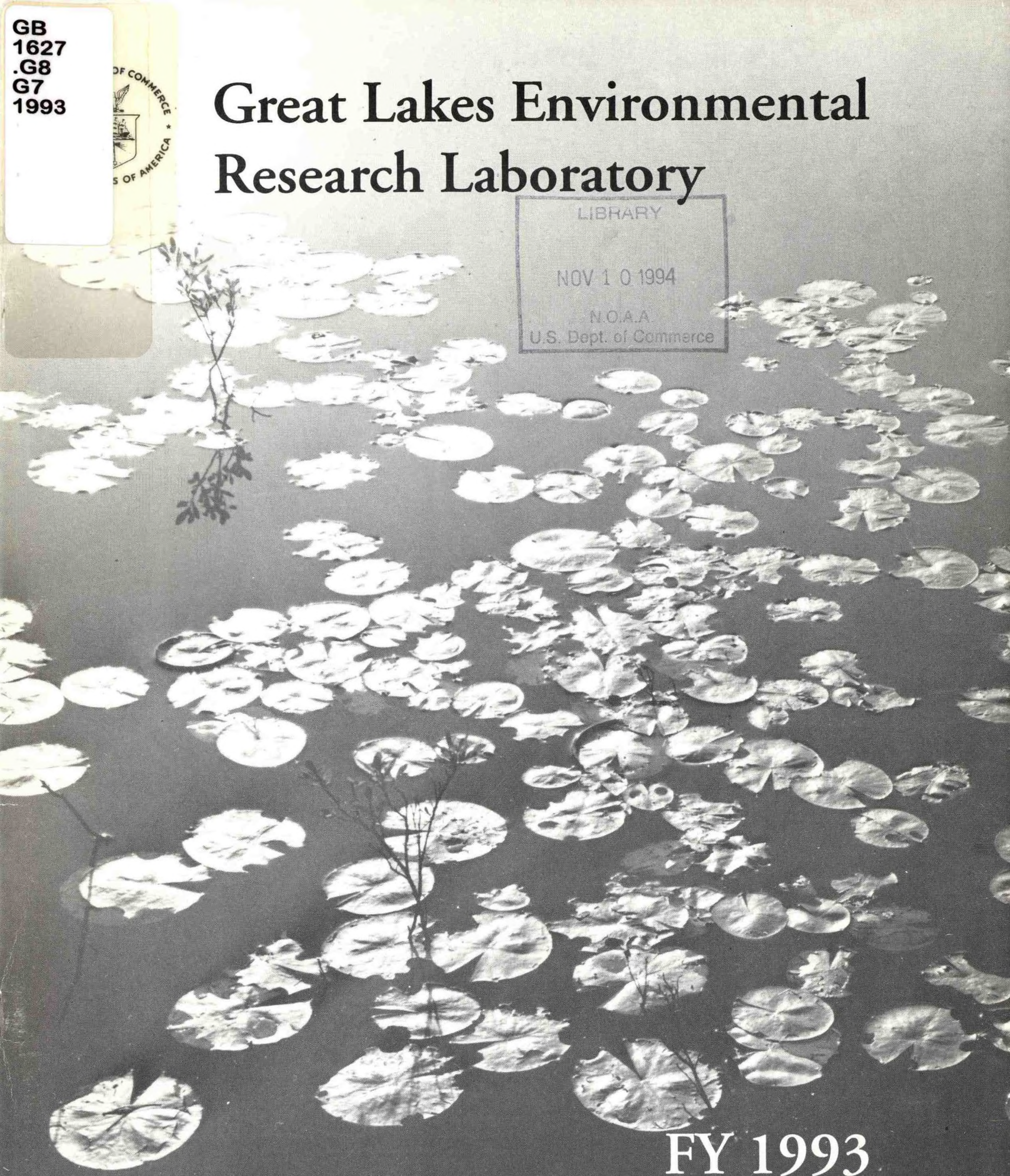
Great Lakes Environmental Research Laboratory



FY 1993 Yearly Report


The Laurentian Great Lakes
CANADA
U.S.A.
ONTARIO
Great Lakes Drainage Basin Limit
MINNESOTA
LAKE SUPERIOR
ONTARIO
Duluth
Sault Ste. Marie
MICHIGAN
Green Bay
Georgian Bay
St. Lawrence River
WISCONSIN
LAKE HURON
Kingston
Traverse City
LAKE MICHIGAN
Toronto
LAKE ONTARIO
MICHIGAN
NEW YORK
N
Muskegon
Grand Haven
ONTARIO
Buffalo
Milwaukee
Lake St. Clair
Detroit
Ann Arbor
LAKE ERIE
PENNSYLVANIA
Chicago
Toledo
Cleveland
Kilometers
ILLINOIS
OHIO
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INDIANA
Great Lakes Drainage Basin Limit

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

YEARLY REPORT FY 1993

Director

Alfred M. Beeton

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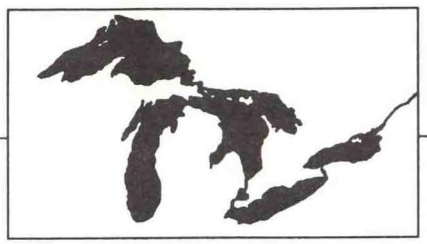


The Great Lakes Environmental Research Laboratory (GLERL), located in Ann Arbor, Michigan, is 1 of 11 environmental laboratories operated by the National Oceanic and Atmospheric Administration (NOAA), Office of Oceanic and Atmospheric Research (OAR), through the Environmental Research Laboratories Directorate.

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 focuses on the biological, chemical, and physical processes occurring in natural ecosystems. 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 and marine coastal ecosystems.

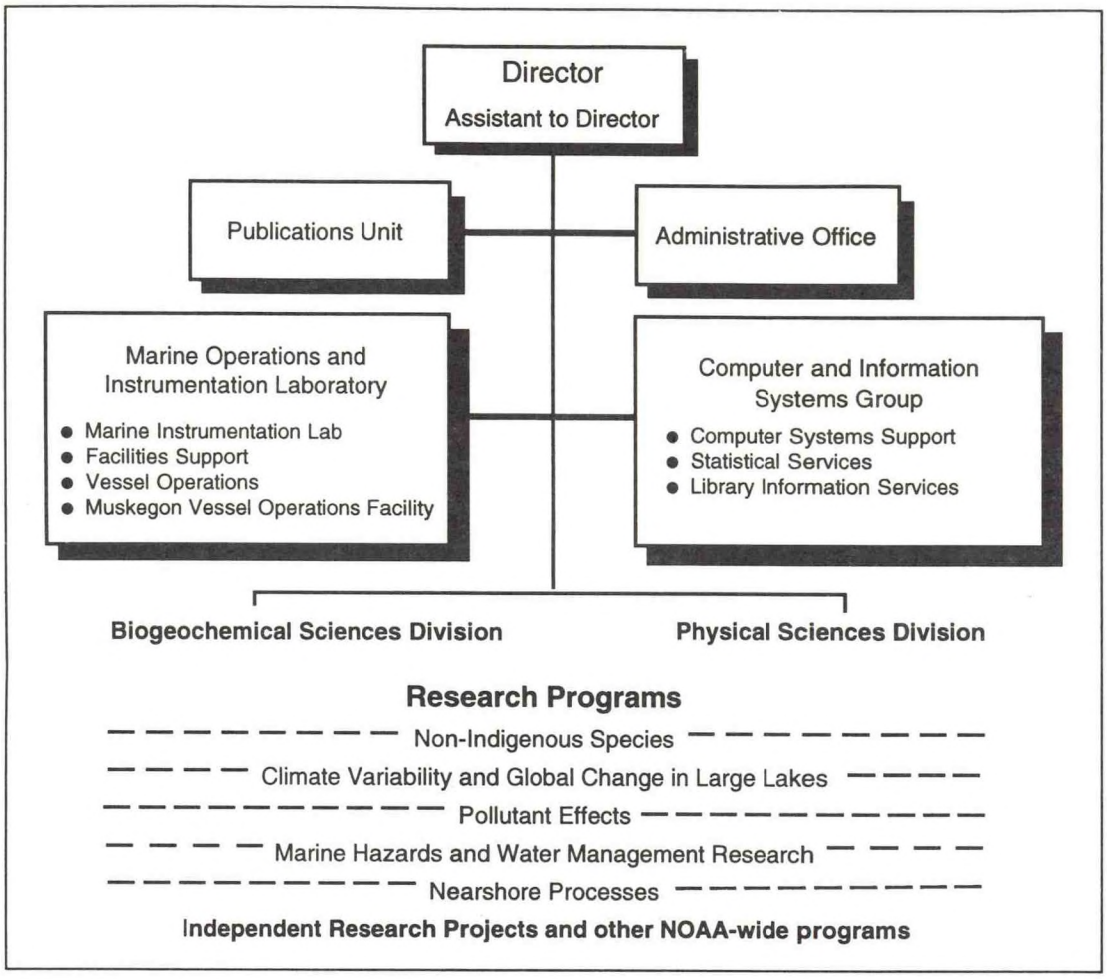
The products of GLERL's research are available as scientific publications, NOAA Technical Series reports, computer programs and computer-based models, brochures, posters, and presentations at scientific and public meetings. These products are used by government, educational, and private organizations and individuals. During FY 93, 52 scientific publications were published by GLERL authors, and 62 presentations were given by GLERL staff at scientific and public meetings and in schools.

This report describes the significant activities and accomplishments of GLERL staff during the period October 1, 1992 - September 30, 1993. 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 research programs that are essential to understanding and solving critical Great Lakes problems and that are in keeping with NOAA's mission: Pollutant Effects, Marine Hazards and Water Management, Non-Indigenous Species, Climate Variability and Global Change in Large Lakes, and Nearshore Processes. In addition, GLERL scientists are also involved in the Nutrient-Enhanced Coastal Ocean Productivity (NECOP) program, the Great Lakes CoastWatch program, and several independent research projects.

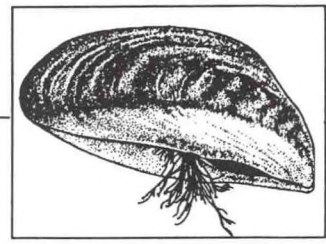
GLERL enhances its research activities through the Cooperative Institute for Limnology and Ecosystems Research (CILER). CILER, which is a joint research enterprise of the University of Michigan, Michigan State University, and GLERL, allows scientists from throughout the Great Lakes basin the opportunity to collaborate on a wide variety of research topics of mutual interest. Many of the projects described here involve participation with CILER Fellows, Visiting Fellows, and other staff. GLERL scientists are assisted by six support units that provide technical, operational, and administrative assistance to the scientific staff:

- the **Administrative Office** provides personnel, budget, purchasing, and facility information and management for the laboratory;
- the **Computer Systems Group** maintains GLERL's in-house computer network, the interface with off-site mainframe and super computers, and provides related user support to GLERL staff and others;
- the **Library** maintains a research collection tailored to GLERL staff needs and offers special retrieval services for materials not in the existing holdings;
- the **Marine Operations and Instrumentation Laboratory** designs, builds, and maintains instruments and systems for hands-on and automated field collection of data;
- the **R/V *Shenehon***, GLERL's research vessel, is the primary platform used by GLERL staff for field operations on the lakes.
- the **Publications Unit** is responsible for providing editorial and publications support to GLERL staff, distributing GLERL publications, responding to related information requests, and designing and fabricating displays.



GLERL's Organization Structure

Non-Indigenous Species



The objective of this program is to expand our knowledge of the biology and the ecological effects of non-indigenous species in the Great Lakes. Research involves field investigations to monitor ecosystem changes and community response to these species and examines biological traits of the organisms themselves. Research also includes laboratory experiments to determine metabolic features and feeding rates and examines toxicokinetic and bioaccumulation of toxics.

Effects of the Zebra Mussel on the Lower Food Web of Saginaw Bay. (Project Scientists: Nalepa, Fahnenstiel, and McCormick)

The objectives of this project are (1) to identify and understand 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 (*Dreissena polymorpha*), (2) to construct a model of carbon flow through the system and determine major changes in pathways which may have been caused by the zebra mussel disrupting the ecosystem, and (3) to monitor changes in the abundance and distribution of the zebra mussel in the bay (Figure 1). Although the number of stations in the monitoring program were decreased in FY 93, the number of master stations in which phytoplankton growth rates and primary production estimates were examined remained the same as in previous years. Preliminary analysis of phytoplankton data indicated that since the zebra mussels became established in the bay, chlorophyll concentrations have declined, light transmittance has increased, primary production is lower than in previous years, and phytoplankton growth rates have remained unchanged since 1990. Clearance rates, or the amount of water cleared of particles per unit time, were measured monthly. The impact of food quality on these rates was determined for water from the inner bay (low quality) and the outer bay (high quality). Clearance rates were higher in the spring and lower in the fall at both sites. In addition, rates were lower in the inner bay, indicating that zebra mussels respond to the type of food available.

Toxicokinetics and Bioaccumulation of Organic Contaminants by the Zebra Mussel. (Project Scientist: Landrum)

This project is assessing the impact of the zebra mussel on the distribution of contaminants in ecosystems dominated by these organisms. The feeding activities of zebra mussels may result in faster deposition of sediments and may also change the composition and mobility of materials on the bottom. The selected chemicals, primarily polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs), are representative of both their class and the physical and chemical characteristics embodied in the chemicals as model compounds. Compounds from other chemical classes will be employed where specific characteristics will be helpful to determine specific processes or mechanisms of action. In FY 93, significant progress was made to develop the methodology for measuring the assimilation efficiency, by zebra mussels, for accumulation of organic contaminants from particles, suspended sediments, and algae. The experimental work on the role of temperature on toxicokinetics was completed and the data analyzed. Results indicate that temperature has little effect on the filtration rate for animals collected from the field except for those that have overwintered. Field samples (zebra mussels, gammarid amphipods, suspended sediment, and fish) were collected to determine the concentration of contaminants in a food chain that includes zebra mussels.

