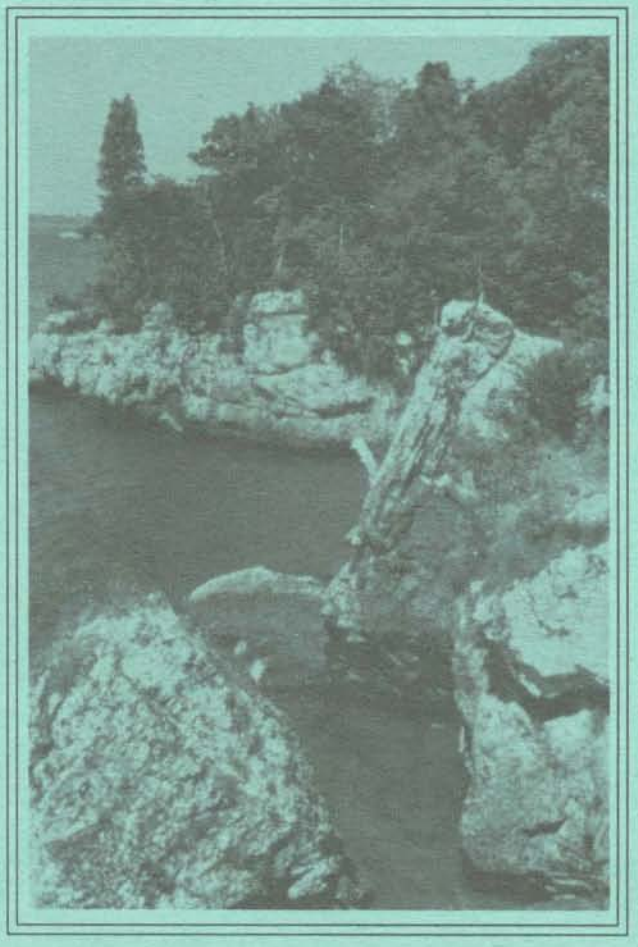
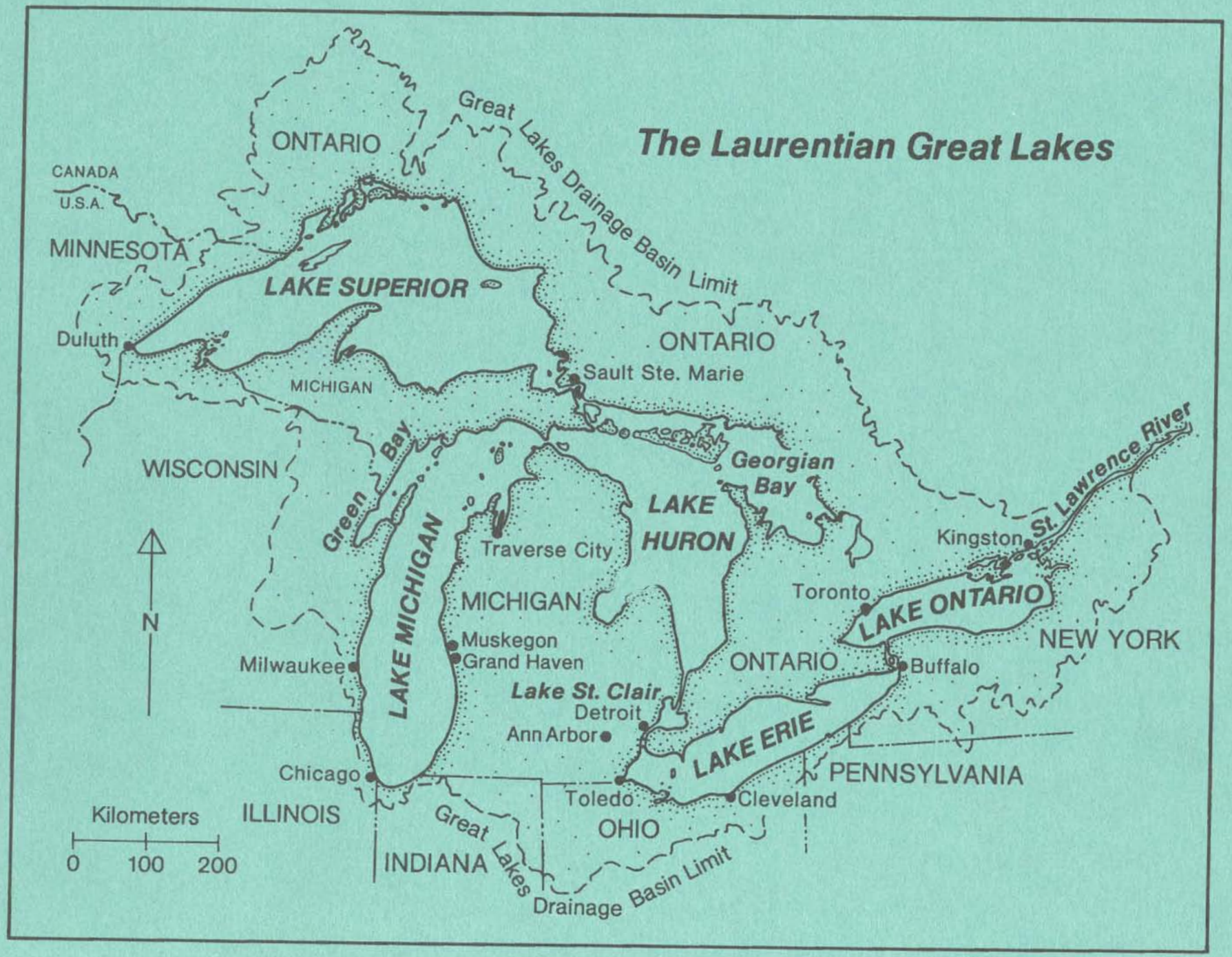
Great Lakes Environmental Research Laboratory



Annual Report FY 91

U.S. DEPARTMENT OF COMMERCE~National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research~Environmental Research Laboratories



On the Cover: Bedrock Cliffs (Put-in-Bay Dolomite) South Bass Island. Photo from C.E. Herdendorf.

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

ANNUAL REPORT FY 1991

Director

Alfred M. Beeton

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
Environmental Research Laboratories
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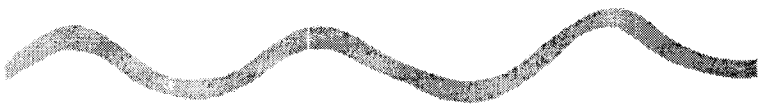

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Introduction

The Great Lakes Environmental Research Laboratory (GLERL), located in Ann Arbor, Michigan, is 1 of 11 environmental laboratories operated by the National Oceanic and Atmospheric Administration (NOAA), Office of Oceanic and Atmospheric Research (OAR), through the Environmental Research Laboratories Directorate.

GLERL's mission is to conduct integrated interdisciplinary environmental research in support of resource management and environmental services in coastal and estuarine waters, with a special emphasis on the Great Lakes. GLERL's research has traditionally been focused on investigations to improve our understanding of, and ability to predict, the biological, chemical, and physical processes occurring in natural ecosystems. Such processes influence the fate and effects of pollutants, the cycling and through-put of nutrients and energy within the food chain, water quality, and water quantity (lake levels and the hydrologic cycle), or they pose a hazard to the human population who use the natural resources of the ecosystem. In addition, GLERL cooperates closely with other federal, state, and local agencies, private industry, academia, and the general public on major environmental projects in the Great Lakes.

The products of GLERL's research are made available on a regular basis as scientific publications, NOAA Technical Series reports, computer programs and computer-based models, brochures, posters, and presentations at scientific and public meetings. These products are used by government, educational, and private organizations for many different purposes ranging from informational to actual applications and operational use. During FY 91, 51 scientific publications by GLERL authors were published, and 57 talks were presented by GLERL staff at scientific and public meetings and in schools.

This annual report describes the significant activities and accomplishments of GLERL staff during the period October 1, 1990 - September 30, 1991. For general information on how to obtain GLERL products, see the Facilities and Services section of this report.

GLERL's scientific programs are organized into five coordinated research programs considered critical to the NOAA mission and to Great Lakes problems (Coordinated Ecosystem Research, Climate Variability and Global Change in Large Lakes, Marine Hazards and Water Management, Pollutant Effects, and Non-Indigenous Species), the Nutrient Enhanced Coastal Ocean Productivity (NECOP) and CoastWatch programs, and several independent research projects. There is also a number of support units that provide technical, operational, and administrative assistance to the scientific staff:

- a Marine Instrumentation Laboratory, where instruments and systems for hands-on and automated field collection of data are designed, built, and maintained;

- a Computer Systems Group that maintains GLERL's in-house computer network, the interface with off-site mainframe and super computers, and provides related user support to the GLERL staff and others;

- a Publications Unit that is responsible for providing editorial and publications support to the GLERL staff, distributing GLERL publications, and responding to related information requests;

- a Library that maintains a research collection tailored to GLERL staff needs and which offers special retrieval services for materials not in the existing holdings;

- the R/V SHENEHON, GLERL's research vessel and the primary platform used by GLERL staff for field operations on the lakes;

- and an Administrative Office that provides personnel, budget, purchasing, and facility information and management of the laboratory.

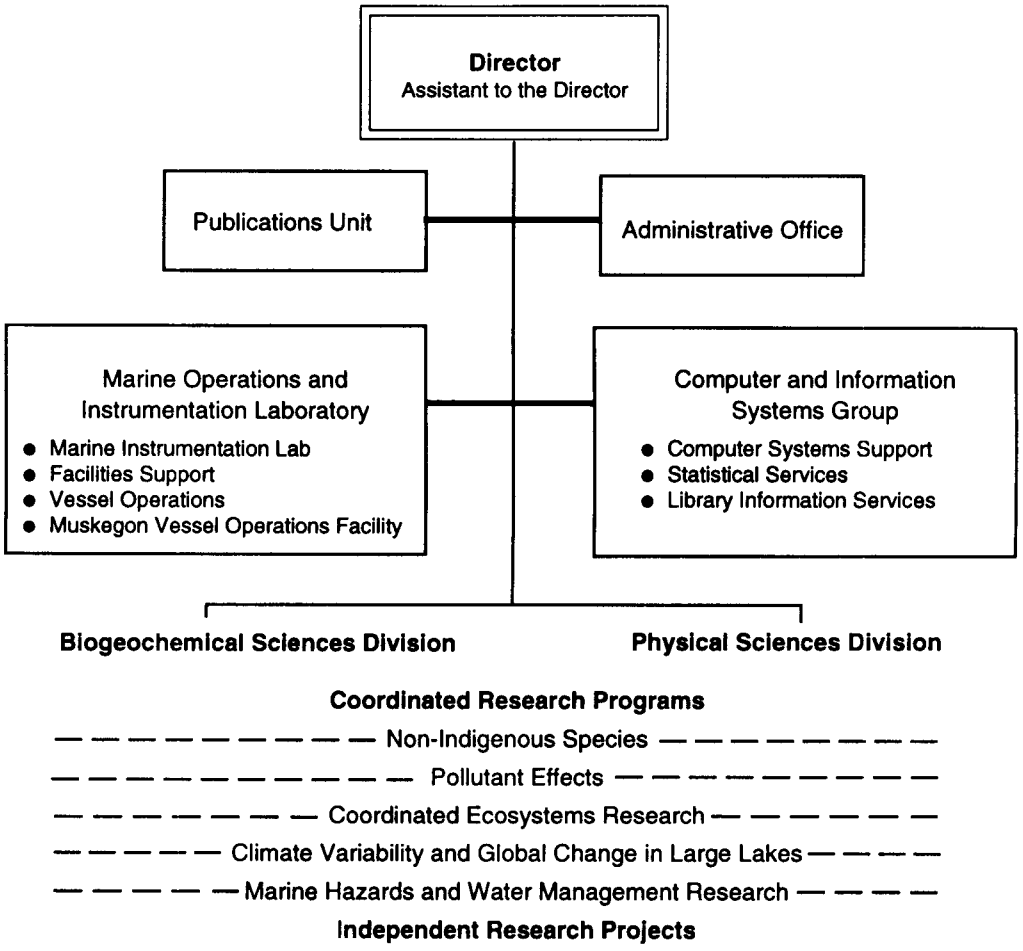

Figure 1. GLERL's Organizational Structure

Non-Indigenous Species

T.F. Nalepa, Program Leader

Recently, two species were introduced into the Great Lakes that have the potential to dramatically alter trophic relationships of the entire ecosystem: the zebra mussel (*Dreissena polymorpha*), and the spiny water flea (*Bythotrephes cederstroemi*). *Dreissena* is capable of increasing in numbers very rapidly. This species will likely have ecological implications to other species and have a profound impact on the cycling of materials. *Bythotrephes* has become a dominant member of the plankton in all of the Great Lakes. Our own preliminary work suggests that *Bythotrephes* is a voracious selective predator. Recent shifts in Lake Michigan zooplankton community structure from *Daphnia*, the favorite food of *Bythotrephes*, to copepods have been hypothesized to be caused by *Bythotrephes*. The goal of this program is to expand our knowledge of the biology and ecological impacts of non-indigenous species in the Great Lakes. Individual scientific studies within this coordinated research program including FY 91 accomplishments follow.

Examining the Impacts of the Zebra Mussel, *Dreissena polymorpha,* on the Lower Food Web of Saginaw Bay.

The objectives of this project are (1) to define changes in the abundance, biomass, and composition of the lower food web of Saginaw Bay that have resulted from the invasion of the zebra mussel, (2) to construct a model of carbon flow through the system and determine process-oriented changes, and (3) to monitor changes in the abundance and distribution of the zebra mussel in the bay. In FY 91, a meeting was hosted to plan agency coordination and resource pooling resulting in an agreement between GLERL, the Michigan Department of Natural Resources (DNR), the U.S. Environmental Protection Agency (EPA), and the U.S. Fish and Wildlife Service (FWS) to provide resources to enhance research efforts. A request for proposals was issued to address research gaps through academic institutions. Consultations with potential collaborators, reviews of proposals, and relevancy to planned GLERL activities in Saginaw Bay provided a basis for funding grants. An expanded sampling program was initiated in Saginaw Bay in April 1991. A total of 26 sites were sampled monthly until November. In June 1991, two sequential sediment traps were placed in the bay to determine seston settling rates. Also, six current meters were placed in the outer bay to determine water exchange rates between the inner and outer bay. Artificial substrates were constructed and placed at four sites in the bay to document the rate and temporal variability of settling by zebra mussel veligers. Divers were employed to document zebra mussel densities in the bay. Mesocosms were constructed, and preliminary experiments were conducted to determine small-scale changes in nutrients, bacteria, phytoplankton, and zooplankton as a result of the filtering activities of zebra mussels (Figure 2).

