Photo Credit: Janet Vail

R. B. Annis Water Resources Institute

YEAR IN REVIEW 2013

The Mission of the Robert B. Annis Water Resources Institute (AWRI) at Grand Valley State University is to integrate education, outreach, and research to enhance and preserve freshwater resources. Located in Muskegon, Michigan, the Institute's work centers around three main focal areas:

Research into major questions about aquatic ecology, chemistry and toxicology, fisheries ecology, hydrology, microbial ecology, aquatic molecular ecology, ecosystem restoration, and ecological modeling.

Information Services uses state-of-the-art geospatial technology to collect and analyze data, and condense them into useful information for those who make critical decisions about natural resources management.

Education & Outreach to graduate and undergraduate students, K-12 students, policymakers, educators, and the general public.

Grand Valley State University
Robert B. Annis Water Resources Institute

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Water Resources in the 21st Century

Dr. Alan Steinman, Director

Not very long ago, water resources management in the US was largely thought of as delivering potable water and treating our wastewater. While those issues continue to be vital to today's society, emerging trends such as the water-energy nexus, sustainability, blue water economy, climate change, biodiversity, invasive species, and harmful algal blooms, to name just a few, are changing the face of water resources. It is essential that we at the Annis Water Resources Institute remain vigilant, nimble, and creative, as we tackle these complex challenges. And to that end, I am proud to say that we continue to enjoy considerable success.

2013 was another banner year for AWRI. Not only did we officially dedicate and open the Robert B. Annis Field Station, but the faculty, students, and staff engaged in a variety of projects that reflect the complexity of 21st century water resources management: providing potable, sustainable water in developing countries; understanding the fishery in our own Muskegon Lake; restoring the ecological health of impaired wetlands, watersheds, and water bodies; examining harmful algal blooms in novel ways; and gearing up to launch a business enterprise based on research conducted here at AWRI and hence giving real meaning to the concept of public-private partnerships. These stories, and many others, are described in the following pages.

It is impossible to effectively address these challenges without resources. We are incredibly fortunate to have a donor base that believes in our mission, and generously provides us with both moral and financial support. Combined with AWRI's talented intellectual capital, these fiscal investments result in better science, better collaboration, and better solutions for water: our most precious natural resource.

Studying Algal Blooms 120 Meters ABOVE Muskegon Lake

Student researcher Alex Ebenstein holding AWRI's third generation UAV used in chlorophyll studies during summer 2013.

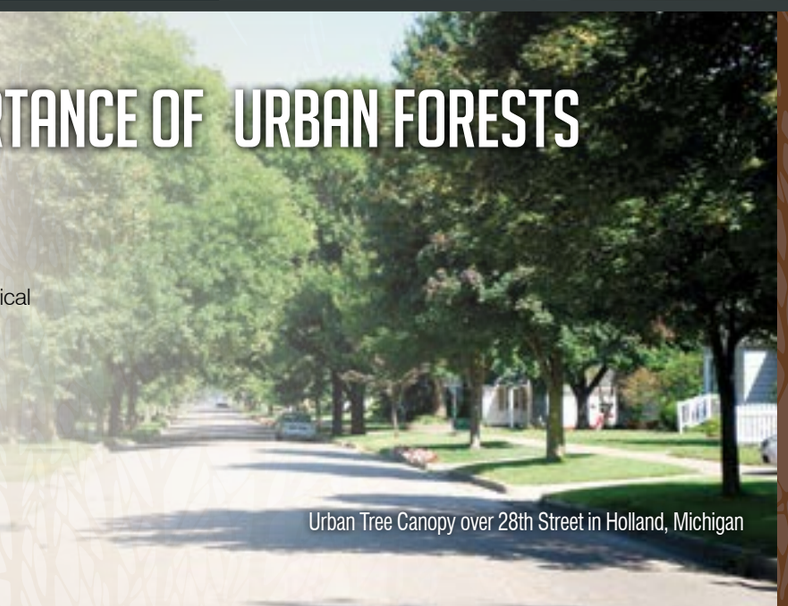
Imagine how powerful it would be to measure lake health by taking a picture! Satellite images have been used to estimate water quality in larger water bodies for years, but these techniques have not worked well in smaller systems. GVSU undergraduate student Alex Ebenstein, with his AWRI mentor John Koches, thought an unmanned aerial vehicle (UAV) might be just the tool needed.

Ebenstein and Koches used a UAV equipped with a near infrared (NIR) sensor to estimate algal biomass, one of the key indicators of lake water quality. The NIR images measure light reflected by the water's surface. Values stored in each image were statistically compared to chlorophyll concentrations in Muskegon Lake determined by a water quality probe. The comparison of NIR images with known chlorophyll concentrations made it possible to construct a statistical model to predict chlorophyll concentrations from images alone.

