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Research Summaries

Ohio Sea Grant

College Program

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The Ohio State University

Sea Grant
Ohio Sea Grant College Program

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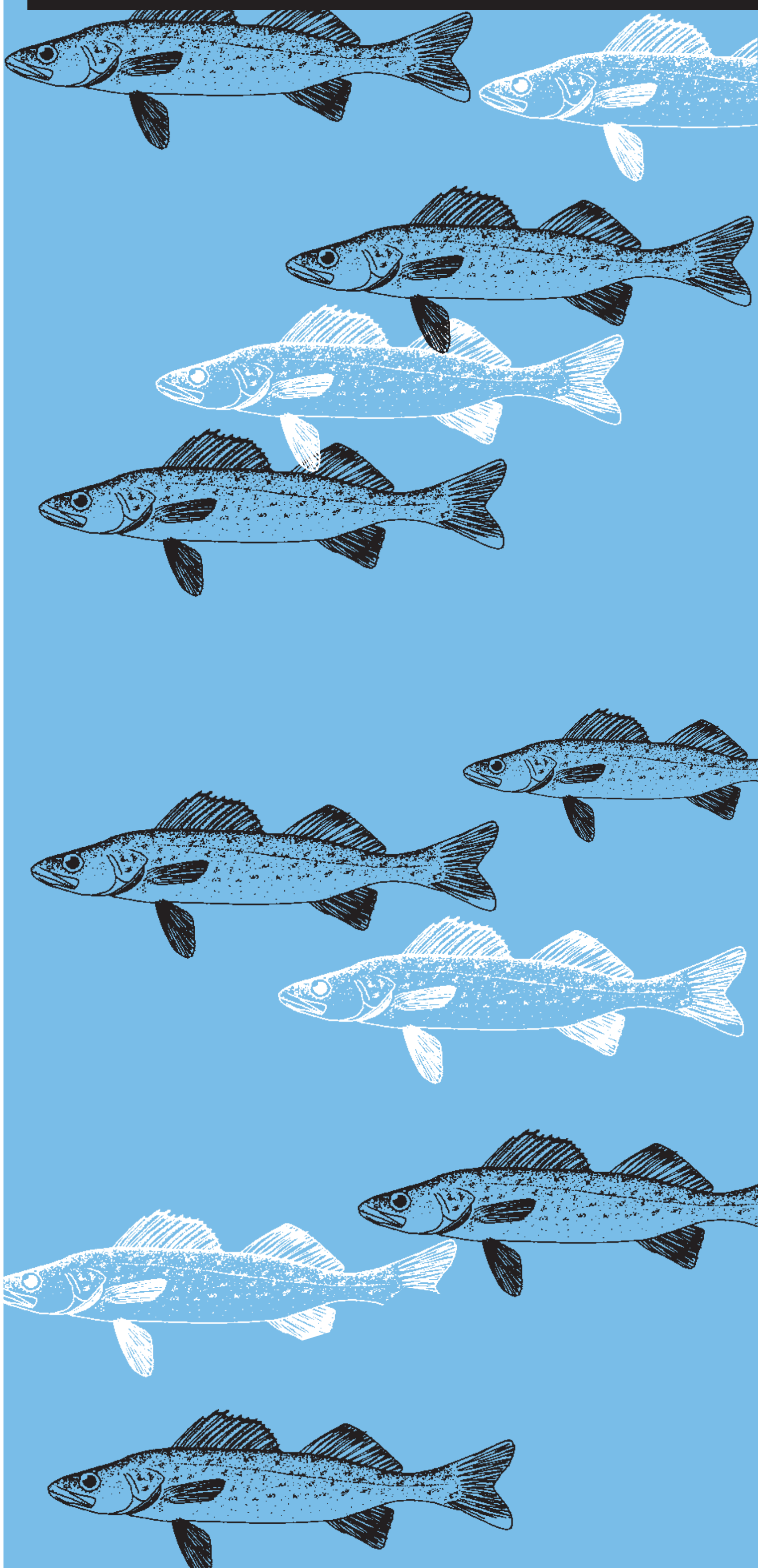
TWINE LINE

The educational newsletter of Ohio Sea Grant, covering issues, events, and research related to Lake Erie and the Great Lakes



Research Review:
Genetic Diversity Helps Keep Walleye Populations Strong

by Jeromy Applegate, Ohio Sea Grant Communications

Known as the "walleye capital of the world," Lake Erie attracts millions of anglers each year who hope to take a few walleye home for dinner. Many factors, such as abundant food supply, adequate habitat, and regulation of fishing pressure, come to mind when asked why walleye have been so successful in Lake Erie waters. However, another important factor is genetic diversity. In Lake Erie, not all walleye are the same. There are many "stocks," or groups of walleye that are genetically similar to others within the stock, but differ from fish in other stocks. Each stock of genetically similar walleye may possess a distinct set of biological adaptations that allows it to survive in its environment. As an entire species, this genetic diversity among stocks may enable walleye to inhabit a variety of environments and withstand perturbations, such as fishing pressure, habitat degradation, and effects of invading species.

Ongoing Ohio Sea Grant funded research is being conducted by Dr. Carol Stepien, of Case Western Reserve University, to identify different genetic stocks of walleye in Lake Erie. Dr. Stepien is using DNA sequencing to characterize the genetic relationships of walleye in the western, central, and eastern basins of Lake Erie. In addition to testing whether

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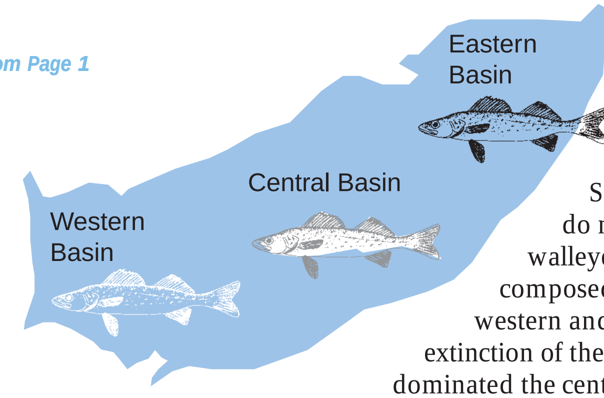
GENETIC DIVERSITY *Continued from Page 1*



While walleye that spawn in the western basin of Lake Erie are genetically different from those that spawn in the eastern basin; walleye in the central basin have genetic similarities to both.

walleye in each basin consist of separate genetic stocks, Dr. Stepien is also testing to see if different spawning groups contain unique genetic make-ups. The occurrence of genetically unique spawning groups is believed to be caused by natal homing, the tendency for an organism to return to the same spot to spawn in which it was born. Spawning sites that are being sampled include the Sandusky and Maumee Rivers in the western basin, the Grand River (OH) in the central basin, and the Van Buren Bay and Grand River (Ontario) in the eastern basin.

To find the genetic relationships of Lake Erie walleye, Dr. Stepien is examining the make-up of their DNA. With the help of the Ohio Division of Wildlife, Dr. Stepien has collected fin clips (obtained by cutting off a portion of the pectoral fin, without harming the fish) of walleye during their spawning runs in the tributaries of Lake Erie. Eggs and larval fish were collected on reef-spawning sites. In the laboratory, the DNA of the fish tissue is examined. By examining differences in certain sections of DNA, Dr. Stepien can determine if two fish are genetically similar. Using statistics, it is then determined if each group of walleye differs significantly from other groups.

Results of this ongoing research have shown that fish from the eastern and western basins of Lake Erie are made up of separate genetic stocks. Some groups of walleye from different spawning sites within each basin have also been determined to be genetically separate stocks. Spawning sites in the central basin, however, do not contain separate genetic stocks of walleye. Walleye that spawn in the central basin are composed of fish that are genetically similar to both western and eastern basin fish. This could be due to the extinction of the blue pike, a subspecies of walleye that once dominated the central basin of Lake Erie. As blue pike disappeared from the central basin, walleye may have colonized the spawning sites that the blue pike once occupied.

Dr. Stepien's research will help resource managers identify specific spawning stocks of walleye that help to maintain the genetic diversity of the entire species. She has begun examining walleye from additional spawning sites within Lake Erie (both reef and tributary) and is sampling walleye from the other Great Lakes as well. In addition to characterizing walleye genetics, Dr. Stepien is also examining genetic stocks of yellow perch. Dr. Stepien intends to expand the base of genetic data for walleye and yellow perch and put this database on the Internet. She states that "Fishery managers and scientists around the world will be able to access it. We will thus learn a lot about walleye populations and how to protect their genetic diversity." She also plans to develop easy genetic markers that can be used by the Division of Wildlife and other agencies to quickly determine genetic relationships. With this expanding availability of genetic information, fishery managers will be better able to maintain genetic diversity and keep walleye populations strong in the future. *TL*

For more information on this Ohio Sea Grant funded project, contact Dr. Stepien at ***cas20@pop.cwru.edu.***

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How to Win Back the Beaches

by Jill E. Jentes, Ohio Sea Grant Communications

Covering miles of shoreline and accommodating over 1.4 million visitors last year, Lake Erie public beaches have traditionally been centers for summertime activities. With millions visiting, these beaches have evolved into key income generators, contributing over $21 million each year to local communities. But as this summer approaches, many vacationers will be packing up and heading to other sources of summer entertainment. For many, Lake Erie beaches have lost some of their luster, causing visitation at state park beaches to decrease 20 percent over the past five years.

Lake Erie beaches are not alone. Public beaches across the nation have noticed a drastic decrease in beach visitation over the past 15 years. For many vacationers, public beaches are no longer the focal points for summer fun. Water parks and municipal pools with their added amenities now compete for the beachgoers' attention. How much do amenities really influence a vacationer's choice?

New Ohio Sea Grant research by Dr. Brent Sohngen and Chris Murray of Ohio State University's Agricultural, Environmental, and Development Economics Department investigated visitation patterns at 15 of Lake Erie's public beaches. In the two-year study, they found that beach amenities, such as picnic tables, lifeguards and beach water quality advisories, influence a beachgoer's choice of beach.

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Every year beach advisories at Lake Erie beaches cost $3.75 million in lost visitor spending.
The reduction of one beach advisory at all beaches could result in an economic increase of $100,000 per beach for local economies.

BEACHES ***Continued from Page 1***

Reducing sand grain size, zebra mussel shells, and cobbles on beaches **by 10%** is worth an estimated **$708,646.**

Beach advisories, which are issued when pathogens, such as E. coli reach hazardous levels in shoreline waters, are normally a result of sewage entering surface water due to defective septic tanks, sewage overflows, or animal waste from agricultural run-off. Although visitors can swim when advisories are issued, the study indicates that beach advisories affect a beach user's decision to visit.

"When beach advisories are issued, visitors will make a choice – they either stay at that beach, select a different beach, or choose another activity all together. This study shows that beach advisories are heavily valued by beach users," states Murray, the project's research associate. These advisories affect more than just visitor numbers. "Each Lake Erie beach advisory costs an average of $100,000 per beach in lost visitor spending within 10 miles of a beach. With an average of 2.5 beach advisories per season, the effect of advisories on a beach's local economy is about $250,000," states Murray. Applying state park visitation estimates to all 15 beaches, a reduction of beach advisories by one would create an estimated $3.75 million in visitor spending each year.

Although beach managers themselves cannot reduce beach advisories, local communities can diminish contamination occurrences by eliminating combined sewer overflows, adjusting sewage treatment methods, and better supervising agricultural run-off. However, these policies can be very costly to implement. Murray emphasizes that communities must look at the projected yearly reduction of visitor spending if new practices are not implemented. "Policymakers have the ability to control beach advisories. There is evidence that combined sewer overflows and storm sewer overflows are significant sources of bacterial contamination in the water. By reducing the number of combined sewer overflows and increasing a wastewater treatment plant's ability to handle them, beach visitation and spending would increase," says Murray.

Beach managers can do something to lessen the effects of beach advisories. Increasing the number of amenities at a Lake Erie beach can offset the loss of beach visitation. The study found that beachgoers highly value sand quality characteristics such as finer sand grains, reduced zebra mussel shells on the beaches, and decreased cobbles. By improving these amenities and adding more lifeguard hours and picnic tables, the study suggests that visitation can improve. "Some of the beaches studied had higher than average beach advisories. Visitation, however, remained fairly high because the other beach amenities like sand quality could still attract visitors. Swimming wasn't necessarily the primary focus when other amenities exist," explains Sohngen.

This project was jointly funded by Ohio Sea Grant and the Ohio Lake Erie Commission's Lake Erie Protection Fund. For more information about this project, contact Dr. Brent Sohngen at *sohngen.1@osu.edu* or 614 / 688-4640 or Chris Murray at 614 / 292-6972 or *murray.255@osu.edu*. Fact sheets such as *The Value of Lake Erie Beaches* (FS-078), *The Economics of Lake Erie Beaches* (FS-082), and addendums (FS-082 a-o), detailing the economics for each of the 15 beaches studied are available at ***www-agecon.ag.ohio-state.edu/Faculty/ bsohngen/ beach/ beachin.htm*** or by contacting Ohio Sea Grant (see back cover for order form). ***TL***

Five additional picnic tables per beach is worth an estimated **$29,908.**

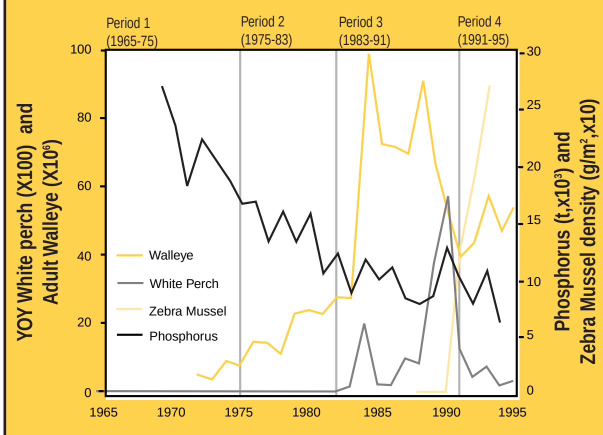
Estimates in annual single day beach user benefits are based on state park beach visitation data.

Research Review:

Zooplankton Abundance – Vital for Young Fish Survival

by Lisa Denlinger, Ohio Sea Grant

In order to maintain high populations of Lake Erie's sport and forage fish, it is helpful for resource managers to know what factors contribute to a young fish's survival. Recruitment models that determine first-year survival rates of young fish, however, have traditionally focused on water temperature and predation by adult walleye as the key indicators for young fish survival. Recent Ohio Sea Grant research by Dr. David Culver at The Ohio State University, reveals that the biggest indicator may be the availability of zooplankton for juvenile fish.



The four-period timeline depicts the number of young walleye and white perch in relation to zebra mussel density and phosphorus loading, based on sampling collected on South Bass Island in western Lake Erie.

To correlate the data patterns, Culver and his graduate team developed a four-period timeline. The researchers combined their own records on zooplankton abundance, fish diet, and zebra mussel population with annual fish abundance surveys taken by the Ohio Division of Wildlife. The timeline depicted the relative amounts of specific fish species alongside the amount of externally loaded phosphorus from 1965 to 1993, as shown by the diagram. The compilation was then used to confirm the relationship between zooplankton availability and the young fish population.

Period 1

The amount of phosphorus that entered the lake during this period steadily decreased. The zooplankton population did not suffer because the mineral became incorporated within the lakebed. Later, when a stable zooplankton community was established, the fish populations began to increase as well.

Period 2

A continuation in the decrease of phosphorus loading and the increase of adult walleye was documented during this timeframe. Alewife populations also decreased in the latter half of period two. The alewife is not preyed upon by the walleye, but its diet is restricted to zooplankton. These data infer that the alewife population decline may have been the result of competition with other fish for zooplankton, combined with its inability to utilize other food sources.

Period 3

Phosphorus loading began to stabilize as the walleye population reached the top of the chart. At the same time, the white perch was introduced. White perch consume zooplankton, benthos, and fish. This fish's versatile diet enabled it to compete with other species despite its status as prime walleye prey. The population of white perch continued to increase until 1988 when the zebra mussel appeared.

Period 4

The researchers caught about 15 percent fewer forage fish, during the fourth period. They projected that this may be the result of competition between gizzard shad and zebra mussels since both of these organisms consume zooplankton through very efficient filter feeding. Since walleye eat forage fish, it was logical that the number of walleye seemed to decline when the population of foragers declined. Whether or not the walleye actually decreased as much as the graph shows, is unknown since water clarity increased at this time making it easier for the walleye to evade capture.

Meanwhile, the amount of phosphorus pollution externally loaded into the lake has remained relatively constant. The bottom dwelling zebra mussels increase the amount of phosphorus in the water by ingesting phosphorus-filled benthos. That benthos, which was incorporated within the sediment, is forcefully excreted upward through the water column by the zebra mussels. This process adds to the total amount of phosphorus available to fertilize cyanobacteria (blue-green algae), which competes with zooplankton for living space and sunlight. The researchers infer that the amount of phosphorus suspended in the water will increase as zebra mussel abundance and activity increase. The consequent reduction in zooplankton is then expected to make it more difficult for young fish to survive. This will especially impact the fish that are only able to eat zooplankton.

The results suggest that change in zooplankton abundance has had a more drastic effect on young fish survival than the abundance of walleye adults, the main predators of young fish. This means that variation in the nutrients that support algal food on which zooplankton depend is essential for young fish survival. Management of Lake Erie's fisheries requires being able to predict the number of reproducing adult fish required to maintain a healthy, enjoyable fish population. Culver's research emphasizes the importance of the dynamics of nutrients, phytoplankton, and zooplankton in maintaining high recruitment of Lake Erie's sport fish and forage fish populations. *TL*

This article is based on an Ohio Sea Grant funded project by Dr. David Culver of The Ohio State University and this former graduate students, Gouthaman Gopalan, Lin Wu, and Bruce Trauben. For more information about this research, contact Dr. Culver at culver.3@osu.edu or 614/292-6995.

Research Review:

Zebra Mussels have Negligible Effect on Microbenthic Community

by Jill E. Jentes, Ohio Sea Grant Communications

While the appearance of zebra mussels in Lake Erie has been shown to impact the community structure of organisms in the water column, very little is known regarding their effects on the microscopic bottom dwelling organisms living on and in the lake's sediment. Continuing Ohio Sea Grant research by Dr. Robert Heath at Kent State University and Dr. Joseph Balczon of Westminster College, investigated how zebra mussels, as bottom dwellers themselves, interact with these microbenthic organisms.

The microbenthic community, composed of non-harmful bacteria and benthic fungi, is one of the least studied communities of the Great Lakes. These organisms, many of which reach 10 to 100 million cells per gram of sediment, are responsible for many of the lake's key ecosystem functions. Significant components of the phosphorus, nitrogen, and carbon biogeochemical cycles, for example, are all performed by these organisms.

Because zebra mussels eat at the lake's bottom, it is possible that their feeding activities could disrupt normal processes of the microbenthic community. Current research suggests that zebra mussels alter the structure of planktonic communities by efficiently removing small particles from the water column. "When zebra mussels ingest small particles, they either digest and excrete the particles as fecal pellets or transfer them as pseudofecal pellets through the mussels' inhalant siphons, " states Heath. What once was suspended in the water column is now a new energy source available to the benthic community. Does this energy transfer alter the benthic microbial communities?

To test whether these increases in particulate organic carbon and nutrients affect the community, the researchers used controlled laboratory experiments to replicate microbenthic communities. Their research found that the particulate releases from zebra mussels stimulated bacterial production and significantly increased bacterial numbers in the sediment – but only in sediments very low in organic content. These organic alterations to the sediments also extended protozoan abundance and influenced the protistan species that grew best. Although, zebra mussels' influence on microbenthic communities was greatest in sediments with very low natural organic content, the study showed that their effect appears to be minor in sediments with organic contents similar to those commonly found in Lake Erie.

"Our most reliable observations to date indicate that zebra mussels have a limited effect on the microbenthic community and are not likely to have drastic effects on sediment-based ecosystem functions," states Heath. ***TL***

For more information about this Ohio Sea Grant funded research, contact Dr. Heath at 330.672.7828, **rheath@kent.edu**, *or by visiting his web site at* ***www.kent.edu/wrri/***.

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Can Smallmouth Bass Weather the Storm?

by Lisa Denlinger, Ohio Sea Grant

As the smallmouth bass continues its prominence as a key sports fish in Lake Erie waters, fishery managers have recognized that in order to ensure future populations, they must identify factors that influence the species' spawning season. Ohio Sea Grant recently had the opportunity to assist a team of researchers funded by the Ohio Division of Wildlife at Stone Laboratory on Lake Erie. Led by Dr. Roy Stein, Dr. Elizabeth Marschall, and Geoffrey Steinhart of The Ohio State University, the team explored the most common dangers faced by young smallmouth bass.

"Several factors threaten the survival of young smallmouth bass," states Geoff Steinhart, the project's research associate. "Adequate parental care is crucial for the young along with a parent's ability to ward off the round goby. However, our research has found that the biggest dangers to the young fish are storms," continues Steinhart.

Adult male smallmouth bass guard their nests for approximately four to six weeks. During this time, each adult male fans its nest to protect the young from nest predators, such as the round goby. The fanning action oxygenates the surrounding water and prevents silt from suffocating the offspring.

Using video observations of smallmouth bass nest care along with bioenergetic modeling, the researchers will determine the average amount of energy smallmouth bass expend during nesting. Previous research has shown that when the energy levels of male small-

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mouth bass are depleted, the male will abandon its nest. With this abandonment, the fish forfeits its current offspring to survive long enough to successfully reproduce in the future. Predators that venture near the nest risk being eaten by the male smallmouth bass. The parents who gain nourishment in this way are able to guard their nests for longer time periods. Although attacking the nest-predators is energetically costly, this behavior may help to reduce the rate at which male smallmouths abandon their nests.

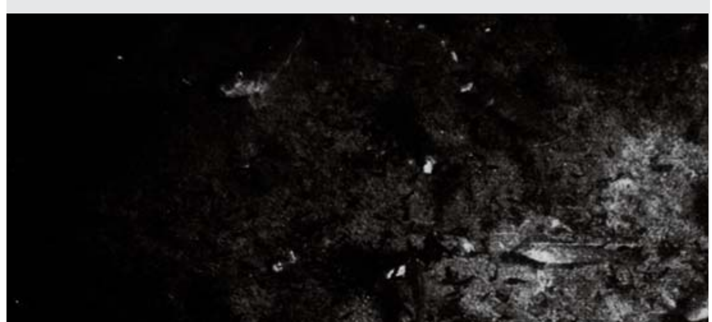
Round gobies may provide a quick meal to the busy male smallmouth bass, but this benefit probably does not balance the threat these invaders pose to smallmouth young. Male smallmouth bass must stay on their nests constantly to ensure that round gobies do not eat any of their offspring. To determine how much damage round gobies can cause to smallmouth bass nests during a catch and release scenario, the team developed an inventive approach to angling. While wearing scuba gear, team members were able to ideally position themselves to identify smallmouths tagged for their project. These divers then used conventional angling equipment to catch male smallmouths. The team found that nests left unattended for five minutes could lose an average of 500 offspring. Percentage loss varies with the age of each nest. Young nests can contain 5000 eggs while older nests contain approximately 2000 fry.

Strong underwater currents caused by storms can scatter debris, destroy nests, and cause young and adult fish to relocate. The researchers found that these events are by far the most lethal of all factors threatening smallmouth populations. Groundbreaking techniques were used to determine the rate at which smallmouth bass nests survive storms. The team constructed artificial nests and eggs by mimicking the measurements, design, and adhesive qualities of actual smallmouth bass structures. Nest replicas were then positioned according to smallmouth bass preferences.

During the initial four to six weeks, a male smallmouth bass fans its nest to protect the young from nest predators, such as the round goby.

Observation of the nests revealed that over the course of a storm, nearly 100 percent of the eggs were dislodged from the nests. This project defined a storm as a period of at least two hours during which winds were sustained at speeds greater than 15 miles per hour. These events substantially reduced nest success because most smallmouth bass spawn only once per season. Only 10 percent of the targeted fish whose nests were destroyed by storms spawned a second time within the area surveyed by Steinhart and his colleagues.

The smallmouth population in Lake Erie currently has one of the highest growth rates in the world. To maintain the abundance of this species in the lake, researchers will continue to identify factors that influence the spawning season of smallmouth bass. Anticipated projects using telemetry will track adult smallmouth bass to determine how their behavioral patterns affect overall population stability. ***TL***



New research found that smallmouth bass nests left unattended by their parents for five minutes could lose an average of 500 offspring due to the round goby.

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A New Look at Lake Erie's Artificial Reefs

by Jill E. Jentes, Ohio Sea Grant Communications

Since their construction beginning in 1984, Lake Erie's artificial reefs have been structures one could only view from under water. Until now. New research by Ohio Sea Grant researchers Scudder Mackey, Jonathan Fuller, Dale Liebenthal, and Dave Kelch has for the first time produced electronic images of eight artificial reefs in the Central Basin of Lake Erie.

Designed and placed in generally structureless bottom areas, artificial reefs have created new and diverse aquatic communities for the Lake. From the 3000 tons of broken sandstone material used for the Lakewood reefs (Big Test Reef and Little Test Reef) in 1984 to the 25,000 tons of Cleveland Stadium debris for the Stadium reefs in 1997, anglers and divers have seen fish concentrations around the reefs 20 to 60 times greater than in non-reef areas. However, until this new research, no guide had been made showing the details of the reefs' location and configurations.

Applying sidescan sonar, the researchers transmitted sound underwater to produce echoes or reflections from objects and materials on the bottom of the lake. The varying intensity, based on the density of the material, produced light and dark areas on the record called backscatter. Using the return from transmitted sound pulses to produce a continuous backscatter record of the lake bottom, the researchers digitized the field using a Triton Elics Data Acquisition system, geo-referenced each record, and assembled the records side-by-side into a mosaic. The side scan mosaics were then imported into Arcview Geographic Information System software, allocating latitude and longitude coordinates.

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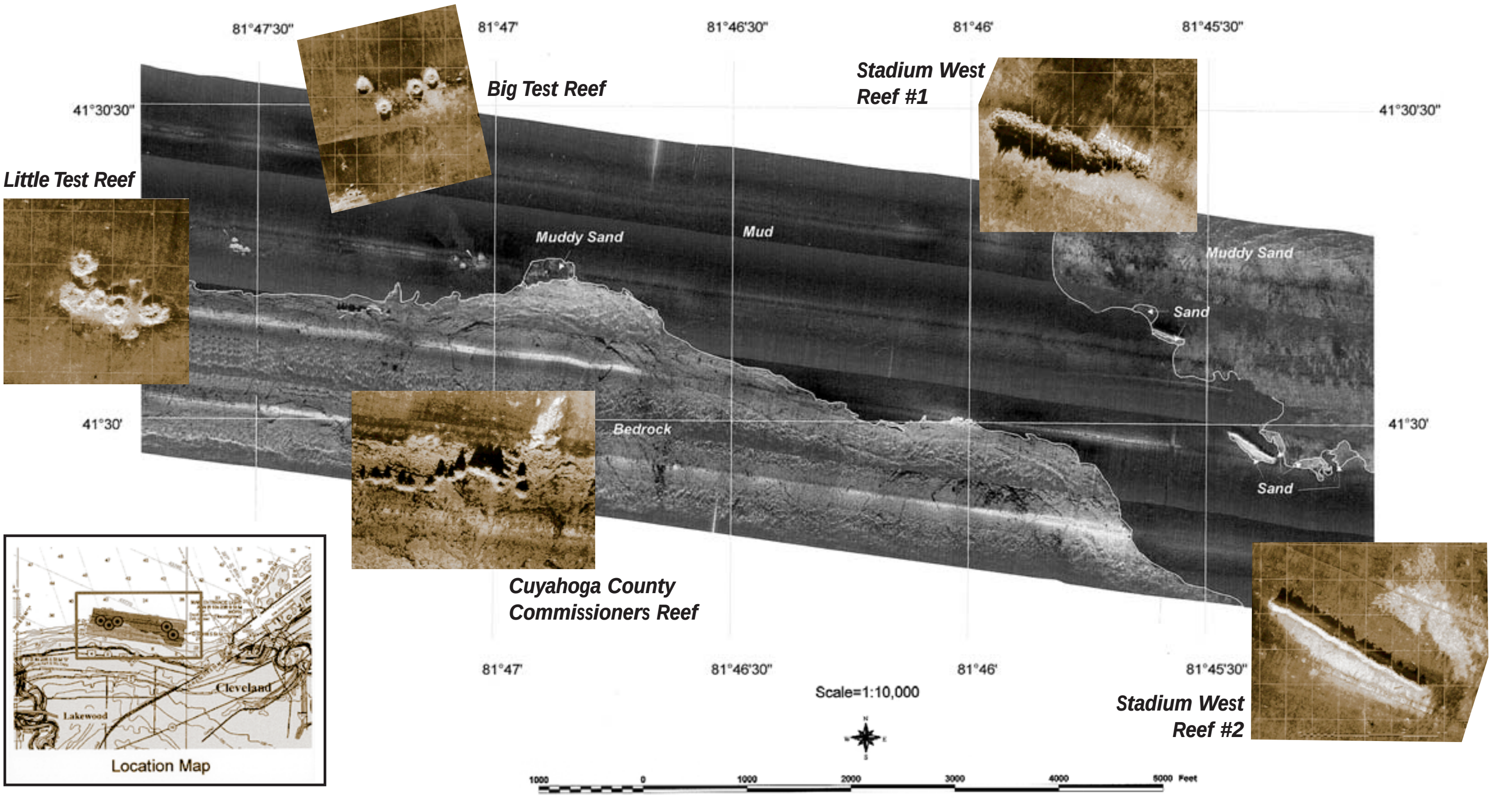
Lakewood and Stadium West Artificial Reef Complex Overall View



Artificial Reef General Mid Points of Area or Main Feature

Year	Reef	Latitude	Longitude	Easting	Northing
1997	**Stadium East**	41° 35' 55.785475" N	81° 33' 48.682088" W	453038.31000	4605389.59000
1997	**Stadium West #2**	41° 29' 58.087320" N	81° 45' 24.552960" W	436832.94000	4594481.68000
1997	**Stadium West #1**	41° 30' 08.748858" N	81° 45' 35.514123" W	436581.70000	4594812.70000
1984	**Big Test Reef**	41° 30' 15.146696" N	81° 47' 03.172584" W	434551.26000	4595028.15000
1894	**Little Test Reef**	41° 30' 16.365287" N	81° 47' 32.032438" W	433882.55000	4595071.83000
1987	**Cuyahoga County Commissioners**	41° 30' 10.688341" N	81° 47' 15.184795" W	434271.53000	4594893.19000
1989	**Lorain Mountain Reef**	41° 28' 08.912933" N	82° 12' 44.971266" W	398753.09000	4591547.94000
1986	**Lorain Polish Fishermans Club**	41° 28' 05.049949" N	82° 12' 43.223573" W	398791.96000	4591428.24000

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The images provide information useful in the construction of artificial reefs. “We learned from the construction of Big Test Reef and Little Test Reef that the ‘Dump scow’ method did not control where material went along with the height of the piles,” states Dave Kelch, Ohio Sea Grant District Specialist. “On the other hand, the ‘flattop barge with a front end loader’ method used in the 1986 Lorain site, caused continuous dumping, to provide a connecting reef for higher visibility for scuba divers. Comparing the different reef images makes it clear that off loading from a flattop barge is far superior to using a dump scow when constructing artificial reefs,” emphasizes Kelch.

