1999

Ohio Sea Grant College Program

Research & Education Projects

Initiated between 1994 and 1999

Aquatic Nuisance Species Projects 1991- 1999

Sea Grant
Ohio Sea Grant College Program

www.sg.ohio-state.edu

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Lake Erie

Lake Erie is Ohio's most valuable natural resource. It provides drinking water for more than 11 million people a day, cooling water for over 20 electric power plants, more fish for human consumption than the other four Great Lakes combined, and a sport fishing industry worth hundreds of millions of dollars. The seven coastal counties account for more than 30 percent of Ohio's $10 billion travel and tourism industry.

In surface area, Lake Erie is the 12th largest freshwater lake in the world and the smallest of the Great Lakes in volume. Lake Erie is the Great Lake that stands out as the "workhorse." For 200 years the lake has been extensively used for transportation, manufacturing, drinking water, and as a waste disposal system. These extensive uses exceeded the sustainable limits 30 years ago when the Cuyahoga River caught fire and Lake Erie became the poster child for this country's pollution problems. With pollution abatement and improvements in natural resources management, Lake Erie is once again a thriving resource that provides abundant recreational opportunities including boating, fishing, diving, swimming, beach-combing, and bird watching.

Even though the Lake Erie basin has the largest population and highest population density in the Great Lakes, cropland is the dominant land use (forests dominate the land in the other basins.) Because of this intensive agricultural use, Lake Erie has more sediments, phosphorus, and pesticides flowing into it than any of the other Great Lakes – about half of all pesticides used in the Great Lakes are used in the Lake Erie watershed. Heavy industry along Lake Erie's shores, especially near the tributaries, has given the lake a legacy of polluted sediments. The International Joint Commission identified 13 out of 43 designated Areas of Concern (areas of impaired water use) in the Lake Erie basin, four of which are in Ohio.

Even with these problems, Lake Erie waters normally produce more fish than the other four Great Lakes combined. Most of the fish caught in U.S. waters are caught by recreational anglers who know the lake as "The Walleye Capital of the World." Lake Erie also has the distinction of being the largest freshwater commercial fishery in the world, due primarily to the large Canadian commercial fishery. There are also more registered boats in Ohio than in 42 other states, more than a third of the Great Lakes charter captains are from Ohio; and Ohio has an average of almost one marina for each mile of shoreline.

Although the uses of Lake Erie are plentiful, so too are the problems: changes to the ecosystem, toxic contaminants, polluted sediments, fish populations and their health, confusion about the safety of eating fish, and balancing economic health of industries with the health of the lake. Lake Erie is experiencing a rapid change in its ecosystem. The introduction of aquatic nuisance species, most notably the zebra mussel, has accelerated the pace of the change.

The Ohio Sea Grant College Program

The Ohio Sea Grant College Program at The Ohio State University is one of 29 Sea Grant programs in the National Sea Grant College Program, NOAA, U.S. Dept. of Commerce. Patterned after the Land Grant system, a Sea Grant program must be a partnership between academia, government, and the private sector. We strive to improve education, the economy, and the environment using a combination of research, education, and outreach. Our primary goal is to enhance utilization, development, and wise management of Lake Erie, Ohio's most valuable natural resource, to enhance

the quality of life for the people of Ohio. Ohio Sea Grant solicits research proposals from every college and university in the state annually or biennially and, working entirely on a competitive basis, has supported projects at 12 Ohio universities. The program also supports an education program to enhance the skills of Ohio teachers, an extension program with 6 extension agents located along Ohio's north coast, and a communications staff intent on making science understandable to non-scientists. Every federal dollar we receive must be matched by at least $.50 from non-federal sources.

Stone Laboratory, created by Ohio State University in 1895, is Ohio's Lake Erie Laboratory and the oldest freshwater biological field station in the country. Each year Stone Laboratory offers 15-20 college courses during the summer, special workshops and field trips for grades 5 through adults during the spring and the fall, and research goes on year-round. Stone Laboratory is also the shared research facility for the 12 Ohio colleges and universities in the Great Lakes Aquatic Ecosystem Research Consortium (GLAERC). Since 1990 students from 40 Ohio colleges and universities, 31 out-of-state colleges, and over 265 high schools have taken courses for college credit at Stone Laboratory.

Ohio Sea Grant's Research Priorities

In developing our research priorities, we review:
· Priorities of the National Sea Grant College Program;
· Priorities and emerging issues identified by the International Joint Commission;
· Needs and opportunities identified by the scientific and management communities;
· Lake Erie Protection Fund status reports and priority setting efforts; and
· Annual surveys we conduct of about 1,000 people at the Cleveland Boat and Sport Shows.

Proposal Preparation and Review Process

Ohio Sea Grant uses two external review panels, preproposals, full proposals, and external written peer reviews when evaluating research proposals. The preproposal process allows investigators to propose projects and receive feedback about anticipated funding success without spending the time required to prepare a full proposal.

An external review panel reviews all preproposals. Full proposals are then solicited from those investigators receiving the best reviews. The number of preproposals selected is based on the quality of the preproposals and an estimate of funding that is available. It is inevitable that budget constraints will eliminate some proposals.

At least three external written peer reviews are obtained for each proposal. Principal investigators are permitted to submit written comments on the peer reviews. A second external review panel is then assembled. After reviewing the proposals, the peer reviews, and the investigator's comments, this panel recommends to the Director which proposals should be supported and included in Ohio Sea Grant's package to the National Sea Grant College Program.

Sea Grant Project Classification

Ohio Sea Grant uses a numbering system that first places all projects into one of four groupings (primary designation): 1.) research, 2.) education, 3.) management, or 4.) advisory service and extension. All research projects have a number that begins with the letter "R", education projects begin with an "E", management projects begin with "M", and advisory service or extension projects begin with an "A". This letter is followed by a slash (/) and then a series of 1-3 letters that further describe the project (secondary designation). The number that follows the secondary designation code is simply assigned chronologically to projects in that designation, i.e. the first project funded in that designation is number 1, the second project is 2, etc. Some project numbers end with the letters "PD". As a program we solicit for large proposals and initiate large grants annually or biennially. However, we accept and support small grants through our Development Fund at any time. These small grants supported with Program Development funds end with the letters "PD".

This program directory includes Ohio Sea Grant funded projects from 1994 - 1999 and selected related projects for the years 1991-1993. For a full funded project list prior to 1994, request a copy of **Program Directory: Projects & Personnel 1977-1994** from Ohio Sea Grant Publications (see inside front cover for order information). Project summaries are updated periodically on-line and can be accessed at the following url: ***www.sg.ohio-state.edu/Project/***

Project Classification Key

Primary Designation

A/	*Advisory Service and Communications*				
E/	*Education*				
M/	*Management*				
R/	*Research*				

Secondary Designation

A	*Aquaculture*	***EO***	*Education Office*	***MRC***	*Marine Recreation*
AID	*Awareness Infusion Development*	***EP***	*Extension Program*	***NIS***	*Nonindigenous Species*
AS	*Other Advisory Services*	***ER***	*Ecosystems Research*	***OE***	*Ocean Engineering*
BT	*Biotechnology*	***ES***	*Environmental Studies*	***P***	*Publication (if A/P -)*
CD	*Course Development*	***GIS***	*Geographic Information Systems*	***P***	*Program (if M/P -)*
CE	*Coastal Engineering*	***I***	*Internships*	***PS***	*Pollution Studies*
CEI	*Coastal Engineering Intern*	***LR***	*Living Resources*	***SEL***	*Socio-Economic and Legal*
CMD	*Coastal Material Development*	***MB***	*Marine Biomedicinals & Extracts*	***SP***	*Socio-Political*
CZS	*CZM – Social Sciences*	***MD***	*Market Development*	***TE***	*Teacher Education*
D	*Development*	***ME***	*Marine Economics*	***TER***	*Teacher Education Research*
EM	*Environmental Models*	***MP***	*Museum Programming*	***TS***	*Transportation Systems*
E	*Education*	***MR***	*Mineral Resources*	***ZM***	*Zebra Mussels*

PD	*Development Fund Projects (Small Grants)*				

Aquaculture Research

R/A-7 9/1/96 to 8/31/98

Extending the Seasonal Availability of Walleye Juveniles Through Environmental/Hormonal Treatment During Reproduction and Evaluating the Quality of Resulting Progeny

Konrad Dabrowski, Natural Resources, The Ohio State University
David Culver, Zoology, The Ohio State University
Joseph Ottobre, Animal Sciences, The Ohio State University

The walleye (*Stizostedion vitreum*) has been deemed a fish of considerable aquacultural potential because of its high market acceptability in the metropolitan areas of the Great Lakes region and its limited supply by commercial fishing. However, the dependence upon eggs collected from ovulated wild fish captured near their spawning grounds results in poor fertilization percentage due to unsynchronized ovulation. To increase the reliability of walleye culture operation, there is a need to induce spawning in captive walleye broodstock and/or develop effective out-of-season induction of maturation and final ovulation. Earlier spring spawning allows hatchery operations to expand the growing season of walleye yearlings, both for aquacultural purposes and stocking larger, healthier fish to the reservoirs. The production of domestic broodstock could be a replacement for the use of wild fish, and facilitate reproduction under intensive, controlled conditions necessary for future industry.

This study examined the extension of the seasonal availability of walleye fry for stocking purposes by stimulating reproduction through manipulation of temperature, light, and gonadotropic hormones. It also developed the behavioral and biochemical assay for the quality of juvenile walleye by measuring swimming stamina, lipid and fatty acid content, and vulnerability to a predator. By translating the results of the biochemical fitness measures into fish quality methods more readily used for hatchery produced fish assessment, the project carried out technology transfer to those most directly involved in stocking fingerlings.

R/A-8 4/1/96 to 3/31/98

Regulation of Function in Spermatozoa of the Sea Lamprey (*Petromyzon marinus*): The First Step in Contraception

Konrad Dabrowski, Natural Resources, The Ohio State University
David Stetson, Zoology, The Ohio State University

With the opening if the St. Lawrence Seaway, non-indigenous sea lamprey gained access to the Great Lakes, successfully colonized their waters, and caused a devastating impact on fish assemblages. Efficient reproduction of lamprey contributed to the undoubted colonization success of this species. However, because of the lack of knowledge on the biology of semen in lamprey, we do not have a full understanding of how the male reproductive system contributes to the enormous reproductive success of the lamprey. Understanding the physiological mechanisms regulating reproduction of the lamprey is a prerequisite for further attempts to control sea lamprey populations.

This study examined the morphology of spermatozoa before and after acrosomal reaction (AR) by scanning and transmission electron microscopy. Besides Computer-assisted Sperm Motion Analysis (CASA) used for motility studies, the relationship between the acrosomal reaction and fertilization was evaluated by means of fertilizing batches of eggs with sperm under controlled conditions and with various degrees and mechanisms of AR blocking. This research described the ultrastructure of spermatozoa of the sea lamprey, characterized the nature and regulation of sperm motion, and identified factors able to inhibit sperm motility. It also characterized the sperm acrosomal reaction and its regulation, developed cryopreservation of sea lamprey sperm, tested the effect of a spermicidal agent, and studied sperm proteolytic activity.

R/A-9-PD 7/1/96 to 3/31/97

A Cost-Effective Trap to Remove Carp and Bullhead from Diked Wetlands

David L. Johnson, Natural Resources, The Ohio State University
Fred Miller, Natural Resources, The Ohio State University

Approximately 84% of Ohio's Lake Erie wetlands are diked to allow water level manipulation for maximizing habitat diversity and aquatic vegetation production. The problem common to these wetlands are large populations of common carp (*Cyprinus carpio*) and bullhead (*Ameiurus* spp.) which degrade water quality and habitat through their spawning and feeding activities. This study designed a cost-effective trapping strategy that used water flow to attract and facilitate removal of these nuisance species from diked wetlands. Using a gasoline-powered water pump to create flow into the wetland, the water was directed by panels consisting of fence posts, chicken wire, and silt screen, with the end of the trap constricting to allow these species to enter but not leave. The project tested the effects of pumpwater source and time of year on numbers and sizes of carp and bullhead removed. The successful development of the trap to reduce common carp and bullhead populations would provide a tool for wetland managers for increasing water clarity, production of submergent vegetation, and diversity of fish and wildlife communities.