Direct Observations on the Trophic Ecology of *Dreissena* Early Life Stages: The Critical Planktonic Period. (Project Scientist: Vanderploeg)

The pelagic phase (eggs and larvae) of the zebra mussel is a weak link in its life cycle, with mortalities of nearly 100% depending on environmental conditions (narrow window of temperature, food,

predation, etc.). This program is (1) observing feeding mechanisms, particle choice, and feeding rates of *Dreissena* larvae, (2) determining nutritional requirements of *Dreissena* larvae, and (3) determining the vulnerability of *Dreissena* eggs and larvae to zooplankton. In FY 93, adult zebra mussels were reared in the laboratory and fed commercial oyster food. Fertilized eggs were produced at all times of year from laboratory-maintained stocks that were spawned with serotonin or a serotonin agonist. A wide variety of freshwater algae (greens, bluegreens, cryptophytes, and chrysophytes) offered in pure cultures of single species or in pairs of species did not promote long-term growth. Initial successes at rearing larvae allowed us to do preliminary experiments on larval feeding. Predation of larvae by omnivorous and predacious calanoid copepods (*Diaptomus*, *Epischura*, *Limnocalanus*) was studied by examining the loss of larvae confined in bottles with the predators. The larvae were highly vulnerable to predation in the trocophore state, the stage before formation of the shell.

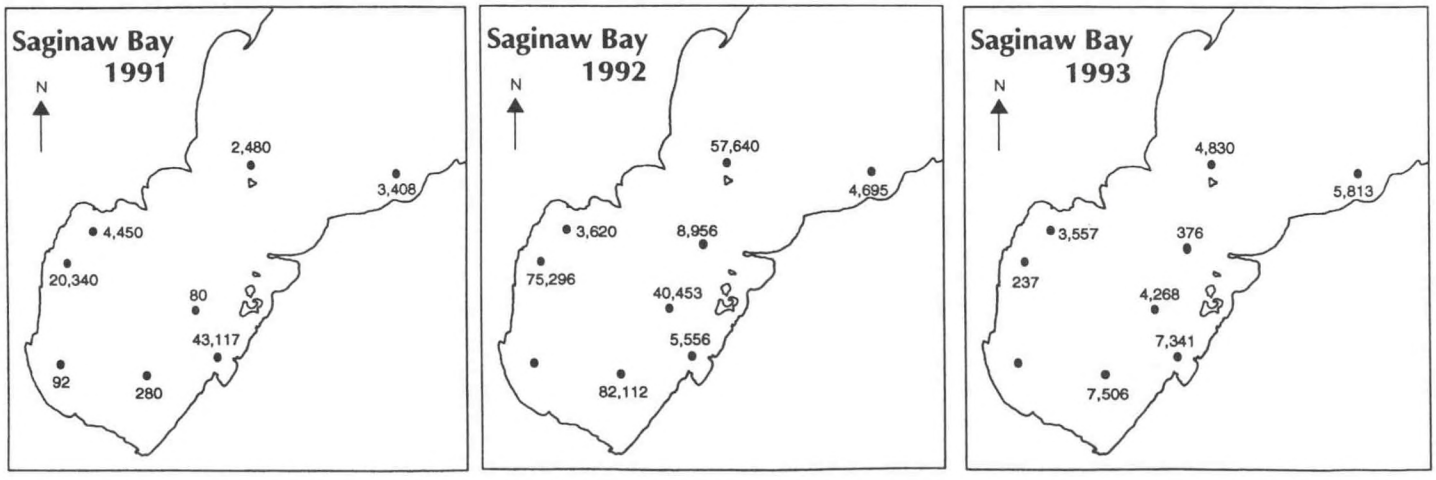
Long-Term Changes in the Resuspendable Sediments of Saginaw Bay. (Project Scientists: Eadie, and Bell)

During feeding, adult zebra mussels capture suspended particulate matter and redeposit it as feces and pseudofeces on the bottom. This activity will possibly change the composition and mobility of materials in the sediment resuspendable pool in Saginaw Bay, resulting in changes in system residence times of particle-associated constituents. This program is (1) deploying autosequencing sediment traps at two locations in Saginaw Bay (one inner bay; one outer bay)for the collection of resuspendable sediments, (2) analyzing these samples for gross compositional changes and for nutrients, carbon, and Cesium-137 to estimate the resuspension flux of these constituents, and (3) measuring the stable isotope composition of the biota to examine carbon and nitrogen pathways and changes caused by the mussel. The ten 1-week trap deployments in 1992 collected more mass and significantly more organic matter than the traps covering the same period in 1991. The increased concentration or organic matter in the resuspendable material is believed to be caused by the repackaging of particulate organic matter by zebra mussels. Stable isotopes are being measured on the trap samples and biota to uncover trophic linkages.

Effects of the Zebra Mussel on Nutrient Cycling and Lower Food Web Dynamics in Saginaw Bay, Lake Huron. (Project Scientist: Gardner)

By altering the phytoplankton and bacterial biomass, both of which compete for phosphorus, and the suspended particulates, zebra mussels may affect nutrient cycles and microbial dynamics in the bay. This task is (1) determining the direct and indirect effects of the zebra mussel on nutrient regeneration and uptake by various trophic components in the lower food web, (2) determining the effects of the zebra mussel on bacteria standing crop, cell size, and growth rates, (3) determining how the

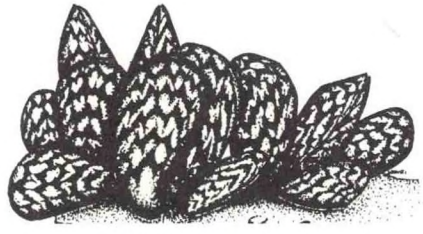
Figure 1. The abundance of zebra mussels (per square meter) in Saginaw Bay in fall 1991, 1992, and 1993.



sources, cycling rates, and fate of labile dissolved organic matter are affected by the presence of the zebra mussel, (4) collecting and determining the "nutritional composition" of feces and pseudofeces produced by the zebra mussel, and (5) comparing field observations of standing stocks and process rates with those predicted from bottle and mesocosm experiments. In FY 93, a seasonal (June-October) field study on the direct and indirect effects of the zebra mussel on community ammonium regeneration and potential uptake rates at two stations in Saginaw Bay was completed. The study revealed some unexpected results: in contrast to the spring period, when zebra mussels quantitatively removed phytoplankton from the water, in the summer period, filtering activity was dramatically decreased when the bluegreen alga, *Microcystis sp.*, became abundant. When *Microcystis* was dominant, the effects of the zebra mussel on the planktonic community was much reduced. Isotope enrichment experiments were initiated to examine the effects of zebra mussels on the dynamics of the interactions between dissolved organic matter (dissolved free amino acids) and bacteria and other microorganisms. Removal of added amino acids was faster in the presence of zebra mussels than in their absence. This observation indicates that zebra mussels can affect bacterial dynamics and the composition of organic substrates available to bacteria. Thus, in addition to directly affecting the phytoplankton, the zebra mussel affects the flow of carbon and nutrients through the microbial food web.

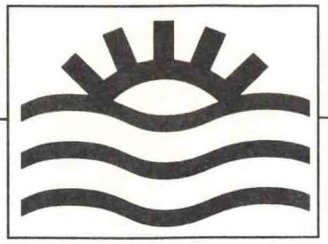
Metabolic Physiology of the Zebra Mussel. (Project Scientist: Nalepa)

Although information is available from Europe about biological and ecological characteristics of the zebra mussel, little is known about its physiological characteristics or variation in its biochemical content. Such data is important because it serves as an indicator of the relative health of the population. Thus,



comparisons of such data from different areas and during different times of the year may lead to a better understanding of the ecological requirements of the organisms and, over time, may provide an understanding of fluctuations in the populations. This program is determining seasonal oxygen consumption, nitrogen (ammonia) excretion of zebra mussels collected from Lake St. Clair, and lipid content and C:N ratios of soft tissue from zebra mussels collected from Lake St. Clair and Saginaw Bay. Zebra mussels are being collected monthly at several different locations in Lake St. Clair and Saginaw Bay. Lipid content, carbon content, nitrogen content, and the amount of soft body tissue per unit length are determined for mussels of different sizes (as measured by shell length). In both water bodies, there were consistent seasonal changes in the body tissue weight per shell length, with highest tissue weight occurring in the spring followed by a general decline to lowest weights in late summer/fall. This is likely related to the reproductive cycle of the organism. However, a general decline was also noted from year-to-year, indicating populations are perhaps becoming food limited.

Climate Variability and Global Change in Large Lakes



The Great Lakes region is rich in human and natural resources, with diverse economic activities and complex infrastructure. The economic and environmental importance of the basin and its sensitivity to climate fluctuations are clear. The potential impacts of climate change and variability on the environment and socio-economic fabric of the region are serious and complex. For example, climate change scenarios suggest that lake levels may decline as much as 2 meters resulting in significant economic losses to shipping, hydropower, and recreational boating. Ecosystem health could be affected through the loss of wetlands and other important habitats, changes in assimilative capacities, warmer temperatures, and increased anoxia due to decreased spring and fall turnovers in the water column.

NOAA and the Canadian Atmospheric Environment Service agreed to develop and conduct a research program for the Great Lakes-St. Lawrence River basin including studies to improve our understanding of the complex interactions between climate change and variability and our social and economic frameworks and the environment, and to provide relevant information and policy options so that informed regional adaptation/mitigation options can be developed for the basin. An emphasis will be on practical applications such as the development and assessment of adaptive strategies in the areas of ecosystem health, water-dependent economic activities, coastal zone management, and lake level fluctuations.

Effect of Climate Change on Large-Lake Ice Cycles. (Project Scientists: Assel; Robertson, USGS)

The duration and extent of ice cover on the Great Lakes have a major impact on the economy of the region by impeding commercial navigation, interfering with hydropower production and cooling water intakes, and damaging shore structures. The ice cover also impacts the water balance of the lake by affecting lake evaporation and other heat and momentum transfers. The biology and chemistry of the lakes are also affected by the length and extent of ice cover. Climate change associated with global warming will possibly affect the ice cover which in turn will affect other physical, chemical, and biological processes. Objectives of this program include (1) developing improved models to better simulate the seasonal cycle of ice formation and loss on the Great Lakes, (2) modeling Great Lakes ice cover for past winters, and (3) providing historical information on lake-scale 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. In FY 93, the evaluation of a linked model for lake ice and lake evaporation was completed, and the model was used to simulate the lake-averaged ice cover climatology for each Great Lake for three base periods. Analysis of Grand Traverse Bay and Lake Mendota ice cover freeze and breakup dates was completed. The long-term freeze-up and ice-loss records at both Grand Traverse Bay and Lake Mendota (which began in the 1850s) exhibit a shift in the average date to later freeze-up, earlier ice-loss, and shorter duration of seasonal ice cover starting about 1890. Another important finding is that the timing of freeze-up and break-up at these two locations represents an integration of air temperatures over slightly different seasons (months). Thus, a gradual warming during the 20th century, which was reflected in a second shift to earlier average ice-loss dates after 1890, was first evident in Grand Traverse Bay ice-loss dates (starting around 1940) and later in the ice-loss dates of Lake Mendota (starting around 1980) (Figure 2). Changes in the average freeze-up and ice-loss dates were quantified in terms of changes in average seasonal air temperature by empirical and

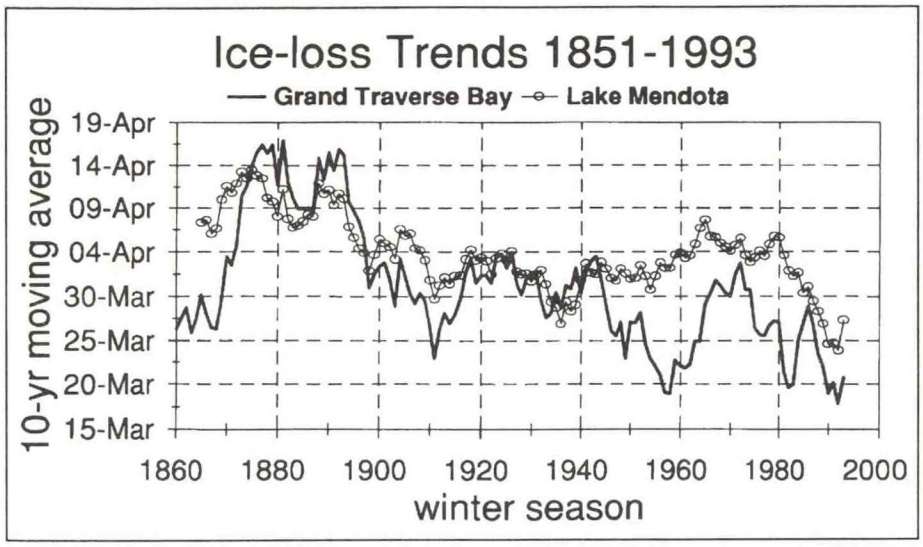


Figure 2. Ten-year moving average of ice loss date (plotted on year 10) for Grand Traverse Bay and Lake Mendota.

process-driven models and used to estimate changes in average air temperature for ice event integration periods over the past 143 years. Future changes in ice cover will be useful to identify and quantify climate change in winter and spring air temperatures. Recent studies of lake whitefish recruitment and planktonic activity under the ice, respectively, have also demonstrated the importance of ice cover on the winter ecosystem of the Great Lakes.

Thermal Structure Monitoring for Climate Change. (Project Scientist: McCormick)

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 study their dependence on meteorological and hydrological forces with emphasis on potential changes in climate, and (2) to concurrently provide data for improving numerical models that can simulate and predict the thermal structure in the lakes. In FY 93, all subsurface moorings were successfully retrieved and the data were recovered. All thermistor chain data were archived. Water temperature data from two shore sites (Green Bay, WI and Sault Ste. Marie, MI) was collected and archived.

Current Velocity Profile Measurements in the Straits of Mackinac Using Acoustic Doppler Current Profilers. (Project Scientist: Miller)

The Straits of Mackinac connecting Lakes Michigan and Huron is an area of complex flow important to determine chemical and biological material flux, heat budgets, and lake flushing. This program is (1) measuring current profiles in a strongly stratified shear flow, (2) relating these data to the numerous bi-lake hydraulic and hydrodynamic forcing processes, and (3) providing the framework for a future expanded study of the water volume transport process through the straits. In FY 93, net volume flux was computed using both the measured currents and the traditional water balance method. For the 136-day June-October period, the water balance method gave a mean transport of 1600 m^3s^{-1} into Lake Huron, a value similar to previous estimates. Measured currents indicated that the net transport was near zero, due mainly to the large inflow into Lake Michigan during October. The discrepancies between methods may be due to (1) the different time scales inherent in the two methods, (2) the Straits have a greater horizontal shear than assumed, particularly during unstratified conditions, or (3) the influence of strait dynamics. A plan to investigate the effects of sills and boundaries on the strait dynamics and mass flux transports between lakes was developed.