The maps will also be important for the many people who use the reefs for recreation. “As the maps are overlayed with the longitude and latitude coordinates used by Global Positioning System (GPS), both anglers and divers should be able to easily locate specific areas of the artificial reefs for fishing and diving,” says Ohio Sea Grant District Specialist, Dave Kelch. The verification of the reefs’ locations will give recreational users a blueprint for the entire reef areas and their proximity to the shoreline. Knowing the exact coordinates will allow researchers to use the side scan maps to determine where exactly they want to research. *TL*

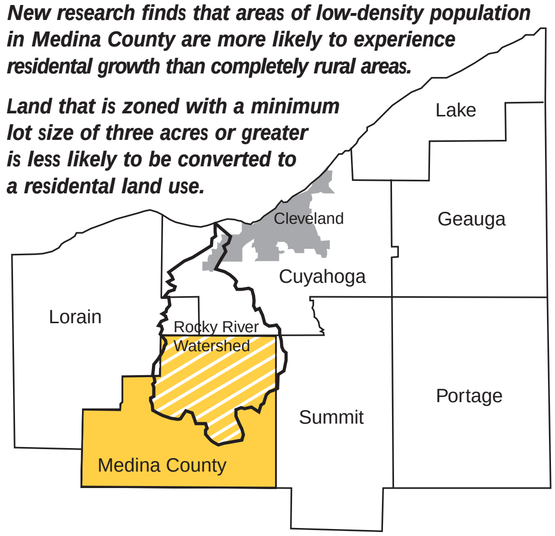
This Ohio Sea Grant funded research was conducted by Scudder Mackey, Dale Liebenthal, and Jonathon Fuller of Ohio Department of Natural Resources, Division of Goelogical Survey; and Dave Kelch of Ohio Sea Grant Extension. For more information about the artificial reef data along with viewing more of the sidescan sonar maps, log onto ***www.sg.ohio-state.edu/Project/f-index.html***.

Understanding the Spatial Pattern of Urbanization in Medina County, Ohio

by Carmen Carrion and Dr. Elena Irwin, Ohio State University, Agricultural, Environmental, and Development Economics

"Urban sprawl" is a term that has often been used to describe the pattern of land use changes in suburban and urban-rural fringe (or ex-urban) areas of the U.S. and in Ohio. The most common definitions include excessive spatial growth of cities, leapfrog development, in which the development pattern is scattered or fragmented, and excessive separation of land uses.

Urban sprawl affects water quality by increasing the rate of urban storm water pollution, which is the most rapidly increasing cause of nonpoint source pollution in Ohio.This pollution has negative impacts on the environmental quality of Ohio's ecosystems which include Lake Erie's tributaries and shoreline. Because urban storm water runoff is determined by the location of urban land relative to aquatic ecosystems, an understanding of the spatial pattern of land use conversion is important.



Rocky River Watershed & Medina County

With funding from Ohio Sea Grant, we are studying the spatial pattern of urbanization in Medina County, located in the Rocky River watershed (shaded area). Our project consists of four phases: (1) describe the spatial pattern of urbanization that has occurred in Medina County over time, (2) statistically identify the main factors that are driving the spatial pattern of conversion of farmland, forests, and other undeveloped land to urban land, (3) predict changes in urbanization patterns under different policy scenarios and (4) draw conclusions regarding the costs and benefits of policies that are most likely to minimize urban storm water pollution.

This article reports on results from the first two phases of our project. The first phase consisted of using parcel-level land use change data from Medina County to construct historical snapshots of the land use pattern between 1956-1996. We then used a variety of landscape measures to quantify different aspects of the spatial pattern of four different land uses at different points in time: residential, commercial, industrial, and undeveloped (including agriculture and forests).

Between 1956 and 1996, the percentage of undeveloped land of the total county area decreased from 95 percent to 77 percent. The rate of this conversion increased in recent years, especially after 1976, from 1.3 percent in 1956 to 3.0 percent in 1996. The amount of land in residential use increased from less than 4 percent of the total county area in 1956 to 18 percent in 1996, and, as of 1996, 85 percent of the developed land was in a residential use.

This rapid growth has been accompanied by an increase in fragmentation of both undeveloped and urban lands. Results from the application of several different landscape measures show that the location of new residential development has been the primary cause of this fragmented land use pattern. Specifically, we find that (1) on average, forested and agricultural areas have become progressively smaller in size over time, while the number of separate "patches" of forest and agriculture has increased; (2) larger undeveloped patches of land have become fragmented into smaller ones specifically due to intervening residential development; and (3) residential development has become less clustered over time, while commercial and industrial development have become more so.

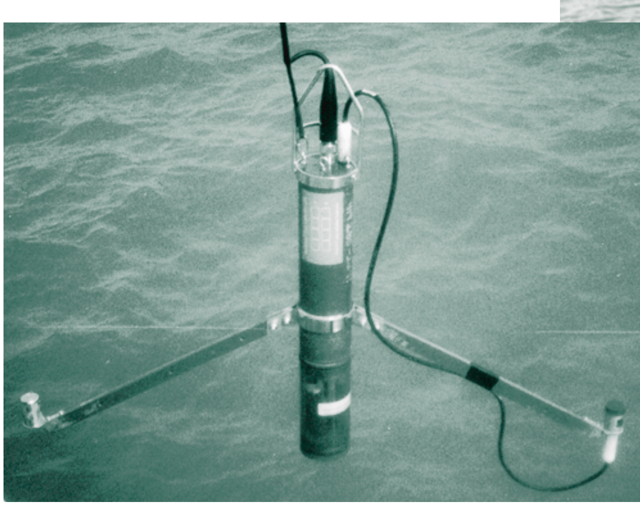
In the second phase of the project, we used statistical techniques to identify some of the determinants of this pattern of residential development. We find that areas of low-density population are more likely to experience residential growth, but also that residential development is less likely to occur in completely rural areas. This implies that people prefer to live closer to existing urban areas, presumably because of the services and accessibility that these locations offer, but at the same time dislike higher density areas that may be characterized by congestion and other negative effects of urbanization. The opposing positive and negative effects of urban areas explain why residential development has spread out, rather than become more clustered, over time.

We were particularly interested in how various government policies, such as land use zoning, have influenced the spatial pattern of growth. We find that the minimum size that a lot is zoned has a significant effect on the likelihood that it is converted to a residential land use. Specifically, land that is zoned with a minimum lot size of three acres or greater is less likely to be converted. This implies that larger minimum lot sizes have increased the dispersal of residential development.

These results can be used to predict the probability of future residential land use conversion for those parcels that are still undeveloped, but that could be developed in the future. In phases three and four of the project, we will use the results from the statistical analysis to predict changes in land use patterns under different policy scenarios, e.g. alternative zoning regulations. Lastly, we will use these results to draw implications about which policies may contain the future pace and pattern of urbanization in ways that reduce urban storm water pollution and minimize the adverse affects of development on the environmental quality of Lake Erie. For more information about this Ohio Sea Grant funded research, contact Dr. Irwin at 614.292.6449 or ***irwin.78@osu.edu*** TL

Lake Erie Monitoring Network Launched

by Dr. Chris Stanton, Ohio Sea Grant



Left: This monitoring instrument is keeping track of physical and chemical conditions in Lake Erie near Stone Laboratory.

Above: Samples collected by students at Stone Lab are now being incorporated into the Lake Erie Monitoring Network (LEMNet)

Many researchers and residents along Lake Erie are referring to this year as "unusual." In addition to lower water levels, the year 2001 has brought a long ice season, an unpredictable mayfly emergence, increased amounts of green algae, and wildly fluctuating oxygen levels. But are these observations truly "unusual?"

In order to answer this question, we need to have long-term records of lake conditions to which to compare current conditions. For example, when a weatherperson on television says, "today's temperature will be unusually mild," that statement is based on comparing the current conditions to the average of years of air temperature records. However, researchers and other interested parties do not have access to such long-term data for most of Lake Erie's vital conditions.

This need for long-term records of lake conditions is accentuated by increased environmental concerns, such as global climate change and aquatic nuisance species. To help address these needs and concerns, Stone Laboratory has launched a monitoring program to compile Lake Erie data and make that information available to anyone interested. Known as LEMNet (Lake Erie Monitoring Network), this effort consists of a multifaceted approach to data collection.

Since 1973 Stone Lab has offered aquatic science workshops during the spring and fall. These popular workshops introduce students and other audiences to the ecology of Lake Erie and the various methods used to study it. The primary component of these workshops is a "science cruise," in which participants go to various parts of the lake on a research boat and collect water data and biological samples, such as plankton, benthos, and fish. Due to enormous interest from school groups, cruises are conducted at least once a day, six days per week. The information collected during each cruise is now being stored in a LEMNet database that will be made available later this year.

During the summer, the workshop program is scaled back in order to offer college-level courses, which have been taught at Stone Lab since 1900. Classes, such as Aquatic Biology and Limnology, sample and record lake conditions in a similar manner to the workshop activities. The observations made by these classes, as well as by classes taught during the Lab's long history, are now being incorporated into the LEMNet database as well.

In order to extend data collection year-round, Stone Lab purchased a monitoring instrument last year with funds from the Ohio State University Office of Research and the Ohio Board of Regents. This instrument has been anchored in the water near Gibraltar Island and is programmed to take hourly readings of ten physical and chemical parameters. Among the conditions being monitored are water temperature, turbidity, dissolved oxygen, chlorophyll, and photosynthetically active radiation (PAR). This unit survived its first winter, recording data under the ice from December to March.

Although other institutions and agencies (such as the EPA and the Ohio Division of Wildlife) also collect similar data, the information is not always accessible to those interested. A key part of LEMNet is to make the information available to everyone, including the students and teachers who have helped with the actual data collection. With this goal in mind, a LEMNet web site has been created that contains Stone Lab data as well as links to other pertinent data sets. The address for this site is ***www.sg.ohio-state.edu/slab/LEMNet/index.cfm***, or it can be accessed from the Stone Laboratory site at ***www.sg.ohio-state***.

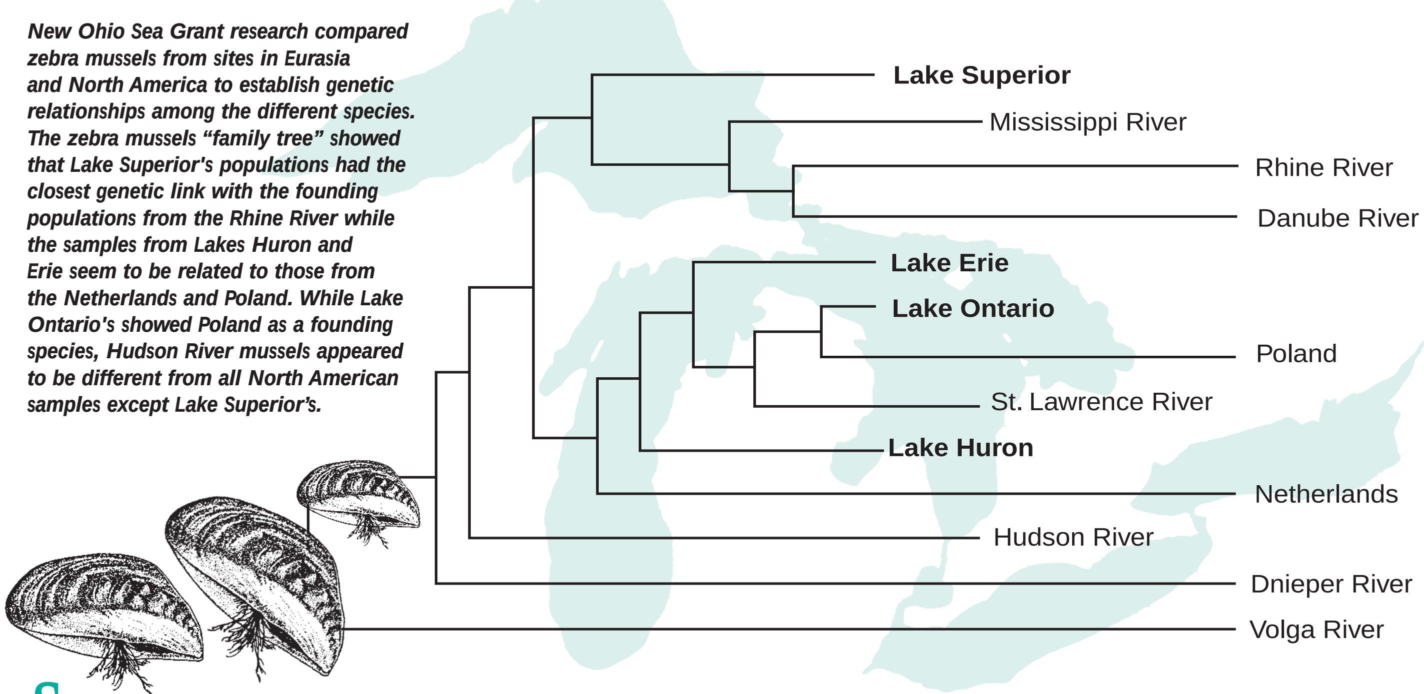
Obviously more monitoring and data collecting is needed to more completely record Lake Erie conditions. However, it is hoped that LEMNet will also serve as an important first step in establishing the kind of long-term record keeping that is needed by researchers and others who are interested in better understanding the lake. Lake Erie is a unique and dynamic system, so determining how unusual conditions are from year-to-year requires more long-term information.***TL***

For information about how to become a part of LEMNet, please contact Dr. Jeff Reutter at reutter.1@osu.edu. *For more information about Stone Lab's workshop program, contact John Hageman at* Hageman.2@osu.edu.

Research Review:
The Origin of the Great Lakes Zebra Mussels

by Jill E. Jentes, Ohio Sea Grant Communications

New Ohio Sea Grant research compared zebra mussels from sites in Eurasia and North America to establish genetic relationships among the different species. The zebra mussels "family tree" showed that Lake Superior's populations had the closest genetic link with the founding populations from the Rhine River while the samples from Lakes Huron and Erie seem to be related to those from the Netherlands and Poland. While Lake Ontario's showed Poland as a founding species, Hudson River mussels appeared to be different from all North American samples except Lake Superior's.



Since the zebra mussels first invaded the Great Lakes in 1988, research has centered around the basic biology of the mussels, methods to control and prevent their spread, and understanding the impacts these mussels have had on the Great Lakes' economy and ecology. But the question of where exactly these mussels came from still lingered. New Ohio Sea Grant research by Dr. Carol Stepien of Cleveland State University has begun to answer that by comparing the genetics and divergence patterns among the zebra mussel populations in North America to their native counterparts in Eurasia.

Stepien analyzed 106 individual zebra mussels (*Dreissena polymorpha*) taken from six sites in Eurasia including Lake IJsselemeer near Amsterdam, Netherlands; the Rhine River at Vuren, Netherlands; Wtoctawek Reservoir, Poland; the Danube River at Budapest, Hungary; the Dnieper River in the Ukraine; and the Volga River in Russia. These individuals were compared with 174 zebra mussel samples from seven locations in North America, including Duluth Harbor, Minnesota, Lake Superior; the Mackinaw Straits between Lakes Huron and Michigan; Put-in-Bay, Ohio, western Lake Erie; Cape Vincent, New York, eastern Lake Ontario; the St. Lawrence River at Gentilly, Quebec; the Hudson River at Struyvesant, New York; and the lower Mississippi River at Baton Rouge, Louisiana.

Stepien found that similar to their Eurasian counterparts, zebra mussels in North American samples had a surprisingly high genetic variability. "Because of their present wide range of genetic differences, the results of this study suggest that there weren't a few zebra mussels, but more than likely, large numbers of different zebra mussels that invaded the Great Lakes," explains Stepien.

The study used its data to construct a zebra mussel "family tree,"depicting the genetic relationship between the North American populations and the Eurasian populations (*see chart*). Stepien discovered that the invasion of the zebra mussels in North America appears to have been founded by many sources in northwestern and northcentral Europe, from which most shipping to the Great Lakes originates. The closest genetic matches were with zebra mussels from the Netherlands, the Rhine River, and Poland. Samples from central, southern, and eastern Europe (encompassing the Danube, Dnieper, and Volga Rivers) were very different from the North American zebra mussels, showing that they did not found the invasive populations. Lake Superior had the closest genetic link to a founding population from the Rhine River while the samples from Lakes Huron and Erie appear to be related to those from the Netherlands and Poland. Samples from Lake Ontario and St. Lawrence River showed a genetic relationship with the sample from Poland and the Mississippi River sample appears to be related to a possible founding source from the vicinity of the Rhine River. Hudson River mussels showed a less clear relationship, appearing most similar to the Rhine River and Netherlands sites and were different from all North American sample except Lake Superior's.

Stepien hopes the results of this study will help us better understand how the zebra mussels are spreading in the Great Lakes. Unfortunately for the Great Lakes, their diverse genetic variations will mean an even harder time for the Great Lakes to try to control them. ***TL***

This Ohio Sea Grant funded research was conducted by Dr. Stepien, Cliff Taylor, and Kora Dabrowska of the Center for Environmental Science, Technology, and Policy at Cleveland State University. For more information about this research, contact Stepien at c.stepien@csuohio.edu *or see her web site at* ***www.csuohio.edu/cestp/ glegl/glegl.html***

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TWINE LINE

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The Algae That Ate Lake Erie

Engineered Algae Could in the Future Bind to Trace Metals in Lake Erie Sediment

by Jill E. Jentes, Ohio Sea Grant Communications

As populations have grown and industrialized around the Great Lakes, major cities of the lakes have been burdened by the increase of trace metal accumulation in lake sediment. The cities of Cleveland and Toledo, with their mining, smelting, and manufacturing operations, now battle the negative outputs of their fortunes. Trace metals like mercury, cadmium, and zinc, by-products of these operations, have accumulated in Lake Erie sediment. Once thought to be forever locked in sediment, zebra mussels and round gobies, have served as the bridge between the metal-laden sediment and humans, with metal concentration levels increasing as they travel through the food chain. Today trace metal pollution is now being linked as a source for various neurological disorders, organ diseases, and some cancers for humans.

Although scientists know what can cause these diseases, the means to retrieve the metals from Lake Erie sediment have been difficult. Unlike organic pollutants, trace metals cannot break down and must therefore, be completely removed from the sediment. To do this, these metals have traditionally been extracted using chemical engineering approaches. While effective, these costly methods cannot select specific metals to remove and result in large amounts of waste. Continuing Ohio Sea Grant research led by Drs. Richard Sayre, and Sam Traina of Ohio State University and Dr. Lada Malek of Lakehead University is developing a new approach to remove heavy metal contamination with the use of the genetically altered alga, *Chlamydomonas reinhardtii*.

A unicellular alga found abundantly all over the world, *Chlamydomonas reinhardtii* was chosen by the research team because of its abilities to be genetically engineered and to be grown quickly and in high volumes. "*Chlamydomonas* can withstand a wide range of heavy metal concentration levels, an important attribute if you want to use it to remove heavy metals. We hope this research increases the alga's ability to attach itself to heavy metals in Lake Erie sediment," explains Sayre, leader of the project.

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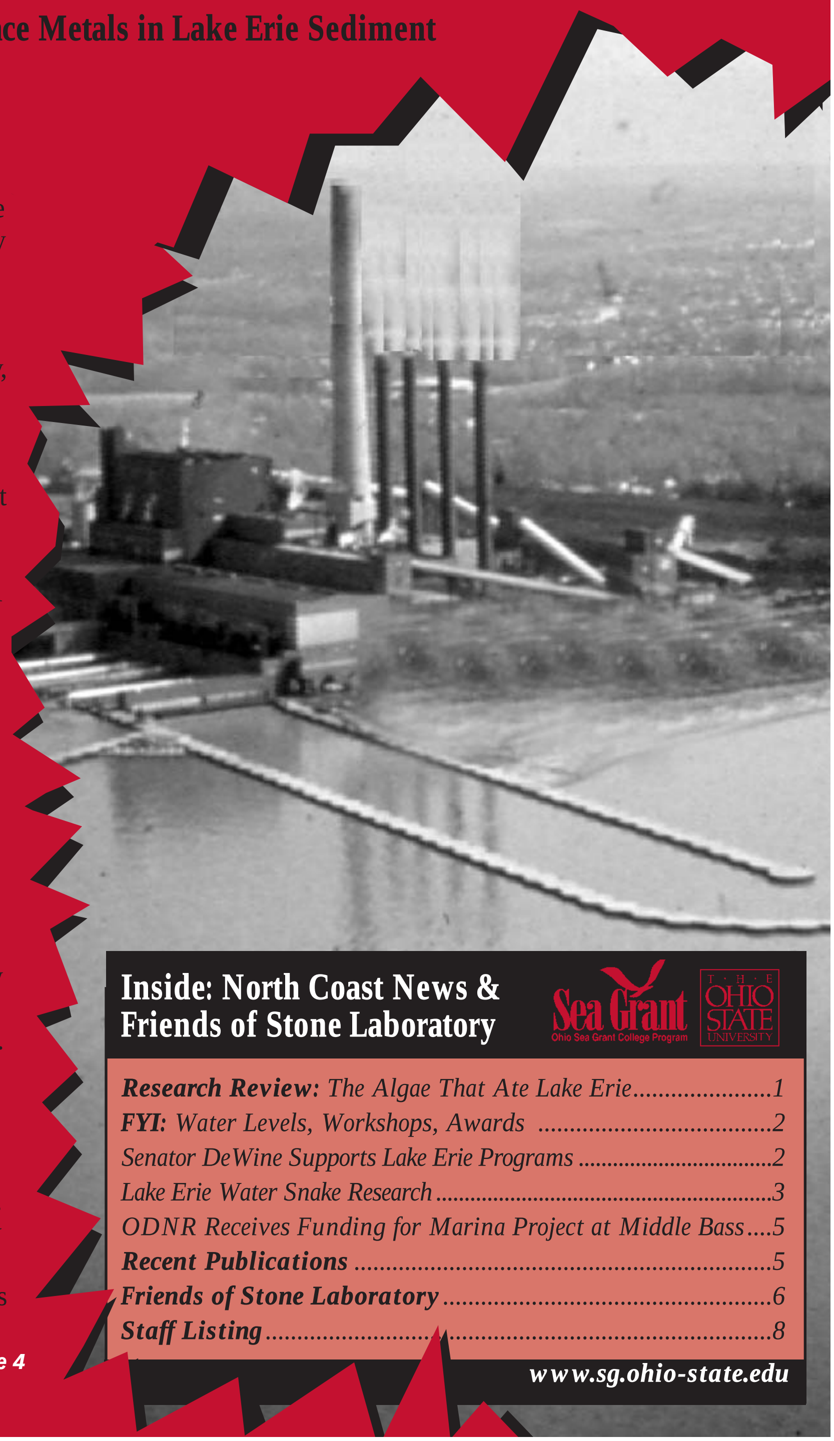

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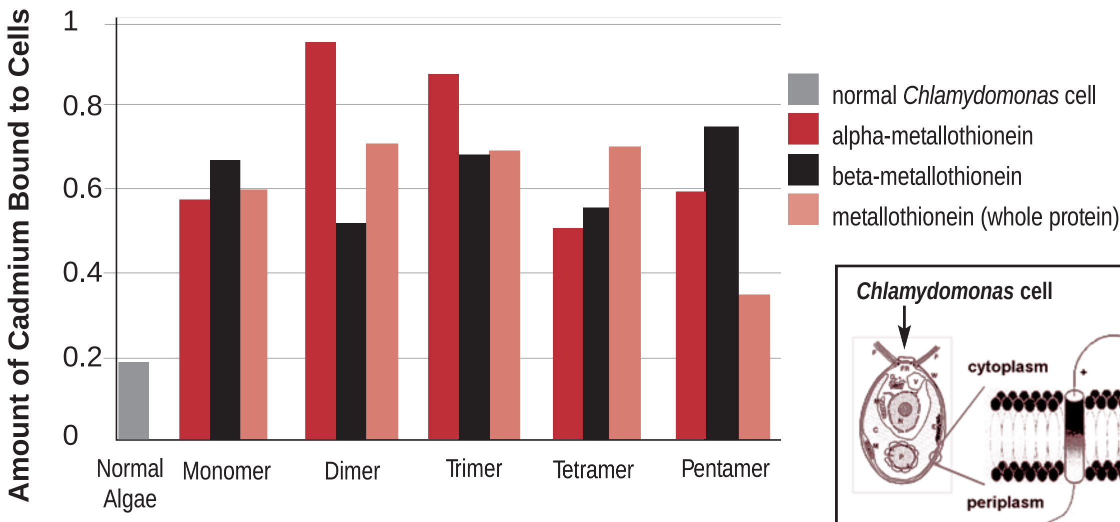

With a variety of sizes and shapes of metallothionein proteins linked to Chlamydomonas *cells, Sayre has been able to increase the ability of its cells to bind to cadmium by 80 to 400+ percent.*

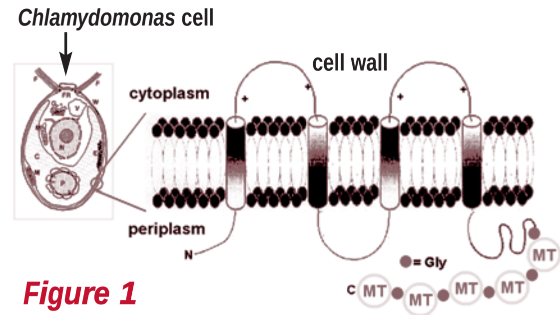

Figure 1

Ohio Sea Grant research attached metallothionein proteins on the outside of Chlamydomonas *cells to see if they would increase the cell's ability to bind to the heavy metals. Attaching the metallothioneins (MT) on the outside of the cell increased heavy metal binding as much as five-fold and allowed the algae to grow roughly three times faster in toxic concentrations of heavy metals.*

Figure 2

Cadmium binding capacity of normal and transformed *Chlamydononas* with several forms of metallothionein (alpha-type, beta-type, and whole protein in chains 1 [monomer] to 5 [pentamer] units long) attached to its cell's membrane and grown in a cadmium solution

ALGAE ***Continued from Page 1***

In separate experiments, the researchers used three different strategies to enhance *Chlamydomonas*' ability to bind metal. They first increased the algae's production of proline. An amino acid produced when a normal cell is stressed, proline keeps the cell from being overly stressed as its heavy metal levels increase. By altering the algae, the team could produce 80 percent more proline within the alga cell. "We found that this increase of proline allows the algae to bind four times more metal than the unaltered normal alga cell," states Sayre.

In another strategy, the study increased the alga's production of cysteine, another amino acid in the *Chlamydomonas* cell. "Because cysteine binds with cadmium in the form of phytochelatins, our interest in this phase is to increase its content in cells," Sayre emphasizes. The study found that *Chlamydomonas* cells having enhanced cysteine synthesis bound 50 percent more metal than normal cells.

The team also attached metallothionein (a protein that binds heavy metals) to the outside of the cell to see whether its presence would increase the *Chlamydomonas* cell's ability to bind heavy metals (see Figure 1). Because the metallothionein protein was outside of the cell, the metallothionein intercepted the metal before it got into the *Chlamydomonas* cell, thus, allowing more metals to bind and preventing the metals from killing the cells. Attaching the entire metallothionein protein (or its alpha or beta components individually) on the outside of the cell increased heavy metal binding as much as five-fold and allowed the algae to grow roughly three times faster in toxic concentrations of heavy metals. To see if that binding could increase as more metallothionein units were added, the team attached chains (polymers) of up to five metallothionein proteins (or its alpha or beta subunits) to the *Chlamydomonas* cell (see Figure 2). "We found that adding up to five intact metallothionein proteins or its alpha or beta domains, increased the *Chlamydomonas* cell's metal-binding capabilities two to five times more than that of a normal cell," explains Sayre.

The researchers plan to continue the study through the next year, determining how much of each trace metal binds to the *Chlamydomonas* cell and preparing to work with engineering firms to test pilot facilities for treatment of contaminated wastes and sites. For these purposes the investigators propose to use dried algal powders to preclude the escape of live algae into the environment. "By increasing the algae's ability to attach to trace metals, we believe this research will be an important step in the identification of the best strategies for reducing heavy metal pollution and the remediation of contaminated sites and waters of the Great Lakes," concludes Sayre. ***TL***

For more information about this Ohio Sea Grant funded project, contact Dr. Sayre at sayre.2@osu.edu or visit his web site at ***www.biosci.ohio-state.edu/~rsayre/index.html****. For a related article, see the July/August '98 issue of* Twine Line, *available on our web site at* ***www.sg.ohio-state.edu.***

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TWINE LINE

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Diner's Choice

New Research Explores How One Exotic Species Affects Another's Behavior

by Jill Jentes Banicki, Ohio Sea Grant Communications

When the round goby invaded the Great Lakes in the 1990s, many scientists scrambled to document what effects this new aquatic nuisance species would have on the Lakes' native species and ecosystems. As in past cases, when a foreign species invades a territory, it can displace its native counterpart and impact the food dynamics of the environment. However, what if there is already another aquatic nuisance species in the environment? How will these species interact and affect each others' behavior in the surrounding ecosystems?

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Continuing Ohio Sea Grant research by Dr. María González of Miami University, is exploring the interactions among three exotic species, the round goby, the amphipod *Echinogammarus ischnus*, and the zebra mussel as well as the effect these exotic species have had on native species of amphipod and fish.

Before the round goby invaded Lake Erie, macroinvertebrates such as the native amphipod, *Gammarus fasciatus (G. fasciatus)*, were abundant in the western basin of Lake Erie. Zebra mussels plagued the Lake by the late 1980s and altered its habitat complexity and food availability like the mussels had in Europe. Benthic invertebrates such as *Gammarus fasciatus* increased dramatically. However, the zebra mussel made the Lake's ecosystem more susceptible to exotic invasions from species associated with zebra mussel colonies.

By July of 1995, the exotic amphipod, *Echinogammarus ischnus (E. ischnus)* was found in western Lake Erie. "We discovered that the exotic species represented 40 percent of the amphipods collected in the western Lake Erie basin," stated González.

"This finding suggested that the exotic was displacing the native amphipod in the zebra mussel habitat before the round goby invasion."

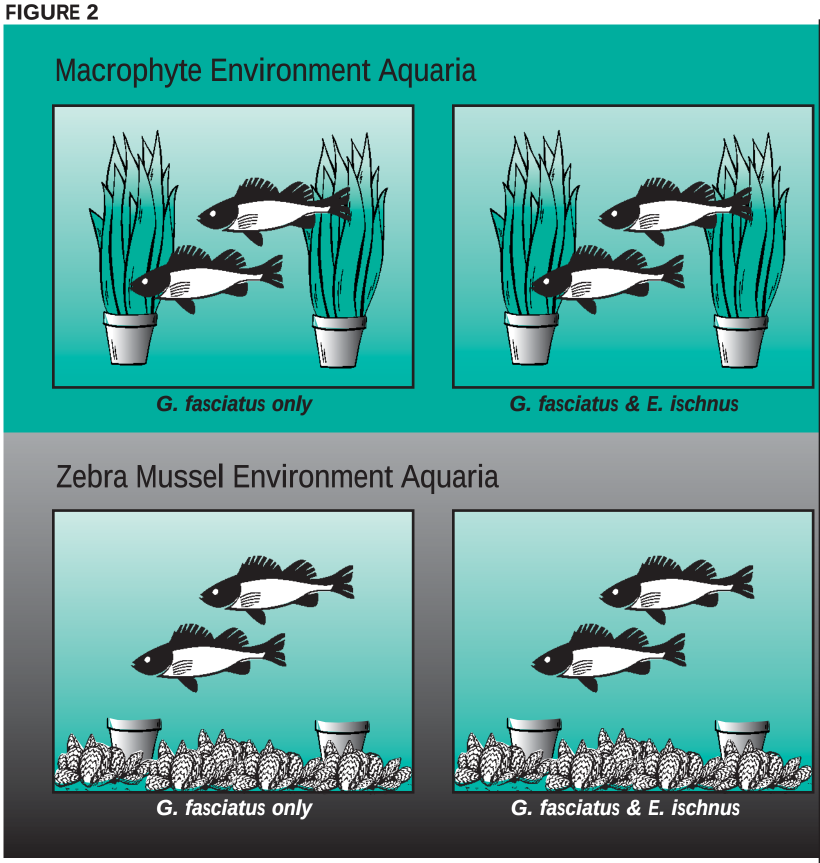
Further field research in 1996 and 2001 observed that the exotic amphipod dominated the native species in the zebra mussel environments by over a 2:1 ratio in 1996 and a 10:1 ratio in 2001 *(Figure 1)*. However by 2001 (after the round goby invasion), the overall amphipod population decreased drastically. The abundance of the exotic amphipod dropped 95 percent and the native species dropped 98 percent from 1996.

But this exotic domination was only in zebra mussel environments. The study discovered that while the exotic amphipod was the prevailing species in a zebra mussel environment, the native amphipod was still the dominant species in the macrophyte environment.