R/EM-10 3/1/98 to 2/28/00

Development of A Non-Destructive Molecular Probe for While-Body Fat Stores in Largemouth Bass

Richard A. Londraville, Biology, University of Akron

The largemouth bass (*Micropterus salmoides*) fishery is one of the most popular recreational fisheries in Ohio, with over 185,000 fish landed annually. However, efforts to enhance this fishery through stocking of juveniles by Ohio Division of Wildlife Hatcheries has all but ceased because of severe juvenile overwintering mortality. Overwintering mortality in *M. salmoides* (as high as 87%) seems to be a function of both fish size and lipid stores. In examining the role of lipid stores in overwintering mortality, researchers must destroy the fish to assay whole-body lipid organic extraction, visual inspection, or bomb calorimetry. Therefore potentially crucial data (such as repeated measurements on an individual through the overwintering period) are unavailable with current techniques. This research examined the possibility of an antibody against largemouth bass leptin, a hormone indicative of whole-body fat stores in mammals, would provide a non-destructive measure of fat stores. Using this probe, this research could measure whole-body lipid literally from a drop of blood, and thus track individual lipid stores across seasons.

This research tested the hypothesis that leptin levels and whole-body lipid stores are correlated in *M. salmoides*. Effects of age, sex, body weight, environmental temperature, nutritional status and circadian cycle on leptin concentrations were measured. It also developed a molecular probe for whole-body fat stores in largemouth bass *Micropterus salmoides*.

R/A-11 3/1/98 to 2/28/00

Fish Genetic Resources Bank—Biodiversity and Superior Fish in Aquaculture

Konrad Dabrowski, Natural Resources, The Ohio State University
D. L. Stetson, Zoology, The Ohio State University
G. Toth, US EPA, Cincinnati, OH

Conservation of fish genetic diversity is important to not only the fish industry, which relies on it as income, but also to those who equate biodiversity with a global equilibrium. Gene banking is a relatively new technique that allows humans to affect populations by genetically altering species within only a few generations. Although genetic selection programs have resulted in increased production of farmed fish, there has been almost no coordination to maintain certain fish species' identities and cultural characteristics.

In order to ensure that genetic diversity is maintained for the future, this project addressed problems of aquacultural development on the Great Lakes region. Specifically, this project developed relatively simple techniques for sperm cryopreservation under conditions typical of commercial production and developed genetically engineered strains of fish to enhance that production. A Fish Genetics Resource Bank of cryopreserved sperm was established as a means of storage to increase genetic diversity and productivity of commercial fish production.

R/A-12 3/1/98 to 2/28/00

Application of New Biotechnology of Micro-Encapsulation

Konrad Dabrowski, Natural Resources, The Ohio State University
Sagiv Kolkovski, Natural Resources, The Ohio State University
C. Thies, Thies Technology, St. Louis, MO

The yellow perch (*Perca flavescens*) is an important commercial fish species in the Midwest and the Great Lakes basin. However, the commercial fishery of yellow perch has declined sharply over the last 20 years and is now significantly regulated in all lakes. This loss and current high demand for yellow perch has sparked an interest in intensive culture of the species. A major problem in intensive culture of the species in the dependence on live zooplankton during the larval stages. To insure a continuous supply of plankton year round, a "food chain" should be established. The production of encapsulated diet particles is an approach that delivers nutrients, vaccines, enzymes, and other substances into small fish larvae.

This research concentrated on the development of encapsulated diets for yellow perch larvae that may be suitable to other important recreational fish in the Great Lakes region. Each capsule would be required to retain the nutrients needed by the larvae until the capsules are ingested by the larvae, would not be rejected by the feeding larvae, and would release its contents completely in the larval gut with no toxicological effects.

Biotechnology Research

R/BT-3 9/1/94 to 8/31/97

Applications of Recombinant Algae for the Treatment of Heavy Metal Contamination in Aqueous Solutions

Richard T. Sayre, Biochemistry and Plant Biology, The Ohio State University
Terry Gustafson, Chemistry, The Ohio State University
Samuel Traina, Agronomy, The Ohio State University
Terry Logan, Agronomy, The Ohio State University

Trace elements occur naturally in low amounts in soil, rock, water, and organisms. Industrial use and processing has concentrated some of these trace elements, making them the major contaminants of many industrial sites worldwide. The current methods for removing these trace elements create huge volumes of waste and are relatively nonspecific with respect to the metal bound. Many of these trace elements are heavy metals, which are toxic to humans and other animals. The only way to make soil, water, or air polluted with heavy metals safe for human consumption or habitation is to remove the heavy metals.

This research was concerned with removing the heavy metals cadmium, cobalt, copper, and lead from contaminated water. It relied on the single celled alga *Chlamydomonas reinhardtii*. This alga is tolerant to high levels of heavy metals. *Chlamydomonas* expresses a small cysteine rich class of nontranslationally synthesized proteins, phytochelatins, which bind heavy metals. These proteins, however, are expressed only when the metals are present at high levels (research has shown them to be induced only at levels >20μM Cd). This project genetically altered *Chlamydomonas* to make it express a second class of heavy metal protein, metallothioneins (from animals), to enhance its capacity to bind heavy metals. The algae, containing bound heavy metals, was then harvested to remove the metals from the contaminated water source. Heavy metals bound by the algae can be recycled by washing the algae in weak acids.

R/BT-4 3/1/98 to 2/28/00

Biocomplexation of Heavy Metals by Engineered Algae

Richard Sayre, Biochemistry and Plant Biology, The Ohio State University
Terry Gustafson, Chemistry, The Ohio State University
Lada Malek, Biology, Lakehead University, Thunder Bay, Ontario
Sam Traina, Natural Resources, The Ohio State University

Heavy metal accumulation in the Great Lakes' sediments has become an increasing concern as agencies and organizations try to develop steps to eliminate pollution in the "hot spots" of the Great Lakes and surrounding areas. This research is developing biological approaches to sequester toxic heavy metals. Unlike traditional chemical engineering approaches which result in large volumes of waste and are generally non-selective for the metals of interest, a system has been developed that uses a single-celled alga that is safe, renewable, and can effectively concentrate the specific trace metal. The unicellular alga, *Chlamydomonas reinhardtii*, has been used for these studies because of its wide range of heavy metal tolerance which enables it to sequester an array of trace metals including copper, zinc, lead, cadmium, cobalt, nickel, mercury, silver, and gold.

This study developed renewable, cost-effective, and environmentally sound systems for the prevention and clean up of heavy metal pollution. This could eliminate or substantially reduce heavy metal pollution from industrial sources and contaminated sites.

Coastal and Ocean Engineering

R/EM-13 9/1/92 to 8/31/94

Evaluation of a Real-Time AVHRR and *in situ* Data System for Use in Surface Heat Flux Predictions

Carolyn J. Merry, Civil Engineering, The Ohio State University
Keith W. Bedford, Civil Engineering, The Ohio State University

A reliable real-time Great Lakes Forecasting System (GLFS) is operational at The Ohio State University to the benefit of Great Lakes users. The purpose of GLFS is to predict and reduce lacusterine hazards ("lake hazards"), to enhance commercial and recreational activities on the lakes, to test hypothetical storms and other events to measure how much damage they might do, and to help preserve natural resources. At the moment, national weather satellites with Advanced Very High Resolution Radiometers (AVHRR) provide only one measurement of Lake Erie surface temperature a day—and can do that only when there is no cloud cover. The ultimate goal of GLFS, on the other hand, is to make lake forecasts every six hours, not only of temperature but also of currents (width and depth), temperature distributions, water levels, wave heights, and shoreline erosion in real time. To do this, GLFS needs to calculate temperature changes at the water's surface (surface heat flux), which changes with the season, air temperature, wind speed and direction, dew point, and water temperature.

Other networks and databases can provide all the data required to calculate surface heat flux except one: actual lake surface temperature at a number of different points. This study provided for the incorporation of point measurements from several automatic temperature sensors *in situ* (on the lake itself) to compare to, and to fill in for, necessary data not provided by satellite information.

R/EM-15 9/1/92 to 8/31/94

Naturally Fluorescent Dissolved Organic Compounds as Tracers of Surface Currents and Mixing in Large Water Masses

Stephen E. Cabaniss, Biological Sciences, Kent State University
Robert T. Heath, Biological Sciences, Kent State University

A large part of Lake Erie's pollution comes from the polluted rivers that flow into it. Therefore, monitoring what flows into Lake Erie specifically and understanding how all rivers mix and circulate with their receiving waters is of regional and national interest. Some naturally occurring dissolved organic matter (DOM) is known to re-emit light waves of a specific wavelength (fluoresce), so that surface sampling for fluorescent materials has been able to follow river plumes offshore into lake waters for up to 50 miles. If specific types of DOM fluoresce under lights of known and different wavelengths (excitation-emission matrices, or EEMs), their signature fluorescence could identify them in river flows and allow a more complex multidimensional analysis of how river and lake waters mix. Following the reliable identification of specific DOM with EEM, the ultimate objective of this research was to map surface water flowing into the Great Lakes using shipboard sampling or monitoring from satellites (Airborne Oceanographic LIDAR).

R/EM-18 9/1/94 to 8/31/96

Naturally Fluorescent Dissolved Organic Compounds as Tracers of Surface Currents and Mixing in Large Water Masses

Stephen E. Cabaniss, Chemistry, Kent State University
Robert T. Heath, Biological Sciences, Kent State University

Tributary rivers bring most of the total pollutant load into Lake Erie, so their flow is directly linked to water quality. Polluted rivers that flow directly across urban drinking water intakes can lead to severe public health problems, such as the *Cryptosporidium* outbreak in Milwaukee in the summer of 1993. While a computer model of currents and transport dynamics in Lake Erie is being developed (GLFS, sponsored by Ohio Sea Grant and others), field data on actual river water flow within the lake is in short supply.

This project took advantage of the fluorescent properties of naturally occurring substances in river waters to provide a fluorescence "fingerprint" of tributary rivers. The fingerprint is influenced by the type of vegetation in the watershed and by algae and other aquatic organisms. Fluorescence analysis is very sensitive and can detect less than one- percent river water mixed with lake water. Since it measures emitted light, fluorescence should be able to observe river-lake mixing from the air via Airborne Oceanographic LIDAR (AOL). Fluorescent fingerprints are potentially much more useful than current methods for examining complex systems of several rivers.

This work emphasized the eliminating or avoiding interferences and testing the performance of the method under field conditions. Cooperative agreements with the City of Cleveland and the Northeast Ohio Regional Sewer Authority allowed field studies in conjunction with their monitoring of Lake Erie.

R/EM-14 9/1/94 to 8/31/96

A Multigrain Size Sediment Resuspension and Transport Model for Great Lakes Tributaries: An Initial Implementation for the Maumee River/Toledo Harbor Region

Keith W. Bedford, Civil Engineering, The Ohio State University

Over one hundred million dollars are spent each year on dredging U.S. ports and harbors of silt, sand, and clay from upland watershed runoff and erosion. The tributaries of the Great Lakes are no exception. Scientists and engineers trying to manage present and future dredging operations, for the most part, rely on models that assume river waters and sediments flow directly into their receiving lake or ocean. Many lake tributaries, particularly those of Lake Erie's shallow western basin, show sediment deposition that is much more complex. In particular, storm surges have caused river flow reversals and the return of solids to the tributary. As the storms abate, weaker currents cause the deposition of heavier sediments back into the tributaries and return of lighter sediments to the lake. Moreover, seiches (oscillating currents that last minutes to hours), as a result of storms, carry solids into the lake in a way not measured by riverine transport models.

This project assembled, tested, and implemented a multigrain-size class sediment resuspension and transport model valid for Great Lakes tributaries. The model accommodated all of the recognized agents for the observed changes in sediment concentration and grain-size distribution, including thermal and sediment stratification, the effects of waves and currents, storm surges and seiches, and the impact of bottom composition undergoing consolidation.

R/NP-1 3/1/98 to 2/28/00

Coastline Mapping and Change Detection Using 1-Meter Resolution Satellite Imagery

Ronxing Li, Civil & Environmental Engineering & Geodetic Science, The Ohio State University

Current coastline mapping and coastline change detection are critical to safe navigation and sustainable coastal development and planning. However, updating this data has been problematic because coastline change is continually changing by natural processes and human activities. Although traditional coastline mapping has been carried out using conventional field survey methods, recent development in Global Positioning Systems (GPS) technology has stimulated an interest in its application in large scale coastline mapping. A new generation of high resolution (1-meter) satellite imaging systems has many advantages such as high accuracy, flexible scheduling, and easy-to-change configuration.

This study examined the mapping potential of the new generation of 1-meter satellite imagery, and specifically analyzed coastline mapping. It researched techniques for determination of accumulative and instantaneous coastlines using the 1-meter satellite images, and analyzed the correlation between the survey coastline changes and associated causes and impacts in Geographic Information Systems.

