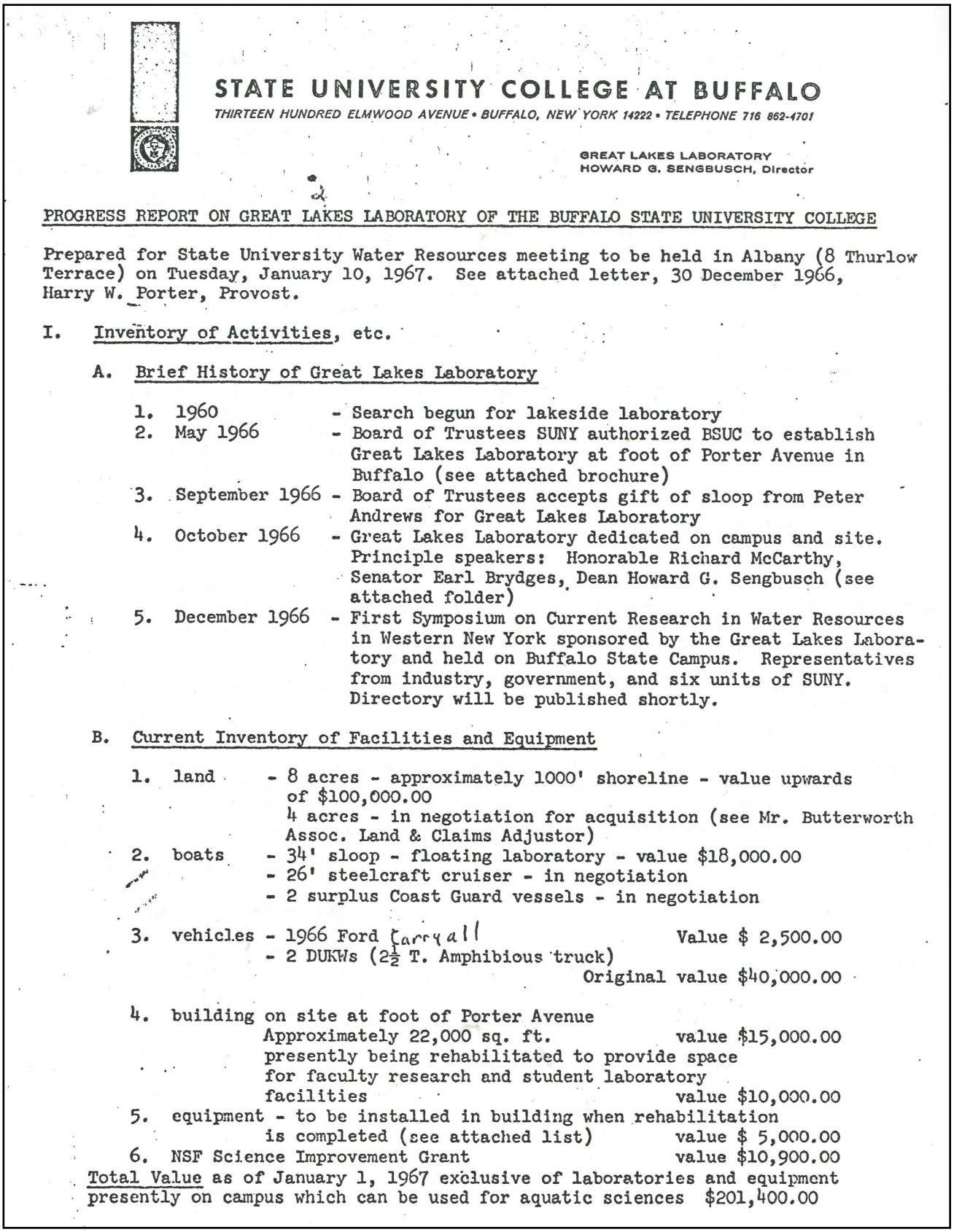
Participants in Tuesday's initial dive are, from the left: Edward Taublie, a graduate UB student working with Dr. Charles J. Cazeau, geologist at that university; Vincent J. Francavilla, graduate biology student; Dr. John F. Storr, UB biologist, and James Sutherland, graduate UB biology student. Coiling the line is cruiser pilot Barry Wech. Dr. Storr and Dr. Cazeau are the principal investigators.

June 28, 1967, Buffalo Evening News article.

50 Years of the Great Lakes Center

by Randy Snyder and Howard Riessen

Dr. Howard Sengbusch, Dean of Arts and Science, helped establish the Great Lakes Laboratory (GLL) in 1966.



STATE UNIVERSITY COLLEGE AT BUFFALO

THIRTEEN HUNDRED ELMWOOD AVENUE • BUFFALO, NEW YORK 14222 • TELEPHONE 716 862-4701

GREAT LAKES LABORATORY
HOWARD G. SENGBUSCH, Director

PROGRESS REPORT ON GREAT LAKES LABORATORY OF THE BUFFALO STATE UNIVERSITY COLLEGE

Prepared for State University Water Resources meeting to be held in Albany (8 Thurlow Terrace) on Tuesday, January 10, 1967. See attached letter, 30 December 1966, Harry W. Porter, Provost.

I. Inventory of Activities, etc.

A. Brief History of Great Lakes Laboratory

1. 1960 - Search begun for lakeside laboratory
2. May 1966 - Board of Trustees SUNY authorized BSUC to establish Great Lakes Laboratory at foot of Porter Avenue in Buffalo (see attached brochure)
3. September 1966 - Board of Trustees accepts gift of sloop from Peter Andrews for Great Lakes Laboratory
4. October 1966 - Great Lakes Laboratory dedicated on campus and site. Principle speakers: Honorable Richard McCarthy, Senator Earl Brydges, Dean Howard G. Sengbusch (see attached folder)
5. December 1966 - First Symposium on Current Research in Water Resources in Western New York sponsored by the Great Lakes Laboratory and held on Buffalo State Campus. Representatives from industry, government, and six units of SUNY. Directory will be published shortly.

B. Current Inventory of Facilities and Equipment

1. land - 8 acres - approximately 1000' shoreline - value upwards of $100,000.00
   4 acres - in negotiation for acquisition (see Mr. Butterworth Assoc. Land & Claims Adjustor)
2. boats - 34' sloop - floating laboratory - value $18,000.00
   - 26' steelcraft cruiser - in negotiation
   - 2 surplus Coast Guard vessels - in negotiation
3. vehicles - 1966 Ford Carryall Value $ 2,500.00
   - 2 DUKWs (2½ T. Amphibious truck) Original value $40,000.00
4. building on site at foot of Porter Avenue
   Approximately 22,000 sq. ft. value $15,000.00
   presently being rehabilitated to provide space for faculty research and student laboratory facilities value $10,000.00
5. equipment - to be installed in building when rehabilitation is completed (see attached list) value $ 5,000.00
6. NSF Science Improvement Grant value $10,900.00

Total Value as of January 1, 1967 exclusive of laboratories and equipment presently on campus which can be used for aquatic sciences $201,400.00

Robert Sweeney (Director from 1966 – 1981)

Dr. Robert Sweeney became the first Director of the GLL in 1966 and laid the foundation for 50 years of environmental research, teaching, and education at Buffalo State College. Research activities at the GLL focused largely on water quality and invertebrates in the Buffalo River, which at the time was suffering from many years of unregulated industrial pollution and environmental neglect. Other research projects examined phytoplankton in the Lake Erie, as well as preliminary work on using Great Lakes fishes as a source of protein concentrate. Funding came from a variety of sources including the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, and the New York State Department of Environmental Conservation. The GLL's main research vessel was the C.A. Dambach, which was transferred to the Maine Maritime Administration in 1982 after Dr. Sweeney left the GLL to take a position with Ecology and Environment, an environmental services firm in Buffalo, NY.

R/V Dambach as it looked in 2014 (photo courtesy of Life Squared Away).

Harish Sikka (Director from 1982 – 1987)

Dr. Harish Sikka became the second Director of the GLL in 1982. Dr. Sikka established a very successful research program focused on toxicology, environmental contaminants, and mechanisms of carcinogenesis. During this time the GLL was able to obtain funding from new sources including the National Institutes of Health, and the scientists working at the GLL were well-known in the Great Lakes scientific community for their work on environmental toxicology. From 1984-1987, Dr. James Spotila, a faculty member in the Biology Department at Buffalo State, served as Associate Director for Fisheries and Ecology in the GLL. His appointment allowed the GLL to establish new fisheries research activities in the Buffalo River, Lake Erie, and the Niagara River. One of the projects directed by Dr. Spotila involved the creation of an artificial reef in Buffalo Harbor to enhance recreational fishing in the area, and another documented successful spawning of walleye in Smokes Creek adjacent to the old Bethlehem Steel Plant in Lackawana, NY. The primary research vessel for the GLL at this time was the Markham III, a 37' twin-diesel vessel loaned to the College from the U.S. Army Corps of Engineers.

R/V Markham III, 1974.

Charles Beasley (Director from 1988-1992)

In 1989/1990, the College wanted to broaden the activities of the original GLL to include more campus departments and a wider array of projects and activities. The GLL was renamed the Center for Environmental Research and Education (CERE) and Dr. Charles Beasley, Chair of the Technology Department at Buffalo State, was appointed Director. CERE had four divisions:

Environmental Toxicology and Chemistry, Aquatic Biology, Water Resources Management, and Environmental Education. A key accomplishment of CERE was a major renovation of the College's Field Station on the Black Rock Canal near Porter Avenue. The original Field Station was a Sea Scout camp that was donated to the college in the 1960's, and before the major renovation occurred the building was little more than a boat garage and workshop. In 1991, CERE was successful in obtaining a large, competitive facilities improvement grant from the National Science Foundation, which provided a total of $700,000 to completely renovate the facility. The modernization nearly doubled the size of the Field Station, added analytical and general purpose laboratory spaces, and provided a source of water from the adjacent Black Rock canal for culture of live fish and invertebrates. Another important accomplishment in 1991 was the establishment of the U.S. Fish & Wildlife's Lower Great Lakes Fisheries Resources Office on the campus of Buffalo State College. U.S. Representative Henry Nowak was instrumental in sponsoring legislation to form the office, with the goals of reviving commercial and recreational fishing, protecting native fishes, and preserving key aquatic habitats in the Lower Great Lakes. For several years, the Fish & Wildlife office was housed in the Science Building and later at the college's Field Station before moving to a larger space in Amherst, NY. The main research vessel for CERE was the R/V Hutchinson, a 42' Chris Craft Commander. In 1992, Dr. Charles Beasley returned to the Technology Department as full-time Department Chair, and Dr. Eric Randall, chair of the Biology Department, served as Interim Director of CERE from 1992-93.

R/V Hutchinson.

Stephen Brandt (Director from 1994-1997)

Dr. Stephen Brandt became Director of CERE in 1994, arriving from the Chesapeake Biological Laboratory in Maryland. He quickly established a large, productive research laboratory at Buffalo State involving many graduate students, postdoctoral fellows, and staff scientists. Research conducted by the Center, which at this time was renamed the Great Lakes Center (GLC), focused on fisheries ecology, bioenergetics modeling, and hydroacoustics. Major accomplishments included hosting the annual meeting of the International Association for Great Lakes Research (IAGLR) at Buffalo State in 1997, and developing a new Multidisciplinary Master's Degree in Great Lakes Environmental Studies. To outfit the newly renovated Field Station, the GLC submitted and was awarded several competitive equipment grants from the National Science Foundation totaling over $400,000, which made it possible to purchase equipment including a high-speed video system, a bomb calorimeter to measure energy content of biological samples, new fish culture tanks and equipment, and a computerized monitoring and alarm system for the live culture laboratories. The main research vessel for the GLC was the R/V Aquarius, which was a 40' steel-hulled vessel built in 1970 and purchased from Wisconsin Sea Grant in 1994. In 1997, Dr. Brandt left the GLC to become Director of the NOAA Great Lakes Environmental Research Laboratory in Ann Arbor, Michigan. Despite having been at Buffalo State for only three years, Dr. Brandt built the GLC into a major regional research and educational institution with a first-class scientific reputation.

R/V Aquarius alongside a much larger vessel in the Black Rock canal.

Gordon Fraser (Director from 1998-2007)

Dr. Gordon Fraser became Director of the GLC in 1998. After his arrival, there was a renewed focus on research involving the Buffalo River, including biological assessments and water quality investigations. Combined sewer overflows (CSO's) are a significant source of pollution in the Buffalo River, the Black Rock canal, and the Niagara River, and many GLC staff and scientists were involved with studies of CSO impacts during this time period. A major accomplishment was the construction of the Dick Smith Teaching Pavilion in 2006, made possible by funds provided by NYS Representative Dick Smith. The Teaching Pavilion is used often for courses, workshops, and social functions by many departments and units at Buffalo State. The main research vessels for the GLC at this time were the R/V Pisces and the R/V Seneca. Dr. Fraser retired as Director of the GLC in 2007.

R/V Pisces.

R/V Seneca.

Alexander Karatayev (Director from 2007 - present)

Dr. Alexander Karatayev became Director of the GLC in 2007 and continues in that capacity today. Since his arrival, grant activity, presentations, and publications have increased dramatically compared to the prior 10 years, and the level of activity at the Field Station has increased markedly as well. An important current area of research at the GLC is invasive species, and Center staff and faculty carry out research on invasive mussels, zooplankton, and fishes in the Great Lakes and in ecosystems throughout the world. Other areas of research focus on protecting and enhancing native fish species such as the emerald shiner and the Lake sturgeon, and investigating water quality and benthic macroinvertebrate communities in the Great Lakes and tributaries as part of long-term monitoring programs. A major accomplishment for the GLC was the development of two new graduate programs, an M.S. (a professional science masters) and an M.A. in Great Lakes Ecosystem Science, both of which have been very successful in bringing new students to Buffalo State. Other significant accomplishments include receiving a five year EPA long-term monitoring grant in collaboration with Cornell University to monitor the lower food webs in the Great Lakes, being chosen to host a local NYS DEC PRISM office to facilitate invasive species outreach and education, deploying an automated buoy in eastern Lake Erie as a part of the Great Lakes Observing System, and acquiring a National Guard building adjacent to the Field Station to house the GLC's growing fleet of research vessels. Large vessels acquired since 2007 include the 28' R/V Privateer and the 27' aluminum-hulled R/V John J. Freidhoff. The latter was named in honor of "Captain John" Freidhoff, former ship's captain and field station manager at the GLC who passed away tragically at age 46 in 2007 as a result of a diving accident in Lake Ontario.

R/V John J. Freidhoff.

GLC Staff and Collaborators

Staff

Over the last eight years the number of full-time faculty and staff in the GLC varied from nine to thirteen. Currently, there are 12 full-time employees and one part-time employee, including five full-time employees supported by externally funded projects.

Director:	Alexander Karatayev
Research Scientists:	Lyubov Burlakova Mark Clapsadl Subodh Kumar (part-time) Knut Mehler Christopher Pennuto Alicia Pérez-Fuentetaja
Research Technicians:	Susan Daniel Joshua Fisher Kit Hastings Brianne L. Tulumello
WNY PRISM Coordinator:	Andrea Locke
Secretary:	Susan Dickinson

For our research projects, we regularly hire research assistants, mostly Buffalo State students. By participating in our research projects, our assistants have an excellent opportunity to learn more about our research and meet our collaborators from other universities, various state and federal agencies and NGO's. The experience and networking contacts can be very useful in future employment. Over the last eight years, the number of research assistants has increased from two in 2007/2008 to 22 in 2014/2015.

GLC staff and research assistants with President Conway-Turner at the Field Station Open House, May 2015.

Collaborators

In addition to full-time employees, we actively collaborate with scientists from other departments at Buffalo State, as well as universities, research centers, and state and federal employees within New York State and on a nationwide and international level. GLC affiliates - Buffalo State faculty and staff that routinely have joint projects and use our facilities - have doubled over the last eight years, reaching twelve in 2014/2015. Three scientists from USFWS and USGS that are involved in joint research and/or advising our graduate students have been granted GLC adjunct professor status.