To explain why there was such a drastic difference in amphipod populations in the zebra mussel and macrophytes, González investigated 1) how the type of environment could affect fish predation patterns; 2) whether intraguild predation (predation among potential competitors) and cannibalism occurs in the amphipod populations; and 3) how the introduction of the round goby has affected the amphipod and yellow perch populations.

The study compared the predation rates of yellow perch and round gobies on amphipods under laboratory conditions using aquaria, imitating macrophyte and zebra mussel environments *(Figure 2)*. To represent macrophytes, a dominant regional macrophyte was used on the aquaria floor along with substrate material. Premeasured zebra mussels attached to rock represented the zebra mussel habitat and two hundred amphipods (100 exotic and 100 native) were used. Two fish were introduced to each aquarium for 24 hours. After the 24 hours, the fish were removed and preserved for stomach content analysis.

FIGURE 2

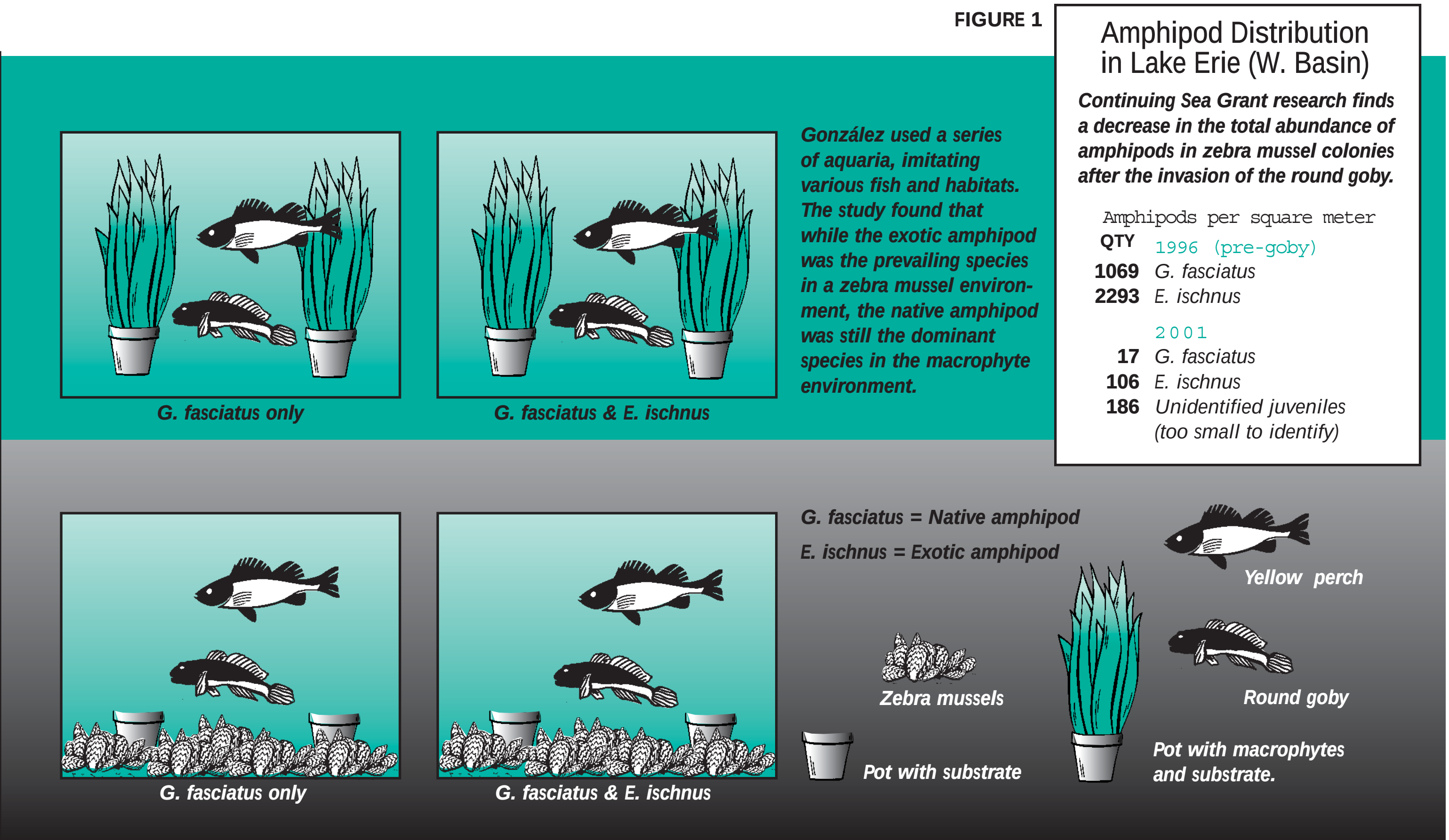


"We observed that both round gobies and yellow perch had a distinct amphipod preference depending on which environment they were in," emphasized González. González's data suggest that both fish consumed a higher number of native amphipods than exotic amphipods in dreissenid colonies. However both fish consumed a higher number of exotic than native in macrophyte beds (*Figure 3*). This can have implications for the coexistence of both amphipod species. These laboratory experiments also showed that round gobies exhibited higher predation rates than yellow perch. "These results indicated that the round goby is a strong competitor for yellow perch in both habitats," explained González.

The differences between the fish predation in macrophyte environments versus those in zebra mussel environments may be partly due to variations in the amphipods' coloration, shapes, and behaviors. González's study observed that whereas the native amphipod likes to cling to surfaces, the exotic species has a tendency to swim, making it easier to become prey. The native amphipod possesses a gray color matching the macrophyte environment, the exotic species maintains a very contrasting brown color highlighted with red antennae. Since fish are visual feeders, the exotic amphipod is more vulnerable to predation in a macrophyte environment.

In a zebra mussel environment, González found that the amphipod body shape may determine an amphipod's resistance to capture. Because the exotic species are more slender in shape than the native counterparts, the exotic

FIGURE 1



amphipods may hide easier in the clustered zebra mussel crevices to elude fish.

The study also investigated whether predation between the two-amphipod species could play a role in the drop of amphipod populations. Under laboratory conditions, González's early research results found that the native amphipods appeared to be more aggressive than their exotic counterparts. Therefore predation of the native amphipod on the exotic is greater than the predation of the exotic amphipod on the native. Males were more aggressive than females or juveniles.

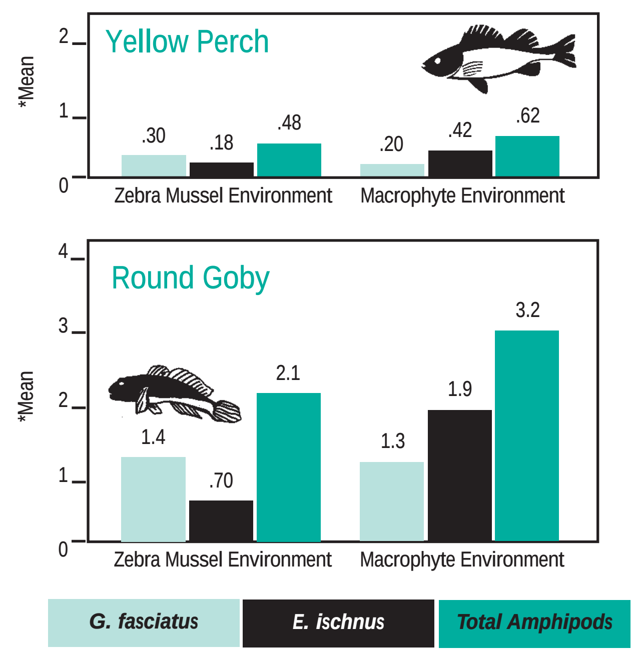
González and her students plan to conduct a large-scale enclosure experiment later this year to test the effect of the round goby on yellow perch growth rate. "Fish managers should be aware of the potential effects of fish enhancement projects which may provide gobies with advantages over more desired species. By comparing the competitive interaction among exotics to their native counterparts, we hope the findings from this study could be incorporated into the decision-making process involving future habitat restoration projects," concluded González.

This project was made possible with the help of graduate and undergraduate students including: Greta Burkart, Lisa Jeter, Kim Kozac, Janelle Duncan, Zackary Sutphin, Leslie Knolls. For more information about this Ohio Sea Grant funded project, contact Dr. Maria González at *gonzalmj@muohio.edu* or 513.529.3189. ***TL***

FIGURE 3

Predation Rates of Yellow Perch and Round Goby in Zebra Mussel and Macrophyte Environments

González found that round gobies exhibited higher predation rates than yellow perch. These results indicate that round gobies are strong competitors for yellow perch in both zebra mussel and macrophyte environments.



**** Number of amphipods consumed by each fish species per grams of fish.***

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TWINE LINE

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Entering the Zone

Aquatic Nuisance Species, Combined Sewers, Agricultural Run-Off, and Low Water Levels May be to Blame for Dead Zone Frequency in Lake Erie

When the Cuyahoga River caught on fire in 1969, the nation watched in amazement as the body of water and symbol of the Great Lakes burned. Phosphorus mainly from sewage treatment plants and agricultural run-off was deemed the problem and the nation wondered how officials would rectify it. Scientists and regulators quickly responded by strategically placing pollution monitoring stations on the Lake's tributaries, upgrading sewage treatment plants, and establishing phosphorus loading targets for the Lake. The Lake reacted to these adjustments with better water quality, an improved fishery, and the return of the mayfly.

But phosphorus levels have risen since 1995, bluegreen algae has returned, and dissolved oxygen has been dropping to create the largest area of low oxygen or "dead zone" since the early '80s.

Scientists thought they had the problem licked by phosphorus controls, but if trends continue for another three years, Lake Erie may confront problems similar to what it had in the '60s and '70s.

This isn't new to Lake Erie. It has experienced these no oxygen zones on and off for years. However, the difference in the last few years has been the consistency and the magnitude of these anoxic areas. Even with phosphorus reduction practices in place, we're still getting areas of anoxia. And recently, we've been getting them consistently and for longer periods of time.

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Lake Erie's Geology

Lake Erie is divided into three basins based on shape and depth. The Western Basin is the area west of Sandusky with an average depth of only 24 feet. The area east of Erie, Pennsylvania is the Eastern Basin, averaging 80 feet in depth and containing the deepest point in the Lake (212 feet). The Central Basin is the large area between Sandusky and Erie with an average depth of about 60 feet. While the Western and Eastern Basins have irregular bottoms with a lot of variation in depth, the Central Basin's bottom is very flat.

Thermocline in Lake Erie

When the surface water is warmed by the summer sun, Lake Erie forms temporary layers. The warmer surface water known as the epilimnion is lighter and "floats" on top of the cold bottom layer or hypolimnion. The line of rapid temperature change between these two layers is called the thermocline and typically forms around 45 to 55 feet from the surface of the Lake. The cold bottom layer of the Central Basin is the home of the dead zones. Based on the depths of the three basins, the Western Basin is too shallow to have a thermocline except on rare occasions. Although the Eastern Basin will have a thermocline, there will be more water (and thus, more oxygen) below it in the cold bottom layer because it is so deep.

At the time the thermocline forms in the spring, there is plenty of dissolved oxygen in the Central Basin's bottom layer. Due to its depth, there is often no way to replenish oxygen in this cold bottom layer until the thermocline disappears in the fall. Oxygen that was present when the thermocline formed, is used by organisms living in this area throughout the summer. Phosphorus from sewage treatment plants and agricultural run-off fertilizes algae in the Lake. When that algae sinks to the bottom and decomposes, the process of decomposition uses up too much oxygen and that portion of the Lake becomes anoxic. If we could reduce the amount of algae, we could reduce the amount of oxygen required to decompose it.

Possible Causes of the "Dead Zone"

The combination of aquatic nuisance species, combined sanitary and storm sewers, agriculture run-off, warm temperatures, and low water levels may be increasing the frequency and area of the anoxic zone in Lake Erie, according to Ohio Sea Grant and EPA researchers. It is likely that further efforts to reduce phosphorus loading will solve the problem. However, research is currently underway in an effort to definitively answer this question.

Human contributions to high phosphorus levels and the ensuing dead zone have plagued Lake Erie for many years. Ohio State University researchers noted the first dead zone off Sandusky Bay as early as 1930. In the 1960s and 1970s, thousands of tons of phosphorus from sewage treatment plants and other sources were dumped in the Lake, causing the entire lake to be declared dead as oxygen was eliminated from up to 90 percent of the bottom waters in the Central Basin.

Researchers in the early days of the Ohio State's Center for Lake Erie Area Research (CLEAR) focused on this problem, which led to the phosphorus reduction strategies. Phosphorus loading was reduced from 29,000 metric tons in 1969 to the target of 11,000 metric tons by the 1980s. This ultimately led to the recovery of Lake Erie.

Since the mid-1990s scientists have observed phosphorus levels in the Lake increasing again. Many are looking at the official phosphorus loading estimates and questioning how accurate they are. Because the figures are based on estimates and volunteer reporting by polluters, they may be lower than what is actually going into the Lake.

It is also probable that zebra mussels may be, in part, to blame for the anoxic state of the Lake. As they process organic matter, they excrete phosphorus into the water column where it can be repeatedly used, instead of allowing it to settle out into the sediments. "The recycling of phosphorus again fuels the growth of plants that die, sink to the bottom, consume more oxygen, and the cycle repeats," states Dr. David Culver, an Ohio Sea Grant researcher. Culver and others have observed that quagga mussels are rapidly replacing zebra mussels and that quagga mussels may release more phosphorus than zebra mussels.

In addition to aquatic species, heavy rains this spring may have increased phosphorus loading to the Lake from agricultural runoff and sewage overflows. Unfortunately, there are still many sewer systems in existence where storm sewers are combined with sanitary sewers. In these cases, whenever there is a significant rain, raw sewage (and phosphorus) is dumped into the environment.

The dead zone problem is also exacerbated by low water levels that reduce the thickness and volume of the hypolimnion, and, therefore, the amount of oxygen it can hold. Some of the problems that have been observed include: low dissolved oxygen levels around Stone Laboratory in 2001, an area of anoxia observed in the Central Basin in 2001, loss of mayflies near Cleveland in 2001 and 2002, and cloudy water (poor visibility) near the artificial reefs in Cleveland (observed periodically since 1999).

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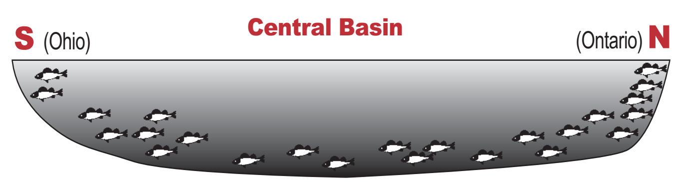
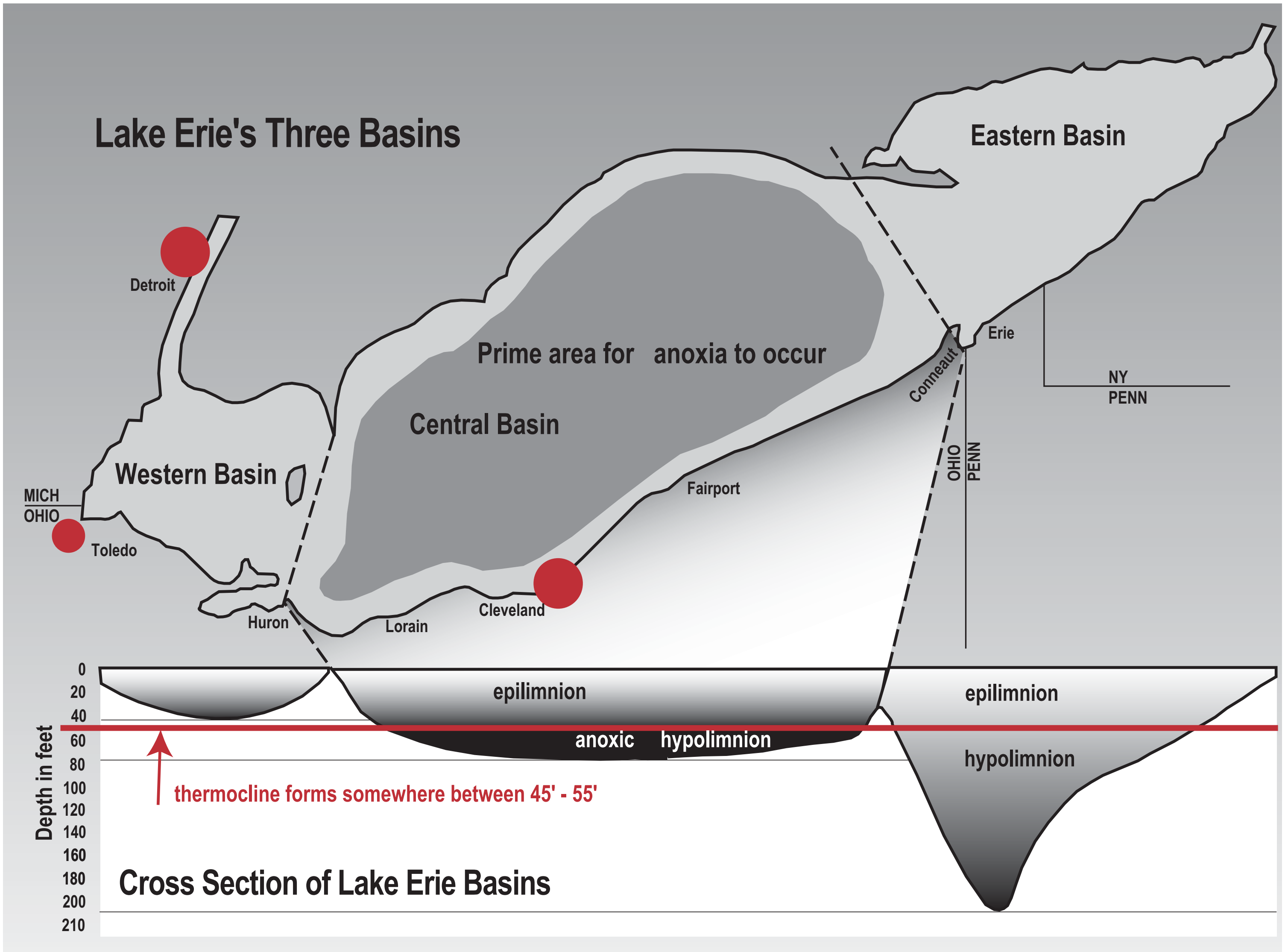
How the "dead zone" may impact aquatic life in Lake Erie

Lake with no stratification *(Fall/Spring)*



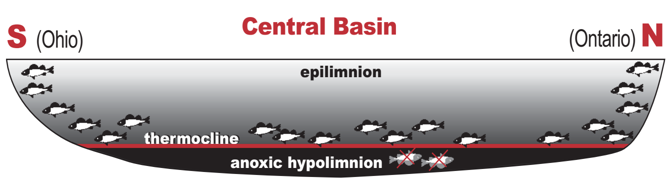
When no stratification (temperature layering) is present, oxygen levels will be sufficient from surface to bottom. Fish location will depend upon the location of food sources and preferred or typical habitats for a given fish species. During the spring, some species will be found closer to shore and in shallower depths for spawning. Food, however, will be the dominant variable in location.



Adapted from the *Lake Erie Report,* Department of the Interior, 1968

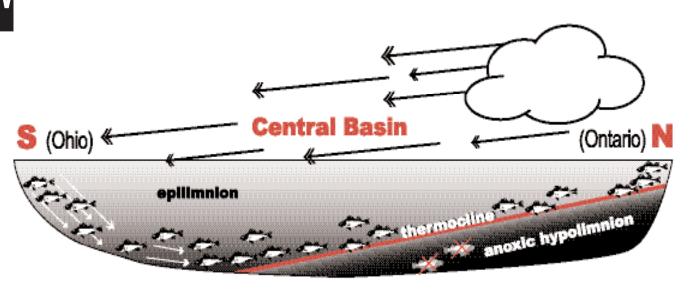
How the "dead zone" may impact aquatic life in Lake Erie

Stratified lake with anoxic hypolimnion *(July/August)*



When stratification occurs the lake separates into 2 distinct layers, a warm top layer (epilimnion) and cooler bottom layer (hypolimnion) with a thermocline (area of rapid temperature change in between layers) forming somewhere from 45 to 55 feet. If anoxic conditions develop in the hypolimnion, fish will seek higher oxygen levels by rising up and into or above the thermocline, or by moving shoreward into shallower water depths, also above the thermocline. Temperatures inside and above the thermocline are cooler than the surface layer, with an abundance of forage species also preferring this cooler, oxygenated water. Fish and other aquatic life not able to escape the anoxic zone will suffocate. Food, however, still remains the critical variable for fish location.

Wind driven rotation of thermocline



If anoxia develops within the hypolimnion, fish kills may occur during periods of sustained high winds from northerly and southernly directions. For example, a strong north wind for a number of days piles the warm surface layer up on the south shore. This forces the thermocline deeper and causes the cold bottom layer to flow to the north shore, pushing anoxic water into shallow depths and trapping fish, resulting in a fish kill on the north shore. The same may happen on the Ohio shoreline with strong, sustained south winds. Strong spring and fall winds, however, generally occur before the development of, or after the breakup of the thermocline when there is plenty of oxygen throughout the water column.

ENTERING THE ZONE *Continued from Page 3*

Seasonal Averages of Phytoplankton Algae Wet Weight in Lake Erie's Central Basin

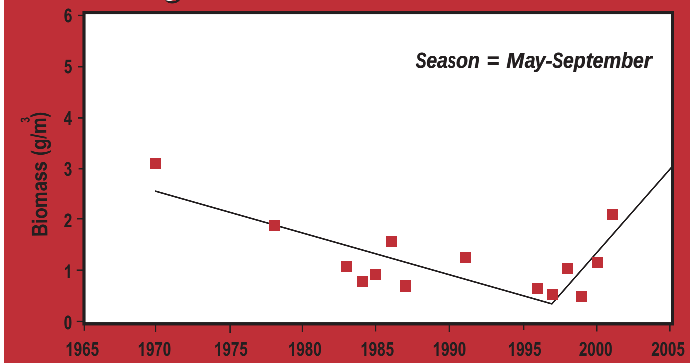


Chart information compiled by Dr. David Culver from four published studies (1970-1992) and his own data since 1995.

Current Research Efforts

In early 2001, Ohio Sea Grant publicized information about a number of unusual readings researchers were getting in Lake Erie. This got the attention of U.S. EPA's Great Lakes National Program Office (GLNPO) in Chicago, as they were also getting unusual readings from Lake Erie. Ohio Sea Grant and GLNPO arranged to jointly host a meeting in Chicago on December 13, 2001 where Lake Erie researchers in the U.S. and Canada were invited to participate. As a result of this meeting, GLNPO designated $500K for a special research project on Lake Erie this past summer (This project involves about 30 investigators. The Principal Investigators are Jan Ciborowski from the University of Windsor, and Gerald Matisoff from Case Western Reserve University).

As part of the special research project, Ohio Sea Grant and the U.S. EPA's Great Lakes National Program Office supported a graduate level Great Lakes limnology course and research cruise this summer. EPA committed its research vessel, the 180-ft *Lake Guardian,* for one week during which Ohio State University offered a Stone Lab course (co-funded by Ohio Sea Grant) on the vessel while the research was being done.

On the July 2002 cruise, Dr. Culver directed water quality analysis of the lake's nutrient levels and experiments to determine zebra and quagga mussels' phosphorus excretion rates. Culver and a group of researchers found oxygen levels of 3.5 ppm at the bottom at a site north of Cleveland, one of 11 sites sampled in the central basin. This concentration is too low for many fish, and at the time indicated a possible initiation of a dead zone in August.

The zebra mussel invaded Lake Erie first, but recent results show that quagga mussels have outcompeted them in all three basins. Dr. Culver's preliminary results showed that both mussels excreted phosphorus, but the quagga mussel may excrete more than equivalent-sized zebra mussels. The results suggest that both zebra and quagga mussels recycle phosphorus, and as their populations continue to grow, so will high levels of phosphorus that contribute to Lake Erie's dead zone.

Future Concerns and Needs

Climate change has exacerbated the dead zone problem in Lake Erie. Since 1997 the water level has gone down by three to four feet. It is important to understand the implications of low water levels because the reduction comes primarily from the cold bottom layer. Therefore, as the water level goes down, the volume or thickness of this layer is reduced, the oxygen reservoir is reduced, and as a result, the area of anoxia will increase and last longer each year. This will hurt fish populations, the charter and commercial fisheries, boating and tourism industries, and public health.

Legislative support is needed to conduct the necessary research to confirm the scientific community's beliefs about this situation. The current GLNPO project should be expanded and continued for at least two more years. Specifically, the following actions are needed to enhance knowledge about the dead zone and its prevention:

- Accurate measurement of phosphorus loading on all of the Great Lakes on a continual basis.
- Research to determine how best to reduce phosphorus loading.
- Research to determine if there is a link between the dead zone and the botulism problems observed in the Eastern Basin.
- Support for developing new technologies to address the oxygen problem, control zebra/quagga mussels and other aquatic nuisance species, remove nutrients at sewage treatment plants, and reduce agricultural runoff.

Because Lake Erie is the shallowest and warmest of the Great Lakes, it is an indicator of what the Great Lakes in general can expect. Now is the time to develop models to extrapolate research results to other bodies of water so that natural resource professionals can be prepared and take preventative actions before problems occur. *TL*

Jeffrey M. Reutter, Dave Kelch, Jill Jentes Banicki, and Frank Lichtkoppler from Ohio Sea Grant contributed to this article.

Gustav Verderber

Research Review:
The Ghost of Summers Past

by Dr. Robert Heath, Kent State University

With the increasing abundance of phytoplankton in Lake Erie and the appearance of large "dead zones" (zones of low oxygen in the lake) in the summer, American and Canadian scientists have begun to wonder whether an old problem – eutrophication – is returning, and if so, whether it can be controlled as it was in the past.

Since the mid-1970s scientists and lake managers have recognized that growth of phytoplankton algae in Lake Erie and the other Great Lakes was dependent on the amount of phosphorus present in the water. Phosphorus (P) is essential for the growth of all organisms; without it they cannot live or grow. When phosphorus is present in a chemical form that algae can take up directly from the water, the algae will grow rapidly until they run out of phosphorus or other nutrients necessary for growth.

In the past, loading too much phosphorus into Lake Erie caused eutrophication – development of an overabundance of algae that die and decay. As algae sank to the bottom of the lake and decayed, dissolved oxygen was consumed, leading to the death of fish and other organisms in the bottom waters.

As long as phytoplankton are limited in their growth by P-availability, eutrophication can be controlled by limiting inputs of P to the lake. This strategy is the basis for much of the Great Lakes Water Quality Agreement. The strategy of limiting amounts of P permitted to enter Lake Erie has worked in the past to control eutrophication. But what if Lake Erie phytoplankton aren't P-limited? Former strategies may not provide an effective control of eutrophication, requiring development of new management strategies.

How do you know when algae are P-limited? When algae are P-limited, they act differently than algae that have enough P to grow rapidly. Ordinarily when algae are provided sufficient phosphorus for maximum growth rates they photosynthesize at their maximum rate and take up phosphate from their surroundings at a relatively slow rate. Also, when algae have sufficient P resources they biochemically store excess P, sort of a biochemical savings account.

Many processes change when algae are P-limited. P-limitation can lower the maximal rate of photosynthesis (P-opt) and greatly enhance the maximal rate of phosphate uptake from the environment (Vmax). Also, the biochemical savings account is depleted and algae develop a "phosphorus debt." Some algae can also produce special enzymes capable of releasing P from organic compounds dissolved in the water. These enzymes, called "phosphatases," are attached to the outside of algal cells and are produced only when algae become starved for phosphorus and when phosphate concentrations in the lake water decline to very low levels.

These different biochemical behaviors allow scientists to identify when algae are P-limited and to predict the success of various management strategies that may be used to control eutrophication. P-limited communities are characterized by having high phosphatase activities, significant P-debts, low maximum rates of photosynthesis (Popt) and high maximal rates of phosphate uptake (Vmax). Usually scientists divide the Popt by the Vmax to get a measure called the Phosphorus Deficiency Index (PDI).

Jane Forsyth

Scientists in recent years have been concerned that even with phosphorus controls in place, the overabundance of algae (like pictured here in 1972) could be returning to Lake Erie.

The problem is that P-limitation is not an "all or nothing" response. Instead, behaviors indicating P-limitation occur over a range from severe P-limitation to weak P-limitation or to none at all. Management strategies designed to control the growth of P-limited phytoplankton are most effective on those algae that are most severely P-limited. Estimating the effectiveness of such a management strategy depends on determining the intensity of the P-limitation. For example, the "phosphorus deficiency index" is variable throughout the lake and changes through the season, the lower the index the more severely P-limited the algal community is; only values less than 30 are considered to indicate severe P-limitation of phytoplankton communities.

Research over the past several years supported by Ohio Sea Grant and the Lake Erie Protection Fund indicates that Lake Erie phytoplankton have decreased in the degree of P-limitation over the past several years. At the height of the growing season this past summer, indicators of phytoplankton P-limitation were uniformly weak: phosphatase activity was very low, P-debt was low, and the PDI equaled 33, indicating only moderate P-limitation. Continuing research will continue to track these indicators to determine the potential effectiveness of management efforts that have worked in the past – and hopefully will continue to work in the future. TL

For more information about this Ohio Sea Grant funded project, contact Dr. Heath at ***rheath@kent.edu****.*

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TWINE LINE

The educational newsletter of Ohio Sea Grant, covering issues, events, and research related to Lake Erie and the Great Lakes

Lights…Wetland…Action!

Nitrates and Sunlight are Keys to Pesticide Degradation in Lake Erie

by Jill Jentes Banicki, Ohio Sea Grant Communications

Wetlands have for years been known for their importance to flood control, shoreline stabilization, nutrient retention, and wildlife habitat. But new Ohio Sea Grant research conducted by Ohio State University's Yu-Ping Chin is documenting how sunlight on Lake Erie's coastal wetlands can play a key role in pesticide degradation.

Modern agriculture practices have relied heavily on fertilizers and agricultural synthetic organic compounds (ASOCs) for pest control. These chemicals enter the tributaries as runoff from crop applications, persist in waterways, and are resistant to degradation. As agricultural production and the reliance on pesticides have increased, so has the pesticides' ability to persist in these waterways. Lake Erie's tributaries are more likely to carry larger pesticide loads than tributaries entering other Great Lakes.

Wetlands, however, may provide a way to manage this nonpoint source pollution. Not only do wetlands allow water to collect from various sources before a final discharge into the Lake, but they also have been observed to improve water quality by eliminating suspended solids and some pesticides. Unfortunately, little is known about the chemistry behind their ability to remove pesticides.

Continued on Page 2

As agricultural production and the reliance on pesticides have increased, so has the pesticides' ability to persist in these waterways. In general, Lake Erie's tributaries are more likely to carry larger pesticide loads than tributaries entering other Great Lakes.

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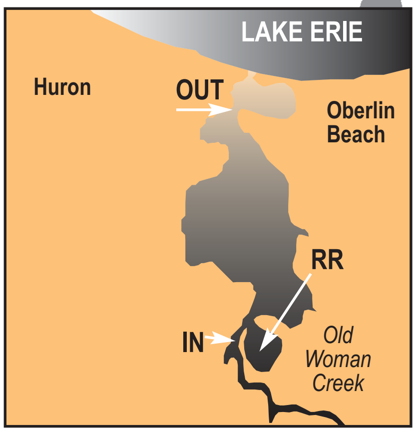
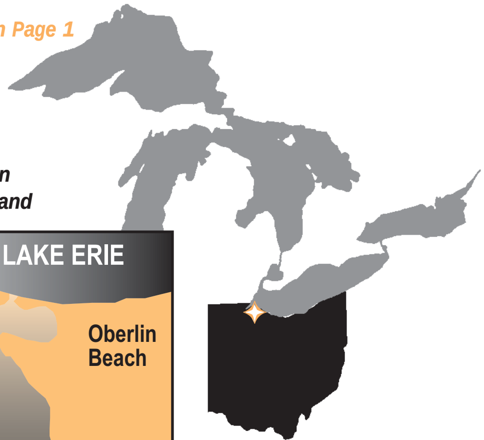
Figure 1
Study area of Old Woman Creek, a 30 hectare wetland





Old Woman Estuarine Research Reserve (OWC) is located in Ohio on the south shore of Lake Erie.