This preliminary study was intended to test the UAV, its ground control systems, and the usefulness of the NIR sensor in water quality applications. The UAV itself performed flawlessly, demonstrating its practical application in the assessment of local lake health.

RECOGNIZING THE IMPORTANCE OF URBAN FORESTS

AWRI has completed an urban tree canopy (UTC) assessment for the Cities of Holland and Zeeland, Michigan. We identified the extent of trees and natural areas in these cities and used the data to model ecological services and estimate beneficial impacts, including the reduction in air pollution. We summarized the results in an atlas for each city. For example, Holland has a UTC of approximately 24%. Annually, we estimate that this UTC provides $662,000 worth of air pollution removal services and stores $255,000 worth of carbon dioxide. Both Holland and Zeeland are now considering the further protection and expansion of their "urban forest."



Urban Tree Canopy over 28th Street in Holland, Michigan

Sensitive Prairie Found as AWRI Prepares Forest Stewardship Plans

Working with the Muskegon River Watershed Assembly and the Muskegon Conservation District, AWRI researchers stumbled upon a unique Dry Sand Prairie in the midst of Cedar Creek Township in Muskegon County. "We were looking for a place to plant trees, and to our surprise we found this beautiful example of a native grassland community complete with big bluestem, prickly pear cactus, and rough blazing star [pictured]!" reports AWRI researcher Rod Denning.

The Robert B. Annis Field Station

Better science, better collaborations, better solutions.

Thanks to the generosity of more than 220 donors, including alumni, community members, faculty and staff, students, foundations, and area corporations, as well as grants from the federal government and support from GVSU, over $3.22 million was raised to make a new research building for AWRI a reality. The new 14,700 square-foot Robert B. Annis Field Station dramatically increases our capability to conduct experimental research at AWRI.

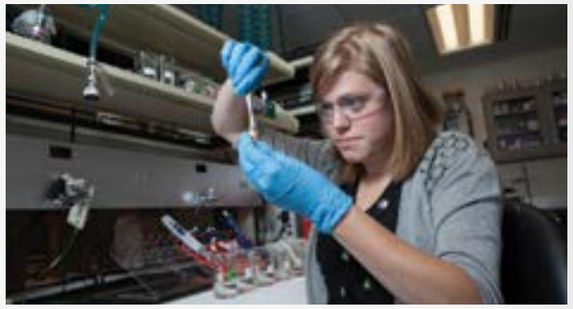
The new field station better enables AWRI to help the Muskegon region, and indeed, all of West Michigan visibly demonstrate leadership for the blue economy, increase opportunities for GVSU students, and facilitate new collaborations with external partners. “The new facility here at the Annis Water Resources Institute is a platform that our students and researchers can use to help innovate and continue to be significant contributors to the blue water economy,” said GVSU President Thomas J. Haas. “Innovation is a central part of what Grand Valley does as a university, and this new field station is a building that will help continue that trend.”

Features of the new building include:

- 3 research laboratories
- Mesocosm (aquatic tanks) facility
- Faculty and graduate student offices
- Conference rooms
- Field equipment storage
- LEED-design

The mesocosm facility consists of 12 tanks that each hold 350 gallons of water. The mesocosms are located in a climate and light-controlled room, which greatly expands the facility’s research possibilities.

Graduate student James Smit is using the Field Biology lab to conduct his research on nutrient release from wetland sediments.



Undergraduate student intern Courtney Cave is using the Environmental Simulation lab to study *Diporeia*, a historically important, but now threatened organism in the Great Lakes food web.

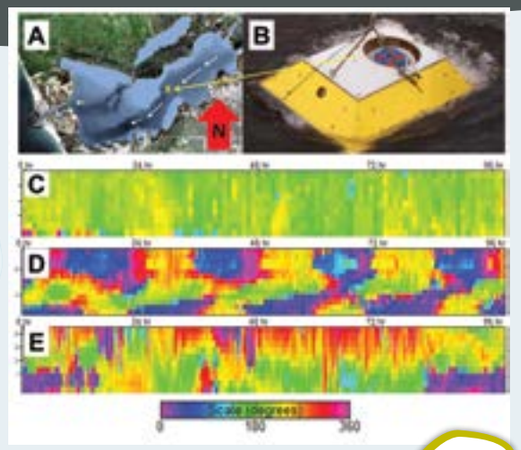
The Robert B. Annis Field Station was dedicated on August 12, 2013. The evening was a celebration of the philanthropic and entrepreneurial spirit of the entire Lakeshore community.

Cyanobacteria: A Moving Tale

Cyanobacterial mats collected from a Lake Huron sinkhole 75 feet under water (bottom figure) exhibit rapid movement in response to light, and can be manipulated to mirror the shape of incoming light passing through a foil cutout (top figure). The amazing ability of microbial filaments to migrate towards light is being studied by the Biddanda lab, as it is key to optimizing photosynthesis and survival in this extreme environment.