GLC Affiliates (at SUNY Buffalo State)

- Kelly Frothingham, Chair of the Geography and Planning Department
- Richard Johnson, Sponsored Programs
- Catherine Lange, Associate Professor, Earth Sciences and Science Education Department
- Susan McCartney, Small Business Development Center
- Mary Perrelli, Geography and Planning Department
- Gary Pettibone, Professor, Biology Department
- Daniel L. Potts, Associate Professor, Biology Department
- Howard Riessen, Professor, Biology Department
- Jill Singer, Professor, Earth Sciences and Science Education Department and Director of the Office of Undergraduate Research
- Randal Snyder, Professor, Biology Department
- Stephen Vermette, Professor, Geography and Planning Department
- Robert J. Warren, Assistant Professor, Biology Department

GLC Adjunct Professors

- Zy Biesinger, Fish Biologist, U.S. Fish and Wildlife Service
- Dimitry Gorsky, Fish Biologist, U.S. Fish and Wildlife Service
- Martin A. Stapanian, Research Ecologist, U.S. Geological Survey

Collaborators in New York State

- Diana S. Aga, Chemistry Department, State University of New York at Buffalo
- Katherine Alben, Wasdworth Institute, Albany
- Joe Atkinson, Environmental Engineering, State University of New York at Buffalo
- Robert Baier, State University of New York at Buffalo
- Gregory Boyer, State University of New York, College of Environmental Science and Forestry, Syracuse
- Mary Alice Coffroth, Department of Geology & Graduate Program in Evolution, Ecology and Behavior, State University of New York at Buffalo
- Clifford Craft, Department of Natural Resources, Cornell University
- Tim DePriest, NY Department of Environmental Conservation
- Dawn Dittman, USGS, Great Lakes Science Center, Tunison Laboratory of Aquatic Science, Cortland
- Donald Einhouse, NY Department of Environmental Conservation
- Kofi Fynn-Aikins, U.S. Fish and Wildlife Service
- Kerry Gallo, Buffalo Niagara Riverkeeper
- Mike Goehle, U.S. Fish and Wildlife Service
- Andrew Hannes, U.S. Army Corps of Engineers
- Jim Haynes, Biology & Environmental Science, SUNY College at Brockport, Brockport, NY
- Renata Kraft, Buffalo Niagara Riverkeeper
- Jenny Landry, Region 8 Bureau of Wildlife, NYS Department of Environmental Conservation, Avon, NY
- Howard Lasker, Department of Geology, State University of New York at Buffalo

- Amy Mahar, NYS Department of Environmental Conservation, Avon, NY
- Denise Mayer, NYS Museum Field Research Laboratory
- Daniel Molloy, State University of New York at Albany
- Dianna Padilla, Department of Ecology and Evolution, State University of New York, Stony Brook University
- Lars Rudstam, College of Agriculture and Life Sciences, Department of Natural Resources, Cornell Biological Field Station, Cornell University
- James Watkins, Cornell Biological Field Station, Cornell University
- Michael Wilkinson, NY Department of Environmental Conservation

Collaborators at other U.S. Institutions

- Darren Bade, Kent State University, Kent, Ohio
- Ashley Baldridge, NOAA Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan
- Richard P. Barbiero, CSC, Chicago, Illinois
- Dima Beletsky, Cooperative Institute for Limnology and Ecosystems Research, University of Michigan, Ann Arbor, Michigan
- David J. Berg, Department of Zoology, Miami University, Ohio
- Jonathan Bossenbroek, Department of Environmental Sciences, University of Toledo
- Tom Bridgeman, University of Toledo, Toledo, Ohio
- David Campbell, Department of Natural Sciences, Gardner-Webb University, Boiling Springs, North Carolina
- Joe Conroy, Ohio Department of Natural Resources
- David De Marini, Environmental Carcinogenesis Division (B-143-06), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina
- Robert Gottfried, Texas Parks and Wildlife Department, Austin, Texas
- Elizabeth Hinchey Malloy, U.S. EPA Great Lakes National Program Office, Chicago, Illinois
- Donald Jerina, Laboratory of Bioorganic Chemistry NIDDK, National Institutes of Health, Bethesda, Maryland
- Vadim A. Karatayev, PhD student, Department of Environmental Science & Policy, University of California, Davis
- Jack Kramer, National Center for Water Quality Research, Heidelberg University, Tiffin, Ohio
- Bob Krebs, Department of Biology, Geology, Environmental Science, Cleveland State University, Cleveland, Ohio
- Kenneth Krieger, National Center for Water Quality Research, Heidelberg University, Tiffin, Ohio
- Kenneth Laali, Chemistry Department, Kent State University, Kent, Ohio
- Gerald Matisoff, Department of Geological Sciences, Case Western Reserve University, Cleveland, Ohio
- Marsha May, Texas Nature Trackers, Wildlife Diversity Branch, Texas Parks and Wildlife Department, Austin, Texas
- Christine Mayer, Department of Environmental Sciences and Lake Erie Center, University of Toledo, Ohio
- Elizabeth Meyer, Pennsylvania Natural Heritage Program
- Pawel Michalak, Bioinformatics Institute, Virginia Tech
- Thomas D. Miller, Lamar Bruni Vergara Environmental Science Center, Laredo Community College, Texas
- Thomas Nalepa, The Graham Sustainability Institute, University of Michigan, Ann Arbor, Michigan
- Don W. Schloesser, USGS, Great Lakes Science Center, Ann Arbor, Michigan
- Astrid N. Schwalb, Department of Biology/Aquatic Station, Texas State University, San Marcos, Texas
- Jake Vander Zanden, Center for Limnology, University of Wisconsin, Madison, Wisconsin
- Mary Walsh, Pennsylvania Natural Heritage Program, Western Pennsylvania Conservancy
- Glenn Warren, U.S. EPA, Great Lakes National Program Office, Chicago, IL

- Daelyn A. Woolnough, Biology Department, Institute for Great Lakes Research, Central Michigan University, Mount Pleasant, Michigan
- David Zanatta, Biology Department, Institute for Great Lakes Research, Central Michigan University, Mount Pleasant, Michigan

International Collaborators

- Demetrio Boltovskoy, University of Buenos Aires, Argentina
- Jan Ciborowski, Department of Biological Sciences, University of Windsor, Windsor, Ontario, Canada
- Renata Claudi, RNT Consulting Inc., Ontario, Canada
- Frank P. L. Collas, Department of Environmental Science, Institute for Water and Wetland Research, Radboud University, Nijmegen, The Netherlands
- Rob Leuven, Radboud University, Nijmegen, The Netherlands
- Manuel Lopes-Lima, ICBAS - Abel Salazar Biomedical Sciences Institute, Laboratory of Ecophysiology, CIIMAR - Interdisciplinary Centre of Marine and Environmental Research, University of Porto, Portugal
- Frances Lucy, Institute of Technology, Sligo, Ireland
- Tamara A. Makarevich, Department of General Ecology, College of Biology, Belarusian State University, Minsk, Belarus
- Sergey Mastitsky, RNT Consulting Inc., Ontario, Canada
- Richard Soare, Department of Geography and Planning, Concordia University, Montreal, Canada
- Anne Yagi, Ontario Ministry of Natural Resources, Ontario, Canada
- Norman Yan, York University, York, Ontario, Canada

Research Activity

Over the last eight years, the Great Lakes Center has seen sustained activity and productivity in research. Our researchers have published over 80 papers (see pages 59-64) and made over 240 presentations at various state, national and international meetings. We were involved in 40 funded projects totaling over $14 million, including over $8 million for Buffalo State (see pages 65-67). The amount of external funding (including multiyear projects) has constantly increased from $1,265,000 in 2007/2008 to $4,860,763 in 2014/2015. The total expenditure (the amount of money generated per year) has increased more than 5-fold over the last eight years. The mean dollar amount per funded project has increased from ~$140K/project in 2007/2008 to over $400K/project in 2014/2015. GLC has become a leader in a number of large collaborative projects. Although the main focus of our research is in the Great Lakes and their watershed, the geography of our research activity is much broader from the most southern Rio Grande to the most northern Lake Superior. In addition, our scientists have been involved in several projects in Canada, Europe and South America. Below are descriptions of several most recent and extensive projects that GLC scientists have been involved in over the last eight years.

Lyubov Burlakova with Alexander Y. Karatayev

Benthos (a community of freshwater invertebrates that live at the bottom of lakes and rivers) is an essential part of the aquatic food web, a major contributor to whole-lake productivity and diversity, and serves as an important indicator of water quality. For example, the disappearance of mayflies *Hexagenia* from western Lake Erie benthos provided one of the strong evidences of water quality deterioration and initiated environmental movement resulting in the Great Lakes Water Quality Agreement of 1972 and consequent improvement of water quality in the Great Lakes.

Sampling of eastern Lake Erie aboard RV Seneca, Lyubov Burlakova (l) and Sergey Mastitsky (r), 2008.

Unfortunately, considering the time and expertise involved in species identification, there are very few long-term studies of freshwater benthic communities. In 2003-2007 we conducted a study of benthos of Lake Mendota (Wisconsin) and using historical data spanning a century of time, demonstrated a dramatic shift in community structure in the middle of the 20th century. This striking change was correlated with multiple factors acting simultaneously, including increased urban development, human population density, intensive agriculture, and the introduction of a major invasive species, Eurasian watermilfoil (Karatayev et al. 2012).

Changes in Lake Erie benthos over the last 50 years: Historical perspectives, current status, and main drivers

From 2008-2012, we sampled Lake Erie benthos and compared our data to historical data in order to understand long-term changes in the lake's ecosystem (Burlakova et al. 2014). During the last 50 years, Lake Erie has experienced major environmental changes, from anthropogenic eutrophication in the 1930-1960's, to nutrient and pollution abatement in the 1970's, and then the introduction of exotic dreissenids in the 1980's. Comparing data from 1960's to 2000's, we found that the Lake Erie benthic community

underwent significant changes during each decade, showing signs of recovery following ecosystem restoration in the 1970's, but then experiencing major structural and functional changes after introductions of exotic dreissenids (*Dreissena polymorpha* and *D. r. bugensis*). Currently, the lake-wide benthic community is dominated by dreissenids, followed by oligochaetes and chironomids. To continue this study, we performed one of the largest surveys of Lake Erie benthos during the 2014 CSMI Lake Erie Year.

Long-term monitoring of Great Lakes benthos

Collecting benthic samples, 2012.

Recognizing that benthos can play an important role both in detecting changes in the lakes, and in the health of the open waters, the U.S. EPA's Great Lakes National Program Office initiated a benthic invertebrate biomonitoring program in 1997. A unique aspect of this monitoring program is the extent of coverage. The annual sampling of 59 permanent stations across all five lakes makes this program one of the largest in the world. Another unique aspect is the fact that a single agency oversees the work, thus ensuring consistency in sampling and analytical methods. In 2012, the Great Lakes Center, in collaboration with Cornell University, was awarded a U.S. EPA Great Lakes Long-term Biological Monitoring grant. Since 2013, we have collected and analyzed benthic data across the five Great Lakes to make the data available to environmental and fisheries managers.

Marissa Hajduk processing benthic samples aboard the EPA RV Lake Guardian, 2009.

Benthic samples from western Lake Erie; note the large mayflies Hexagenia that disappeared from Lake Erie in the 1960's and returned to the lake in the 1990's.

Evaluating 15 years of GLNPO data, we found that the major drivers of the distribution, abundance, and benthic species richness were depth, chlorophyll, and nutrients. Species assemblages change significantly along the depth gradient with the highest density and diversity shallower than 60 meters. We distinguished the major groups of benthic invertebrates along depths and trophic gradients, and analyzed changes in benthic community structure and dominance. These include a dramatic decline of important fish food amphipod *Diporeia* sp. in lakes Michigan, Huron and Ontario, and the invasion of exotic bivalves *Dreissena polymorpha* and *D. rostriformis bugensis*, which were among the most important potential drivers of changes in the benthic communities.

EPA RV Lake Guardian.

Collecting benthic samples on the lower deck of the RV Lake Guardian.

Sorting benthic samples, 2012.

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

Freshwater Unionidae is the most rapidly declining faunal group in North America. From 2003-2014 we were funded by the U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department to conduct statewide surveys of the rare and the most valuable Unionidae populations, and collected unionids from over 70 waterbodies belonging to all major drainage basins of Texas. Analysis of this dataset revealed that, due to the large size and gradients in landscape and climate, Texas has diverse and distinct unionid communities, including numerous regional and state endemic species. Sixty-five percent of Texas unionid species were classified as rare and very rare, including all state and regional endemics that were a critical component in defining the uniqueness of unionid communities (Burlakova et al. 2011a). We found that climate, landscape, geology, and land use type were important factors influencing unionid distribution patterns among biotic provinces, and that increased human population density was associated with the loss of rare species over several decades. Man's ongoing alteration of lotic with lentic waterbodies favors common species, but

Surveying San Marcos and Rio Grande rivers in Texas.

dramatically reduced habitat for endemics, contributing to homogenization of unionid fauna (Burlakova et al. 2011b). We identified hotspots of endemism, prioritized species in need of protection, estimated their population sizes, and recommended changes to their current conservation status. These data were used to add 15 species of freshwater mussels to the state list of threatened species and to submit a petition for their federal listing. In addition, we developed a method to evaluate historical changes in mussel population size and distributional range, and estimated that the total population size of the Rio Grande endemic Texas hornshell has declined > 70% over the last 100 years (Karatayev et al. 2011, 2015). These data are currently used by U.S. FWS to determine the need of species' federal protection. The comprehensive dataset assembled during this study is now a part of the Texas Natural Diversity Database and is being used for species management and protection.

Conservation of native freshwater mussels in Great Lakes coastal zones

Since the introduction of dreissenid mussels into the Laurentian Great Lakes in the late-1980's, the diverse native mussel communities of the region have declined sharply. During 2011-2012, within a large collaborative project funded by the U.S. Fish and Wildlife Service, we surveyed over 190 sites in lakes Erie, Ontario and St. Clair, and the Detroit and Niagara Rivers, and collected over 4,000 unionids from 26 species (Burlakova et al. 2014; Zanatta et al. 2015; Paterson et al. 2015). We also examined unionid genetic diversity/isolation to determine if there is gene flow between coastal refuges and nearby riverine habitats. We found high quality assemblages of native mussels in the St. Clair delta, and in some bays and coastal wetlands in lakes Erie and Ontario, and recorded a major shift in species assemblages in Lake Erie compared to those of the 1950's and 1980's. Examining dreissenids attached to live unionids, we found that the frequency of unionid infestation by *Dreissena* recently declined, and the number of dreissenids attached to unionids in the lower Great Lakes has fallen almost ten-fold since the early 1990's. The rate of infestation depended on the dominant *Dreissena* species in the lake. Since zebra mussels infested unionids much more often and in greater numbers, the proportion of infested unionids and the number and weight of attached dreissenids were lower in waterbodies dominated by quagga mussels (Burlakova et al., 2015). This information will help managers in developing conservation strategies to sustain existing populations in these refuges. Many undergraduate and graduate students were trained during the course of this expansive project, thereby creating a cadre of future scientists and managers who will work to protect this imperiled resource.

Surveys of freshwater mussels in the lower Great Lakes.

Mark Clapsadl

Initially trained as a fisheries biologist, my graduate work focused on the early life history of muskellunge (*Esox masquinongy*) in the St. Lawrence River, with an emphasis on the influence of macrophytes on survival of young-of-the-year muskies. In that work I examined the impacts of aquatic plants that are expanding their range due to anthropogenic impacts (water level manipulations) on the larval fish community and, in particular, the relationship to the available forage for YOY muskellunge as well as the role those plants play in oxygen depletion at the water substrate interface.

I went on to work for the Alaska Department Fish and Game as a Fishery Biologist as the project leader for a large research project examining predation on populations of juvenile pink salmon and herring in the aftermath of the Prince William Sound oil spill. Later I switched roles within ADFG and became an Area Fishery Manager for Kodiak Island and the Aleutian Peninsula. In this position I was tasked with the responsibility to decide whether to open or close fisheries within this very large management area, and vested with Emergency Order authority by the Alaska legislature so that those decisions had the binding force of law.

After leaving fisheries management and returning to NY, I began to focus my efforts on various projects within the Great Lakes region. Since returning to NY I have participated in multiple research projects examining a broad range of topics. I have worked on the trophic transfer of type-e botulism in Lake Erie, examined the diet of steelhead trout in Lake Erie, collaborated on multiple lake nutrient studies in lakes Ontario and Erie as well as collaborating in studies looking at the growth of mussels in deeper portions of Lake Erie.

GLOS Buoy project

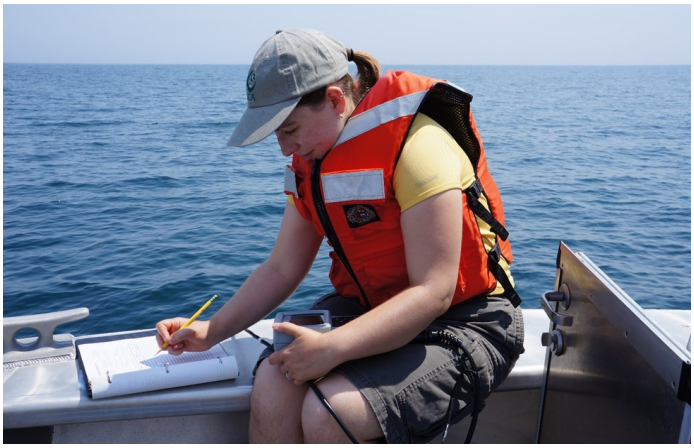
Mark Clapsadl (l) and Josh Fisher (r) launching the GLOS buoy.

Since 2012 I have also been involved in the Great Lakes Observing System (GLOS). Along with collaborators at SUNY College of Environmental Science and Forestry, I have been operating a data collection buoy in Lake Erie approximately five miles NNW of Dunkirk NY. The buoy is a TIDAS 900 and, at a little over 16' long and over 650 lbs., it can be challenging to handle in frequently choppy waters of Lake Erie. The buoy collects a suite of data including solar radiation, wind speed and direction, air temperature and humidity, as well as barometric pressure. It also collects water temperature every 2m down to a depth of 25m, dissolved oxygen levels, and wave height. All of these data are relayed in real time via cellular link back to the GLC Field Station and on to a GLOS website (www.glos.us/) which is publicly available. This site has become very popular with the local fishing Community, as they are often interested in temperature profiles to help them find fish as well as in wave height to decide if conditions are right for heading out on the lake.

The buoy at station in Lake Erie.

Lake Erie Lower Trophic Level Assessment

The Great Lakes Center has been an active member of the Forage Task Group (FTG) of the Great Lakes Fishery Commission. As part of the FTG, we have participated in a long-term monitoring study in eastern Lake Erie since 2008. Starting in early May and running until October, we collect samples from two stations in eastern Lake Erie on a bi-weekly basis. The project technician and person responsible for most of the actual field and lab work for this project since 2008 is Kit Hastings. At each station we collect water samples to be analyzed for zooplankton, phytoplankton, and nutrients (phosphorus). We also collect a temperature/pH/dissolved oxygen profile of the water column as well as secchi depth. Finally, we collect benthic samples from which we separate and identify and count all the benthic organisms. Data are used annually by the FTG to examine the lower trophic levels of Lake Erie, which can give lake managers an idea of the forage base for fish communities in the lake. The results of all of this work are also provided to the NYS Department of Environmental Conservation Fisheries Research Unit in Dunkirk, NY. There the data are combined with data collected from all of the other state, federal or provincial agencies that have management responsibilities on Lake Erie. The long-term continuity of this project makes it extremely important. Changes in ecosystems often operate over time scales that span many seasons or decades and it is rare to have a continuous data set over such a time period. A long term record of water quality parameters and the state of the lower trophic levels of Lake Erie will provide a foundation that can help us understand and face the challenges due to impacts resulting from climate change and invasive species.



Kit Hastings collecting lake profile data.

Emerald Shiner Project

With the Niagara River emerald shiner project, my work is going back to its origins by studying the ecology of a fish in a large river system. Drs. Alicia Perez-Fuentetaja (PI) and Randall Snyder (Co-PI) and myself (Co-PI) have created a team to investigate a wide range of ecological aspects of the life of emerald shiners in the upper Niagara River (UNR). (Please see Alicia Pérez-Fuentetaja's research activity on page 38 for a full description of the project). One of the areas of this project in which I am most active concerns the energy density of shiners in the upper Niagara. Relative energy density in fishes can be a good indicator of overall health and condition and I have been working on making comparison to the emerald shiners in the UNR to the energy density of emerald shiners in other nearby systems, specifically Lake Ontario, Lake Erie and the lower Niagara River. While the work still in progress, we are seeing some interesting differences in these groups of fish. Defining and understanding these differences may help us to better understand the ecology of this species in the upper Niagara River.

Jake Cochran and Chris Osborne with the larval seine in the upper Niagara River.

Chris Osborne and John Lang seining for larval fishes in the upper Niagara River.

Alexander Y. Karatayev with Lyubov Burlakova and Vadim Karatayev

Alexander Karatayev (top) and Lyubov Burlakova (bottom) collecting samples.