Figure 2
Relationship of Nitrate Levels (moles/liter) to the Indirect Photolytic Rate in pH-adjusted OWC Water Samples

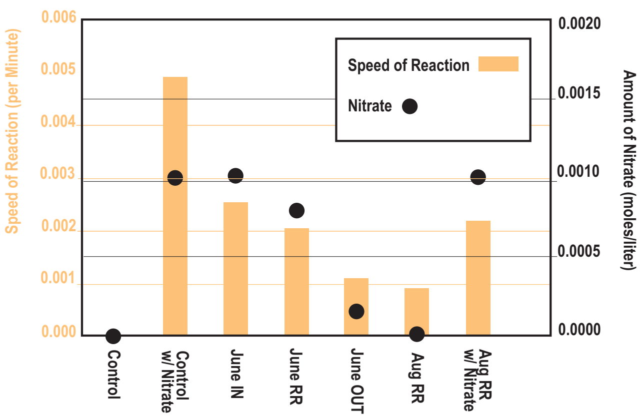
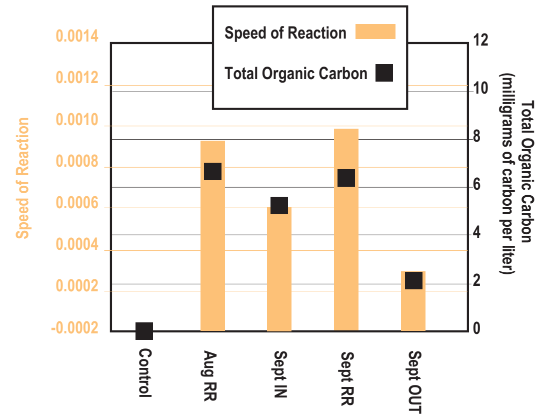


Figure 3
Comparison of the Indirect Photolytic Rate for the Degradation of Carbaryl by Natural Dissolved Organic Matter (milligrams/liter) in Low Nitrate pH-adjusted OWC Water Samples



Ohio Sea Grant research found that nitrate is a naturally occurring photosensitizer that degrades pesticides in Lake Erie's wetlands. When spring runoff occurred and nitrates were high in the water samples (June IN), the speed of the reaction was high. When nitrate levels were low, the speed of the pesticide degradation slowed.

Photo:
Old Woman Creek, Huron, Ohio – Courtesy of Gene Wright

Sunlight-induced reactions or photolysis may play a significant role in the break down of pesticides in wetlands, says Dr. Yu-Ping Chin, an associate professor in Ohio State's Geological Sciences department. While some contaminants have been found to degrade by directly reacting with sunlight (direct photolysis), there are many that cannot. Dr. Chin's team investigated the use of indirect photolysis, the process by which contaminants can degrade in the presence of a photosensitizer.

Because many compounds do not have the chemical structure to absorb light, they need a catalyst or photosensitizer to absorb the sunlight. When that photosensitizer takes up the sunlight, the energy is trapped and transferred to neighboring molecules to create reactive chemical radicals. These highly reactive chemicals react with and transform ASOCs to form other compounds. Dr. Chin's team investigated the role of natural dissolved organic matter (NDOM) and nitrates as potential photosensitizers in wetlands.

To test whether nitrates and/or NDOM can influence the indirect photolytic fate of ASOCs in wetlands, Chin conducted his research at Old Woman Creek Estuarine Research Reserve (OWC), a 30-hectare wetland located on the south shore of Lake Erie (see Figure 1). Water samples were taken from the inlet, the interior (railroad RR), and the outlet of the OWC wetland. Samples were collected in June when spring runoff occurs (shortly after fertilizers are applied), in August and September of 1998 (when fertilizer loads are presumably lower). The wetland water samples were analyzed for total organic carbon (TOC), nitrate, chloride, NDOM, and sulfate before being spiked with alachor, a common agricultural pesticide. With the use of artificial light to simulate sunlight, the samples were subjected to different periods of time, and compounds remaining in the sample tubes were analyzed and calculated.

What Chin found was that during high nitrate levels (June IN), the speed of the pesticide degradation increased (see Figure 2). When nitrates were low, as in Aug RR's sample, the rate of the reaction was proportionally slower. However, when that same sample was spiked with nitrate (Aug RR w/ nitrate) to a level similar to the June IN sample, the speed of the reaction increased to previously seen levels.

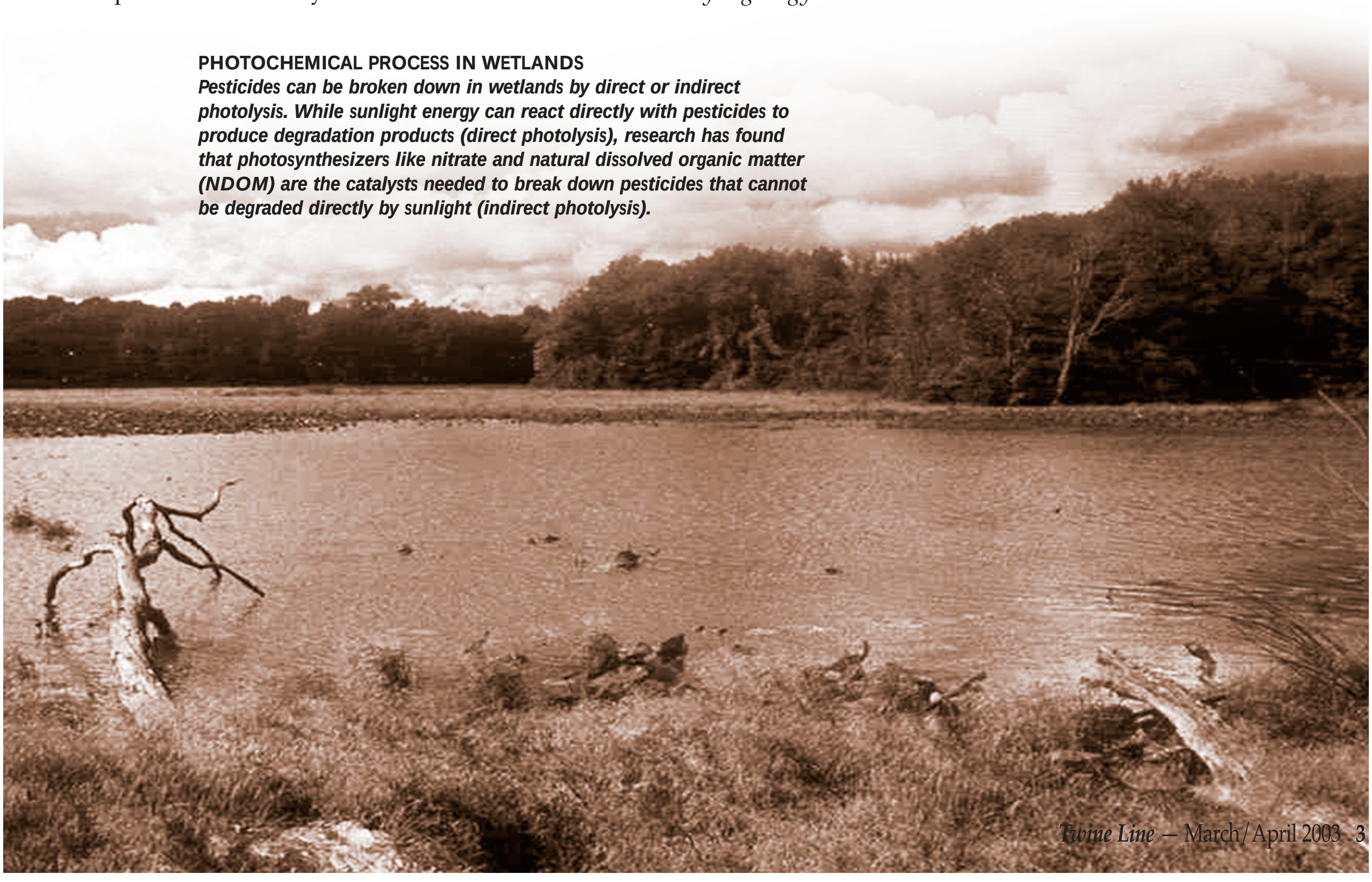
NDOM was also found to play an important role in pesticide degradation in wetlands (see Figure 3). When samples contained low amounts of nitrate as in the August and September samples, NDOM became the principal photosensitizer, and can account for up to 73 percent of the degradation.

As the Lake Erie region continues to be a dominant resource for agriculture, resource managers will need to find a cost efficient solution to its growing nonpoint source pollution problem. Chin says using its coastal wetlands may be a way to battle the problem.

"The preservation of existing and the construction of new coastal wetlands around Lake Erie may provide a means of management needed for our nonpoint source problem. Understanding the photochemical mechanisms that control the changes of ASOCs is key to determining their effectiveness as natural "photochemical reactors" and ultimately whether wetlands can be used to remediate runoff prior to entering the Great Lakes," emphasizes Chin.

Dr. Chin plans to continue his research, examining pesticide degradation by sunlight as a function of depth in the water column, along with identifying the final degradation products resulting from his indirect photolysis experiments. *TL*

For more information about this Ohio Sea Grant funded project, call Dr. Chin at 614.292.6953 or email at *yo@geology.ohio-state.edu*



PHOTOCHEMICAL PROCESS IN WETLANDS
Pesticides can be broken down in wetlands by direct or indirect photolysis. While sunlight energy can react directly with pesticides to produce degradation products (direct photolysis), research has found that photosynthesizers like nitrate and natural dissolved organic matter (NDOM) are the catalysts needed to break down pesticides that cannot be degraded directly by sunlight (indirect photolysis).

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TWINE LINE

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What Goes Down, Must Come Up

Research uses sound waves to remove contaminants locked in Lake Erie sediment

by Jill Jentes Banicki, Ohio Sea Grant Communications

For decades, the Great Lakes region has been battling industrial pollution imbedded in its sediments. Unfortunately, what goes down, must come up. Mother Nature has not allowed pollutants that traveled down to the sediment to stay put. Polychlorinated biphenyls (PCBs) along with heavy metals like mercury have slowly made their way back up into the food chain. Traditionally moving from contaminated algae to zooplankton to fish, these contaminants have increased or biomagnified at each stage of the food chain before being consumed by humans or animals. But now the pace has quickened. Zebra mussels take in PCBs that in the past would have stayed to the sediment. Water level fluctuation has increased wave action, causing sediments to be resuspended. And burrowing insect populations (like mayflies and midges) have grown, bringing PCBs back to the surface. Because of high PCB and mercury levels, more than 30 fish species in Ohio's waterways can only be consumed in limited quantities.

Although there are methods to extract these contaminants from sediment, the methods are costly and can cause a risk for future contamination. Dredging involves physically moving contaminated sediment off-site to a landfill, while capping includes placing a clay cap over the sediment. Both approaches can be effective, yet neither destroys the pollutant. With more than 11 million people relying on Lake Erie for their drinking water, there is a need to find a technology that does not temporarily confine the contaminant, but actually removes and destroys it.

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Photo by B. Kielczewski

REMOVING CONTAMINATED SEDIMENT ***Continued from Page 1***

New research by Dr. Linda Weavers at Ohio State University is investigating whether a new approach, the use of ultrasound or sonication, could be a better treatment to remove contaminants like PCBs and heavy metals from sediment. "Ultrasound could deliver an on-site treatment technology that may be quicker and cheaper than any of the current remediation options," stated Weavers.

The technology uses alternating compression and expansion cycles of ultrasound waves moving through water that create millions of tiny bubbles. These tiny bubbles expand, contract, and then violently implode or collapse in a few microseconds to generate pressures up to several thousand pounds per square inch and temperatures as hot as the surface of the sun (up to 10,000 degrees Fahrenheit). "As the bubbles implode, they form tiny water jets that smash into sediment particles at 100 to 1000 meters per second, thereby desorbing or removing pollutants," clarified Weavers. "That heat causes water vapor and the pollutants in the bubbles to form unstable oxidants that chemically react to produce something less toxic."

Weavers is finding that the energy from these bubbles is effectively removing contaminants. Within the first 15 minutes of the ultrasonic process, one half of PCBs remained in the water and sediment *(see Figure 1)*. After 50 minutes of ultrasound, over 95 percent of the PCBs had been separated and degraded from the particles.

Because sediment contamination is a mixture of organic and inorganic compounds, Weavers is collaborating with Ohio Sea Grant researcher, Richard Sayre, to test the effectiveness of ultrasonic technology on the inorganic pollutants of trace metals nickel, chromium, and mercury. Weavers found that ultrasound increases the desorption rate of nickel to 50 percent within an hour compared to roughly 35 percent by the traditional method of mixing with water (hydrodynamic mixing).

Ultrasound also had a significant effect on the degradation of chromium. "We observed that ultrasound expedited chromium desorption rates four times faster than traditional mixing within a two-hour period," said Weavers.

At low pH levels, ultrasound removed mercury from sediment particles four times more effectively than hydrodynamic mixing *(see Figure 2)*. However, unlike PCBs, where PCBs levels progressively decreased, Weavers noticed that mercury will begin reattaching itself to sediment particles. "After approximately five minutes into the ultrasound process, mercury will begin to reattach itself with stronger bonds to the sediment," said Weavers. "This is likely due to a reduction of the particle size by ultrasound." However, when humic acid was introduced to the sediment particles, mercury desorption decreased 10 to 20 percent.

Weavers plans to later expand the research to investigate how well a mixed treatment system would destroy trace metals. After ultrasound would be used, a treatment of Sayre's genetically engineered alga, *Chlamydomonas reinhardtii*, would be introduced to attach to the contaminants. "If we could initiate the algae treatment to mercury before mercury began reattaching itself to the sediment, ultrasonic treatment could be even more successful," emphasized Weavers.

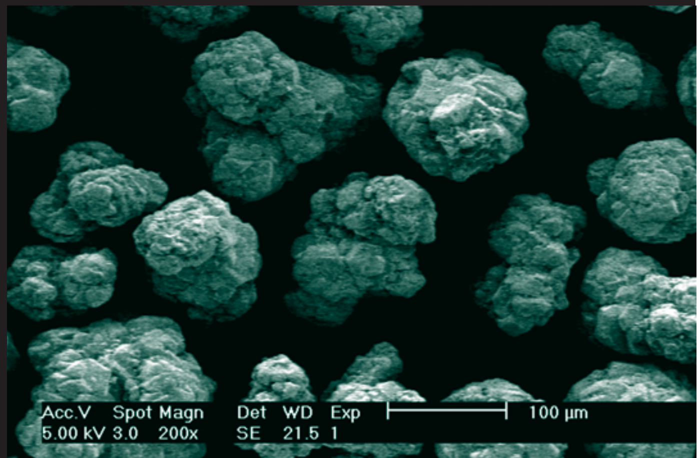
The hope is a specialized system could be attached onboard a Lake Erie ship for on-site treatment without harming wildlife and fish. "Contaminated sediment from Lake Erie would be moved through the ultrasonic system, separating the PCBs and heavy metals from the sediment, before the cleaned sediment would be returned to the lake," stated Weavers. With the recent American Medical Association's report that one in 12 American women of reproductive age have mercury levels above what EPA deems safe, ultrasonic technology may be the quickest, cheapest, and safest option to destroy these pollutants before they make it back up the food chain.

For more information about the Ohio Sea Grant funded projects, contact Linda Weavers at *weavers.1@osu.edu* or visit her web site at ***www.ceegs.ohio-state.edu/faculty/weavers/index.shtml***. For a related article on mercury and Dr. Sayre's *Chlamydomonas* research, see the September/October '01 issue of *Twine Line,* available on our web site at ***www.sg.ohio-state.edu***. *TL*

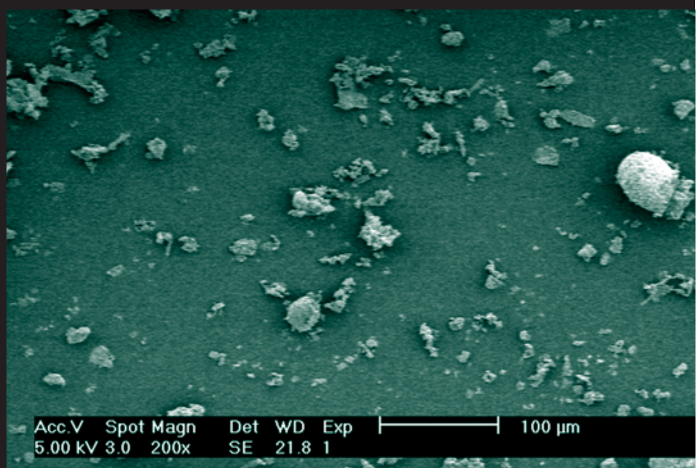
THE POWER OF BUBBLES

Collapsing bubbles generate pressures up to several thousand pounds per square inch and temperatures as hot as the surface of the sun (up to 10,000 degrees Fahrenheit). That energy smashes into the sediment at 100 to 1000 meters per second, removing the pollutants from the sediment particles.

BEFORE ULTRASOUND



AFTER 180 MINUTES OF ULTRASOUND



PARTICLE CHANGES WITH ULTRASOUND (*before/top, after/bottom*)

r. Linda Weavers is determining whether using ultrasound to remove contaminants from Lake Erie sediment may be a feasible alternative to treat contaminated sediment. As contaminated sediment goes through sound waves, contaminants break off of the sediment and are later oxidized to produce something less toxic.

FIGURE 1: THE REMOVAL AND DESTRUCTION OF PCBs

Weavers' study found that close to 50 percent of PCBs were degraded from sediment and water within the first 15 minutes of sonication. Over 95 percent of PCBs were removed within an hour.

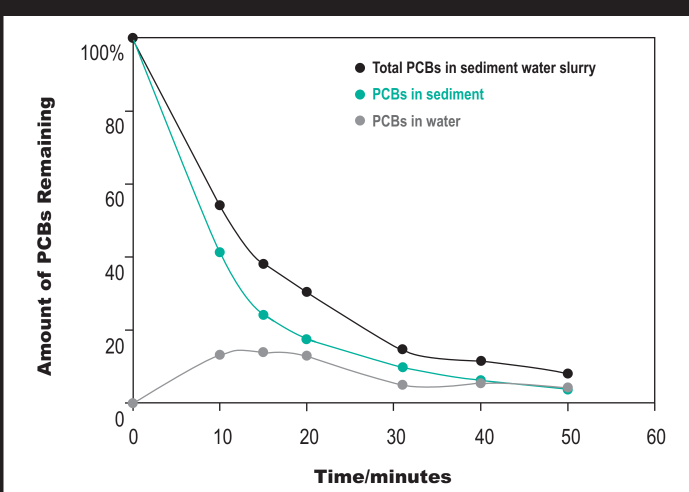
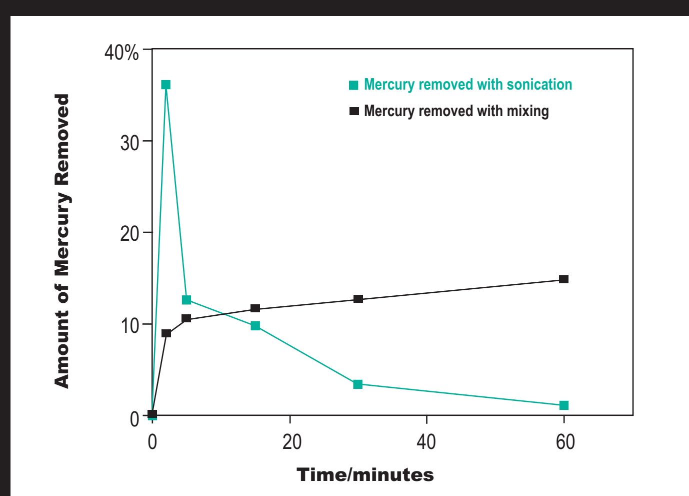


FIGURE 2: MERCURY ***The Removal of Mercury from Sediment Particles***

Sonication removed mercury from sediment particles four times more effectively than the traditional method of mixing with water (hydrodynamic mixing). However, Weavers found that after five minutes into the process, mercury will begin to reattach with stronger bonds to the sediment.



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TWINE LINE

The educational newsletter of Ohio Sea Grant, covering issues, events, and research related to Lake Erie and the Great Lakes

You Can't Judge a Mussel by its Cover

Sea Grant Research Uses Mussel DNA to Differentiate Species and Trace their Origin

by Jill Jentes Banicki, Ohio Sea Grant Communications

When the zebra mussel was discovered in Lake Erie waters in 1988, little was known about the species' characteristics aside from its distinct striped shell. Like many invasive species, this dreissenid mussel has behaved very differently in Lake Erie than in its native European waters and quickly invaded its new habitats. Its cousin, the quagga mussel, soon followed and has now become the prevailing invasive mussel. But not all mussels look alike. Identifying species by physical traits alone, has caused many to be incorrectly classified. What species will be next? And more importantly, will we be able to differentiate any new species from other mussels if they invade the Great Lakes or other coastal areas of the U.S.? Using genetic characteristics, therefore, could be the key to distinguishing a species from others that have similar physical features and ultimately determine the regions where each mussel species originated.

Dr. Carol Stepien of Cleveland State University continues her Ohio Sea Grant research to plot the zebra mussel's genetic history by examining the genetic relationships and the divergence patterns among four species of the bivalve family Dreissenidae — the invasive zebra (*D. polymorpha*) and quagga mussels (*D. bugensis*), along with their two native counterparts, the Lake Okhrid native mussel (*D. stankovici*) and the Caspian Sea native mussel (*D. rostriformis*).

"By comparing DNA samples of each species, we can map out the genetic code of existing species and decipher their genetic histories—which species are another's ancestors; when they evolved into another species; and what characteristics are unique to each species," states Stepien. "With the use of these genetic markers, species identification can be faster and more accurate when classifying a new invasive species."

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MUSSEL DNA ***Continued from Page 1***

Stepien's team extracted DNA from tissue samples of several individuals representing the four bivalve species, isolated two DNA gene regions from each, and compared them to establish unique markers and evolutionary genetic markers. Using the DNA tools, the team established a genetic history of each species and determined a "molecular clock" by matching the number of genetic mutations with geological events.

She verified that two primary mussel lineages, *D. polymorpha/stankovici* and *D. rostriformis/bugensis*, separated 9 to 11 million years ago in Eurasia. Geological events and salinity fluctuations in the Paratethys Region (modern Black, Azov, Caspian, and Aral Seas) caused the species to split with the *D. rostriformis/bugensis* species inhabiting both fresh and saltwater regions, and the *D. polymorpha/stankovici* species restricted to solely fresh-water habitats.

Decreasing salinity from river inflow in the Pliocene, followed by a salinity increase with an oceanic connection caused the bivalve branches to readjust their distributions with the geological events. Stepien's research found that *D. stankovici* was isolated in the lakes of Albania/Macedonia and split from *D. polymorpha* (zebra mussel) around 4.5 million years ago.

The future Black and Caspian Seas were connected through the present-day northern Caucasus region, which then rose to form mountains, gradually isolating the Caspian Sea. "Because of this separation, *D. bugensis* diverged in fresh water in the Black Sea and *D. rostriformis* were restricted to salt waters in the Caspian Sea region," states Stepien.

When the Black Sea again became connected to the Mediterranean Sea and the world ocean in the late Pleistocene, the rise in salinity likely isolated *D. bugensis* (quagga mussel) in the upper rivers of the middle Black Sea region and led to the disappearance of any remnants of the *D. rostriformis* lineage from this area.

While the species *D. stankovici* diverged from the lineage shared with *D. polymorpha* about 4.5 million years ago, *D. bugensis* and *D. rostriformis* diverged only about 300,000 years ago. "Our data sets show genetic divergence between the *D. bugensis* and *D. rostriformis* groups, indicating their relatively recent separation," emphasizes Stepien. "However, our research also verified that *D. rostriformis* is likely a separate species from *D. bugensis*."

When Stepien examined the quagga and zebra mussel specimens from the Great Lakes, she found that they exhibited high levels of genetic diversity, with numbers similar to the native European populations. "Results indicate that invasions of both species involved a large number of individuals from multiple founding sources," emphasizes Stepien.

Zebra mussels from Lake Superior significantly differ from samples in the lower Great Lakes. This suggests that the zebra mussel in the Great Lakes did not spread from a single species.

Because of the family's historic ability to diversify, genetic testing may be the only clear way to identify species. By establishing genetic markers, Stepien will be able to quickly classify an invasive mussel. "If *D. rostiformis,* the quagga's saltwater cousin, got to the U.S. salt marshes or the East Coast, we would be able to verify what mussel we're dealing with within a few days," states Stepien.

Stepien will expand her research by increasing the number of samples and bivalve populations sites in order to resolve more genetic relationships and determine the founding sources for the Great Lakes bivalve invasions. *TL*

This Ohio Sea Grant funded research was conducted by Dr. Stepien, Cliff Taylor, Igor Grigorovish, Sergei Shirman, and Kora Dabrowska of the Center for Environmental Science, Technology, and Policy at Cleveland State University along with Robert Wei and Alexei Korniushin. For more information about this research, contact Stepien at *c.stepien@csuohio.edu* or her web site at ***www.csuohio.edu/cestp/glegl/glegl.html***. Stepien's previous zebra mussel work can be found on line at ***www.sg.ohio-state.edu*** in *Twine Line's* July/August 2001 issue.

Lineage of the Mussel

New research finds that while the species* D. stankovici *diverged from the lineage shared with D. polymorpha about 4.5 millions years ago,* D. bugensis *and* D. rostriformis *diverged only about 300,000 years ago.

Miocene Epoch
5 to 7 million years ago

Cause: Formation of Eurasian Mountain Range

Effect: Divergence of *D. polymorpha/stankovici* from *D. rostriformis/bugensis*

Late Miocene/Early Pliocene Epoch
3 to 5 million years ago

Cause: Decreasing salinity from river inflow; salinity increase by ocean connection

Effect: *D. polymorpha* and *D. stankovici* split around 4.5 million years ago

Effect: *D. stankovici* diverge into Lakes of Albania

Pliocene Epoch
1 to 3 million years ago

Cause: Paratethys Seas become more freshwater; Mountains from Mediterranean isolates Caspian Sea

Effect: Expansion and contraction of range of *D. polymorpha* and *D. rostriformis/bugensis*

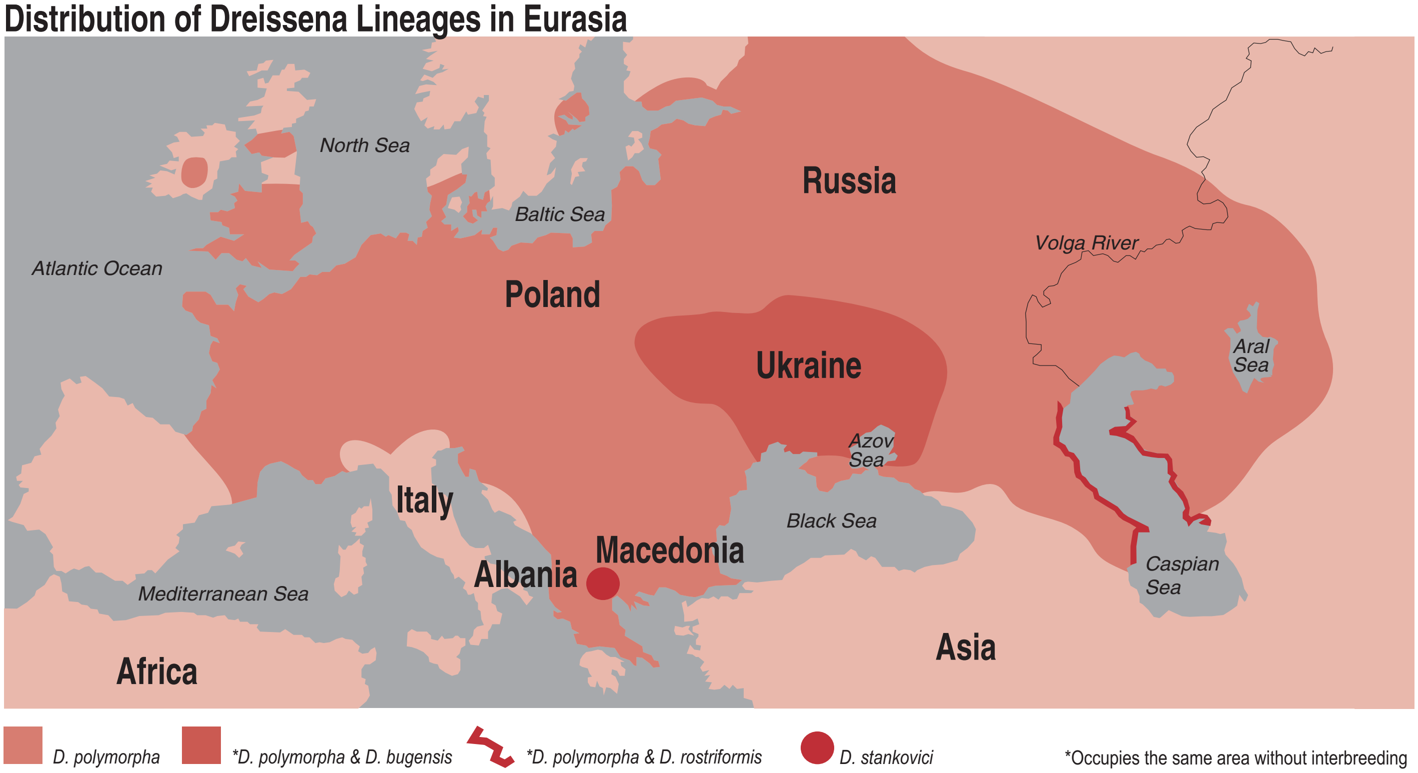
Pleistocene Epoch
10,000 - 1 million years ago

Cause: Black Sea connected to Mediterranean Sea and ocean

Effect: Rise of salinity in region led to *D. rostiformis* disappearance; Isolated *D. bugensis* in Black Sea

Effect: *D. bugensis* and *D. rostriformis* separate; *D. rostriformis* to salt water (Caspian Sea) and *D. bugensis* to freshwater (Black Sea)

Distribution of Dreissena Lineages in Eurasia



Map adapted from *Aquatic Invaders* Vol.14, No. 2, 9

Ohio Sea Grant College Program
The Ohio State University
1314 Kinnear Road
Columbus, OH 43212-1194

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A Lo$$ for Lake Erie Beaches

Research Finds Beachgoers Willing to Pay $29 Million for No Beach Advisories

by Jill Jentes Banicki, Ohio Sea Grant Communications

With Labor Day as the official close to the beach season, one thing is for certain; visitors on Lake Erie beaches didn't get much swimming in this summer. For another summer of fun has meant yet another summer of beach advisories due to high *E. coli* levels with the number of advisories increasing over 50 percent since 1998.

But according to Ohio State University's Brent Sohngen, what has cost the beachgoer some sun, has cost the local economy some revenue. "Our research found that each time an advisory is posted at a Lake Erie beach, local communities potentially lose $75,000 in single-day visitor spending within 10 miles of a beach," states Sohngen. Because each Lake Erie beach now averages about four beach advisories per season, over $300,000 could be lost every year at each beach.

Although the original study investigated visitation patterns of single-day visitors at 15 of Lake Erie's public beaches, Sohngen and graduate student, Chia-Yu Yeh, broadened the scope to include multiple-day travelers (or overnight visitors) into the study. "We discovered that almost 30 percent of beachgoers surveyed were engaged in multiple-day trips," emphasizes Sohngen. "With the average multiple-day traveler spending $381.98 during their trip (compared to $27.53 for the single-day visitor), multi-day travelers boost the local economy."

The study found the two groups differed in terms of what each valued at the beach. While beach amenities like picnic tables, lifeguards, and sand quality influenced a single-day user's choice of beach, such amenities didn't affect a multiple-day user's choice. "Beach time is not as much of a focal point for multiple-day travelers because they are doing other activities besides going to the beach," says Sohngen.