MUSKEGON LAKE: HOW IT FLOWS!

The Biddanda lab is measuring water direction and speed in Muskegon Lake (A) using a high-tech acoustic Doppler current profiler (B) located on the lake bottom. The 3 data panels each show several days of water direction data, represented as colors, from lake surface to bottom during last winter’s iced-over period showing an expected and consistent S-SW river flow (C), summer showing a typical day/night flow pattern where daytime 11-12 knot winds, and calmer nighttime winds, cause top/bottom directional shifts (D), and a strong 20-37 knot multi-day wind event (E). These results demonstrate that forces of ice, wind, and river combine to shape the lake’s complex flow patterns.



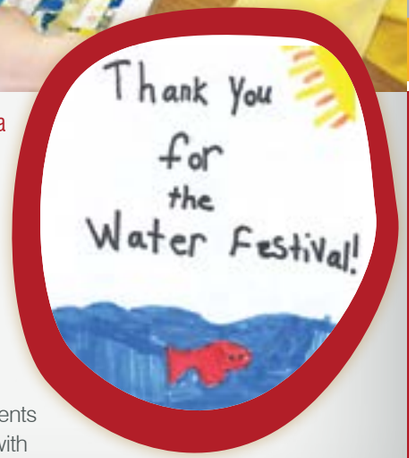
Reaching Out to Students and Teachers

Through grant support from the Alcoa Foundation, hundreds of students in Whitehall and Montague experienced a variety of water education activities at AWRI and in their communities. Six classes from Whitehall Middle School, four classes from Montague Middle School, and two classes from Montague High School enjoyed educational cruises on the *W.G. Jackson* and programs in the R.B. Annis Educational Foundation classroom.

Additionally, water festivals were held where students rotated through water-themed activities. Water festivals for the 3rd grade students in Whitehall were held at Ealy Elementary School in the spring. Students from Montague High School who received training at the inaugural Muskegon County Water Festival led activities for the 3rd grade water festival in Montague in the fall. Volunteers from Alcoa Howmet participated in both water festivals.

An additional component of the outreach was a teacher training in Project WET (Water Education for Teachers). AWRI is the State of Michigan Coordinator for this international program. Many of the water festival and classroom activities were drawn from WET.

Elementary students doing a water festival activity.



According to Dr. Janet Vail, "We are pleased that the Alcoa Foundation is continuing its support of hands-on water education for K-12 students at AWRI through 2016 with an additional three-year grant."

Former AWRI intern Amanda Maycroft (far left) and her middle school students participated in Great Lakes Restoration Initiative funded (GLRI) Making Lake Michigan Great (MLMG) cruises in Michigan City, Indiana, where she now teaches. Other MLMG ports visited by AWRI's *W.G. Jackson* in 2013 were Port of Indiana, IN; Waukegan, IL; and Holland, Grand Haven, Whitehall, and Muskegon, MI.

The International Association for Great Lakes Research (IAGLR) awarded its highest outreach honor to Dr. Janet Vail (left) at their 2013 annual conference. The Jack R. Vallentyne award goes to those who have contributed substantially to educating the public and informing policymakers about Great Lakes issues, leading to protection and restoration of great lakes of the world.

How invasive and native sediment-dwelling organisms affect lake water quality

Zebra and quagga mussels, iconic invasive species of the Laurentian Great Lakes, can greatly alter food resources for other species through their filter-feeding and excretion activity at the water–sediment interface. Post-doctoral researcher Dr. Geraldine Nogaro conducted laboratory experiments using sediment cores to examine how the filtering/excretion activity of invasive mussels and the burrowing activity of native chironomid larvae (e.g., blood worms) affect nutrient release and water quality in Muskegon and Bear Lakes.

Her results showed that the burrowing activity of native chironomids mixed and ventilated the sediments, increasing oxygen penetration in the sediment and affecting the chemistry of water held within the sediments. The invasive mussels did not mix sediments, but rather enhanced nutrient release to the water column. Burrowing chironomids had a greater influence in the mucky sediments of Bear Lake, whereas invasive mussels had a greater effect when associated with the sandy sediments of Muskegon Lake. These results have management implications, as the effects of invasive mussels in the Great Lakes region and elsewhere can alter nutrient dynamics and promote harmful algal blooms. Dr. Nogaro's research was recently published in the scientific journal *Oikos* (Nogaro and Steinman 2013).

Sediment cores used to evaluate invertebrate effects on nutrient release (top). Native chironomids created oxygenated burrows (bottom left, see arrows), while invasive mussels stimulated nutrient release at the sediment surface (bottom right, see arrows).