Metabolic Physiology of the Zebra Mussel, *Dreissena polymorpha.*

Objectives of the program are (1) to seasonally determine oxygen consumption, nitrogen (ammonia)

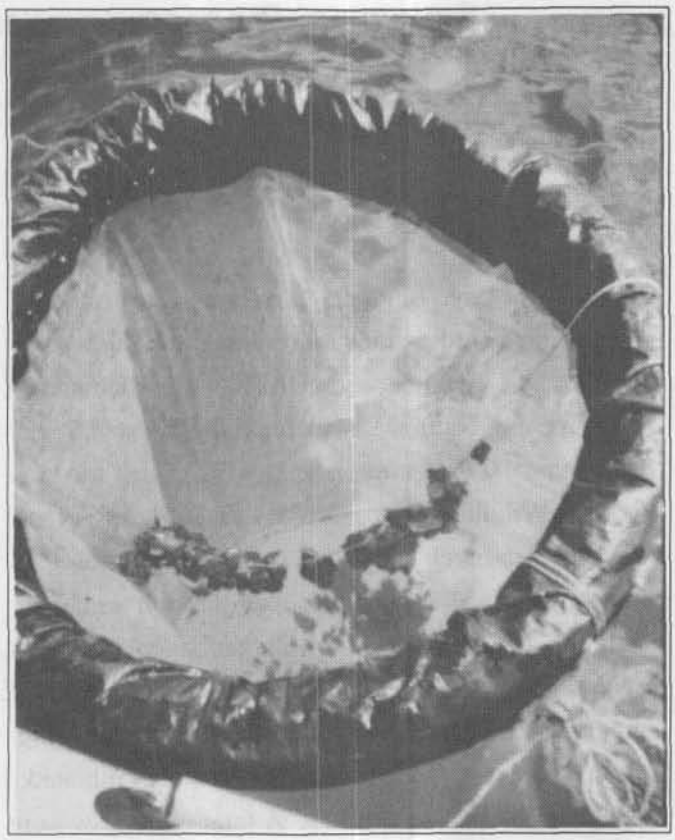

Figure 2. Mesocosms were constructed and placed in Saginaw Bay to determine small-scale changes in nutrients, bacteria, phytoplankton, and zooplankton as a result of the filtering activities of zebra mussels. This photo shows a downward view of a mesocosm in the bay. The zebra mussels are attached to a line in the center of the mesocosm.

excretion of zebra mussels collected from Lake St. Clair, and (2) to seasonally determine lipid content and Carbon:Nitrogen ratios of soft tissue from zebra mussels collected from Lake St. Clair. Analysis of data collected in Lake St. Clair in FY 90 continued, and preliminary results show that lipid levels in zebra mussels are very site-specific and possibly a function of abundance. A population survey of zebra mussels was conducted in Lake St. Clair in the fall of 1990 to determine abundances and biomass on a lake-wide basis. All mussels were counted and measured for length. In addition, the proportion of mussels attached to different types of substrates were determined. Excretion rates (phosphorus and nitrogen) of mussels collected from Lake St. Clair were measured monthly beginning in April 1991.

Direct Observations on the Trophic Ecology of *Dreissena* Early Life Stages: The Critical Planktonic Period.

The pelagic phase (eggs and larvae) is probably the weak link in the life cycle of *Dreissena* with mortalities of nearly 100% depending on environmental conditions. The larvae are at potential risk from starvation and from predation by zooplankton. Compared to the adults, little is known about the larvae. Before we can understand the potential of the invasion of an environment by *Dreissena*, its role in the ecosystem, and the possibility of its biological control, we need to understand the trophic ecology of the pelagic phase. Objectives of this new project are (1) to observe feeding mechanisms, particle choice, and feeding rates of *Dreissena* larvae, (2) to determine nutritional requirements of *Dreissena larvae*, and (3) to determine vulnerability of *Dreissena* eggs and larvae to zooplankton. In FY 91, we maintained adult zebra mussels in the laboratory and initiated the development of methods to induce spawning of the mussels to produce a supply of veligers. The growth kinetics of algae to be used as food for veligers were also determined.

Toxicokinetics and Bioaccumulation of Organic Contaminants by the Zebra Mussel.

This project will primarily employ selected members from two classes of compounds, the chlorinated hydrocarbons, primarily polychlorinated biphenyls (PCBs), and the polycyclic aromatic hydrocarbons (PAHs). These selected chemicals will be representative of both their class and of the physical/chemical characteristics embodied in the chemicals as model compounds. Compounds from other chemical classes

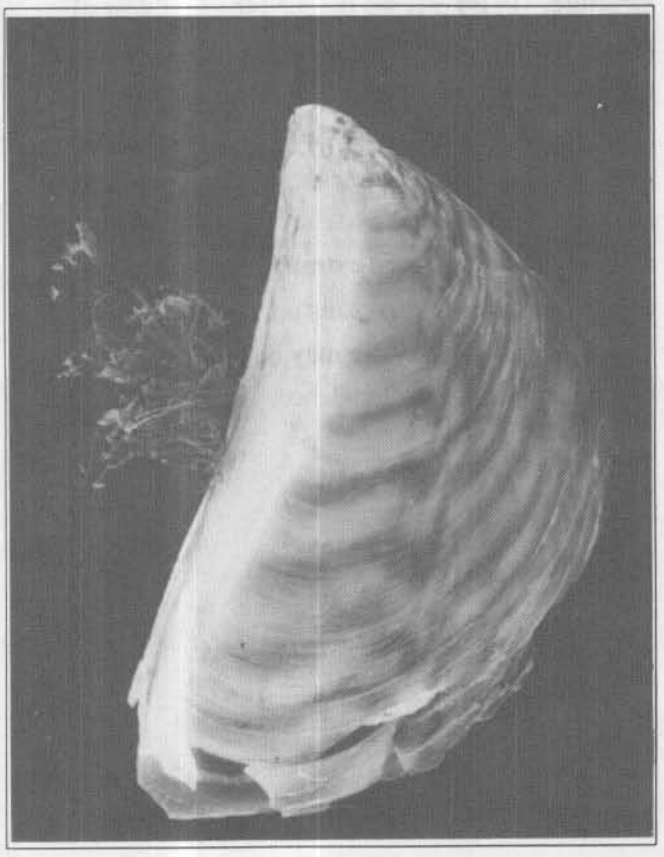

*Figure 3. Close-up of a zebra mussel (*Dreissena polymorpha*). The adult mussels can filter up to 1 liter of water per day.*

are to be employed where specific characteristics will be helpful to determine specific processes or mechanisms of action. Methods have recently been developed to hold zebra mussels in the laboratory safely and in good health for toxicokinetic studies. An experimental design was developed that permits the measurement of the toxicokinetics of organic contaminants in zebra mussels that were exposed only through the water. Calculations of the toxicokinetics required significant modification of existing kinetics models to calculate the uptake rate coefficient. Both uptake and elimination of benzo(a)pyrene, 2,4,5,2',4',5'-hexachlorobiphenyl, DDT, 3,4,3',4'-tetrachlorobiphenyl, and pyrene were determined. Efforts continue to refine the measurement of filtration rates.

Zooplankton Grazing vs. Zebra Mussel Filtering in Saginaw Bay: An Experimental and Modeling Study.

Zooplankton grazing is a major force in determining particle and food web dynamics in the Great Lakes. It is anticipated that major changes in particle abundance and foodweb structure will occur in Saginaw Bay as a result of the zebra mussel invasion, owing to their prodigious filtering rates (Figure 3). This new study will compare zooplankton grazing and zebra mussel filtering.

Long Term Changes in the Resuspendable Sediments of Saginaw Bay.

In shallow systems, the behavior of particle-associated constituents are strongly mediated by sediment/water exchange. The influence of this coupling on the concentrations, transport, and residence times of these constituents is a function of the extent of bioturbation and the rate of resuspension of these materials back into the water column. The introduction of zebra mussels into this system will likely modify the sediment/water exchange rate either by (1) changing the repackaging of particulate matter resulting in changes in sediment cohesion and resuspendibility, (2) influencing the development of increased macrophyte populations, or (3) changing the density/distribution of benthos and thereby the rate and extent of bioturbation. In FY 91, the first year of this new program, two autosequencing sediment traps were deployed.

Ecology of an Invader: The Physiological Ecology of *Bythotrephes* and its Direct Effect on Food Web Structure in the Great Lakes.

Objectives of the program are to (1) determine *in situ* selectivity and predation rates of *Bythotrephes cederstroemi* on zooplankton in the Great Lakes and examine the effect of *Bythotrephes* on food web structure, (2) determine spatial distribution of *Bytho-*

trephes and its prey, and relate vertical distribution to light climate, (3) directly observe predation mechanisms of *Bythotrephes* using Schlieren videography to observe swimming and attacks and use high-speed videography to observe prey handling of tethered animals, (4) determine Nitrogen excretion, lipid content, respiration, and reproductive condition of *Bythotrephes* to understand its bioenergetics, life-cycle strategy, and ability to survive in the Great Lakes, and (5) develop a model of selective predation by *Bythotrephes* to predict its impact on Great Lakes community structure. In FY 91, we finished the first year of nearly weekly collections of *Bythotrophes* at the offshore monitoring station and at an inshore station. Analyses of a collection of tows made during day, dusk, and night of the same day over all depth strata showed highest abundances at night, second highest abundances at dusk, and extremely low abundances during the day. These results are consistent with net avoidance and suggest we may be grossly underestimating *Bythotrephes* abundance.

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Pollutant Effects

P.F. Landrum, Program Leader

The Pollutant Effects coordinated research program pursues research to increase our understanding of the dynamics and effects of contaminants in the ecosystem. The studies are developed within a conceptual framework focused around the basic toxicological concept that effects are related to the attainment of a critical dose of contaminant for a specific duration. This research will strive for a generic understanding of contaminant dynamics and effects that can be applied to many different systems using sites and processes from the Great Lakes as specific examples. The effort will be a combination of process studies and mathematical modeling that will improve our understanding and ability to predict contaminant fate and effects in the Great Lakes. This program will attempt to address the following questions: (1) For a given load of toxic contaminant, what level of exposure can be expected for various biota? (2) What is the assimilative capacity for toxic contaminants defining no-effect loads for both species and communities? (3) What kind of prediction can be applied to catastrophic events to insure best management decisions? (4) What are the effects of long-term low-level contaminant exposures?

The program on contaminant cycling in an aquatic ecosystem can be broken down into five major areas of study: (1) Environmental monitoring for load estimates, validation of model, and field estimates of laboratory-derived parameters for model calibration. (2) Physical, chemical, and biological processes affecting the fate, transport, and degradation of contaminants. (3) Exposure, bioavailability, toxicokinetics, and biodegradation of contaminants. (4) Effects of contaminants at all levels of biological organization within an ecosystem and biological early warning measures of effects. (5) System assessments and predictive simulation modeling. While all the above research areas are important for a complete understanding and prediction of effects, resources limit the scope of the program. The program focuses primarily on toxic organic contaminants with emphasis on exposure and effects with a lesser emphasis on fate and assessment. Since the role of contaminated sediments remains among the least well understood, but probably among the most important, of the exposure pathways, much of the current research effort is focused on sediment-associated contaminants and exposure to benthos. Individual scientific studies within this coordinated research program including FY 91 accomplishments follow.

Bioavailability of Sediment-Associated Toxic Organic Contaminants.

This project focuses research efforts on factors that influence the bioaccumulation of organic contaminants by benthos, e.g. what is the assimilation efficiency for contaminants obtained through ingestion of sediment particles, and how does sediment particle size affect the bioavailability of sediment-associated contaminants? One important issue that should be addressed in this project is improving the connection between laboratory and field research. To date, the research has focused on laboratory-dosed sediments. Several studies have suggested that material in the field may be different from that produced in the laboratory because of the

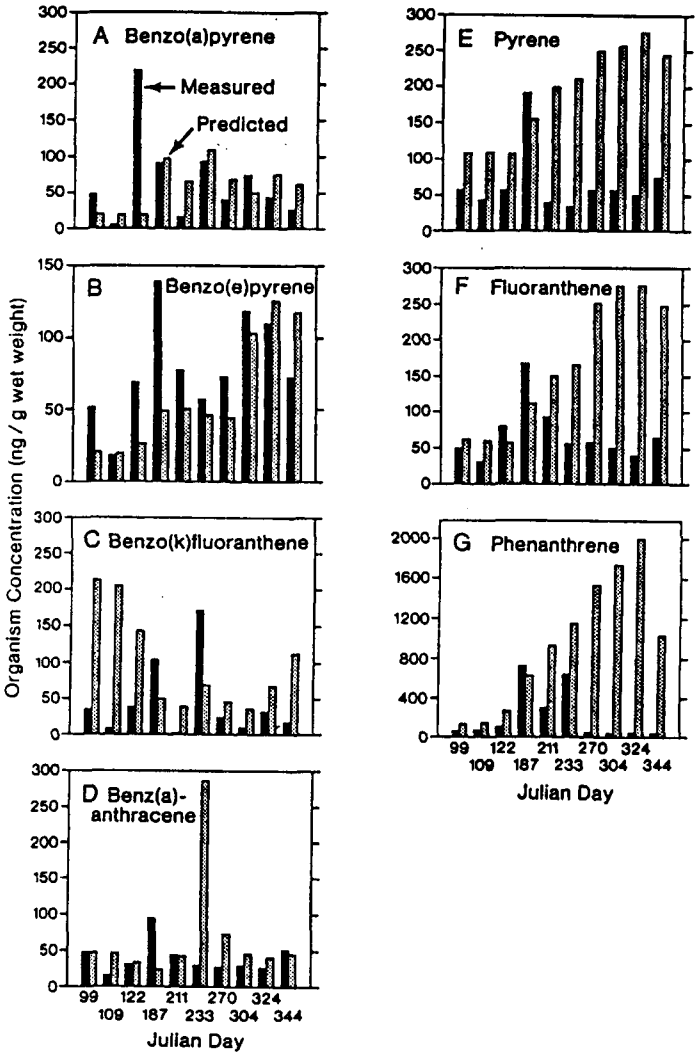

Figure 4. Field validation of our kinetically driven accumulation model yields good prediction including the seasonal variation of strongly sediment-sorbed PAH such as benzo(a)pyrene but over-estimates accumulation of more water-soluble PAH such as phenanthrene.

different contact times between the contaminants and the particles in the field and those in the laboratory. In FY 91, quantitative structure activity models were employed to examine a set of data on the toxicity of organophosphorous and carbamate insecticides to the midge *Chironomids*. The study incorporated exposures to water only and to sediment-associated contaminants.

Assimilation efficiency studies for accumulation of sediment-associated contaminants by *Diporeia* are under way. Preliminary findings suggest that the assimilation efficiency for benzo(a)pyrene is similar to that for other non-polar contaminants in other benthos. The relationship between the organic carbon content and toxicokinetics of sediment-associated contaminants was completed.

Contaminant Effects and the Relationship to Exposure.