What influenced whether multiple-day visitors would go to a beach were beach advisories. The study showed that a multiple-day visitor would be willing to pay between $6.93 and $7.39 per trip to eliminate one beach advisory, compared to approximately $2.06 for single-day visitors. With over 240 beach advisory days during the 2003 season, beachgoers would be willing to pay over $29 million for no beach advisories.

Despite making fewer trips, multi-day visitors experience larger impacts in total than single-day visitors. One reason may be due to a multiple-day visitor's lack of options. "Multi-day trip travelers have fewer opportunities to delay planned trips due to beach closings, for example, or they have fewer options for shifting from one beach site to another when they are already on their trip," states Sohngen. "Reducing beach advisories by improving water quality would enhance the quality of experience many visitors have, and could, in the long-run, enhance visitation." TL

For more information about this Ohio Sea Grant project, contact Dr. Brent Sohngen at *sohngen.1@osu.edu* or 614.688.4640. To learn more about beach amenities and the single-day visitor, see the May/June 2000 *Twine Line.* Fact sheets such as The Value of Lake Erie Beaches (FS-078), The Economics of Lake Erie Beaches (FS-82) are available at ***www-agecon.ag.ohio-state.edu/Faculty/bsohngen/beach/beachin.htm*** or by contacting Ohio Sea Grant.

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TWINE LINE

The educational newsletter of Ohio Sea Grant, covering issues, events, and research related to Lake Erie and the Great Lakes

Research Finds Reopening Coastal Wetlands to Lake Erie Largely Increases Fish Diversity

by Jill Jentes Banicki, Ohio Sea Grant Communications

When Lake Erie's coastal wetlands were diked starting in the late 1800s, the motivation was habitat preservation — to control the water levels in areas surrounding Lake Erie while protecting remaining marshland from encroaching farmland and development. But what is gained by controlling wetland waters with dikes is at times countered by a loss of diversity of aquatic habitat and fish populations. Isolating coastal wetlands from Lake Erie to manage their water levels promotes food production for migrating waterfowl, but can leave the associated fishes low in numbers with assemblages of low diversity. Many fish species need the ability to venture to and from the wetlands as 47 of Lake Erie's fish species depend on wetlands for some aspect of their life cycles.

New Ohio Sea Grant research by Dr. Dave Johnson of Ohio State University is finding that an experimental dike used in the renovation of Lake Erie's Metzger Marsh could be a new method for marsh management that dramatically increases fish diversity in Lake Erie coastal wetlands.

Through a 1992 joint project, the ODNR Division of Wildlife, the U.S. Fish and Wildlife Service, and Ducks Unlimited began a wetland restoration project of Metzger Marsh, a 906-acre coastal wetland located along Lake Erie's southwest shore. The ODNR Division of Wildlife and the U.S. Fish and Wildlife Service's Ottawa National Wildlife Refuge now jointly manage the site. Restoration efforts incorporated a dike to mimic the protective function of a natural barrier beach, along with never-before-used water-control gates in the dike that allowed a hydrologic

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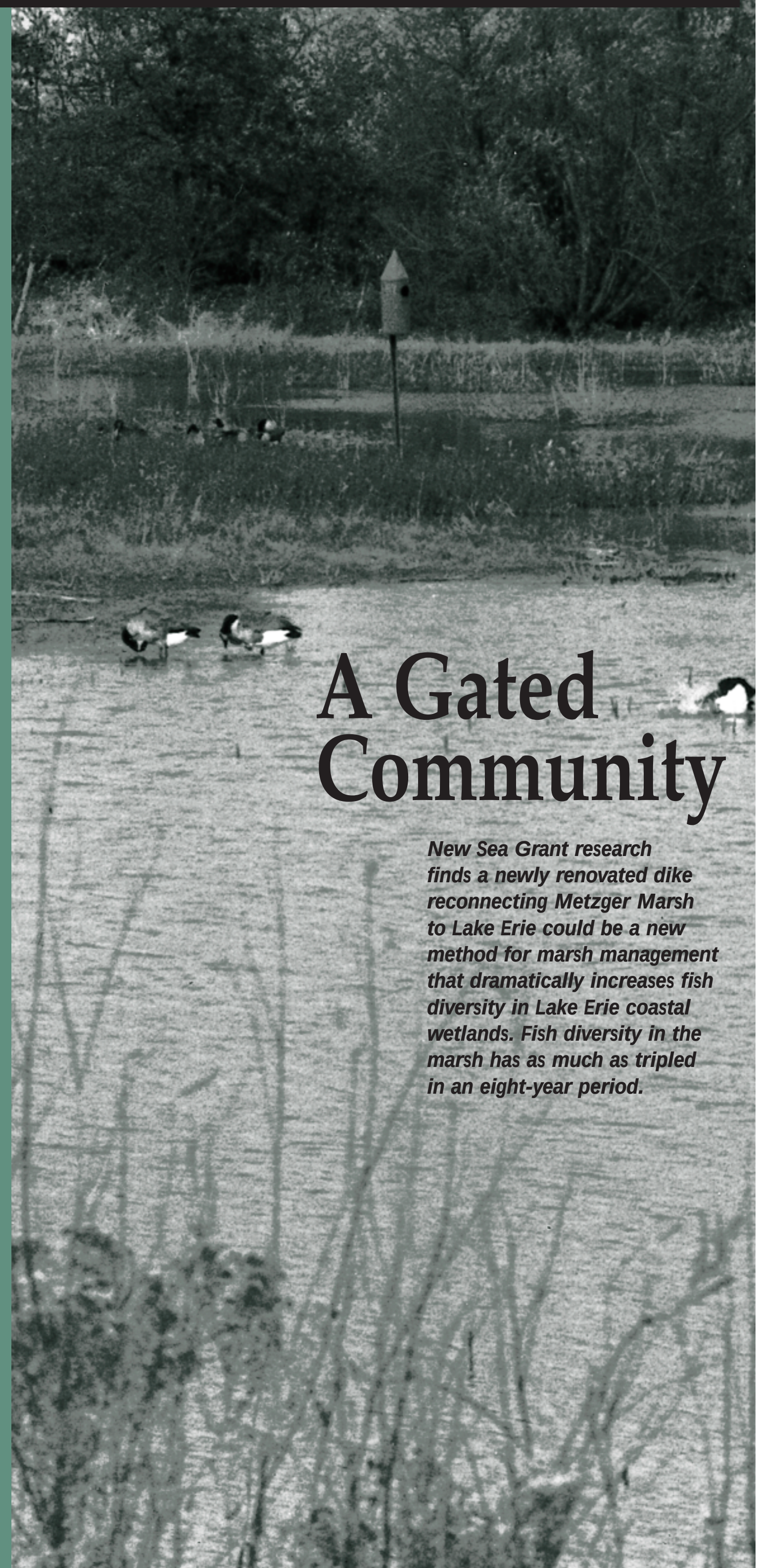

A Gated Community

New Sea Grant research finds a newly renovated dike reconnecting Metzger Marsh to Lake Erie could be a new method for marsh management that dramatically increases fish diversity in Lake Erie coastal wetlands. Fish diversity in the marsh has as much as tripled in an eight-year period.

Inside: North Coast News & Friends of Stone Laboratory

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GATED COMMUNITY *Continued from Page 1*

connection with Lake Erie. The structure included a fish-control system to exclude mature common carp while still allowing passage of large native fish by way of manual traps. These gates were left open for a four-year period starting in 1999 to permit the marsh's water levels to fluctuate and reconnect "naturally" with lake levels.

Johnson and his team collected and cataloged adult and juvenile fish species within the marsh in 1994 prior to the dike construction as well as every year since the gates were opened.

When first sampled in 1994, Metzger Marsh was an open embayment subject to storm surges and wave action. Vegetation was limited to only the most protected areas and consequently the marsh was dominated by such lake-associated species as the gizzard shad, emerald shiner, white bass, and white perch.

What Johnson has discovered is the evolution of a different type of fish assemblage in the wetland after its restoration (*see Figure 1*). "Phytophilic (vegetation-loving) fishes, like the largemouth bass and pumpkinseed, were rare in the marsh prior to the dike. As Metzger's vegetation increased (post-dike), we now find approximately 100 times as many largemouth bass and pumpkinseed compared to that in 1994," emphasizes Johnson. Both increased in the marsh although numbers of each have decreased in Lake Erie over the last few years.

Figure 1

Average Catch per Unit of Effort for a Sample of Fish Species in Metzger Marsh

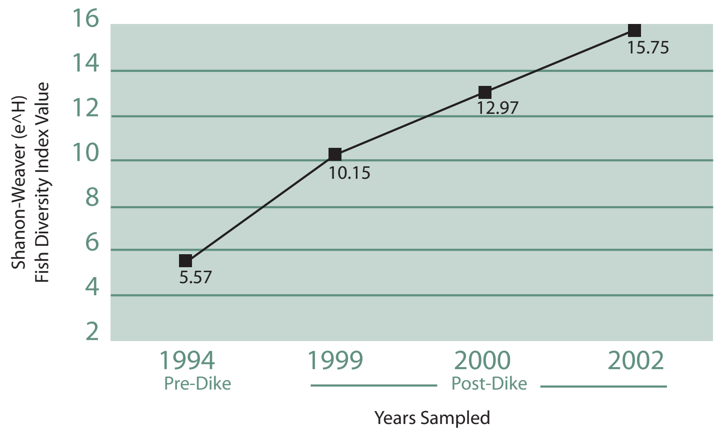
Species		1994 Pre-Dike	1999 Post-Dike	2000 Post-Dike	2002 Post-Dike
Gizzard shad *Dorosoma cepedianum*	LT	64.81	1.60	9.83	6.58
Goldfish *Carassius auratus*	P	0.43	4.47	3.67	7.44
Common carp *Cyprinus carpio*	T	1.47	9.97	*20.74	7.03
White perch *Morone americana*	L	10.63	0.33	1.21	0.83
White bass *Morone chrysops*	L	27.27	-	0.67	0.28
Pumpkinseed *Lepomis gibbosus*	P	0.25	22.77	9.70	16.03
Bluegill *Lepomis macrochirus*	P	0.30	22.90	23.95	9.89
Largemouth bass *Micropterus salmoides*	P	0.10	16.30	14.67	10.55

P = **Phytophilic** species; **L** = **Lake** associated species; **T = Tolerant** species

*Common carp were artificially over represented in the 2000 catch because an epidemic made them abnormally susceptible to trapping.

Diversity is not only determined by the number of species present (or species richness), but also by the evenness of the distribution amongst species. "Before its restoration, Metzger Marsh had more than 34 different fish species, with some species only represented by a few individuals," explains Eugene Braig, an Ohio State research associate working on the project. "We found the number of fish species didn't substantially change after restoration. However, numbers were more evenly distributed among species without the domination of a few." Using the Shannon-Weaver diversity index to chart the increase, they found that diversity has dramatically increased, as much as tripled, within an eight-year period (*see Figure 2*).

Figure 2 Fish Diversity in Metzger Marsh



Johnson's research discovered that fish diversity is 3 times greater (2002) than prior to the dike's construction (1994).

This evenness of distribution measured at Metzger Marsh is not typical of diked wetlands. Where most traditionally diked wetlands are dominated by a few tolerant species like carp, goldfish, and white crappie, Metzger has developed a mixture of phytophilic fish along with some representation of lake species. This increased diversity is more than likely because of the hydrologic connection to the lake says Braig. Fish species like emerald shiner, that are unusual in many diked wetlands, serve as an important food base for predators within Metzger. As a result, Johnson's team has collected native, non-introduced northern pike in Metzger Marsh, a first occurrence for them in diked wetlands. The northern pike went from complete absence in 1994 to a consistently increasing presence starting in 2000. "Tolerant, invasive shallow-water species, like the carp and the goldfish, are still present in the marsh and have increased in number, but they have increased an order of magnitude less than native shallow-water species, like the largemouth bass and bluegill," states Braig. Johnson's team is currently analyzing the 2003 fish samples.

Metzger Marsh's control gates likely will be periodically closed to manage against Phragmites, an aggressive grass species. It is important to continue study of the fish assemblage there to document how the closure may affect it says Johnson. "Metzger Marsh demonstrates that we can still take advantage of the benefits of dikes (wetland habitat protection) without compromising natural hydrology, aquatic habitat diversity, or fish populations," states Johnson. "Until Metzger Marsh, we had never measured such high fish diversity in a diked wetland. By reconnecting coastal marshes with the Lake's hydrology and occasionally closing these systems to manage invasive plant species, Lake Erie's wetlands could be restored and managed as coupled systems to again serve all biota." *TL*

For information about this USGS and Ohio Sea Grant funded project, contact Dr. Dave Johnson (614.292.9803 or johnson.46@osu.edu) or Eugene Braig (614.292.9841 or braig.1@osu.edu).

Steelhead Trout: A Money Fish for Ohio

Research Finds Steelhead Angling Beneficial to Anglers and Economy

by Dave Kelch & Frank Lichtkoppler, Ohio Sea Grant Extension; and Brent Sohngen & Adam Diagneault, Ohio State University

Steelhead trout have been stocked into Lake Erie tributary streams since 1975 through a very successful program administered by the Ohio Department of Natural Resources, Division of Wildlife. The success of the program has grown over the years, resulting in increased stocking numbers and the addition of more streams. During 2003, over 400,000 steelhead smolts were stocked in five Lake Erie tributaries. This program provides Central Basin anglers with the opportunity to catch trophy class rainbow trout (steelhead) during the summer months in the open waters of Lake Erie, and in tributary streams during the fall, winter, and spring months. Over 98 percent of steelhead are caught are in Ohio's two lake districts (#2 and #3) that stretch from Huron to Conneaut.

Creel data is collected annually by the ODNR Division of Wildlife to assess open lake steelhead angler success. During 2002, private and charter boat anglers caught approximately 41,357 steelhead in the open lake; an increase of over 41% compared to 2001, and the highest on record since the program began. When compared to past years harvest (1995 = 3,500 and 1997 = 4,000) the increased stocking has resulted in a significant benefit to angler harvest. Unfortunately, very little is known about the harvest of steelhead from tributaries.

To learn more about this steelhead stream fishery, Ohio Sea Grant initiated a research effort to survey these anglers during the 2002-2003 tributary angling season. This is the first time an economic survey of Ohio Lake Erie steelhead stream anglers has been conducted. While the state of Ohio and other Great Lakes states have intensive management programs aimed at enhancing the steelhead fishing experience for anglers, little is known about the tastes, preferences, and values of Ohio steelhead anglers

From October 2002 through April 2003, Ohio Sea Grant personnel contacted anglers at popular streamside locations (from Vermilion to Conneaut) seeking their participation in a survey to better understand steelhead angler fishing habits, economic expenditures, and angling/visitation needs. Anglers were asked basic creel data questions and were also asked to participate in a mail survey related to the day of contact and other seasonal angling questions. Overall, 487 anglers were contacted for survey participation, with 375 surveys returned.

Within the steelhead fishery, most anglers (94%) appear to take single-day trips. Due to the low number of respondents for multiple-day trips, the study has focused on single-day trips. Respondents on single-day trips indicated taking an average of 44 steelhead fishing trips per year. About 72% of the trips individuals take are taken to the site where individuals were intercepted. Most trips are taken in fall of 2002 and spring of 2003, with a smaller proportion taken in winter. This was largely because most, if not all of the prime steelhead fishing streams were frozen solid and unfishable in most of January, February, and much of March 2003.

Anglers indicate that they keep approximately 12% of the fish that they catch (7.1 fish kept vs 58.4 fish caught), and that they eat approximately 49% of the fish they kept (3.5 fish eaten vs 7.1 steelhead kept). Anglers catching relatively few steelhead tend to keep a higher percentage of the fish they catch than anglers who catch large amounts of steelhead.

The survey did not consider other types of fishing in which the individuals potentially engage, but it does provide information on the way individuals fish for steelhead. Approximately 65% of steelhead anglers spin cast with bait or artificial lures while a smaller proportion fly fish (30%). The average angler surveyed had 9.0 years experience fishing for steelhead.

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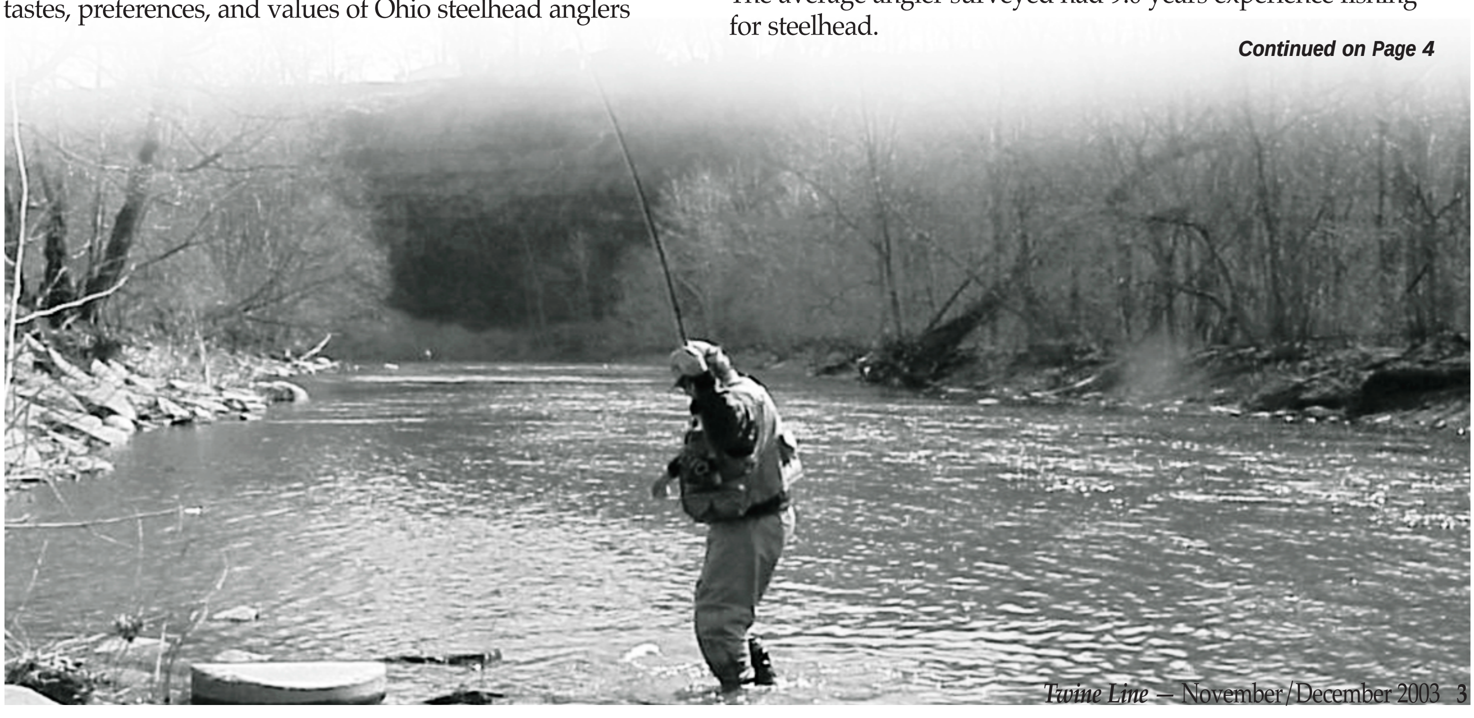

STEELHEAD *Continued from Page 3*

Individuals responded that they spend approximately $26 per trip, with more than 60% of these expenditures within 10 miles of the sites where they are fishing, suggesting that each trip generates nearly $16 in local expenditures. For just the 311 visitors in our single trip angler sample, taking 44 trips per year on average, this generates $218,000 in annual expenditures locally on steelhead fishing. It is not possible, unfortunately, to extrapolate the expenditure values to all steelhead anglers since the sampling protocol provides no information on the proportion of the total population that fishes for steelhead. However, if as many as one percent of the 754,704 licensed resident anglers in Ohio in 2001 fished for steelhead this would give us a total of 7,547 anglers x 44 trips x $26 = $8.6 million.

The study explored the factors that affect steelhead catch rates and the value of steelhead fishing in tributaries to Ohio's portion of Lake Erie. Overall, the results suggest that steelhead fishing is a very valuable activity in Ohio. The travel cost model used estimated that the value per trip for anglers taking part in our study ranged from $36 to $50.

The study results also made it possible to consider the value of a single fish caught. On average, individuals in the sample catch 1.33 fish per trip. This suggests that the value of each fish caught ranges from $27 to $38 per fish. Over all fish caught by the anglers in just our survey (approximately 20,323), the estimated value of catching fish is $591,300 to $832,200. In 2002, ODNR Division of Wildlife stocked 411,601 fish, for a cost of approximately $590,000 per year. These results do not fully capture all benefits of the stocking program, but suggest that the benefits of stocking do outweigh the costs.

While these results suggest that steelhead angling is highly valued by a segment of anglers in Ohio, we cannot fully estimate the benefits for all Ohioans from the limited sample collected. In the future, more thorough data collection would provide information on other anglers who fish for steelhead less frequently. Further, it would be useful to have independently collected creel data to assist in benefit cost analysis of the stocking program. Finally, the results of the survey suggested strong differences in seasonal trips, and access to a variety of sites. Further evaluation of the timing of trips and access could provide additional useful information. *TL*

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TWINE LINE

The educational newsletter of Ohio Sea Grant, covering issues, events, and research related to Lake Erie and the Great Lakes

An Alga a Day
Keeps the Doctor Away

Engineered Algae as a New Means to Vaccinate Fish

by Jill Jentes Banicki, Ohio Sea Grant Communications

When Ohio Sea Grant researcher Dr. Richard Sayre of Ohio State University started his research on engineered algae 10 years ago, his focus was on bioremediation methods. *Chlamydomonas reinhardtii*, a unicellular alga found abundantly all over the world, could be genetically altered to recover harmful heavy metals locked in sediments. Over the years, he has been able to enhance its binding capabilities, resulting in a significant step toward remediation of contaminated sites and waters of the Great Lakes.

But recently, his scope has broadened. "We realized that if *Chlamydomonas* could bind to heavy metals so effectively, why couldn't it be used to deliver needed vitamin supplements or a vaccine to an animal?" asks Sayre.

Sayre along with Dr. Richard Wagner expanded their research to see if the mircoalgae could be used as a way to vaccinate fish for Infectious Hematopoietic Necrosis Virus (IHNV), a viral disease that kills 30 percent of the U.S. trout population.

Controlling fish diseases has long been a problem for the aquaculture industry, adds Sayre. Antibiotics are not only useless for viral and many parasitic diseases, but they can only be partially absorbed by fish. Although fish vaccines are a more successful alternative, they can be costly, labor intensive, and stressful for the fish.

"Unfortunately, the trouble with producing many vaccines is you need to identify the pathogen and then you need time to culture it," explains Sayre. "Our system doesn't

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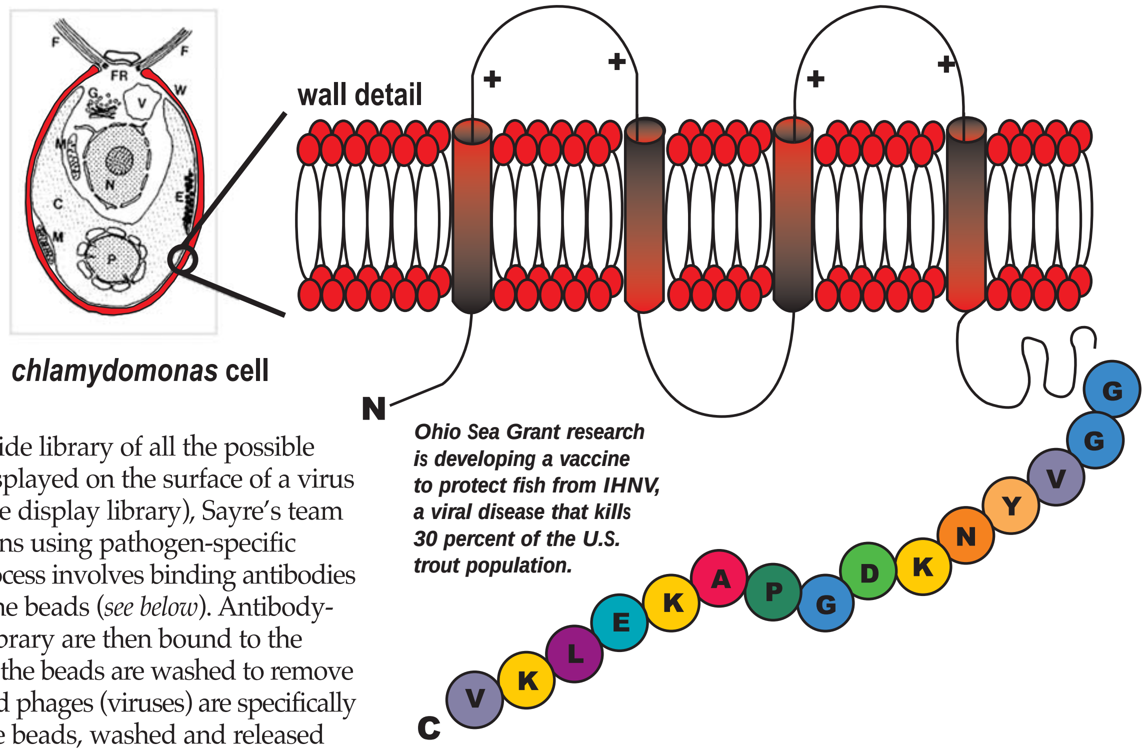
ALGA continued from Page 1

A unicellular alga found abundantly all over the world could be an effective means to deliver vaccines to fish. By attaching the correct antigen to the outside of the Chlamydomonas cell, the algae can be fed to the fish and induce an immune response to the disease.



***chlamydomonas* cell**

Ohio Sea Grant research is developing a vaccine to protect fish from IHNV, a viral disease that kills 30 percent of the U.S. trout population.

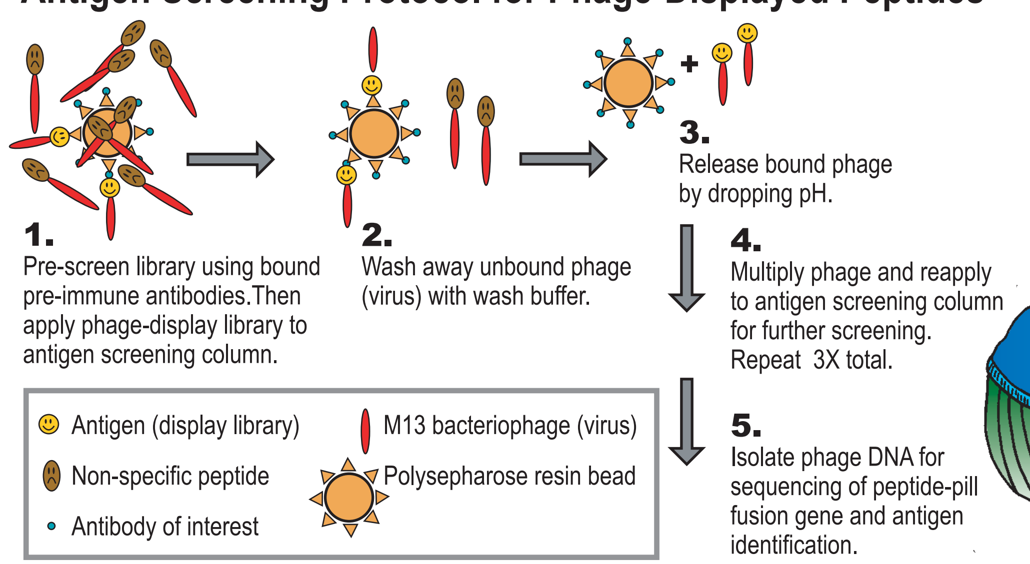
require either. "Using a peptide library of all the possible amino acid combinations displayed on the surface of a virus (called a combinatorial phage display library), Sayre's team can rapidly screen for antigens using pathogen-specific antibodies. The screening process involves binding antibodies from a sick fish to polystyrene beads (*see below*). Antibody-binding peptides from the library are then bound to the beads via the antibody. After the beads are washed to remove loose phage, the tightly bound phages (viruses) are specifically released and reapplied to the beads, washed and released repeatedly for several rounds of purification. "When the antigen is isolated by the screening process, we compare it to the known IHNV genome and known antigenic determinants to see if the process produced a viable antigen," states Sayre. His research has found a tentative antigenic peptide.

Sayre and his team plan to test those antigens by conducting vaccine trials later this year. The antigens will be attached to the outside of the *Chlamydomonas* cell, which will in turn be delivered to the fish through either food or immersion (water). "When fish (that are fed the algae) express antibodies against the antigen bound to the algae, we'll know this approach works, and we'll extend it toward other diseases," states Sayre. A patent is currently pending for this microalgal antigen delivery system.

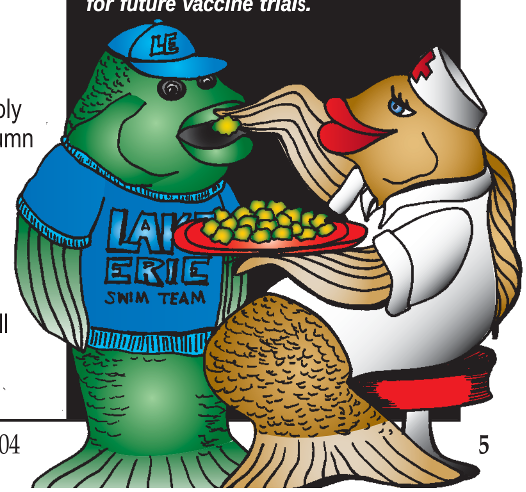
Last year, Sayre broadened the alga's capabilities once again in another Sea Grant project—this time as a heavy metal biomonitor. With the addition of fluorescent proteins attached to the alga, a fluorescent color will signal if there is the presence of a heavy metal. With the help of the alga, Sayre hopes to have a simple, rapid, and non-invasive system for quantifying heavy metals in the environment. *TL*

For more information about this Ohio Sea Grant funded project, contact Dr. Sayre at *sayre.2@osu.edu* or visit ***www.biosci.ohiostate.edu/~plantbio/Faculty/sayre.htm***. For a related article about his heavy metal bioremediation research, see *Twine Line's* Sept/Oct 2001 issue at ***www.sg.ohio-state.edu***.

Antigen Screening Protocol for Phage-Displayed Peptides



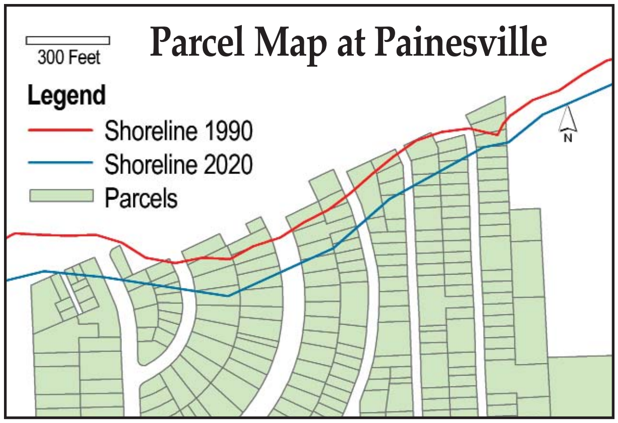
Before a vaccine can be attached to the algal cell, an antigen for the virus first needs to be isolated. Sayre is using a combinatorial phage display library, to screen for peptides that bind to antibodies obtained from sick fish. The candidate antigens may be used for future vaccine trials.



Shifting Sands

Predicting the Movements of Lake Erie's Shorelines

by Jill Jentes Banicki, Ohio Sea Grant Communications



This map shows the shoreline of Painesville, Ohio, in 1990 (red line) and in model-predicted 2020 (blue line). Landowners will soon be able to access such predictions about individual parcels through a web site available later this year.

When Native Americans and early pioneers walked the Lake Erie shorelines 250 years ago, they experienced a different terrain than what exists today. Not only have many of the shoreline areas been developed, but they have also vastly shifted and eroded over time. In an effort to better determine what is here today but will be gone tomorrow, scientists are developing methods to predict the ebb and flow of shorelines.