R/OE-11 9/1/94 to 8/31/96

Development of a Smart Underwater "Wet" Welding Process

Chon L. Tsai, Welding Engineering, The Ohio State University

Underwater welding technology can be applied worldwide to underwater pipelines, offshore drilling rigs, docking

facilities, ships, barges, dams, locks, nuclear power plants, and more. Currently, to produce code-quality welds on structures underwater, a large pressurized chamber must be used to exclude water from the work area. The cost, however, is prohibitive. Wet welding performed manually on the spot is much cheaper, but the savings is outweighed by the weld's inferior quality. The surrounding water quenches the required heat for a proper weld and the water's hydrogen makes the weld material brittle.

This project developed a flux-cored arc welding process, which includes a self-contained, waterproofed welding gun that excludes water from the welding area on a local scale. A double walled rubber blanket attached to the gun and inflated by a separate air tank at the site insulates the weld from water. It also creates a micro-environment for which temperature and gas pressure sensors can monitor conditions. The information is fed back to the welder controller, which automatically adjusts the welding current and electrode feed rate to maintain proper welding conditions. An illuminated, translucent gas cup allows the welder to view the work.

R/OE-12 9/1/92 to 8/31/94

A Climatology Protocol for Characterization of Long Term Entrainment and Resuspension

Keith W. Bedford, Civil Engineering, The Ohio State University

Dredging waterways presents two problems: the cost of dredging, and the placement of the dredged material so that it remains where placed. At present, the placement of choice of the Army Corps of Engineers is offshore because it is the least expensive. Data, however, showing how, when, where, and at what rate the dredged material might move are imprecise. Other studies have examined movement of dredged material based on the physical character of the material and based on the surface upon which it is placed. Predicting where dredged material will be transported in the long term, however, depends on understanding storms and their attendant energy in wind and waves, which can re-suspend and transport dredged material.

This research monitored climatological events and resulting movement of dredged material using direct measurements form Acoustic Resuspension Measurement System (ARMS) and High-frequency Acoustic Non-destructive Particle Sizer (HANDS). Long term evaluations of entrainment have been performed on river channels, but the unidirectionality of a river's flow and its wave action require that the same evaluations be made for lakes for comparison.

R/OE-13 9/1/96 to 8/31/98

Control Algorithm for Underwater "Wet" Flux-Cored Arc Welding Process

Chon L. Tsai, Welding Engineering, The Ohio State University

With the increasing use of submerged structures such as underwater pipelines, ships, and nuclear power plants, the industrial community has called for improved underwater welding technology to efficiently repair such structures. However, until recently these advancements have been minimal. Water can cause underwater repairs to become brittle. Hydrogen, a component within water, can chemically react with newly welded material to create a brittle weld, or can cause delayed cracking in the welded area hours or days after repair. This limits the longevity of the repair. Water also induces rapid cooling of the area, causing detrimental microstructures to form and brittleness to occur if the weld is not properly treated after welding.

By improving the chemical make-up of the flux and the waterproof coating of the rod, this research has developed a new rod that decreases the magnitude of water's effect on welded material. The newly improved flux created better and more efficient chemical reactions with the base metals, providing easier clean up of the weld residue.

R/OE-14 3/1/98 to 2/28/00

Development of a Microprocessor-Based Joint Tracking and Operation Guidance System for Underwater Welding

Chon L. Tsai, Welding Engineering, The Ohio State University

Because of the significance of offshore, coastal, inland waterway, big lake and port facilities to the economical survival of a given region, the ability to cope with all aspects relative to safety and damage due to hurricanes and earthquakes and resulting storm surges and possible tsunamis has become a pressing responsibility of the engineering profession. To sustain safe operations, secure environmental quality, and maintain efficient utilization of resources, a distinct knowledge of the interacting forces of these natural disasters and the expertise necessary to develop mitigating measures are required. Underwater "wet" welding is an important and efficient technique to restore the damaged structures. Recent advancement in the "wet" welding technology enhances the ability of mitigating structure damage with fast response at reasonable costs. However, underwater "wet" welding is still plagued with difficulties due to poor visibility, limited joint accessibility, and restricted maneuverability under many adverse underwater conditions.

This project aimed to develop an intelligent underwater welding operation guidance system with a high speed spinning arc as the torch-joint position sensor and a microcontroller control unit. The microprocessor-based joint tracking system and the intelligence built into the flux-cored arc welding system would circumvent the difficulties associated with

underwater wet welding and improve the weld quality.

Environmental Models Research

R/EM-19 9/1/96 to 8/31/98

An Integrated Watershed-Lake Erie Forecasting System: Part 1

Keith W. Bedford, Civil, Environmental, and Engineering Graphics, The Ohio State University
Thomas E. Croley, NOAA, GLERL

Because of high concentrations of human populations and their related commercial and recreational activities surrounding Great Lakes harbors and tributaries, the increasing pressure to ascertain accurate and timely information to make decisions for land use planning has never been greater. However, the data required to make these decisions are difficult to obtain. The project goal was to have a fully integrated, calibrated system which can, on an hourly basis, make forecasts, nowcasts, and hindcasts of the watershed runoff volume, heat, and sediment loads to Lake Erie and their subsequent redistribution and fate in the lake.

R/EM-20 3/1/98 to 2/28/00

Spatial Dynamic Modeling of Large Lake Lower Trophic Level Dynamics: Effects of Zebra Mussels and Nutrient Loading

David A. Culver, Zoology, The Ohio State University
Murray N. Charlton, National Water Research Institute, Burlington, Ontario
John P. Coakley, National Water Research Institute, Burlington, Ontario
Paul F. Hamblin, National Water Research Institute, Burlington, Ontario
Mark Loewen, Mechanical and Industrial Engineering, University of Toronto

Since 1970, decreased phosphorus and increased nitrogen input have affected the functioning of the Lake Erie pelagic ecosystem (including algal, zooplankton, and fish abundance) even before the introduction of zebra mussels further altered biological balances in the lake. Yellow perch, walleye, and white bass landings have declined over time, with profound differences between the magnitude of changes in Canadian and Ohio waters. Furthermore, the western basin blooms of Microcystis in 1995 and 1996 suggest that available nutrients may be increasing, at least locally, either as a result of increased external loading, or regeneration of nutrients by zebra mussels, or both. At the same time, year-class strength has been good for many fish taxa over the past five years. These observations suggest that diverse changes in water quality and trophic function have occurred since the point-source phosphorus targets were met in 1982/83. With the use of two modeling approaches, this research will test whether variation in phosphorus and nitrogen loading can explain changes in the seasonal and spatial plankton dynamics of Lake Erie and determine the relative importance of algal consumption and nutrient excretion by zebra mussels on the function of the Lake Erie plankton.

Ecosystems Research

R/ER-27 9/1/94 to 8/31/97

Use of Electron Transport System Enzyme Activity to Estimate Respiration in Bioenergetics Models of Juvenile Fish: Growth and Compensation of Zooplankton

David A. Culver, Zoology, The Ohio State University
Sharook P. Madon, Illinois Natural History Survey, Pace University

Zooplankton eat phytoplankton. Larval and juvenile fish eat zooplankton. For many years, phosphorus-laden pollution has contributed to the growth of phytoplankton, so there's good reason to wonder what effect reduced phosphorus loading due to the Clean Water Act will have on juvenile fish populations.

This study developed bioenergetics models for walleye (*Stizostedion vitreum*), yellow perch (*Perca flavescens*), and hybrid striped bass (*Morone saxitalis x M. chrysops*) juveniles based on growth, food consumption, and respiration relative to how much food is available. The bioenergetics models were based on the measured growth and diet of fish raised in experimental hatchery ponds. Respiration associated with activities such as swimming are impossible to measure in the wild, therefore, the respiration of the juvenile hatchery fish were measured and then compared to the activities of their respiratory (electron transport system or ETS) enzymes. These respiratory enzymes can be measured in the wild, so that the levels of enzymes in the hatchery fish at controlled food abundances may be used as a yardstick to measure the respiratory activities of fish caught in the wild. This allows researchers to tell how well fish in the open waters of Lake Erie are growing and surviving relative to how much food measurements show is available to them.

R/ER-29-PD 9/1/94 to 8/31/96

The Relationship Between Resource Heterogeneity and Growth of Larval Walleye (*Stizostedion vitreum*) on Nursery Grounds

Jeffrey G. Miner, Biological Sciences, Bowling Green State University
David J. Berg, Zoology, Miami University

In marine systems, a principal feature of the critical period during early ontogeny is patchy distribution of food resources leading to differences in growth rates and survival among individuals within and between food patches. Differential growth rates translate into differential survival because vulnerability to predation is negatively correlated with body size. Using these concepts from marine fisheries to examine the relationship between habitat heterogeneity and early life of the walleye, this project developed a model that uses RNA-DNA ratio and water temperature to predict growth rates of larval walleye. It also field tested this model and used it to examine spatial variation of growth rates among walleye larvae on their Maumee Bay nursery grounds.

R/ER-31-PD 1993 & 9/1/94 to 8/31/96

Genetic Studies of the Lake Sturgeon, *Acipenser fulvescens*, in the Great Lakes Region

Paul A. Fuerst, Molecular Genetics and Zoology, The Ohio State University
Ted M. Cavender, Zoology, The Ohio State University

The lake sturgeon, *Acipenser fulvescens*, once inhabited all of the Great Lakes and many of their tributaries. After having been an important part of the Great Lakes ecosystem and a productive commercial fishery in the 1800s, the sturgeon population declined precipitously and permanently by the first decade of the 1900s. Because male and female sturgeon are not reproductive until twenty-plus years, they were unable to replace themselves at the same rate that commercial fishermen were taking them. Today, the sturgeon is present in all of the Great Lakes, but its numbers are so low it is considered rare and even endangered by some government agencies.

Present efforts by the U.S. and Canada to restore sturgeon populations in the Great Lakes would be greatly aided by genetic analysis. This study examined the DNA of hatchery stocks to see if they provided the genetic variability necessary to keep wild populations healthy. Some wild populations could be weakened by the introduction of hatchery stock—if, for example, a wild population spawns exclusively in a lake or in a tributary. Genes unique to those types of spawning could be eliminated in the offspring of wild sturgeon mated with hatchery sturgeon. Likewise, populations in the lakes must be analyzed for comparison among themselves. Any lake sturgeon community showing a relative lack of

genetic variation will be studied to identify and possibly change the conditions that caused the genetic loss.

R/ER-32 9/1/94 to 8/31/96

Littoral Vegetation in the Old Woman Creek NERR: Community Dynamics and Energy Flow

David A. Francko, Botany, Miami University

Old Woman Creek (OWC) is the only Great Lakes representative among the National Estuarine Research Reserves (NERR). Like other wetlands it acts as a sort of "metabolic gate" in processing nutrients, pesticides, herbicides, and other organic and inorganic materials before its waters reach Lake Erie. Population expansion and changing land use are impairing OWC and other coastal wetlands so that wetland managers must understand the dynamics of the ecosystem as thoroughly as possible for effective conservation and management. The aquatic vegetation of all wetlands plays a pivotal role in the management of these systems, yet plant communities and interactions in general remain poorly understood. Because the flora of the OWC estuary has changed markedly from recent and historical reports, and because the flora is more diverse than previously thought, part of this study was devoted to a four-year record of mapping and quantifying the estuary's major and minor flora. In addition, *in situ* field experiments and lab experiments measured how much the plants are affected by competition from other plants (including two exotic invaders), and how much by abiotic factors, such as sunlight, nutrients, or sediment. Carbon flow was measured to verify previous findings that wetlands contribute far more energy to receiving waters than previously thought. The OWC seed bank was also evaluated to determine future plant communities.

R/ER-33-PD 9/1/95 to 6/30/96

Spatial Variation and Identification of a Source Population for *Bythotrephes cederstroemi* in the Great Lakes

David J. Berg, Zoology, Miami University
David W. Garton, Biological Sciences, Georgia Tech.

This study examined the genetic structure of *Bythotrephes* populations from Lakes Erie, Huron, Michigan, and Superior and from Lake Lagoda, Russia to determine whether allele frequencies, genotype frequencies, and genetic structure of recently established *Bythotrephes* populations have diverged since 1989 as these populations adapt to environmental differences among the Great Lakes. It also compared allele frequencies, genotype frequencies, and genetic structure of the Lake Lagoda population with those from the Great Lakes and European lakes sampled in 1989.