We have a long history of research on the spread, population dynamics, distribution, growth, and ecosystem impacts of exotic bivalves. Our first research on zebra mussel ecology and impacts date back to 1970's and 1980's, when we conducted the first assessment of *Dreissena* impact on the whole-lake ecosystem in Belarus. Most of these studies were published in Russian but later were summarized in several review papers in order to make studies published in the former Soviet Union readily available for western scientists.

Our recent studies on exotic dreissenids were conducted at the Great Lakes Center starting in 2007/2008. Many of the recent projects (including lake-wide surveys conducted on board R/V Lake Guardian) are sponsored by the U.S. EPA and are part of large collaborative efforts (for more information please check the Great Lakes Center webpage (http://greatlakescenter.buffalostate.edu/) and our publications, pages 59-64). Our most recent studies include:

Contrasting the rates of spread of zebra and quagga mussels at different spatial scales

In Europe zebra mussels began to spread from their native range in the Ponto-Caspian basin the early 1800's. In contrast, quagga mussels remained restricted to its native range until the 1940's. Therefore when quagga mussels started to spread across Europe, most lakes they invaded were already colonized by zebra mussels, making it difficult to compare their rates of spread. Because North America was colonized by both species at approximately the same time (1980's) and in the same area (Lake Erie), their rates of spread in North America are directly comparable. We found that by 2008, zebra mussels had colonized twice as many U.S. states as quagga mussels, almost eight times more counties, and over 15 times more water bodies. We also found that the time lag between when each species was first detected in a waterbody and it reached its maximum population density was about 5 times shorter for zebra than for quagga mussels, which may be the key to their invasion success. The ability of zebra mussels to rapidly capitalize on secondary spread is likely responsible for the escalating rates of spread at various spatial scales.

L. Burlakova and S. Mastitsky study growth and mortality of zebra and quagga mussels under different thermal regimes.

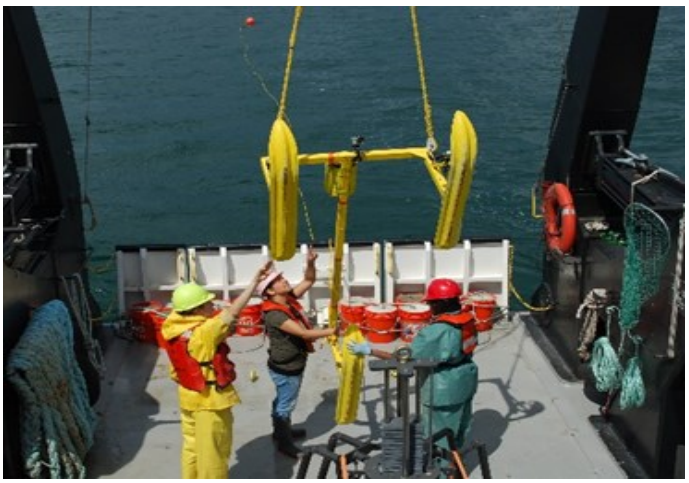
Differences in growth and survivorship of zebra and quagga mussels

The zebra mussel and its congener, the quagga mussel, are both invaders in freshwater, but have very different invasion histories, with zebra mussels attaining substantially faster rates of spread at virtually all spatial scales. However, in waterbodies where they co-occur, quagga can displace zebra mussels. To determine if the mechanisms for this displacement are associated with different survival and growth, we kept mussels in our Field Station's aquaculture facility in flow-through tanks for 289 days with two temperature regimes that mimicked the

natural surface-water (littoral zone) and hypolimnion conditions of Lake Erie. We found quagga mussels had higher survivorship and grew more than zebra mussels under environmental conditions that mimicked the thermal environment of the profundal zone, where they were expected to perform well. Surprisingly, they also outperformed zebra mussels in terms of survivorship and growth in the thermal environment reflecting the littoral zone of Lake Erie. This result supports the notion that quagga mussels have a greater energetic efficiency than zebra mussels, and this advantage is not temperature dependent. For both species, we found that the size of the mussel entering the winter season was critical for survivorship. Larger mussels had a higher probability of surviving the winter across all treatments.

Long-term dynamics of zebra and quagga mussels populations in Lake Erie

Lake Erie has the longest history of colonization by both *Dreissena* species in North America, and is therefore optimal for the study of long-term dynamics of dreissenid species. During the initial stage of colonization, all three Lake Erie basins were widely populated by dreissenids, with zebra mussels being the dominant species in most of the lake. However, by the late 1990's, quagga replaced zebra mussels in the central basin and especially in the deepest eastern basin, with zebra mussels being still common in the shallow western basin. In 2014, we collected 322 samples from 112 sites using ponar grabs and SCUBA diving to estimate the density and distribution of dreissenids in Lake Erie. The highest densities of mussels were found in the eastern basin and the lowest in the central basin, where dreissenids were limited by hypoxia. Quagga mussels were found at all depths and in all basins, while zebra mussels were common only in the western basin where they still represent about 30% of the combined dreissenid density. Size-wise, in the western basin, *Dreissena* spp. were much smaller than in the eastern basin. The near-bottom hypoxia was the most important environmental factor to govern the spatial distribution of dreissenids in the central basin of Lake Erie, resulting in almost complete elimination of mussels at depths over 20 meters. Periodic hypoxia may also be an important factor limiting long-term survival of dreissenids in the western basin, reducing competition between dreissenid species, and allowing survival of zebra mussels for almost 30 years without being completely replaced with quagga mussels. Therefore, the monitoring of *Dreissena* occurrence and length-frequency distribution can be an effective tool in mapping the extent and frequency of hypoxia in freshwaters.

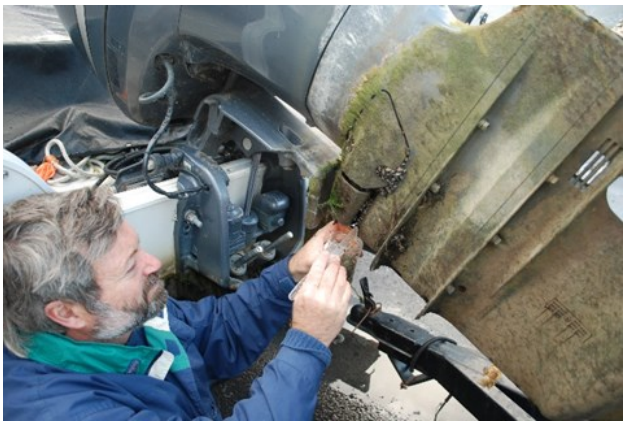


Readying the benthic sled for deployment, Lake Erie, 2014.

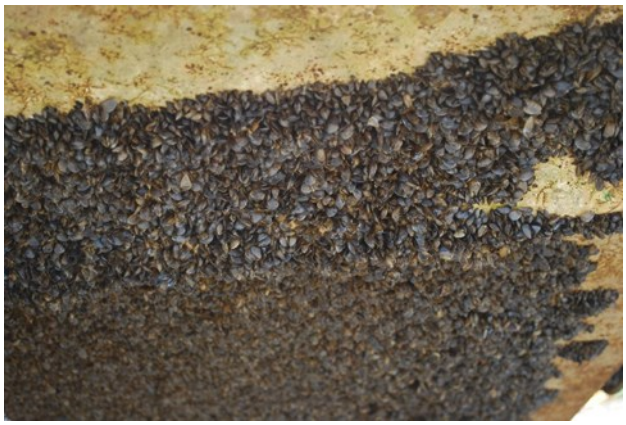
Lake Guardian crew, EPA and GLC scientists during Lake Erie benthic study, 2014.

Could the lower Great Lakes dominated by quagga mussels be a source for spread of zebra mussels?

As recreational boats are the main vector of spread for dreissenids in North America, we examined whether lakes Erie and Ontario could still be sources for the spread of zebra mussels. We found that although quagga mussels compose ~ 99% of dreissenids in eastern Lake Erie and in Lake Ontario, on boats at most marinas sampled, zebra mussels were usually more abundant and were significantly larger than the quagga mussels.



A. Karatayev collecting Dreissena samples from boats.



Boat hull covered with Dreissena.

Refugia for zebra mussels were found in bays, tributaries, and upper littoral zones with high wave activity. In addition, zebra mussels were more likely to resist dislodgment than quagga mussels due to their flattened ventral shell surface and higher rate of byssal thread production, and may be more abundant on floating substrates, such as buoys and boats, which experience greater water motion. Thus, although quagga mussels are now more abundant than zebra mussels within the Lower Great Lakes, these waterbodies still have the potential to be a source for the spread of zebra mussels, and for some vectors, the propagule pressure from zebra mussels is likely greater than for quagga mussels.

Eutrophication and Dreissena invasion as drivers of biodiversity: a century of change in the mollusc community of Lake Oneida

Changes in nutrient loading and invasive species are among the strongest human-driven disturbances in freshwater ecosystems, but our knowledge on how they affect the biodiversity of lakes is still limited. We conducted a detailed historical analysis of the mollusc community of Oneida Lake based on our lake-wide study in 2012 and previous surveys dating back to 1915. In the early 20th century, the lake had a high water clarity, with abundant macrophytes and benthic algae, and hosted the most diverse molluscan community in New York State, including 32 gastropod and nine unionid species. By the 1960's, lake turbidity increased during a period of anthropogenic eutrophication, resulting in a 38% decline in species richness and 95% reduction in abundance of native gastropods grazing on benthic algae. Following the invasion of *Dreissena* spp. in 1991, water clarity improved, and by 2012, native gastropod species richness increased by 37% and abundance increased 20-fold. In contrast, filter-feeding unionids were unaffected by increased turbidity during the period of

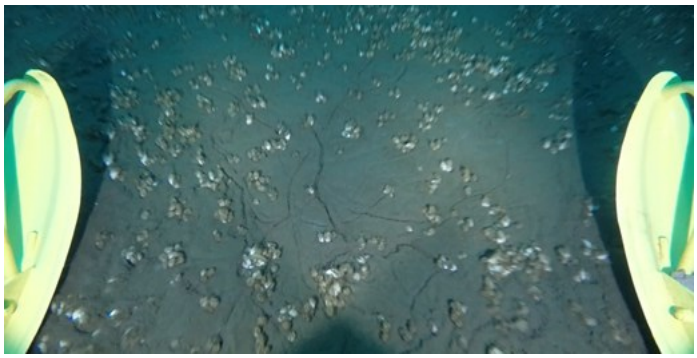
Photo of benthic sample (l) collected by Baker in 1917 and our sample (above), 2012. Note the large Sphaeriid disappeared from the lake long before Dreissena spp. invasion.

Collecting samples in Lake Oneida, 2012.

eutrophication but were extirpated by dreissenids. Through contrasting effects on turbidity, eutrophication and *Dreissena* spp. have likely driven the observed changes in native grazing gastropods by affecting the abundance of light-limited benthic algae. Given the high species richness and ecological importance of benthic grazers, monitoring and managing turbidity is important in preserving molluscan diversity.

Underwater video is an effective tool to reveal Dreissena spatial distribution and biomass

Almost every study of *Dreissena* in the Great Lakes has relied on bottom grabs to characterize mussel presence and biomass, but until now, the scale at which mussel cover varies has largely been unknown. In 2015, in collaboration with the U.S. EPA, University of Michigan, and NOAA, we collected 469 ponar grab samples from 158 sites, and 616 underwater video images to estimate the spatial distribution of quagga mussels in Lake Michigan. We developed a novel method, which analyses video footage recorded from a GoPro camera on a towed benthic sled, to estimate dreissenid cover and biomass. Across 40 sites sampled in Lake Michigan in 2015, we compared *Dreissena* cover and biomass estimates based on three replicate ponars versus 500m-long video transects. Overall, replicate ponar samples were biased and yielded very high errors in estimates of dreissenid presence, especially at sites with low to moderate mussel cover, because replicate bottom grabs collect samples at smaller spatial scales than those at which mussel cover typically varies. As a result, this method offers a straightforward, inexpensive (and fun) method to drastically reduce uncertainty in lake-wide estimates of *Dreissena* presence, especially in regular monitoring surveys which study a small (<50) number of sites.



Lake Michigan bottom image with quagga mussels, 54 m depth, 2015.

Elutriating benthic samples in Lake Michigan, 2015.

GLC crew in survival suits on board R/V Lake Guardian, 2014.

Parallels and contrasts between Limnoperna fortunei and Dreissena spp.

Zebra and quagga mussels and *Limnoperna fortunei* (the golden mussel) are considered among the most aggressive freshwater invaders in the northern and southern hemisphere respectively. *L. fortunei*, native to mainland China, colonized South America in the 1990's where it had already spread across five countries and had strong ecological and economic impacts. Because in the future the golden mussel may colonize North America, in collaboration with South American colleagues we studied *L. fortunei* in Argentina and compared ecology and biology of this species with *Dreissena* spp. All three species share several biological traits, such as their sessile mode of life attached to hard substrata by a byssus (although quagga mussels can also dwell on muddy bottoms), similar sizes, similar longevity, and similar time to sexual maturity. The spawning period, however, is usually longer for *L. fortunei*. Ecologically, they also share similarities (e.g., suspension feeding mode), but the dreissenids thrive and reproduce in colder waters (especially *D. r. bugensis*), and are significantly less tolerant to low pH and calcium concentrations, hypoxic conditions, and pollution. Rates of intra-basin spread of *L. fortunei* in South America are roughly similar to those of *D. polymorpha* in North America, but inter-basin spread is generally faster for the zebra mussel, probably partly due to cultural and economic differences between their respective invasive ranges. Geographic spread of quagga mussels has been much slower than that of zebra mussels, but once the former colonize waterbodies already populated by zebra mussels, they usually become dominant, both spatially and numerically. Judging from their respective environmental tolerance limits, in particular calcium concentrations, it is expected that both species of *Dreissena* may eventually colonize much of Europe, Asia, and North America, but colonization of South America, Africa, and Australia is less likely. In contrast, *L. fortunei,* which tolerates much lower calcium concentrations, could spread to areas presently occupied by the dreissenids as well as to Africa and Australia. Should the three species overlap, it seems likely that *L. fortunei* will outcompete the dreissenids in warmer, more polluted, less oxygenated, and more acidic waters as well as in waters with lower calcium concentrations. However, the outcome of their competitive interactions when conditions are suitable for all three species is unclear. *L. fortunei* and both species of *Dreissena* are functionally similar, and as a consequence, many of their impacts on the systems they invade are also similar, yet the magnitude of these effects, and in some cases even their sign can differ widely depending on the invasive species and environmental constraints. Future research on the golden mussel should focus on shedding light on the many unknown aspects of its biology and ecology, which are particularly critical for a comprehensive assessment of its interactions with local biota. For more information please see Karatayev, A., D. Boltovskoy, L. Burlakova, and D. Padilla. 2015. Parallels and contrasts between *Limnoperna fortunei* and *Dreissena* species. In: D. Boltovskoy (ed.) *Limnoperna fortunei*, Invading Nature – Springer Series in Invasion Ecology, 261-297. DOI 10.1007/978-3-319-13494-9_15 and other papers (see pages 59-64).

Exotic Limnoperna fortunei attached to native clam, Rio Tercero Reservoir, Argentina.

Subodh Kumar
Environmental Chemistry and Toxicology Laboratory

The Division of Environmental Toxicology and Chemistry Laboratory (ETCL) of the Great Lakes Center has historically been involved in applied and basic research on the biological (human health and ecological) fate of toxic environmental contaminants since 1983. These toxic chemicals are widely distributed in our environment, including the Great Lakes and their tributaries. The ETCL research staff has been represented by an interdisciplinary group of Ph.D. scientists with expertise in areas including environmental and bio-chemical toxicology, environmental chemistry, biochemistry, molecular biology, organic chemistry, plant physiology, and microbiology.

Subodh Kumar purifying a synthetic sample by column chromatography.

Summaries of ETCL Projects Funded by Federal, State, and Private Agencies

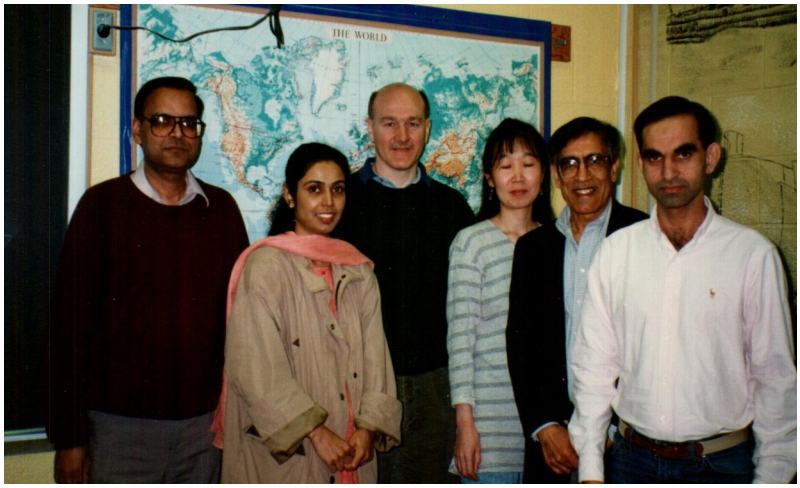
The research program of ETCL from 1983 to present has centered around six series of research grants:

- Metabolism, metabolite mutagenicity and tumorigenicity, and mechanism of carcinogenesis of ubiquitous environmental carcinogens that include various polycyclic aromatic hydrocarbons (PAHs) and their heterocyclic analogues, such as, benzo[a]pyrene, benzoquinolines, dibenz[a,h]acridine, dibenz[a,c] anthracene, benzonaphthothiophenes, benzophenanthrothiphenes in mammalian species
- Metabolism of PAHs and methylated PAHs, polychlorinated dibenzofuran, polychlorinated dibenzo[p] dioxin, and acetylaminofluorene (AAF) by mammals and several species of fish
- Environmental fate and microbial degradation of PAHs and their heterocyclic analogs
- Mechanism of the potentiating effect of co-occurring cadmium on benzo[a]pyrene-induced carcinogenicity
- Potentiating effect of alcohol consumption on lung cancer in smokers
- Environmental monitoring for polychlorinated biphenyls (PCBs), pesticides, PAHs, and certain heavy metals in fish, river water and sediments of Buffalo River.