Lakeshore landowners will soon have tools to see where their property lines could be in 20, 30, or even 50 years from now, according to new research by Ohio Sea Grant researcher, Dr. Ron Li.

Landowners of shoreline property have always had to battle the uncertainty of soil erosion. Caused by either natural processes or human activities, coastlines have never been stable and in some areas they continue to erode at alarming averages of one to two meters (3 to 7 feet) per year.

The use of new technology, however, could help landowners plan for a proactive approach. "Our research could assist land managers and owners to see the future "hot spots" (in terms of shoreline loss) so they can better prepare for preventative measures," says Xutong Niu, Dr. Li's research associate in the project.

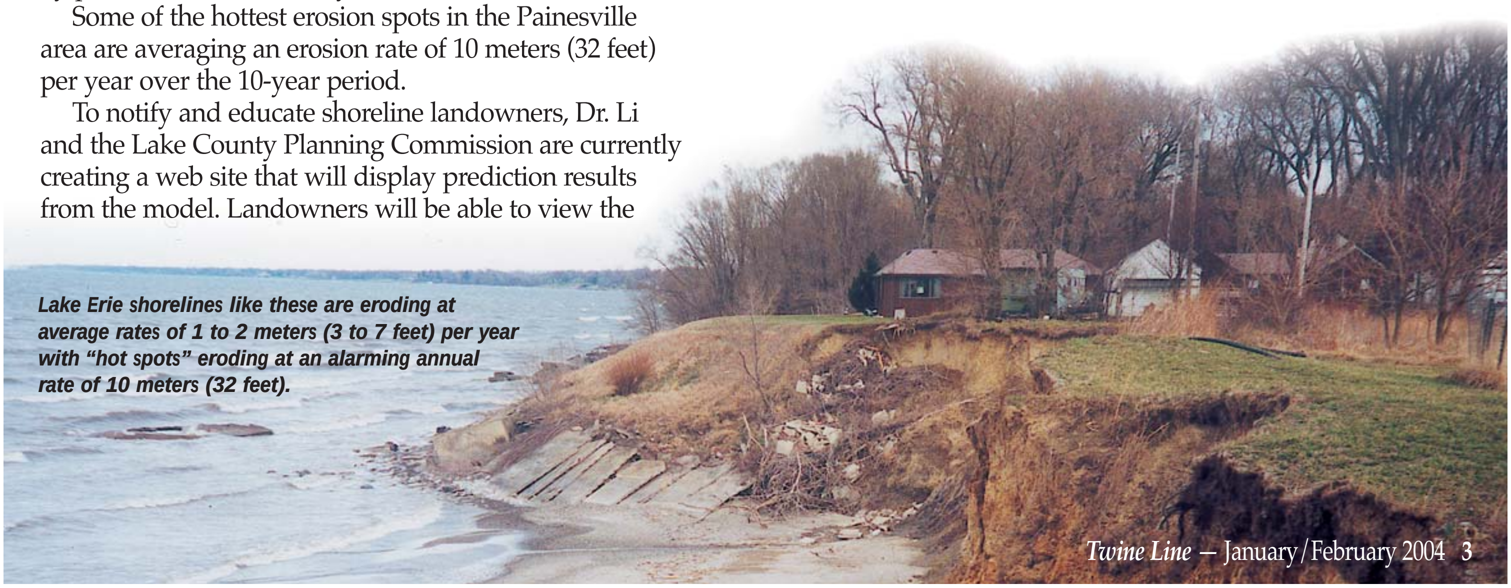
With the aid of previous Lake Erie coastline data from 1973, 1979, and 1990 provided by NOAA, ODNR and Ohio State, Li and his researchers created a shoreline prediction model that could forecast shoreline changes by parcels in annual or 10-year increments.

Some of the hottest erosion spots in the Painesville area are averaging an erosion rate of 10 meters (32 feet) per year over the 10-year period.

To notify and educate shoreline landowners, Dr. Li and the Lake County Planning Commission are currently creating a web site that will display prediction results from the model. Landowners will be able to view the shoreline changes to specific shoreline parcels and see how they will change (i.e. how much land is lost into the lake) over specific durations of time. Accessible later this year, the site will also include shore bluff erosion photos taken from 1994 to 1996 by a United States Geological Survey video camera and a three-dimensional display of the terrain along the Lake's shoreline.

Niu points out that this research is only a part of a much bigger project to document coastline changes. Through funding and support by NOAA, ODNR, and the National Science Foundation, Li's researchers are incorporating 1-meter resolution satellite images of Lake Erie shoreline into their data set. "This technology will greatly enhance the efficiency and capabilities of coastline mapping and spatial analysis in coastal management," states Li. Besides satellite images, the team will add water surface changes from radar altimetry along with daily water level from tide gauges. The hope is to document a 19.2-year history of Lake Erie's coastline changes. "By comparing data from tide gauges, altimetry, and the Great Lakes Forecasting System's model, we can determine their past accuracy and ultimately establish a 19.2 year record of Lake Erie's shoreline," states Niu.

Drs. Keith Bedford, C.K. Shum, Raul Ramirez, and A. Zhang are investigators overlooking other research areas in this project in addition to the above Sea Grant activities. For more information about this research, go to ***http://shoreline.eng.ohio-state.edu/research/diggov/DigiGov.html*** or contact Dr. Li at *li.282@osu.edu*. TL



Lake Erie shorelines like these are eroding at average rates of 1 to 2 meters (3 to 7 feet) per year with "hot spots" eroding at an alarming annual rate of 10 meters (32 feet).

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TWINE LINE

The educational newsletter of Ohio Sea Grant, covering issues, events, and research related to Lake Erie and the Great Lakes

Catching a Wave

Applying Radar Waves and GPS Data to Coastal Weather Forecasting

by Jill Jentes Banicki, Ohio Sea Grant Communications

The weather along Lake Erie can be as unpredictable as it can be violent. To better understand the climatic changes and movement in the Great Lakes region, scientists are using the latest technology to measure minute variations in order to improve coastal forecasting reliability.

Great Lakes coastal forecasting has historically been based upon data obtained from satellite winds and temperature and water level gauges. Although accurate, these methods have been limited in the winter and clouds and could be benefited by other spatial data (such as water vapor and wind speed) useful for precise forecasting. Incorporating all-weather satellite radar altimeters and Global Positioning System navigation satellites (GPS) into the existing forecasting system, however, can potentially enhance the precision and the predictability of Great Lakes weather forecasting, says C.K. Shum, an Ohio Sea Grant researcher at Ohio State University.

As part of a project within the National Ocean Service (NOS) Partnership, Dr. Shum along with other researchers of Ohio State's Laboratory for Space Geodesy and Remote Sensing began an international project in 2001 to improve long-term monitoring of the Great Lakes. The project included establishing permanent GPS base stations at more than 10 Great Lakes stations with each having wind sensors, water temperature sensors, and other meteorological sensors (for air temperature, barometric pressure, and relative humidity), around the U.S. and Canadian coasts of the Great Lakes.

"These satellite radar altimeter missions provide an unprecedented opportunity to use five concurrent operating radar altimeters to enhance the temporal and spatial resolution of the oceans as well as large inland lakes," says Kevin Cheng, Shum's research associate of the project.

Employed for over a decade, spaceborne altimeters such as NASA's and CNES' (French Space Agencies') TOPEX/POSEIDON satellite, bounce radar waves off the Earth to precisely measure the precise height of an ocean or lake's sea surface with respect to the center of the Earth. The altimetric satellites also measure the amount of integrated (total) water vapor in the air along the

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radar path, as well as wind speed and wave height at the radar footprint on the water surface. In addition, the permanent GPS stations around the Great Lakes provide integrated water vapor measurements along the GPS radar path from their antennas to the respective GPS satellites which are orbiting some 20,000 km above the Earth. "All such factors can then potentially be added to existing models for ultimately better weather forecasting," states Shum.

GPS and specifically the use of GPS-buoys within the Great Lakes waters determine accurate geocentric sea or lake elevation measurements and possibly wave measurements. "The advantage of a GPS-buoy as compared to conventional water level gauges is it can theoretically be deployed in the middle of the lake or further away from the shoreline for data gathering," explains Shum. Unlike water level gauges that are influenced by the moving land (erosion or uplift), GPS buoy water level measurements uses the center of the earth as its measurement benchmark.

Because of this project, it has been demonstrated that the use of data from five altimeters for the Great Lakes could potentially evolved into an operational observing system that can measure lake level changes in the Great Lakes with an accuracy of less than three centimeters and with measurements as frequent as daily.

That ability to measure specific points at small intervals of time is extremely important when it comes to monitoring the progress of phenomena like post-glacial rebound in the Great Lakes region. Postglacial rebound is a phenomena resulting from solid Earth slowly rebounding from the weight of ancient ice sheets covering North America (from Hudson Bay to most of the Great Lakes) since the last Ice Age 18,000 years ago. "Using a decade of TOPEX/POSEIDON radar altimetry and several decades of water level gauge data, our research is finding that the lands surrounding the Great Lakes region are currently uplifting between one to five millimeters each year. Continually documenting these changes will better predict future changes," emphasizes Shum.

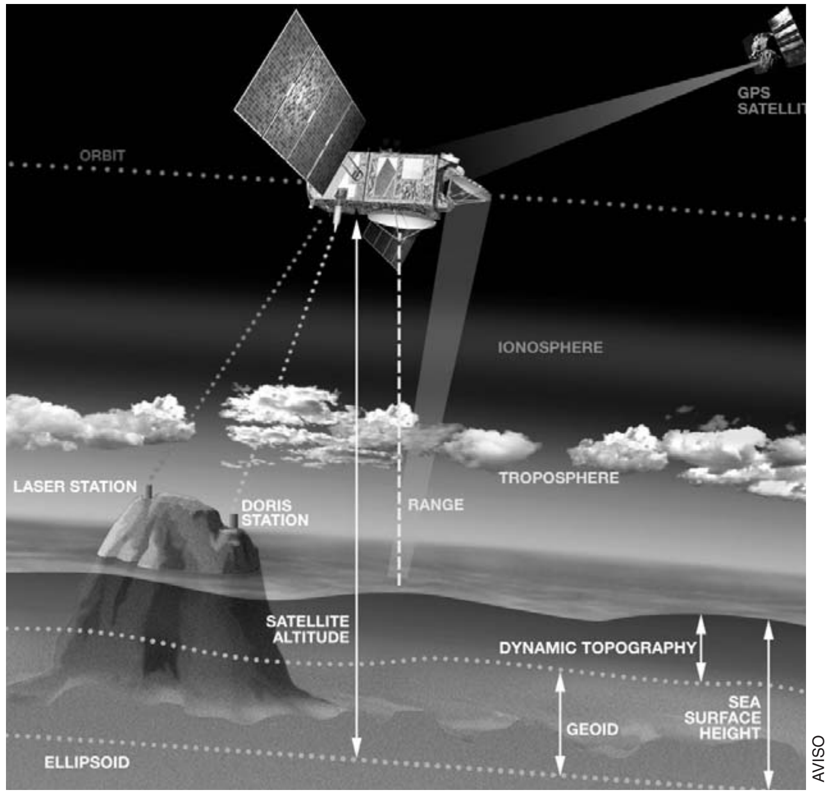
To begin recording the lake level changes, the research team analyzed an historic water database from 25 water level gauge stations of NOAA and 23 Canadian stations. The database included radar altimetry data from 1989 to the present.

What the researchers observed was a significant absolute lake level drop measured by the TOPEX/POSEIDON radar altimeter in Lake Erie, Lake Michigan, and Lake Huron since mid-1997. "Over a long time span (1993-present) the entire Great Lakes has been falling at a rate of 5.3 centimeters per year," states Shum. "Lake Erie specifically has been falling at a rate of 6.9 centimeters per year."

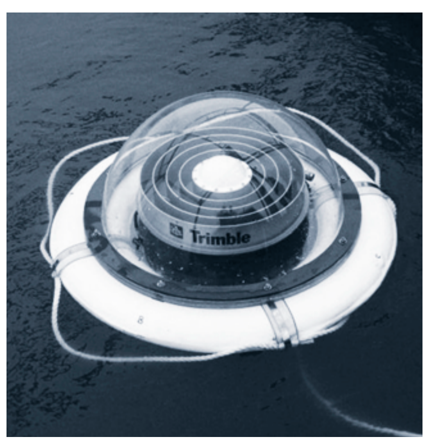
During the second and third years of the project, the researchers used GPS-buoys to link to existing water level gauges at Marblehead and Cleveland, Ohio, in Lake Erie to create accurate reference datums. Water level measurements (from the water gauge) were converted into geocentric measurements (from the GPS system) and linked to the benchmarks at the water level gauges. These measurements also complemented another research project which, led by Dr. Ron Li of Ohio State, includes precise mapping and prediction of Lake Erie shoreline changes.

The expectation is this information can serve as a complementary dataset to help models better measure global sea level and climate changes. "Space geodetic measurements are cost-effective means to help provide all-weather data for monitoring environmental concerns of the Great Lakes. Our plan is by proposing to incorporate such data into existing coastal forecasting models, we could potentially improve their future accuracy and reliability," concludes Shum.

For more information about this Sea Grant research or the NOS partnership research, contact Dr. Shum at 614.292.7118 or *ckshum@osu.edu* or Kevin Cheng at *cheng.168@osu.edu*.



The altimeter emits a radar wave and tracks the return signal that bounces off the sea surface. Sea surface height is the difference between the satellite-to-ocean range (calculated by measuring the signal's round-trip time) and the satellite's position on orbit with respect to an arbitrary reference surface (the Earth's center or ellipsoid). Besides sea surface height, altimeters can measure wave height and wind speed by looking at the return signal's amplitude and waveform.



A new project within the NOS Partnership links GPS-buoys to existing tide gauge stations on the Great Lakes. Use of such all-weather technology like radar altimetry and GPS will increase environmental monitoring and weather forecast predictions.

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TWINE LINE

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Mass Aquatic Transit

Seiches Transport Organic Matter Between Wetlands and Lakes

by Jill Jentes Banicki, Ohio Sea Grant Communications

We've all seen them—the rippling waves and the gradual rise and fall of the coastal waters along the Great Lakes. Even though these water movements, or seiches, symbolize the Great Lakes to many people, they also serve an important biological role for aquatic ecosystems. New Ohio Sea Grant research by Dr. Virginie Bouchard investigated whether seiche events could be a form of aquatic transport between coastal wetlands and the adjacent Lake Erie.

For more than 40 years, scientists have recognized how important tides are to the transfer of organic matter from the salt marshes in Europe to their adjoining marine waters. Known as "outwelling," tides can force the transport of organic matter produced in the marshes to the connecting water body. This ability to transfer nutrients, organic matter, and species from one ecosystem to another has shown to drive the ecological integrity of both systems.

Yet, for freshwater ecosystems, there is very little information about whether outwelling exists between the Great Lakes and their adjacent wetlands. "Great Lakes seiche events could act as key vehicles to transport massive amounts of organic matter (like phytoplankton and zooplankton) to the adjacent lake," states Bouchard. Once in the lake, the nutrients can be replenished back into the aquatic food webs.

To determine whether the outwelling concept can be applied to such ecosystems, Bouchard used Metzger Marsh, a 906-acre wetland located along Lake Erie, as her test site. "By examining its controlled opening to the Lake, we can estimate how much or if at all organic matter travels between the two ecosystems."

Before organic matter could be traced, she first needed to establish if there was a water exchange between the wetland and Lake Erie. To do this, Bouchard designated 18 sites in and outside of Metzger Marsh and took water samples from each site. Samples were examined to determine the amount of oxygen and hydrogen each had. "Every site has a unique amount of hydrogen and oxygen or what is called an isotopic signature that we can use to track where water from each site goes. If we find that signature in the Lake Erie water, we know that water traveled from a specific spot in the wetland into Lake Erie," explains Bouchard.

Bouchard's team took water samples every hour during entire

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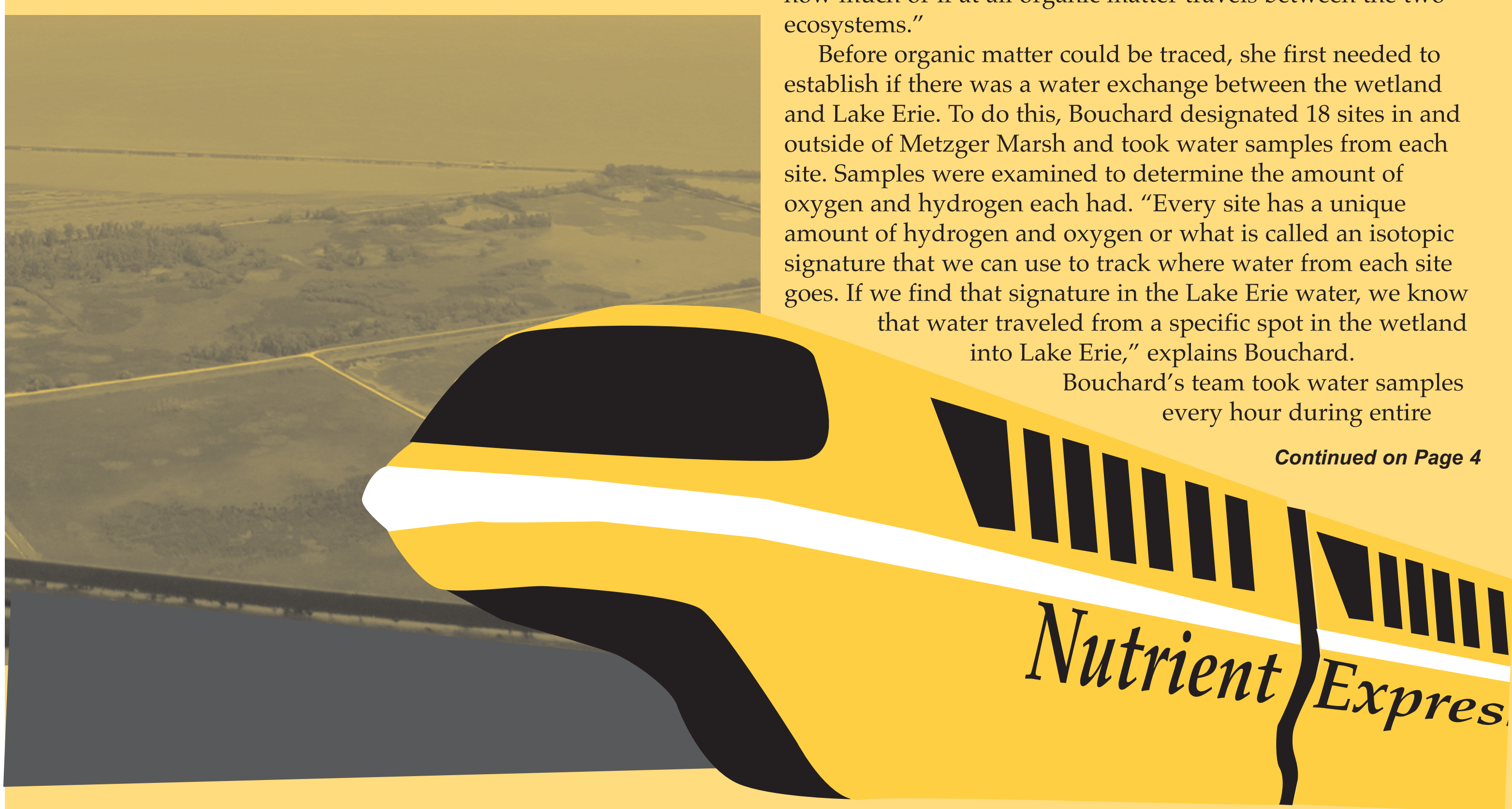


MASS AQUATIC TRANSIT *continued from Page 1*

seiche and storm events in the springs and falls for three years (2001-2003). The events ranged from a few hours to up to 20.

What she found was 75 percent of the wetland had a hydrologic connection to Lake Erie on a daily basis. “Water that originally was deep in the wetland traveled almost two and a half kilometers across the wetland into the waters of Lake Erie.” When it was a storm event, that number rose to almost 100 percent of the wetland.

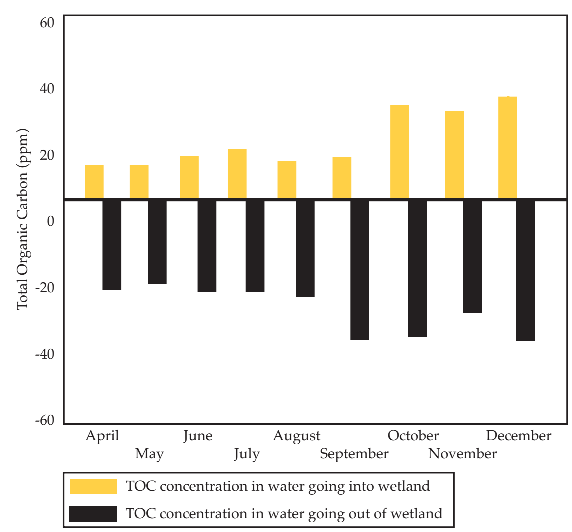
By discovering a definite water exchange between the two ecosystems, Bouchard could then determine if the seiche events carried anything besides water. Carbon, a sign that organic matter is present, was used as the isotopic signature for each of the 18 sites.

“Our research found that in general, water going out of Metzger had more organic matter than the water coming into the wetland,” explains Bouchard. Many of her sampling found total organic carbon levels 50 to 70 percent higher in the water going out of the wetland. “This data unequivocally confirms that outwelling occurs between freshwater wetlands and their connected lake,” states Bouchard. “Metzger Marsh with its highly productive vegetation gets the needed organic matter out to Lake Erie.”

Bouchard’s next step will be to see which aquatic food webs the organic matter travels into once it is in Lake Erie. To do this, Bouchard will again use carbon and nitrogen as her isotopic signatures and track the integration of the isotopes into the food web.

“We hope to show that not only is the export of organic matter between a wetland and a lake substantial, but outwelling serves an overall beneficial role to the lake food web,” concludes Bouchard. “We may need to have a mosaic of wetlands in the Great Lakes—connected and diked wetlands—in order to benefit all types of needs.”

Average TOC Fluxes at Metzger Marsh Outlet During Seiche Events (Sept. 2001-July 2003)



Dr. Bouchard found outwelling definitely exists within freshwater ecosystems. By analyzing water exchanges between Metzger Marsh and Lake Erie, she discovered that more organic matter was flowing from the wetland to the Lake than was coming into the wetland. For more information about this research, contact Dr. Bouchard at 614.688.0268 or bouchard.8@osu.edu.

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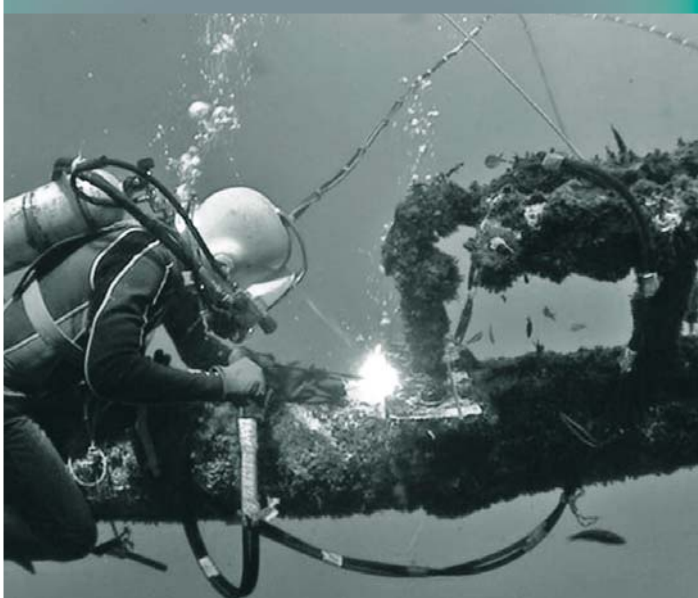
TWINE LINE

The educational newsletter of Ohio Sea Grant, covering issues, events, and research related to Lake Erie and the Great Lakes

The Welding Wizard

Researcher Builds Upon Achievements of Past Sea Grant Projects

by Jill Jentes Banicki, Ohio Sea Grant Communications



When Dr. Chon Tsai started his career in welding engineering over 30 years ago, "wet" welds—those made under water—were considered inferior to those made on land. Ships had to be dry docked to be fixed; underwater pipelines took too long to repair; and bridge construction and restoration were costly and inefficient. Now with cutting-edge research, a handful of international awards, and the only accredited college program of its kind in the nation, Dr. Tsai is a world leader in underwater welding technology.

And it all began in 1985 with one research project from Ohio Sea Grant.

"Our underwater welding program here at Ohio State started with that first Sea Grant project almost 20 years ago," says Tsai. "The industrial community cried out for new underwater welding technology and Sea Grant saw the urgency and opportunity to advance it."

First pioneering a method where a welding repair was done partly on land and partly underwater, Dr. Tsai's work with underwater welding has developed as a series of steps in a long learning process. "Each Sea Grant project has built upon the achievements of the previous projects—as a problem was discovered by one of our projects, the next Sea Grant project would resolve it," states Tsai.

One of the biggest hurdles to overcome, Tsai points out, has been the water itself. "Water creates problems for welders because it causes welded material to cool too rapidly," explains Tsai. "The hydrogen in the water chemically reacts with the welded material,

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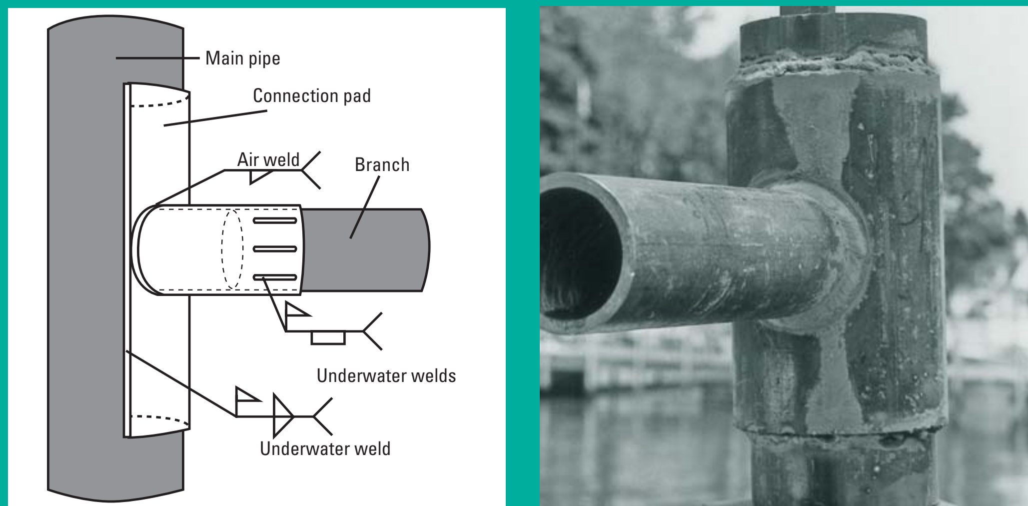
making wet welds brittle and traditionally inferior to welds done on land."

To decrease water's impact and presence, Tsai's first Sea Grant project limited the amount of wet welding in a repair by developing a method that combined air (land) welds with wet welds. The resulting product was a metal "pad" in 1989 that was first welded together on land and then submerged and attached to an underwater structure using wet welding (see Figure 1). By reducing the amount of wet welding, Tsai's innovative device decreased underwater welding costs by half.

Figure 1: By combining land welds with wet welds, Tsai's innovative metal "pad" cut underwater welding costs by half in 1989.



But Tsai's goal was to get underwater welds equal in strength and ductility to the air weld. So he looked toward the existing technology.

Similar to land-based welding, underwater welding attaches pieces of metal by intense heat from an electric arc (see Figure 2). Shielded metal arc welding (most commonly used in underwater welding) uses a metal rod coated with minerals, metal powders, and organic materials (the flux) to create an arc of energy. As electricity flows through the rods to chemically react with the base metal, the arc protects the molten weld from the water by creating a gas "bubble" or "arc-bubble" around the arc area. "The rods being used in the early '90s, however, did not create an efficient arc-bubble to keep the water away from the weld," explains Tsai. Because of the rods' shortcomings, divers had to spend 70 percent of their welding time cleaning off the welding residue. Tsai wanted to find a way to improve those rods.

By enhancing the chemical make-up of the rod's flux (the chemicals that react with the arc and the base metal) and the waterproof coating, Tsai developed a new rod that decreased the water's effect on welded material. The improved flux created better and more efficient chemical reactions and arc and provided easier residue clean-up. Now used internationally, Tsai's new rods permit divers to double their welding time and cut their chipping time by half.

There were still problems with the existing technology—the rods only had a one-minute life; water still caused welds to be brittle; and welders still couldn't see their welds underwater.

Through another Sea Grant project in 1995, Dr. Tsai set out to eliminate the use of rods and instead incorporate an alternative technology called flux-core arc welding (FCAW). "Unlike the shielded metal arc process that requires changing the rod every minute, the FCAW arc is fed by a continuous wire feed which increases the welding time and ultimately the strength of the weld," states Tsai. Since there is a continuous energy source, FCAW reduces the weak spots in the weld left where the rods would be changed and reignited.

With an alternative to rods, Dr. Tsai still wanted to find a way to better shield the weld from the water and allow a welder to directly observe the weld. Enter Dr. Tsai's "Smartshroud" system in 1998. The product of several Sea Grant projects, the "Smartshroud" system is an intelligent system that integrates four basic elements: the

Achievements *(in chronological order)*

1985: First Sea Grant project is funded. Innovative Connection Pad design is estimated to save up to half the current costs of underwater welding.

1988: Conducts field evaluation of design and fabrication methods for underwater welding at Sea Grant's Stone Laboratory facilities on Lake Erie.

1990: The Thomas Edison Program of the State of Ohio joins Sea Grant in support of the development of new underwater welding electrode.

1991: Receives William H. Hobart Memorial Medal Award from American Welding Society (AWS) as a result of connection pad design and contributions to pipe welding, the structural use of pipe or similar applications.

1993: National Coastal Research Institute (NCRI) joins Sea Grant in support of the development of new underwater welding electrode.

1993: Conducts Sea Grant underwater welding technology dissemination workshop at the Ohio State University.

1994: U.S. Navy joins Sea Grant in support of a project for engineering assessment of weld joint design for underwater "wet" welds.

1995: Develops new underwater welding electrode that doubles welding time over existing rods.

1995: Receives Arsham A Mirikian Memorial Maritime Welding Award for underwater welding electrode design and improvement through the substitution of new methods in welding of maritime structures.

"Smartshroud," a spinning-arc joint tracking and arc status detection subsystem; an operation guidance console; and a helmet-mounted monitor. "By protecting the weld from the water and having the ability "see" the arc, we were on our way to make the wet weld just as strong and easy to monitor as a land weld," emphasizes Tsai.

The "Smartshroud" itself is an oval-shaped rod cover that shields the welding area and electric arc from water as the welder goes through a welding pass (see Figure 3). Equipped with welding parameter sensors and peripheral water curtain nozzles, the "Smartshroud" system allows a welder to monitor the welding current, arc voltage, and wire feed rate during the welding process. Water nozzles with flow control maintain a stable barrier to contain gas in the shroud. The spinning arc joint tracking system monitors the location of the arc, while the operation guidance console displays gaseous atmosphere inside the shroud, arc stability, and welding parameters. "Together with an in-helmet visual display, a welder can see whether his weld is on target and know exactly what parameters may need to be adjusted to make a good weld," emphasizes Tsai. "Being able to do this during the welding process is a big advancement over previous technology."

Tsai's team later enhanced the shroud by adding sponge or rubber layers to its base. This water jet shroud could better contour to the welding area and protect the arc from intruding water.

"We realized that not all welding surfaces are flat so we eliminated the sponge and added brush bristles to the shroud," explains Tsai. This shroud brush dam allowed the shroud to better shape to corners and hard angles.

Further tests analyzing the porosity and the strength of the weld confirmed that the "Smartshroud" system produces a strong weld. "Welders can now produce air-quality welds using the "smartshroud" system," says Tsai.