Impacts of Climate Change on the Hydrology of the Great Lakes. (Project Scientist: Croley)

The primary goal of this task is to determine potential impacts of future climate change on the hydrology of the Great Lakes basin, and specifically on net basin water supplies. Of particular concern is how various climate regimes may affect variability from year-to-year in net basin supplies and in lake levels. In FY 92, two geographic areas representing potential future climates in the Great Lakes basin were chosen. They represent "hot and dry" and "hot and wet" possibilities for the Great Lakes. In FY 93, the second two geographic areas, representing potential future climates in the Great Lakes basin, were identified by the Midwest Climate Center (MCC). They represent the "very hot and dry" and "very hot and wet" possibilities for the Great Lakes. MCC prepared the climate data for each geographic region, however, additional data are required for the eastern part of each area (particularly in North Dakota, South Dakota,

Virginia, and parts of Georgia). MCC transferred all overland and overlake meteorological station data required for the four climate scenarios to GLERL; it is also investigating the availability of the additional data identified above. GLERL identified the actual stations to be used in running the hydrologic model for these second two scenarios and has computationally transferred them to the Great Lakes basin. GLERL has almost completed determination of the areal average meteorology for all variables of interest by using its Thiessen-weighting algorithms and data reduction software. GLERL's hydrological simulation models for basin runoff and lake thermodynamics and the Canadian Climate Centre's general circulation model of the atmosphere were used to estimate Great Lakes double CO_2 climate change impacts for the International Joint Commission (IJC) in their Water Levels Reference Study (see Marine Hazards and Water Resources Research). Water temperatures increased, and the lakes changed from dimictic (two turnovers a year as density passes through maximum at 3.98°C) to monomictic (single turnover a year as temperatures stop declining, above 3.98°C, and start rising) between 24% and 98% of the time. The monomictic turnover occurred earlier in the year than the dimictic turnovers, and was deeper (Figure 3).

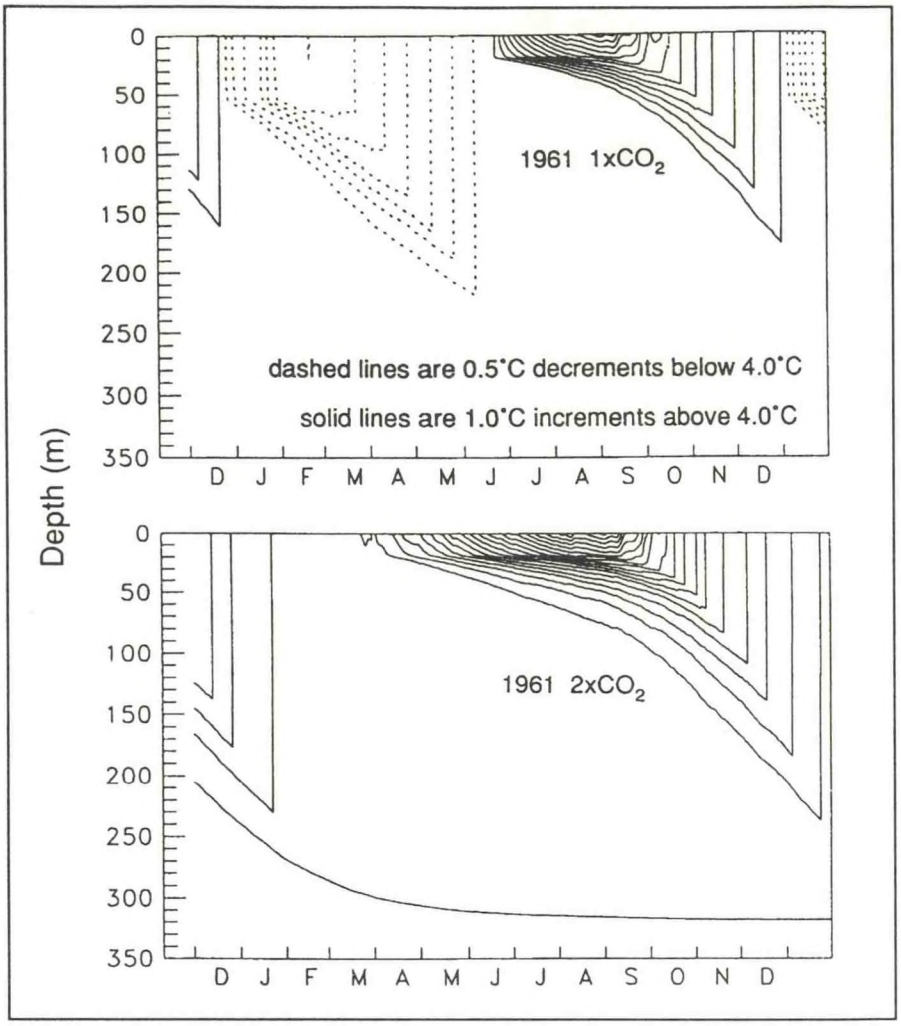


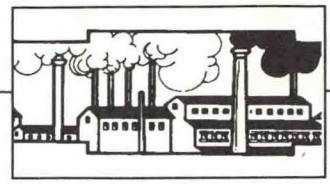
Figure 3. Steady-state Lake Superior depth-time temperature isolines.

Winter Ecology in Lakes. (Project Scientists: Vanderploeg, and Bolsenga)

This program involves laboratory and field studies to determine the effects of ice cover on ecological and related processes for selected sites on Great Slave Lake in the Canadian Northwest Territories (in collaboration with the Canadian National Hydrology Research Institute), on the Laurentian Great Lakes, on the Mongolian large lakes, and on certain small lakes to contrast impacts.

Data from the trip to Great Slave Lake were analyzed. Both *Limnocalanus* and *Diaptomus sicilis* had higher lipid concentrations in Great Slave Lake than in Lake Michigan even though ovary development and egg carrying were high and about the same in both lakes. Feeding rate of *Diaptomus sicilis* in ice covered Great Slave Lake was lower than ever observed in open or ice-covered Lake Michigan. Lowered feeding effort and low quality and concentration of the seston of Great Slave Lake were the reasons for the difference. Stored lipids must be fueling much of the reproduction in Great Slave Lake. These results give us insights on how these copepods, important to large lake ecosystems from the Canadian arctic down to the Laurentian Great Lakes, cope with winter. This information will be useful for designing future studies to evaluate the effect of climate change on these large lakes.

Pollutant Effects

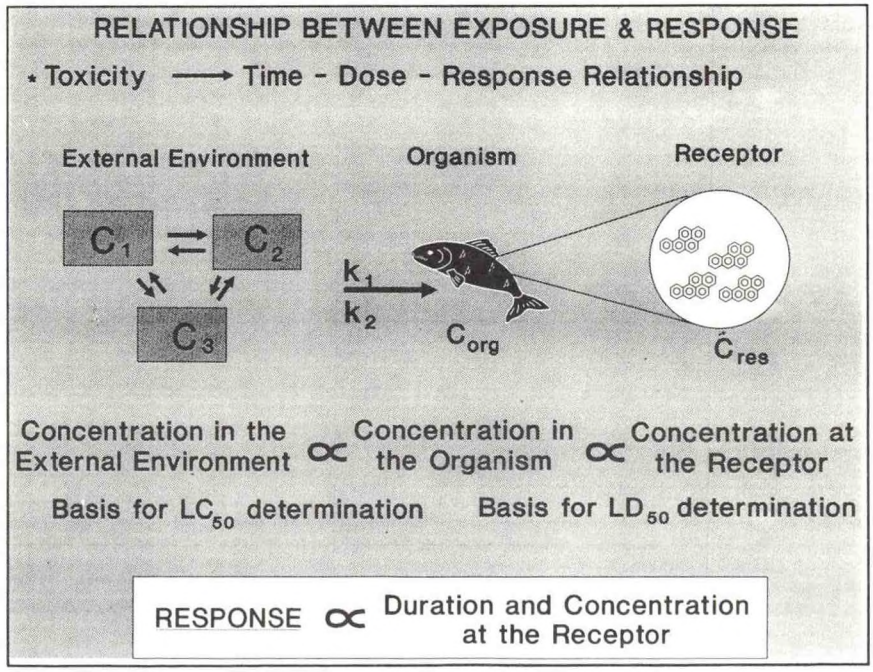


This program pursues research to increase our understanding of the dynamics and effects of contaminants in the ecosystem. The conceptual framework for this research is the basic toxicological concept that effects are related to the attainment of a critical dose of contaminant for a specific duration. This research strives 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 research effort combines process studies and mathematical modeling to improve our understanding and ability to predict contaminant fate and effects in the Great Lakes. The program focuses on toxic organic contaminants, with primary emphasis on exposure and effects and 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 is focused on sediment-associated contaminants and exposure to benthos.

Contaminant Effects and the Relationship to Exposure. (Project Scientist: Landrum)

This project focuses on developing the relationship between contaminant exposure and contaminant effects on biota (Figure 4). To accomplish this goal, new bioassays are being developed and the body burdens required to elicit the effects of these contaminants are being followed. In FY 93, sample analyses of pyrene exposed *Diporeia* (amphipod) and *Lumbriculus* (oligochaete) were completed. The amphipod *Diporeia* did not exhibit a predictable dose response when sediment concentration was the measure of exposure (Figure 5a). However, a good dose response was exhibited when body residue was used to provide the extent of exposure (Figure 5b). The observed LD_{50} (lethal dose which results in 50% mortality of population) was similar to that predicted for nonpolar organic compounds in the range of 6 $\mu mol\ g^{-1}$ in the organism and confirms the previous data for the mixture that produced toxicity at a similar internal concentration. For the worm *Lumbriculus,* no LC_{50} (lethal concentration in environment resulting in 50% mortality) or LD_{50} could be determined for the exposure because the worms exhibited significant avoidance of the sediment at the higher doses, and the lower doses were not sufficient to cause mortality. The EC_{50} (effective concentration at which 50% of worms will

Figure 4. The relationship between the external exposure concentration and the toxic response of the organisms. The response is proportional to the concentration at the receptor which is, in turn, proportional to the concentration in the organisms and subsequently the exposure concentration.



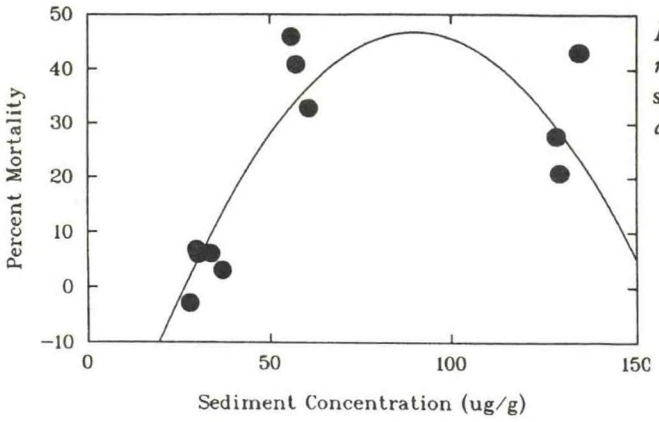


Figure 5a. The response of Diporeia spp. *exposed to pyrene contaminated sediment.*

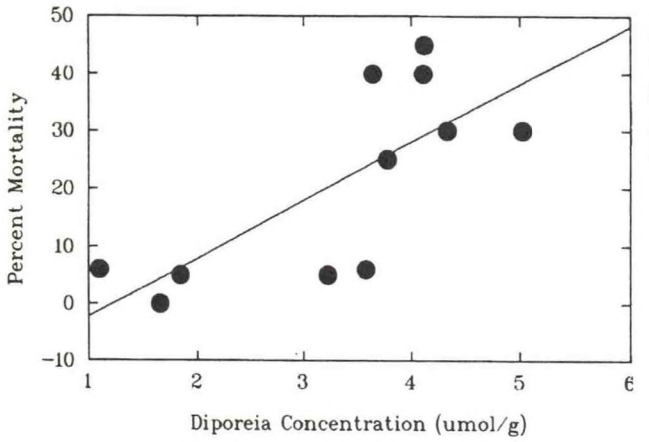


Figure 5b. The response of Diporeia spp. *based on accumulated pyrene concentration.*

leave sediment) for avoidance was 226 μg g^{-1} dry sediment. The uptake clearance (the volume or mass of the source compartments scavenged of contaminant per mass of organisms per time--g dry wt sediment g^{-1} organism h^{-1}) for *Lumbriculus* declined with increasing concentrations of pyrene in the sediment, which reflected the sediment avoidance and perhaps a change in feeding behavior.

Physical and Biological Diagenetic Processes in Sediments.

(Project Scientist: Landrum)

This research examines the feeding, burrowing, and other locomotive activities of benthic invertebrates that contribute to sediment bioturbation and the effect of contaminants on these processes. The effect of bioturbation processes on porosity, particle size distribution, and distribution of organic matter including contaminants is also examined. In FY 93, bioturbation studies using DDT and marine organisms were completed and the samples analyzed.

Long-Term Trends in Benthic Populations.

(Project Scientist: Nalepa)

The objectives of this project are to determine trends in benthic populations in selected areas of the Great Lakes, and, if trends are detected, to determine the most probable reasons for the changes observed such as increases in contaminants in the sediments. In FY 93, samples were collected at 40 sites in southern Lake Michigan in the spring, summer, and fall. The benthic community will be examined and compared to the community found in 1987-87 and 1980-81. This research is closely linked to EPA's EMAP program whose objective is to assess the status of the benthic community in the nearshore waters of the lake. Also, as part of EMAP, benthic samples were collected in the nearshore waters of Lake Superior.

Bioavailability of Sediment-Associated Toxic Organic Contaminants.

(Project Scientist: Landrum)

In order to assess the risks of contaminated sediments, there is a need to determine the conditions under which sediment associated toxic organic compounds accumulate in benthic organisms, to determine if the toxins are transferred up the food chain, and to develop models for describing bioaccumulation. In FY 93, methods to measure assimilation efficiencies in benthic invertebrates ingesting sediment-associated contaminants continued to be developed. The previous finding that Chromium-51 would not serve as an appropriate nonassimilated tracer for organic contaminants led to investigations of the use of organic carbon as a tracer. The question of the importance of feeding was also investigated in several bioassays. Careful studies employing *Diporeia,* an organism that feeds intermittently, showed that feeding was very important for accumulation of hydrophobic organic contaminants such as benzo(a)pyrene (BaP) and hexachlorobiphenyl (HCBP). Overall, the assimilation efficiency for sediment-sorbed BaP is approximately 15-30% for *Diporeia* and 20-30% for *Lumbriculus variegatus.* The assimilation efficiency for HCBP was estimated to be about 60% for *Diporeia,* but considerable effort

must be made before more accurate values can be determined. Sediment aging was investigated in a series of studies with BaP. This effort extended over the course of 1 year. The distribution of contaminant particles of different sizes was examined as one measure to help explain the variability in bioavailability among different sediment and for different classes of compounds that could not be explained by organic carbon normalization. The studies examining the relative exposure for *Chironomus riparius* (midge), *Lumbriculus variegatus,* and *Diporeia spp.* to whole sediment, elutriates, and pore water continued and were completed. Part of the effort to better define the exposure involved studying the partitioning to the dissolved organic matter.