Wetland Restoration & Water Quality

Bear Lake (Muskegon County) suffers from poor water quality primarily due to excess phosphorus. AWRI graduate student James Smit and his advisor Dr. Al Steinman are researching how a proposed wetland restoration project on former celery fields will affect nutrient loading to Bear Lake. Specifically, James is interested in whether the celery field sediments will retain or release nutrients once they are reconnected to Bear Creek, the major tributary to Bear Lake, and how climate change could affect this process. Preliminary results indicate a potential for nutrient release, rather than retention, in some areas of the restoration site.

AWRI graduate student James Smit collecting sediment cores as part of his research.

GVSU participants with the I-Corps teaching faculty at CUNY in New York City. From left to right: Frank Rimalovski, Lindsey Marshall, Syndell Parks, Ryan Thum, Linda Chamberlain, and John Blaho.

From Research to Business: Groundwork Being Laid for Commercial Genetics Service

AWRI graduate student Syndell Parks and faculty member Dr. Ryan Thum, along with Dr. Linda Chamberlain, were awarded a grant from the National Science Foundation's Innovation Corps Program (I-Corps). I-Corps prepares scientists and engineers to extend their focus beyond the laboratory and broaden the impact of their NSF-funded basic-research projects. Parks, Thum, and Chamberlain participated in the intense eight-week program to translate research findings on the genetics of native, invasive, hybrid, and herbicide resistant watermilfoils (a submerged aquatic plant that can form massive weed beds) into a commercial service offering genetic identification of these otherwise visually indistinct watermilfoils. The service thus has environmental, social, and economic benefits associated with improving the management of invasive aquatic plants. "The sheer amount of work and dedication required for the course threw me completely off guard, but I learned more than I thought possible in such a short period of time," said Syndell Parks of her I-Corps experience. Indeed, the experience was a transformative one, and has impacted the team members' abilities to transform basic research into achieving the vision of AWRI: to enhance and preserve freshwater resources.

BIOECONOMICS OF CONTROLLING INVASIVE AQUATIC PLANTS IN LAKES

Invasion of lakes by aggressive invasive plants is a widespread and growing problem around the Great Lakes. Dense populations of invaders may exclude native aquatic plants and make a lake unsuitable for recreational activities, resulting in reduced property values around affected lakes. Thus, it makes both ecological and economic sense for lake managers to prevent these invasions from occurring. However, in lakes where invasive plants have already established, management of their growth and spread is often desired.

But, attempting to control an invasion can be costly. Herbicides and the labor required for their application are expensive, and the more aggressively an invasion is treated, the higher these costs become. In cases where invading species closely resemble native species, genetic identification may be required in order to be sure which plants are the invaders, further increasing at least the short-term cost. The control problem becomes still more complicated and costly if sources of invaders in surrounding lakes also need to be addressed, especially if they are found in different political jurisdictions.

What level of control, then, is optimal? AWRI scientists Drs. Ryan Thum and Jim McNair are currently working on this bioeconomics problem with invasive watermilfoil populations, using a combination of laboratory, field, and modeling studies.

Another twist in the bioeconomics problem is created by evolution of herbicide resistance in the invading species. The research of Drs. Thum and McNair also addresses this often-ignored aspect of the problem, using methods and models from the field of population genetics.

A rake sample of a highly invasive hybrid watermilfoil from an invaded lake.

In the words of GVSU undergraduate student Danielle Grimm, "The mesocosm facility in the new Field Station is awesome!" The facility has facilitated year-round research on invasive aquatic plants, including studies that will find the genes responsible for nuisance growth and herbicide susceptibility versus resistance.

Danielle Grimm (GVSU undergraduate student, left) and Lindsey Schulte (AWRI graduate student, right) conduct an herbicide experiment with watermilfoil in the new Field Station mesocosm facility.

AWRI researchers are developing an early detection tool for invasive aquatic species using environmental DNA (eDNA), or "DNA in the water". This tool will help aquatic plant managers identify invasive species before they have gained a foothold in our water bodies.

AWRI research assistant Jeremy Newton looks for invasive aquatic plant DNA in the water using environmental DNA techniques.

AWRI/USGS Expand Research of PCB Uptake by Burbot

AWRI researchers Dr. Richard Rediske and James O'Keefe are collaborating with US Geological Survey (USGS) scientists Drs. Martin Stapanian and Charles Madenjian to study the uptake of PCBs in burbot (a fish) from Lake Erie and Great Slave Lake in Canada (GSL). Larger than Lake Erie and deeper than Lake Superior, Great Slave Lake lacks industrial source inputs of PCBs and is influenced only by atmospheric deposition.

In a study published this year in the scientific journal *Chemosphere*, male burbot from Lake Erie accumulated higher levels of PCB compounds with 6 chlorine atoms while females had higher levels of PCBs consisting of 7-9 chlorine atoms. Because males potentially visit areas of sediment contamination in Lake Erie, the inclusion of GSL as a control lake was necessary to prove if differential uptake occurred between sexes.