With a new goal in mind, Dr. Tsai continues his research by introducing the "Smartshroud" system to the deeper water environment. "Now that we have the weld equivalent to the air weld, we need to get the technology down to areas where it is difficult for welders to venture," says Tsai. His next step is to make the "Smartshroud" attachable to a mechanical arm. "Our hope is that with such technology, welders will safely reach and repair welds that are deep in our waters without physically going down there," concludes Tsai. Considering Dr. Tsai's track record, that goal will likely be reached.

For more information about Dr. Tsai's Sea Grant research, contact him at *tsai.1@osu.edu* or 614.292.0522. *TL*

Figure 2: A rod used to repair underwater structures, is coated with a water-proof layer and the flux. As the flux chemically reacts to the components of the base metal, an arc of energy is produced to protect the molden weld from water. Tsai's new electrode in 1995 enhanced the chemical make-up of the rod's flux which doubled welding time over the existing rods.

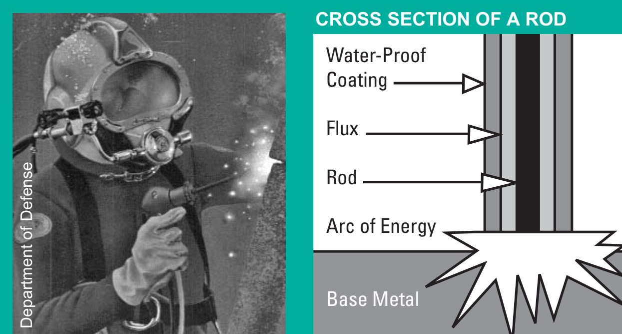
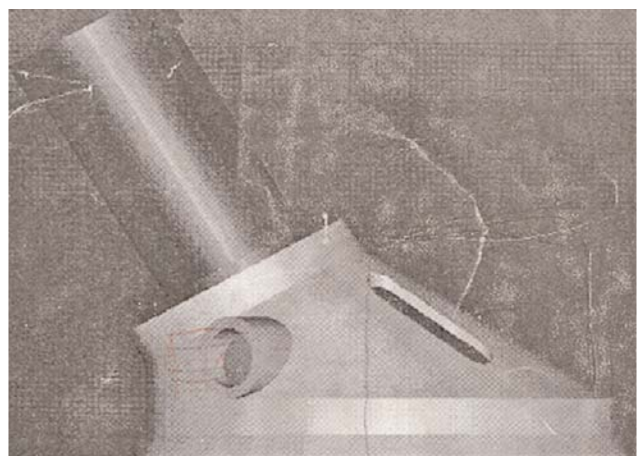


Figure 3: Tsai's "Smartshroud" is an oval-shaped cover (attached to the end of a rod) that holds the arc-bubble in order to shield the weld from the water. This device along with a tracking system, guidance console, and an in-helmet visual display, allow a welder to literally "see" a weld in progress and adjust parameters to make a good weld. Using Tsai's innovative "Smartshroud" system, welders can now produce air-quality welds.



1995: Establishes welding industry consortium, Ohio Underwater Welding Center, through support of Ohio State's Office of Research; College of Engineering; Industrial, Welding, and Systems Engineering Department; and Ohio Sea Grant.

1995: Conducts a one-day underwater welding clinic at the Ohio State University.

1996: Incorporates new FCAW process into Sea Grant and University research to use flux-cored wire for semi-automatic underwater welding and increase strength of wet welds.

1997-1998: Receives the A. F. Davis Silver Medal and Award twice in consecutive years for the excellence of papers on underwater welding repairs and joint design in the field of maintenance and structural design.

1997: Develops smart underwater "wet" welding gun for underwater GMAW and FCAW welding process that improves bend ductility of the weld.

1998: Leads a joint US and Canadian construction diving team testing the new underwater welding electrode in the diving tank at Edison Joining Technology Center at the Ohio State University.

1999: Leads Sea Grant sponsored national workshop at Put-in-Bay testing new underwater welding technologies.

2000: Leads Sea Grant co-sponsored international welding workshops in Taiwan.

2000: Develops microprocessor-based joint tracking and operation guidance system to increase arc stability.

2000: Elected to American Welding Fellow in recognition of outstanding and distinguished contributions that have enhanced the advancement of the science, technology and application of welding.

2002: Develops the "Smartshroud" system, a four element system that ultimately produces air-quality weld.

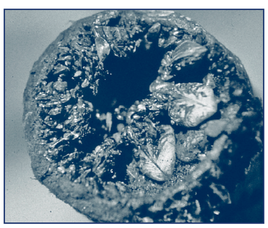
TWINELINE

2005 WINTER EDITION VOL.27/NO.1

If You Can't Take the heat

Research Examines Heat Tolerance in Zebra Mussels

by Jill Jentes Banicki, Ohio Sea Grant Communications



Since the first ballast water was exchanged in Lake Erie and zebra mussels were released, zebra mussels have impacted their surroundings. From clogging intake pipes to unlocking contaminants from lake sediments, zebra mussels have aggressively dominated species and rapidly changed the dynamics of ecosystems. But as zebra mussels continue to create problems in the Great Lakes, research continues to investigate ways to control them. Could high levels of heat control their numbers? Maybe. The first step to knowing how to control them, however, is by determining what factors make them so dominant in the first place. Those answers, says Miami University's Dr. Curt Elderkin, may lie in their genes.

Over the past five years, Elderkin, along with Drs. James Stoeckel, Paul Klerks, and David Berg have investigated whether a zebra mussel's ability to adapt to high temperature environments may be hereditary. "Zebra mussels have a substantial amount of genetic diversity which could contribute to their rapid spread throughout North America," states Elderkin. The more genetic factors upon which natural selection can act, the higher probability the species can adapt and survive in a new environment.

But to determine whether heat tolerance is a result of "survival of the fittest," the trait must be in zebra mussels' genes, points out Elderkin. The researchers used a full-sib half-sib experimental design that would eliminate variation due to the environment and maternal effects. "By taking out the environmental and maternal factors, we can solely focus on whether a trait (such as heat tolerance) is passed on from one generation to another," says Elderkin. They examined full-sib families, half-sib families (different mother, same father), and their offspring, exposing each to lethal temperatures in order to determine an individual time-to-death.

What the researchers found surprised them. "We had previously tested a small sample of zebra mussel adults and found there was a genetic component to heat tolerance," explains Elderkin. "This made sense considering how diverse zebra mussels are." Testing a larger population of zebra mussel veligers (larvae), however, they discovered that the heritability of heat tolerance among veligers was extremely low. "Our research found zebra mussels couldn't pass heat tolerance onto their offspring," says Elderkin.

Although their research suggests that heat tolerance may not be genetically determined, Elderkin's previous results using mussels from warmer climates indicated otherwise. "We realized that there was a drastic genetic change in mussels (along the Mississippi River from Minnesota to Baton Rouge) at one particular gene we sampled," states Elderkin. That change correlated to an as-much-as five-degree (Celsius) temperature difference between the zebra mussels living in the North (Great Lakes region) compared to those colonizing in the southern region. "Zebra mussels in the South could withstand higher heat temperatures than those in the North," explains Elderkin.

What could this difference mean? The results of the veliger-heritability study seem to contradict the evidence collected using southern zebra mussel populations. Zebra mussels in the southern regions are either using a heritable genetic component to heat tolerance or they simply adjust with long-term exposure to higher temperatures. "The longer they live, the more tolerant they become to high temperatures," says Elderkin. But to answer any of these questions, more work will be needed. "If using high heat could be a means to control zebra mussels, we needed to first know if zebra mussels could just genetically adjust to it," concludes Elderkin. "Our research, at least for now, indicates that they can't." TL

For more information about this Sea Grant funded research, contact Dr. Elderkin at *elderkcl@muohio.edu.*

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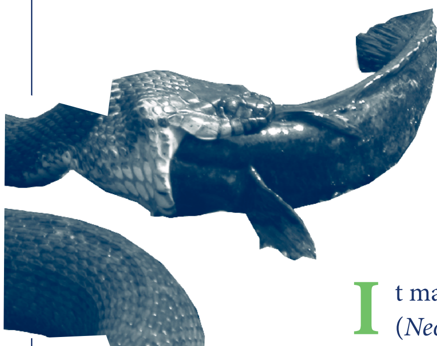
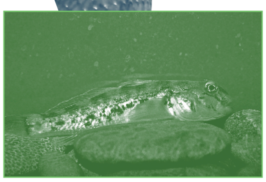
LEWS just LOVE Gobies!

by Kristin Stanford, Stone Laboratory





It may not be news that the round goby (*Neogobius melanostomus*) is an abundant and destructive invasive species that has spread through the western basin of Lake Erie. However, did you know that our federally threatened and state endangered LEWS or Lake Erie water snake (*Nerodia sipedon insularum*) has taken advantage of the prevalence of these troublesome little fish and is consuming them at surprisingly high levels? In fact, snakes are eating so many goby, that goby now constitute the majority of the snake's diet!

Water snakes haven't always had the goby to gorge on. Historically, water snakes have fed on native fishes (e.g., catfishes, logperch (*Percina caprodes*), and spottail shiner (*Notropis hudsonius*)) and amphibians (e.g., mudpuppy (*Necturus maculosus*)) (Fig.1). Round goby first appeared in diet samples of the snakes soon after the goby's invasion in 1995 and has between 1996 and 1998 constituted about 24 percent of the samples recovered by Dr. Richard King of Northern Illinois University and his graduate students. More recently, a new examination in 2003 and 2004 showed that round goby now constitute 92 percent of the snake's diet. Additionally, native fish consumption by water snakes was reduced to less than 2 percent of the prey samples recovered. Interestingly, this diet shift has occurred in less than two water snake generations (less than 6 years) and is seen in all size classes of snakes, from juveniles to adults.

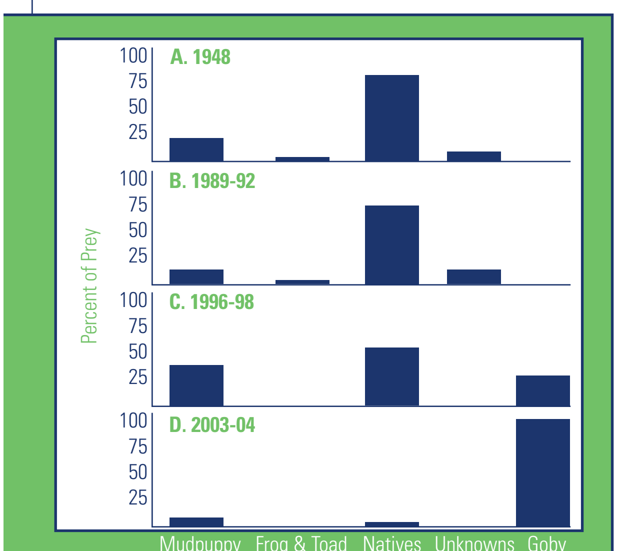


Figure 1. Frequency histograms showing change in Lake Erie water snake diet composition before (A, B) and after (C, D) the round goby invasion. Data in A are based on an unspecified number of prey recovered from 23 individual snakes collected on Pelee Island (Hamilton 1951). Data in B, C, and D are based on 45, 46, and 322 prey recovered from 31, 45, and 299 individual snakes, respectively. Histograms represent percent by number of snakes (A) or by number of prey (B, C, D).

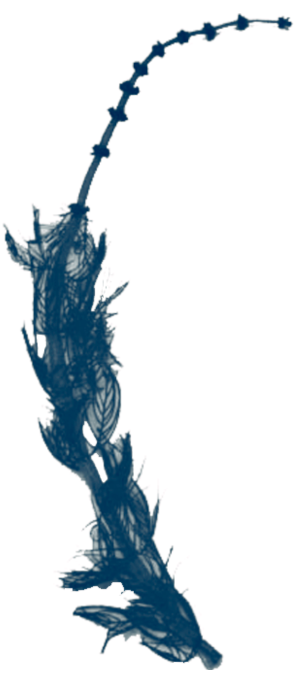
Often, introduced species such as the round goby have negative impacts on the native species and communities that they invade (see Sept/Oct 2000 issue of *Twine Line*). Surprisingly, however, the recent shift in diet from native fishes to round goby by the water snakes seems to be having beneficial effects for snake populations. Since the shift, water snakes have been able to grow faster and attain larger body sizes. By growing faster, water snakes can outgrow potential predators (e.g., shorebirds) more rapidly, reach sexual maturity faster, and produce larger litters of offspring. Since these factors can also positively effect important population regulating mechanisms (e.g., survival and reproduction), the invasive round goby may be indirectly contributing to the recovery of this federally listed species. Researchers believe this is one of the very few cases where a harmful and usually devastating invasive is resulting in positive effects for a native and threatened species. TL

Susan Warren

Some ask *Why?* OTHERS *Why* NOT?

by Robin Taylor, Ohio Sea Grant Communications

Eurasian watermilfoil (*Myriophyllum spicatum*) is a submersed plant that is highly invasive, having spread throughout all of North America's temperate zone since its introduction only 60 years ago. So when Eurasian watermilfoil was first documented in Old Woman Creek National Estuarine Research Reserve (OWC) on the eastern edge of Lake Erie's western basin in 1992, researchers and wetland managers took a deep breath...and are still holding it. Despite its notorious invasiveness, the growth of Eurasian watermilfoil in OWC has so far been—zero. It has reappeared many times only to disappear. So report Dr. Robert Whyte of Antioch College and Dr. David Francko of Miami University, who documented the plant's 1992 appearance. Since then, the researchers have systematically sampled the aquatic vegetation from the OWC, time and again rediscovering the plant growing in various sites—one in 1993, 21 in 1995, and two in 1996. Yet time and again the invader has apparently not taken hold. As suits scientific investigation, most researchers ask *why*? But in some cases, researchers can't resist asking *why not*? although such a question is impossible to answer. There may be any number of reasons to explain why something *doesn't* happen, and even finding one reason may not explain them all or even the most important ones.



The *why* of Eurasian watermilfoil's invasiveness is understood from observations of its invasion across the country: it grows quickly, it outcompetes other submersed plant species like itself, and it can grow from stem fragments, which are easily dispersed. Whyte and Francko can only speculate regarding the present *why not* of OWC's invasion, despite the many sites where Eurasian watermilfoil has taken root (only to disappear in subsequent years). The researchers suggest four qualities of OWC that might have contributed, so far, to protecting it from invasion, not to suggest that future invasion isn't possible.

One quality is that the plant might be susceptible to Lake Erie's freezing temperatures, which the plant experiences during natural winter drawdown of the already shallow (less-than-one-meter) estuary. In that same vein, plants and their root crowns near the shore may be sheared off by ice movement.

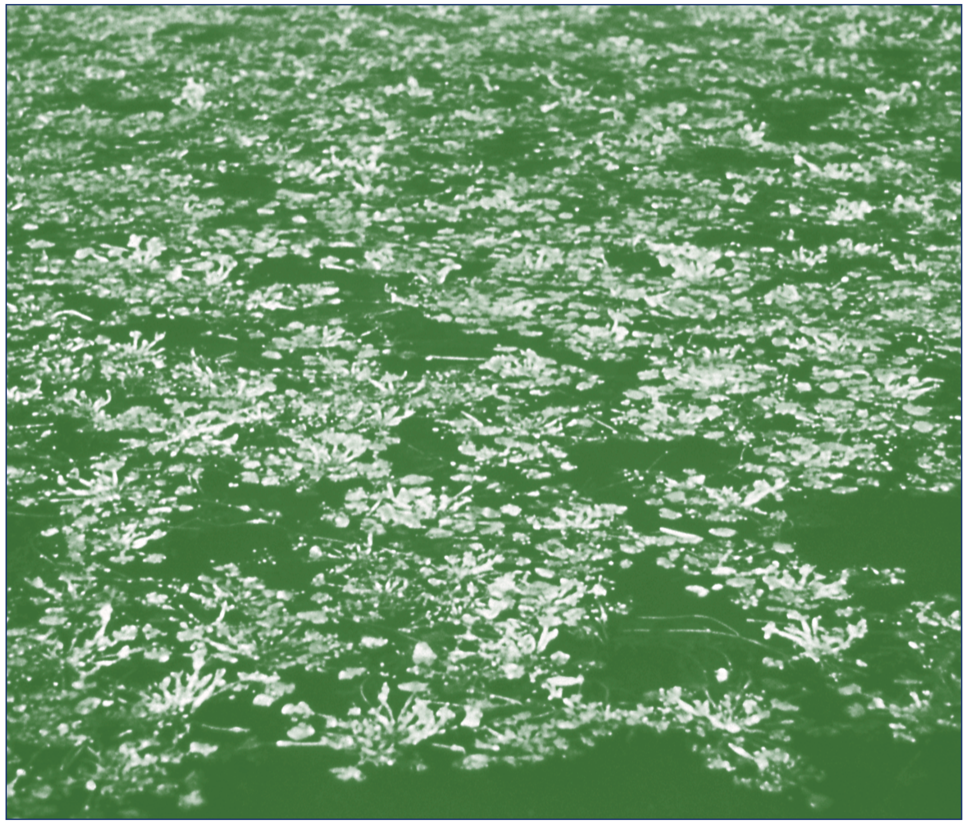
Second is that although Eurasian watermilfoil appears to find safe harbor and has taken root in the quiet waters created by stands of American water lotus (*Nelumbo lutea*), the researchers have also reported that American water lotus may produce an alleleopathic agent, a chemical that organisms can produce in different forms to kill or stunt their rivals. In this particular case, the agent would be a sort of natural herbicide to reduce rivals that compete for resources, such as space, nutrients, or light.

Gene Wright

Third, Whyte and Francko suggest that OWC's turbidity might hinder Eurasian watermilfoil's growth. The estuary is shallow and its sediments are primarily silts and clays, which are easily stirred. The resulting turbidity is such that limited light, the researchers say, may play an important role not only

WATERMILFOIL PG. 5 ▶

▶ **WATERMILFOIL** from PG. 3



in limiting the growth of Eurasian watermilfoil but also that of other plants.

Fourth, the estuary is protected from Lake Erie to its north by a barrier beach. This last form of protection makes sense when you know that Whyte and Francko's vegetation surveys so far show Eurasian watermilfoil entering the estuary only from the North, by way of Lake Erie waves that carry the plant and plant fragments. Still, this barrier is often open to lake waters, allowing plants and fragments to flow in. It may, in fact, even help direct the flow of the plants into the estuary. That these plants have yet to establish and create new populations indicates that, more than the barrier beach, some other quality of the estuary seems to protect it.

To suggest that OWC may somehow now be protected from Eurasian watermilfoil is in no way to imply that it is out of harm's way. In fact, the estuary's resistance to invasion may be a simple matter of numbers—not enough plants and plant fragments have yet been introduced in the estuary at one time to establish a stable population. Little can be known about the evolution of an invasion, such as how many times or in what critical numbers invasive species must be exposed to a new environment to take hold. That's because we usually aren't aware of an invasion until the invasive species shows itself, often in explosive numbers. Or, in the very rare case of OWC, we encounter an invader when it makes first contact because the area is already being so carefully monitored and surveyed for what is already there, in a healthy state. This is what makes the continued surveillance of OWC so valuable—researchers may be observing the introduction of an invasive species at its very beginnings. They may be observing the many false starts that invasive species undergo before they are able to establish new populations. Eurasian watermilfoil may continue to fizzle in OWC. It may, on the other hand, one season take hold and explode, and unless someone's there to see it, we'll have a much harder time understanding *why*. TL

For more information about this Ohio Sea Grant funded research, contact Dr. Whyte at *rswhyte@antioch-college.edu* or Dr. Francko at *franckda@muohio.edu.*

Whyte, Robert S. and David A. Francko. 2001. Dynamics of a pioneer population of eurasian watermilfoil (*Myriophyllum spicatum L.*) in a shallow Lake Erie wetland, Journal of Aquatic Plant Management. 39: 136-139.

From OHSU-RS-270. This work has been supported in part by grants R/ER-32 and R/ER-46 from the Ohio Sea Grant Program.

The Relatives that Won't Leave

by Robin Taylor,
Ohio Sea Grant Communications

Phragmites australis, or common reed, is a towering 12-foot-tall perennial grass found worldwide that is also native to North American wetlands. Found in every state, *Phragmites* (frag-MY-teez) is most abundant in wetlands along the Atlantic coast, although, according to Cornell University's program web site for the Ecology and Management of Invasive Plants, *Phragmites* recently has been expanding its range across the U.S. In fact, despite its being native—implying that time has tempered it to coexist harmoniously with other native species—during the last 100 years, across the country, as well as in our own Lake Erie wetlands, *Phragmites* has been aggressively crowding out and replacing other native plants.

What could cause a native plant suddenly to become aggressive? The explanation lies in the discovery that it is not the North American native *Phragmites* that is behaving aggressively, but a European relative. Such an invasion by nearly identical relatives, which scientists call a cryptic invasion, had been hypothesized by researchers but only now confirmed. Kristin Saltonstall at Yale University has identified 27 lineages of *Phragmites australis* worldwide, 11 of which are native to North America. These North American natives do live harmoniously in their communities and, although widespread, have been described as rare or not common. During the last 100 years, however, these native lineages have been replaced by a single European lineage, referred to as Type M. In the *Proceedings of the National Academy of Sciences* (2002) Saltonstall describes Type M as "highly competitive and aggressive." Her comparisons of modern plants with old herbarium specimens show Type M plants, in just 60 years, have replaced entirely the three lineages native to New England. Type M is spreading west, is becoming prevalent in the Midwest, and now populates southeastern states, where native *Phragmites* had never been found.

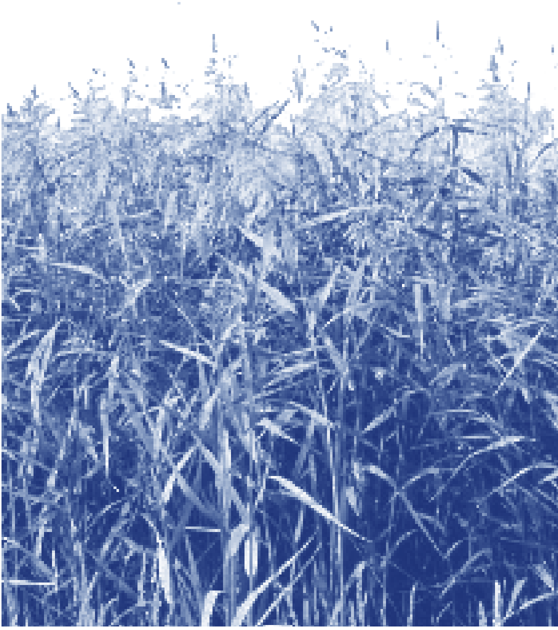
As a result of now realizing this cryptic invasion—which Saltonstall surmises started in Atlantic ports and has been facilitated by railroads and highways—and as a result of understanding the lager invasion in North American wetlands, three things have occurred: 1) In 2005, Saltonstall and two co-authors determined the North American *Phragmites* to be a subspecies, *Phragmites australis* ssp. *americanus*, distinguishing it from its European relative; 2) land managers have undertaken to protect native *Phragmites*, which are now subject to being outcompeted by Type M; and 3) land managers are looking for ways to eliminate or control Type M, which makes goal two all the more difficult.

Looking for ways to control *Phragmites* Type M in Lake Erie's East Harbor has been the work of Dr. Craig Davis and his graduate student Jennifer Morgan in Ohio State University's School of Natural Resources. Coinciding with 30 years of manmade changes around East Harbor, Type M has rapidly expanded in the marshes there. Where there were once historically small isolated populations of native *Phragmites*, now large monodominant stands of Type M shade out other plant species. Lost is not only plant diversity but animal diversity, because many different types of animals—here, covering the gamut from fish to fowl—require many different types of plants that only a diverse habitat can provide.

According to Morgan and Davis, land managers have tried a number of methods to control or eradicate the non-native *Phragmites*, such as herbicides, fire, and cutting. But herbicides kill many nontarget species along with the target, and fire (unless it burns the roots) and cutting can't touch what even weekend gardeners know to be a lifeline of many pestiferous plants—the underground rhizome. (You can cut a single plant to the ground, but new plants, or ramets, will come back from the rhizome.) One other remedy, particularly suited to lakeside marshes, is flooding. Plants cut to the ground and inundated are cut from their supply of oxygen, which induces a slow suffocation. A few seasons of

PHRAGMITES PG. 5 ▶

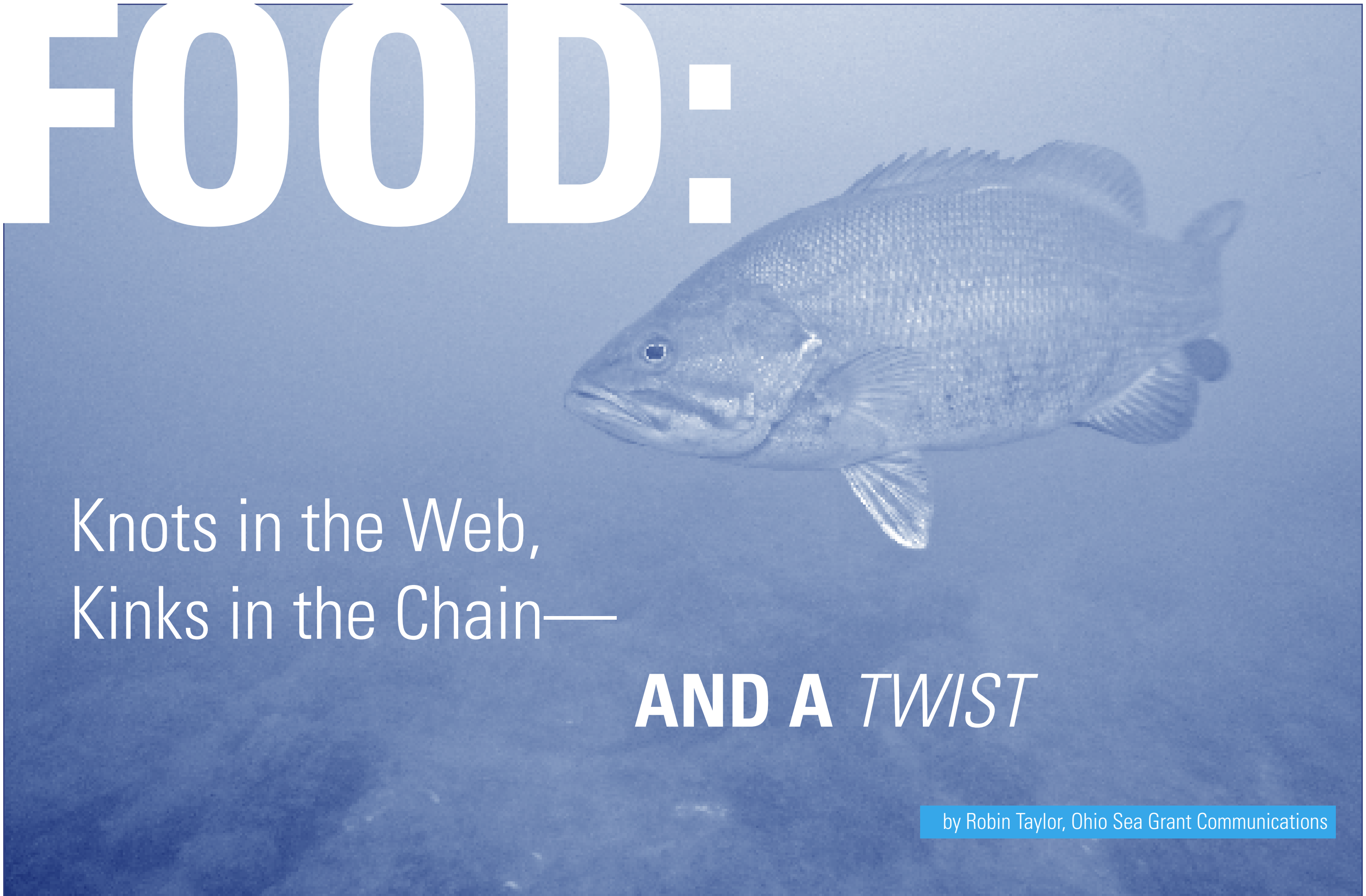
▶ **PHRAGMITES** from PG. 3



inundation may eventually destroy an entire stand. Like herbicides, however, flooding can be indiscriminant and nontarget plants in addition to Type M can suffer the consequences. To what degree nontarget plants suffer became the question of Morgan and Davis. More specifically, they asked, how much water does it take to effectively "drown" *Phragmites* and what will be the effect of this flooding on the desirable native species community?

Working in the East Harbor marsh in the growing season of 2003, Morgan and Davis established 24 plots of 8 different treatments created through a combination of soil treatment (excavating and plowing, plowing [which breaks up the rhizomes] or neither), water depth (25 cm or 70 cm), and *Phragmites* (cutting down emergent plants or not). At the end of a single season the researchers concluded that the fewest *Phragmites* plants were growing in plots that were plowed, inundated to 70 cm, and in which the *Phragmites* stems were cut as they emerged. This supports in the field what other researchers have found in the lab, that deep water may provide a means of controlling or eliminating non-native *Phragmites*.

Flooding does have its costs, however. Many more plants can grow in damp or wet soil than in deeply flooded soil, and this study supports others by showing that deep water changes the plant community. It creates an environment that supports only a certain type of plant—members of the submersed and floating aquatic guild (SFA). The total numbers of plants (stem density) may go up, therefore, but plant variety, that is species richness, goes down. But, say the researchers, such loss of plant diversity need only be temporary. Seeds from the damp/wet plant community are stored, or banked, in the flooded soil, and after two or three years of flooding to kill invasive *Phragmites*, a plot can be returned to its original water level, allowing the reemergence of damp/wet species. TL



FOOD: Knots in the Web, Kinks in the Chain—AND A *TWIST*

by Robin Taylor, Ohio Sea Grant Communications

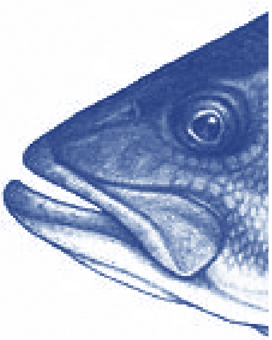
Ask researchers and anglers on Lake Erie, and they will both tell you that the lake has changed hugely in the past 20 years. The waters of Lake Erie have become clearer, partly due to reductions in nutrients entering from agricultural and urban lands. With greater water clarity, more sunlight could penetrate and stimulate algal growth on the lake's bottom, termed the benthic zone. As a result, more aquatic insects feed on the benthic algae, more prey fish eat these insects, and more benthic sport fish eat these benthic prey fish. Not surprisingly, many researchers will describe the lake at present as benthic-oriented.

Anglers would probably agree that fishing has become more benthic-oriented, too. Since 1990, Ohio anglers spent more time trying to catch benthic sport fish, such as yellow perch and smallmouth bass, and less time fishing for walleye, a more open-water species. As far as anglers are concerned, these changes are pretty straightforward, and if benthic sport fish are in greater supply than, say, walleye, they should catch more benthic sport fish and be happy, right?

You would expect the answer to be a simple yes. But decreased nutrient input, pollution, and three alien species—zebra mussels (*Dreissena polymorpha*), quagga mussels (*D. bugensis*) and round gobies (*Neogobius melanostomus*)—complicate the simple yes into a knotty issue of maybe yes/maybe no. The tangle begins with how these new organisms in the lake affect one of the most fundamental aspects of any ecosystem—the existing food chain (or food web) of who eats whom. The newest knot, or kink, may involve polychlorinated biphenyls (PCBs), newly introduced round gobies, and native smallmouth bass (*Micropterus dolomieu*).

Back when life was simple, or at least well established, before pollution and exotic invasions, zooplankton (microscopic animals) ate phytoplankton (microscopic plants), little fish ate zooplankton, bigger fish ate little fish, and humans ate the bigger fish. When pollutants were added to the lake inadvertently, and the focus here is on PCBs, phytoplankton became tainted with PCBs by being in contact with the water; zooplankton magnified the PCBs in their bodies by eating the phytoplankton; little fish magnified the PCBs in their bodies by eating the plankton; bigger fish magnified the PCBs in their bodies by eating the little fish; and humans...... began to worry.