Metabolism Fate and Mechanism of carcinogenic action of Various Environmental Contaminants in Mammals and Aquatic Species

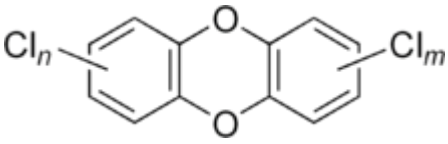
We have investigated the metabolic fates of certain PAHs, and their nitrogen and sulfur analogs and the mechanism(s) by which these carcinogens produce their carcinogenic effects. These studies were supported by multiple multiyear grants from National Institutes of Health, United States Environmental Protection Agency, and Philip Morris International. These chemicals are widespread environmental contaminants and are introduced in our environments including the Great Lakes and their tributaries from a variety of sources, such as coal combustion, incineration, petroleum processing and oil spills. The carcinogenic effects of PAHs and their analogs result from the metabolic conversion of the parent compounds to reactive metabolites which covalently bound to cellular DNA, thereby initiating carcinogenesis. In our investigation, we have identified the products resulting from the metabolic transformation of these chemicals by rats, and have studied the interaction of the respective metabolites with cellular DNA. These projects have included the synthesis of potential metabolites of PAHs and their heterocyclic analogs as well as studies on the mutagenic and carcinogenic activities of individual metabolites. These studies also resulted in very active collaboration

with the scientists at the National Institutes of Health, Dana Research Institute of American Health Foundation, University of Kentucky at Lexington, Kentucky, and University of Akron at Akron, Ohio. In addition to advancing our fundamental knowledge of how PAHs and related compounds induce their carcinogenic effects, the contribution made through research done on the above projects may be useful in developing various strategies to minimize or prevent the hazards associated with exposure to these environmental pollutants as well as in developing various therapeutic measures for the cure of this dreadful disease.



ETCL scientists D. Kumar, graduate student Sumira Munir, visiting scientist, Zhi-Xin Yuan, Harish Sikka, Akmal Siddiqui, 1996.

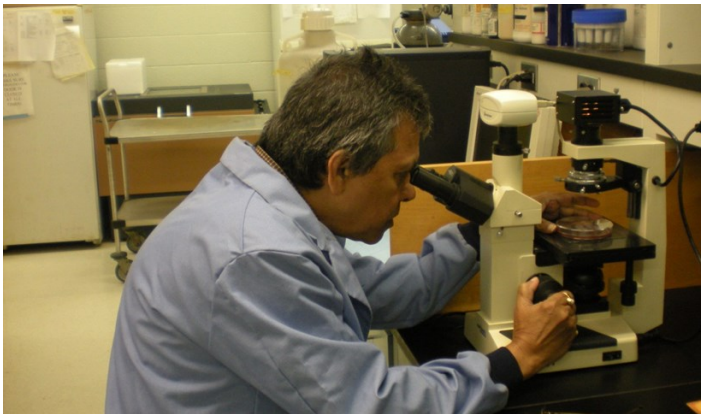
ETCL was also engaged in developing the synthesis of the potential metabolites of polychlorinated dibezodioxins (PCDDS), dibenzofurans (PCDFs), and the flame retardants, polybrominated diphenylethers (PBDEs). These compounds were used while investigating the disposition and metabolism of these chemicals in fish. These chemicals are widespread environmental pollutants which are commercially produced (PCBs and PBDEs) or present as contaminants (PCDDs and PCDFs) in commercial preparations of herbicide agent orange or produced as by-products of waste incineration and bleaching of paper pulp. The contamination of aquatic environment by these chemicals is of great concern because of their bioaccumulation in fish and subsequent human exposure to these chemicals via fish consumption. The results obtained from our studies on the toxicokinetics and the metabolism of these respective chemicals, in combination with the data on bioavailability of these contaminants to fish, are useful in predicting bioaccumulation of these compounds in fish, and contributed in assessing the risk that these chemical pose to humans who eat Great Lakes fish.



General structure of PCDD.

Scientist from our lab have obtained data on the metabolism of xenobiotics by fish. These studies have been supported by multiyear grants from U.S. EPA, National Cancer Institute, and NY Sea Grant. It has been noted that certain species of fish, when captured from environments highly contaminated with carcinogenic chemicals such as PAHs (e.g. benzo[a]pyrene) show a high frequency of liver tumors, whereas other species collected from the same area appear to be relatively resistant. The objective of this research has been to determine the biochemical basis for this species difference. We initially hypothesized that there might be differences in the metabolic capabilities of susceptible species (brown bullheads) vs. resistant species (e.g. common carp). In order to test the hypothesis, the metabolic activation of benzo[a]pyrene (a widely spread environmental carcinogen) to carcinogenic metabolites capable of binding to cellular DNA as well as the detoxification (e.g. via conjugation reactions) of these potentially carcinogenic

Graduate student Jaquan Williams operating Scintillation counter for measuring radioactivity in research sample.



Jagat Mukerjee visualizing cell lines by microscope.

metabolites. These in vitro studies (using microsomes and hepatocytes) were validated by studies done in the intact fish. Our data indicated that only very low levels of ultimate carcinogenic metabolite benzo[a]pyrene diol epoxide and subsequently produced DNA adducts were formed in the liver of common carp (cancer resistant species). In contrast, brown bullheads (cancer susceptible species) apparently produced significantly larger amounts of benzo[a]pyrene diol epoxide, and subsequently produced DNA adducts in liver, kidney, as well as in muscle. Thus, the data obtained in ETCL validated our hypothesis by showing that the greater susceptibility of brown bullheads compared to common carp for induction of PAH-induced liver cancer is in part attributed to the levels of benzo[a]pyrene diol epoxide and its DNA adducts produced in the liver of these species.

Similar comparative studies have also been undertaken on the metabolism of chrysene and methylchrysenes by fish in order to obtain information on the effect of methyl substitution on the metabolism of the parent PAHs by fish. The data obtained from these studies were also compared with those obtained with rat liver.

ETCL was also involved extensively on the investigation of the metabolism of 2-acetylaminofluorene (2-AAF) by rainbow trout. These studies, which were funded by National Institutes of Health, were carried out to explain the factors underlying the resistance of rainbow trout to hepatocarcinogenesis in response to 2-AAF, which is a well-known hepatocarcinogen in several species of animals including rats. These studies involved (1) in vitro metabolism of 2-AAF, N-hydroxy-2-AAF by trout liver microsomal and cytosolic fractions, (2) in vitro metabolism of 2-AAF by freshly-isolated trout hepatocytes, (3) disposition and metabolism of 2-AAF in vivo, (4) formation and persistence of 2-AAF-DNA adducts in trout liver in vivo, and (5) comparison of the data on the metabolism of 2-AAF in trout and rat. The results of this investigation exhibited that rainbow trout is relatively resistant to hepatocarcinogenesis initiated by 2-AAF, in part, because of a very small rate of metabolic activation to its carcinogenic metabolite (N-hydroxy-2-AAF) that binds to DNA for cancer induction, and very high rate of metabolic detoxification with the consequent excretion of 2-AAF and its metabolites from the organism. This conclusion was consistent with the data showing a level of DNA adducts formation in the liver of trout in vivo with 2-AAF, which was about three order of magnitude lower than the level of DNA adducts found in the liver of 2-AAF-treated rats which are relatively susceptible to hepatocarcinogenesis.

Common image of a rainbow trout.

Microbial Degradation of PAHs

ETCL was also funded for two projects by New York State Center for Hazardous Waste Management, and the U.S. Army Corps of Engineers, Buffalo District. These projects were devoted to the investigations of the microbial degradation of PAHs and their environmental fate, binding to sediment and metabolic fate in fish.

The objective of the microbial degradation research was to investigate the degradation of selected 4 to 5-ring carcinogenic PAHs by an enriched bacterial culture, with particular emphasis on the characterization of products resulting from the degradation of these chemicals. The discovery of microorganisms having the

ability to degrade PAHs to non-toxic products is expected to greatly help in the development of cost effective bioremediation technologies for treatment of PAH-containing hazardous waste located at manufactured gas plant sites and elsewhere.

Work study student Kayode Olorunfemi and S. Kumar working on a DNA sample at the UV spectrophotometer.

The research funded by the U.S. Army Corps of Engineers assessed some of the hazard associated with the sediments (contaminated with PAHs, PCBs, and heavy metals) dredged from the Buffalo River and deposited at Times Beach, Buffalo, NY. In this study, ETCL investigated the binding of three PAHs with three types of sediments collected from the Time Beach site. ETCL also investigated the tissue distribution and metabolic fate of benzo[a] pyrene in fish, as well as the degradation of this chemical by microorganisms in soil and sediment collected from the Time Beach site. Finally, as a part of this project, scientists from ETCL analyzed hazardous chemicals (PCBs, pesticides, PAHs, and trace metals) in fish collected from ten Great Lakes Tributaries. The finding of this study helped the Army Corps of Engineers to identify point sources and localities which should receive priority concern and further surveillance.

Research on tobacco smoke constituents

For the past 10 years, we became interested in finding out how various constituents of cigarette smoke and other habits of cigarette smokers may influence the potential induction of liver cancer in humans. It is now well known that tobacco smoke not only contains carcinogens (PAHs, nitrosamines, etc.), but also a number of phenols which are not carcinogenic but promote lung cancer in animals exposed to cigarette smoke. In addition, the common public who are smokers are also habitual in consuming alcohol on a regular basis. Unfortunately, alcohol has been found to potentiate lung cancer induced by cigarette smoke. These two separate studies which were funded by National Institutes of Health were carried out in ETCL in order to understand the underlying mechanism for these observed effects.

The results of our research indicate phenolic constituents of cigarette smoke may promote lung cancer by down regulating protein kinase C (PKC). Importance of down regulation of PKC in tumor promotion has been suggested in the literature. However, while studying the mechanism underlying the potentiating effect of alcohol drinking on lung cancer in smokers, it appears that the effect of alcohol on ERK/MAPK appears to be responsible for the potentiating effect of alcohol on smoking-induced carcinogenesis.

S. Kumar processing synthetically prepared metabolite of an environmental carcinogen.

In a separate study funded by Phillips Morris International, scientists of ETCL demonstrated that cadmium salt, a major constituent of cigarette smoke elicits synergistic enhancement of cell transformation when

combined with tobacco smoke constituent benzo[a]pyrene and other PAHs by inhibiting apoptosis of DNA damaged cells, and consequently carcinogen induced apoptosis, and consequently promoting the survival of cancer cells.

Monitoring of Chemical Contaminants in the Buffalo River: Buffalo River Mass Balance Project

A three-year project funded by Great Lakes Program Office of the U. S. Environmental Protection Agency was carried out in ETCL. This extensively multi-year funded project was designed to study the levels of selected environmental pollutants (PCB congeners, selected pesticides, and selected PAHs, and trace metals) in ppb and ppt levels at the navigable portion of the lower Buffalo River, which is designated as an Area of Concern (AOC) defined in the "Buffalo River Remedial Action plan, 1989" published by the New York State Department of Environment Conservation (NYSDEC). The objective of this study was to provide data on pollutant loadings and ambient pollutant concentrations to calibrate a mass balance/exposure and food web model of the lower Buffalo River. The data obtained from this study was provided to the Environmental Protection Agency in order to calibrate a mass balance/exposure and food chain model of the lower Buffalo River. This project also helped ETCL for acquiring State of the Art fully automated high pressure liquid chromatography and gas chromatography, and several specialized equipment.

J. Williams and S. Kumar operating HPLC.

Training to the Operators of Wastewater Treatment Plants

ETLC has been involved in organizing five training courses (Basic Laboratory, Basic Operation, Activated Sludge, Grade 3 Supervision, and Grade 4 Management) each semester for the past 30 years. These New York State Department of Environmental and Conservation (NYDEC) mandated courses are required to be taken by the wastewater operators for certification.

Modernization of Environmental Toxicology and Chemistry Laboratory

ETCL received two major grants from National Science Foundation and U. S. Department of Education to support the extensive renovation of our research laboratories, as well as furnishing of these laboratories with state of the art equipment necessary to conduct research in the area of environmental toxicology and chemistry.

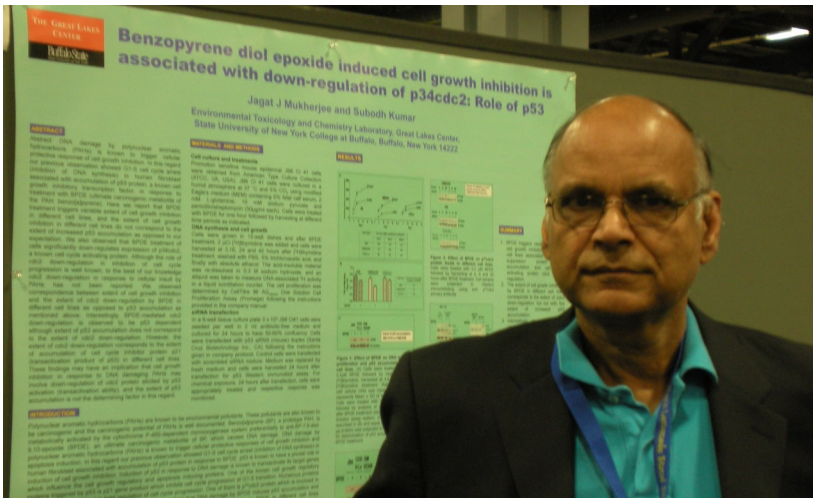
J. Mukherjee and K. Olorunfemi in a new laboratory in the Science and Math Complex on the SUNY Buffalo State campus.

Training

ETCL trained more than 27 post-doctoral Research Associates and about 10 graduate students for an M.A. in Chemistry and Biology. A number of Research Assistants with undergraduate and Master degree also received training from ETCL.

Research Presentation

Scientists and graduate students from ETCL presented their research findings regularly in the National and International Conferences organized by American Association for Cancer Research, American Chemical Society, and many other organization actively involved in cancer research.



S. Kumar, Research and Creativity Fall Forum, 2012.

Publications

The findings of our research on the projects discussed above have resulted in more than ninety peer-reviewed papers in several National and International journals, including *Tetrahedron Letters, Synthesis, Journal of Organic Chemistry, Journal of Chemical Society Perkin Transaction, Organic and Biomolecular Chemistry, Journal of Heterocyclic Chemistry, Journal of Agricultural and Food Chemistry, Fundamental and Applied Toxicology, Biochemistry, Carcinogenesis, Cancer Research, Cancer Letters; Toxicological Sciences, Chemico-Biological Interaction, Chemosphere, Mutation Research, Toxicology, Proceedings of National Academic of Sciences, Comparative Biochemistry and Physiology, Toxcology and Applied Pharmacology, International journal of Biochemistry, Aquatic Toxicology, Marine and Environmental research, Environmental Toxicology and Chemistry, environmental Science and Toxicology, Chemosphere, Chemical Research in Toxicology, Journal of American Chemical Society,* and *Polycyclic Aromatic Compounds*.

Peter Ruddock analyzing fish samples on HPLC.

S. Kumar using Scintillation Counter.

Suresh Gupta studying a natural product for evaluating its anti-cancer activity using a mammalian cell line.

Knut Mehler with Eric Bruestle

Investigating Lake Sturgeon habitat use, feeding ecology and benthic resource availability in the lower Niagara

One research project I am currently involved in is 'Investigating Lake Sturgeon habitat use, feeding ecology and benthic resource availability in the lower Niagara River'. This project is funded by the Ecological Greenway Fund for three years (2014 through 2016). The Niagara River is an important feature of the Great Lakes Basin. As a connecting channel between Lake Erie and Ontario, the Niagara River drains the combined watersheds of four of the five Great Lakes and supplies 3% of the tributary flow to Lake Ontario. The lower Niagara River is home to a remnant population of native Lake Sturgeon (*Acipenser fulvescens*) and contains important feeding and spawning habitats. Lake sturgeon are some of the largest and longest-lived freshwater fish in North America, reaching upwards of 2 m in length and 100 years of age. One has to feel deep respect for such a venerable fish species.

A lake sturgeon ready to be tagged by the U.S. Fish and Wildlife Service.

Lake sturgeon were historically abundant throughout the Great Lakes but impacts such as overfishing and habitat degradation caused dramatic population collapses. For much of the 20th century the species was thought to be on the road to extinction. However, in the last 50 years, there has been evidence that populations are starting to recover under the support and protection of management agencies. Currently, lake sturgeon population sizes across the Great Lakes remain just a small, but growing, fraction of what they were historically. In the lower Niagara River, the population has recently been found to be larger than expected and is showing signs of recovery.

The goal of this study is to advance our understanding of the Lake Sturgeon recovery by characterizing (1) the habitat use and feeding ecology of lake sturgeon, and (2) to assess the diversity, distribution, and density of benthic forage resources in the lower Niagara River. The results of this study will help researchers and managers identify opportunities to protect and enhance the lake sturgeon recovery in the lower Niagara River.

Eric Bruestle with a lake sturgeon about to be released into the Niagara River after being tagged.

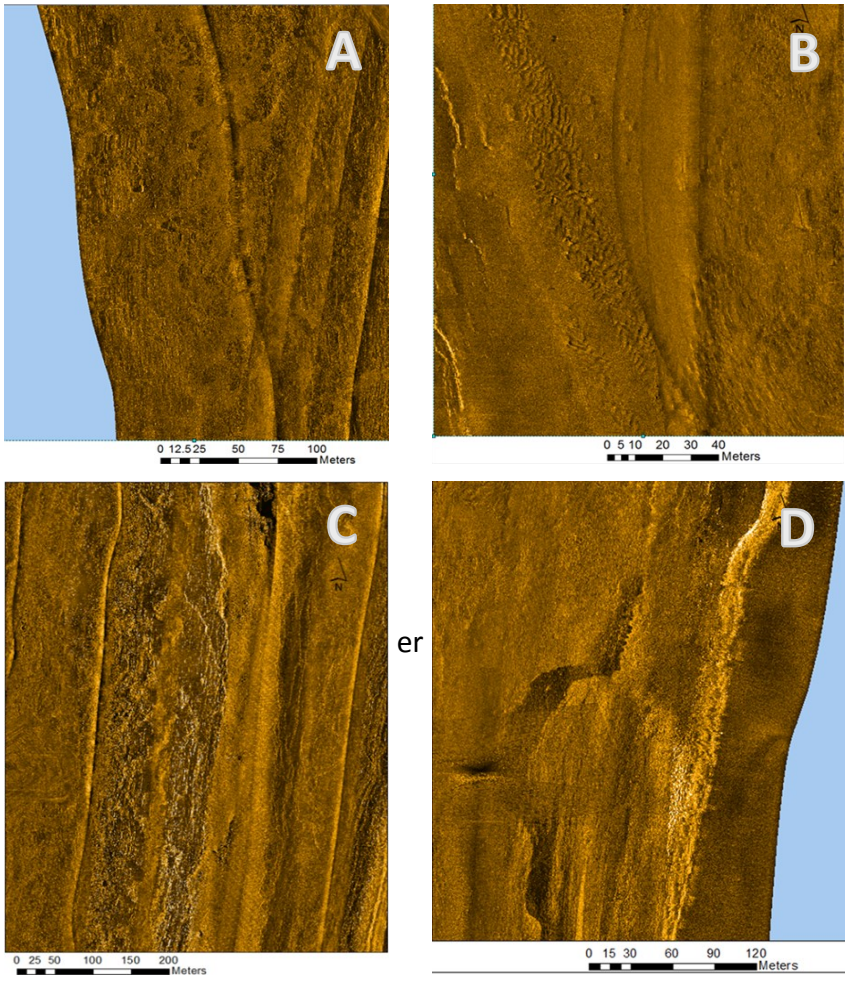
The first objective of our study seeks to describe the movements and habitat use of lake sturgeon, as well as to identify their prey base. In the past two years, our collaborators, a team of USFWS biologists led by Dimitry Gorsky, have tagged 60 adult lake sturgeon with acoustic transmitters. These tags emit ultrasonic pulses that are detected by 39 stationary passive receivers that have been strategically deployed throughout the lower river and at the mouth in Lake Ontario. The acoustic array tracks the movements of sturgeon up and down the river, identifies areas where they spend the majority of their time, and documents when sturgeon enter and exit the river from and to Lake Ontario.