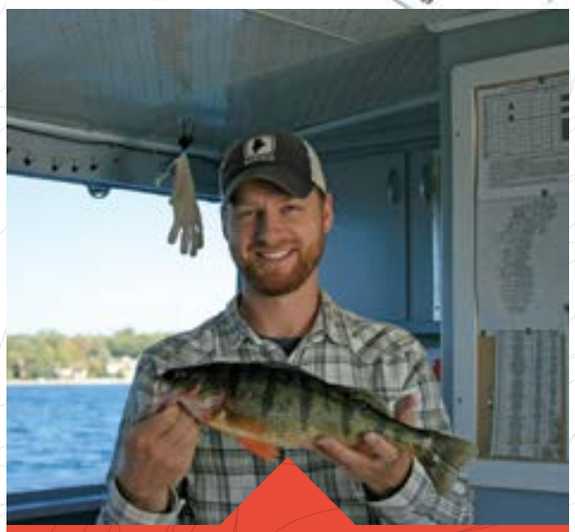
Results from GSL showed distinct differences in PCB uptake between sexes, with males accumulating higher levels. Metabolic differences between sexes may be responsible for this difference, as male fish are generally more active than female fish and also have greater resting metabolic rates. These results underscore the need to remove areas of contaminated sediment in order to lower PCB levels in resident fish and have important implications for setting fish consumption advisories.

AWRI at work 2013

AWRI director Al Steinman celebrates the dedication of the Robert B. Annis Field Station with Chuck and Laurel Angus.

Briana Hauff, AWRI/MSU graduate student, examining the effects of climate change (heat stress) on corals infected by pathogens in the Florida Keys.

The 2013 crew of the *D.J. Angus*: standing (from left) - Cheri Gerhart, Kevin Fitch, Paula Capizzi, Gerry Weinert, Bob Pennell, Les DeVries, Diane Veneklasen; kneeling - Paul Carlson.



Post-doctoral researcher David Janetski holds a yellow perch captured in Lake Michigan in a study to examine their population genetic structure.

AWRI staff and students with the debris they hauled out of our beachfront area during a beach clean-up day. Pictured from left to right are Jennifer Waller, Meagan McPherson, Maggie Weinert, Tonya Brown, Jesse Wesolek, Ryan Thum, Kurt Thompson, and James Smit. (Not pictured: Roxana Taylor)

Post-doctoral researcher Geraldine Nogaro and graduate student James Smit aboard the *W.G. Jackson*, collecting macroinvertebrates from lake bottom sediments during a Muskegon Lake monitoring cruise.

Graduate student Leon Gereaux heads out on board a NOAA research vessel to deploy the Muskegon Lake Buoy Observatory (www.gvsu.edu/buoy).

Graduate student Michael Snider (left) and Professor Bopi Biddanda (right) work over shallow sinkholes along Lake Huron, studying purple microbial benthic mats.

Target Inquiry teacher Jennifer Woods (Muskegon Area Career Tech Center) counts aquatic invertebrates for drift experiments in Mosquito Creek.

Education and Outreach assistant Tara Eilers presenting a program in the R.B. Annis Educational Foundation Classroom.

Where are they now?

Garry Sanders,
former AWRI graduate student

Crooked River Watershed Council Project Manager Garry Sanders stands at the site of a dam removal project on the Crooked River in Oregon. Garry planned and implemented the removal of this dam.

Garry Sanders earned an M.S. in Biology in 2008 while working with Dr. Bopaiah Biddanda on submerged sinkhole environments in Lake Huron. Garry has been a Project Manager for the non-profit Crooked River Watershed Council in Prineville, Oregon since 2010. He works collaboratively with private landowners and government agencies to fund, plan, and implement on-the-ground projects including stream restorations, dam removals, and riparian fencing and planting projects. Reflecting back on his AWRI experience, Garry says: "The interdisciplinary nature of the AWRI graduate program was instrumental in preparing me for the multi-faceted watershed restoration field, where management actions are based on a combination of hydrology, ecology, and geomorphology."

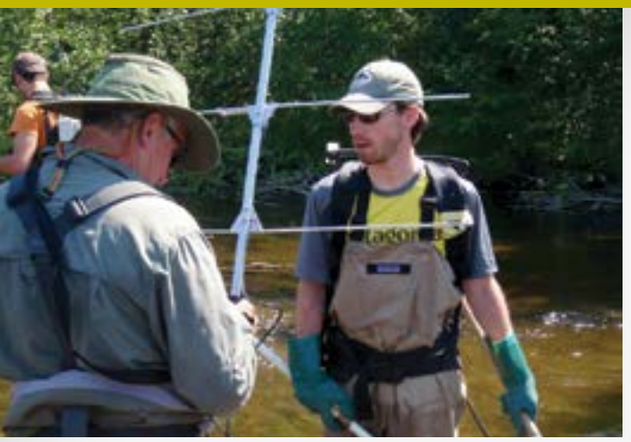
New Biosand Filter Model Holds Promise

AWRI prototype (grey) and Hydraid® BioSand filters (blue) tested for *E. coli* removal.