This task combines research performed under two tasks previously titled Physiological and Biochemical Measures of Contaminant Effects and Sediment-Associated Toxic Organics: Fate and Effects. The project will develop bioassays focused on solid phase sediment studies which will be useful for assessing the extent of contaminated sediments. This research will continue the development of the 28 d *Diporeia* mortality bioassay and the avoidance/preference bioassay. Additionally, the relationship between the duration and level of exposure for a particular effect and the amount of accumulated contaminant to produce the effect will be investigated. In FY 91, two cruises were made to examine the relationship between respiration and excretion for *Diporeia* found under differing conditions in Lake Michigan. The oxygen consumption was the same for organisms taken from all depths while nitrogen excretion increased for organisms collected from the deeper stations. Data analysis on the impact of increased contact time between the sediment and the contaminant was completed. With increasing duration of contact, the bioavailability is reduced (Figure 4). This reduction is rapid enough to affect the bioavailability of laboratory-dosed sediments. Data analysis examining the relationship between respiration and contaminant accumulation from water was completed. The accumulation of selected PAH was approximately four times the respiration rate for *Diporeia,* suggesting

either a low efficiency for oxygen consumption or accumulation of PAHs across more than just the respiratory membrane. Data analysis and modeling were completed for examining the field validation of the accumulation of PAHs by *Diporeia* sp.

Physical and Biological Diagenic Processes in Sediments.

This new project, which combines some of the previous activities in the Pollutant Effects coordinated research program, examines the activities of benthic invertebrates common to bioturbation including feeding, burrowing, and other locomotive activities which may be specific to certain species, such as swimming and tube construction. Other features of secondary importance include examination of the alteration of porosity, particle size distribution, and the distribution of organic carbon by animals. This study utilizes a unique instrument (the Gamma Scan System) to non-destructively track the movement of particles by benthic organisms. The rate of particle movement for conveyor belt feeding organisms reflects the rate of feeding and can be used as a measure of effects of contaminants as well as to understand the basic processes involved in particle and contaminant transport. Data from the initial bioturbation studies were analyzed, and the reworking rate was found to decline significantly with increasing concentrations of DDT. New models to improve the data analysis of reworking data collected by the gamma scan system were written to continue the data analyses of the above experiments.

Bioenergetics of the Great Lakes Amphipod *Diporeia* sp.

This project establishes the production and energy budget for *Diporeia* which is the dominant benthic organism in the Great Lakes on a mass basis, is a primary prey item for most Great Lakes fish, and has a large bioaccumulation capacity (Figure 5). Because of

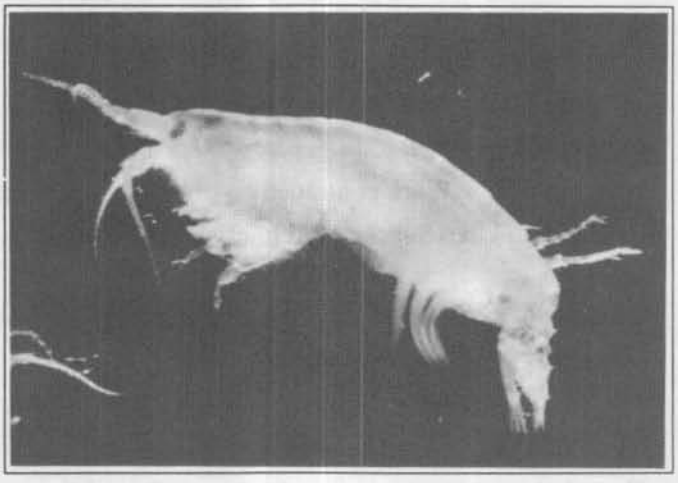

Figure 5. The amphipod Diporeia sp. *is used in many GLERL studies.*

these features, establishing the bioenergetics along with the toxicokinetics from the above and previous projects will permit the estimates of the contaminant flux entering the food chain through this important sediment link. In FY 91, PONAR grab samples of *Diporeia* sp. collected periodically during 1984-1988 at two stations (45 m and 100 m) in southeastern Lake Michigan were analyzed for productivity. A complete data set describing *Diporeia* sp. abundance, biomass, length, weight, production, and production to biomass ratio (P/B) during 1984-88 for the 45-m station and during 1988 for the 100-m station was compiled. A first-cut bioenergetics model was developed.

Long-Term Trends in Benthic Populations.

This study serves as the only true monitoring project to follow the potential effects of environmental change in the Great Lakes. The factors that produce population change include nutrient changes, habitat changes, and contaminant introductions. All of the potential variables will act in concert to produce population shifts. This monitoring can help demonstrate important changes in the ecosystem. However, the mechanisms for observed changes must be established through process research. In FY 91, progress

was made in identifying and processing organisms collected in Saginaw Bay in 1987-88. Biomass estimates were obtained for all *chironomids* and *sphaeriids* in the samples. Work continued on processing samples collected in Lake Superior's Whitefish Bay in 1988.

Particle Transport and Contaminant Cycling in the Upper Great Lakes.

This new study examines the cycling and accumulation of strongly particle-sorbed contaminants in the Great Lakes. It is an outgrowth of a smaller-scale carbon biogeochemistry effort to better identify the major transport processes for organic contaminants and establish the quantitative relationships for the processes. Results from that effort developed an extensive analytical effort centered on trap samples.

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Coordinated Ecosystems Research

G.L. Fahnenstiel, Program Leader

The dynamics of Great Lakes ecosystems, including those of their fish populations, are controlled by the actions of man and nature. Long-term observations of ecosystem components (e.g., the abundance of fish, plankton, nutrients, etc.) demonstrate that they can be highly variable in time and space. Identifying the causes of this variability is a worthy goal because it will lead to an understanding of the relative importance of the influences of man and nature on ecological dynamics. The goal of the Coordinated Ecosystem Research (CER) program is to improve predictions of ecological change that result from natural and man made perturbations. The CER program is currently under review and will be reformulated during the upcoming year. Currently active ecosystem dynamics projects are described below.

Microplankton in the Great Lakes: Whole-Lake Biomass and Production Estimates and their Associated Temporal and Spatial Variability.

This program seeks to provide whole-lake estimates of microplankton biomass and examine the spatial and temporal variability, to provide production estimates of microplankton, preferably on a whole-lake basis, and to provide support information as is needed to evaluate the role of microplankton.

Food Quality in Pelagic Food Webs.

The objective of this program is to develop mechanistic models of the effect of food quality on selection, ingestion, assimilation, and lipid storage by zooplankton. Progress in FY 91 includes continued collaboration with Michigan State University to understand feeding mechanisms of surface feeding by the larvae of *Anopholes* mosquitoes (Figure 6), a vector of malaria. Data analysis of lipid storage as it relates to life-cycle strategy of *Diaptomus sicilis,* a dominant suspension-feeding copepod in the Great Lakes, was completed. The feeding mechanisms of copepods (*Diaptomus spp., Limnocalanus, Senecella, Epischura*) were examined using high-speed microcinematography to correlate mouthpart usage and behavior as they relate to creation of scanning current (to sense prey), swimming behavior, and mode of perception (chemo- and mechno-) of prey.

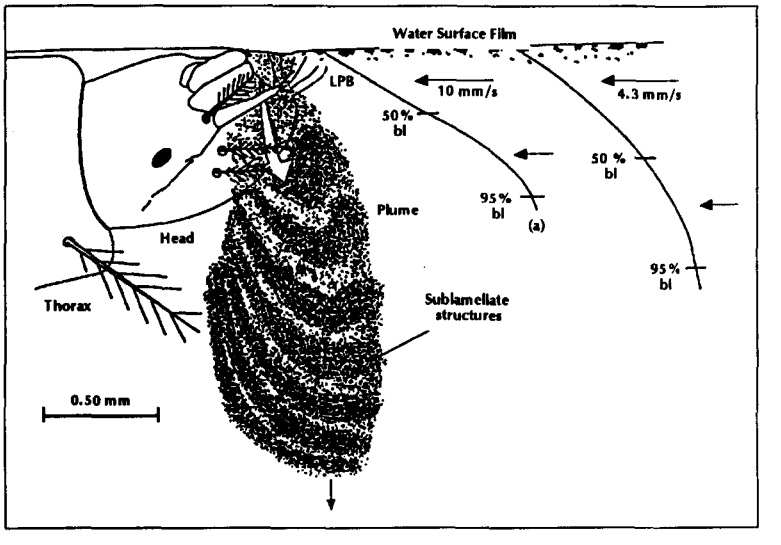

Figure 6. Lateral view of interfacial feeding Anopheles *larva with India ink particles in the surface microlayers. Results of high-speed movies like these show that the food is selected in a microlayer below the surface film, concentrated in the mouth, and the "filtered" water is pushed below the animal. The plume with distinct lamellae demonstrate that the flow is laminar.*

The Microbial Food Web in the Great Lakes.

This program seeks to develop a carbon based model of the microbial food web that can be interfaced into existing plankton models and provide relevant experimental and descriptive data on the microbial food web as needed for the carbon based model. In FY 91 we compared cellular production rates of picoplankton populations in the Gulf of Mexico and in the Great Lakes with differential filtration and autoradiography. We also conducted two cruises designed to examine the importance of red fluorescing picoplankton and the chromophore composition of *Synechococcus*.

Pelagic/Benthic Energy Transfer and Bioenergetics Models of Macroinvertebrates.

The objectives of this study are (1) to develop a model for the seasonal transfer of carbon from the pelagic euphotic zone to benthic macroinvertebrates, (2) to examine mechanisms of energy transfer from phytoplankton to *Diporeia* sp. and *Mysis relicta*, (3) to provide data and develop energetics (carbon flow) models for the benthic macroinvertebrates *Diporeia* (and *M. relicta*), and (4) to estimate *Diporeia* production rates and variability at one site in Lake Michigan. Last year, carbon transfer from ^{14}C-labeled *Melosira* sp. to *Diporeia* sp. was quantified in laboratory microcosm experiments. Seasonal input rates of "new carbon" reaching the benthos were quantified using sediment trap collections. A carbon budget was developed to quantify the input, alteration, and burial rates of carbon from settling particles in Lake Michigan (Figure 7).

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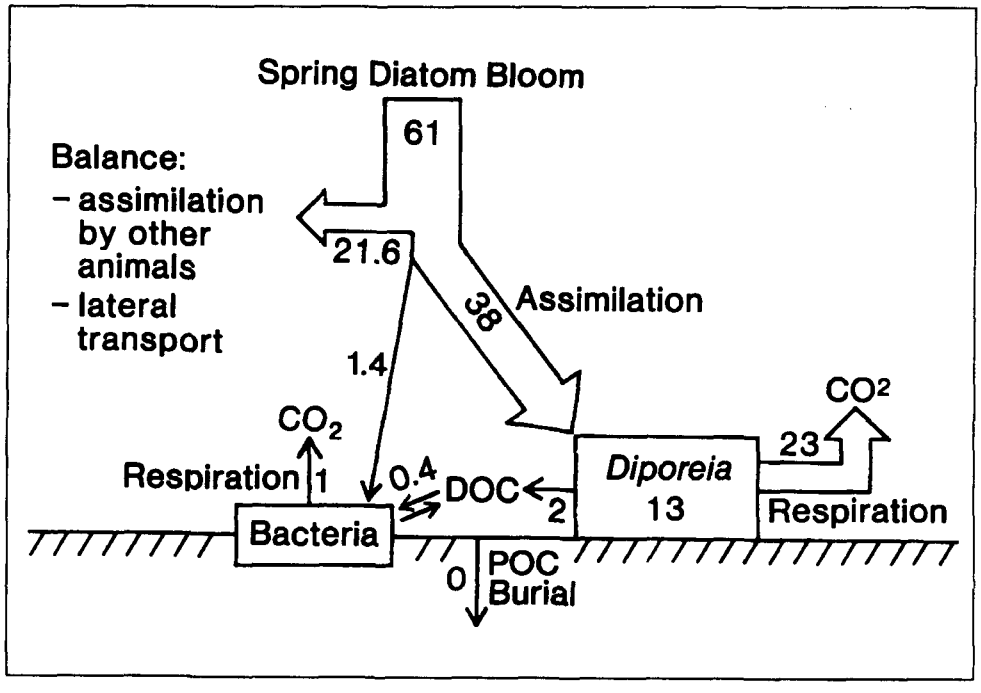

Figure 7. Budget for spring algal carbon for nearshore Lake Michigan. Numbers associated with arrows or in boxes are fluxes for the spring bloom period of 78 days and have units of μmol m^{-2}. The balance of algal carbon that is not accounted for by Diporeia *assimilation or bacterial uptake is likely either taken up by other benthic animals or is transported laterally to deeper portions of the lake.*

Climate Variability and Global Change in Large Lakes

S.J. Bolsenga, Program Leader

In order to adequately understand climate change, the processes included in the General Circulation Model (GCM) analyses must be extensively studied. Some of these processes include vertical dynamical heat fluxes, heat transport by deep lake currents, deep lake convective dynamics, deep water circulation, biogeochemical cycling, and the effect of ice. It is in the better understanding of these processes and in studying the regional aspects of climate change, that the GLERL Climate Variability and Global Change in Large Lakes coordinated research program seeks to contribute to the immense problem of understanding global climate change. A limited number of ongoing studies have been internally funded and are currently producing results. Additional studies have been proposed for outside funding both by GLERL researchers and by GLERL researchers jointly with scientists from the joint GLERL/University Research Institute, the Cooperative Institute for Limnology and Ecosystems Research (CILER). Planning activities are currently underway for involvement with the NOAA Ecological Systems and Dynamics Project, National Science Foundation (NSF) Long Term Ecological Research Sites and Global Change Research, the Freshwater Initiative, the Global Exchange and Water Cycle Experiment, U.S./U.S.S.R. Working Group VIII, and the Joint U.S./Canadian Study on the Impacts of Climate Change on the Great Lakes. Individual scientific studies within this coordinated research program including FY 91 accomplishments follow.

Climate Impacts on Large Lake Hydrology.

This research will lead to a reassessment of the effect of global warming, as represented by a doubling of atmospheric CO_2, on large-lake water supplies and has the following objectives: (1) Refine hydrologic modeling abilities for basin runoff and lake evaporation. (2) Assess and improve linkages between hydrologic models and the development of atmospheric mesoscale models and atmospheric GCMs. (3) Estimate hydrologic impacts of anticipated or experimental climate changes. This year we began to compile the Russian data for theVolga River basin, to adapt and calibrate GLERL's runoff model to parts of the Caspian Sea basin (Figure 8), and began to jointly assess GCM simulations to study hydrological aspects of climatic change in Russia.

Current Velocity Profile Measurements in the Straits of Mackinac using Acoustic Doppler Current Profilers (ADCPs): A Pilot Study.

This study seeks to (1) measure current profiles in strongly stratified shear flow, (2) relate these data to the numerous bi-lake hydraulic and hydrodynamic forcing processes, and (3) provide the framework for a future expanded study of the water volume transport process through the Straits. We retrieved two ADCP moorings in October 1991. Preliminary analysis indicates the data are of high quality, extended through the stratified season, and the long-term mean profile clearly shows two-layered flow.