R/ER-36 9/1/96 to 8/31/98

Effects of Habitat Modification by *Dreissena* spp. On Burrowing Mayfly Survival and Fitness

David J. Berg, Zoology, Miami University
Kenneth A. Krieger, Water Quality Laboratory, Heidelberg College

This project examined the interactions of mayfly (*Hexagenia*) nymphs with zebra/quaggra mussels to determine if successful recolonization of Lake Erie by mayflies is dependent on mussel density or if it is limited to areas that have few mussels. To determine whether *Dreissena* has a net positive or negative effect on abundance and fitness of *Hexagenia* nymphs, this study used laboratory experiments to determine if 1) mussel shells reduce the suitability of mud habitats for *Hexagenia* recolonization; 2) living mussels enhance suitability of mud habitats for *Hexagenia* recolonization by creating additional food sources for nymphs; and 3) Observations of *Hexagenia* abundance and fitness in western Lake Erie are correlated with mussel density in a manner consistent with experimental results.

R/ER-38 9/1/96 to 8/31/98

Ecosystem State Changes in Western Lake Erie: Expansion of Invading Mussel Assemblages on Soft Substrates

Paul A. Berkman, Byrd Polar Research Center, The Ohio State University
David W. Garton, , Georgia Tech
John E. Gannon, National Biological Service
Gregory Kennedy, National Biological Service
Scudder D. Mackey, Ohio Geological Survey

Since the invasion of zebra mussels (*Dreissena polymorpha*) in the Great Lakes in the mid 1980s, many have wondered what was the extent of the zebra mussels' colonization capacity. Although the establishment and impacts of *Dreissena* populations on hard substrates in the Great Lakes and surrounding waterways are well documented, the magnitude of

Dreissena invasions on soft substrates, which represent the vast majority of benthic habitats in these watersheds, is virtually unknown. Understanding the population invasion capacity of these exotic species is central to predicting the consequences of their invasions.

This research projected integrated Side Scan Sonar (SSS) and Remotely Operated Vehicle (ROV) surveys along with *in situ* SCUBA collections to interpret and predict the lake-wide distribution and abundance of *Dreissena* assemblages on soft substrates in Lake Erie. Specifically, it concentrated on the coverage of *Dreissena* assemblages on different soft-substrate types in Lake Erie; characterized the *Dreissena* assemblages (size frequency, density, and species composition) on different soft-substrate types; assessed the expansion of *Dreissena* assemblages on different soft-substrate types; and predicted the overall soft-substrate distributions and abundance of *Dreissena* assemblages in Lake Erie.

R/ER-39 3/1/98 to 2/28/00

Strategies to Control Exotic Invasive Plant Species in Great Lakes Wetlands: A Field Evaluation

David A. Francko, Botany, Miami University

The native aquatic and wetland flora of Great Lakes coastal wetlands are threatened by exotic invasive plant species. Work at the Old Woman Creek National Estuarine Research Reserve (OWC) and other Lake Erie coastal wetlands has tracked the dynamics of two exotic invasive plant species, *Myriophyllum spicatum* (water milfoil) and *Phragmites australis* (common reed), from the early colonization phase through range extension. Field work conducted at Old Woman Creek in 1998 on replicated 1m-2 plots suggested that cutting emerging spring growth shoots of *Phragmites australis* followed by herbicide application prevented the recruitment of mature plants during the growing season. Cutting alone is much less effective. Recruitment of other herbaceous species in Phragmites removal plots was low, varying between ca. 1 and 5% cover at the end of the growing season. Data suggested testable, non-herbicidal, and potentially cost-effective mitigation strategies for two invasive plants that adversely impact Great Lakes wetland diversity. Preliminary work suggests that small-scale control of Phragmites may be possible without massive habitat disruption, and that at least some seedbark recruitment may occur if Phragmites is controlled.

R/ER-40-PD 9/1/96 to 8/31/98

Preliminary Field and Laboratory Tests of the Hypothesis that Zebra Mussels Release Phytoplankton Populations from P-Limitation

Robert T. Heath, Biological Sciences, Kent State University
Conrad E. Wickstrom, Biological Sciences, Kent State University

Phosphorus availability (as phosphate) frequently limits phytophlankton growth in freshwater communities. Algal species respond physiologically to P-limitation by increasing cell carbon content and alkaline phosphatase activity. This research conducted a preliminary test to determine whether phytoplankton communities in the western basin of Lake Erie (WB-LE) heavily affected by zebra mussels, are released from P-limitation because of the remineralizing activities of zebra mussels. Physiological status of phytoplankton communities at selected sites near and far from dense zebra mussel colonies were surveyed using currently accepted indicators of P-limitation. This study provided information on the current nutritional status of the WB-LE, useful in considering the validity of current management strategies, augment other investigations of zebra mussels, and provide preliminary data in support of a larger proposal.

R/ER-41-PD 6/1/96 to 5/31/97

Observed Effects of Cormorant Predation on Nearshore Fish Populations

David O. Kelch and Fred L. Snyder, Ohio Sea Grant Extension, The Ohio State University

This study conducted underwater video observations of the fish communities (with attention on smallmouth bass, *Micropterus dolomieu*) in nearshore cormorant (*Phalacroccrax auritus*) feeding areas versus the fish communities in similar habitats not routinely used by cormorants and determined if statistically significant differences exist.

R/ER-43 3/1/98 to 2/28/00

Effects of Zebra Mussels on Benthic Microbial Activity

Robert T. Heath, Biological Sciences, Kent State University
Joseph M. Balczon, Biology, Westminster College

Investigations of effects of zebra mussels indicate that zebra mussels drastically alter plankton community structure. Zebra mussels have shown to remove phytoplankton and microzooplankton biomass from the water column and add ammonium and phosphate to the water, potentially stimulating phytoplankton growth and altering the microbial plankton community. Zebra mussel grazing also causes increased light penetration and nutrient concentrations in the benthos, the site of many microbially-dependent activities important for ecosystem function. Although many studies have examined the effects of zebra mussels on macrobenthic organisms such as macrophytes, none has examined microbenthic organisms and the microbial community upon which they feed. This research tests the hypothesis that zebra mussel feeding activity increases benthic particulate and dissolved organic carbon and nutrient concentrations resulting in the increased structural and functional complexity of the microbenthos.

R/ER-46-PD 9/1/96 to 8/31/97

Analysis of Lake Erie Coastal Wetland Communities

David A. Francko, Botany, Miami University
Robert Whyte, Botany, Miami University

This research tested species abundance and distribution of macrophyte communities in shallow wetlands of Lake Erie's western basin and influence by the relative competitive fitness of the individual species present. It also tested whether water level fluctuation in shallow Lake Erie wetlands regulates species diversity by altering the available light regime; whether species composition, diversity, and patch dynamics of major coastal wetland types along the south shore of Lake Erie are statistically similar to the Old Woman Creek NERR; and whether macrophyte carbon fixation represents the major source of fixed carbon available to grazing/detrital food webs in Lake Erie coastal wetlands during midsummer.

R/ES-5 9/1/92 to 8/31/94

Efficiency of Carbon Flow Through Algae, Bacteria, and Zooplankton in Nearshore and Offshore Communities

Robert T. Heath, Biological Sciences, Kent State University
Karl E. Havens, Biological Sciences, Kent State University
Charles E. Herdendorf, Zoology, The Ohio State University

The growth and development of organisms in any environment are based on the flow of energy. Carbon is the foundation of this energy, and enters the food chain through plants, which fix carbon from the atmosphere during photosynthesis. In freshwater, carbon enters the food chain through phytoplankton. The flow of carbon can be direct and efficient. Algae, for example, are eaten by zooplankton, which are then eaten by fish. The flow can also be indirect and less efficient. In this case, carbon takes the form of dissolved organic compounds (DOC), which are released by algae. Taken up by bacteria, the carbon is eaten by protozoans and zooplankton, which are then eaten by fish. Under some conditions, this microbial pathway may be more important than thought (more likely in nearshore than offshore environments). Knowing the different pathways of carbon flow is useful for developing fisheries management plans and may be useful for anticipating the impact of nonindigenous species.

This study tested whether the efficiency of carbon transfer from algae to macrograzer zooplankton will increase and the relative significance of "microbial" pathway will decrease along an axis of decreasing DOC from nearshore stations to the open water of Lake Erie. It directly measured the rate of photosynthesis, rate of release of DOC, rate of bacterial utilization, and rates of grazing on algae and on bacteria.

R/LR-3 3/1/98 to 2/28/00

Genetic Characterization of Walleye Stocks Based on Mitochondrial and Nuclear DNA Sequences

Carol Stepien, Biology, Case Western Reserve University

The walleye, *Stizostedion vitreum,* is a native keystone piscivore that is widely distributed in freshwater systems throughout much of northeastern, northcentral, and southeastern temperature North America. The center of its distribution and diversity, however, occurs in the Great Lakes. While the walleye is of key ecological importance in top-down regulation of communities, consuming the early life history stages of most fish species, it also provides economically valuable sport and commercial fisheries. Knowing genetic variability and stock structure of walleye in the Great Lakes are important in maintaining diversity for successful fisheries and ecological management.

This study builds on the sequence data base for the mitochondrial DNA control region established by previous studies of six spawning sites in Lakes Erie and St. Clair. This allows genetic stock structure and spatial patterning of walleye populations in spawning regions, lake basins, and among the Great Lakes to be determined, in order to evaluate diversity and delineate essential areas for its maintenance by fisheries management.

Marine Economics Research

R/ME-16 9/1/92 to 8/31/93

Economic Evaluation of Artificial Reefs: The Case of the Lorain County, Ohio Artificial Reef

Leroy J. Hushak, Agricultural, Environmental, and Development Economics, The Ohio State University
David O. Kelch, Ohio Sea Grant &The Ohio State University Extension

Historically, reference to Lake Erie as "Walleye Capital of the World" was most likely referring to the lake's western basin, which contained most of the fishery. In 1984, however, the fishery expanded into the central basin making that part of Ohio's north coast ripe for economic and recreational development. Access to the central basin is more difficult than for the western basin, and walleye (*Stizostedion vitreum*) there tend to occupy deeper waters. Therefore, placement of artificial reefs in nearshore areas of the central basin seemed to be a good way to attract fish and anglers to safer nearshore locations. Following the construction of the Cuyahoga County reef in 1984, the Lorain County artificial reef was completed in 1989, and consists of two reef structures, 1,200 and 600 feet long.

This research measured the economic productivity of the Lorain County artificial reef for the benefit of future Ohio north coast development. Reports of success of the reefs had all been anecdotal, requiring some more rigorous evaluation in the form of carefully developed surveys and follow-up questionnaires. These allowed a numerical estimation of the economic value of the reef to anglers and the impact of the reef on the local economy.

R/ME-17-PD 3/1/96 to 9/1/96

Communication of Results from Policy-Oriented Research

Alan Randall, Agricultural, Environmental, and Development Economics, The Ohio State University

This project prepared reports, executive summaries, and other forms of communication to effectively communicate the results and conclusions of dissertation research to policy-makers and other interested parties. It also presented these results and conclusions in at least one face-to-face meeting with policymakers.

R/ME-18-PD 4/1/94 to 3/31/96

Surveys of Ohio's Charter Captains, Part of a GLSGN-wide Effort

Frank R. Lichtkoppler, Ohio Sea Grant Extension, The Ohio State University

The charter industry is a significant part of the Lake Erie sport fishing industry. The nature of the charter industry is one of continual change as the Lake Erie ecosystem changes in response to natural factors, human-induced inputs and exotic species (zebra mussels). The needs and desires of charter clientele are also changing and need to be documented if the charter industry is to compete with other forms of recreation. Without a coordinated research effor, it is difficult to compare the charter business in Ohio to that in New York or to compare the charter industry on Lake Erie to that of Lake Michigan. The charter industry needs to know where it is going and what its customers want if it is to continue to be a vital part of the Lake Erie coastal economy. A unified Great Lakes wide database will help the charter industry work for federal legislation that will have positive impacts on this changing industry.

This study documented the economic impacts, business trends, and current characteristics of the Ohio charter boat industry and profiled the needs and preferences of the clients who hire charter services. This also coordinated these studies with similar ones to present a more complete description of the charter industry in the Great Lakes.

R/ME-20-PD 6/1/97 to 12/31/97

Estimating the Recreational Value of Two Lake Erie Beaches

Brent Sohngen, Agricultural, Environmental, and Development Economics, The Ohio State University

Lake Erie beaches provide multiple recreational opportunities, ranging from swimming, to sunbathing, to watching the sunset, yet policy makers and managers know little about beach users, their tastes and preferences, and the economic value they place on this resource. This study proposes to survey users of two Lake Erie beaches in Ohio to determine their willingness to pay for beach recreation. We will use the travel cost technique to estimate the marginal willingness to pay for a day's recreation at a beach. The results will allow us to determine the value recreational users place on two public beaches. In addition, this study will provide a basic set of data and results that can be linked with a future, larger study focused on valuing the impact of environmental change (ie. changes in water quality) across a wider selection of beaches.