Clean water is a critical need in many developing countries. AWRI graduate student Sarah Stamann and Target Inquiry teacher Joe Lutz (Grand Haven Middle School) worked with Dr. Richard Rediske to develop and test a biosand filter prototype that could be built with locally available materials in developing nations. The biosand filter was based on a design concept developed by GVSU students Ross Ezinga and Christine Sauer using a waste receptacle and injection molded fittings made from plastic bags. Preliminary results showed the prototype design exceeds the *E. coli* removal efficiency of commercially-available Hydraid® BioSand filters.

AWRI graduate student Nicole Horne went to Ghana in 2013 to study the quality of drinking water sources and the performance of household water treatment systems. She serviced 18 Hydraid® BioSand filters and conducted evaluations of village water supplies. Flow rates were dramatically improved after servicing and the filters continue to be effective in removing *E. coli* bacteria after more than 3 years of use.

AWRI graduate student Nicole Horne collects samples for coliform analysis from a village water source in rural Ghana.



Dr. Mark Luttenton (left) and AWRI graduate student Bryan Giordano (right) radio tracking tagged brown trout.

Tracking Au Sable River Brown Trout

Using radio telemetry to track nearly 35 different brown trout for more than a year, Dr. Mark Luttenton, graduate student Bryan Giordano, and dozens of volunteers are starting to determine where these fish prefer to live and how they move throughout the Au Sable River. The data suggest that fish have one preferred daytime location and one nighttime feeding site a short distance away (and no, Mark and Bryan are not giving away those locations!). During warm months, fish will leave their preferred site to find colder water, which has implications for changing climate patterns. Their findings will help guide future habitat restoration projects.

WHIRLING DISEASE has had significant impacts on many trout populations, but trout in the Au Sable River appear to have avoided a substantial outbreak. A new genetic study of the intermediate host conducted by Dr. Mark Luttenton, undergraduate student Megan Zawacki, and Dr. Jennifer Winther (GVSU Biology Department) suggests that the appropriate host may not be common in the Au Sable River, and that the trout population is not at risk from this disease.

Can Coral be Used to Cure Cancer?

Throughout the millennia, humans have used natural products to treat diseases. Many well recognized anti-cancer and anti-viral compounds discovered early in the 1950s were isolated from marine sponges. Compounds from coral have also shown interesting results. For example, Xenicane from the soft coral *Xenia* sp. has shown effectiveness at inhibiting cancer cells. Research by Dr. Kevin Strychar and members of his lab has shown that extracts from the deep-water coral *Paragorgia arborea* inhibit the human pathogens *Streptococcus* sp. and *Bacillus* sp. Their continued efforts will explore the effects of these extracts on tumor and cancer cells, malaria, and AIDS-opportunistic infections.

Cold-water coral *Paragorgia arborea* near Nova Scotia, Canada.

DO WE UNDERSTAND WHAT DRIVES FISH SPECIES DIVERSITY IN LAKES?

An essential part of managing Michigan's natural resources is assessing patterns in fish abundance and species diversity in lakes. For years, AWRI researchers have monitored fish communities in several lakes connected to Lake Michigan, and it turns out the patterns observed across these lakes also provide insights relevant to ecological theory.

In an analysis led by post-doctoral researcher David Janetski, higher fish diversity was found in lakes connected to each other via Lake Michigan than in inland lakes isolated from one another. In lakes connected to each other, fish communities of lakes in close proximity were more similar to one another than lakes located farther apart. These patterns support ecological theory in that connectivity, which allows fish to migrate from one lake to another, plays an important role in driving species diversity.

Dr. Janetski's findings, which were recently submitted for publication with co-author Dr. Carl Ruetz, have implications for fisheries management. Policy-makers often set regulations based on local factors relevant to individual lakes rather than regional factors, such as connectivity, that influence networks of lakes. Next summer, Drs. Janetski and Ruetz plan to work to disentangle the importance of connectivity and environmental variation in shaping fish species diversity in lakes.

Lab technician Amanda Chambers (left), David Janetski (middle), and GVSU undergraduate intern Jennifer Waller (right) conduct fish sampling with fyke nets in Muskegon Lake.

Does Lake Michigan have enough food for Asian carp?