Results showed that aqueous extracts of whole sediment did not accurately represent the exposure observed in whole sediment. Generally, the aqueous extracts underexposed organisms compared to whole sediment, even after adjusting accumulation to the fraction of organic carbon in the test media. Bioaccumulation and contaminant clearance data suggest that a number of factors such as the indicator species, exposure media, and chemical/physical properties of individual contaminants are responsible for the accumulation differences observed among the tested media. Normalizing bioaccumulation to the amount of organic carbon in a source compartment adjusted for bioavailability differences of only some contaminants. We suggest that the bioavailability of contaminants such as those tested cannot be accurately predicted in bioassays that expose organisms to aqueous representations of whole sediment.

Assessment of Extractability and Bioavailability. (Project Scientist: Van Hoof)

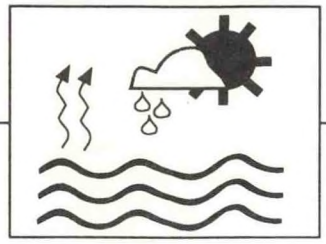
Currently, a major topic of interest in assessing the exposure of benthic organisms to hydrophobic organic compounds (HOCs) is the relative importance of uptake via the bulk overlying water, interstitial pore water, or ingestion of sediment. The bioavailability of HOCs is a function of the kinetics of desorption from particles and dissolved organic matter, mass transfer and assimilation from the aqueous phase, and ingestion of particles and assimilation. The context of the HOC association with sediment particles is important to the measurement of these rates. For example, two factors often neglected in laboratory studies, which may significantly influence the extent of sorption, are pollutant-sediment contact time and physicochemical processes involved with environmental weathering. Consequently, there is a significant need to compare benthic organism accumulation of HOCs from laboratory-dosed sediment exposures to accumulations obtained from field contaminated sediments. This project is assessing the importance of environmental factors such as contact time and weathering on HOC sorption to sediment and bioaccumulation by the benthic organism *Diporeia sp.* In addition, the potential of using chemical extraction kinetics to assess bioavailability is being explored.

In FY 93, analytical methods were established for the extraction of PAHs in tissue and sediment and for extract cleanup. A method for the quantification of PAHs was also established using an isotope dilution technique by gas chromatography/mass spectrometry (GC/MS). Time courses for *Lumbriculus* uptake of laboratory-dosed isotopically labeled PAHs were measured simultaneously with those of field contaminant PAHs. Uptake clearance rate calculations are in progress. Supercritical extraction instrumentation was installed and demonstrated. Significant progress was made to establish the best available technique to measure truly dissolved trace organics in lake water. The XAD (cross-linked polystyrene) resin extraction was used instead of the logistically difficult gas-purging technique. Consultation with experts of both techniques confirmed that both methods gave similar results. The apparatus is currently under construction and will be field tested in August.

Bioenergetics of the Great Lakes Amphipod *Diporeia sp.* (Project Scientist: Quigley)

The overall project objective is to obtain a detailed energy (carbon flow) budget for *Diporeia* sp. In FY 93, all data analyses were completed and manuscripts are being written.

Marine Hazards and Water Resources Research



Great Lakes water is used for drinking, power generation, commercial shipping and recreation, and it supports an extensive commercial and sport fishery. Both natural (evaporation) and anthropogenic (diversions, consumption) influences threaten this valuable resource. Astute water management must be practiced to preserve the Great Lakes water supply. This program relates to prediction, climatology, statistics for decision making, process studies, and interfaces with policy and decision makers. Marine hazards are a result of a variety of environmental phenomena. Such hazards 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 hazards in the Great Lakes system and (with the exception of low lake levels) in other coastal areas as well. Human-caused hazards also pose serious threats, especially spills of petroleum products and chemicals. This program is providing models and other service products to assist in marine hazard prediction, emergency response, damage prevention and reduction, and more effective management of water resources.

Great Lakes Evaporation and Heat Storage. (Project Scientist: Croley)

This program seeks to (1) derive lake surface temperature and cloud cover models using NOAA and Geostationary Operational Environmental Satellite (GOES) data, (2) classify and interpret lake surface temperature patterns with special respect to weather situations, (3) develop a lake surface temperature model on the basis of NOAA satellite data to derive surface temperature patterns when no satellite data are available, and (4) develop and refine spatially distributed models of the heat fluxes at the lake surface by using satellite and meteorological data, including a model to determine lake evaporation. In FY 93, nonproprietary image processing software to automatically detect cloud cover, extract water surface temperature for each lake, display and manipulate temperature images, and provide interfaces to other image processing software and hardware was developed, tested, and used. A database containing all available surface temperature images, all cloud masks, and all cloud-free images was created for each lake. All available cloud-free images were used to create a normal temperature database to describe the long-term normal annual cycle of the two-dimensional temperature patterns. This database was combined with the normal ice cover reported in the Great Lakes Ice Atlas to yield a database for normal temperature and ice cover for each Great Lake. This database was used to simulate temperature and ice cover patterns in the newly developed two-dimensional thermodynamic model of the Great Lakes. The model uses meteorological measurements from different sites and satellite-derived surface temperatures to estimate energy flux patterns at the water surface as depicted in Figure 6.

Great Lakes Hydrology and Ice Data Bases. (Project Scientists: Assel, and Lee)

This program develops and maintains historical Great Lakes hydrology and ice cover databases. It develops and maintains geographic information data bases of the Great Lakes basin and links the hydrology and ice cover databases with the geographic databases for spatial analysis. In FY 93, pre-1948 historic monthly precipitation data for the eight Great Lakes states was digitized, except for 70 stations. Work has begun to digitize the pre-1948 monthly air temperature data. An interactive computer animation of the normal temperature and ice cover for the Great Lakes was produced.

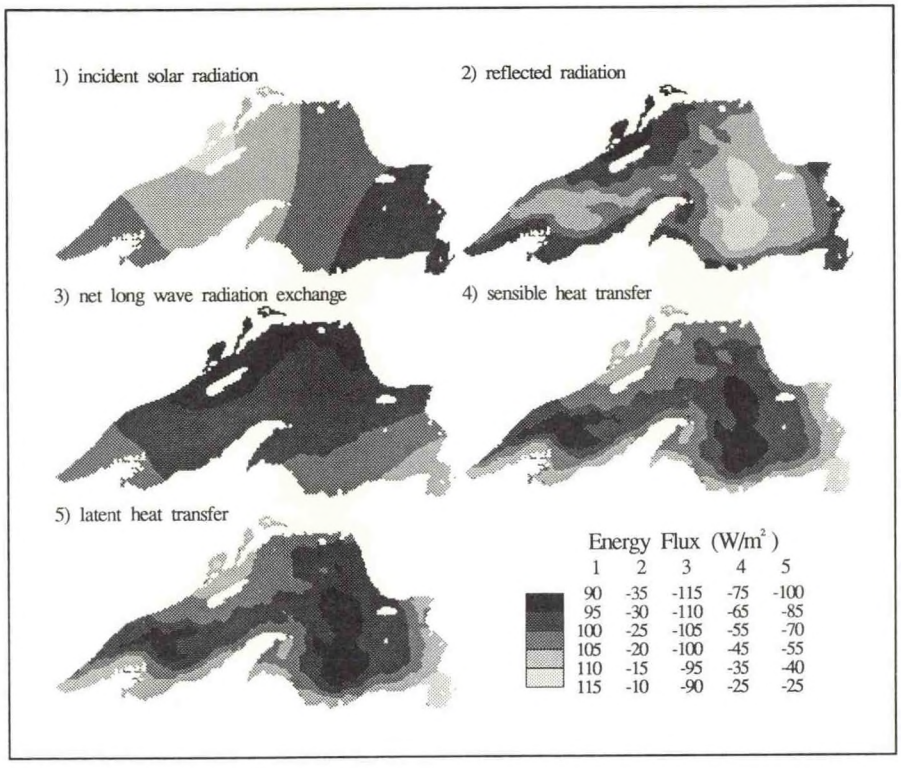


Figure 6. Lake Superior surface energy fluxes. From the GLERL Geographic Information System (GIS) Laboratory.

Lake Circulation and Thermal Structure Modeling. (Project Scientists: Schwab, McCormick, and O'Connor)

The objectives of this project are (1) to develop and test improved hydrodynamic models that can simulate and predict the three-dimensional structure of currents and temperatures in the Great Lakes, and (2) to extend the models to simulate and predict the transport and diffusion of pollutants and nutrients and to participate in coupling these models to aquatic ecology and water quality models. In FY 93, heat fluxes calculated using Great Lakes Forecasting System (GLFS) algorithms were compared with calculations using other methods; the results were comparable. The GLFS combines data from satellite, land, and lake-based systems with computer models for real-time prediction of the status of the Great Lakes. The system, linking existing models, computer systems, and data networks, is a joint development of NOAA/GLERL and The Ohio State University (OSU). Investigations into the coupling of wind wave dynamics with three-dimensional circulation were initiated. A suite of sample products from the GLFS for display on PC-based GLFSView (computer program to view GLFS output) were developed and evaluated for user interest. These include plots of vertically integrated currents, surface water temperature, water level, and satellite-derived fields. A detailed comparison of three-dimensional model results with observational data was initiated for the 1979 Lake Erie US/Canada Joint Experiment dataset and for the 1991 CoastWatch dataset. Lake Erie nowcasts on OSUs Cray computer continued through 1993. Tests showed that nowcasts produced on a Unix workstation at GLERL with a 5-km grid compare favorably with OSU's nowcasts on the 2-km grid.

Great Lakes Water-Level Statistics for Decision-Making. (Project Scientists: Quinn, Lee, and Herche)

The long-term objective of this project is to develop improved water-level statistics that reflect (1) existing hydrologic and hydraulic conditions, (2) the long lag response of the lakes to meteorological variability, (3) secular changes in climatic regimes, and (4) the needs of diverse Great Lakes decision makers.

Hydro-Quebec recently undertook a study of the spillway adequacy of the Beauharnois-Les Cedres control structures located in the St. Lawrence River, upstream of Montreal, Quebec. A GLERL scientist served on the committee established to provide consultation and review of the development of a probable maximum flood (PMF). GLERL was contracted to model Lake Ontario outflows as part of the study.

Stochastically generated Great Lakes net basin supplies were used by GLERL in a Great Lakes hydrologic response model to obtain Lake Ontario levels and outflows. Nearly 50,000 years of Lake Ontario outflows were simulated and analyzed (Figure 7). Historical Lake Ontario outflows could not be used for the study because of anthropogenic effects reflected in the data, the statistically short record length, and autocorrelation of the data. A significant problem was the lack of robustness in the Lake Superior and Lake Ontario regulation plans during simulations with extreme water

supplies. GLERL modified the regulation plans consistent with the IJC's regulation criteria and past operational actions to give reasonable results under these conditions. It was found that some of the regulation criteria cannot be met simultaneously under extreme conditions and that historical water supplies, the current standard for the design and evaluation of modifications to the operational regulation plans, should no longer be the sole test of the plans.

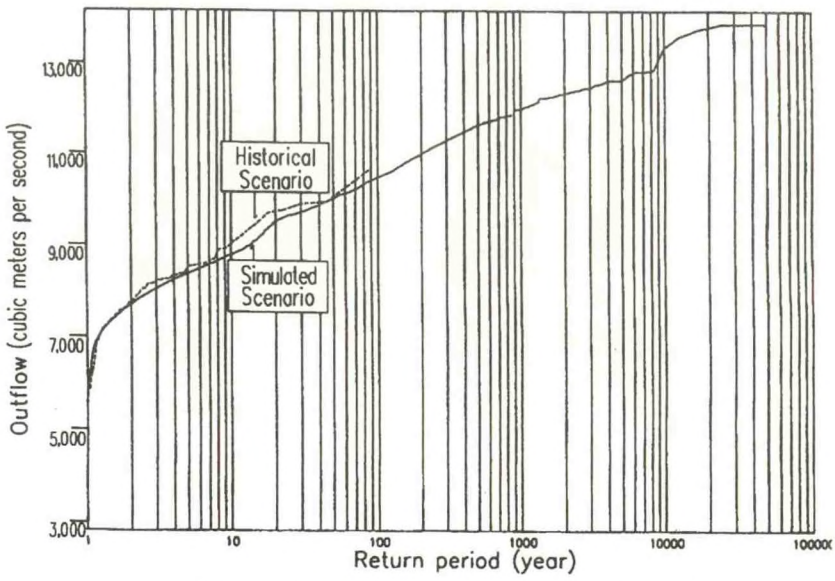


Figure 7. Cumulative frequency of quarter monthly maximum annual flows in Lake Ontario.

Coastal Hazards. (Project Scientist: Schwab)

Meteorological and oceanographic conditions in coastal areas can sometimes become dangerous enough to cause significant damage to property (boats, ships, structures, etc.) and result in loss of human lives. Therefore, it is imperative to have an operational system in place that will provide timely warnings of impending adverse natural conditions to the coastal community so that precautions can be taken to mitigate the damages. The primary factor responsible for producing hazardous conditions is the marine surface wind. The wind is a hazard by itself for boats, ships, and other structures, but the danger to these is increased by wind-generated waves, storm surges, and generated currents. This project addresses the development of models for coastal wind forecasts since these are first-order factors in creating hazardous conditions in coastal regions. The primary objectives of this study are to test, evaluate, and make refinements to marine boundary layer physics in the mesoscale models for wind predictions over the Great Lakes. GLERL researchers work closely with researchers at the National Meteorological Center (NMC) who are involved in developing the Eta-coordinate model. Specifically, the focus will be on testing model performance over the Great Lakes region and looking for necessary changes in the grid representation of the coastline geometry and topography, and modifications to the boundary layer physics to improve its performance. In FY 93, we began to acquire Eta model forecasts from the 40 km semi-operational run in April 1993. Surface fields for friction velocity, heat flux, and wind vectors are being archived at GLERL. Comparisons with the National Data Buoy Center (NDBC) buoy data in the Great Lakes were begun.