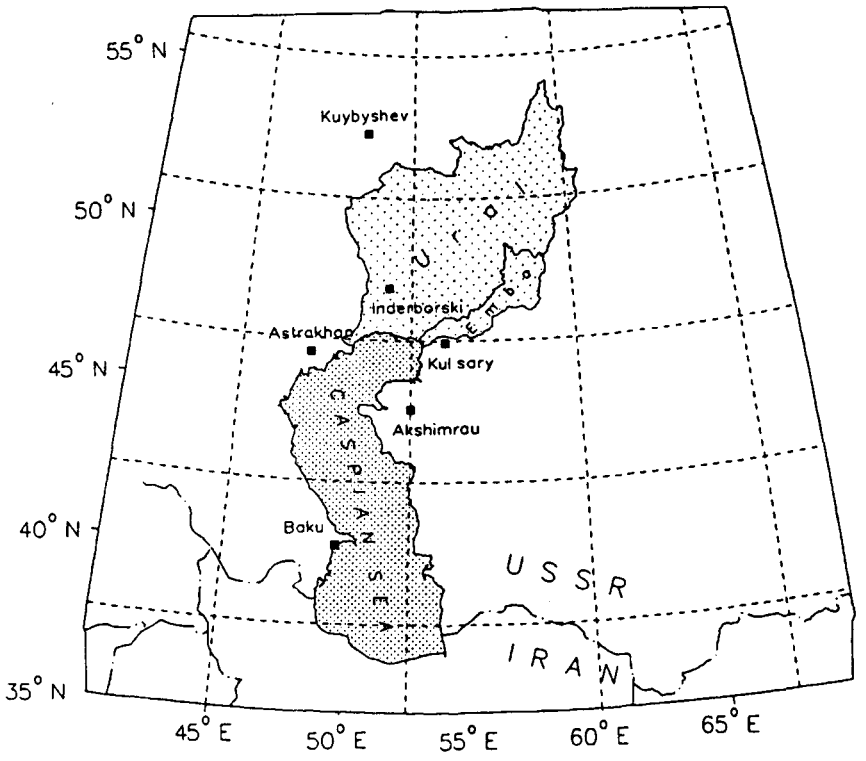

Figure 8. Location map showing the Caspian Sea and the Embe and Ural River basins.

Thermal Structure Monitoring for Climate Change.

The main objectives of this project are (1) to develop improved climatological information (via observations, new instrumentation, and improved analysis) on the distribution and variability of coastal and offshore temperatures and to study their dependence on meteorological and hydrological forces with emphasis on potential changes in climate, (2) to concurrently provide data to improve numerical models that can simulate and predict the thermal structure in the lakes, and (3) to improve our understanding of the physics of lakes by analyzing the results of objectives (1) and (2). Last year, the first year's data from the vector averaging current meter (VACM) mooring and the subsurface thermistor chain were successfully recovered. Most of the VACM data appears to be useful. Fresh VACMs and thermistor strings were deployed. Analysis of the thermistor data began shortly after their retrieval.

Environmental Radiotracers.

One objective of this program which is related to climate change is to develop geochronological information from sediment radionuclide profiles for paleolimnological studies. Other portions of this program are detailed under "Independent Research Projects." In FY 91, gamma emitter analysis of all sediment cores from the 1988 collection was completed. In July, cores from both the central Lake Erie basin reference site and eastern basin reference site were collected. Very high quality box cores were obtained, sub-cored, and sectioned for radiometric analysis.

An Exploratory Study of Great Lakes Climate Variability using Chaotic Dynamics.

The objective of this study is to explore the applicability of chaotic dynamics for the analysis of Great Lakes climate changes as well as other physical and biogeochemical processes. In FY 91, we initiated studies on the measuring and characterization of

chaotic processes and extracting dynamics from time series data.

Impact of Climate Change on Large Lake Ice Cycles.

The objectives of this program are (1) to develop improved models to better simulate the seasonal cycle of ice formation and loss on Lakes Erie and Superior, (2) to define trends in Grand Traverse Bay and Lake Mendota freezeup, breakup, and ice cover over the past 140 years and quantify (model) these changes in terms of seasonal changes in air temperature, (3) to reconstruct the past 140 years of Lake Michigan ice cover, and (4) to provide historic information on ice cover trends, cycles, and variations on the Great Lakes that will be useful in placing the ice cover of the 1990s and beyond in historical perspective. Regression ice cover models of Lake Superior were developed this year using a lake evaporation model. The modeled ice cover data were then used to re-calibrate the lake evaporation model.

Figure 9. Remotely operated vehicle (ROV) used in cooperative GLERL/U.S. Fish and Wildlife pilot studies of under-ice ecology. The large lakes winter ecology program provides increased knowledge of climate variability and global change.

Large Lakes Winter Ecology.

Many climate change scenarios indicate that significant changes in the ice cover of large lakes of the world will occur. In order to better understand climate change and its implications, current wintertime ecological conditions must be known in order to compare with conditions if and when climate change occurs. Growth and survival of freshwater phototrophic phytoplankton in winter depends on the amount of incident photosynthetically available radiation which penetrates through snow and ice surfaces. Results of a GLERL pilot study (Figure 9) suggest that ice cover on large lakes can actually enhance productivity because the ice forming there is often relatively clear and that the ice cover stabilizes the water column to allow development of phytoplankton blooms. Ice cover may also affect nutrient availability to plankton in spring because it is during winter storms that nutrients are released from resuspended bottom sediments. This same turbulence resuspends algal resting spores for seeding the plankton and may also affect zooplankton feeding. This program involves laboratory and field studies to determine the effects of ice cover on these and related processes by measuring them during ice cover for selected sites on Great Slave Lake (Canadian Northwest Territories in collaboration with M.S. Evans of the National Hydrology Research Institute), on the Laurentian Great Lakes, in Mongolian large lakes, and on certain small lakes to contrast impacts. In FY 91, we completed a one-week sampling program on Great Slave Lake. Sampling, which included metered and unmetered net tows, Niskin casts, light measurements, and collection of animals, was conducted during temperatures ranging from -20° to -50° F.

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Marine Hazards and Water Management Research

P.C. Liu and D.J. Schwab, Co-Program Leaders

Natural hazards encompass a wide variety of environmental phenomena that pose threats of loss of lives or property and social or economic disruption. Large waves, high and low lake levels, heavy snowfalls, ice, and erosion are significant natural hazards in the Great Lakes system and (with the exception of low lake levels) for other coastal areas as well. Human-caused hazards also pose serious threats, especially spills of petroleum products and chemicals. This program is comprised of four broad components: Prediction, Climatology and Statistics for Decision Making, Process Studies, and Interface with Policy and Decision Makers. Individual scientific studies within this coordinated research program including FY 91 accomplishments follow.

Lake Circulation and Thermal Structure Modeling.

This project is concerned with numerical simulation and prediction of temperatures and currents in the Great Lakes. These variables influence chemical, biological, and most other environmental processes on a wide variety of time and space scales. However, little is known about the quantitative impact of temperatures and currents on chemical, biological, and other environmental processes. In order to better predict the effects of physical processes on the ecosystem and to fill in the gaps in observational data, numerical models of circulation and mixing are used. The results of this project will be useful to scientists studying any part of the Great Lakes ecosystem that is affected by lake circulation, such as transport of toxic material or nutrient regeneration processes. During FY 91, we adapted a three-dimensional model code for use on the new Department of Commerce Consolidated Scientific Computing System (CSCS) Cray YMP supercomputer. We also began to implement an operational system for thermal and circulation structure forecasts for Lake Erie in collaboration with Ohio State University.

Great Lakes Snow Characteristics.

The objectives of this study are to compile monthly, yearly, and period of record snowfall maps for the Great Lakes basin (Figure 10), to analyze the spatial and temporal variation of the snowfall using 5, 10, 20, and 30 year monthly averages over the period of record of the data base, and to develop quantitative relationships between northern hemisphere circulation patterns and Great Lakes snowfall/snow cover. In FY 91, the database was searched for maximum snowfall occurrences at long-term stations—information useful to designers, planners, and resource managers. Relationships were found between maximum snowfalls and latitude, longitude, and elevation. New digital methods were established to delineate and quantify distributed parameter snowfall variability. Snowfall within the Great Lakes drainage basin was shown to have increased throughout this period due to increased lake effect and not continental snowfall. A preliminary analysis was made of upper air teleconnections with regional monthly averages of snowfall, air temperature, and ice cover on the Great Lakes.

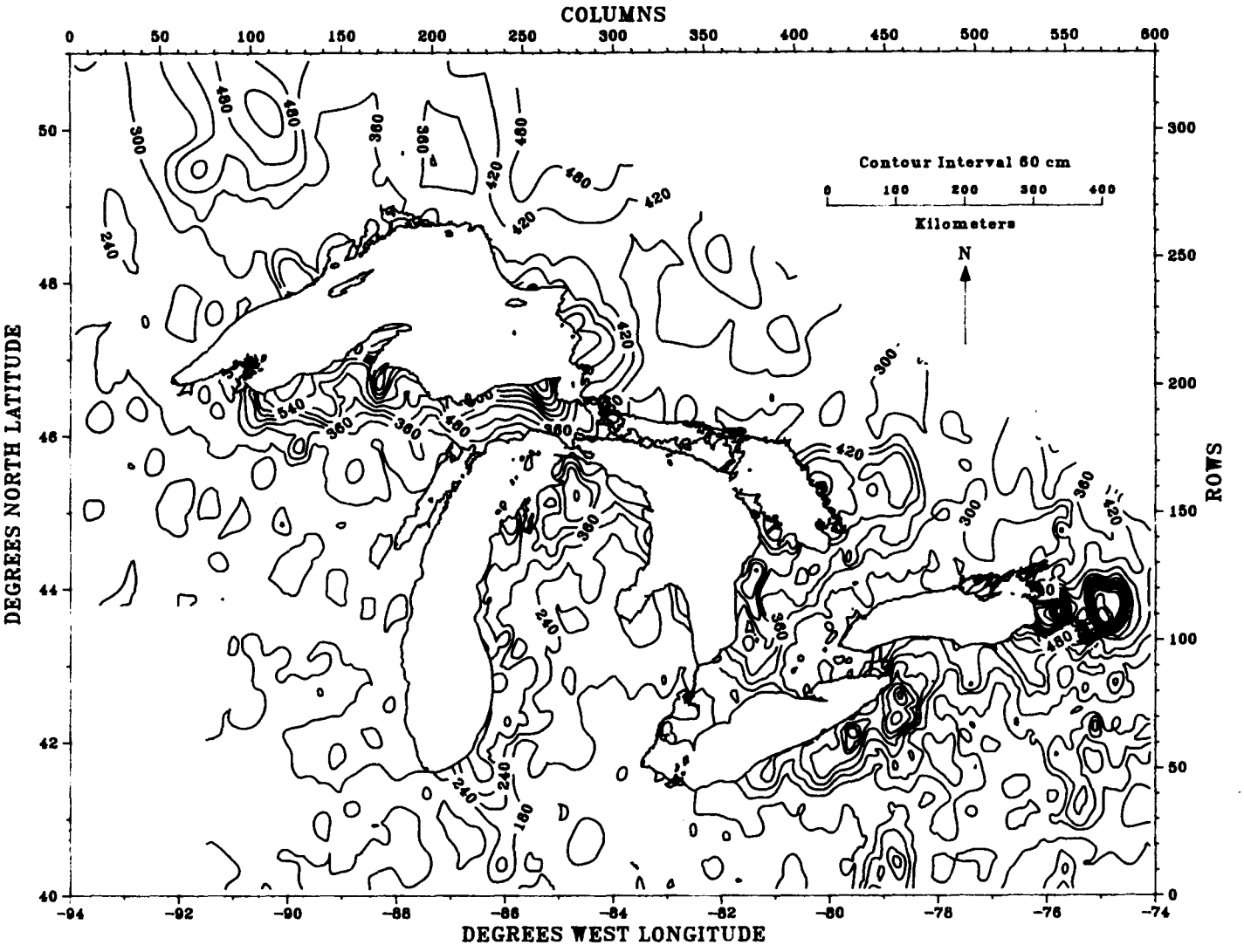

Figure 10. Maximum 1951-1980 Great Lakes snowfall.

Great Lakes Evaporation, Forecasting, and Simulation.

The objectives of this study are (1) Lake Evaporation: assess potential of determining groundwater fluxes using the evaporation models; update hydrometeorological data report; develop models on lake segments with ice-cover models; build lake surface temperature and cloud cover models; classify lake surface temperature patterns with special respect to the weather situation; develop models of the heat flux at the lake surface. (2) Water Supply Forecasting: add capability for generating probabilistic outlooks to forecast package; make forecast package easily used and implemented; evaluate package to assess adequacy in forecasting net basin supplies to appraise worth of improved lake evaporation techniques, to further determine error components, to analyze the importance of initial conditions, and to examine the utility of gamma aerial snowpack water equivalent measurements for Great Lakes water supply forecasting; compare forecast package with climate-based and existing trend-regression analyses. (3) Water Supply Simulation: develop Integrated-System Hydrologic Package use for use by intra- and inter-division person-

nel and outside agencies. This year the evaporation model was refined with better heat storage models and was incorporated into the forecast package. We finished modifying the forecasting package algorithms to allow package use in simulation settings. We also finished development of a monthly runoff and net supply model package that incorporates approximations for over-lake evaporation. This model is usable for simulations with early historical data where only monthly data are available. We also began Great Lakes response simulations to extreme climate scenarios for the International Joint Commission.

Great Lakes Water Level Statistics for Decision Making.

This project is to develop improved water level statistics that reflect existing hydrologic and hydraulic conditions, the long lag-response of the lakes to meteorologic variability, secular changes in climatic regimes, and the needs (e.g., varied planning horizons, understanding the limits of lake level statistics) of diverse Great Lakes decision makers. We have thus far established an international network of researchers interested in improving Great Lakes water level statistics under the auspices of Phase II of the IJC Levels Study Reference, and meetings have been held to plan the course of this program.

Objective Analysis of Great Lakes Marine Meteorological Observations.

The main objective of this project is to develop and test improved techniques for objective analysis of overwater meteorological fields and to apply these techniques to practical problems of hindcasting and forecasting winds, waves, storm surges, and lake circulation. In FY 91, a prototype operational program for objective analysis of Great Lakes winds was developed. Analyzed wind fields from the Fleet Numerical Oceanography Center (FNOC) Field by Information Blending (FIB) (Figure 11) procedure were collected and stored for comparison with wind fields developed in this project.

Assessment of Shallow Water Effects on Great Lakes Wind Waves.

This program seeks to quantitatively assess the importance of shallow water effects on wind waves in the Great Lakes, identify as well as quantify the circumstances and locations in which shallow water effects have a significant impact on deep water waves, and improve understanding and prediction techniques of shallow water waves. During the past year, the proper correlation and parameterization of wind waves has led to further advanced understanding and insights on the equilibrium range of the wave spectrum and its relation with wave dissipation and wave breaking. Continued collaborative efforts with scientists at the National Water Research Institute of Canada on the study of surface waves have led to the development of simple algebraic formulation of realistic wave growth relations. Joint efforts with the Coastal Engineering Research Center show that the accuracy of the wind field input is as important as differences in models in explaining differences between observed and hindcast waves.