AWRI researchers Dr. Dave Janetski and Dr. Carl Ruetz are collaborating with the Illinois Natural History Survey to assess zooplankton abundance in coastal areas of Lake Michigan. The research aims to evaluate whether food resources in the habitats surveyed are likely to be sufficient to support the invasive Asian carp if they ever reach this area.

Dr. Carl Ruetz received the Distinguished Graduate Mentoring Award from GVSU's Center for Scholarly and Creative Excellence (CSCE). The award was established to recognize and encourage outstanding mentoring of graduate students by GVSU faculty members. Dr. Robert Smart, Executive Director of CSCE, noted that "Carl understands the importance of his role as a researcher, but also understands his role as a teacher and mentor."

Diporeia:
On the verge of extinction or making a comeback?

When considering how important and how fragile food webs are in the Great Lakes, one should look no further than the impacts of climate change and invasive species on a tiny shrimp-like organism called *Diporeia*. Prior to its decline, *Diporeia* was considered the most abundant benthic invertebrate in the Great Lakes, composing ~70% of all biomass deeper than 30 m. Laden with fatty oils, many fish species depended upon *Diporeia* as a staple food source. During the early years of the *Diporeia* decline, ca. 1995, it was believed that the arrival of zebra mussels, and the resultant increased competition for food, caused *Diporeia's* decline.

Today, there is mounting evidence that during the *Diporeia* decline, there was a concurrent global outbreak of several viruses in the shrimp and prawn industry. Because *Diporeia* are taxonomically very close to shrimp, cross-infection might have occurred. Research being conducted by Dr. Kevin Strychar and members of his lab aims to determine if the *Diporeia* decline was caused by disease and if *Diporeia* populations are stable in the absence of disease. If this is the case, they hope to show that *Diporeia* can "bounce back" to be as dominant as they once were, and perhaps help restore the Great Lakes' food web.

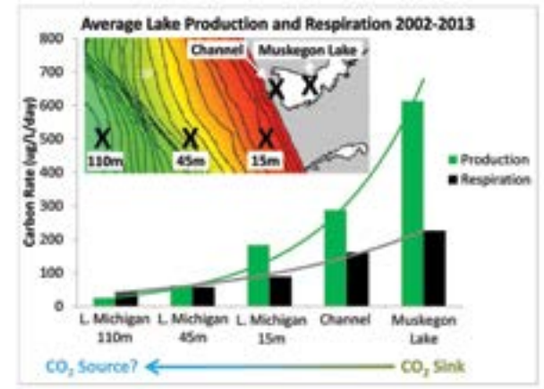
Lake Michigan amphipod *Diporeia* sp., once the most important food source for fish in the Great Lakes. *Photo credit: Courtney Cave*

CHANGING TIMES: THE CHANGING CARBON CYCLE OF LAKE MICHIGAN

The carbon economy is one of the largest exchanges on Earth and freshwater environments play a key role. Intense carbon cycling begins with photosynthetic organisms like algae, which absorb carbon dioxide during photosynthesis and convert it into carbon biomass while releasing oxygen. Organisms then consume oxygen while "burning" carbon for energy, releasing carbon dioxide in a process called respiration. Unbalanced photosynthesis/respiration ratios lead water bodies to be either carbon sinks or sources.

Our long-term study has helped clarify the importance of the changing carbon cycle in this Great Lakes environment, and could advance the understanding of carbon balance in coastal environments elsewhere.

Over the last decade, Dr. Bopi Biddanda and his lab measured photosynthesis/respiration rates along a gradient from shallower, nutrient-rich Muskegon Lake to deeper, nutrient-poor Lake Michigan. As expected, the rates of both processes systematically decreased from Muskegon Lake to Lake Michigan. However, along the nearshore-offshore gradient, photosynthesis decreased much faster than respiration. These findings indicate that the nearshore environment is a net sink for atmospheric CO_2, whereas the offshore waters are more balanced and sometimes even a net source of CO_2. The findings also show why nearshore areas support better fisheries and how offshore ecosystems need to be subsidized by inputs of terrestrial and nearshore resources.



Production and respiration decrease along a gradient from Muskegon Lake to Lake Michigan at depths of 15, 45, and 110 m. Sampling locations are indicated by an "X" in the inset map.