R/ME-19 3/1/98 to 2/28/00

Valuing Great Lakes Beach Recreation: An Economic Assessment of the Recreational Value of Freshwater Beaches

Brent Sohngen, Agricultural, Environmental, and Development Economics, The Ohio State University
Frank Lichtkoppler, Ohio Sea Grant Extension, The Ohio State University
Mary Bielen, Ohio Sea Grant Extension, The Ohio State University

While Ohio Sea Grant has supported many projects to study sport-fishing and other tourism activities associated with Lake Erie, no studies have investigated beach recreation along Ohio's northern coast. This lack of information on freshwater beach recreation exists not only in Ohio, but throughout the U.S. For Great Lakes states like Ohio, where remaining open space and public access along the shoreline is scarce, understanding recreational attitudes and value can provide important information for public decision-makers and private businesses. Public policy makers can use this information to decide the allocation of additional resources for such recreational amenities as beaches, forests, and parks. Local visitor bureaus may find the information useful to specify target markets, enabling them to define strategies for specific market segments that frequently visit their areas. Beach managers can also use the information to answer questions dealing with resource allocation.

This research estimated the value of Great Lakes beach recreation along Ohio's Lake Erie coastline and used the results to estimate the value of specific beaches and amenities. It also developed a measurable data set of beach amenities which can be used by managers on a repeated basis to measure and value improvements in beach value and an analysis of alternative management options in coordination with public officials in charge of managing beaches.

R/ME-21-PD 6/1/98 to 2/28/99

Valuing the Ottawa River: Recreational Value and Direct Economic and Fiscal Impacts of Dredging

Leroy Hushak, Agricultural, Environmental, and Development Economics, The Ohio State University
Mary Bielen, Ohio Sea Grant Extension, The Ohio State University

Ottawa River residents, businesses, and direct users face two critical problem. During periods of low Lake Erie water levels and resulting shallow depths in the Ottawa River, passage by all but small boats of the shallowest draft is prohibited. Water quality of the Ottawa River is classified as highly polluted with swimming, fishing and related water activity considered as unsafe. As part of the Maumee River RAP, federal assistance may be available for dredging and water quality improvement. However, a local partner and local revenues must be generated to obtain federal assistance. This research will help local people evaluate whether a local partnership is economically viable.

This study evaluated the economic rationale for financial participation of a local partner in the dredging and cleanup on the Ottawa River by estimating the effects of dredging on the recreational value of boating on the Ottawa River. It also estimated the effects of changes in water quality on the recreational value of boating on the Ottawa River and the direct economic and fiscal impacts on the local economy of dredging the Ottawa River for recreational purposes and water quality changes.

R/ME-22-PD 7/1/98 to 6/30/99

Ohio Division of Watercraft Project

Leroy Hushak, Agricultural, Environmental, and Development Economics, The Ohio State University

As recreational boating increases on Ohio waters, so do boaters' needs for boat repairs, fuel, and equipment. However, Ohio does not currently have a comprehensive data base of Ohio's boater expenditures and impacts. As a result, the Division of Watercraft and other divisions of the Ohio Department of Natural Resources, and state and local legislators lack an empirical data base from which to assess the importance of recreational boating and associated boater safety and aquatic ecosystem issues. The data base and analysis generated by this study will provide a current baseline on which to base policy and resource allocation decisions, to include the role of Lake Erie as a resource to Ohio's recreational boaters.

This study conducted a survey of 6,000 recreational boaters in Ohio to obtain information on trip related and annual boat related expenditures, and the economic value of boating along with compiling boater expenditures for Ohio, for four subregions (Lake Erie, Central Ohio, Southwest Ohio, Rest of Ohio), for four types of water (Lake Erie, Ohio River, inland lakes, inland rivers), and for each county. 500 marine trades businesses (including all boat manufacturers and all liveries) and 300 6-passenger charter fishing captains were surveyed. This information will help to estimate the economic impacts of recreational boating and of marine trades for the State of Ohio along with the economic value of boating to recreational boaters.

R/MRC-3-PD 4/15/95 to 4/15/96

Cinetransect Underwater Video Assessment of the Lakewood Artificial Reef Near Cleveland, Ohio: A Continuation of Effort

David O. Kelch, Ohio Sea Grant, The Ohio State University
Fred L. Snyder, Ohio Sea Grant Extension, The Ohio State University
Jeffrey M. Reutter, Ohio Sea Grant, The Ohio State University

This research determined fish species diversity, abundance, and seasonality on the Lakewood Artificial Reef at Cleveland, Ohio and compared that data with the results from the 1992-93 underwater video assessment at the Lorain Artificial Reef. The reefs are attracting 20-60 times as many fish as the surrounding non-reef areas. Smallmouth bass (*Micropterus dolomieu*) is the most abundant fish on the reefs.

Pollution Studies Research

R/PS-9 9/1/92 to 8/31/94

The Mobility of Contaminant-Laden Colloids in the Sedimentary Porewaters of the Great Lakes

Yu-Ping Chin, Geological Sciences, The Ohio State University

Until recently, it was widely assumed that harmful compounds discharged into Lake Erie eventually became attached to natural particles of clay, silt, and sand, and were removed from the water column when the particles settled out to form sediment. The harmful compounds, it was assumed, could then be broken down biologically, could be removed by dredging, or could be covered over with clay. However, minute unsettlable, or mobile, particles ("colloids") have been discovered within the water trapped in the sediment. These colloids are capable of binding ("adsorbing") harmful compounds to their surface and therefore concentrating them. As the mobile colloids move randomly, they eventually move to the top of the sediment layer where they are then released into the waters overlying the sediment. The results are a very local concentration of toxins, or a toxic "hot spot," and the re-pollution of the water. Re-pollution is obviously more likely if the sediment is disturbed by storms or organisms.

This study examined the distribution of these colloids and their abundance in selected Great Lakes sediments. It determined how they move and their ability to concentrate harmful compounds (PCBs and PAHs). A computer model considered how well these particles transport pollutants back into the waters above the sediment. A small-scale model or micro-environment of sediment and water measured changes and the results were compared to model predictions.

R/PS-10 9/1/92 to 8/31/94

Mechanisms of Bioaccumulation: The Relative Importance of Absorption Versus Ingestion in Sediment-Dwelling and Detritus-Feeding Invertebrates

Susan W. Fisher, Entomology, The Ohio State University
Samuel Traina, Natural Resources, The Ohio State University

In the Great Lakes, bioaccumulation of contaminants, such as polychlorinated biphenyls (PCBs) and polynuclear aromatic hydrocarbons (PAHs) begins in aquatic invertebrates. The traditional view of this accumulation assumed that invertebrates get their body burden of contaminants by absorbing them directly from the water, because laboratory studies have indeed shown that direct sorption results in the highest relative rate of accumulation. Sediments, on the other hand, have been thought to act as a sink for contaminants by acting as a point of attachment ("adsorption"), which then settles out of the water column.

Benthic invertebrates may ingest sediment only by accident as they search for food, but little attention has been given to the contamination of invertebrates through their ingestion of contaminated sediment solids. These solids are capable of concentrating contaminants, and ingestion could contribute substantially to the animal's body burden (although at a lower rate than for absorption). To test the role of ingestion of sediments in bioaccumulation, more must be learned about the feeding habits of aquatic organisms, and more must be known about how different sediment materials adsorb and desorb contaminants.

This research compared water-dwelling and sediment dwelling invertebrates and what and how much they eat. It also examined different solid materials and their tendency to absorb contaminants and measured the organisms' rates of and total contaminant bioaccumulations.

R/PS-13 9/1/94 to 8/31/97

Partitioning of Priority Pollutants into Edible Fish and Quantitative Human Risk Assessment

Susan W. Fisher, Entomology, The Ohio State University
Henryka Dabrowska, Entomology, The Ohio State University
Konrad Dabrowski, Natural Resources, The Ohio State University

The residues of DDT and PCBs in freshwater fish collected from the Great Lakes, Ohio River, and Upper Mississippi River systems show little change over the recent past and continue to be the highest in the nation. The specifics of how

these contaminants get into the tissues of fish are in dispute among scientists. Until recently, fish were thought to get most of their contaminants through direct absorption from the water. Direct absorption is by far the fastest way for fish to accrue DDT and PCB contaminants, and mechanically, it is the best understood and the easiest to quantify. The mechanics of accruing contaminants from diet are more complex and occur more slowly than for absorption, but recent studies show that the long-term effects of diet may be the more important.

Lipophilicity (the chemical attraction to fat) is the quality of DDT and PCBs that makes them so susceptible to collecting in the tissues of fish and other animals. Therefore, this study tested the hypothesis that the amount of PCBs a fish takes up from contaminated food depends on how much fat the food contains. PCB uptake also was measured against how much fat the fish itself contains and also against how much its tissues are already contaminated.

R/PS-14 9/1/94 to 8/31/97

The Relationship Between Critical Body Burden of Hydrophobic Contaminants and Biological Endpoints in Aquatic Biomonitoring Organisms

Susan W. Fisher, Entomology, The Ohio State University
Peter Landrum, GLERL at NOAA

Some environmental monitoring studies assess the health of an ecosystem by measuring its concentration of chemical contaminants. Contaminants can be measured in air, soil, water, and sediments and in the tissues of plants and animals. Unfortunately, providing some single measure of an area's contamination is difficult because different materials exposed to the same level of pollution will show different concentrations of contamination. The water of lakes contaminated with PCBs, for example, have lower concentrations of PCBs than do the sediment solids in those lakes. Likewise, organisms in these lakes can vary in the concentration of contaminants in their tissues, depending on where they live and what they eat. It seems, then, that where pollutants are involved, the best measurement of an ecosystem's health is in measuring how much "harm" contamination poses to the organisms that live there. Harm is defined here as an effect on reproduction and growth or as evidence of the contaminants accumulating (bioaccumulation) in an organism's tissues.

This study tested the hypothesis that different bottom-dwelling organisms exhibit the same indications of harm (e.g., changes in feeding habits) when they have the same concentration of contaminants in their tissues. Three sediment-dwelling organisms (each recommended by the U.S. Environmental Protection Agency as a freshwater biomonitor) were exposed to four types of PCBs. This exposure determined the level of contaminants required to cause each organism harm. These levels were then compared to the concentrations required to cause biological endpoints, such as death.

R/PS-15-PD 9/1/96 to 8/31/98

Economic and Hydrologic Analysis of Integrated Wetland Reservoir and Subirrigated Agricultural Production Systems

Larry C. Brown, Food, Agriculture, and Biological Engineering, The Ohio State University
Marvin T. Batte, Agricultural, Environmental, and Development Economics, The Ohio State University

The Maumee River valley, which drains into Lake Erie is characterized by flat topography with soils that are predominantly heavy clay--glacial deposits and lakebed sediments. Since 1850, a series of extensive drainage projects has permitted the area to be drained, cleared, and farmed, resulting in a very productive farming region, but one which is very dependent on surface and subsurface drainage improvements. Sediment, phosphorus, and nitrate in agricultural runoff are of great concern in the region. Substantial subirrigation research from Ohio and Michigan established the basis of the demonstration project. However, no research has been conducted on hydrologic interactions within the direct linkage of an agricultural production system and a wetland/reservoir ecological system in the Lake Erie basin. Runoff and drainage from prior converted cropland seasonally feed the wetland/reservoirs, which provide water quality and wildlife habitat functions. An equally important function is supplemental water supply to increase corn and soybean yields through a state-of-the-art subirrigation crop production system. This innovative, ecologically sound crop production system will greatly reduce discharge to streams, will improve water quality, will increase wildlife habitat, will increase wetland acres, and will enhance farm profitability. Currently, no work of this focus and extent is being conducted elsewhere in the U.S.

This study analyzed and modeled the hydrologic interactions between integrated subirrigated agricultural production and wetland/reservoir systems. It also evaluates the farm-level economics of integrated subirrigated agricultural production and wetland/reservoir systems.