When dreissenid (zebra and quagga) mussels were introduced in the lake in the late 1980s, even



though they lived on the bottom of the lake, in addition to filtering the PCB-tainted sediment around them, they filtered the water column *above* them for plankton. Now *they* were magnifying PCBs in *their* bodies. They were also stealing plankton from fish. So dreissenid mussels, in addition to costing the public millions of dollars each year to eliminate them from water intake pipes, competed with fish for food. On the other hand, the naturally sessile mussels helped sequester PCBs at the bottom of the lake where they remained anchored. They ate tainted sediment and plankton, they stayed put, and they were unpalatable because of their hard shell. Hardly anything ate dreissenid mussels....until now.

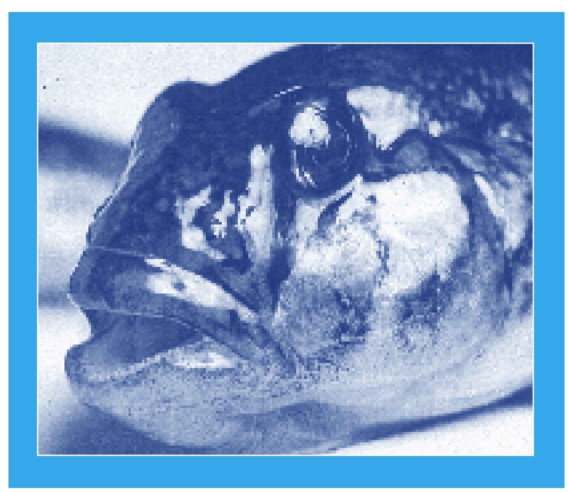
Enter the round goby, a small exotic fish that became established in the Great Lakes in the mid-1990s. It comes from the same part of the world as dreissenid mussels and already has them as a natural part of its diet. Where dreissenid mussels once locked PCBs—and nutrients—at the bottom of the lake in the benthic zone, now round gobies might be bringing them back up....... and up, if smallmouth bass eat round gobies in sufficient quantity. This could be a good thing if nutrients get back into the food web, a bad thing if PCBs do.

And here the story takes an odd twist. Since 1990, Ohio angler effort, harvest, and catch rate for yellow perch have all increased. And up until around 1998, the same could be said about smallmouth bass. Since 1998, however, just three years after round gobies became established in Lake Erie, effort, harvest and catch rate for smallmouth bass began to decline steadily. And yet these are both benthic sport fish, and smallmouth bass, it has been suggested, gain nutritionally from eating round gobies. Why have these fisheries gone in opposite directions? Answering that question has been part of the goals of Ohio State University Ph.D. candidate and John R. Knauss Marine Policy Fellow, Gene Kim, working under Drs. Roy Stein, Elizabeth Marschall, and Susan Fisher on a project funded by Ohio Sea Grant and the Lake Erie Protection Fund.

For part of his dissertation, Kim asked three straightforward questions: 1) Given a choice of round gobies and their native prey, minnows or crayfish, would smallmouth bass continue to choose native prey or replace it with gobies? 2) When smallmouth bass eat PCB-tainted round gobies, how much of the PCBs do they concentrate into their own tissues and return to the food web, and 3) by eating gobies, how much energy do they return to the food web?

For the first question, Kim brought Lake Erie smallmouth bass into the laboratory to determine if smallmouth bass prefer this new food item over traditional Lake Erie prey items. If the smallmouth bass eat round gobies, then either nutrients or PCBs or both can work their way back up the food chain from dreissenid mussels that trapped them in their body tissues. Kim and Matt Gearhiser, project research technicians, analyzed smallmouth bass feeding behavior when given equal numbers of round gobies, minnows, and crayfish in a large laboratory observation tank. They recorded how much time smallmouth bass spent pursuing each prey type, their success rate of catching and eating each prey type, and prey avoidance behaviors. What did they find? Smallmouth bass appeared to prefer minnows to gobies by making more attempts to catch them. But they wind up eating more gobies (49%) than minnows (42%) because minnows have a better-developed avoidance behavior—typical between prey and predators that have coexisted for a long time. Crayfish (9%) accounted for a small part of the prey. These results were similar to field data collected by Kim and others, and they reflect what smallmouth bass are actually consuming in the lake. Stomach contents of field-caught smallmouth bass from 1999 to 2000 show that gobies made up 33 to 100% of the diet (by weight), peaking in mid-summer. Minnows were less prevalent and no crayfish were found. Between 1997 and 2001, gobies in smallmouth bass diets increased from 17% (1997) to 75% (2001), reflecting their year-to-year growing abundance in the lake.

So data from both the laboratory and from fieldwork in Lake Erie show that smallmouth bass do eat more round gobies than other prey types on their revised dinner menu. To address the declining catch rates of smallmouth bass, Kim and his colleagues will next investigate the consequences of an increased goby diet on smallmouth bass growth and PCB concentration. They are finishing work to see what the nutritional levels and PCB levels are in round gobies from Lake Erie and in the laboratory. This way, they can forecast the results of smallmouth bass eating more and more gobies. TL



TWINELINE

2005 SUMMER EDITION VOL.27/NO.3

PROCEED WITH CAUTION HEAVY METALS PRESENT

by Robin Taylor,
Ohio Sea Grant Communications

You don't have to be a miner to know about the canary in the mine. Miners took canaries with them into mineshafts to act as indicators of harmful gasses, particularly carbon monoxide. A distressed canary meant trouble. Organisms that act like canaries in the mine are called bioindicators, indicating by their health or sickness the status of their (and our) environment. They indicate not only the presence of environmental pollutants, but also the susceptibility of live organisms to their uptake.

It is this susceptibility of live organisms that Drs. Richard Sayre and Sathish Rajamani hope to capture in their development of a biosensor for heavy metals in water. The researchers want not only to identify and measure heavy metals, but to determine their bioavailability, that is, what metals at what levels an organism will incorporate into itself. Exposure to heavy metals such as copper, zinc, cadmium, mercury, lead, silver, and gold at toxic levels causes nerve damage and cancer.

But exposure to these metals even at low levels can be harmful because they don't break down, they bioaccumulate up the food chain, and exposure to them is chronic and inescapable. Coal combustion, for example, discharges heavy metals into the air. Mining, industrial plating, and electronics manufacturing discharge heavy metals into the water.

To make this biosensor relevant and useful, the researchers need two things: 1) an organism that is everywhere there are heavy metals (which is everywhere) to act as a sort of standard organism, and

SAYRE PG. 5 ▶

INSIDE TWINELINE

The educational newsletter of Ohio Sea Grant, covering issues, events, and research related to Lake Erie and the Great Lakes

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2) some clear signal at the time and place of sampling (rather than back in the lab) that indicates the presence of heavy metals.

For the organism "standard" Sayre and Rajamani are using *Chlamydomonas reinhardtii*, a ubiquitous microalga that occurs in both soil and water (fresh and marine), in environments from the Sahara to Antarctica. The microalga is amenable to the genetic manipulation required to turn it into a sensor, and at the same time is amenable to the creation of barriers that keep the new design from reproducing in nature. For the clear signal, the researchers have expressed in *Chlamydomonas* a protein indicator from which a fluorescent yellow is sign that heavy metals are present.

The fluorescent signal is at the heart of this biosensor's efficiency. It relies on Sayre's and Rajamani's creation of a three-protein "sandwich." Two proteins (from jellyfish) that fluoresce blue or yellow flank a third protein called metallothionein (from chickens), which provides attachment sites for heavy metals. In the absence of heavy metals, metallothionein is a relaxed coil holding the two fluorescent proteins far apart, each contributing to a fluorescence ratio of about 1:1. When heavy metals from the environment bind to it, metallothionein folds more tightly into a dumbbell shape, bringing the two fluorescent proteins closer together. In this closer proximity, exciting both proteins with light of a specific wavelength causes energy from the blue protein to transfer to the yellow protein, causing the ratio of yellow to blue fluorescence to more than double. Enhanced yellow fluorescence indicates heavy metals in the environment. Binding sites on metallothionein have different affinities for different metals, something Sayre and Rajamani also hope to exploit to make the protein more metal-specific.

Having expressed their heavy metal biosensor in strains of *Chlamydomonas*, the researchers will now measure the protein's fluorescent response in the presence of various metals at various concentrations. Eventually they plan to concentrate and sequester these engineered *Chlamydomonas* cells in sealed probes and adapt them to existing optic systems. The result should be portable fluorescence devices that efficiently identify and quantify bioavailable heavy metals at the sites of contamination. TL

For more information about this Sea Grant project, contact Dr. Sayre at 614.292.9030 or *sayre.2@osu.edu*

invasion *predictions*

by Robin Taylor, Ohio Sea Grant Communications

some background

Organisms that accidentally get transported a long way from home and are able to establish themselves in a new environment are called pioneers. Depending on the number of pioneers that get transported, get established, and then reproduce, the subsequent populations can either be as genetically diverse as their relatives back home (the native population) or less genetically diverse. Lots of pioneers usually mean lots of diversity; fewer pioneers mean less, because only a few pioneers will not contain all the genetic variability of the original population. Less genetic diversity means that pioneer organisms might have a harder time establishing themselves in a new habitat with entirely new conditions, such as new food sources, new weather, new water and soil conditions, and so on. (If they do survive but are less genetically diverse, their descendants are said to exhibit founder effect). Their genetic diversity is important not only to the pioneers but also to us, particularly when the pioneers are invasive species. Lowered genetic diversity might hinder an invasive pioneer from spreading into its new environment. Conversely, high genetic diversity makes the invader more adaptable, and, likely, more successful.

prediction 1

Dr. Carol Stepien and members of her Great Lakes Genetics Laboratory (Lake Erie Center of the University of Toledo) studied the DNA of the Eurasian round goby, an invader in all of the Great Lakes not long after its estimated 1990 introduction, to show that the round goby populations here are every bit as genetically diverse as the native populations from which they came. That, according to the researchers, suggests that when the round gobies were transported here they arrived in large numbers (of diverse individuals). The researchers found the same for zebra mussels and for quagga mussels. This may sound like 20/20 hindsight, that is, the invasions were long ago successful, so it's not surprising to find that the pioneers were many and diverse. But the information actually makes for two predictions. One is that if the original invasions of zebra mussels and of quagga mussels and of round gobies were all fueled by transportation of large numbers of genetically diverse pioneers, then the chances are high that future invasions will be of a similar nature, of large numbers of organisms, most likely with similar characteristics (such as more types of gobies), from the same geographic area, that will develop in the same way—quickly and successfully. That is, unless, ballast water regulations are strictly enforced. Otherwise, we just have to wait. And, depending on what's worse, lots of different invaders invading the same geographic area or a single invader expanding its habitat, the second prediction may be more bleak.

prediction 2

The DNA analyses by Dr. Stepien and her laboratory showed that round gobies in the Great Lakes are actually more genetically diverse than their native populations. Their sample populations revealed that although gobies here live in fresh water the native gobies back home often prefer brackish waters. With their greater genetic diversity, populations here, then, should also tolerate brackish waters. And that's what the researchers predict, that, given this tolerance, round gobies will eventually extend their range into North American salt marshes and marine estuaries. And they should even find plenty of food in the form of blue mussels, which the native goby populations also eat back home. TL

For more information about this Ohio Sea Grant project, contact Dr. Stepien at 419.530.8362 or ***carol.stepien@utoledo.edu***.

THE MINI DEAD ZONE

An old problem in a new area in Lake Erie

by Joe Conroy, Stone Laboratory

A name like the "Dead Zone" may frighten many people away, but Lake Erie scientists flock to the lake at the mere mention of these words. The Dead Zone is located in the Lake's central basin between Lorain, Ohio and Erie, Pennsylvania, and consists of bottom water with low oxygen concentrations. During this past summer, a large group of researchers participated in the 2005 International Field Year on Lake Erie to study the well-known phenomenon (see *Twine Line* Vol. 24 No. 5 from September/October 2002) using large research vessels from the National Oceanic and Atmospheric Association. This research was supported by a large group of funding agencies, including Ohio Sea Grant. A smaller group of researchers from Stone Laboratory on Gibraltar Island investigated the frequency and duration of low dissolved oxygen concentrations in what is becoming known as the 'Mini Dead Zone' in the Sandusky subbasin. This work was supported by the Ohio Lake Erie Protection Fund, Ohio Sea Grant, and research endowments from Stone Laboratory.

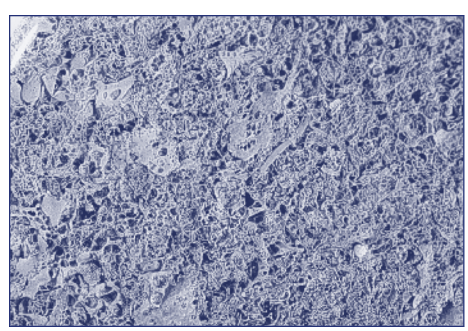
To measure the progression of the 'mini' dead zone in the Sandusky subbasin and how loading from the watershed affected it, Joe Conroy and other researchers from F.T. Stone Laboratory took biological samples in the Sandusky Bay, such as the phytoplankton sample shown here.

On cruises aboard F.T. Stone Laboratory's *R/V Erie Monitor*, the scientists sampled 11 stations from the mouth of the Sandusky River, into Sandusky Bay, and out into Sandusky subbasin from June through mid-August to determine how nutrients from the Sandusky watershed and algae from Sandusky Bay affect the development of areas of low dissolved oxygen in the Sandusky subbasin (what they call the Algal Loading Hypothesis). What they found was a bit of a surprise.

Based upon sampling of one station in the middle of the Sandusky subbasin during summer of 2002, the scientists predicted that only parts of the subbasin would become hypoxic (have oxygen concentrations less than 4 mg/L) or anoxic (oxygen concentrations approaching 0 mg/L). They discovered, however, that nearly the entire subbasin deeper than 12 m (40 ft) was anoxic by mid-July (approximately 200 km^2, an area the size of the island of Aruba or one-third the size of Lake County, Ohio). This Mini Dead Zone remained nearly devoid of oxygen until late-August when the combination of cooler temperatures and wind allowed the bottom waters to mix with surface waters, replenishing oxygen concentrations throughout the water column.

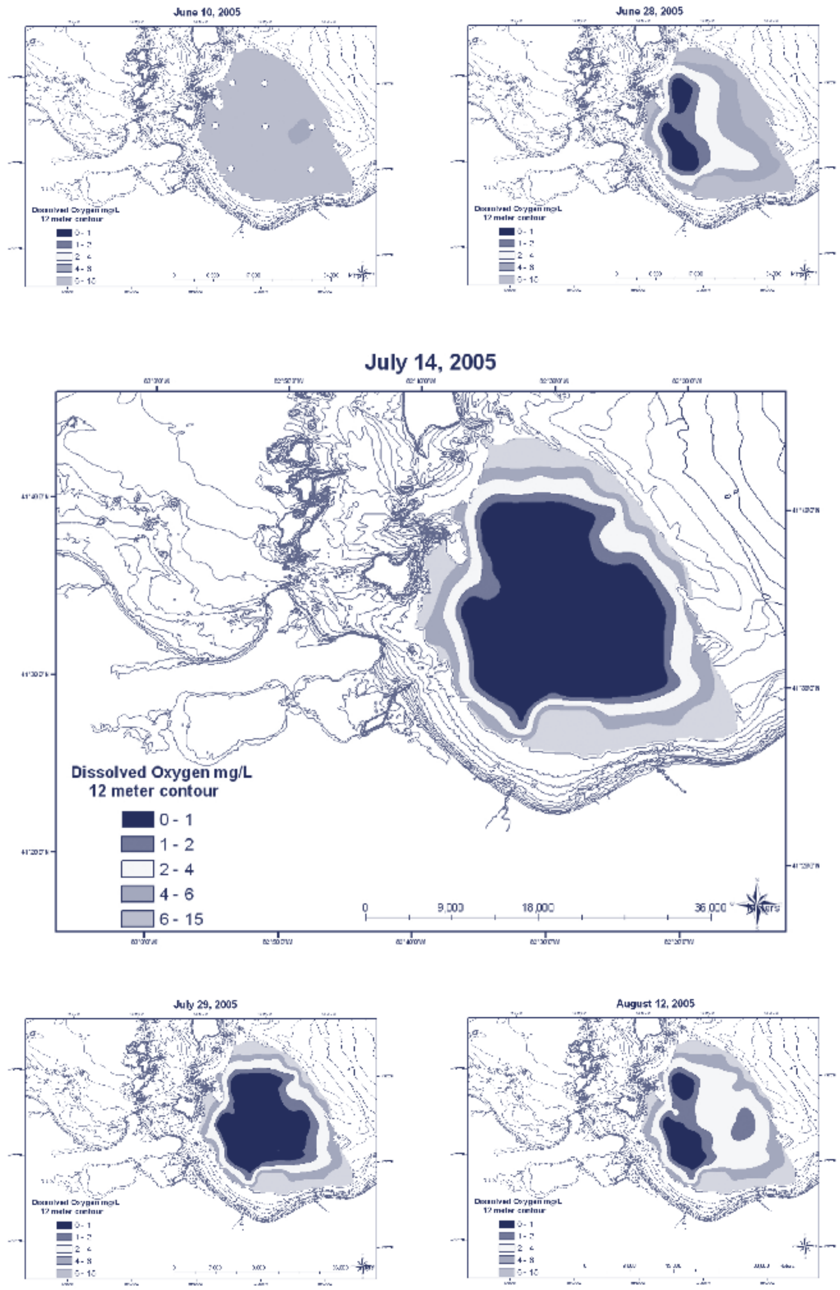
Scientists studying the Mini Dead Zone believe that processes similar to those causing the Dead Zone in the central basin cause low oxygen concentrations in the Sandusky subbasin, namely, high phosphorus loading, which stimulates excess algal growth. However, understanding how algal growth in Sandusky Bay affects the timing and duration of low oxygen concentration zones in the Sandusky subbasin remains the focus of ongoing research.

So how does the Mini Dead Zone affect organisms living in the Sandusky subbasin? Certainly most invertebrate animals (such as mayflies) living at the bottom of Sandusky subbasin would not be able to tolerate the low oxygen levels found this summer. Potentially more important is the effect of the Mini Dead Zone on fish populations that like to stay in the bottom waters, including walleye and yellow perch. These species would avoid water with oxygen concentrations as low as those found this summer in the Sandusky subbasin, possibly staying higher in the water column or moving to areas with higher



oxygen concentrations (like parts of the western or central basins), but understanding what the fish actually do remains to be studied.

While the existence of the Mini Dead Zone was known, its large area and duration were not. Its presence can have many detrimental effects, but further research into understanding how it forms and how it affects other organisms in the lake (including game fish) needs to be completed. Controlling its size or eliminating it completely may only be accomplished through further remediation in the watershed, which requires an active and interested group of citizens to, as was often heard as a rallying cry when Lake Erie was “dying” in the late-1960s, “Save our Lake!” TL



Development of a zone of hypoxia (low oxygen) and anoxia (no oxygen) in Lake Erie’s Sandusky subbasin during the summer of 2005: Scientists from F.T. Stone Lab originally predicted only parts of the subbasin would have low oxygen concentrations but instead found that nearly the entire subbasin deeper than 40 feet was anoxic by mid-July and remained low in oxygen until late August. This area was nearly one-third the size of Lake County, Ohio and could restrict fish species such as walleye or yellow perch from using the deep water in this area.

The Battle of the Bottom Dwellers

by Daniella Nordin,
Ohio Sea Grant Communications

Just how much of an impact do invasive species have on sport fishing in Lake Erie? More than we had thought, according to Chris Winslow, an instructor of Biological Sciences at Bowling Green State University. Over the past two summers, Winslow and his colleagues measured the impact that invasive species like round gobies have on young smallmouth bass growth rates and survival in Lake Erie.

Winslow's research, partially funded by Ohio Sea Grant, confronted the problem that invasive species may have a long-term effect on the smallmouth bass fishery. The research measured the survival, growth rate, and behavioral alterations of young smallmouth bass (less than two inches) and the way they interacted with round gobies.

Young smallmouth bass and round gobies are both bottom dwellers, preferring rock, rubble, gravel, and sand substrates over open water. The round goby, however, is known to be aggressive and highly competitive, often out-competing other native species for food and shelter from predators.

To observe the interaction between round gobies and smallmouth bass, Winslow constructed "cages" made of mesh and wire to simulate the bottom of Lake Erie. Some cages had smallmouth bass alone, while others housed both smallmouth bass and round gobies.

What he discovered was that round gobies do in fact have an impact on young smallmouth bass' behavior and growth.

Winslow places mesh cages at the bottom of Lake Erie to observe smallmouth bass and round gobies interaction.

"When smallmouth bass were left alone, they preferred the bottom of the cage, the location of abundant food and shelter," says Winslow. "However, when round gobies were present, they drove the smallmouth bass to the top of the cage."

As a result, Winslow found the smallmouth bass that had round gobies in their cages were half the size of those that had no round gobies.

But could part of that 50 percent growth reduction be due to both species competing for the same food? Winslow analyzed their diet to find that when smallmouth bass were alone, they ate benthic (bottom) prey but when the two species were together, the round goby ate the benthic prey and the smallmouth bass ate prey from higher in the water column.

"The decrease in the growth rate of smallmouth bass was attributed, not to the competition for the same food but rather, to the physical aggressiveness of the round goby and its ability to force the smallmouth bass into habitat with less food and out of the protection of its bottom-dwelling shelter, potentially making it more susceptible to predators," explains Winslow. "Additionally, gobies move young smallmouth bass away from macroinvertebrates, their preferred food."

When the fish reach two inches in size, their diet switches to include less macroinvertebrates and more fish and their survival rate increases dramatically. At this size and life stage, the smallmouth bass consider gobies prey. With an estimated 10 to 30 gobies per square meter in Lake Erie, the larger smallmouth bass have an ample food supply.

Round gobies push smallmouth bass up in the water column, potentially subjecting them to higher predation.

But Winslow points out the problem is getting the fish to that point. "The juvenile stage (of smallmouth bass) is the time when the most dramatic impacts are felt," states Winslow. "Not only do round gobies decrease the bass' growth by half, but they push the bass up in the water column, potentially subjecting them to higher predation."

Knowing these data can offer fisheries managers predictive tools to better sustain smallmouth fish populations. "If fisheries managers know when fish communities are most vulnerable and know which invasives adversely affect them, the hope is they can change management policies or enact regulations that better protect that life stage," emphasizes Winslow.

Smallmouth bass survival is of special concern because of its significance as a sport fish in Lake Erie. An Ohio Department of Natural Resources survey found that anglers spend approximately 480,000 hours fishing in Lake Erie for smallmouth bass every year. With fishing demand increasing (up 550% since 1975) fishery managers are concerned with how invasives like round gobies and zebra mussels can affect the survival of this popular fish.

Winslow says, however, that this research is just a piece of the puzzle. He plans to conduct more research on the effect that abiotic factors, such as storms, as well as other invasive species, have on smallmouth bass survival. He stresses the importance of the need to understand the complexities of invasion biology and the methods through which invasions can impact specific communities. TL

Conducted at Stone Lab, this research is the work of research is the work of Chris Winslow, Dr. Jeff Miner, Dr. Dan Wiegmann, and Sarah Opfer of Bowling Green State University. For more information about this Ohio Sea Grant-funded project, contact Chris Winslow at cjwinsl@bgsu.edu.

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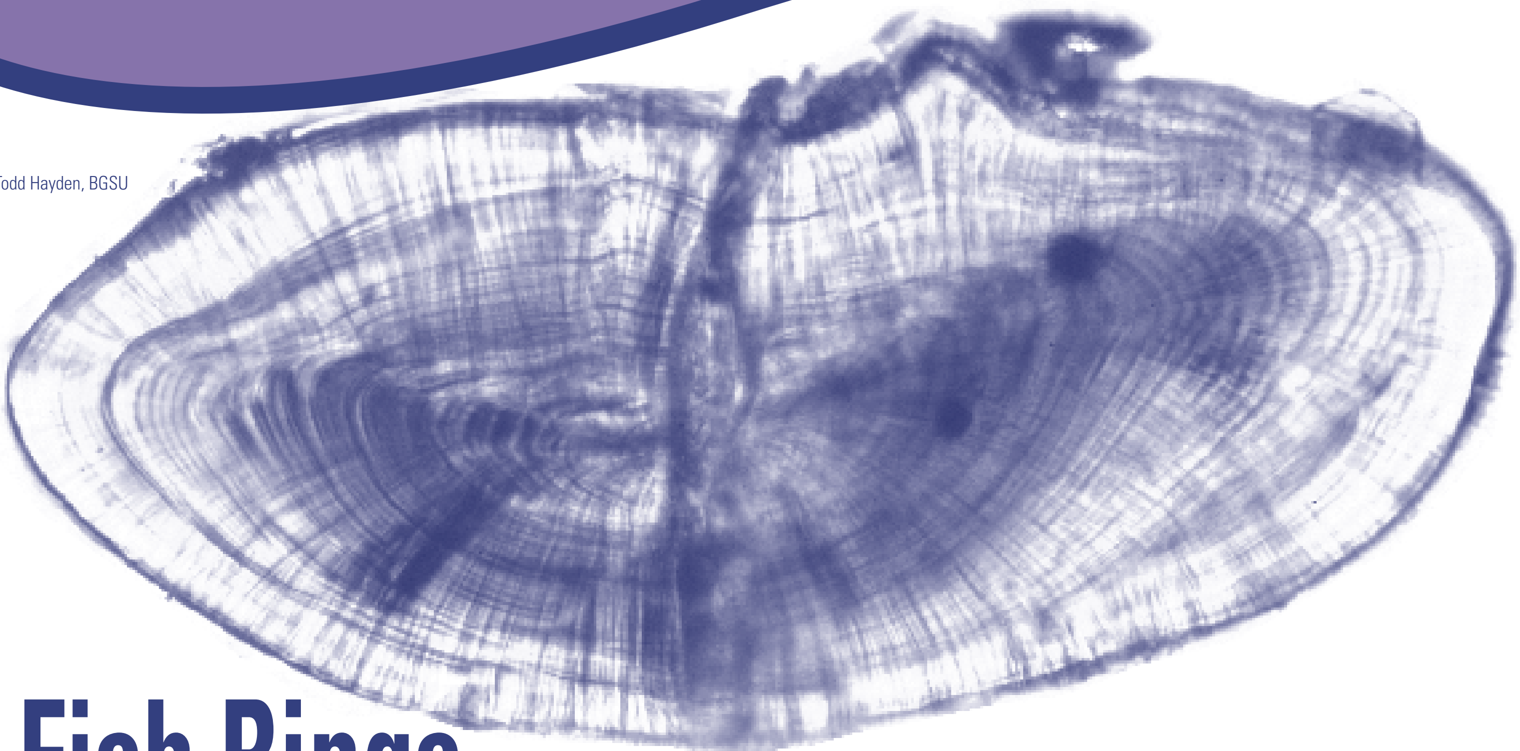

Todd Hayden, BGSU

Fish Rings

Research finds fish ear stones may provide historical map of fish migration

by Jill Jentes Banicki, Ohio Sea Grant Communications

New Ohio Sea Grant research could help fishery managers determine where they can better focus their fish habitat conservation efforts in the Great Lakes. And the answer may lie in little ear stones fish use for balance.

Ohio Sea Grant researchers Drs. John Farver and Jeffrey Miner from Bowling Green State University are investigating whether the otolith, a bone-like structure in the heads of fish, could track where sport and commercial fish spawn and travel during their life.

"Our research is finding that the composition of a fish's otolith can provide a natural tag indicating where in Lake Erie a fish was born and where it migrates as it matures," explains Farver.

Known as ear stones, otoliths are small bone-like structures located in a fish's inner ear that fish use for balance. But Farver and Miner's research suggests that otoliths may have another important function.

"Otoliths are distinctive because they incorporate trace metals as the fish grow that reflect the chemistry of the environment in which the fish are living," states Farver. Like tree rings, otoliths grow more in the summer. But more interestingly, with every ring, otoliths record what is in the fishes' environment at that moment in time.

"Different locations in Lake Erie have a different water chemistry signature—identifiers that are unique to that specific area of the lake at that

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The educational newsletter of Ohio Sea Grant, covering issues, events, and research related to Lake Erie and the Great Lakes

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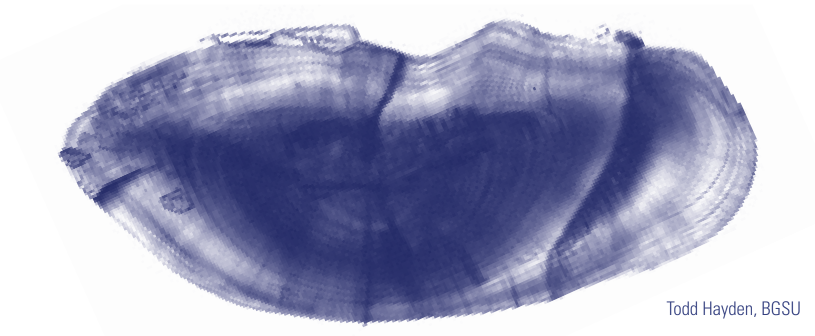
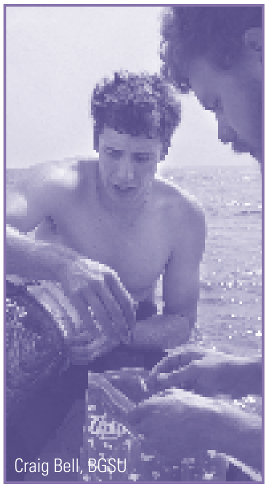
▶ **FARVER** from PG. 1

New Ohio Sea Grant research finds that fish otoliths (like the magnified otolith on right) may hold a key to mapping where Lake Erie fish migrate through their lifetimes. Like tree rings, otoliths can tell researchers the chemical make-up of the fishes' environments at specific moments in time.



Todd Hayden, BGSU



Craig Bell, BGSU

Craig Bell, BGSU

Researchers found a distinct chemical difference between the otoliths of white bass from the Maumee and Sandusky rivers. The research is a step toward using otoliths to map fish migration in the Great Lakes.

specific time," explains Farver. "If we can match an otolith's chemical make-up with that of a specific area in Lake Erie, we can hopefully use these water signatures to track the migration of the fish throughout its lifetime."

To test their theory, the researchers and their team of graduate and undergraduate students placed mesh cages in nine locations around western Lake Erie in the summer of 2005, including important spawning and nursery areas in Maumee and Sandusky bays. Juvenile (one-inch) yellow perch were placed in the mesh cages and were periodically sampled to compare their otoliths' chemical profile with the chemical profile of the water they lived in.

Preliminary results on their otoliths data will come out later this year, but the hope is that the team can go back in the next two or three years and again compare the adult fish spawning in those specific areas in Lake Erie with the original otolith signatures.

By placing the cages in different locations around Lake Erie, the team also plans to investigate how much the water chemistry varies spatially as different water sources mix and whether stress or other variables like water temperature may play roles in how much a fish may absorb trace metals. "If signatures match, we know the fish remained in a particular region of Lake Erie. If not, then we may be able to track mixing patterns of different populations or stocks," says Farver.

These data will build on previous work with adult white bass, from which these researchers found that there is indeed a distinct chemical difference between the otoliths of white bass spawning in the Maumee and Sandusky rivers. But the team needed a baseline signature to track the migration of the fish, and specifically to determine if the fish returned to where they were spawned. They conducted their study last summer to find these baseline signatures.

"Since our research is trying to match the chemical signatures of the otoliths from adult fish when they are spawning, we needed to know what that signature would have been the year that they were spawned," states Farver.

Farver points out that their research results will assist fishery managers beyond better mapping of fish migration. "If we know that a specific area of Lake Erie is contaminated with heavy metals and we know that the area is a key spawning habitat for walleye or yellow perch, our hope is that fishery managers and elected officials will use this information to prioritize conservation and clean-up efforts," concludes Farver. **T**L

This research is the work of Dr. John Farver, Dr. Jeff Miner, PhD student Todd Hayden, MS student Chris Pepple, and undergraduates Jim Verhoff and Ray Popik of Bowling Green State University. For more information about this Ohio Sea Grant-funded project, contact Dr. Farver at 419.372.7203 or jfarver@bgnet.bgsu.edu.

Craig Bell, BGSU

Researchers from Bowling Green State University placed cages at various locations around western Lake Erie to record water and otolith signatures.