Next-Generation Runoff Model. (Project Scientist: Lee)

GLERL has developed conceptual model-based techniques for simulating moisture storages and runoff from the 121 watersheds draining into the Laurentian Great Lakes. The existing hydrologic process models are lumped-parameter models that apply to irregular-shaped areas of 30-100 km and periods of 1-30 days. This program seeks to refine runoff models so that they can be integrated with atmospheric process models in another task and can incorporate recent advancements in measurements of hydrometeorological data. Linking the surface hydrology process models with atmospheric process models will allow feedback between climate and land surface and result in more accurate estimates of regional and local impacts of climate change. The goals of this program are to (1) develop the next-generation runoff models with gridded land surface parameterizations from 1 to 30 km, which can be incorporated into mesoscale atmospheric models and water supply simulation and forecasting packages, and (2) to implement the improved models at agencies responsible for water resources forecasting and management. In FY 93, we acquired a geographic information system for water resources and began acquisition and development of spatial databases.

Coupled Hydrosphere Atmosphere Research Model.

(Project Scientist: Croley)

Hydrologic-atmospheric impacts of climate and their management and changes in the Great Lakes are important and share several interesting aspects. Understanding how the Great Lakes affect the weather and understanding how the weather affects the Great Lakes will allow more informed decisions to be made concerning potential impacts of an altered climate scenario and also concerning highly anomalous (wet) seasonal weather patterns such as that experienced in parts of the midwest during the summer of 1993. The main goal of this research is to assess the hydrologic-atmospheric dynamics within the Great Lakes basin. This is supported by three objectives: (1) develop a Coupled Hydrologic-Atmospheric Research Model (CHARM) from existing atmospheric and hydrologic models by using two-way dynamic interactions, (2) enhance the model with second-generation surface parameterizations for lake thermal flux and runoff, and (3) refine earlier climate change estimates and estimates from other mesoscale modeling efforts by developing one-way linkages between them and the Great Lakes hydrology models. In FY 93, we acquired a Regional Atmospheric Modeling System (RAMS) and have modified it to accommodate a version of the GLERL runoff model.

International Joint Commission (IJC) Great Lakes Levels Reference Study.

(Project Scientists: Lee, Croley, and Quinn)

On August 1, 1986, the Canadian and U.S. Governments, in response to record high Great Lakes water levels, issued a Reference to the IJC to examine and report on methods of alleviating the adverse consequences of fluctuating water levels in the Great Lakes-St. Lawrence River Basin. Phase II began in November 1990 and was completed in March 1993 with the submittal of the Study Board's recommendations to the Commission.

GLERL scientists served as members of Working Committee 3, charged with addressing existing regulation, system-wide regulation, and crises conditions responses. The focus was on the hydraulics and hydrology of the Great Lakes-St. Lawrence River system, climate and climate changes, and on the improvement of water level forecasting and statistical techniques. Water supply scenarios for the testing and evaluation of proposed regulation plans were prepared and included an historical net basin supply series, wet and dry years analogues, and a global warming scenario. A Basis of Comparison was also prepared—a 90-year set of lake levels and flows reflecting a consistent hydraulic regime in the Great Lakes-St. Lawrence River system. These levels and flows were used to assess the effects of modified lake regulation and climate change. In addition, a probabilistic net basin supply forecast technique was developed using GLERL's Great Lakes Forecast Package. A group of experts convened to develop improved water level statistics, and to assess specific statistical and forecasting informational needs of those affected by Great Lakes water levels.

NECOP

The Nutrient-Enhanced Coastal Ocean Productivity (NECOP) program is one of a series of NOAA-wide activities within the Coastal Ocean Program dealing with major problems in the coastal ocean. The central hypothesis is that increased nutrient input from the Mississippi River has led to increased productivity, with undesirable consequences. GLERL is involved in several studies that have been underway for 3 years.

Fate and Effects of Riverine (and Shelf-Derived) Dissolved Organic Carbon and Nitrogen on Mississippi River Plume-Gulf Shelf Processes. (Project Scientists: Gardner, and Eadie)

The objectives of this study are to define the chemical and isotopic composition of riverine and Mississippi River Plume/Gulf Shelf (MRP/GS) dissolved organic nitrogen (DON) and determine the biological reactivity of dissolved organic carbon (DOC) and DON. Isotopic analysis allows us to distinguish between riverine input nutrients and shelf-derived nutrients and also to measure rates of nutrient recycling. In FY 93, sample analysis from 1992 cruises was completed and samples and data were collected on the July 1993 NECOP process cruise. Preliminary analysis reveals that nitrogen recycling by bacteria and invertebrates is a major process providing nitrogen to phytoplankton, and that nitrogen recycling is also strongly dependent on primary production.

Dark bottle incubations and $^{15}NH_4$ isotope dilution experiments, in incubators designed to simulate natural light and temperature conditions, were conducted on six cruises to estimate nitrogen regeneration rates.

Retrospective Analysis of Nutrient-Enhanced Coastal Ocean Productivity in Louisiana Continental Shelf Sediments (Project Scientists: Eadie, and Robbins)

The objectives of this program are to (1) identify areas in the coastal region where sediments with coherent geochronologies 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, and stable isotopes).

Records of nutrient loads into the Gulf of Mexico from the Mississippi River only extend back to the 1950s. To estimate nutrient loading from the Mississippi-Atchafalaya River (MAR) system prior to that time we looked at commercial fertilizer consumption records (solid area shown in Figure 8). Since most of the fertilizer consumed in the U.S. is used within the Mississippi River basin, the commercial fertilizer consumption records provided useful information regarding nutrient loads to the Gulf via the MAR system. A substantial increase in fertilizer use began after 1935 and continued to increase until the mid-1970s. Our hypothesis was that the increased load of nutrients from the Mississippi River increases primary productivity in the shelf region when that additional organic matter settles to the bottom waters and is decomposed by bacteria. Oxygen is then used faster than it can be replaced, and hypoxia occurs. Analysis revealed that a change in the isotopic composition of the carbon in the shells of bottom dwellers begins after 1950. This is caused by an increase in the delivery of organic material to the bottom waters, the fuel that causes hypoxia. Our results indicate that sometime after World War II, increased nutrient loads from the Mississippi River to the Gulf of Mexico caused an increase in the amount of organic matter delivered to the stagnant bottom waters, resulting in an increase in the consumption of oxygen, causing hypoxia.

Buoyancy and Nutrient Exchange in the Mississippi River Outflow Region. (Project Scientists: Bratkovich, and Dinnel)

The focus of research in this program is the examination of processes contributing to the advective exchange of environmentally significant fields in the Mississippi River outflow region. The primary objectives of this study are to establish an historical relationship between

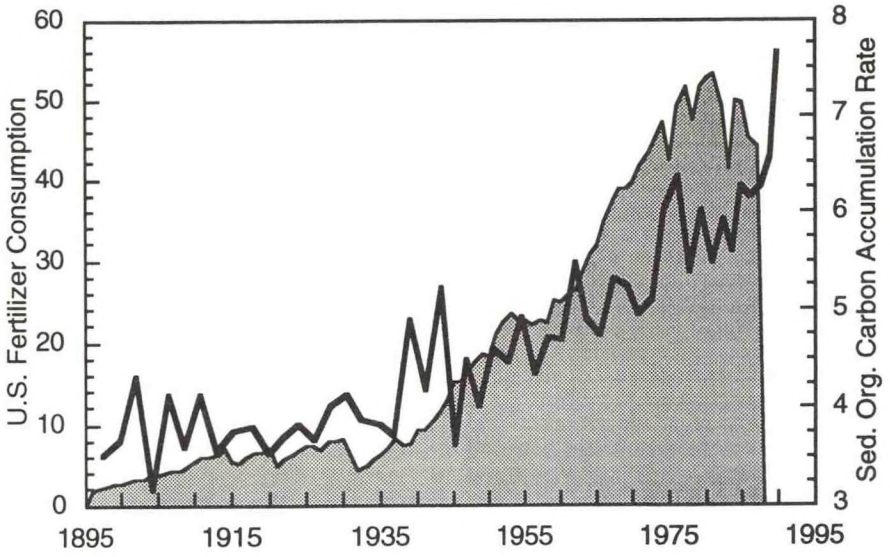


Figure 8. Comparison of U.S. fertilizer consumption (shaded area) with amount of organic carbon accumulation in the sediment (line) in the region of seasonal hypoxia.

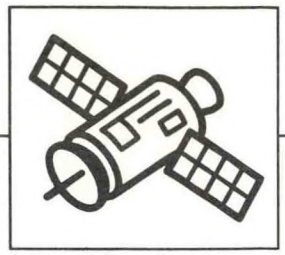
buoyancy and nutrient fluxes for the Mississippi-Atchafalaya River (MAR) system and to quantitatively determine the scales of variability for buoyancy and nutrient fields in a shelf region dominated by riverine sources. In FY 93, field work and analyses of field data and the historical database continued. In addition, a simple plume model for physical-biological interactions was constructed.

Primary Production and Vertical Flux of Organic Carbon. (Project Scientists: Fahnenstiel, Redalje, and Lohrenz)

This research is addressing the following objectives: (1) characterize photoautotrophic community dynamics in relation to optical conditions, nutrient inputs, and other aspects of the physical and chemical environment, (2) examine the relationship between phytoplankton production, growth, and biomass, and the vertical export of fixed carbon from the surface waters of the MRP Inner Gulf Shelf (IGS), and (3) develop conceptual and predictive models that describe the production and fate of fixed carbon as a function of optical conditions, nutrient inputs, and other environmental variables. In FY 93, we participated in the NECOP cruise and workshop.

Primary production is difficult to measure directly. In the study region, primary production was estimated using a model based on the Great Lakes Primary Production Model. The model was calibrated with measured values of daily variations in surface light, depth variations in photosynthetic characteristics, light penetration, and chlorophyll concentrations. These direct measurements were taken at 30 stations during five NECOP cruises. By applying these measured values to the model, primary production could be estimated. Results indicate the highest integral production was generally seen at regions of intermediate salinities where plume and oceanic waters mixed.

CoastWatch



CoastWatch is a NOAA-wide program within the Coastal Ocean Program. As a CoastWatch Regional Site, GLERL is establishing operations of the Great Lakes Regional National Ocean Communications Network (NOCN) Node (RNN), identifying regional CoastWatch users and their NOAA data needs, and supplying useful products to participants in the Great Lakes CoastWatch Program.

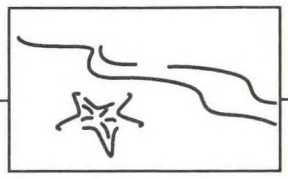
Great Lakes CoastWatch and NOAA Ocean Communications Network. (Project Scientist: Leshkevich)

The objectives of this task are to (1) establish operations of the Great Lakes RNN, (2) identify regional CoastWatch users and supply their NOAA data needs, and (3) research and develop related products and uses specific to the Great Lakes region using CoastWatch data. In FY 93, Great Lakes CoastWatch users were increased from 15 to 20 and their CoastWatch data needs were supplied. Downloading of Great Lakes water-level data from the National Ocean Service (NOS) was begun and the data were incorporated (redistributed) as a CoastWatch product on an experimental basis. The Great Lakes CoastWatch Users Guide and viewing and printing software were distributed to current local users. Also Ocean Map (OCNMAP) multi-channel sea surface temperature (MCSST) and non-linear sea surface temperature (NLSST) data were compared with NDBC buoy measurements of surface water temperature for approximately 1 year of data.

Great Lakes CoastWatch Product Development and Research. (Project Scientist: Leshkevich)

The objectives of this task are to evaluate and help validate Great Lakes CoastWatch products, provide input to the National Environmental Satellite, Data, and Information Service (NESDIS) for product needs and development, and research and develop related products and uses specific to the Great Lakes region using CoastWatch data. In FY 93, field work to collect ground truth for synthetic aperture radar (SAR) data analysis was completed. Naval Research Laboratory (NRL) Satellite Image Processing System (NSIPS) image processing software was obtained from Stennis Space Center for use in SAR data analysis.

Nearshore Processes



This new program, in cooperation with the State of Wisconsin, the University of Wisconsin, and the U.S. Geological Survey, was begun to provide much needed information on the nearshore environment. This information is essential to wise management of the Great Lakes ecosystem.

The specific objectives of this program are to (1) synthesize the results of research studies on coastal hydrodynamics, biological processes, and water chemistry of the nearshore region and apply them to practical problems of coastal environmental management and planning, (2) sponsor basic and applied scientific research to critical coastal environmental problems requiring unique expertise available in academic and NOAA laboratories, and (3) cooperative closely with other federal agencies, such as the USEPA, USGS, USFWS, and NBS in their areas of expertise, to develop comprehensive knowledge (biology, chemistry, and physics) of each study area.

Biological Productivity Along Thermal Fronts and in Coastal Waters (Project Scientists: Brooks and Sandgren, Univ. of WI; Bratkovich, GLERL)

The objective of this project is to collect data in the Wisconsin nearshore area to define the physical and chemical conditions in the water column on either side of the thermal front as the front progresses offshore. The data collected will also document onshore-offshore gradients of physical water mass structure and associated chemical and biological variables in the coastal zone near Milwaukee.

In FY 93, a joint study on the biological productivity along the thermal front in nearshore areas was conducted for both the west shore and east shore of Lake Michigan. The study is aimed at assessing the role thermal fronts play as barriers to, or facilitators of, advective transport of heat, nutrients, and biota from the coastal zone to offshore areas. Successful weekly cruises were conducted during May and June.

Wisconsin Nearshore Water Study (Project Scientists: Lee, Univ. of WI; Liu, GLERL)

This project focuses on understanding the factors affecting lakeshore erosion and property damage along the western Lake Michigan shoreline. Wind and wave models will be identified for evaluation with wind and wave data measured with the nearshore NDBC buoy. Furthermore, an array of wave measurements in shallow water will be made to study the shoaling effects.

In FY 93, the measured wind, wave, and current data are being used to develop a detailed numerical hydrodynamical model to cover Milwaukee Harbor and the nearshore lake waters. The results help understand and manage water quality in Milwaukee Harbor and the nearshore area of Lake Michigan.