R/PS-16 3/1/97 to 9/31/98

Round Gobies and Zebra Mussels: Trophic Interactions Affecting Contaminant Cycling in the Great Lakes

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Paul C. Baumann, Natural Resources, The Ohio State University

Polychlorinated biphenyls (PCBs), recognized to cause cancer and birth defects, have long plagued the U.S., finally provoking their ban in 1979. Sediment, such as that covering the bottom of the Great Lakes, is considered the primary depository, with an estimated 97 percent of released PCBs retained in these areas. Originally thought to be locked within sediment and safe from dispersion, many have become concerned with PCBs reentering the food chain. Zebra mussels have been suspected to be a key to this PCB redistribution because of their high filtering capacity and tendency to feed on contaminated sediment and algae. Recent findings show zebra mussels with significant PCB residues in their tissues thus, increasing the potential for high contaminant transfers to organisms feeding on zebra mussels. Moving from contaminated algae to zebra mussels to round gobies to smallmouth bass, PCBs are thought to increase or biomagnify at each trophic level before being consumed by humans or animals. The question is how much PCB biomagnification occurs at each of these levels. This research tested zebra mussels within laboratory and field work to confirm that zebra mussels increase in their PCB concentration to approximately 100 parts per billion (ppb) after eating contaminated sediment and algae. While PCB concentrations were around 100 ppb in zebra mussels, round gobies' concentrations ranged between 200 to 800 ppb. PCB concentrations within smallmouth bass however, increased with ranges between 1100 to 1800 ppb.

R/PS-17 9/1/96 to 8/31/98

Immunological Biomarkers and Contaminant-Associated Immunosuppression in Fish-Eating Birds of the Lower Great Lakes

Keith A. Grasman, Wright State University

Fish-eating birds have proven to be effective "sentinel species" to help assess the effects of toxic contaminants on the health of the Great Lakes ecosystem. Over the last 30 years, numerous studies have documented associations between environmental contaminants and biochemical, physiological, reproductive, and population-level problems in these birds. HAH can casue immunosuppression in laboratory birds and mammals at concentrations comparable to those found in Great Lakes wildlife. The developing immune system is particularly sensitive to xenobiotics. Fish-eating birds are excellent species in which to study immunotoxicity of HAHs because of their high exposure to contaminants that biomagnify and their colonial nesting habits, which provide large sample sizes and may facilitate the spread of disease. Reduced resistance to infectious diseases could reduce survival and contribute to population-level impacts in wild animals.

This research examined the associations between environmental contaminants and immunosuppression in fish-eating birds of the lower Great Lakes by investigating exposure-response relationships in individual birds. It also evaluated new biomarkers of immunotoxicity in wild avian species and compared them to previously developed biomarkers.

R/PS-21 9/1/96 to 8/31/98

The Relationship Between Particle Size Composition of Suspended Sediments and Particulate Pollutant Transport in Rivers

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David B. Baker, Water Quality Laboratory, Heidelberg College
R. Peter Richards, Heidelberg College

This research characterized the particle size composition of suspended sediments in water samples collected over storm hydrographs, for storms of differing sizes and seasons at six U.S. Geological Survey stream gauging stations in the Lake Erie Basin. It also determined particulate-pollutant/suspended-sediment ratios for discreet particle size fractions from representative storm event samples of each of the stations and tested the hypothesis that variations in the ratios of particulate-pollutant/suspended-sediment among individual samples are a function of variations in particle size composition of those samples.

R/PS-23 6/1/97 to 9/30/98

Environmental Transmission of Hepatitis A Virus (HAV) in a Zebra Mussel Dominated Foodchain

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Paul Stromberg, Veterinary Pathology, The Ohio State University

Many of the characteristics that make zebra mussels efficient accumulators of organic contaminants may also allow them to become sites for pathogen accumulation and to pass the pathogens to higher trophic levels. These factors include: a high filtering rate; residence in polluted areas; zebra mussels constitute a large biomass; zebra mussels are part of a well defined foodchain which extends to man. If it exists, the ability of zebra mussels to transmit pathogens to higher trophic levels will be limited to a small number of pathogens which are environmentally persistent, capable of withstanding gut passage in vertebrates, can be bioconcentrated from water by zebra mussels and have a high probability of coming into contact with zebra mussels. Hepatitis A virus (HAV) has all of the requisite characteristics and is a demonstrably important pathogen to humans. The purpose of this research is to survey existing populations of zebra mussels in the Lake Erie basin for the presence of HAV in areas where HAV is likely to be present, e.g. the outfalls of sewage treatment plants. In addition, samples of the sediment and water in the areas from which zebra mussels are collected will be screened for HAV. This will establish whether HAV is present in environmental media and, if so, whether zebra mussel filtering activity results in bioconcentration. In areas where insufficient zebra mussels are collected, caged mussels will be deployed if HAV is detected in water or sediment. Finally, laboratory experiments will be performed to determine the ability of zebra mussels to concentrate HAV from water and to pass HAV to a predator, the round goby. The method of isolating and detecting HAV in all tests will be reverse transcriptase-polymerase chain reaction amplification followed by oligoprobe hybridization. These studies will permit an evaluation of human risk from zebra mussel-directed pathogen transfer.

This study collected zebra mussels (*Dreissena polymorpha*), sediment and water samples from sites in the Lake Erie drainage likely to be contaminated with HAV and analyzes them for the presence of HAV. Caged zebra mussels were placed at the outfalls of sewage treatment plants and monitored for the presence of HAV over time. HAV-contaminated zebra mussels were fed to round gobies (*Neogobius melanostomus*) which were monitored for the accumulation for HAV over time.

R/SP-4 9/1/94 to 8/31/96

Policy Instruments for the Virtual Elimination of Persistent Toxics in Great Lakes Industries

Alan Randall, Agricultural, Environmental, and Development Economics, The Ohio State University
Leroy J. Hushak, Agricultural, Environmental, and Development Economics, The Ohio State University

Virtual elimination of persistent toxic discharges in the Great Lakes region has been an established policy goal since 1978. As of the date of this study, however, no persistent toxic pollutant has been eliminated. To remedy this, the U.S. Environmental Protection Agency has proposed a Great Lake Water Quality Guidance (1993), relying primarily on command-and-control (CAC) regulation. Economic literature and experience, however, suggest that incentive-based (IB) regulation, which uses effluent taxes and emissions trading, may be more efficient. Installing the most cost-effective pollution abatement policy is particularly important for an area such as the Great Lakes region, the economy of which has been under stress since 1970.

This study was concerned with the economic welfare of the Great Lakes population. To maintain the competitive position of the regional economy, it sought the most cost-effective pollution control policies that will meet virtual elimination. Microeconomic models evaluated the effects of alternate policy instruments (for example, IB or CAC). The models identified the best abatement targets and the best timeframe for abatement at a minimum cost of public and private resources for abatement, monitoring, and enforcement.

Nonindigenous Species Research

R/ZM-1 10/1/91 to 9/30/93

Accumulation and Trophic Transfer of Organic Xenobiotics by the Zebra Mussel, *Dreissena polymorpha*: The Role of Route of Exposure and Lipid Content

Susan W. Fisher, Entomology, The Ohio State University
Peter F. Landrum, GLERL at NOAA

Some of the most harmful and persistent contaminants in the environment are PCBs and PAHs. These chemicals are hydrophobic and therefore do not dissolve easily in water, but rather adhere or adsorb to particles. They do, however, dissolve very easily in fat, making them lipophilic. This lipophilic quality helps make such toxins so persistent by allowing them to enter and remain in the food chain. All living things contain lipids, and bigger organisms survive by eating smaller organisms, so lipids accumulate in each higher link of the food chain, resulting in biomagnification of contaminants. Organisms exposed to PCBs and PAHs that contain more lipids than others are therefore more deleterious links in the food chain. Zebra mussels fall into this category. Moreover, by virtue of living near sediment, zebra mussels are more likely to be exposed to, and expose other organisms to, these contaminants. What the mussels don't find palatable, such as some algae and sediment, they filter from the water and glue together into potentially contaminated pseudofeces, which other organisms will eat.

This study measured the transfer, accumulation, and elimination of PCBs and PAHs in zebra mussels from contaminated water, contaminated sediment, and contaminated palatable and unpalatable algae. It also measured the transfer, accumulation, and elimination of these contaminants in a crustacean that eats zebra mussel pseudofeces and dead zebra mussels.

R/ZM-2 9/1/92 to 8/31/94

The Impact of Zebra Mussels on the Dynamics of Heavy Metals

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Paul L. Klerks, Biology, University of Southwestern Louisiana

Organisms require minute amounts of some metals to survive. Beyond this amount, metals become poisonous. Some, such as mercury or lead, are poisonous in any amount. The zebra mussel (*Dreissena polymorpha*) not only absorbs metals directly from the waters of Lake Erie, it ingests contaminated particles, such as algae, taking up the contamination. Although it filters out other possibly contaminated particles, such as unpalatable algae or sediment, the mussels glue these together with mucous to form pseudofeces, which other organisms eat.

This research measured the changes in the location and concentration of heavy metals in the water column of Lake Erie as a result of the zebra mussel invasion. Copper, zinc, and nickel were measured in the water column, in the zebra mussels, and in the mussels' pseudofeces. A change in metal cycling in the lake may have an effect on the metal content of algae and an effect on the metal content of fish.

R/ZM-4 10/1/91 to 9/3/92

Zebra Mussel-Fish Relations and Their Effects on Nutrient/Energy and Contaminant Dynamics

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Paul Baumann, U.S. Fish and Wildlife Service, National Contaminant Research Center

Zebra mussels (*Dreissena polymorpha*) are efficient filter feeders and concentrate various contaminants in their tissues. Selective predation on zebra mussels by some fish, therefore, may affect the transfer of contaminants to these fish and the resulting accumulation of contaminants in their tissues. Some Lake Erie sport fish, yellow perch (*Perca flavescens*) in particular, could be affected by this transfer.

This research studied the ecological relationships between fish and zebra mussels and what effects the mussels have on the flow of energy and contaminant transfer. Specifically, it examined yellow perch and freshwater drum (*Aplodinotus grunniens*) and their preferences for zebra mussels and mussels of a certain size in their diets. Mussels were evaluated for

how much energy they are capable of providing and how much energy is actually gained by the fish by measuring how zebra mussels filter out phytoplankton and zooplankton, removing food from other organisms, such as fish. By eating these particles or gluing them together and depositing them on the lake floor as pseudofeces, they have increased the nutrients available on the lake bottom. By removing sediment during their filtration, they have dramatically increased the amount of sunlight (necessary for plant growth) that reaches to the lakes' depths.

This study investigated the effects of zebra mussels on the abundance of open water phytoplankton, coupled with changes in the types and abundance of bottom dwelling algae and a possible shift in the lakes' food resources at the very base of the food web. To assess changes in these food web dynamics, these researchers were in the unique position of having studied the condition of Saginaw Bay's benthic algal communities *before* the zebra mussel invasion. Data on the benthic algal community structure and photosynthetic capacity at several depths were collected in early 1991 before any significant invasion in the bay. By late 1991, zebra mussels appeared in significant numbers. By 1992 and after, the populations exploded.

R/ZM-7 9/1/92 to 8/31/94

Influence of Zebra Mussel Invasion on Nutrient Dynamics in Plankton Communities: Field Verification of Mesocosm Findings in Saginaw Bay

Robert T. Heath, Biological Sciences, Kent State University
Wayne S. Gardner, GLERL at NOAA

Zebra mussel (*Dreissena polymorpha*) populations have been reported in all of the Great Lakes and are increasing in density; they are particularly dense in portions of Lake Erie and Lake St. Clair. They are intense filter feeders, although bacterioplankton are not eaten much by zebra mussels, suggesting that the role of bacteria in lake waters will increase, and the role of algae (food for zebra mussels) will decrease. Research suggests that bacterioplankton play significant roles in planktonic carbon (C), phosphorus (P), and nitrogen (N) dynamics (particularly in eutrophic lakes), which profoundly affect the plankton community at the base of the food web, in turn affecting the resource base for fish populations.

This study built on previous work that showed bacterioplankton activities to be very sensitive to even modest zebra mussel densities. It tested two hypotheses: one, that C-, N-, and P-dynamics in the field will be the same as have already been observed in controlled lab and in manipulated, contaminated field mesocosm experiments; and two, that changes in bacterial N- and P-dynamics may be due to a change in bacterioplankton responding to the loss of essential carbon (labile dissolved organic carbon, LDOC) produced by phytoplankton, the food of zebra mussels. These changes may act as early warning indicators of zebra mussel problems.

R/ZM-9 9/1/93 to 8/31/96

Genetics of the Zebra and Quagga Mussels: A comparative Analysis of Mitochondrial DNA Sequence Data

Carol A. Stepien, Biology, Case Western Reserve University

Since the initial discovery of the Great Lakes invasion by the zebra mussel, *Dreissena polymorpha*, and later the quagga mussel, *D. bugensis*, much effort has been given to understanding their ecological and economic impacts. Important to that understanding is knowing the makeup of the European parent populations of the Great Lakes mussels and also knowing the variability of the mussels themselves that landed here. Knowing that parentage and variability might help researchers better predict where and what the mussels might be able to colonize next. All of this can be achieved through DNA sequencing.