Preliminary results indicate that the movements of lake sturgeon are not easy to generalize. Some fish remain in the river for the duration of the year, whereas others will move out into Lake Ontario for the winter and return in the spring. Fish are also documented using the entire length of the lower river, often moving from the mouth to the upper reaches within the course of a day.

The second component of the first objective is to describe diet of lake sturgeon and identify important prey items using stomach content analysis and stable isotope analysis. Stomach content analysis identifies organisms that were recently ingested, and stable isotope analysis documents diet history over the past few months. These two techniques, when used in conjunction, can estimate the proportional importance of prey items at different time scales.

We found that lake sturgeon are utilizing invasive species as a food source to a much greater degree than native prey species. By weight, exotic round goby are the dominant prey item found in the stomachs of lake sturgeon. Additionally, an invasive amphipod is the most frequently found prey item. Quagga mussels, another invasive species, is consumed to a lesser degree than has been found in other water bodies.

The second objective of this study uses remote sensing to examine the spatial and temporal distribution of prey items throughout the lower Niagara River in order to locate important feeding grounds. Remote sensing is used in GPS navigation, air traffic control, and observing large-scale algae blooms in the Great Lakes. We applied remote sensing techniques to classify the benthic substrate of the river. Substrate is one of the most important abiotic factors in determining the spatial distribution of benthic communities. Using side scan sonar (SSS), video streams, and sediment data we were able to classify different types of bottom substrates and create substrate maps for the lower Niagara River. Interpretation of the SSS image is performed by visual inspection based on tones and surface roughness. Rocks, gravel, sand and silt reflect acoustic energy differently and appear as different tones, ranging from yellow to dark brown. Hard surfaces, such as rocks, reflect more acoustic energy, show irregular perimeters and appear as bright as a mixture of yellow tones and dark acoustic shadows. In contrast, silt yields a very weak acoustic energy return and is associated with a smooth seabed, and appears as dark brown tone in the image. Very dark areas normally mean the absence of back-scattered sound, indicating a shadow behind objects. Common substrate that appears in the Lower Niagara River is shown in the images to the right: (A), gravel with a few large rocks in the center-left part of the image, (B) sand and sand ripples, (C) bedrock base and boulder along the center of the image, and (D) silt with varying organic matter content along the shore of the river.



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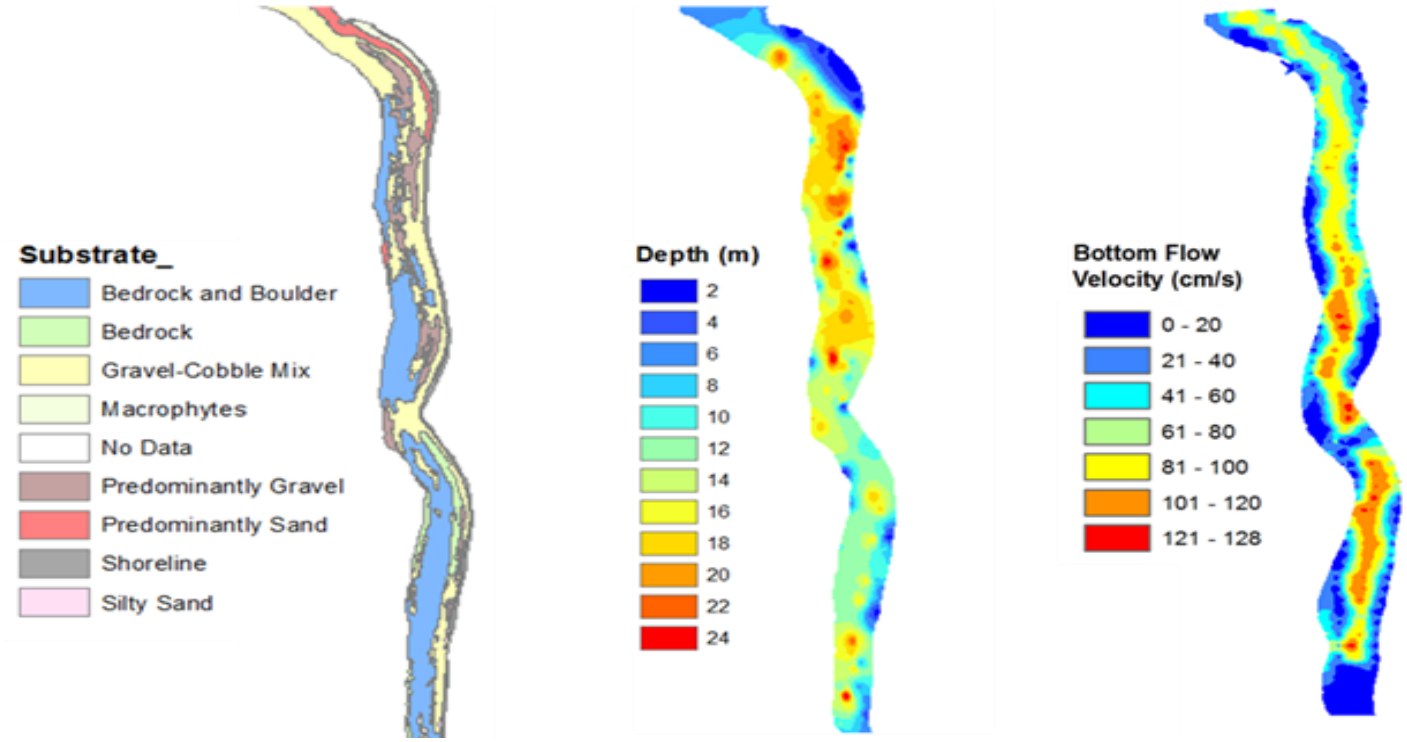
Additionally, Acoustic Doppler Current Profiler data were used to create additional maps, including bathymetry and bottom flow velocity. All three abiotic factors can have tremendous effects on the spatial distribution of the benthic community. After the substrate map was created, 257 sites were chosen along the



Acoustic Doppler Current Profiler data.

lower Niagara River and sampled throughout July and August, with 147 benthic samples obtained by using a petite Ponar. Benthic invertebrates were identified to the lowest possible taxonomic level and diversity, biomass, and community composition for each of the 147 samples. The next step is to link information about the benthic fauna with physical habitat information by using statistical analyses and habitat models in ArcGIS. Data on the spatial distribution of benthic biomass will then be used in conjunction with sturgeon diet information to locate and map critical habitats as feeding grounds for the lake sturgeon.

GLES and Biology graduate students with a lake sturgeon.

Knut Mehler using a petite Ponar.

Chris M. Pennuto

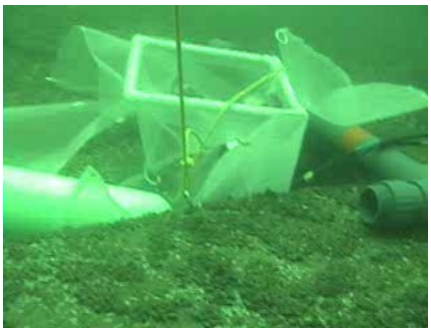
Tributary streams and large lakes: how invasive species might link nearshore nutrient dynamics and ecosystem function.

Processing mussel samples for the LONNS project. C. Pennuto (c), A. Fischer (l).

As a stream ecologist, I bring a different perspective to big lake ecology (even though, like most stream ecologists, I was trained first as a limnologist). That perspective is to approach lake ecology in terms of resource subsidies, since ultimately lake resources are derived from their watershed and conveyed there through streams and rivers. My contribution to several research projects on the lower lakes (i.e., LONNS, NOLENS, and LENONS described below) benefitted from this simple perspective.

Prior to joining the Great Lakes Center in 2003, I had a 10-year career as a pure stream and aquatic insect ecologist, doing lots of biomonitoring and water quality type research. Transitioning to the Great Lakes Center required some adjustments back to big lakes, but the proximity of the Buffalo River AOC and the then recent upstream expansion of invasive round gobies allowed me to remain in the flow and continue some good water quality and stream invertebrate work. The Buffalo River mercury project, predator avoidance behavior by native and invasive amphipods, crayfish learning and memory of native and invasive predators, and a series of round goby projects made up the bulk of my more stream-focused activities since joining the GLC.

Nearshore dynamics in the lower Great Lakes Erie and Ontario



Mussel-collecting gear on the lake bottom, LONNS project.

In 2007, then GLC Director Gordon Fraser was part of a small research group beginning an investigation of nearshore conditions in Lake Ontario and had me join the conversation. This led to the first multi-investigator, multi-institution collaborative project on large lake nutrients and benthic communities for the new GLC under Dr. Karatayev's directorship, the LONNS project (Lake Ontario Nearshore Nutrient Study), led by Dr. Joe Makarewicz from SUNY College at Brockport. Our part of this project was to update the population status of Dreissenid mussels, round gobies (*Neogobius melanostomus*), and the benthic alga *Cladophora glomerata*. We spent a summer aboard the R/V Seneca and diving the nearshore waters collecting data on this nuisance species triad. This project ultimately led to my involvement in five peer-reviewed publications (Pennuto et al 2012a, Pennuto et al. 2012b, Pavlac et al. 2012, Makarewicz et al. 2012, and Higgins et al. 2012) appearing in a special issue of the Journal of Great Lakes Research. We concluded that round gobies were still hyper abundant in the nearshore, estimating ~700,000,000 fish were present between 0 and 20 m depth (~2.5 fish /m^2). We also suggested that, although round gobies consume significant numbers of *Dreissena* mussels in the 5-10 mm size range, they likely will not lead to a significant reduction in mussel density

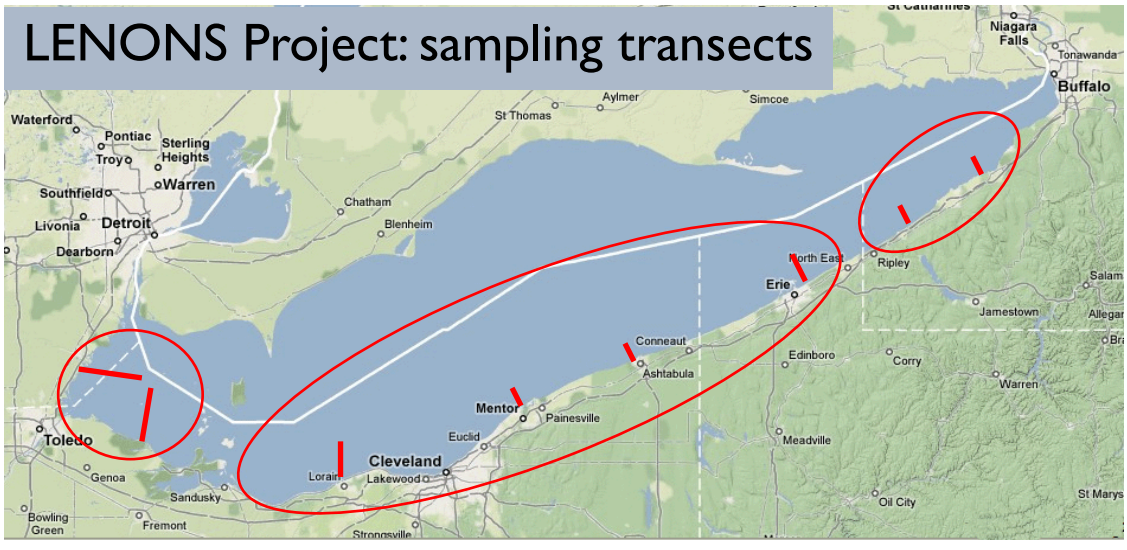
M. Clapsadl with gear aboard R/V Seneca, LONNS project.

over time. Lastly, we determined that *Cladophora* abundance was extremely heterogeneous within the nearshore environment, being controlled by local point sources (e.g., heated thermal effluents from power generation, wastewater treatment plant effluent, tributary inputs). This work led us directly to the SENES project where we estimated benthic algae density near the Fitzpatrick Nuclear Power plant in Oswego, NY. Our partners on this project were trying to produce predictive algorithms to allow the plant to prepare for *Cladophora* outbreaks that clogged cooling water intake pipes at the plant. Our temporal estimates of in-lake growth and biomass were coupled with satellite spectral images for this work.

Many of the NOLENS participants (left-to-right): A. Karatayev, M. Wydish, A. Clapsadl, M. Clapsadl, S. Mastinksy (kneeling), student, A. Perez-Fuentetaja, L. Burlakova, B. Barrols, C. Janik, C. Basiliko, G. Matisoff, C. Pennuto.

After completion of the LONNS project, I joined the Lake Erie millennium network and put together a large research team to address nearshore and offshore nutrient dynamics for the first GLRI call. The NOLENS project (Nearshore-Offshore Lake Erie Nutrient Study, 2009-2010) brought together eight researchers from five institutions to assess nutrient conditions in Lake Erie. This worked involved all GLC personnel plus a large number of graduate and undergraduate students. After this initial research, I led another research group to secure our next GLRI award (LENONS, 2010-2013), the Lake Erie Nearshore and Offshore Nutrient Study. This project specifically addressed several predictions laid out by Hecky et al. (2004) concerning the nearshore shunt hypothesis (NSSH) and the role of *Dreisena* mussels in altering lake-wide nutrient conditions. This project, plus the earlier NOLENS project, led to a series of 11 papers appearing in the Journal of Great Lakes Research for which I was a contributor on four (Pennuto et al. 2014a, Pennuto et al. 2014b, Karatayev et al. 2014, Burlakova et al. 2014). We were able to show that sediment nutrients behaved as predicted by the NSSH, accumulating in the offshore direction, but also that mussel internal nutrient quantities responded to environmental quantities. Our sampling fortuitously spanned a record wet and record dry year, providing a time series of extremely high and low nutrient availability whose signature was discernable in mussel tissue. We also supported earlier research and suggested that mussels held a significant fraction of nutrients within their tissues on a lake-wide basis and thus required inclusion in discussions of nutrient abatement or nutrient dynamics in nearshore Lake Erie.

Diving for mussels on Lake Erie, C. Pennuto, C. Basiliko, C. Janik.



Tributary streams and invasive species

Although my early stream ecology funding was primarily for applied biomonitoring and water quality type projects, I focused some of my efforts on water quality effects on behavioral ecology, particularly predator-prey dynamics. Upon arrival and joining the GLC, it became clear non-native species were a significant concern for the Great Lakes community. Thus, I started a series of projects focusing on behavioral ecology and predator-prey dynamics with non-native and native taxa. This led to a series of graduate student theses and published papers on invasive amphipod predator avoidance behavioral ecology (Pennuto and Keppler 2008), round goby effects on stream invertebrate communities (Krakowiak and Pennuto 2008, Pennuto et al. 2010), round goby upstream range expansion (Pennuto and Rupprecht 2016), and native and invasive crayfish learned predator avoidance (Dong and Pennuto, in review). Along the way multiple graduate and undergraduate students had projects filling in gaps to help understand how predator guild structure (i.e., presence or absence of invasive round gobies) affected stream ecosystem function (A. Fisher: gobies and microbial community change; Janik: gobies and stream primary production; Cudney: gobies and stream leaf litter decomposition; Chapman: gobies and stream drift; Tetinger: gobies and crayfish interactions on leaf litter decay). Collectively, these works used the recent upstream range expansion of round gobies as a natural experiment in altered predation pressure to show how a generalist invertivore can decouple or create trophic cascades in streams, increasing periphyton biomass and reducing leaf litter decomposition.

C. Janik and A. Brown electroshocking for round gobies in Ellicott Creek.

K. Cudney performing winter Surber collections in streams with and without round gobies.

Experimental stream mesocosm for testing round goby effects on litter decomposition and periphyton production (Janik and Cudney thesis work).

Round gobies.

Lastly, in keeping with my past work on water quality, the lab has investigated a broad range of physical and chemical constituents in stream or river environments and their effects on resource flux or invertebrate communities. Cross-system resource subsidies are a common theme for stream ecologists where terrestrial leaf inputs link in-stream communities and function directly to terrestrial habitats. But it is also true that reverse subsidies can be important. A relatively new line of research in environmental ecotoxicology is focusing on the development of better models to understand contaminant flux from aquatic-to-terrestrial habitats and its implications for pollution policy. This led us to examine mercury flux from the Buffalo River AOC and show that emerging insects carried enough mercury to increase contaminant content in riparian spiders (Pennuto and Smith 2015). The patterns of flux also suggested that the current upstream boundary of the AOC is insufficient for the protection of riparian communities.

Buffalo River mercury flux project.: (l) Bridge orb-weaver spider in a web from gabion walls along the river, ® D. Keppler aspirating spiders for sample collection.

Similarly, other student projects have shown that high erosion rates in the Buffalo River watershed lead to suspended food resources with high inorganic content (i.e., inorganic silts and clays), leading to reduced mussel growth rates (K. Sortisio, MS project) and altered C:N:P ratios (C. Perschyn, URM project). Lastly, Buffalo River sediments contain elevated levels of a wide variety of metal and organic contaminants. R. Gilbert, another MS project student, showed that fluctuating asymmetry (FA) patterns in crayfish captured from within the AOC were greater than the FA pattern in crayfish from upstream, clean-sediment locations. Again indicating that sediment conditions with the AOC remained problematic.

Samples collected during the LONNS project.

Alicia Pérez-Fuentetaja

Alicia aboard the R/V John J. in the Black Rock Canal.