The Pollution Plume Outside Milwaukee Harbor and its Relationship to the Quality of the Drinking Water Taken into the Howard Avenue Treatment Plant (Project Scientists: Christensen, Univ. of WI; Bratkovich, GLERL)

This project is aimed at investigating how the Milwaukee Harbor pollution plume impacts the quality of the intake water from nearshore Lake Michigan and whether the intake pipe will be extended or relocated. The primary product will be analyzing available existing data and a collection of regularly observed pollution plumes documented by curves of constant value of water quality parameters.

In FY 93, initial evaluations were made of the pollution plumes in the outer Milwaukee Harbor and nearshore areas based on turbidity, ammonia, and chloride data collected at the Milwaukee Metropolitan Sewer District.

Dynamics of Nearshore Fronts/ Plumes and Related Ecological Issues (Project Scientist: Bratkovich)

Coastal fronts and buoyant plumes are two related classes of hydrodynamic phenomena found in nearshore waters. Fronts and plumes can have a variety of ecological impacts including the deterioration or enhancement of coastal water quality, a recent topic of concern since Milwaukee residents have experienced drinking water problems.

The objectives of this project are (1) to acquire physical, chemical, and biological data appropriate to the study of fronts and plumes in the vicinity of Milwaukee Harbor on the west side of Lake Michigan, (2) to acquire similar data in the vicinity of Grand Haven, MI on the east side of Lake Michigan, (3) to analyze these data sets to look for similarities or contrasts in the variability and structure of related fields and underlying kinematic, thermodynamic, or dynamic principles. In addition to the above, we will continue to gather, organize, and analyze historical data base components pertinent to meteorological forcing and limnological response functions.

Current Measurements in the Nearshore Milwaukee Area (Project Scientist: Miller)

The nearshore zone is the most environmentally sensitive area in the Great Lakes and also the region where the major nutrient and contaminant inputs occur. There is a need for increased understanding of the physical dynamics in this region and the mass exchange processes that occur between the nearshore region and the open lake. This project involves long-term measurement of the current structure and variability in both the nearshore and adjacent offshore areas.

The objectives are (1) to obtain current velocity and temperature data in the coastal zone near the NDBC buoy near Milwaukee Harbor, WI for 1 year, (2) determine the magnitude of the interaction between the nearshore and offshore dynamics on a cross-lake transect between Grand Haven, MI and Milwaukee, WI, and (3) to identify the processes responsible for the transport of materials across the lake slope.

In FY 93, one mooring of current meters was deployed to measure current speed and water temperatures at two depths.

Surface Wind, Wave, and Temperature Measurements in the Nearshore Milwaukee Area (Project Scientist: Liu)

Wind and waves are primary driving forces for water movements in the oceans and lakes and are major basic factors in determining nearshore hydrodynamics. GLERL has successfully studied, developed, and tested deep water wave prediction models for the Great Lakes, but shallow water effects that alter waves in the nearshore zone remain unexplored. A coupled approach of experimental analysis and model development for shallow water wave effects in the Great Lakes is essential and presently nonexistent. To remedy this critical deficiency, a collection and synthesis of wind and wave data should be the first and foremost task in a comprehensive nearshore hydrodynamics study. The NDBC buoy was deployed and collected wind and wave data in the center locations of the Great Lakes since 1979. While nearshore areas of the Great Lakes are most environmentally sensitive and intensely utilized, a similar data collection system for the nearshore area is, however, completely lacking and urgently needed.

The objectives of this project are to obtain detailed measurements, quantitative analyses, and couple them with model studies to provide the presently unavailable nearshore wind and wave information needed for the nearshore hydrodynamics studies.

In FY 93, A NOAA/NDBC buoy was deployed near Milwaukee Harbor to provide meteorological and directional wave information. The excellent data sets obtained from this buoy are useful for supporting the nearshore research studies and for assisting the National Weather Service in providing more accurate real-time information for the lake nearshore area.

Also in FY 93: (1) two workshops were held to discuss and initiate needed studies on physical processes for the Wisconsin nearshore environment toward developing effective Great Lakes coastal nearshore management strategies. (2) Deployed and retrieved GLERL WRIPS wave measurement buoy in nearshore western Lake Michigan southeast of Milwaukee Harbor. Measurements from this buoy will be used to compare wave characteristics with nearshore and open lake measurements from NDBC buoys. (3) Analyzed WRIPS buoy measurements collected during 1988 and 1989 from other areas in the Great Lakes. The analysis using Wavelet Transform techniques showed the importance of wave grouping characteristics.

Exchange Processes in Coastal Environments. (Project Scientist: Bratkovich)

This project 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 that 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 that affect variability in fields of environmental concern.

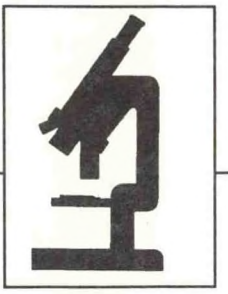
In FY 93, several historical data sets have been organized and documented in report format. A river plume simulation model was also constructed and tested with the intent of tracing riverine constituent evolution as they encounter and mix with receiving reservoirs (lakes or oceanic shelf waters). Finally, a scientific journal article was published on the topic of oil spill advection in a coastal setting.

Analysis of Sediment Resuspension Data in Southern Green Bay (Project Scientist: Hawley)

The objectives of this project are to develop an empirical model of wave-induced sediment resuspension in Green Bay, and to evaluate this model using the field observations collected during the summer of 1989 at several sites in the southern part of the bay.

In FY 93, several existing models of resuspension were evaluated for use (including those developed by Lavelle, by Glenn and Grant, and by Hawley and Lesht), but since they all assume lateral homogeneity, they were unsuitable for use. This is because water depth changes substantially over short distances in Green Bay. This makes resuspension a very local occurrence and increases the importance of lateral advection as a process affecting the measured concentrations of suspended sediment. In order to evaluate the data collected, either the model must include advective effects (which will require a three-dimensional circulation model), or the effects of these advective episodes must be removed from the data being used to evaluate the simulation.

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.

(Project Scientist: Robbins)

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.

During FY 93 analyses of sediment cores from Lake George and Portage Lake, both of which are at or near EPA Superfund sites, were completed. Bromine was found to be strongly correlated with biogenic silica, which is a surrogate for determining diatom biomass. Previous sediment trap studies at GLERL showed that bromine is least subject to removal from the epilimnion of the lakes because of its low affinity for particulate matter and high biological activity, which allows much of it to recycle within the epilimnion. The correlation in sediment cores with biogenic silica may allow bromine to also be used as a surrogate for biomass. To explore this further, biweekly plankton sampling was initiated to determine the seasonal variations in elemental composition, especially bromine.

The reworking rates of *Yoldia* were measured using the gamma scan system, providing the first measurements of its apparent rate and range of diffusive mixing of sediments. Existing bioturbation models were employed with suitable revision for interpretation of the data. Neutron activation studies were also carried out, establishing the feasibility of using activated metal-doped glass particles of specified size to study particle-selective reworking of sediments using the gamma scan system.

Radiocesium profiles were collected from Lake Baikal as part of a collaboration with the University of Wisconsin. Analyses of these samples by neutron activation and development of a Lake Baikal mass balance model to be used for interpreting the data were begun. A profile of radiocesium in a well-characterized core from Lake Coeur D'Alene was completed as part of a project with the USGS. The radiocesium profile exhibited several correspondences with atmospheric loadings, which permitted development of a first cut model of long-term transport in the lake/river/watershed system.

Carbon Biogeochemistry in Lakes and Coastal Ecosystems.

(Project Scientist: Eadie)

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 parameter 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.

During FY 93, analyses of C-13 and N-15 in sediments from all of the Great Lakes were completed and revealed evidence for a basin-wide increase in productivity beginning in the mid-nineteenth century. In Lake Erie, we also found a clear signal of reduced productivity after the mid 1970s due to the implementation of nutrient load reductions. The sediment record of nitrogen isotopes in Lake Erie also clearly documented a major isotopic shift beginning around 1875, which we attribute to the onset of extensive denitrification associated with widespread water column oxygen depletion. We also started evaluating the use of stable isotopes as possible tracers of the pathways of energy and trace contaminants through the food web.

Autosequencing trap samples were recovered in support of GLERL's Biogeochemistry Project and also the EPA-EMAP Program, to determine mass and organic carbon flux as well as provide samples for analyses of contaminants, nutrients, and biota. These data are being evaluated under the EMAP program for their utility as integrated ecosystem indicators and will also be used under GLERL's Biogeochemistry Project for developing mass balances for several chemical species.

Lake Circulation and Bottom Boundary Layer Studies. (Project Scientists: Saylor and Miller)

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 portion 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.

GLERL began a cooperative research program to study currents and sedimentary processes of Lake Champlain in 1991. Moorings were placed throughout the basin. Results have revealed remarkable episodes of large amplitude internal seiche propagation within the lake basin. These waves, which propagate on the thermocline, occur only during the summer period when the lake water is density stratified. Wave heights reach 30-40 m and the wave periods are close to 4 days in length. The internal waves drive high speed currents back and forth along the north-south trending lake basin axis. The currents at the lake bottom are large enough to resuspend the lake flow sediments and inject sediments contaminated with many toxic materials into the lakewater, providing a continuing source of toxins to the lake as the sediment particles interact with it. The studies have revealed a complex and dynamic physical environmental that we have just begun to understand.

Nitrogen Dynamics. (Project Scientist: Gardner)

This study is providing (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.

In FY 92, a capillary electrophoresis instrument with a post-column reactor and detector for laser induced fluorescent detection has been designed and assembled. During FY 93, the system is currently being evaluated to test its potential applicability to the measurement of ammonium in water samples.

Dr. Janusz Tomaszek, Rzeszo'w University of Technology, Rzeszo'w, Poland came to GLERL to do preliminary research on denitrification in Old Woman Creek, Lake Erie. The preliminary results indicate that denitrification is a major sink for nitrogen in Old Woman Creek and that this process may substantially reduce concentrations of dissolved inorganic nitrogen coming into the system from agricultural runoff.

Pelagic/Benthic Energy Transfer and Bioenergetics Models of Macroinvertebrates. (Project Scientists: Gardner, and Cavaletto)

The objectives of this study were to (1) 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.

A small study on factors that might affect hydrolysis of lipids in invertebrates while samples are being dried for lipid analysis. The results did not show great differences among drying methods but hydrolysis of lipids was lowest under the normal drying conditions (55°C under nitrogen).

Analysis of a *Diporeia* study comparing lipid levels and lipid classes in Lakes Michigan and Ontario was completed. Results show that total lipid levels were higher in *Diporeia* from Lake Ontario than from Lake Michigan. This result may be an indicator of food quality and quantity differences between the two lakes.

Microplankton in the Great Lakes: A Comparative Study of Lakes Huron, Michigan, Ontario, and Okeechobee. (Project Scientist: Fahnenstiel)

The microplankton (bacteria, algae, and protists) occupy a key position in the food web of large lakes and may constitute most of the pelagic biomass as well as control carbon and nutrient cycling. Although these organisms occupy a key position, very little is known about the biomass and production of this important taxa. The goal of this project is to examine the dynamics of microplankton including key processes in several large lakes in order to further our understanding of the food web.

In FY 93 we participated in the first Great Lakes cruise and made initial measurements of growth rates during spring conditions in Lakes Huron, Michigan, Erie, and Ontario. In addition, a chlorophyll-labeling technique was developed for use in the Great Lakes.

The Microbial Food Web in the Great Lakes. (Project Scientist: Fahnenstiel)

In the past few years, aquatic food webs have been discovered to be far more complex than previously thought. The discovery of the microbial food web has forced a revision of contemporary models of plankton dynamics. These new discoveries have changed our ideas of the classical food web to include the recognition that photosynthetic and heterotrophic picoplankton can play a dominant role in nutrient cycling, that pelagic plankton food webs include a much greater number of trophic levels, and that a large percent of primary production is not consumed directly by zooplankton but rather is channelled through a detrital pool.

While GLERL has been a leader in freshwater microbial research, there is still much uncertainty regarding the microbial food web in the Great Lakes, particularly with reference to linkages between picoplankton production and the metazoans.

In FY 93, data evaluation continued and manuscript preparation is in progress.

Ecological Monitoring. (Project Scientist: Pernie)

Maintaining long-term data to provide a basis for recognizing and forecasting changes in plankton dynamics due to climate changes is needed because potential change in both absolute temperature and the onset and duration of thermal stratification could lead to substantial changes in Great Lakes ecology. The primary objective of this project is to monitor plankton dynamics to recognize changes due to climate change caused by increase in atmospheric CO_2. Collection of a detailed data set capable of separating normal seasonal dynamics and year to year variability from long-term changes is necessary to detect climate-driven effects. These data will also be useful for detecting long-term changes due to nutrient loadings, exotic species invasions, fish management, and other general ecological events.

In FY 93, seasonal carbon analysis comparison study between the oxidation and combustion methods was completed. Weekly data collection continued in Lake Michigan both during the formation of the thermal front in the spring and during late summer for *Bythotrephes* population monitoring.

Zebra Mussel Protocol . (Project Scientist: Reid)

A committee of academic and government scientists, chaired by David Reid (GLERL), developed a draft Zebra-Mussel-Specific Containment Protocol for use nationally by the research community as an "Approved Species-Specific Protocol," (ASSP) as defined by the Nonindigenous Species Research Protocol of the Interagency Aquatic Nuisance Species Task Force. The draft Zebra-Mussel-Specific Containment Protocol was presented at a special session of the 3rd International Zebra Mussel Conference in Toronto, Canada, in February, 1993, revised based on comments and inputs received there, and submitted to the ANS Task Force Research Protocol Committee for final comment and/or approval. Final action is still pending.

Facilities and Services

GLERL's research facility contains 17 laboratories equipped with general laboratory equipment. In addition, GLERL has a stable isotope mass spectrometer (SIMS), several gas chromatographs and liquid scintillation counters, a high pressure liquid chromatography system, a multi-channel Coulter Counter, growth chambers and incubators, stereo and inverted microscopes, and a fully equipped multi-purpose epifluorescence microscope. GLERL also has high speed micro-cinematography equipment located in a temperature-controlled environmental chamber which is maintained for conducting experiments and growing biological cultures at low temperatures. A new Geographic Information System Laboratory was established at GLERL during FY 93. See page 28 for more information.