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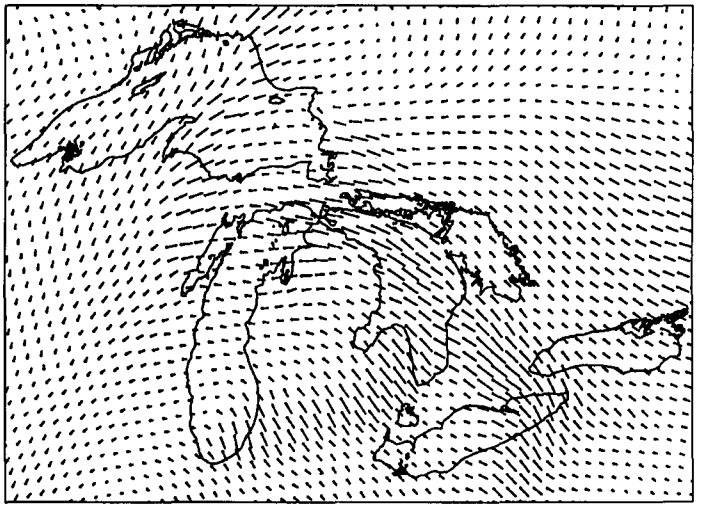
Figure 11. Example of an analyzed wind field for the Great Lakes region.



NECOP

B.J. Eadie, Program Leader

The Nutrient Enhanced Coastal Ocean Productivity (NECOP) program is one of a series of NOAA-wide programs dealing with major problems in the coastal ocean. The central hypothesis is that the increased nutrient input from the Mississippi River (Figure 12) has led to increased productivity with undesirable consequences. GLERL is involved in the following studies, all of which began in FY 90.

Buoyancy and Nutrient Exchange in the Mississippi Outflow Region.

The primary objectives of this study are to establish an historical relationship between buoyancy and nutrient fluxes for the Mississippi Atchafalaya River system and to quantitatively determine the scales of variability for buoyancy and nutrient fields in a shelf region dominated by riverine sources. In FY 91, we continued field work and analysis activities both on historical data base and new data.

Retrospective Analysis of Nutrient Enhanced Coastal Ocean Productivity in Sediments from the Louisiana Continental Shelf.

The objectives of this program are to (1) identify areas in the coastal region where sediments with coherent geochronologies covering a period of approximately 200 years can be collected, and (2) examine the selected cores for tracers of past water and ecosystem conditions (e.g. Carbon, Nitrogen, diatom frustules, stable isotopes, etc). Two sediment cores from NECOP-I have been analyzed for C-13 and N-15, neither shows as large a signal as cores from Lakes Erie or Ontario. The implication is that anthropogenic effects are smaller.

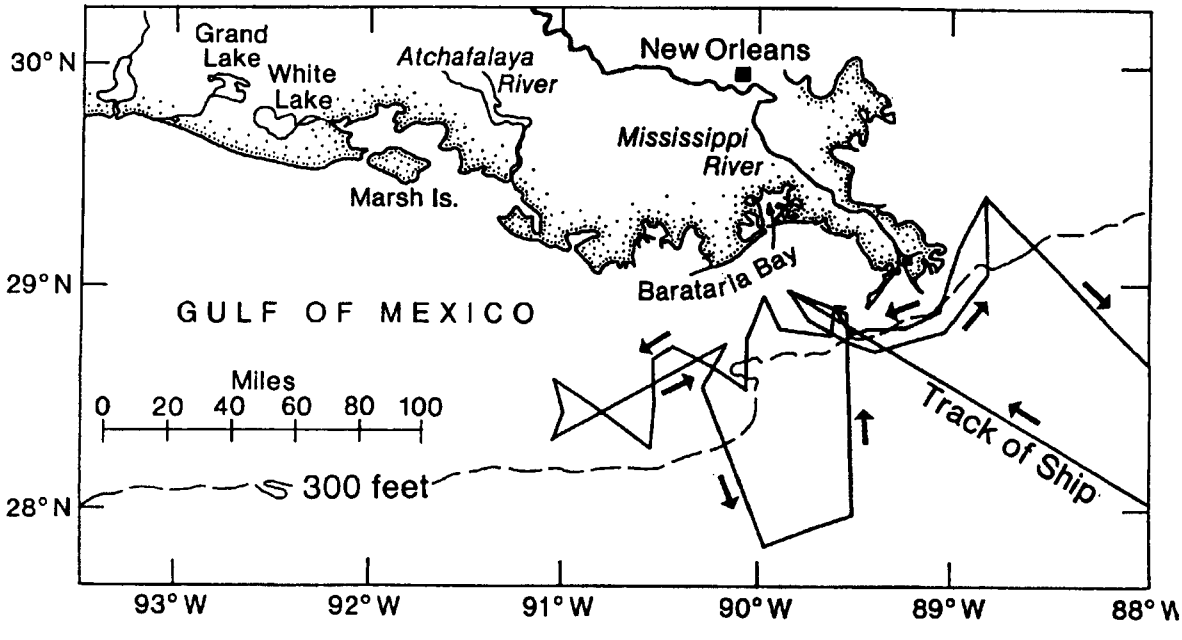


Figure 12. Map of the Gulf of Mexico showing the route taken by the NECOP research team aboard the R/V Baldridge.

Primary Production and Vertical Flux of Organic Carbon from Mississippi River Plume and Adjacent Shelf Waters.

The research will address the following objectives: (1) Characterize photoautotrophic community dynamics in relation to optical conditions, nutrient inputs, and other aspects of the physical/chemical environment (Figure 13). (2) Examine the relationship between phytoplankton production, growth, and biomass, and the vertical export of fixed carbon from surface waters of the Mississippi River plume/Inner Gulf Shelf. (3) Develop conceptual and predictive models which describe the production and fate of fixed carbon as a function of optical conditions, nutrient inputs, and other environmental variables. Last year we began analysis of track autoradiographs from the first R/V *Baldridge* cruise.

Suspended Sediment on the Louisiana Continental Shelf: Concentrations, Compositions, and Transport Pathways.

This study has three major objectives: (1) To map the spatial distribution and, to the extent possible, the temporal variations, of suspended particulate material (SPM) concentrations and compositions in the MRP and adjacent shelf waters. (2) To determine, within the limits imposed by the budget, the importance of lateral transport of SPM in the study region. (3) To determine what, if any, relationships exist between the existence and extent of nepheloid layers and other characteristics of the water column such as vertical temperature and salinity structure, ambient current velocity, wave activity, and river discharge. Transparency calibrations have been completed for the 25 cm transmissometers on both cruises. Preliminary examination of the data shows that there may have been resuspension episodes at both anchor stations during the winter cruise, but no such activity is evident from the summer data.

The Fate and Effects of Riverine (and Shelf-Derived) Dissolved Organic Nitrogen (DON) on Mississippi River Plume/Gulf Shelf (MRP/GS) Processes.

The objectives of this study are to define the chemical and isotopic composition of riverine and MRP/GS DON and determine the biological reactivity of dissolved organic carbon (DOC) and DON. Last year five separate incubation experiments were run. Calculated oxidation rates of the organic matter ranged from 0.002 to 0.012 in deep and plume waters respectively. Analysis of the DOC showed a strong relationship with salinity. We were able to show that a large fraction of the DOC that was transported offshore was carbohydrate, a fact not previously recognized. A new high performance liquid chromatographic method, developed to directly determine nitrogen isotope ratios of ammonium in isotope dilution experiments, is being used to calculate nitrogen turnover rates.

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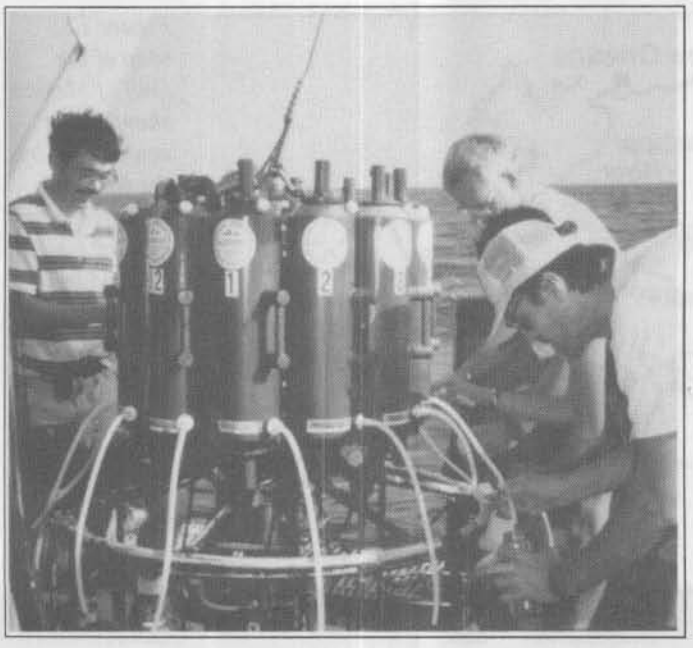

Figure 13. Water samples taken from the conductivity/ temperature/depth (CTD) rosette sampler were analyzed for a wide array of parameters by several of the 17 prinicpal investigators aboard the NOAA R/V Baldridge.

CoastWatch

D.J. Schwab and G.A. Leshkevich, Co-Program Leaders

CoastWatch is a NOAA-wide program within the Coastal Ocean Program (COP) designed to focus on specific regional and national priorities in the coastal environment. NOAA resources are being brought together to provide a cohesive and near-real time delivery system to allow time-critical "decision support" in response to rapidly emerging coastal environmental situations. GLERL has been chosen as the focal point in the Great Lakes region for this program. Last year we surveyed potential local CoastWatch data users and have started to receive positive replies. Computer equipment for operation of Great Lakes Regional Network Node (RNN) was installed. Center for Great Lakes Studies personnel at the University of Wisconsin were trained on operation of the Interactive Digital Image Display and Analysis System workstation and a prototype CoastWatch user site was established at Milwaukee, WI. At GLERL, satellite-derived water surface temperature data was calibrated against water temperature from NOAA weather buoys in the Great Lakes (Figure 14).

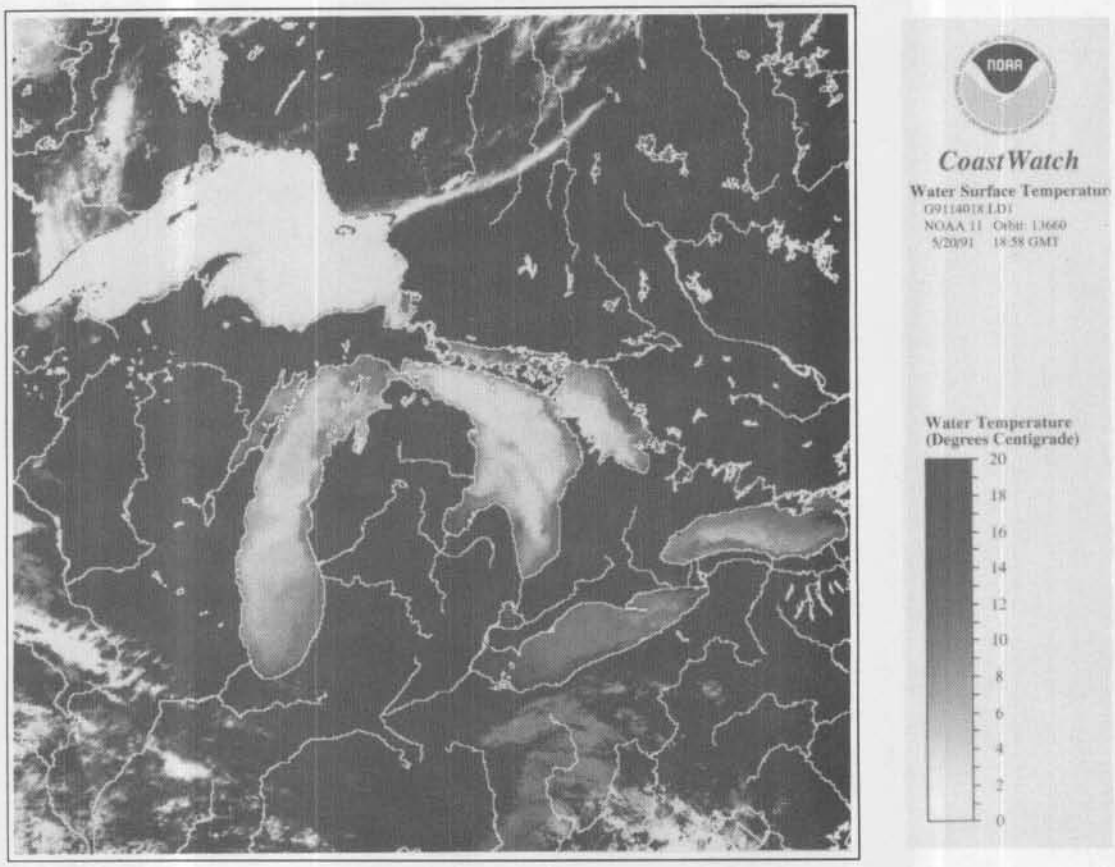

Figure 14. A CoastWatch product: satellite-derived surface temperature.

Independent Research Projects

Several independent research projects are also included in the GLERL research program. These projects are considered important to the GLERL mission, but do not currently integrate into one of the coordinated research programs.

Environmental Radiotracers.

This project encompasses studies of diverse aquatic systems and emphasizes the use of radiotracers to identify and model fundamental lake/watershed transport processes. Objectives of the program are (1) to identify principal transport mechanisms in aquatic systems and determine associated space-time scales and rates, (2) to investigate and quantify sediment depositional and geochemical processes, (3) to develop geochronological information from sediment radionuclide profiles for paleolimnological studies, (4) to determine and account for relationships between system loadings and sedimentary records of tracers, contaminants and other constituents, and (5) to apply techniques, insights, and models arising from radiotracer studies to specific problems of ecosystem dynamics, environmental contamination, and regional effects of climate change.

Exchange Processes in Coastal Environments.

This program seeks to observe, analyze, and quantitatively characterize exchange processes impacting variable fields of environmental concern. An essential first step in this sequence is to measure (observe) a range of physical, biological, or chemical fields which affect or characterize the variability of the target field (usually horizontal current components, water density or temperature, impacting critical biological or chemical fields). The objectives are (1) to evaluate the relative importance of advective exchange mechanisms, (2) to identify and investigate the dominant intervariable relationships which form the linkage of these exchange mechanisms, and (3) to develop realistic conceptual, statistical, and analytical models of specific exchange processes which affect variability in fields of environmental concern.

Carbon Biogeochemistry in Lakes and Coastal Ecosystems.

Great Lakes and coastal ecosystems are continually subject to a series of stressors that are transient in nature. These lead to issues such as the biogeochemical response of systems to increased or decreased nutrient loads, man-induced changes in the carbon cycle and climate, and the introduction of toxic contaminants and their effects. This project focuses on these issues through research on processes regulating the major biogeochemical cycles and fluxes with an emphasis on carbon. The long-term goal of this research is the development of a hierarchy of calibrated numerical models of processes regulating the biogeochemical cycle of carbon in the Great Lakes with subsequent applications to coastal ecosystems. In order to accomplish this, a series of tasks need to be undertaken to provide insight into and rates for important processes including CO_2 gas exchange, remineralization of organic carbon (primary production is assumed known from published data, but this param-

eter is very weak), formation of $CaCO_3$, vertical flux of carbon species, dissolution rate of $CaCO_3$, and remineralization of carbon in sediments and transport across the sediment water interface.

Resuspension of Bottom Sediments in Lake Superior.