This study applied mtDNA sequencing to answer a number of questions regarding zebra and quagga mussels, such as, what is the genetic divergence between the two species, and is the quagga identical to the European species? What European populations are the probable "parents" of the Great Lakes invaders, and what sorts of environments do they inhabit? How does the genetic variability of the populations in the Great Lakes compare to the parental? Do North American populations show geographic genetic identity, that is, do mussels that inhabit lakes differ genetically from those that inhabit rivers? What is the genetic variability among populations and between species? Are there more cryptic species in addition to the quagga? Ultimately, this work hopes to analyze the spatial dynamics of the North American invasion and the spread of these *Dreissena spp.*

R/ZM-10 2/1/92 to 1/31/94

Influences of Temperature and Diet on Physiological Energetics of Growth and Reproduction of *Dreissena polymorpha*

David W. Garton, Biological and Physical Science, Indiana University at Kokomo

In western Lake Erie, the zebra mussel displays strong seasonal patterns in its reproductive cycle, abundance of veligers in the plankton, and settling of post-planktonic juveniles onto substrates. These seasonal patterns are sensitive to annual environmental variation, as patterns observed in 1990, for example, differed from seasonal patterns of 1989. In 1989, spawning was a highly synchronous event within the local population, whereas in 1990 gametes were released over a longer period—weeks versus days. The abundance of veligers between the two years also varied. Temperature has often been identified as the primary factor in timing of reproduction, but other studies have found temperature alone to be ineffective for inducing spawning.

This research determined the patterns of growth and reproduction of the zebra mussel as a function of water temperature and quantity and quality of phytoplankton in controlled laboratory experiments. Initial studies have shown that the zebra mussel's metabolism is not very sensitive to changes in temperature. They also have shown that rapid changes in metabolism affect reproduction. Observed rapid changes in body mass may be the result of food abundance or reproductive process.

R/ZM-12 9/1/93 to 8/31/95

Present and Expected Economic Costs of Zebra Mussel Damages to Users with Great Lakes Water Intakes

Leroy J. Hushak, Agricultural, Environmental, and Development Economics, The Ohio State University

The costs of zebra mussels (*Dreissena polymorpha*) to some electric power generating facilities and municipal water systems have been large, but current estimates of the total costs of zebra mussels to water intake facilities, electric power generating facilities, municipal water systems, and industrial plants, are fragmentary.

With many water intake facilities now having four to five years of experience with zebra mussels, a brief history of zebra mussel control and maintenance expenditures can be obtained along with the history of research expenditures to increase understanding of the zebra mussel and how it can be more cost-effectively controlled in these facilities. The purpose of this research was to survey Great Lakes water intake facilities and develop a history of zebra mussel control costs and expenditures. From this history, the reduction in costs from learning to more cost-effectively control zebra mussels will be used to generate preliminary estimates of the expected rate of return for zebra mussel research.

Great Lakes electric power generating facilities, municipal water systems, and industrial water users were surveyed to provide annual zebra mussel maintenance and control costs and research expenditures over the period of their exposure to zebra mussels. A sample of research investigators was surveyed to learn about expenditures on various types of basic research, applied research, and technology transfer being conducted, which led to new knowledge and more cost-effective zebra mussel control technologies.

R/ZM-13 8/1/91 to 7/31/93

The Economic Costs of the Zebra Mussel to Ohio's North Coast Economy

Leroy J. Hushak, Agricultural, Environmental, and Development Economics, The Ohio State University

The waters of Lake Erie support several major activities. Ohio's North Coast has developed into a major recreational economy with the aid of a large and growing recreational fishery. The Bass Islands, Cedar Point, Sea World, and Lakeside all have been developed to attract nonangling visitors. In addition, the waters of Lake Erie support a large population and a large industrial base. The invasion of the zebra mussel (*Dreissena polymorpha*) has imposed major changes on Lake Erie and potentially large costs on each of these activities.

The purpose of this research was to investigate how the zebra mussel has changed recreational behavior and the costs it has imposed on recreational visitors. The goal was to develop a comprehensive view of how an exotic species such as the zebra mussel affects Ohio's North Coast economy and to estimate changes in economic value and economic impacts on the economy associated with this species.

Questionnaires were mailed to about 3,000 Ohio and Michigan residents, surveying the Ohio and Michigan populations to investigate changes in recreational behavior and to estimate costs incurred as a result of the zebra mussel's presence. Models were estimated to determine changes in economic values placed on Ohio's North Coast recreational and

environmental amenities. Economic impacts on the tourism industry and how impacts change in response to the mussel's presence were also evaluated. The results showed rather small changes in recreational behavior related to the zebra mussel and correspondingly small changes in economic values of the lake's resources and in economic impacts on the recreational fishery.

R/ZM-14 9/1/92 to 8/31/94

A Policy Framework for Nonindigenous Species in the Great Lakes

Alan Randall, Agricultural, Environmental, and Development Economics, The Ohio State University

The Great Lakes aquatic ecosystem has proven repeatedly to be vulnerable to invasion by nonindigenous species. The zebra mussel (*Dreissena polymorpha*), sea lamprey (*Petromyzon marinus*) , and purple loostrife (*Lythrum salicaria*) are current examples. In particular, the zebra mussel is a recent arrival that has become established, is spreading rapidly, and has demonstrated the potential to cause significant ecological and economic damage. The Great Lakes are vulnerable to invasion by exotic species via several routes—of these, international shipping presents the greatest danger. Exotics have also been purposefully introduced by individuals to serve as pets, for example, or ornaments, which have then escaped and become established. Considering the obvious harm and astronomical costs of some invasions, It is important to develop a coherent, workable policy regarding nonindigenous species.

This study identified the basic principle fundamental to a coherent policy regarding introduction and control of nonindigenous species, not only for the Great Lakes, but applicable at a national level. It developed policy for three types of introductions—inadvertent, purposeful private, and purposeful by public authority. It measured the benefits and costs of planned and inadvertent introductions, and it completes an empirical cost case study of an introduction that has already occurred in the Great Lakes.

R/ZM-14 9/1/92 to 8/31/94

Zebra Mussel Mediated Shifts in Benthic Algal Communities in Saginaw Bay, Lake Huron

Rex L. Lowe, Biological Sciences, Bowling Green State University
Robert W. Pillsbury, Biological Sciences, Bowling Green State University

The zebra mussel, *Dreissena polymorpha*, is an effective filter feeder accidentally introduced to the Great Lakes in the mid-1980s. The zebra mussel reproduces so well and filters out organic and inorganic particles so efficiently that affected areas of the Great Lakes have a pronounced increase in light penetration. This increase in light will likely increase the depth at which plants and algae can grow in the affected lakes and allow the growth of benthic algae. On the other hand, although the growth of benthic algae in Saginaw Bay, Lake Huron, has increased, most of that increase is due to filamentous green algae, whereas the total benthic algal biomass has become increasingly limited by the decreased abundance of phosphorus in the lake water. Clearly, these communities and conditions are in a state of flux, and by monitoring them we learn about their effects on one another as an aid for making predictions in other ecosystems. A shift in the food web, whereby phytoplankton is decreased and bottom-dwelling filamentous green algae increased, for example, could have profound effects on an aquatic ecosystem.

This research began in Saginaw Bay prior to the zebra mussel's invasion there. It continued to monitor the density of the zebra mussels and their effects on the density and structure of the benthic algal community. It also studied changes in the invertebrate communities that graze on benthic algae.

R/ZM-21 9/1/93 to 8/31/95

Foodchain Contamination of Edible Fish Through Zebra Mussel Directed Trophic Transfer

Susan W. Fisher, Entomology, The Ohio State University
Peter F. Landrum, GLERL at NOAA

Zebra mussels (*Dreissena polymorpha*) have an exaggerated ability to concentrate some contaminants, such as PCBs and PAHs. They accumulate these (based on the mussels' filtering rate, size, and lipid content) directly from contaminated water, from contaminated algae they eat, and from contaminated algae and sediment they filter out and glue together into pseudofeces. Zebra mussels not only seem to funnel contaminants into the benthic foodchain, they are also hypothesized to direct contaminants into the upper levels of the benthic foodchain through two routes. One is a direct route, through fish that eat contaminated zebra mussels. The other route is indirect, whereby lake bottom invertebrates eat zebra mussel tissue and/or the contaminated feces and pseudofeces of zebra mussels, and these now contaminated invertebrates are then eaten by fish.

This research measured the amount of contamination zebra mussels take up from contaminated sediment and three types of contaminated algae. It also determined filtering rate as a function of particle concentration. It determined assimilation efficiencies for at least four chemicals in the mussel's tissue, feces, and pseudofeces; assimilation of contaminants in invertebrate tissues by way of zebra mussels; and assimilation of contaminants in fish directly and indirectly by way of zebra mussels.

R/ZM-23 9/1/94 to 2/28/97

Effect of Zebra Mussels on *Gammarus* Populations: A Mechanistic Approach

Maria J. Gonzalez, Biological Sciences, Wright State University

Because of its efficient filtering capacity, the accidentally introduced zebra mussel *Dreissena polymorpha* is expected to reduce phytoplankton in all of the Great Lakes. This could shift the lakes' energy flow from the pelagic food web to the benthic food web, with severe implications for fish. On the other hand, the amphipod *Gammarus* has notably increased in abundance where zebra mussels are present. Amphipods have been reported as food items for economically important fish such as yellow perch (*Perca flavescens*), walleye (*Stizostedion vitreum*), and bluegill (*Lepomis macrochirus*). This population increase in amphipods, however, could either be due to more food created by the presence of zebra mussel feces and pseudofeces, or could be due to the mussels themselves providing more places for amphipods to hide from predators. If the increase in amphipods is due to a greater food source, then there is the possibility that amphipods will help transfer contaminants up the food chain, because zebra mussels can remove contaminants from the pelagic zone and concentrate them in the feces and pseudofeces. If, however, the mussels give amphipods more places to hide and escape predation, then that may indicate even more difficulty for yellow perch, walleye, and bluegill in finding food.

This study set up treatments in the laboratory and in the western basin of Lake Erie to determine the effects of zebra mussels on amphipod populations, and to determine whether population increases are due to increased food or increased hiding places (i.e., decreased predation).

R/ZM-24-PD 6/18/95 to 7/22/95

Effects of Colonization of Soft Substrate by Zebra and Quagga Mussels on the Amphipod *Gammarus*

Maria J. Gonzalez, Biological Sciences, Wright State University

Recent studies documenting effects on benthic invertebrate populations in the Great Lakes by zebra mussels have shown significant increases of the amphipod *gammarus* between areas with and without zebra mussels in rocky habitats. Other studies have reported the invasion of soft substrate by zebra and quagga mussels. These observations have important implication for the benthic invertebrate communities in the Great Lakes. If dreissenid mussels colonies are a preferred substrate for *gammarus*, a higher abundance should be expected of this amphipod associated with the patches of derissenid mussel on soft substrate than on soft bottom. This research proposed to document to what extent zebra mussel colonization on soft bottoms affects *gammarus* populations using survey information and field experiments. The impact of dreissenid mussels colonizing soft bottom habitats on *gammarus* population was investigated in the field. The research was conducted in the western basin of Lake Erie in the Bass islands region.

R/ZM-25 9/1/94 to 8/31/96

Influence of Zebra Mussels on Carbon and Phosphorus Dynamics in Plankton Communities: Long-Term Effects in the Western Basin of Lake Erie

Robert T. Heath, Biological Sciences, Kent State University

The growth and development of any organism is based on the flow of energy within its environment. Carbon is the foundation of this energy, and in freshwater it enters the food chain through phytoplankton, which fix carbon from the atmosphere during photosynthesis. This carbon then travels through the food chain.

By the same token, the growth of phytoplankton hinges on the availability of phosphorus (in the form of phosphate), which is mostly assimilated by bacteria. These planktonic bacteria also get their carbon largely from dissolved organic carbon (DOC) released by the phytoplankton following photosynthesis. Bacteria depend on a continuous supply of this DOC for their vital activities. Therefore, by selectively filtering out certain phytoplankton and leaving behind bacteria, the zebra mussel, *Dreissena polymorpha,* is likely to alter both the carbon and phosphorus dynamics at the base of the Great Lakes food web. This research tested whether plankton communities exposed to large numbers of zebra mussels for a long time have decreased C-flux from algae to zooplankton (all because of reduced phytoplankton).