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- Dave Fisher, Marine Engineer *WGJ*
- Kevin Fitch, Captain *DJA*
- Robert Marx, Deckhand *WGJ*
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- Amanda Chambers, Technical Call-in
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- Alexander Ingersoll, Technical Call-in
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Bryan Giordano, AWRI Assistantship (major advisor: Mark Luttenton)
Brandon Harris, AWRI Assistantship (major advisor: Carl Ruetz)
Meagan McPherson, AWRI Assistantship (major advisor: Jim McNair)
Syndell Parks, AWRI Assistantship (major advisor: Ryan Thum)
Lindsey Schulte, AWRI Assistantship (major advisor: Ryan Thum)
John Skutnik, AWRI Assistantship (major advisor: Kevin Strychar)
James Smit, AWRI Assistantship (major advisor: Alan Steinman)
Michael Snider, AWRI Assistantship (major advisor: Bopi Biddanda)
Sarah Stamann, AWRI Assistantship (major advisor: Rick Rediske)
Jessica Wesolek, AWRI Assistantship (major advisor: Carl Ruetz)
Brian Zuber (major advisor: Rick Rediske)

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Elizabeth Mullins
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David Boyer
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Anna Harris
Morgan Jones, volunteer
Zachary Kuzniar
Samantha Morsches
Jeff Pashnick
Anthony Weinke

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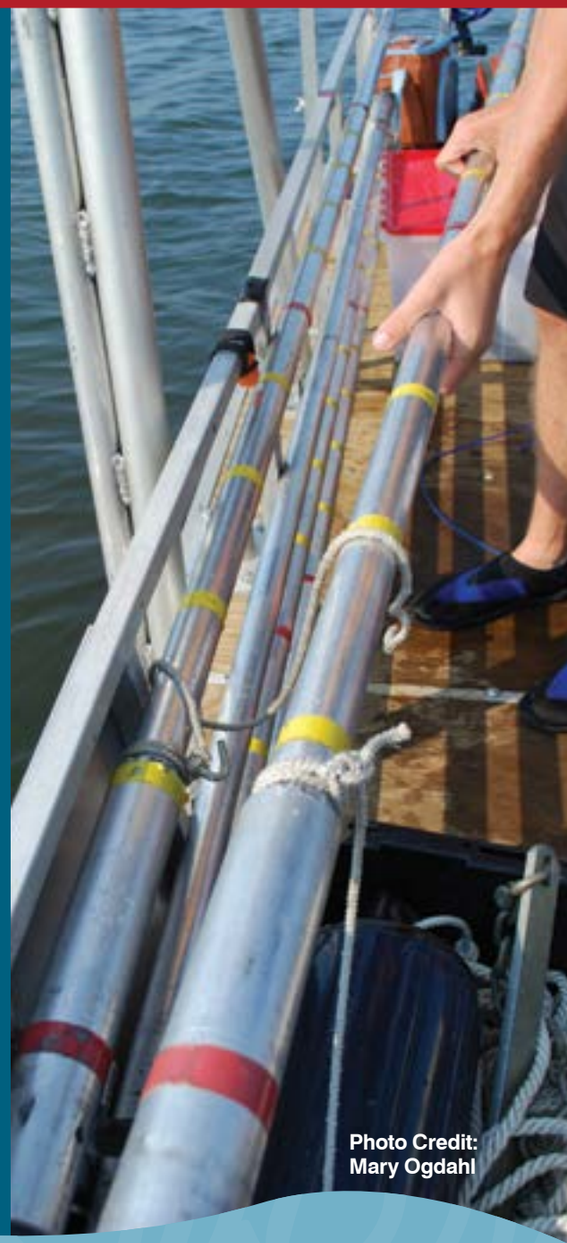

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Internships & Scholarships

AWRI provides opportunities for students to pursue their interests in our environment. The following students received internships during 2013.

D. J. Angus-Scientech Educational Foundation Interns:
Danielle Grimm
Anna Harris
Adam McMillan
Megan Zawacki

Herbert VanderMey Intern:
Sarah Stamann

Robert B. Annis Foundation Interns:
Courtney Cave
Sarah Stamann
Jennifer Waller

Bill and Diana Wipperfurth Scholarship:
Kathy Roberts

Ron Ward Scholarship:
Funded by the D.J. Angus-Scientech Educational Foundation
Katlyn Granahan
Rachel Hughart
Steve Ossim
Riley Waco
Jack Heiniger
Scott Ossim
Courtney Talbot

Target Inquiry Teachers:
Joe Lutz
Ashley Meyer
Kevin Sylvester
Jennifer Woods

AWRI 2013 Peer-Reviewed Publications

Photo Credit: James Smit

AWRI staff in bold
Graduate Students*, Undergraduate Students**

Allan, J.D. et al. (22 authors including **A.D. Steinman**). 2013. Joint analysis of stressors and ecosystems services to enhance restoration effectiveness. Proceedings of the National Academy of Sciences 110(1): 372-377. DOI:10.1073/pnas.1213841110

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AWRI staff in bold
Graduate Students*, Undergraduate Students**

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Vail, J. 2013. Research Vessel *W. G. Jackson* 2012 Use Report. CR-2013-2.

Vail, J. and **A. Syers.** 2013. Michigan Environmental Education Curriculum Support (MEECS) Unit Training – Climate Change: Science and Impacts. Michigan Department of Environmental Quality.

If you would like more information about AWRI's programs, please contact us.

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