Computer Facility

The GLERL computer facility can be best characterized as a Local Area Network (LAN) of distributed computing resources. This network currently consists of 8 VAXs, 5 UNIX/RISC workstations, 15 PCs which are connected by an ethernet, and approximately 80 additional PCs able to access the network via a communications switch. The LAN is connected to the Internet via a router to MichNet.

A variety of scientific applications, including real-time and near real-time data acquisition, data reduction, graphics, large scale modeling, statistical and mathematical analysis, electronic mail, and remote file transfer are accessed by GLERL personnel and collaborators.

GLERL is the Great Lakes Redistribution Node of the National Ocean Communication Network (NOCN), and, as such, makes satellite imagery available to government, private, and academic users throughout the Great Lakes region.

Library

The GLERL library has a program-oriented research collection maintained in support of the laboratory's research activities. The collection reflects an emphasis on freshwater studies, particularly in the Great Lakes basin. The library currently receives 198 periodical subscriptions. Most GLERL books dating from 1980 onward, as well as many earlier books, are included in the online union catalog by OCLC Online Computer Library Center, Inc. These books are also reflected in the NOAA Library Catalog which is available via remote online access, commercial CD-ROM, and the library's public access workstation. Both EPA and NOAA libraries participate in the catalog. Library records may be interactively searched using Boolean search options and displayed in various formats. GLERL library facilities are open to the public for reference use during normal business hours.

Library holdings include 5,640 periodical volumes and 8,166 books/technical reports covering the subject areas of climatology, contaminant organics, hydraulics, hydrology, ice, limnology, mathematical models, meteorology, nutrients, oceanography, sediments, and wave motion.

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 93, the main library in Ann Arbor was supplemented by a small, branch library established at the Muskegon Vessel Operations

Facility; two CD-ROM based databases were added to the public access workstation, and library owned dissertations were cataloged in to a PC based database. The Muskegon branch library materials are primarily intended for the immediate reference needs of researchers while they are working at the lake-side facility. The added CD-ROM databases provide indexed coverage of materials in the Sea-Grant Depository Library as well as water resource publications from Environment Canada and other international sources. The new dissertation database permits both quick access for researchers using printed indexes and computer access when detailed searching is required.

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 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 displays concerning GLERL's work.

Research products generated during FY 93 include 52 scientific articles, reports, and books and 60 formal presentations. There were 1,855 documented requests for GLERL information, with 3,501 items mailed in response to those requests.

If you would like to be added to GLERL's mailing list, or would like additional information on GLERL's research, please write to:

Publications Office
NOAA/GLERL
2205 Commonwealth Blvd.
Ann Arbor, MI 48105

The Publications Unit maintains a mailing list for distribution of GLERL publications. The GLERL Yearly Report and the Six Month Update are automatically distributed according to this mailing list. All new publications, including NOAA reports, journal articles, and books, are added to our six-month update listing of new publications to keep our users informed of GLERL's latest product releases.

Vessel Operations

- Muskegon Vessel Operations Facility

The GLERL Vessel Operations Facility is located in Muskegon, MI in a former Coast Guard Base that includes three buildings and research vessel dockage.

This facility has great potential for the establishment of a lake-side laboratory that 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 are 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 GLERL building is used for storage of research equipment. It has been renovated to include a new chemical laboratory. Equipment installation was completed in 1993.

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 (Location Radio Navigation-Coordinates) 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 Onan diesel generator. 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 on-board 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 and filtering equipment.

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.

Two small boats are used as auxiliary research platforms. A 23-foot Monark workboat, *The Remorse*, is outfitted as a research launch with navigational and safety equipment and an electric winch and crane.

A SeaArk workboat, *The Cyclops*, measures 28.5 feet in length, including a 2.5 foot deck extension, and is used primarily for the Non-Indigenous Species Program in Saginaw Bay and Lake St. Clair. This boat is transported by trailer to remote sites as required. Navigation equipment includes a radar, magnetic compass, a 91-channel radiotelephone, a LORAN-C, a 50-kHz digital depth sounder with digital display and auto pilot. There are two sounder wells. An electric winch and 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*, the 28-foot, 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 1993, numerous cruises were made by the *Shenehon* in Lake Michigan, and one cruise was made into Lake Huron and Saginaw Bay.

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 at one station in Lake Michigan and at one station in Green Bay to monitor the vertical mass and chemical flux. Current and temperature sensors were deployed in the center of the southern basin of Lake Michigan and in Saginaw Bay.

Three GLERL-designed sequential sediment traps were deployed over the winter of 1992-1993 in Lake Michigan and will be recovered in 1994. One trap mooring was established in Green Bay in conjunction with the University of Wisconsin. One 2-day cruise was made in Thunder Bay (Alpena, MI) to

GLERL scientists working aboard the Cyclops.

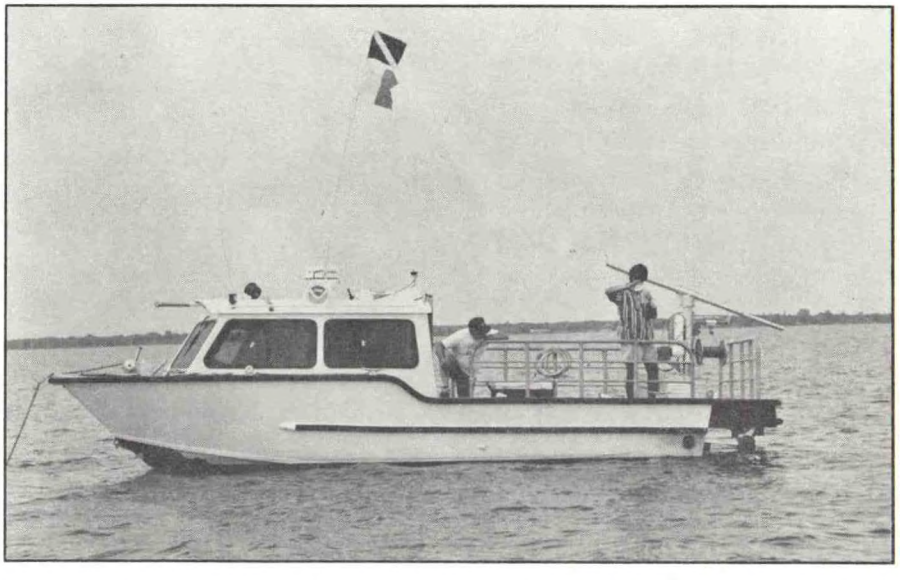


Photo by D. Fanslow

evaluate the conditions in the proposed Marine Sanctuary. This cruise followed a 2-week cruise in Saginaw Bay.

The R/V *Shenehon* continues to attract attention as she cruises the lakes. Vessel operations supported a GLERL-Muskegon school project to monitor the population and growth of zebra mussels in Muskegon Lake. Several newspaper articles were written during the year covering research efforts supported by the *Shenehon.*

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 43 AMF Vector Averaging Current Meters, 14 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. RDDR-1200 Acoustical Doppler Current Profiler (ADCP), 2 RDSC-600 ADCPs, 1 RDSC broad band ADCP, and 7 sequential sediment samplers.

In FY 93, MIL staff evaluated and initiated procurement of five more acoustical releases. Instruments prepared and developed by MIL staff went to southern Lake Michigan, Green Bay, WI, Saginaw Bay, Lake Champlain, NY, Cape Hateras, NC, and the Gulf of Mexico in support of National programs such as NECOP and SABRE as well as EPA contracts and nearshore hydrodynamics.

A meteorological data collection platform was installed on the Gravelly Shoal Lighthouse located in Bay City, MI and serviced by MOIL to provide real-time meteorological data through the GOES satellite system for the zebra mussel experiments being conducted in Saginaw Bay.

A new photosynthetron was constructed to measure photosynthesis irradiance for use in primary production studies and resulted in a number of inquiries from academia. A refined design was constructed through Great Lakes Engineering Company who plans to build and supply these as a commercial item.

Geographic Information System Laboratory

The development of GLERL's Geographic Information System (GIS) laboratory was initiated in the fall of 1992. The laboratory is composed of commercial GIS software resident on a UNIX workstation, 10 GB external disk storage, a high accuracy digitizer, color thermal wax transfer printer, CD-ROM drive, and is connected to GLERL's computer network and the Internet. A full-time GIS specialist operates the system.

GIS technology has become an essential tool of spatial data management. It has enhanced the efficiency and analytic power of traditional mapping and provides a powerful system for developing environmental process models. GLERL's GIS laboratory was initially developed to support GLERL's hydrologic modelling research. The development of distributed parameter hydrologic process models requires the management of large spatial data sets, easily done within the framework of the GIS. In addition, the recent development of information-rich land-surface data sets necessitates a GIS for acquisition and use. In support of GLERL's hydrologic research, detailed topography, soils, land use/land cover, and hydrography have been obtained for the Great Lakes region.

Use of the GIS laboratory in support of other GLERL research has increased. In support of the Great Lakes Ice Cover Data Rescue Program, Great Lakes ice charts are being digitized. Along with ice cover extent, ice characteristics such as type and thickness are being preserved. The GIS has been used to produce maps of monthly and annual thermal fluxes for each of the Great Lakes, to provide conversion factors between the irregular shaped areas of the lumped parameter runoff model and the 40 km gridded RAMS atmospheric model to enable linkage of these models, and to develop various graphical products in support of technical papers and presentations.

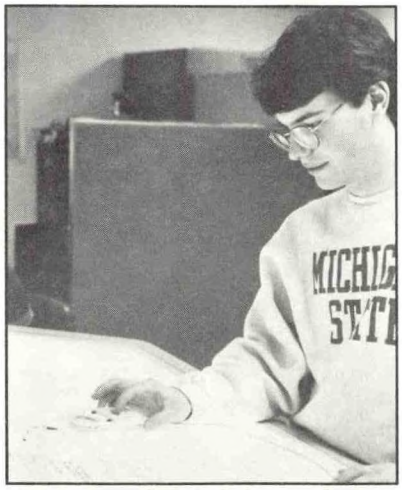
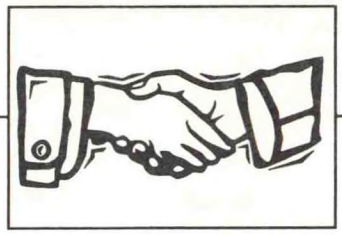


Photo by K. Sparks

Digitizing of Great Lakes ice charts using the GIS laboratory.

Outreach



The GLERL mission includes the development of environmental information, data, and service tools for users in government and private organizations. Staff participation on boards, commissions, task forces, and committees helps to identify environmental information needed by our users and to guide our research focus and the development of usable products. During FY 93, GLERL staff participated as members of the following boards, committees, and task forces:

International Joint Commission

- Council of Great Lakes Research Managers (A. Beeton, member)
- 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 (U.S. Co-chair, F. Quinn, 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, D. Lee)
  - River Flow Subcommittee (F. Quinn)
- International Great Lakes Levels and Flows Advisory Board (F. Quinn, U.S. Co-chair)

Other interagency, professional society, and international activities:

- American Institute of Hydrology - Michigan State Section (T. Croley, President)
- American Society for Testing and Materials Sediment Toxicity Subcommittee (P. Landrum)
- American Society for Limnology & Oceanography
  - Editorial Board (H. Vanderploeg)
  - Finance Committee (A. Beeton, chair)
- American Society of Civil Engineers
  - Task Committee on Hydrodynamics of Lakes (P. Liu)
- American Water Resources Association - Michigan State Section
  - Vice President and Program Committee Chair (D. Lee)
- Assessment and Remediation of Contaminated Sediments (ARCS, USEPA)
  - Toxicity/Chemistry Work Group (P. Landrum)
  - Management Advisory Committee (D. Reid)
- *Chemosphere*, Board of Editors (P. Landrum)

- Critical Reviews in Environmental Science and Technology, Editorial Board (P. Landrum)
- Eastern Snow Conference Steering Committee (D. Norton)
- Environmental Reviews, Assoc. Editor (A. Beeton)
- Great Lakes Commission
  - Drought Management and Great Lakes Water Levels Task Force (F. Quinn)
  - Great Lakes Panel on Non-Indigenous Species (T. Nalepa, V. Chair; A. Beeton)
  - Great Lakes Speakers Bureau Directory (G. Pernie, F. Quinn)
  - Task Force on Emergency Preparedness (D. Reid)
  - Ecosystem Charter Committee (A. Beeton)
  - Observer delegate (A. Beeton)
- Great Lakes GIS Coordinating Committee (G. Leshkevich)
- Great Lakes Protection Fund
  - Technical Advisory Committee (A. Beeton)
- *Hydrobiologia*, Special Issue
  - Associate Editor (B. Eadie)
- International Association for Great Lakes Research
  - Board of Directors (T. Nalepa, M. Quigley, G. Fahnenstiel)
  - IAGLR Membership and Endowment Committee (M. Quigley, Chair; B. Eadie, Liaison with SIL)
  - *Journal of Great Lakes Research* (F. Quinn, D. Schwab, T. Nalepa, P. Landrum, Associate Editors)
- International Association of Theoretical and Applied Limnology (A. Beeton, U.S. Representative)
- International Great Lakes - St. Lawrence Ice Information Working Group (R. Assel,U.S. Co-chair; S. Bolsenga, D. Norton, G. Leshkevich)
- Interagency Non-Indigenous Species Research Protocol Committee (D. Reid, Member)
- International Mathematics and Statistical Library (IMSL) North American Users Group (L. Herche, Chair)
- Michigan Sea Grant Research Advisory Committee (J. Saylor, A. Bratkovich)
- Midwestern Climate Center
  - External Advisory Panel (T. Croley II)
  - Research Review Committee (T. Croley II)
- Mississippi-Alabama Sea Grant Program reviewer (A. Beeton)
- National Research Council
  - Postdoctoral Program (A. Beeton, W. Gardner, H. Vanderploeg, P. Landrum, A. Bratkovich, D. Schwab)
- National Sea Grant Zebra Mussel Review Panel (T. Nalepa)
- National Sea Grant Chesapeake Bay Review Panel (P. Landrum)
- NOAA Climate and Global Change Program
  - Technical Advisory Committee (H. Vanderploeg)
- NOAA Coastal Ocean Program
  - Coastal Fisheries Ecosystem Technical Advisory Committee (D. Reid)
  - Great Lakes Forecasting System (D. Schwab, M. McCormick)
  - Coastal 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, W. Gardner)
- CoastWatch Program (G. Leshkevich, D. Schwab, G. Spalding)
- CoastWatch SAR Implementation Team (G. Leshkevich)