This program seeks to measure the frequency, duration, and magnitude of sediment resuspension episodes using instrumented platforms deployed in Whitefish Bay and off the Keewenaw peninsula, to experimentally measure erosion threshold velocities using a bottom-resting flume, and to relate these measurements to the properties of the bottom material.

Dynamics of the Bottom Boundary Layer in Lake Michigan.

The existence of a persistent benthic boundary layer has been documented in the offshore regions of all of the Great Lakes. Although the layer contains only a small proportion of the total suspended material found in the lakes, sediment trap studies have shown that the bulk of the mass flux occurs within the bottom 25 m. This study will quantify the distribution of bottom current intensities as functions of space and time in order to parameterize the distribution and frequency of resuspension events (Figure 15).

Nitrogen Dynamics.

This study will provide (1) improved methodologies to measure fluxes of important nitrogen compounds that reflect nitrogen dynamics in lakes, wetlands, or marine coastal regions, (2) identify, quantify, and compare major processes controlling nitrogen regeneration from lake and marine coastal sediments, and (3) identify and quantify major nitrogen regeneration processes in lake and/or marine pelagic waters (Figure 16).

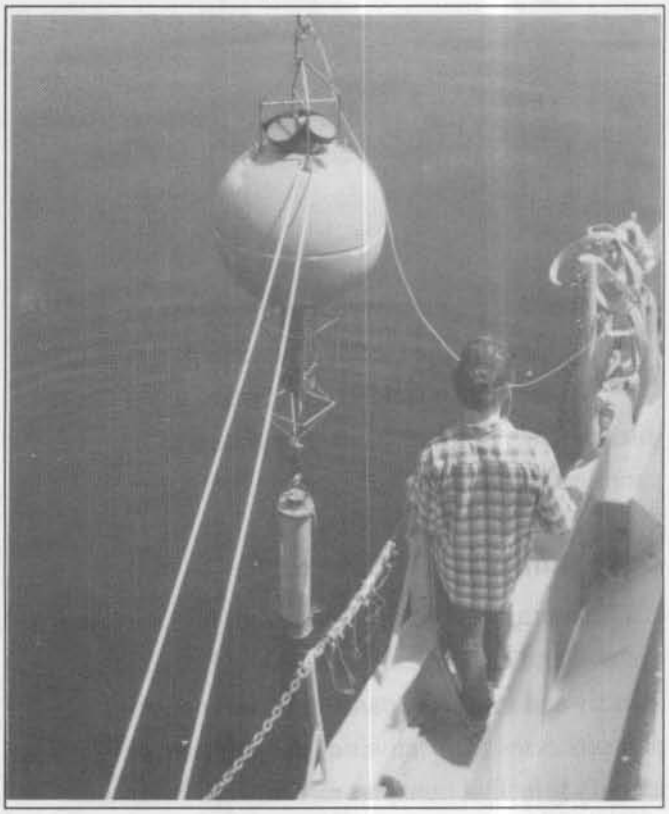

Figure 15. An Acoustic Doppler Current Profiler (ADCP) is being lowered into the lake. The ADCP is anchored near the lake bottom and measures current velocity at 1 m intervals from surface to bottom.

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Facilities and Services

GLERL's research facility is a modern building with over 24,600 square feet of usable space, including 20 laboratories, conference rooms, a library, and computer resources. In addition to general laboratory equipment, GLERL has a fully-equipped low-level radioisotope analysis laboratory, a stable isotope mass spectrometer (SIMS), several gas chromatographs and liquid scintillation counters, a high pressure liquid chromatography system, a multi-channel Coulter Counter, a full complement of growth chambers and incubators, stereo and inverted microscopes, and a fully equipped multi-purpose epifluorescence microscope. GLERL also maintains and operates a High Speed Microcinematography Laboratory housed in a temperature-controlled environmental chamber. In addition, a separate Cold Room is maintained for conducting experiments and growing biological cultures at low temperatures.

Computer Facility

The GLERL Computer Facility consists of a Local Area VAXcluster (LAVc) of nine VAX computers on site and the capability of accessing a Cyber 855 mainframe and a Cray YMP supercomputer at the National Institute of Standards and Technology (NIST) in Gaithersburg, MD. GLERL is one of five remote nodes to the NIST facility, which is known as the Department of Commerce Consolidated Scientific Computing System (CSCS). GLERL is also the Great Lakes Regional Node of the National Ocean Communications Network.

User terminals and microcomputers throughout the GLERL facility are hardwired to a communications switch that allows users to access the LAVc as well as the Cyber computers in Gaithersburg. Off-site access to the system is available through telephone lines and a private network that links NIST and all remote connections to the CSCS systems.

A variety of applications, including real time and near-real time data acquisition, data reduction, graphics, large scale modeling, statistical and mathematical analysis, telecommunications, and word processing support more than 80 accounts. Laboratory office automation, administrative/accounting functions, and scientific applications are supported by more than 85 loosely networked microcomputers.

The Computer and Information Systems Group continued the inventory of data bases archived at GLERL. The program is an ongoing activity of the GLERL Data Committee and contributes to the larger-scale NOAA effort of archiving usable data and making that data available for use by all interested scientists. A listing of the data base categories and the scientists responsible for collection/archiving is given below.

Current Meter and Water Temperature

1. Lake Huron Nov. 1974 thru 1975 - Miller
2. Lake Michigan 1976 thru 1989 - Miller
3. Lake Erie 1979 thru 1980 - Miller

Drifter Data

1. Lake Erie 1986 - Miller
2. Lake Michigan (Green Bay) 1989 - Miller

Wave Data

1. Lake Michigan 1973 - Liu
2. Lake Michigan 1975 thru 1977 - Liu

Computerized Bathymetry Data

1. Lake Superior - Schwab

2. Lake Michigan - Schwab
3. Lake Huron - Schwab
4. Lake St. Clair - Schwab
5. Lake Erie - Schwab
6. Lake Ontario - Schwab

Meteorological Data (Air Temperature, Wind Speed and Direction)

1. Lake St. Clair 1986 (July thru October) - Hawley
2. Detroit River 1987 thru 1989 - Derecki
3. Lake Michigan (Green Bay) May 1989 thru May 1990 - Hawley

Vertical Velocity Profiles

1. St. Clair River 1984 thru 1986 - Derecki
2. Detroit River 1986 thru 1986 - Derecki

Biological and Chemical Water Data

1. Lake Michigan, Offshore 1983 thru 1990 - Laird Pernie

Sediment Trap Data (Mass flux, Some Chemical Characteristics)

1. Lake Michigan 1977 thru 1990 - Eadie
2. Lake Michigan (Green Bay) 1989, 1990 - Eadie
3. Lake Superior 1984 thru 1985, 1987 thru 1988 - Eadie
4. Lake Huron 1984 thru 1985, 1987 thru 1988 - Eadie

Water Data (Temperature Profiles)

1. Lake Michigan April, May 1989 and 1990 - Bratkovich

Water Temperature Data XBT

1. Lake Superior for the Autumn Months 1976 thru 1979 - Assel
2. Lake Superior for the Winter Months 1973 thru 1976 - Assel

Water Data (Temperature, Salinity, Transparency, etc.)

1. Lake Michigan (Green Bay) May 1989 thru May 1990 - Hawley
2. Lake St. Clair 1986 (May thru October) - Hawley
3. Lake Michigan 1975 thru 1990 - Bell
4. Gulf of Mexico (North) June, July 1990 - Bratkovich

Water Characteristics (Chemical, Physical, Bottom Sediment, etc.)

1. Lake Erie, June thru Nov. 1965, April thru Dec. 1967 - Bell
2. Lake Huron, May thru Nov. 1966 - Bell
3. Lake Superior and St. Marys River, May thru Nov. 1968 - Bell
4. Lake Superior, May thru Nov. 1969 - Bell
5. Lake Michigan, May thru Nov. 1970 - Bell
6. Lake Michigan, May thru Nov. 1975 - Bell
7. Lake Ontario, Oswego, Rochester Harbor, May thru Nov. 1971 - Bell
8. Lake Ontario, Oswego Harbor, May thru Nov. 1972 - Bell
9. Lake Ontario, 4 cruises July thru Nov. 1972 - Bell
10. Straits of Mackinac, May thru Nov. 1973 - Bell
11. Lake St. Clair and Detroit River, May thru Nov. 1974 - Bell.

Shipboard Meteorological Data

1. For all Great Lakes cruises from 1965 thru 1975 - Bell

Library

The GLERL library has a program-oriented research collection maintained in support of the laboratory's research activities. The collection reflects an emphasis upon freshwater studies—particularly in the Great Lakes Basin. Current holdings include 4,879

books, 5,220 unbound periodical volumes, and 3,076 technical reports in the subject areas of climatology, contaminant organics, hydraulics, hydrology, ice, limnology, mathematical models, meteorology, nutrients, oceanography, sediments, and wave motion. The library also receives 209 current periodical titles. The library facilities are open to the public for reference use during normal business hours.

Library staff maintain the collection and provide library and information retrieval services in support of laboratory researchers, laboratory-affiliated personnel, and visiting scientists. Special retrieval services are provided when the collection does not meet the needs of individual scientists. Library services include acquisition, circulation, document delivery, interlibrary loan, reference, and online information retrieval.

During FY 91, the library staff continued efforts to place the complete library holdings into machine readable format and include them in the Online Computer Library Center's (OCLC) catalog. Approximately 2,200 items (submitted in FY 90) were added through an automated, retrospective conversion project while an additional 480 items were cataloged individually. Virtually all GLERL books dating from 1980 onward, as well as a large number of earlier books, are now accessible through the OCLC catalog. These books are reflected in the CD-ROM based, computerized NOAA Library Catalog available in the library. Added holdings records are shared with other NOAA Libraries in a union catalog. Records can be interactively searched using Boolean search options and displayed in various formats including a full MARC record. Also during this fiscal year the library set record high numbers in both interlibrary loan/document retrievals and acquisitions.

The GLERL library is a member of the Michigan Library Consortium (MLC), Washtenaw-Livingston Library Network (WLLN), Federal Library and Information Network (FEDLINK), NOAA Library and Information Network (NLIN), and the Online Computer Library Center (OCLC).

Information Services - Publications Unit

The Publications Unit staff are responsible for providing editorial and publications support to the scientific staff, for preparing and distributing GLERL publications, and for responding to publications and information requests from the public. They also produce and update reports, brochures, and informative fixed and portable displays concerning GLERL's work and/or important environmental issues.

Research products generated during FY 91 include 51 scientific articles, reports, and books and 57 formal presentations. There were over 1,000 documented requests for GLERL information, with over 3,700 items mailed as a result of those requests.

The Publications Unit maintains and updates eight mailing lists for GLERL products. New NOAA-series publications are automatically distributed according to these mailing lists. All new publications, including journal articles and books, are added to our six-month update listing of new publications, which keeps our users informed of GLERL's latest product releases. If you would like to be added to GLERL's mailing list, or would like additional information on GLERL's research activities, please write to:

Publications Office
NOAA/Great Lakes Environmental Research Lab
2205 Commonwealth Blvd.
Ann Arbor, MI 48105-1593.

Vessel Operations

- **Muskegon Vessel Operations Facility**

The base for Vessel Operations was moved from Grand Haven, MI during June 1990 to Muskegon, MI.

The old Coast Guard Base with two buildings were declared surplus and are currently used by GLERL to establish a Vessel Operations Facility. In the Fall of 1990 Congressional action transferred the title for the property from the Coast Guard to the Department of Commerce, NOAA, for use by GLERL. This transfer was completed largely through the supporting efforts of Representative Robert W. Davis (Coast Guard and Navigation Subcommittee of the House Merchant Marine and Fisheries Committee) and Representative Guy Vander Jagt (Ways and Means Committee). Mr. Rick Chapla, Department of Planning and Economic Development, City of Muskegon, continues to be very helpful in establishing and developing the base.

This facility has great potential for the establishment of a lake-side laboratory which has a continuous supply of lake water, and will allow some studies to be conducted that are not feasible at the laboratory in Ann Arbor. At present, samples must be transported to Ann Arbor for analysis. A separate garage building is being used for a crew office, a workshop, and for storage of ship supplies and equipment. The third building, on city property, is used for storage of research equipment. Negotiations are in progress to have the City of Muskegon transfer the title of the land under this building to the Department of Commerce.

There is dockage for the R/V *Shenehon* and one of the smaller research launches in the Coast Guard mooring basin adjacent to the main building. There is an additional 100 feet of dockage in the Government mooring basin currently being leased from the Corps of Engineers and located approximately 0.3 mile from the main building.

• Research Vessels

The *Shenehon* is owned and operated by GLERL. The *Shenehon* is based at the Vessel Operations Facility, Muskegon, MI and is the primary platform used in support of GLERL's open lake field investigations. The vessel is 65.6 feet long, with a 6.5-foot mean draft, a 700-nautical-mile cruising range, and a 10-knot cruising speed. Navigation equipment include a Sperry Gyrocompass, Raytheon Radar, two LORAN-C units, Sperry Auto Pilot and a Raytheon Depth Sounder. A 55-channel radiotelephone is available for ship to shore communication. Electrical power is provided by a modern 20-kW, 3-phase Onan generator, and a 30-kW, 3-phase diesel generator which is original equipment. An electro-hydraulic articulated crane is used for deployment and retrieval of water and bottom sediment samplers and heavy instrument moorings. Electrohydraulic winches handle hydrographic wire and multiconductor cable for sample casts and in-situ measurements of water variables. An onboard wet laboratory is available for onsite experiments and sample processing. Scientific equipment includes various sizes of Niskin samplers, reversing thermometers, bottom samplers including a small box corer.

The *Shenehon* is a designated NOAA weather reporting station, and has a Shipboard Environmental (Data) Acquisition System (SEAS) installed by the National Ocean Service. This system provides increased capability to collect and transmit weather data using satellite communications.

A data acquisition system of GLERL design, separate from the SEAS system, records and plots data from a Sea Tech transmissometer which is coupled to an electronic bathythermograph. The system includes equipment to record, process, and plot water temperature data collected using Sippican Expendable Bathythermograph (XBT) probes.

The 25-foot Bertram launch used in previous years requires extensive repairs if continued use is planned. Two small surplus boats were acquired during 1991 and put into service as auxiliary research platforms. A surplus 30-foot launch was obtained from the Corps of

Figure 17. The 28.5 ft Sea Ark used in the Zebra Mussel Program in Saginaw Bay and Lake St. Clair.

Engineers, equipped as an auxiliary research boat with a hydraulic winch, crane, and navigation equipment from the Bertram, and will be used, for the present time, to supplement the work of the *Shenehon* in Lake Michigan. A 23-foot Monark workboat was obtained from the Corps of Engineers, outfitted as a research launch using an electric winch and crane from the Bertram, and used extensively in the Saginaw Bay Zebra Mussel Program.

A new SeaArk workboat (Figure 17), 28.5 feet in length, including a 2.5 foot deck extension, was delivered in September and will be used primarily in the Zebra Mussel Program in Saginaw Bay and Lake St. Clair. This boat replaces the 25 foot Bertram cruiser used in 1990 as an auxiliary research platform and will be transported by trailer to other remote sites as required. Navigation equipment include a radar, magnetic compass, a 91-channel radiotelephone, a LORAN-C, a 50-kHz digital depth sounder with digital display. There are two sounder wells. A hydraulic winch and articulated crane are available for deployment and retrieval of sampling equipment. Safety equipment includes an inflatable life raft and an EPIRB (emergency transmitter).