I am a broadly trained aquatic biologist with an interest in food web ecology and trophic interactions among organisms. Because species interact in multiple ways and we live in an increasingly anthropogenic environment, the study of food webs has led me to expand into other fields such as aquatic toxicology, the study of epizootics that are related to feeding relationships, and species invasion biology. In my PhD I focused on predator-prey interactions in aquatic ecosystems and explored the concepts of stability and resilience after a disturbance to the food web.

I continue to apply these concepts to the many research projects that I have undertaken since graduation. My personal interest is in the factors that destabilize aquatic ecosystems from a trophic perspective: I study the response of organisms to changing food web conditions. I have expanded my original ecology background through collaborations with colleagues from the fields of genetics, veterinary medicine, environmental chemistry and biochemistry. As a result, my research spans different perspectives, from wildlife diseases caused by food web transmission (type E botulism), to the transfer of bioaccumulative contaminants through the food web (PCBs and PBDEs), to the feeding ecology of invasive species (blood-red shrimp), to the effects of calcium decline on the plankton of Canadian Shield lakes.

Emerald shiners in the Niagara River.

And lately, my research interests have also expanded into the importance of prey-species in migratory ecosystems and to the remediation of habitat degradation. More on this. I am currently investigating a little understood prey species in the Niagara River, the emerald shiner (*Notropis atherinoides*) with the help of my colleagues Mark Clapsadl and Randal Snyder, and a large group of researchers that includes three universities, a federal agency, two state offices, a non-governmental organization and a Canadian federal agency. This small minnow species is a vital part of the ecosystem, helping maintain the bird biodiversity of the Niagara migratory corridor, which is internationally recognized as an Important Bird Area (IBA). The emerald shiners are also prey to the sport fish in the river, such as smallmouth bass, walleye, muskellunge and steelhead trout, and are commercially harvested as bait. Multiple historical alterations to the Niagara River have transformed shorelines into vertical bulkheads and have increased water velocities at many sites, jeopardizing shiner movements between Lake Erie and the river. The emerald shiners play a paramount role in local sport fish growth and condition and are a vital food source for the brood success of the New York State threatened common tern (*Sterna hirundo*) in the Niagara River and for other migrating birds. Therefore, the health of the emerald shiner in the Niagara River ecosystem provides enormous regional ecological benefits. Failure of these fish to reproduce or migrate in the river has important cascading effects to their predators: sport fish populations and avian species using the river. However, despite being a very prominent species sustaining the Niagara River food web, this native fish species has been

John Lang collecting emerald shiner's predators, in this case a smallmouth bass, to determine stomach contents.

Students Chris Osborne (left) and Jake Cochran (right) using a fish larval seine in Grand Island shoreline.

subjected to widespread modifications of spawning and nursery habitats, competition with non-native fish, damming, water diversions and overall changes in water velocities along their movement routes in and out of Lake Erie. For instance, historical river channel modifications and shoreline alterations, including installation of vertical bulkhead structures, have increased water velocity in sections of the river that shiners are known to attempt to traverse in order to migrate upstream to Lake Erie, potentially jeopardizing their migration success. Our work focuses on defining how this species utilizes nursery habitats in the Niagara River, the factors that determine reproductive success, and the timing of their migration. With the information collected we are addressing questions about the emerald shiner's life history in the river, their ecological needs, their genetic make-up, and also their swimming ability and what obstacles they must overcome to migrate to Lake Erie. Our ultimate goal is to provide tools for the management of this species and for the restoration of coastal wetland habitats used as nurseries by fish and to create mitigating structures to facilitate migration movements by fish in the Niagara River.

Students working in the emerald shiner project processing the "catch". Jake Cochran (left), John Lang (center), Chris Osborne (right).

Steve Fleck collecting aquatic macrophytes to evaluate fish nursery habitats.

Night-time electrofishing in the Niagara River.

Education

The GLC fulfills its educational mission directly through the classes its researchers teach, through its Master of Arts (MA) and Master of Science (MS) graduate programs in Great Lakes Ecosystem Science, through the support we offer to faculty teaching classes pertaining to environmental sciences, through the seminar speakers we sponsor, and through our educational activities in the community.

The Great Lakes Center Offers Two Master's Programs in Great Lakes Ecosystem Science

by Kelly Frothingham

The Great Lakes Center (GLC) administers two interdisciplinary applied environmental science programs in Great Lakes Ecosystem Science (GLES). The GLES programs provide an opportunity for students to pursue graduate studies through a thesis-based Master of Arts (MA) and an internship-based Master of Science (MS). Both programs provide students with the opportunity to attain a broad understanding of the physical, chemical, biological, and social factors that comprise the Great Lakes ecosystems. GLES graduates are prepared to provide a leadership role as they address a broad range of problems and issues related to the management of resources within the Great Lakes and surrounding watersheds.

History of the Programs

The current GLES programs grew out of ideas and efforts originally started in the late 1990s. At that time, several GLC-affiliated faculty members were advising graduate students studying Great Lakes environmental issues through Buffalo State's Multidisciplinary Studies program. After years of sustained enrollment in the Multidisciplinary Studies program, it was clear there was a need for a more structured program with a greater variety of professionally focused courses and both students and faculty agreed that there would be benefits derived by students earning a degree with a title that reflected the content of the program. A Great Lakes Center Graduate Program Committee was formed in 2009 to discuss creating a program that would meet the needs of Buffalo State students and faculty interested in Great Lakes environmental science issues. Committee members represented the GLC and the following departments: Biology, Chemistry, Earth Sciences and Science Education, and Geography and Planning. After thorough planning, course and curriculum development, an external review of the programs, and Buffalo State's approval of the MA and MS programs, full program proposals were submitted to SUNY and the New York State Education Department in early 2013. SUNY and State Education approvals came quickly and the GLES MA and MS programs were launched in Fall 2013.

The Programs in Detail

Both programs share a set of required core courses that provide a foundation in Great Lakes environmental science and a common set of research skills, including quantitative analysis and Geographic Information Systems (GIS). The electives portion of each program includes coursework in ecology, biology, chemistry, physical geography, and geology. Program electives offer flexibility in coursework to strengthen a specialty area.

Thesis research in progress.

A GLES MS student working on an internship project.

Students enrolled in the GLES MA program complete a thesis that allows them to gain research experience in, for example, biogeochemistry, ecology, and hydrology of watersheds and wetlands; environmental geochemistry and environmental methods; global climate change and atmospheric science; food web dynamics, limnology and stream ecology; watershed planning and management; and biodiversity and conservation of freshwater ecosystems. GLES MA graduates are prepared for research careers in academia, industry, and governmental agencies, but graduates also are prepared for consulting firms and non-governmental organizations. The GLES MS program was designed as a Professional Science Master's (PSM) and, as such, students take courses that prepare them to enter the workforce with necessary communication, leadership, and project management skills. GLES MS students take courses in technical communication and project management and complete an internship with industry, consulting firms, non-governmental organizations, or governmental agencies. The internship allows students to apply knowledge gained in their program to real-world problems in a professional setting. GLES MS graduates are prepared for environmental careers in industry, consulting firms, non-governmental organizations, and governmental agencies.

The GLES MS program received official PSM affiliation status in March, 2014 after a rigorous application process. Affiliation is granted through the PSM National Office for a five-year period and benefits of affiliation include promotional assistance to increase recruitment to PSM programs, professional meetings that focus on best practices, and research and advocacy for PSM programs. All PSM programs are required to have an active and engaged advisory board of leaders from industry, business, government, or non-profit organizations. The GLES PSM advisory board was initially convened in 2011 to help with curriculum development. Several current board members were part of that original team and agencies represented on the board include Buffalo Niagara Riverkeeper; Ecology and Environment, Inc.; Erie County Department of Environment and Planning; Erie County Soil and Water Conservation District; New York State Department of Environmental Conservation; US Army Corps of Engineers; US Fish and Wildlife Service; USDA Natural Resources Conservation Service; and WNY PRISM.

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Current Status of GLES

After starting the programs with just seven students, there are now 22 students enrolled in the GLES programs, with nine students in the MA program and 13 in the MS. It is noteworthy that current enrollment exceeds expectations outlined in the program proposals. Students in the GLES programs typically come from biology, environmental science, or geography undergraduate programs and while many GLES students completed their Bachelor's degrees at Buffalo State, some are from other SUNY institutions, Buffalo-area private colleges, and institutions in Ohio and Maryland. Three GLES students are from China and they

Most of the original GLES cohort.

have studied here in a 3+2 program whereby they earn an undergraduate degree from their Chinese university and a GLES graduate degree. Each GLES student must have a principal advisor to guide them through their course of study and advisors have included faculty from the GLC and the Departments of Biology and Geography and Planning.

One student has graduated from the MA program and their thesis research investigated the spatial distribution of Japanese knotweed distribution and habitat conditions in Erie County. Several theses are currently underway and topics include visualizing urban buildings and trees in Erie County, New York using LiDAR data; investigating lake sturgeon habitat use and diet in the Lower Niagara River; and studying the ecology of the young-of-the-year emerald shiner in the Upper Niagara River.

Two students have graduated from the MS program. Both students completed their internships with Buffalo Niagara Riverkeeper. One of those graduates is currently employed as natural resources coordinator with Riverkeeper and the other graduate is a park ranger with Erie County Department of Parks, Recreation, and Forestry. One additional MS student completed their internship with Ecology and Environment, Inc.

Finally, one important component of the GLES programs is the GLC 600 *Great Lakes Seminar*. The seminar is offered every semester and MA students are required to take this course three times and MS students take it twice. The seminar is a forum for speakers from academia and environmental agencies to present their work on physical, biological, chemical, socio-Economic, and management issues in the Great Lakes basin. The seminar is also a venue for GLES students to present on their thesis research and internship experiences. Several Buffalo State faculty members have presented in the GLC 600 seminar and other academic presenters have come from UB, SUNY Brockport, and Niagara University. Additional speakers have represented numerous environmental agencies including consulting firms, governmental agencies, and non-governmental organizations. The presenters and the topics they cover are relevant to GLES students that are interested in basic research in environmental science and ecosystem processes, as well as those that approach Great Lakes environmental issues from a more applied standpoint.

A recent GLC 6oo presentation.

Seminars

In order to expand student education, facilitate collaboration between the GLC personnel and leading experts in aquatic ecology and related sciences, and increase visibility of the Center, we invited over 50 speakers from various universities, research centers, state, and federal agencies and NGO since 2007. Many of these presentations were supported through the Gretchen Stevenson Environmental Education Award Fund.

1. Dawn Dittman, USGS, Tunison Laboratory. “Offshore benthic invertebrate community of Southern Lake Ontario,” December, 2007.
2. Timothy Kratz, UW-Madison, Trout Lake Station. “Toward a global lake ecological observatory network,” January 24, 2008.
3. Winfred Arnold, Copper Development Association Inc. “Modeling copper bioavailability to freshwater organisms: The science behind the policy,” February 14, 2008.
4. Daniel Molloy, New York State Museum. “Parasites and other endosymbionts of zebra and quagga mussels: What's their significance?” April 3, 2008.
5. David Strayer, Cary Institute of Ecosystem Studies. "The effects of the zebra mussel invasion on aquatic ecosystems: The Hudson River and beyond," April 24, 2008.
6. Charlotte Roehm, Great Lakes Center, Buffalo State College. “Bioavailability of terrestrial organic carbon to lake bacteria: The case of a degrading sub-arctic permafrost mire complex,” October 16, 2008.
7. Charles Ramcharan, Laurentian University, Ontario, Canada. “The abiotic-biotic model for community re-assembly,” October 30, 2008.
8. Lars Rudstam, Cornell University. “Interactions at the edge of distributions - on the importance of understanding distributions in Great Lakes pelagia,” November 13, 2008.
9. Hugh MacIsaac, University of Windsor, Great Lakes Institute for Environmental Research, Ontario, Canada. “Ballast water management: Will it work for the Great Lakes?” December 2, 2008.
10. Sergey Mastitsky, Great Lakes Center, Buffalo State College. “New data on biology of the zebra mussel (*Dreissena polymorpha*): Case studies from Belarus,” February 2009.
11. Dianna Padilla, Professor, Ecology & Evolution, SUNY Stony Brook. “Invasion by an ecosystem engineer dramatically alters benthic communities in and out of marine reserves,” April, 2009.
12. Greg Boyer, SUNY ESF. “Toxic cyanobacteria in the Great Lakes: Problems, issues and solutions,” December 7, 2009.
13. Thomas Hahn, Division of Applied Marine Physics, Rosenstiel School of Marine and Atmospheric Science, University of Miami. “Acoustics of pelagic fish schools,” November 19, 2009.
14. Kenneth Krieger, Water Quality Lab, Heidelberg University. “Benthic invertebrates as indicators of lake quality in Lake Erie,” March 25, 2010.
15. Kit Hastings, Great Lakes Center Buffalo State College. “Long-term lower trophic level monitoring of eastern basin, Lake Erie, 2008-2009,” April 15, 2010.
16. Dmitry Beletsky, CILER - School of Natural Resources and the Environment, University of Michigan, Ann Arbor. “Modeling thermal structure and circulation in the Great Lakes,” May 13, 2010.
17. Martin Stapanian, U.S. Geological Survey, Lake Erie Biological Station. “Change in diel catchability of young-of-year yellow perch associated with establishment of dreissenid mussels," September 23, 2010.
18. Ernest Khurshut, Institute of Zoology, Academy of Sciences of the Republic of Uzbekistan, Tashkent, Uzbekistan. “Aral Sea ecological crisis and invasive fishes in the Aral Sea basin, arid Central Asia,” September 29, 2010.

19. Katya Kovalenko, University of Windsor and Mississippi State University. “Indirect effects of invasive species and the role of habitat complexity," December 9, 2010.
20. David Bruce Conn, Berry College, Museum of Comparative Zoology, Harvard University, and U.S. Office of International Health & Biodefense. “A Hitchhiker’s Guide to the Planet: Parasites and invasive species on the move,” April 22, 2011.
21. David Zanatta, Biology Department, Central Michigan University. “Patterns of post-glacial colonization for freshwater mussels in the Great Lakes,” October 27, 2011.
22. Daelyn Woolnough, Biology Department, Central Michigan University. “Determining the spatial linkages between hosts and parasites: Can we use fish to predict the condition of freshwater mussel communities?” October 27, 2011.
23. Daniel Molloy, Department of Biological Sciences, University at Albany. "Unraveling the mystery of rotifer deaths at a remote Adirondack lake," November 17, 2011.

D. Zanatta, A. Karatayev, D. Woolnough, L. Burlakova.

24. Martha Patricia Celis-Salgado, Post-Doctoral Fellow, Faculty of Science and Engineering, York University, Ontario. “The biological recovery of Sudbury lakes from historical metal damage: Evaluation, trends and emerging stressors," December 2, 2011.
25. Don Schloesser, USGS, Great Lakes Science Center, Ann Arbor. “Restoration of burrowing mayflies *(Hexagenia* spp.) in the Laurentian Great Lakes,” December 8, 2011.
26. Martin Stapanian, U.S. Geological Survey, Lake Erie Biological Station. “Evidence for predatory control of the invasive round goby by burbot," January 26, 2012.
27. Irina Feniova, Institute of Ecology and Evolution, Russian Academy of Sciences, Fulbright Scholar at Oklahoma State University. “The effects of temperature on the species composition and biomass of cladoceran communities,” April 26, 2012.
28. Gregory Andraso, Professor of Biology, Gannon University. “Predation by round goby (*Neogobius melanostomus*) on dreissenid mussels: Some pieces of an interesting puzzle,” October 11, 2012.
29. Clifford Kraft, Cornell University. “Thiamine deficiency and reproductive failure in great lakes fishes: New insights regarding an unsolved mystery,” December 6, 2012. Seminar funded by Great Lakes Research Consortium.
30. Thomas Hahn, Great Lakes Center Buffalo State College. “The value of neonicotinoid seed treatment in the European Union,” February 7, 2013.
31. Jorge Luis Romeu, Syracuse University. “Design of experiments in ecological systems: Some methods and issues,” April 18, 2013. Seminar funded by Great Lakes Research Consortium.
32. Thomas Nalepa, Graham Institute, University of Michigan, and Great Lakes Environmental Research Laboratory, NOAA (emeritus). “Effects of dreissenids (zebra and quagga mussels) on the Great Lakes ecosystem: A broad overview,” May 16, 2013.
33. Sarah Delavan, University at Buffalo. “Predator avoidance behavior? Patterns in clam excurrent siphon velocity according to external environmental cues,” November 14, 2013.
34. Jason Fridley, Syracuse University. “The modern invasive species problem: A world Darwin envisioned?” November 22, 2013.
35. Knut Mehler, Desert Research Institute, Las Vegas. “Understanding effects of changes in land use, environmental parameters, and habitat characteristics on the benthic macroinvertebrates in the Walker River, Nevada,” December 4, 2013.

36. Dimitry Gorsky, U.S. Fish and Wildlife Service. “Restoring Lake sturgeon in the Great Lakes: A U.S Fish and Wildlife perspective,” February 27, 2013.
37. Ronald Griffiths, Oregon State University. “Benthos powers lake dynamics,” February 27, 2013.
38. Martin Stapanian, U.S. Geological Survey, Lake Erie Biological Station. “Soil and vegetation indices for wetland quality: A predictive modeling approach," April 10, 2014.
39. Zy Biesinger, U.S. Fish and Wildlife Service. “Habitat effects on the space use and growth of reef-oriented fish in the Gulf of Mexico,” March 20, 2014.

Seminar presenter F. Lucy (c).

40. Frances Lucy, Centre for Environment Research Innovation and Sustainability (CERIS), Department of Environmental Science, Institute of Technology, Sligo, Ireland. “Freshwater invasives networking for strategy,” June 3, 2014.
41. Richard Barbiero, CSC. “Recent changes in the lower food webs of the Great Lakes,” September 25, 2014.
42. Robert Warren II, Department of Biology, SUNY Buffalo State. “Ghosts of cultivation past - Native American dispersal legacy persists in tree distribution,” October 9, 2014.
43. Christopher Barnhart, Professor of Biology at Missouri State University. “Where there’s a gill, there’s a way-Parasitism by freshwater mussels,” October 23, 2014.
44. Elizabeth Hinchey, U.S. EPA Great Lakes National Program Office. “The role of seabed dynamics in structuring an estuarine macrobenthic community,” December 4, 2014.
45. Ronald Griffiths, Oregon State University. “Effect of *Dreissena* on benthos,” January 28, 2015.
46. Katharina Dittmar de la Cruz, University at Buffalo, Department of Biological Sciences. “Evolutionary trends and ecological drivers of eye reduction in parasites," February 19, 2015.
47. Martin Stapanian, U.S. Geological Survey, Lake Erie Biological Station. “Polychlorinated biphenyls and mercury in burbot: Latitudinal effects and sex differences,” April 23, 2015.
48. Thomas Nalepa, Graham Institute, University of Michigan, and Great Lakes Environmental Research Laboratory, NOAA. "Trends in benthic macroinvertebrates throughout the Lake Huron system," April 30, 2015.