A chronic effect of zebra mussels may also be for them to deplete their own food source and alter phytoplankton communities from edible to inedible species. Short-term lab exposure to zebra mussels showed if long-infested waters are less affected by the addition of zebra mussels than are waters exposed for the first time (because zebra mussel grazing of some types or sizes of phytoplankton has resulted in a less edible phytoplankton taking its place).

R/ZM-26 9/1/94 to 8/31/96

Design and Test of a Novel Device for the Control of Zebra Mussel Infestation in Water Piping Systems

Tiao Jen Chang, Civil Engineering, Ohio University

Unlike native freshwater clams and mussels, which burrow into sediment and gravel, the exotic, invading zebra mussel, *Dreissena polymorpha*, spends its adult life firmly attached to the substrate. This has made underwater structures, such as water intake pipes for power plants and water treatment plants, particularly susceptible to encrustation. Furthermore, a growing zebra mussel population uses itself as a substrate on which to grow so that pipes become not only encrusted but completely clogged, requiring the periodic shutdown and costly maintenance. Current cleaning methods are either expensive or toxic to other organisms.

This proposal for the removal of zebra mussels from intake pipes took advantage of the zebra mussel's susceptibility to low concentrations of dissolved oxygen (DO). The organism thrives at saturation levels above 90 percent and is stressed in water with DO saturation levels below 40 to 50 percent. A tank with inflow and outflow control adjusted to the same rate was outfitted with an air mixer in the bottom and a vacuum pump at the top. The mixer disturbed the water body, causing oxygen to leave it, and the oxygen was collected in an air space and was removed from the tank by the air pump. Laboratory tests show that this method can achieve a DO saturation level of 50 percent.

R/ZM-27-PD 6/1/96 to 5/31/97

Field Testing of a Mechanical Device for the Control of Zebra Mussel Infestation in Water Piping Systems

Tiao Jen Chang, Civil Engineering, Ohio University

The project conducted the field testing of a mechanical device for the control of zebra mussel infestation in water conduits at the Avon Lake Water Plant, Avon Lake, Ohio, and gathered further information for the future installation of a pilot device at the site that has been infested by zebra mussels. The device was developed based on the mechanical reduction of dissolved oxygen in the water conduits by a vacuum system, which has been successfully tested in the laboratory at Ohio University.

R/ZM-28 3/1/98 to 2/28/00

Substrate and Zebra Mussels: Controls and Impacts on Fish Reproductive Habitiat—Western Basin Reefs

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Kenneth Baker, Biology, Heidelberg College
Michael Bur, Lake Erie Biological Station, USGS
Edward Roseman, Fisheries and Wildlife, Michigan State University

The reefs in Lake Erie differ in composition, size, depth, and exposure to currents, and have been shown to be important as spawning and reproductive habitat for numerous fish species. Because of recent losses of former breeding grounds from habitat degradation and damming of Lake Erie tributaries, reefs have become an essential spawning habitat for walleye (*Stizostedion vitreum*), possibly influencing the reproductive biology of the walleye. The introduction and spread of the zebra mussel (*Dreissena polymorpha*) into the Great Lakes may have significantly altered the physical characteristics of both hard and sof substrates in Lake Erie. This research mapped and quantified substrate characteristics over six reefs in the western basin of Lake Erie and assessed how the physical and biological structure of reefs might influence the quality of fish reproductive habitat. This was done by developing detailed substrate maps of six reefs within the bedrock reef complex of western Lake Erie; determining patterns of zebra mussel coverage of substrate surfaces within and among the six reefs; assessing the possible effects of variation in substrate on zebra mussel coverage and on habitat use of fish for spawning and reproduction; and assessing potential impacts of the exotic round goby (*Neogobius melanostomus*) on zebra mussels and habitat use by fish for spawning and reproduction.

R/NIS-3 3/1/98 to 2/28/00

Benthic-Pelagic Coupling: Community Responses to Round Goby Predation on Zebra Mussels

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The Great Lakes and many systems contiguous with the Great Lakes have become dominated by the zebra mussels since their introduction over ten years ago. Zebra mussels have not only had dramatic impacts on ecosystems through a variety of mechanisms, but have had limited predators who have an aggregative ability to control them. Round gobies, however, have many characteristics which suggest they may be effective zebra mussel predators. This research proposed to determine the extent to which round gobies can reduce zebra mussel abundance and quantify the effects this would have on the benthic macrinvertebrate and periphyton communities through a series of cage manipulations set up at Ohio State Ujniversity's Stone Laboratory. This research also proposed to quantify phytoplankton and zooplankton responses to reduced filtration rate and changes in the ratios of nitrogen and phosphorus available for nutrient cycling.

R/NIS-4-PD 3/1/97 to 12/31/97

Genetic Characterization of Invasive Gobies in the Great Lakes

Carol A. Stepien, Biology, Case Western Reserve University

Many scientists and fishery managers believe that exotics are now the most serious threat to native populations of the Great Lakes. Invasions by the Eurasian round and tubenose gobies compound the problems perturbing the Great Lakes ecosystem, notably the repeated successes of other nonindigenous species. Since its introduction, the round goby has spread to all five Great Lakes--faster than any previously introduced fish. The proposed research produced essential baseline data of the round goby *Neogobius melanostomus* and the tubenose goby *Proterorhinus marmoratus* specifically the number and description of genetic variants (ESUs); their geographic distribution(s); possible origin(s) in order to the genetic variability of these two goby species in the Great Lakes to Eurasian populations. This provides valuable information for interpreting their relative success in comparison with each other and with other exotic species, at present and in the future.

R/NIS-5 9/1/97 to 8/31/98

Genetic Relationships of Ruffe Populations in North America and Eurasia Based on DNA Sequences

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The purpose of this investigation was to compare DNA sequences of ruffe from the Great Lakes with Eurasian populations in order to assess relative levels of intraspecific variability and to test for distinguishing markers among areas of its present distribution. Specifically this research characterized the genetic structure of the initial ruffe population in the Great Lakes and establish groundwork for continued monitoring; provided baseline data for genetic identification of potential future colonization; and determined whether samples from Eurasian regions and North America were genetically similar or different.

R/NIS-107-SG 9/1/97 to 8/31/98

Zebra Mussels as Determinants of Benthic Macroinvertebrate Community Composition in Western Lake Erie: A Systematics Approach to Species Responses

Jeffrey G. Miner, Biological Sciences, Bowling Green State University

Previous studies have demonstrated that Dreissena has caused dramatic changes in the Great Lakes ecosystem. However, mechanisms for Dreissena's impacts on most species are poorly known. Through integrated use of field experiments, identification of organisms to the species level, and multivariate statistics, this research proposed to quantify interaction strengths between Dreissena and other species. Additionally, mechanisms for Dreissena's effects on community structure were explained. This research proposed to use a field experiment, high taxonomic resolution (identification of organisms to the species level), and multivariate statistics, to quantitatively describe effects of Dreissena and large predators (fish and crayfish) on a benthic macroinvertebrate community in Lake Erie. Results generated from such studies contribute to an improved understanding of Dreissena's effects on community properties and energy flow through aquatic food webs.

R/NIS/108-SG 9/1/97 to 8/31/98

Systematics and Population Genetic Divergences of Invasive Dreissenid Mussels in North America Versus Native Eurasian Populations

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Since discovery in the Great Lakes in 1988, considerable effort and financial support has been directed toward examining the ecological and economical impact of the dreissenid mussel invasion. This proposed study provided essential data for testing the dynamics, systematic relationships, and patterns of genetic relationships among the Eurasian and North American zebra and quagga mussel populations. It determined genetic differences between zebra, quagga, and variant mussels and analyzed whether or not intraspecific genetic polymorphisms are defined among geographic regions. Systematic and population relationships were determined among zebra, quagga, profundal-type variants, and outgroup species and additional information relating to the origin of parental stocks were provided.

R/NIS-109-SG 9/1/97 to 8/31/98

Systematic Relationships Among North American Ruffe (*Gymnocephalus cernuus*) Eurasian Populations, and Related Species Based on Mitochondrial DNA Sequences and Morphology

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Since the Eurasian ruffe's (*Gymnolcephalus cernuus)* introduction to the Lake Superior/St. Louis Harbor region in the mid-1980's, the ruffe population has spread rapidly east to Lake Huron to as far north as Ontario, Canada. Its high fecundity, rapid growth rate, tolerance to variable environments, and lack of commercial value are several key factors which make the ruffe a great concern to the Great Lakes ecosystem. This project compared DNA sequences of the ruffe from several Eurasian and North American population areas in order to identify and distinguish genetic types (and possible cryptic species) of *G. cernuus.* Meristic and morphological data were used to compare divergence of genetic types. These data were then compared with the other three members of the genus *Gymnocephalus* (*G. baloni, G. schraetser, and G. acerina)* in order to test their phylogenetic relationships and gauge species level separations.

Education

E/CMD-3 9/1/94 to 8/31/96

The Ohio Sea Grant Education Program: Cooperative Curriculum Enhancement and Teacher Education for the Great Lakes

Rosanne W. Fortner, Natural Resources, The Ohio State University
Victor J. Mayer, Education, The Ohio State University (Emeritus)

Previous Ohio Sea Grant research has shown that students who live in the Great Lakes region know far more about the oceans than about the Great Lakes. As future voters and policy makers, these students must learn more about the lakes and their resources and issues. To accomplish this, teachers must first be educated in integrated sciences and classroom processes that were not part of their original teaching preparation. These processes include students engaging in hands-on activities and analyzing data, integrating science with other subjects, exploring how science and technology affect their lives and society, and making logical connections between what is learned inside and outside of the classroom. The impetus to restructure the science curriculum in Ohio comes from national efforts (for example, of the American Association for the Advancement of Science, 1989) to prepare society for understanding science in the next century.

This project built on the results of another project supported by the Great Lakes Protection Fund, "Environmental Data for Teaching About Great Lakes Pollution Prevention." In addition to providing environmental data, it restructured material in the Oceanic Education Activities for Great Lakes Schools (OEAGLS), developed by Ohio Sea Grant. The materials were made more amenable to group learning now advocated by teachers nationally. By first teaching "teacher leaders" these materials, the program's goal was to educate all teachers to use an Earth Systems approach, which relates Sea Grant research and aquatic information to important issues in both science and education.

E/E-1 9/1/96 to 8/31/98

Evaluation of Program Effectiveness and Classroom Technology Use in Great Lakes Education

Rosanne W. Fortner, Natural Resources, The Ohio State University
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In its 20 years, Ohio Sea Grant education has built a reputation for leadership in curriculum development, teacher education, and educational research. Through curriculum research and teacher education, this project fostered development of demonstration schools in the Great Lakes states, as sites for introduction and intensive evaluation of Great Lakes/Earth Systems education curriculum materials and methods. This project also analyzed national and Ohio science standards for existing and potential areas of application of Great Lakes/Earth Systems education, including science database and classroom technology use, cooperative learning methodologies, and subject matter applicability. Baseline data was collected and compared, documenting students' levels of Great Lakes knowledge, students' information seeking behaviors (related to data and using technologies), and the teachers' uses of cooperative learning, science data, and Sea Grant education activities. This project evaluated how its science databases and technology advance information-seeking skills in other region classrooms and compared those with demonstration schools in this project in order to document a necessity to include its model into the U.S. Department of Education's National Diffusion Network.

E/TER-1 3/1/98 to 2/28/00

Development of Internet-Linked Instructional Materials and Teacher Education Research for Earth Systems Education of the Great Lakes

Rosanne Fortner, Natural Resources, The Ohio State University
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The National Oceanic and Atmospheric Administration has identified education as a fundamental instrument to increase public knowledge about scientific and social issues and to stimulate interest among young people who may consider science or resource management vocations. Ohio Sea Grant has supported those efforts by introducing an integrated earth systems approach to education that links curriculum development with Great Lakes topics and issues.

With the introduction of the World Wide Web as a new teaching tool, there are new avenues opening for education and a need for Sea Grant to meet those challenges with new materials and services. This research was designed to help "technologize" secondary level teachers of Great Lakes sciences in order to provide them with tools, enhancing presentations and supplementing existing materials with current information. The project developed simulated Internet sessions used as facilitation for science and social studies teachers; engaged Ohio's marine advisory service agents in inservice programs to experience use of computer technologies for presentations and investigations; and provided educators with survey data on teacher knowledge, teacher use of technologies in instruction, perceived importance of Great Lakes topics, and student interest in the topics.

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1999 Ohio Sea Grant College Program

Research & Education Projects

Initiated between 1994 and 1999

Aquatic Nuisance Species Projects 1991- 1999

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