• Research Support

The majority of the work supported by the *Shenehon* and the 23-foot launch was connected with biological studies in Lake Michigan and in Saginaw Bay. These studies included benthic, planktonic, and bacterial experiments relating to algal growth, zooplankton grazing, food chain transport in the aquatic environment, fate and effects of sediment-associated toxic organics, and long term trends of benthic fauna. Exotic species, such as the zebra mussel and *Bythotrephes* continue to be a very important part of the studies.

During FY 1991, numerous cruises were made by the *Shenehon* in Lake Michigan, and two long cruises were made into Lakes Huron and Superior, Straits of Mackinac, Saginaw Bay, and into Green Bay. The cruises into Green Bay were made as part of a cooperative study with the Environmental Protection Agency (EPA). The 23-foot research launch was used primarily for biological and zoological studies in Saginaw Bay and Lake St. Clair.

The 100-meter station off Grand Haven, MI continued to be the site monitored using sediment traps and periodic water and plankton samplings to study the temporal variations in water quality, and the vertical mass and chemical flux as determined by samples from the traps. Particular emphasis was placed on carbon pools and the rates of transfer. Several cruises were made during the spring using the *Shenehon* along traverses in the vicinity of Grand Haven and Muskegon, MI in connection with studies of frontal processes and thermal bar development and decay.

Sediment traps were deployed in 1991 at one station in Lake Michigan, four stations in Lake Huron, six stations in Lake Superior, and two stations in Saginaw Bay to monitor the vertical mass and chemical flux. The traps in Lakes Huron, Superior, and Saginaw Bay were recovered in September 1991. Two Acoustic Doppler Profilers were removed from the Straits of Mackinac in October 1990. Current and temperature sensors were deployed in the center of the southern basin of Lake Michigan, in Whitefish Bay, and near Copper Harbor in Lake Superior.

A prototype sediment trap of GLERL design for collecting sequencial samples in the water column was deployed over the winter in Lake Michigan (Figure 18). Six more traps of the GLERL design were constructed and will be deployed over the winter of 1991-1992 in Lake Michigan.

The wire line sweep technique developed by GLERL was successfully used again to recover sediment trap and current meter moorings from submerged positions in Lakes Michigan and Superior. The technique continues to pay dividends due to a rapid and inexpensive recovery of lost equipment.

The R/V *Shenehon* continues to attract attention as she cruises the lakes. A total of 132 people visited the boat, including 60 Cub Scouts from the Tawas area. Several newspaper articles have been written covering the research efforts supported by the *Shenehon*.

Figure 18. The GLERL-designed sequential sediment trap ready for deployment in Lake Michigan.

Marine Instrumentation Laboratory

The marine instrumentation laboratory (MIL) staff select, calibrate, repair, and, when necessary, adapt or design instruments to collect data in the lakes and their environs. Engineers and technicians in this unit work closely with GLERL researchers to ensure that instruments are compatible with their needs. They also participate in field experiments by providing support for the deployment and retrieval of field equipment, assistance with the collection of samples and data, and in-field maintenance or repair of equipment. GLERL's data collection equipment includes 44 AMF Vector Averaging Current Meters, 16 AMF Acoustical Releases, 7 Mini-TOD Drifter Buoys, 1 Adamo-Rupp Waverider WRIPS Buoy, 5 Aanderaa Thermistor String Recorders, 5 Marsh McBirney 585 Current Meters, 1 RD Instrument Co. RDRR-1200 Acoustical Doppler Current Profiler, and 2 RDSC-600 Acoustical Doppler Current Profilers.

As a result of successful prototype development last fiscal year, MIL staff, in conjunction with the Great Lakes Engineering Company, Ann Arbor, MI, built and tested six sequential sediment samplers (Figure 18) that can withstand a working pressure of 200 meters with 23 discrete samples of individual preset exposure times from 1 minute to 1 year. A microcomputer is the controller of the system and serves as a data logger for *in situ* measurements.

In FY 91, MIL staff worked with scientists from the Biogeochemical Sciences Division on the design and development of a prototype mesocosm experimental chamber for use in the zebra mussel project in Saginaw Bay. These large experimental enclosures (2 m^3) were used to assess the ecological impact of zebra mussel on the Saginaw Bay ecosystem (see Figure 2, page 4).

Work has begun to add GPS to our drifting buoys, and a new LORAN/GPS buoy is being prototyped with data which will report through the ARGOS/GOES satellite system. This improvement will extend the useful geographic range of the buoys.

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Outreach Activities

The GLERL mission includes the development of environmental information, data, and service tools for users in government and private organizations. Participation on boards, commissions, task forces, and committees helps GLERL staff to identify environmental information needed by our users and helps to guide our research focus and the development of usable products. Participation also helps to maintain staff involvement in programs concerned with environmental problems and issues of water- and land-oriented resource development and management issues. The Publications Unit also plays an important role by making GLERL's products available to those who need them, answering information requests, and creating displays and general literature concerning GLERL's products and work.

During FY 91, GLERL staff participated as members of the following boards, committees, and task forces:

International Joint Commission

- Great Lakes Science Advisory Board (A. Beeton, U.S. Chair)

- Council of Great Lakes Research Managers (D. Reid, Observer)

- Corporate Management Committee (A. Beeton)

- Great Lakes Water Quality Board, Surveillance Work Group
  - Great Lakes Surveillance Subcommittee (B. Eadie)
  - Lake Michigan Task Force (B. Eadie)
  - Lake Erie Task Force (J. Robbins)
  - Lake Huron Task Force (T. Nalepa)
  - Upper Connecting Channels Task Force (J. Derecki)
  - Workshop on Applications of Mass Balance to the Management of Toxic Substances in the Great Lakes (B. Eadie, Co-chair)

- Great Lakes Water Levels Reference
  - Working Committee 3: Existing Regulation, System-wide Regulation, and Crises Conditions (F. Quinn)
  - Working Committee 3, Task Group 1: Regulation Studies (D. Lee).
  - Working Committee 3, Task Group 2: Support Studies (F. Quinn, U.S. Co-chair; D. Lee)
  - Working Committee 3, Task Group 3: Crises Conditions (D. Lee).

- Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data
  - Hydrometeorology and Modeling Subcommittee (T. Croley II)
  - River Flow Subcommittee (F. Quinn)
  - International Great Lakes Datum of 1985 Workshop and Brochure (D. Lee)

- International Great Lakes Levels and Flows Advisory Board (F. Quinn, U.S. Co-chair)

- Biennial Meeting 1991 Program Subcommitte (A. Beeton)

Other interagency, professional society, and international activities:

- American Society for Limnology & Oceanography
  - Editorial Board (H. Vanderploeg)

- International Association for Great Lakes Research
  - Board of Directors (T. Nalepa, President; M. Quigley, G. Fahnenstiel)
  - IAGLR Membership and Endowment Committee (M. Quigley, Chair)
  - *Journal of Great Lakes Research* (F. Quinn, D. Schwab, Associate Editors)

- National Research Council
  - Postdoctoral Program (A. Beeton, W. Gardner, H. Vanderploeg, P. Landrum, A. Bratkovich)

- The University of Michigan
  - Cooperative Institute for Limnology and Ecosystems Research (CILER) Board of Directors; Council of Fellows (A. Beeton, S. Bolsenga, B. Eadie, T. Nalepa, F. Quinn, D. Reid)
  - Biological Station Executive Committee (A. Beeton)
  - Ph.D Committees (A. Beeton, A. Bratkovich, G. Fahnenstiel, J. Saylor)

- Michigan Sea Grant Research Advisory Committee (J. Saylor, A. Bratkovich)

- Ohio Sea Grant
  - Zebra Mussel Project (A. Beeton, T. Nalepa, D. Reid)

- American Chemical Society
  - Associate Editor, *Organic Substances and Sediments in Water* (B. Eadie)

- American Society for Testing and Materials Sediment Toxicity Subcommittee (P. Landrum)

- Assessment and Remediation of Contaminated Sediments (ARCS, USEPA)
  - Toxicity/Chemistry Work Group (P. Landrum)
  - Management Advisory Commiteee (D. Reid)

- *Chemosphere*, Board of Editors (P. Landrum)

- Department of Commerce Consolidated Scientific Computing System Technical Committee (G. Spalding)

- Department of Energy, Ocean Margins Program
  - Review Panel (B. Eadie)

- Eastern Snow Conference Research Committee (D. Norton)

- Great Lakes Commission
  - Drought Management and Great Lakes Water Levels Task Force (F. Quinn)
  - Great Lakes Speakers Bureau Directory (G. Laird Pernie, F. Quinn)
  - Task Force on Emergency Preparedness (D. Reid)
  - Observer delegate (A. Beeton)

- Great Lakes Environmental Action Program (Great LEAP/USCOE) (A. Beeton, G. Leshkevich)

- Great Lakes Protection Fund
  - Technical Advisory Committee (A. Beeton)

- Great Lakes GIS Coordinating Committee (G. Leshkevich)

- *Handbook of Environmental Chemistry*, Advisory Board (P. Landrum)

- *Hydrobiologia*, Special Issue
  - Associate Editor (B. Eadie)

- Huron River Watershed Council
  - Portage Lake Project (A. Beeton)

- Interagency Non-Indigenous Species Research Protocol Committee (D. Reid, Member)

- International Mathematics and Statistical Library (IMSL) North American Users Group (L. Herche, Co-chair)

- International Association of Theoretical and Applied Limnology
  (A. Beeton, U.S. Representative)

- National Sea Grant Zebra Mussel Review Panel (W. Gardner)

- NCAR Great Lakes Climate Change Program (S. Bolsenga)

- NOAA Climate and Global Change Program
  - Marine Ecosystem Response Project Advisory Panel (D. Reid)
  - Technical Advisory Committee (H. Vanderploeg)

- NOAA Coastal Ocean Program
  - Coastal Fisheries Ecosystem Scientific Advisory Committee (D. Reid)
  - Observations and Predictions Component Interline Office Development Team (A. Bratkovich)
  - Physical Hazards Component (D. Schwab)
  - NOAA/ERL Satellite Requirements Committee (S. Bolsenga, G. Leshkevich)
  - NOAA Mississippi River Plume/Gulf Shelf Region Research Planning Workshop (W. Gardner, G. Fahnenstiel)
  - NOAA NECOP Technical Advisory Committee (B. Eadie, A. Bratkovich)
  - NOAA/NESDIS Coastwatch Program (G. Leshkevich, D. Schwab, G. Spalding)

- NOAA Measurement Technique Development/ Ocean Acoustic Techniques and Climate Change Committee Member (M. McCormick)

- NOAA/SABRE Technical Advisory Committee (A. Bratkovich)

- NOAA Technical Subcommittee, New Bedford Superfund Action (B. Eadie)

- NSF Long-Term Ecological Research Network (S. Bolsenga)

- Regional Response Team (RRT), Region V
  - Department of Commerce Alternate Representative (D. Reid)

- State of Michigan, Department of Natural Resources
  - Great Lakes Information System Technical Advisory Committee (A. Beeton)
  - Michigan Great Lakes Fund (A. Beeton, S. Bolsenga)
  - Toxic Substances Control Commission (A. Beeton, Commissioner)

- State University of New York (SUNY) Buffalo, Great Lakes Programs
  - Advisory Board (F. Quinn)

- Thurston Nature Center Advisory Committee (A. Bratkovich)

- U.S.-Canada Ice Information Working Group
  - Great Lakes Ice Issues Subcommittee (R. Assel, U.S. Co-chair)
- International Great Lakes - St. Lawrence Ice Information Working Group (R. Assel, U.S. Co-chair, S. Bolsenga, D. Norton, G. Leshkevich)
- U.S. Environmental Protection Agency Policy Committee (A. Beeton, S. Bolsenga Alternate)
- U.S. Soil Conservation Service (A. Beeton, Technical Advisor)
- U.S. Department of State
  - Cooperative Study on Chernobyl Fallout in Masurian Lakes, Poland (J. Robbins)
  - Mongolian Cooperative Research Program (S. Bolsenga)
- Wayne County Community College
  - Technical Advisory Committee (H. Booker)

GLERL scientists also:

- Conducted cooperative research study of evaporation and climate change with scientists from the USSR Academy of Sciences.

- Conducted cooperative research with scientists at Michigan State University, Department of Fish and Wildlife.

- Provided statistical consulting to scientists from The University of Michigan and The University of British Columbia.

- Continued coordination with the Midwestern Climate Center and the Illinois State Water Survey to develop a Midwestern Climate Information System (MICIS).

- In cooperation with researchers from Ohio State University, NOAA Center for Ocean Analysis and Prediction (COAP), and the National Weather Service, developed the Great Lakes Forecasting System, a prototype coastal ocean prediction system for the Great Lakes.

- Conducted cooperative research with scientists at NASA/Goddard to measure bidirectional reflectance of ice.

- Conducted cooperative research with the Naval Ocean and Atmospheric Research Lab (NOARL).

- Conducted cooperative research with Weber State University to study currents in the Great Salt Lake.

- Conducted cooperative research with the U.S. Fish and Wildlife Service on the effects of currents and water temperatures on Lake Trout recruitment in Lake Superior.

- Collaborated with scientists at Michigan State University to study the ecology of the larvae of the mosquito *Anopholes*, a vector of malaria.

- Conducted cooperative research with scientists from Middlebury College and Lamont-Doherty on physical processes in Lake Champlain.

- Conducting cooperative research with the Canadian National Hydrology Research Institute on under-the-ice ecology.

- Serving as adjunct professors at The University of Michigan.

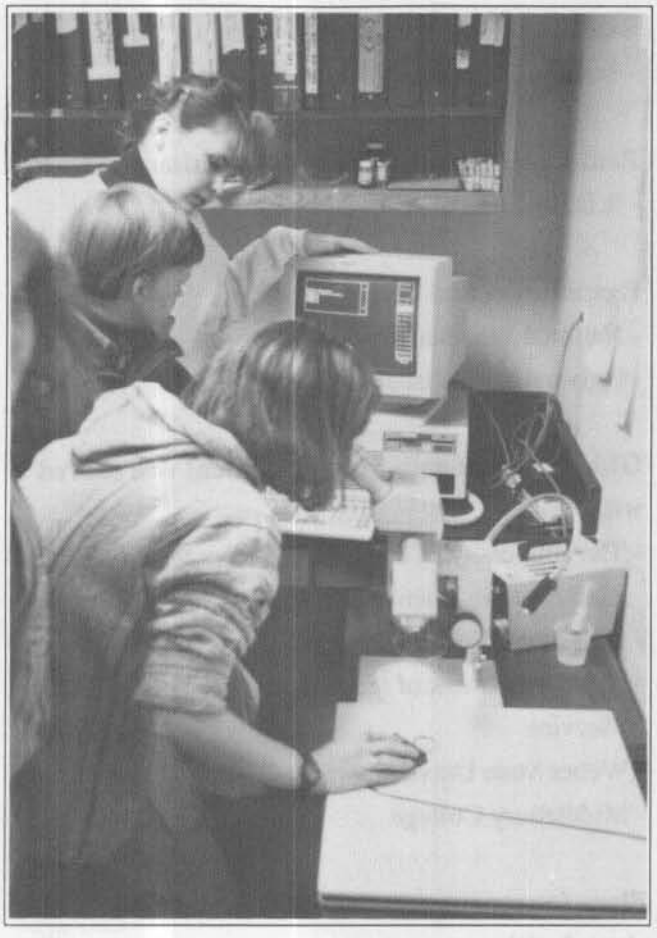

Figure 19. As part of our outreach activities, GLERL hosts science classes from several area schools. Here, students are shown how a digitizer is used to make accurate measurements of macroinvertebrates.