Seminar presenter R. Barbiero (r).

51. Serghei Bocaniov, Graham Sustainability Institute, University of Michigan. "Three-dimensional modeling: A powerful tool for the improved scientific understanding and management of Lake Erie," October 15, 2015.
52. Katya Kovalenko, University of Minnesota Duluth. “Coastal biota and anthropogenic stress in the Great Lakes,” January 21, 2016.
53. Ashley Baldridge, NOAA Great Lakes Environmental Research Laboratory. "Dreissenid mussel population trajectories and associated patterns in mussel growth and condition," March 3, 2016.
54. Mary-Alice Coffroth, University at Buffalo. "Coral-algal symbioses," March 4, 2016.

Workshops and Conferences

In order to improve qualification, learn new technique and increase the visibility of Great Lakes Center research activities, we hosted several professional workshops and the "Second International Meeting on Biology and Conservation of Freshwater Bivalves".

Aquatic invertebrate identification workshop

In May of 2015, we hosted an aquatic invertebrates identification workshop led by Dr. Ron Griffiths, an internationally recognized taxonomist who has taught many similar workshops in different countries around the world. The workshop was funded by the US EPA within the Great Lakes Long-Term Biological Monitoring project. Almost 20 participants enrolled, including Buffalo State faculty and staff, students, and our colleagues from USFWS. The workshop was very intense and extremely productive. At the end of the workshop participants successfully passed the test and received training certificates.

Dr. Ron Griffiths led a taxonomic workshop focusing on Great Lakes benthos such as molluscs, crustaceans, and aquatic insects.

PRIMER workshop

In November of 2015, in collaboration with the Cornell Biological Field Station, we organized a workshop in multivariate statistics taught by Prof. K. Robert Clarke, a PRIMER-E Director and Fellow of Plymouth Marine Laboratory, UK. This 5-day training PRIMER **7** and PERMANOVA workshop was designed to introduce users to the new version of the software and to advanced methods in multivariate statistics. Twenty-one scientists and students from the U.S., Canada, and Chile participated in the workshop.

Participants of the PRIMER workshop.

Second International Meeting on Biology and Conservation of Freshwater Bivalves

The Second International Meeting on Biology and Conservation of Freshwater Bivalves was hosted by the Great Lakes Center of Buffalo State College from October 4-8, 2015. The meeting brought together over 80 scientists from 19 countries and four continents. Fifty-six oral talks and 26 poster presentations covered diverse topics including biogeography, conservation and threats to species and ecosystems, genetics, invasive species, physiology, systematics and taxonomy, and fish-host relationship. Field trips to Niagara Falls and Letchworth State Park, and a picnic at the Field Station were organized for the fourth day of the meeting. Conference sponsors were the Freshwater Mollusk Conservation Society; EnviroScience; U.S. Fish and Wildlife Service; Great Lakes Research Consortium; NY Department of Environmental Conservation; Great Lakes Center. The Malacological Society of London provided travel funds for student participants.

BUFFALO NY, USA, 4-8 OCTOBER 2015
2nd INTERNATIONAL MEETING ON BIOLOGY AND CONSERVATION OF FRESHWATER BIVALVES

Participants of the Second International Meeting on Biology and Conservation of Freshwater Bivalves.

GLC researchers and graduate students attending the 58th Annual Conference on Great Lakes in Burlington, Vermont, 2015.

The Great Lakes Research Consortium 19th Annual Student Faculty Conference in Syracuse, 2009. Our students received more awards that any other institution.

Outreach

The Great Lakes Center serves the Western New York/Southern Ontario region as a technical and intellectual resource for resolving environmental issues, as well as for continuing education and specialized training. Through various research and monitoring activities, we obtain, process, and provide information and guidance to students, scientists, local, state, and federal agencies, industry, environmental groups, and others with interests in the Great Lakes and their watershed to improve decision-making and governance, sustain the natural resources of the basin, and promote the economy of the Great Lakes. This is accomplished through high quality research, informed graduate and undergraduate education, and dissemination of information to the public through outreach.

Great Lakes Long-Term Biological Monitoring Program

The EPA Monitoring Program is designed to provide managers access to biological data on zooplankton and benthos to support decision-making. In collaboration with Cornell University, we collected benthos (Buffalo State), zooplankton, and chlorophyll data (Cornell University) across the five Great Lakes from 2013 to 2017. The data was then analyzed and made available to environmental and fisheries managers. Long-term monitoring of Great Lakes water quality and fish food resources produces data important for over 30 million people living on the Great Lakes watershed. During this project we trained over 20 undergraduate and graduate students who assisted in sampling and analysis, thereby creating a cadre of future scientists and managers who will work to protect the Great Lakes.

Emerald shiner habitat conservation and restoration study in the upper Niagara River: Importance for sport fish, common terns and public education

An important aspect of the Emerald Shiner Project is outreach and education for the general public and water enthusiasts alike. By increasing awareness about the importance of the emerald shiners, and their critical role in the aquatic ecosystem, we ensure the protection and long term survival of this keystone species. Buffalo State and Buffalo Niagara Riverkeeper have partnered to host various education events to teach the public about the emerald shiners, their habitat, and their contribution to the health of the Niagara River. For additional information on this study, see pages 38-39.

GLES student Jo Johnson and Lin (BN Riverkeeper) in an outreach event featuring the emerald shiner project.

Investigating Lake Sturgeon habitat use, feeding ecology and benthic resource availability in the Lower Niagara River

The Niagara River is an ecologically important corridor for wildlife and fish. One species that receives considerable attention is the iconic lake sturgeon (*Acipenser fulvenscens*). Once thought to be on the road to extinction, lake sturgeon are making a remarkable recovery. To better understand this recovery, a three year study (2014-2017) was funded by the Niagara River Greenway Fund to study the habitat use and feeding ecology of lake sturgeon in the lower Niagara River. Our colleagues from the U.S. Fish and Wildlife Service tagged 60 lake sturgeons to trace their way throughout the lower Niagara River. Additionally, stomach content samples were taken to identify preferable food items, substrate mapping was performed, and extensive benthic sampling was done. Benthic habitat maps were generated from this data, linking physical habitat with biological data and allowing us to locate important lake sturgeon feeding grounds. Our study has already received attention within the university environment and from the public. We have presented four talks at international meetings and conferences, presented 10 talks to the public, published articles in various journals, including *Environmental Monitoring* and *The Record*, and submitted manuscripts to scientific journals. By furthering our understanding of the sturgeon recovery and disseminating our results to the public, we are helping ensure that future generations have their chance at meeting a lake sturgeon face to face. For additional information on this study, see pages 31-33.

Shana Chapman and Dimitry Gorsky from USFWS transferring a lake sturgeon from boat to holding pen before tagging.

Implementation of the Great Lakes Observing System

Since 2012, the GLC has been involved in the Great Lakes Observing System (GLOS). The Great Lakes Observing System consists of a varied membership of universities and government agencies that operate a system of observation stations throughout the five Great Lakes. Along with collaborators at SUNY College of Environmental Science and Forestry, we have been operating a data collection buoy in Lake Erie. All collected data are relayed to a GLOS website which is open to the public and all stakeholders. This site has become very popular with the local fishing community as they are often interested in temperature profiles to help them find fish, as well as in wave height to decide if conditions are right for heading out on the lake. For additional information on this study, see page 18.

Long-term monitoring on Lake Erie

The GLC has been an active member of the Forage Task Group (FTG) of the Great Lakes Fishery Commission. collecting samples on a bi-weekly basis. Results of this sampling are provided to the NYS Department of Environmental Conservation Fisheries Research Unit where it is combined with data collected from all of the other state, federal or provincial agencies that have management responsibilities on Lake Erie. This long term record of water quality parameters and the state of the lower trophic levels of Lake Erie will provide a foundation that can help us understand and face the challenges due to impacts resulting from climate change and invasive species. For additional information on this study, see page 19.

Conservation of freshwater mussels

Data collected during surveys of unionids in Texas and in the lower Great Lakes region were published in 11 research papers, and presented at over 30 meetings in the U.S. and abroad. Many graduate and undergraduate students were trained in the course of these projects. Data collected in Texas was used to add 15 species of freshwater mussels to the state list of threatened species and to submit a petition for their federal listing. This information is now part of the Texas Natural Diversity Database and is being used for species management and protection. The survey of unionids in the lower Great Lakes area gathered extensive baseline data and identified viable unionid refuges to inform management decisions and to develop management plans for nearshore habitat in order to protect and conserve remaining lower Great Lakes unionids communities and enhance their survival.

Invasive Species Awareness

Through its function as the host for WNY PRISM, the Center supports aquatic and terrestrial invasive species awareness in the region. WNY PRISM personnel engage public citizen volunteers on invasive species removal projects, present workshops at various venues, and spread the word on priority concern invasive species at 'tabling' events like farmer's markets, festivals, art shows, or county fairs. In the last two years, WNY PRISM has participated in 90 outreach events, making direct contact with nearly 6,000 individuals. To become active in invasive species management in the region, visit the WNY PRISM website (http://www.wnyprism.org/). For additional information regarding PRISM activities, see pages 51-57.

Dissemination of information to the public is accomplished through various types of activities including:

- Constantly updated Center website (http://greatlakescenter.buffalostate.edu/)
- Participation in local, state, national, and international meetings and conferences (over the last eight years, GLC scientists presented over 240 talks at various conferences)
- Annual report publications (eight reports have been published since 2008 and are available our website)
- Semiannual newsletters (available online since 2012)
- Fall and Spring Open Houses
- Multiple interview to mass media
- Public tours and lectures

A. Karatayev gives an interview for TV Tokyo America on zebra mussels, June 2009.

Western New York Partnership for Regional Invasive Species Management (WNY PRISM)

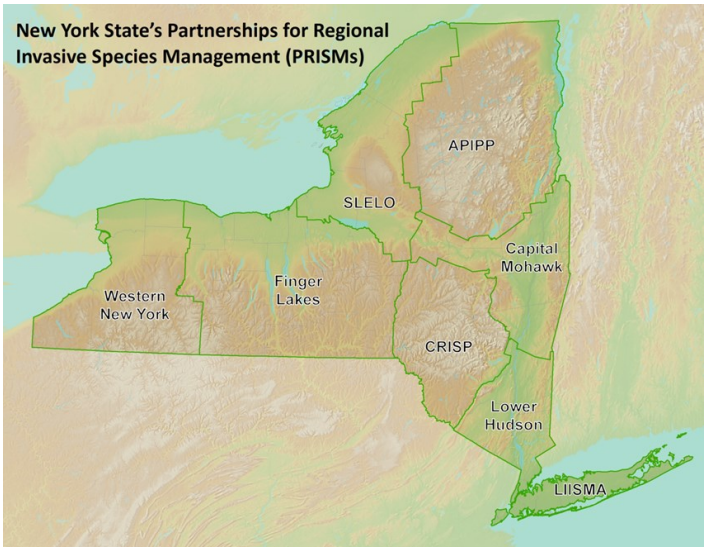
Partnering to Protect Western New York From Invasive Species

by Andrea Locke

Background

Invasive species are those species which are non-native to the ecosystem under consideration and whose introduction causes, or is likely to cause, economic or environmental harm or harm to human health. Recognizing the growing threat of invasive species, New York State (NYS) established the Invasive Species Task Force (ISTF), a multi-stakeholder working group made up of agencies, conservation organizations and business co-led by the NYS Departments of Environmental Conservation (DEC) and Agriculture and Markets (DAM), with the purpose to investigate invasive species issues and provide recommendations to the Governor and Legislature. The ISTF report, presented in 2005, identified 12 key recommendations which when implemented, would allow for NYS to effectively address invasive species.

Based upon the recommendations from the ISTF, NYS established the Invasive Species Council, Invasive Species Advisory Committee, and formed the Invasive Species Coordination Unit (ISCU) within the DEC. Among the remaining 12 key recommendations was one that supported the creation of PRISMs, regional private-public partnerships designed to strategically deliver invasive species management functions. PRISMs coordinate invasive species management functions including coordinating partner efforts, recruiting and training citizen volunteers, identifying and delivering education and outreach, establishing early detection and monitoring networks and implementing direct eradication and control efforts. By spring 2014, eight PRISMs had been established, providing regional coverage for all of NYS. The Western New York Partnership for Regional Invasive Species Management (WNY PRISM) is one of these eight partnerships, and was established in January 2014. The establishment of the statewide PRISM network signifies a long-term commitment on the part of New York State to address the threat of invasive species and ensure cooperation for invasive species management. Funding for WNY PRISM is provided by the Environmental Protection Fund through a contract with DEC. WNY PRISM is hosted by the Great Lakes Center and is a sponsored program of the Research Foundation for SUNY Buffalo State.



Once established, the WNY PRISM Office quickly began work to develop our regional partnership for the effective management of invasive species and to fulfill our ambitious Mission. WNY PRISM is a highly visible program that builds community awareness and participation. In just two years, the WNY PRISM Network has grown to include over 60 Partner organizations who bring together an incredible wealth of knowledge, drive and expertise in diverse fields including conservation, natural resources, habitat restoration, research, agriculture, urban planning, education and partnership building. Our dedicated Steering Committee includes non-profit organizations, businesses, federal and statewide agencies, and universities.

2016 WNY PRISM Steering Committee

Buffalo Niagara Riverkeeper
Ecology & Environment, Inc.
Chestnut Ridge Nursery/Certified Nursery Landscape Professionals
Conewango Creek Watershed Association
Cornell Cooperative Extension, Erie County
The Nature Conservancy
New York Sea Grant
NYS Department of Environmental Conservation
NYS Department of Transportation
NYS Parks, Recreation and Historic Preservation
SUNY Buffalo State
US Army Corps of Engineers
US Fish and Wildlife Service
USDA Natural Resource Conservation Service

Strategic Goals and Mission

The Mission of WNY PRISM is to proactively identify, evaluate and address invasive species priorities in western New York using a coordinated partnership of local professionals, organizations and private citizens to improve, restore and protect local aquatic and terrestrial resources. In order to achieve our mission, and as part of a 5-year Strategic Plan, the WNY PRISM Steering Committee has established six Goals, along with related Objectives, Strategies, Outputs and Outcomes. WNY PRISM goals are Partner and Network Coordination, Information Management, Education and Outreach, Prevention, Early Detection and Rapid Response, and Management and Habitat Restoration.

Partner/Network Coordination

Goal - Establish a partnership network and communication for those involved in invasive species information and management within the WNY PRISM region. Facilitate opportunities for cooperation including sharing of information, personnel, equipment and expertise.

WNY PRISM Fall Full Partnership Meeting held at Iroquois National Wildlife Refuge, including Andrea Locke (WNY Prism Coordinator), far right, 2014

One of WNY PRISM's key strategies for building our network is the improvement of communication between Partners and Stakeholders, including the sharing of information and resources and providing assistance and collaboration opportunities. To fulfil this, WNY PRISM has held Full Partnership Meetings, developed Working Groups, hired seasonal staff and interns, participated in Partner planning efforts and provided assistance to Partners seeking funds to support invasive species management projects.

Information Management

Goal - Collect, utilize, and share information regarding invasive species management including species, pathways of invasion, surveys, infestations, control methods, monitoring, research, current efforts/projects and opportunities for partner collaboration.

WNY PRISM works with and promotes the use of iMapInvasvies, an online mapping tool and database used by citizen scientist and professionals throughout New York State and other parts of the country. Our efforts have included filling information and distribution gaps for established invasive species, providing training for Partner organizations and volunteers, and conducting surveys in connection with management planning and projects. The WNY PRISM Crew has submitted 4,524 observations including 87 different species, and our regional efforts have involved 21 organizations with 70 individual users.

WNY PRISM Crew taking invasive species observation points at Bergen Swamp during survey for slender false brome (photo courtesy of NY iMapInvasives Online Database), 2014.

iMapInvasives mapping at Reinstein Woods completed by WNY PRISM Crew in 2014.

WNY PRISM began the process of determining our regional invasive species priorities with the formation of Working Groups. Separate Terrestrial and Aquatic Invasive Species Working Groups established priority species lists through a coordinated effort that included the use of NYS Invasiveness Rankings, western New York distribution data, broader landscape distribution data, local expertise and other available information. Through this process, three species lists were created: Terrestrial, Aquatic, and Early Detection.

Terrestrial priorities include species that were primarily seen as management priorities by our Working Group. While some are widely distributed and well known within the WNY landscape, they continue to have significant negative impacts on our natural areas. Species identified should be strongly considered for removal in locations where they have the potential to spread and impact natural areas. Aquatic priorities were selected using a similar method, however an added emphasis on the availability of methods to manage these species was necessary. Many aquatic species, while having significant negative impacts, are so well established within our waters, methods of removal, if they exist, are prohibitive.

Early detection priorities round out our regional species lists. In order to qualify as an early detection species, the species must occur on three or fewer sites within the WNY Region, based on current known infestation data. Each of these early detection species were originally identified as either a terrestrial or aquatic priority, but moved to the early detection list when it was determined they met this criteria.

Terrestrial Management Priorities

1. *Adelges tsugae* Hemlock Woolly Adelgid
2. *Agrilus planipennis* Emerald Ash Borer
3. *Cirsium arvense* Canada Thistle
4. *Cynanchum louiseae* Black Swallow-wort
5. *Cynanchum rossicum* Pale Swallow-wort
6. *Lonicera spp.* Bush Honeysuckles
7. *Phalaris arundinacea* Reed Canary Grass
8. *Phragmites australis* Phragmites/Common Reed
9. *Reynoutria spp.* Knotweeds
10. *Rhamnus cathartica* Common Buckthorn

Aquatic Priorities

1. *Corbicula fluminea* Asian Clam
2. *Hemimysis anomala* Bloody Red Shrimp
3. *Hydrilla verticillata* Hydrilla
4. *Hydrocharis morsus-ranae* European Frog-bit
5. *Orconectes rusticus* Rusty Crayfish
6. *Scardinius erythrophthalmus* Rudd
7. *Trapa natans* Water Chestnut

Early Detection Priorities – "Watch List"

1. *Anoplophora glabripennis* Asian Longhorned Beetle
2. *Brachypodium sylvaticum* Slender False Broome
3. *Channa argus* Northern Snakehead
4. *Eichhornia crassipes* Water Hyacinth
5. *Hypophthalmichthys molitrix* Silver Carp
6. *Hypophthalmichthys nobilis* Bighead Carp
7. *Microstegium vimineum* Japanese Stiltgrass
8. *Persicaria perfoliata* Mile-a-Minute
9. *Pistia stratiotes* Water Lettuce

Education and Outreach

Goal - Increase the public, partner, and stakeholder awareness, understanding and participation in invasive species issues and management within the WNY PRISM region, through effective educational and outreach efforts.