- Served as expert advisors for the U.S. Navy acoustics research program in Lake Pend Oreille, ID.

- Served on a review panel for the Department of Interior's Natural Resource Damage Assessment Model for the Great Lakes, a 2-year effort to develop a computer program for assessing financial damages for environmental accidents on the Great Lakes.

- Participated in Cooperative Student Programs with The University of Michigan and Eastern Michigan University.

- Provided lipid data to scientists at Trent University, Ontario, Canada.

- Continued a cooperative Great Lakes bathymetry charting project with scientists at NOAA's National Geophysical Data Center and extended this project to formally include scientists at the Canada Hydrographic Service.

- Hosted students from several area schools. The students were given laboratory tours and briefed on GLERL activities (Figure 19).

Meetings and Presentations

An integral part of the scientific development of GLERL staff is attendance and participation in scientific and technical meetings. During FY 91, GLERL sponsored 33 in-house seminars as part of the GLERL Informal Seminar Series. Our staff made 57 presentations concerning GLERL's work at public and professional meetings.

In FY 91, GLERL staff members served as co-chairman of the following sessions:

- Organic Substances and Sediments in Water: Biological Processes: Bioaccumulation and Bioturbation 199th National Meeting of the American Chemical Society.

- Nutritional Biochemistry, Behavior, and Physiology at the National Science Foundation workshop Future Directions in Zooplankton Biology.

Technology Transfers

GLERL staff responded to approximately 1,000 requests for information during FY 91 and provided more than 3,700 items to service those requests. Many of the products that GLERL produces and distributes involve a transfer of both technology and data. During

FY 91, GLERL's outreach of this nature involved the transfer of the following:

Great Lakes Freezing Degree Day Ice Cover Model
- Canadian Climate Center

Great Lakes Snowfall Maps
- Interactive Concepts, Inc.

Great Lakes CoastWatch Data
- Center for Great Lakes Studies, Univ. of Wisconsin
- Dept. of Civil Engineering, Ohio State University
- Lake Superior Ecosystems Research Center
- Michigan Technological University
- Hammond Bay Biological Station, U.S. Dept. of the Interior
- Lake Superior Center, Duluth , MN

Hydrologic Response Model
- Ohio State University

Net Basin Supply Forecast Package
- U.S. Army Corps of Engineers, Detroit District

Water Resources Simulation Package
- Harvard University
- Atmospheric Environment Service (Canada)

Wave Forecast Model
- National Weather Service, Cleveland, OH

"Pathfinder" Trajectory Prediction System
- U.S. Department of the Interior
- U.S. Coast Guard
- McMaster University

Thiessen Weighting Package
- Atmospheric Environment Service (Canada)

Satellite Drifter Programs
- Scripps Institution of Oceanography

Real-time Interactive Data Acquisition Software
- R.D. Instruments Co.

Evaporation and Other Data
- National Weather Service
- University of Wisconsin

GLERL's data gathering equipment was shared with:
- The University of Michigan (Center for Great Lakes and Aquatic Sciences; College of Engineering)
- U.S. Army Corps of Engineers
- U.S. Department of the Interior, Fish and Wildlife Service
- Weber State University
- Middlebury College

Plans for construction of sediment traps were shared with:
- Ocean Sciences Centre, Newfoundland, Canada
- University of Stockholm, Sweden
- Great Lakes Engineering Company
- University of Michigan
- University of North Carolina

- Filtration device developed at GLERL is being marketed by a small business (St. John Associates).

Lipid Methodology

New micro-methods developed at GLERL to measure lipids in aquatic invertebrates were transferred to:

- Savannah River Ecology Laboratory, Aiken, GA

GLERL and Great Lakes Education - Partners for Excellence

In conjunction with NOAA's desire to better inform the public of its research activities, GLERL is involved in a number of Great Lakes community educational programs. In FY 91, GLERL continued its involvement with the Science Department of the Ann Arbor Public Schools' Partners for Excellence Program (T. Nalepa, GLERL Coordinator). The partnership seeks to enrich the public schools' curriculum in the area of environmental science, particularly with respect to the Great Lakes and aquatic sciences. Designated partnership activities include:

- Providing mentors to help students with science fair projects.
- Providing practical "hands-on" experience to promising science-oriented students via participation in a Student Volunteer Program.
- Providing information on careers in environmental science and acting as consultants for the science curriculum.
- Inviting science teachers to laboratory-sponsored seminars.

In 1991, GLERL staff also helped students at a local school upgrade their meteorological station and provided CoastWatch SST imaging and display software for use in their curriculum.

Southeast Michigan Science Fair

In conjunction with the 33rd Annual Southeast Michigan Regional Science Fair, GLERL sponsored awards for outstanding projects in aquatic science in each of the Science Fair divisions: Senior Projects, Junior Projects, and Junior Models and Collections. GLERL staff (T. Croley, D. Schwab, H. Vanderploeg, J. Saylor, A. Beeton, N. Butler, and J. Cotner) acted as general Science Fair judges and also as judges for the GLERL award in the Southeast Michigan and local junior high science fairs.

Student Volunteer Program

GLERL and the Ann Arbor Public Schools established a Student Volunteer Program authorized by the Civil Service Reform Act of 1978 (Public Law 95-454). This program provides selected high school students with the opportunity to perform volunteer work at GLERL after school.

Teacher-at-GLERL Project

During FY 89, GLERL scientists (A. Beeton, and D. Reid) initiated a project to host a middle school science teacher at GLERL for a one-semester sabbatical funded by the Ann Arbor Public Schools (AAPS) System. After several discussions with AAPS officials and a formal written proposal, the project was accepted and sabbatical funds were allocated for the 1991 school year. Ms. Sandy Aquino, a science teacher at Tappan Middle School, was selected for the project and was resident at GLERL from January to June, 1991. She has developed curriculum enhancements in the area of aquatic environmental science. At her suggestion, we have put together a Curriculum Kit filled with curriculum ideas, booklets, videos, posters, and maps dealing with the Great Lakes and related environmental issues. The kit is available on a loan basis to interested teachers. Please call Cathy Darnell at (313) 668-2262 for more information.

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FY 91 Staff

Office of the Director

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Noble, P.E. - Secretary
Bolsenga, S.J. - Asst. to Director
Johengen, T.H.*

Administration

Mark, S.V. - Head
Lashbrook, E.K.
Lee, J.P.
Mull, R.C.

Information Services

Bolsenga, S.J. - Head
Darnell, C.M.
Sparks, K.J.

Library Facility

Carrick, B.J. - Librarian
Threm, S.M.

Computer and Information Systems Group

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Lojewski, N.L. - Secretary
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Shrum, A.F.

Physical Sciences Division

Quinn, F.H. - Head
Lawton, B.J. - Secretary
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Carver, Y.M.†
Clites, A.H.
Croley, T.E., II
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Dong, D.Y.†
Erickson, C.*
Gottlieb, E.S.*
Hartmann, H.C.
Hawley, N.
Huff, L.E.†
Hunter, T.S.
Kelley, R.N.
Kulaszewski, M.†
Leshkevich, G.A.
Licalzi, E.L.†
Lilley, K.†
Liu, P.C.
McCormick, M.J.
Miller, G.S.
Muhr, G.C.
Norton, D.C.
Pazdalski, J.*
Saylor, J.H.
Schwab, D.J.
Sellinger, C.E.
Shenot, J.M.*
Stretch, B.D.†
Wise, C.D.†

Biogeochemical Sciences Division

Reid, D.F. - Head
Williams, R.S. - Secretary
Bell, G.L.
Butler, N.■
Calhoun, C.C.†
Cavaletto, J.F.
Cotner, J.◆
Eadie, B.J.
Fahnenstiel, G.L.
Faust, W.R.
Fitzgerald, S.■
Ford, M.A.
Gardner, W.S.
Gordon, W.M.†
Gossiaux, D.C.
Hentz, N.G.†
Ikuma, A.E.*
Laird Pernie, G.A.
Landrum, P.F.
Lansing, M.B.
Lang, G.A.
Liebig, J.R.
Marcovitz, M.◆
McElroy, K.D.*
Morehead, N.R.
Nalepa, T.F.
Niester, J.M.*
Patton, T.R.†
Quigley, M.A.
Ramaley, T.B.†
Robbins, J.A.
St. Pierre, L.M.†
Tarapchak, S.J.
Thoms, S.R.
Vanderploeg, H.A.
Wagoner, B.B.
Wimmer, M.†
Wojcik, J.A.◆
Woo, R.Y.†

* - Indicates WAE Employee
† - Indicates Co-op Employee
■ - Indicates NRC Fellow
◆ - Indicates CILER Employee

Marine Operations and Instrumentation Laboratory

Soo H.K. - Head
Lojewski, N.L. - Secretary
Booker, H.L.
Kistler, R.D.
Lane, J.C.
Miller, T.C.
Muzzi, R.W.
Stickney, J.D.*

R/V *Shenehon*
Morse, D.V. - Master Mate
Burns, W.R.
Grimes, J.E.
Marquardt, J.W.*

	Full Time	Part Time	Other
Office of Director	10	1	1
PSD	18	2	12
BSD	22	1	16
MOIL & Shenehon	5	4	2
CISG	7	1	0
TOTAL	62	9	31

Visiting Scientists

GLERL has hosted visiting scientists from many areas of the world who participate in cooperative research projects with GLERL scientists or who perform separate, but related, research. Following is a list of the scientists who were resident at GLERL in FY 1991.

Ms. Danielle DeLuca
Tufts University, Medford, MA.
Ms. DeLuca began her 2-month visit in June 1991 to gather information on the zebra mussel issue for her thesis. She observed and participated in our research program and conducted interviews with GLERL researchers.

Dr. Sergei Ferronsky
Academy of Sciences of the USSR, Moscow.
Dr. Ferronsky was at GLERL for approximately 1 month beginning in February 1991 to work with Dr. Tom Croley and other GLERL scientists on the joint GLERL/Soviet Geophysical Committee project titled "Climate Change Impacts on the Hydrology of the Caspian Sea."

Dr. Malkiat S. Guram
Voorhees College, Denmark, SC.
Dr. Guram spent 2 weeks at GLERL beginning in July 1991. His stay here exposed him to our programs in toxics, coordinated ecosystem research, nutrient enhanced coastal ocean productivity, marine hazards and water resource management, and exotic species. With this information, he plans to upgrade the environmental sciences curriculum at Voorhees.

Ms. Gail Harkey
Memphis State University, Memphis, TN.
Ms. Gail Harkey is a Ph.D. student and will spend up to 2 years at GLERL conducting her Ph.D. research with Dr. Peter Landrum.

Dr. Robert Heath
Kent State University, Kent, OH.
Dr. Heath began his 1 year sabbatical starting in August 1991. He is collaborating with Dr. Wayne Gardner and others on the Saginaw Bay zebra mussel project. His interests are with carbon and phosphorus cycling and the lower food web.

Dr. Peter McCall
Case Western Reserve University, Cleveland, OH.
Dr. McCall spent 5 months at GLERL as a visiting scientist working with Dr. Peter Landrum and Dr. John Robbins on an EPA-funded project titled "Laboratory Radiotracer Studies of Biological Mixing in Shallow Marine Sediments."

Dr. Don McNaught
University of Minnesota, Minneapolis, MN.
In September 1991, Dr. McNaught began a 1 year sabbatical to work with various GLERL and U.S. Fish and Wildlife Service scientists on the zebra mussel problem.

Mr. Nathanian Ostrum
Memorial University, St. Johns, Newfoundland.
Mr. Ostrum, a Ph.D student, was at GLERL for 6 months working with Dr. Brian Eadie to customize a sample preparation system and to calibrate our instrument for nitrogen isotopes.

Dr. Walter Pfeiffer
University of Constance, Germany.
Dr. Pfeiffer began working with Dr. John Robbins in August 1991. During his 2 month stay at GLERL his work focused on radiotracers in sediments.

Dr. Paul Walline
Lake Kinneret Limnological Laboratory, Israel.
Dr. Walline began his 14 month sabbatical at GLERL in June 1991. He is working with various GLERL and outside scientists on ecosystem and fisheries related activities.

FY 91 Seminars

Research on hydrophobic organic contaminants in the Baltic. Dag Broman, University of Stockholm, Sweden. October 18, 1990.

Nitrogen nutrition in Lake Kenneret phytoplankton. David Wynne, Kinneret Limnological Laboratory, Tiberias, Israel. October 23, 1990.

Toxicity of contaminants to the amphipod, Diporeia *sp.* P.F. Landrum, GLERL. October 30, 1901.

Lake surface temperature measurements of Lake Constance using Landsat-TM and NOAA-AVHRR data. Karl Schneider, Institute for Physical Geography, University of Freiburg, Germany. November 1, 1990.

The influence of DDT on the sediment reworking rate of Stylodrilus heringianus. S. Lindner, GLERL. November 8, 1990.

Ecotoxicology: Effects of toxicants on the Zebra mussel, Dreissena polymorpha. Michiel Kraak, University of Amsterdam, The Netherlands. November 21, 1990.

Long-term changes in production, abundance, and biomass of the Great Lakes amphipod Diporeia *sp.* M.A. Quigley, and G.A. Lang, GLERL. November 28, 1990.

Phytoplankton lipid production in freshwater ecosystems and zooplankton interactions. Bruce Wainman, York University, Toronto, Ontario. December 7, 1990.

Degree of taste discrimination among suspension-feeding copepods and cladocerans: Implications for detritivory and herbivory. W. Charles Kerfoot, Michigan Technological University, Houghton, MI. January 28, 1991.

Epilimnetic scavenging of Chernobyl fallout radionuclides in Lake Constance. J.A. Robbins, GLERL. February 25, 1991.

Measurements of currents and temperature distributions in Green Bay. J.H. Saylor, GLERL. February 13, 1991.

Research on sediment transport at GLERL: Problems, progress, and future plans. N. Hawley, GLERL. February 14, 1991.

Water volume exchange between upper and lower Green Bay. G.S. Miller, GLERL. February 19, 1991.

Field evaluations of a satellite and LORAN-C tracked drifters. M.J. McCormick, GLERL. March 7, 1991.

Zebra mussel research in Lake St. Clair and Saginaw Bay: Accomplishments and plans. T.F. Nalepa, GLERL. March 11, 1991.

Great Lakes forecasting system. D.J. Schwab, GLERL. March 12, 1991.

Chaos, a distant encounter. P.C. Liu, GLERL. March 14, 1991.

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