A. Locke presenting at Roger Tory Peterson Institute as part of 2016 National Invasive Species Awareness Week.

WNY PRISM educational display.

Over the course of two years, WNY PRISM has planned, hosted or otherwise participated in 90 Education and Outreach Events held throughout our region. Events included trainings and workshops, presentations, volunteer workdays, Partner events, and festivals which saw a combined 640,000 attendees. WNY PRISM Staff and Volunteers recorded 5,891 direct contacts, which includes those individuals with whom we had direct interaction through conversations or presentations.

WNY PRISM launched our website (www.wnyprism.org) in June, 2015. Input from all of our Partners was solicited in order to create a website that would meet the broad needs of the western New York region. Up-to-date information, single source of information and ease of use were the top Partner requests for a WNY PRISM website. The website addresses each of these, as well as many additional aspects that were identified by WNY PRISM and Partners. The WNY PRISM website will continue grow and add content as we strive to meet the needs of our region. We will work to provide the most current and accurate information available to ensure our regional invasive species management efforts remain effective and efficient.

Prevention

Goal - Facilitate the prevention of new occurrence, spread, and further establishment of invasive species within the WNY PRISM region through understanding of pathways of invasion and targeting of priority conservation areas. Prevention measures must address both the movement of invasive species in and out of the WNY PRISM region.

In recent years, the increased awareness over Pathways of Invasion has led to the desire to establish spread prevention programs. This desire and need is especially great in the western New York region, where current efforts are limited in scope. WNY PRISM has been working with Partners to develop aquatic invasive species prevention programming through increasing the availability of train-the-trainer and program development resources. We have also worked to increase the understanding of needs with the region, to provide information on the potential for Lake Association program development. In addition, WNY PRISM has been working on developing a boot brush station pilot program to assist in keeping terrestrial invasive species spreading into natural areas by way of trails and trailheads.

Early Detection and Rapid Response

Goal - Develop effective early detection, assessment and rapid response protocol(s) for the WNY PRISM region including mapping procedures, volunteer training/involvement, Best Management Practices, permit regulations and response teams, and provide assistance to partners for implementation of recommended protocols.

WNY PRISM has worked on a number of early detection projects with our Partners including assisting U.S. Army Corps of Engineers (USACE), DEC and the U.S. Fish and Wildlife Service (USFWS) on implementation of the Tonawanda Creek/Erie Canal Hydrilla Control Demonstration Project. Our Crew spent a couple of days working on boats doing pre-treatment surveys, and staffed the informational booth at Canal Fest of the

Tonawandas alongside Partners. We also worked with DEC on their WAVE (Water Assessments by Volunteer Evaluators) Program. In addition to volunteers collecting benthic macroinvertebrates to assist in determining water quality of wadeable streams, they are now also encouraged to look for invasive species as part of their surveys.

Surveying for and pulling water chestnut within the Chautauqua Lake Outlet, 2015.

Surveying for hydrilla using a rake toss as part of the Tonawanda Creek/Erie Canal Hydrilla Control Demonstration Project (photo courtesy of USACE Buffalo Field Office).

The WNY PRISM Crew surveyed the Chautauqua Lake Outlet for invasive species, focusing on water chestnut (*Trapa natans*) and hydrilla (*Hydrilla verticillata*). Hydrilla was not found during this survey, but we did map and remove a single, small infestation of water chestnut. Our Crew also surveyed for oriental weatherfish (*Misgurnus anguillicaudatus*) in Ball Creek, where it has been periodically found, beginning in 2004. A single fish was found and removed during this survey.

Management and Habitat Restoration

Goal - Assist partners with control of invasive species (eradication, containment, suppression) on high priority conservation areas based on identified regional conservation targets. Assist with the establishment of long-term management and monitoring, and the restoration of impacted sites to healthy native vegetation, to provide increased resilience against future invasions.

WNY PRISM Crew collecting Galerucella Beetles from nursery on the Tonawanda Wildlife Management Area in partnership with NYS DEC, 2015.

WNY PRISM's management and habitat restoration efforts have followed two distinct strategies. First, WNY PRISM works closely with our Partners to implement on-the-ground invasive species management projects, providing the much needed assistance to move these priority projects forward. Our second strategy involves developing a broader understanding of management planning within our region and among our Partners. We held a management planning workshop at Buffalo Audubon's Beaver Meadow

WNY PRISM Crew Member Lucy Nuessle backpack spraying reed canary grass at the WNY Land Conservancy's Niagara Escarpment Preserve, 2015.

Preserve that was well received, and assisted multiple Partners with review of invasive species removal and habitat restoration plans.

Projects WNY PRISM has assisted with include water chestnut removal with Jamestown Audubon, reed canary grass removal at Evangola State Park, ash seed collection, knotweed removal at the Great Lakes Center Field Station and Erie County Natural Habitat Parks, purple loosestrife biocontrol collection, and multiple species removal projects at Tifft Nature Preserve and Niagara Escarpment Preserve. In addition, WNY PRISM held a Native Planting and Habitat Restoration Tour during Invasive Species Awareness Week. The tour included visits to five restoration sites in the Buffalo area: Buffalo Niagara Riverkeeper's River-Bend, Erie County's Seneca Bluffs, Buffalo Creek Oxbow Wetland, Times Beach Nature Preserve, and Tifft Nature Preserve. Each of these restoration sites highlighted a different stage of restoration and management strategies based on their unique goals and site conditions.

Invasive Species Awareness Week Native Plantings and Habitat Restoration Tour, hosted by WNY PRISM, 2015.

Stem-injector herbicide application method on knotweed at Tift Nature Preserve, 2015.

Gretchen Stevenson Environmental Education Award Fund

The Fund

The Gretchen Stevenson Environmental Education Award Fund provides support to undergraduate and graduate students involved in research and activities that promote environmental education and awareness. Funds have been awarded to students in support for research work; attendance to conferences and trainings; workshops; and seminars, just to name a few.

The Visionary

Gretchen Schulz attended the Buffalo State Teachers College, graduating in 1931 with a degree in elementary education. As a student, she was a staff member of the *Record*, and a member of the YWCA, the Sociology Club, and the Current Events Club. After graduation, she married Richard Stevenson in 1935, and taught at the elementary and junior high levels in the Lake Shore School District for 31 years.

Mrs. Stevenson and her husband were life-long advocates for the environment. She was a member of the Buffalo Audubon Society, the Buffalo Ornithological Society, the Society of Natural Sciences of the Buffalo Museum of Sciences, the National Audubon Society, the World Wildlife Federation, the Wilderness Society, the Sierra Club, the Nature Conservancy, and was responsible for establishing the Southtowns SPCA. She received many awards for her conservation efforts and deeds for the protection of wildlife.

Mrs. Stevenson continued her involvement with Buffalo State by supporting the college's alumni association, establishing a trust, and making endowments and contributions for environmental education.

Mrs. Gretchen Schulz Stevenson with husband, Richard, 1998.

*Historical information and photo supplied by College Relations department at Buffalo State College, and the Buffalo News.

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Perez-Fuentetaja, A., S.A. Mackintosh, L.R. Zimmerman, M.D. Clapsadl, M. Alaee, and D.S. Aga. 2015. Trophic transfer of flame retardants (PBDEs) in the food web of Lake Erie. *Canadian Journal of Fisheries and Aquatic Sciences*, 72: 1886-1896.

Zanatta, D.T., J.M. Bossenbroek, L.E. Burlakova, T. Crail, F. de Szalay, T.A., Griffith, D. Kapusinski, A.Y. Karatayev, R.A. Krebs, E.S. Meyer, W.L. Paterson, T.J. Prescott, M.T. Rowe, D.W. Schloesser, and M.C. Walsh. 2015. Distribution of native mussel (Unionidae) assemblages in coastal areas of Lake Erie, Lake St. Clair, and connecting channels, twenty-five years after a dreissenid invasion. *Northeastern Naturalist*, 22(1): 223–235.

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Pennuto, C.M. and S.M. Rupprecht. 2016. Upstream range expansion by invasive round gobies: Is functional morphology important? *Aquatic Ecology,* 50: 45-57.

GLC Projects

Funded Projects Beginning 2006

Burlakova L. E., Karatayev A. Y. Potential Effects of Zebra Mussels in the Madison Lakes - Wisconsin DNR Aquatic Invasive Species Grants Program. **$49,037.** 2006-2008.

Funded Projects Beginning 2007

Burlakova L. E., Karatayev A. Y. State-Wide Assessment of Unionid Diversity in Texas. State Wildlife Grants, U.S. Fish and Wildlife Service, and Texas Parks and Wildlife Department. **$69,375.** 2007-2008.

Burlakova L. E., Karatayev A. Y. Effect of Natural Factors on Rate of Spread of Aquatic Invasive Species. Buffalo State College Research Council Incentive Funds. **$6,284.** 2007-2008.

Pennuto C. Assessing barriers to round goby migration into Great Lake tributary streams. NY Sea Grant. **$89,300**. 2007-2009.

Pennuto C. URM: The watershed as a model for training minority undergraduate Biology majors for graduate careers. National Science Foundation, Division of Biological Infrastructure. **$721,000**. 2007-2011.

Funded Projects Beginning 2008

Burlakova, L. E. and A. Y Karatayev. State-Wide Assessment of Unionid Diversity in Texas in 2009. State Wildlife Grants, U.S. Fish and Wildlife Service. Texas Parks and Wildlife Department. **$67,514.** 2008-2009.

Mukherjee, J. J. Phenolic component of tobacco smoke as tumor promoter. National Institutes of Health. **$214,500.** 2008-2011.

Pennuto C. Lake Ontario Nearshore Nutrient Assessment. U.S. EPA. **$57,200**. 2008.

Pennuto C. Verification of Cladophora biomass near the FitzPatrick nuclear power facility, Lake Ontario. Senes Consulting, Inc. **$55,460**. 2008.

Funded Projects Beginning 2009

Karlsson, J., C. Roehm, T. Christensen, N. T. Roulet. Greenhouse Gas Emissions from Lakes in Northern Permafrost Areas: Quantitative Importance and Climate Impacts. Swedish Research Council. **$490,950** (not to BSC). 2009-2012.

Pennuto, C. M., A. Y. Karatayev, A. Pérez-Fuentetaja, L. E. Burlakova, G. Matisoff, J. Kramer, and J. Conroy. The Nearshore and Offshore Lake Erie Nutrient Study (NOLENS). U.S. EPA Great Lakes National Program Office, Lake Erie Central and Eastern Basin Studies of Nearshore/Offshore Nutrient Fluxes and Interactions. **$150,000 ($75,000 for BSC).** 2009.

Pérez-Fuentetaja, A., M. Clapsadl, D. Aga, and M. Alaee. Food web–mediated transport and bioaccumulation of flame retardants (PBDE) in sport fish from eastern Lake Erie. New York Great Lakes Protection Fund. Large Grants Program. **$100,000.** 2009-2011.

Roehm, C. L. Arctic: The Unexpected Frontier. Geography and Planning Department lecture series. Buffalo State Faculty Student Award (FSA). **$1,000.** 2009.

Roehm, C. L. Wetland Remapping. EPA/NYS DEC. **$100,000**. 2009-2011.

Funded Projects Beginning 2010

Burlakova, L. E, A. Y. Karatayev, and M. Goehle. Preliminary Risk Assessment of the Parasites of Aquatic Exotic Invertebrates in the Great Lakes Region. Great Lakes Research Consortium, NYGLPF Small Grants Program. **$9,473**. 2010-2011.

Lange, C., B. Martinez-Hackert, J. Carbonara, J. S. Sabato, C. L. Roehm, K. Huffner, J. Zawicki, T. Tang, K. Williams, B. Tomaselli, D. Henry, D. MacIsaac. NASA-NSPIRES, STUDIES (Students and Teachers Using Data from Investigations in Earth Systems). **$654,250.** 2010-2013.

Makarewicz, J., C.M. Pennuto with 4 others from 4 institutions. Phase 3: Lake Ontario Nearshore Nutrient Study (L.O.N.N.S.). NY DEC. **$20,000** (sub-contract through SUNY Brockport). 2010-2011.

Pennuto, C. M., A. Y. Karatayev, A. Pérez-Fuentetaja, L. E. Burlakova, D. Bade, G. Matisoff, J., Kramer, and C. Mayer. The Lake Erie Nearshore and Offshore Nutrient Study (LENONS). U.S. EPA Great Lakes Restoration Initiative 2010. **$615,813. ($365,101 for Buffalo State).** 2010-2013.

Roehm, C. L., S. Vermette, M. Janis. Hydrological characterization of Woodlawn Beach State Park: Implications for E. Coli. NYS Water Resource Institute, USGS National Institutes for Water Resources (NIWR). **$55,517.** 2010-2011.

Roehm, C. L., S. Vermette, D. Beletsky, E. Anderson. Observing Systems and Monitoring in Nearshore Lake Erie. EPA Great Lakes Restoration Initiative 2010. **$962,583** (**$793,528 for BSC**). 2010-2012.

Snyder, R. J., L. E. Burlakova, D. B. MacNeill, and A. Y. Karatayev. Taking the Battle Overseas: Using Russian Literature in the War Against Invasive Fishes. U.S. EPA Great Lakes Restoration Initiative 2010. **$111,264**. 2010-2011.

Vermette, S., K. Irvine, C. L. Roehm. Pre-Restoration Wetland Characterization and Chemical Mass Balance Study: Woodlawn Beach State Park, New York. New York Great Lakes Research Consortium. **$9,940.** 2010-2011.

Zanatta, D., L. Burlakova, A. Karatayev, R. Krebs, M. Hoggarth, F. de Szalay, J. Bossenbroek, E. Meyer, M. Walsh; Collaborators: M. Schlesinger, R. Haas, T. Crail, P. Badra, N. Welte, L. Holst. Conservation of native freshwater mussel refuges in Great Lakes coastal zones. Great Lakes Fish and Wildlife Restoration Act FY 2010. **$327,363 ($71,054 for BSC).** 2010-2013.

Funded Projects Beginning 2011

Burlakova, L. E., A. Y. Karatayev, M. E. May, and B. Lang. U.S. Fish and Wildlife Service, and Texas Parks and Wildlife Department, Traditional Section 6, Bilateral species conservation effort in New Mexico and Texas. **$35,000**. 2011.

Burlakova, L. E., A. Y. Karatayev, M. E. May, M. D. Warriner, and B. Gottfried. Survey of threatened freshwater mussels (Bivalvia: Unionidae) in Texas. State Wildlife Grant Program, U.S. Fish and Wildlife Service, and Texas Parks and Wildlife Department. **$38,000**. 2011-2012.

Hahn, T. and A. Y. Karatayev. Effects of Multiple Acoustic Scattering from Realistic Oceanic Bubble and Fish Assemblages. **$151,468**. 2011-2013.

Karatayev, A. Y. and M. Clapsadl. Implementation of the Great Lakes Observing System. U.S. Department of Commerce. **$87,678**. 2011-2014.

Funded Projects Beginning 2012

Burlakova, L. E., A. Y. Karatayev. Zebra/Quagga Mussel Viability Test. U.S. Fish and Wildlife Service, Pacific Region. **$24,962**. 2012-2013.

Burlakova, L. E., A. Y. Karatayev, M. E. May, and B. Lang. Survey of Texas Hornshell Populations in Texas. U.S. Fish and Wildlife Service, and Texas Parks and Wildlife Department, Traditional Section 6, Bilateral species conservation effort in New Mexico and Texas. **$108,000**. 2012-2013.

Mukherjee, J. J., and S. Kumar. Alcohol and PAH-induced carcinogenesis. National Institutes of Health. **$147,000**. 2012-2014.

Pennuto, C. M. Administration of the Western New York PRISM (Partnership for Regional Invasive Species Management). NY DEC. **$1,100,768**. 2012-2017.

Rudstam, L., A. Y. Karatayev, and L. E. Burlakova. Great Lakes Long-term Biological Monitoring Program. U.S. EPA. **$3,867,525 ($1,094,726 for BSC)**. 2012-2017.

Snyder, R. J., L. E. Burlakova, D. B. MacNeill, and A. Y. Karatayev. Enhanced Early Detection of Invasive Ponto-Caspian Fishes in the Great Lakes. U.S. EPA Great Lakes Restoration Initiative. **$99,756**. 2012-2013.

Funded Projects Beginning 2014

Karatayev, A. Y., L. E. Burlakova. Lake Erie & Lake Michigan Benthos: Cooperative Science & Monitoring Initiative. U.S. Geological Survey. **$500,000**. 2014-2016.

Karatayev, A. Y., L. E. Burlakova, and D. Gorsky. Investigating Lake Sturgeon habitat use, feeding ecology, and benthic resource availability in the lower Niagara River. Greenway Ecological Standing Committee. **$835,829.** 2014-2017

Pérez-Fuentetaja, A., M. Clapsadl, R. Snyder, T. DePriest, M. Wilkinson, D. Einhouse, A. Hannes, R. Kraft, D. Potts, K. Hastings, S. Delavan. Emerald shiner habitat conservation and restoration study in the upper Niagara River: Importance for sport fish, common terns and public education. Niagara Greenway Ecological Fund. **$766,488.** 2014-2016.

Pérez-Fuentetaja, A., M. Clapsadl, R. Snyder, T. DePriest, M. Wilkinson, D. Einhouse, A. Hannes, R. Kraft, D. Potts, K. Hastings, S. Delavan. Emerald shiner habitat conservation and restoration study in the upper Niagara River: Importance for sport fish, common terns and public education. Great Lakes Remedial Action Plan. U.S. Army Corps of Engineers. **$1,331,247** (Funds are in-kind). 2014-2016.

Funded Projects Beginning 2015

Tang, T., M. Perrelli, C. Pennuto, J. Gould. The use of low-altitude unmanned helicopter remote sensing to detect invasive plant species in the Erie Canal System: method development applied to water chestnut (*Trapa natans*). Great Lakes Research Consortium Small Grants Program. **$12,464**. 2015-2016.

A very special thank you to the Great Lakes Center 50th Anniversary Celebration Planning Committee: Bill Benfanti, Lyubov Burlakova, Mark Clapsadl, Susan Dickinson, Rick Johnson, Alexander Karatayev, Sue McCartney, Michelle Rudnicki, Mark Severson and Randy Snyder.