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

◆ NOAA/NOS Thunder Bay Marine Sanctuary

◆ NOAA/NURP University of Connecticut/Avery Pt. Center
- Proposal Review Panel (D. Reid)

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

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

◆ Ohio Sea Grant
- Zebra Mussel Project (A. Beeton, T. Nalepa, W. Gardner)
- Ph.D. Committees (D. Schwab)
- Research program participation (S. Bolsenga)

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

◆ Society of Environmental Toxicology and Chemistry
- Board of Directors (P. Landrum) (P. VanHoof, D. Gossiaux, members)

◆ State of Michigan, Department of Natural Resources
- Great Lakes Information System Technical Advisory Committee (A. Beeton)
- Michigan Great Lakes Fund (A. Beeton, S. Bolsenga)
- Ecosystem Management Workshop (A. Beeton)
- Saginaw Bay National Water Quality Initiative Tech. Advisory Committee (W. Gardner)

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

◆ 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, D. Schwab, A. Bratkovich)
- Biological Station Executive Committee (A. Beeton)
- Ph.D Committees (A. Beeton, A. Bratkovich, G. Fahnenstiel, J. Saylor, B. Eadie, H. Vanderploeg)
- School of Natural Resources, Adjunct Prof. (J. Robbins) (G. Fahnenstiel)
- School of Public Health, Dept. of Environmental Health, Adjunct Prof. (A. Beeton)
- Task Force on Environmental Studies (A. Beeton)

◆ 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)

◆ U.S. Department of Commerce Consolidated Scientific Computing System Technical Committee (G. Spalding)

◆ U.S. Department of Energy, Ocean Margins Program

- Review Panel (B. Eadie)

- U.S. Department of State
  - Cooperative Study on Chernobyl Fallout in Masurian Lakes, Poland (J. Robbins)
  - Mongolian Cooperative Research Program (S. Bolsenga, D. Norton)
  - Russian cooperative research programs (A. Beeton, S. Bolsenga)
- U.S. Environmental Protection Agency
  - Binational Executive Committee/USA-Canada (A. Beeton)
  - Policy Committee (A. Beeton; S. Bolsenga, Alternate)
  - State of the Lakes Ecosystem Conference Steering Committee (H. Vanderploeg)
- U.S. Soil Conservation Service (A. Beeton, Technical Advisor)
- University of Nebraska - Ph.D. Committee (B. Eadie)
- University of Wisconsin - Ph.D. Committee (B. Eadie).
- University of Wisconsin Sea Grant Institute (A. Beeton, Site Team Member)
- Wayne County Community College
  - Technical Advisory Committee (H. Booker)
- Zebra Mussel Coordination Committee (A. Beeton, Chair)

International Activities

Cooperative research is often performed with scientists from around the world. In FY 93, this included scientists from Canada, Chile, Germany, Israel, Russia, Poland, Mongolia, and Venezuela.

Visiting Scientists

- University of Minnesota
- Case-Western Reserve University
- Kent State University

Cooperative Research was performed with the following organizations:

- Argonne National Laboratory
- Canadian Climate Center
- Canada Hydrographic Service
- Canadian National Hydrology Research Institute
- Center of Limnology, University of Wisconsin, Madison
- Illinois State Water Survey
- Memorial University, Newfoundland, Canada
- Michigan State University
- Middlebury College and Lamont-Doherty
- Midwest Climate Center
- NASA/Goddard
- Naval Ocean and Atmospheric Research Lab (NOARL)
- NOAA AOML
- NOAA ERL Air Resources Laboratory, Silver Spring, MD

- NOAA/NESDIS
- NOAA National Geophysical Data Center
- Ohio State University
- State University of New York - Stony Brook
- Stockholm University, Sweden
- USSR Academy of Sciences
- U.S. EPA, Environmental Monitoring Systems Laboratory
- U.S. EPA, Great Lakes National Program Office
- U.S. Fish and Wildlife Service
- U.S. Geological Survey, Water Resources Division, Madison, WI
- University of Munich, Germany
- University of Waterloo, Ontario, Canada
- University of Wisconsin-Milwaukee on Yellowstone Lake and Green Bay
- University of Wisconsin on Nearshore Hydrodynamics
- Weber State University

GLERL also:

- Convened and chaired a committee to develop zebra mussel specific research protocols.
- 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.
- Provided hydrologic consulting to Hydro-Quebec for their Beauharnois-Les Cedres Extreme Flood Study.
- Serve as adjunct professors at The University of Michigan.
- Serve as adjunct professors at the University of Wisconsin
- Serve as adjunct professors at the University of Nebraska
- Serve as adjunct professors at The Ohio State University.
- 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.
- Guided students on tours of our facility and gave briefings of GLERL activities.
- Muskegon Vessel Operations Facility used in Muskegon Area Labor Day Telethon for Muscular Dystrophy.

Meetings and Presentations

An integral part of the scientific development of GLERL staff is attendance and participation in scientific and technical meetings. During FY 93, GLERL sponsored 9 in-house seminars as part of the GLERL Informal Seminar Series. Our staff made 62 presentations concerning GLERL's work at public and professional meetings.

Technology Transfers

GLERL staff responded to 1,855 requests for information during FY 93 and provided more than 3,501 items to service those requests. Many of the products that GLERL produces and distributes involve a transfer of both technology and data. During FY 93, 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 CoastWatch Data

- Argonne National Laboratory
- Bloom Trail High School
- Center for Great Lakes Studies, University of Wisconsin-Milwaukee
- Department of Civil Engineering, Ohio State University
- Eastern Michigan University
- Environmental Research Institute of Michigan (ERIM) (STEP Program)
- Illinois-Indiana Sea Grant Program
- Lake Superior Center, Duluth, MN
- McMaster University, Environmental Hydraulics Program
- Miami University, Department of Geography
- Michigan DNR Forest Management Division
- Michigan Sea Grant Program
- Michigan State University
- Michigan Technological University
- U.S. Army Corps of Engineers, Chicago District
- U.S. EPA, Environmental Monitoring Systems Lab
- U.S. EPA, Great Lakes National Program Office
- U.S. Department of Interior, Hammond Bay Biological Station
- U.S. Department of Interior, National Fisheries Research Center, Great Lakes
- U.S. Department of Interior, USGS, Water Resources Division
- University of Florida, Dept. of Fisheries and Aquatic Sciences
- University of Wisconsin-Madison (Wisconsin Sea Grant Program)

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

- Canada Centre for Inland Waters
- Scripps Institution of Oceanography

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
- Canadian Centre for Inland Waters
- University of Wisconsin
- University of S. Mississippi
- Middlebury College
- U.S. EPA, Environmental Monitoring Systems Laboratory, SUNY Stony Brook
- GLERL-designed photosynthetron was shared with Kent State Univ., SUNY, and the Univ. of San Francisco.

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 Florida
- University of North Carolina
- University of Minnesota
- Duke University

Other:

- Filtration device developed at GLERL is being marketed by a small business (St. John Associates).
- Great Lakes Engineering Co. is using plans developed at GLERL to build and market a photosynthetron.

GLERL and Great Lakes Education

In keeping with NOAA's desire to better inform the public of its research activities, GLERL is involved in a number of Great Lakes community education programs. In FY 93 GLERL staff:

- participated as role models in the Girls Excel in Match and Science (GEMS) conference held at North Canton High School.
- made presentations concerning the Great Lakes and GLERL programs at area schools and have given several tours of our facility to interested students and teachers.
- In conjunction with the Lake Michigan Federation, the R/V *Shenehon* worked with students from Muskegon High School studying zebra mussel densities in Lake Michigan (J. Grimes, Coordinator). In addition, the Shenehon was used several times to provide cruises for various student groups.
- participated in a hands-on science fair hosted by the Alpena Public School system.
- represented GLERL at several community environmental awareness functions.

Partners for Excellence

This year marks our fifth year involved in a partnership with the Science Department of the Ann Arbor Public Schools' Partners for Excellence Program (T. Nalepa, GLERL Coordinator). This program seeks to enrich the 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.

Photo by K. Sparks

Scientist Margaret Lansing oversees the collection of water samples for processing at the lab. These girls are participants in "Take a Girl to Work Day."

Great Lakes Education Kit

The Publications Unit has compiled and is continually updating a kit composed of materials for teachers who wish to integrate Great Lakes education into their curriculum. The kit is available on a loan basis. Contact the Publications Unit for more information.

Southeast Michigan Science Fair

In conjunction with the 34th 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, 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.

Satellite Technology Education Program (STEP)

This is a NASA and NOAA program to introduce and use satellite images and data in the classroom (K-12). This program was coordinated and implemented by the Environmental Research Institute of Michigan (ERIM). GLERL participates by providing CoastWatch data and products.

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.

ERL Equal Employment Opportunity (EEO) Outreach

In FY 93, GLERL hosted a 17-year-old high school graduate from Ann Arbor Pioneer for a 6-week summer internship in cooperation with the ERL/EEO Minority Outreach Program.

Take A Girl to Work Day

GLERL's Federal Women's Program Coordinator, Eugenia Lashbrook, organized GLERL's participation in the first annual "Take a Girl to Work Day." Six girls spent the day at GLERL observing and working with several GLERL employees. Some of their activities included collecting and testing water samples, labelling sample containers, grinding sediment samples, and digitizing zebra mussels.

Seminars

The following seminars were held at GLERL during FY 93:

Mass fluxes of nutrients and phytoplankton in the Jet/ Eddy system of the northern California coastal transition zone. B. Jones, GLERL National Research Council Senior Fellow, University of Southern California. November 4, 1992.

Patterns of temperature and energy fluxes at the Great Lakes surface. K. Schneider, GLERL NRC Post Doc, Institut fur Geographie, Universitat Munchen, Germany. December 8, 1992.

Photoautotrophic picoplankton and the microbial food web in the Laurentian Great Lakes: New paradigms for limnologists. G. Fahnenstiel, GLERL. February 4, 1993.

Initial response of submersed macrophytes to increased water clarity in Saginaw Bay. J. Skubinna, Michigan State University. April 2, 1993.

NOAA Earth System Data Directory: Guide to Environmental Data. P. Grimm, NOAA/NESDIS/EIS. June 22, 1993.

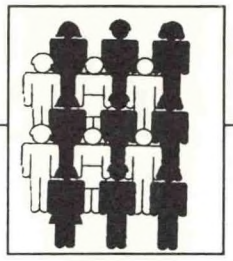
Burrowing mayflies (*Hexagenia*) and caddisflies (*Oecetis*) as indicators of ecosystem health in the Great Lakes: Early signs and possible causes of population recovery. K.A. Krieger, Research Associate, Water Quality Laboratory, Heidelberg College, Tiffin, OH. July 6, 1993.

Organic pollutants in sediments: Sediment distribution, toxicity and bioaccumulation to benthic organisms. J. Kukkonen, GLERL Visiting Scientist, University of Finland. July 8, 1993.

Hydrodynamic modeling and pollutant transport studies at McMaster University. I. Tsanis, McMaster University. August 10, 1993

The last NECOP Cruise: Tales from the Gulf of Mexico. B. Eadie, GLERL. August 13, 1993.

Staff



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Wiliams, R.S. - Secretary
Bolsenga, S.J. - Asst. to Director
Kulpanowski, K.A. - Certified Industrial Hygienist

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Lashbrook, E.K.
Mull, R.C.

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Miller, T.C.
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Faust, W.R.
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Gluck, A.A.=
Gordon, W.M.=
Gossiaux, D.C.
Gostenik, G.W.*
Harkey, G.A.[C]
Johengen, T.H.[C]
Johnson, J.R.[C]
Krause, A.E[C]
Landrum, P.F.
Lang, G.A.
Lansing, M.B.
Liebig, J.R.
Lynn, J.A.
Morehead, N.R.
Nalepa, T.F.
Nelson, A.S.*
Pernie, G.L.
Quigley, M.A.
Robbins, J.A.
Rood, R.W.[C]
Vanderploeg, H.A.
VanHoof, P.A.
Wagoner, B.B.
Wimmer, M.=
Wojcik, J.A.[C]

Physical Sciences Division

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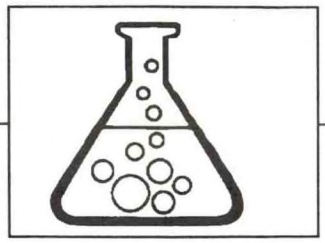
Lawton, B.J. - Secretary

Assel, R.A.
Blythe, K.L.=
Bratkovich, A.W.
Carter, B.S.=
Clites, A.H.
Conklin, P.A.=
Croley, T.E., II
Dong, D.Y.[C]
Hawley, N.
Hibner, B.A.[C]
Hunter, T.S.
Jones, B.H.[N]
Lee, D.H.
Leshkevich, G.A.
Liu, P.C.
Lofgren, B.M.[C]
McCormick, M.J.
Meyer, D.E.
Miller, G.S.
Muhr, G.C.
Nicolini, S.=
Norton, D.C.
O'Connor, W.P.[C]
Presley, J.W.=
Ridley, A.[C]
Saylor, J.H.
Schneider, K.[N]
Schwab, D.J.
Sellinger, C.E.

* - Indicates WAE Employee
= - Indicates Co-op Employee
[N] - Indicates NRC Fellow
[C] - Indicates CILER Employee

Visiting Scientists



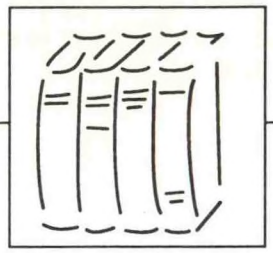
Dr. Ladd Johnson
Williams College, Mystic, CT
Dr. Johnson conducted post-doctoral research on zebra mussel distribution. He began his work here in December 1991.

Dr. Jussi Kukkonen
Academy of Finland.
His research focuses on the fate, bioavailability, and toxicity of organic pollutants in freshwater sediments. Dr. Kukkonen is performing collaborative research with Dr. Peter Landrum from February 92 - July 93.

Dr. Sandor Mulsow
Case Western Reserve University
Dr. Mulsow is working on an EPA project investigating bioturbation with Dr. Peter Landrum and Dr. John Robbins from January 1992 - January 1993.

Dr. Janusz Tomazek
International Research and Exchanges Board, Inc.,
Rzeszo'w University of Technology, Rzeszo'w, Poland.
From September - December 1992, Dr. Tomazek conducted research on denitrification in Old Woman Creek with Dr. Wayne Gardner.

FY 93 Publications



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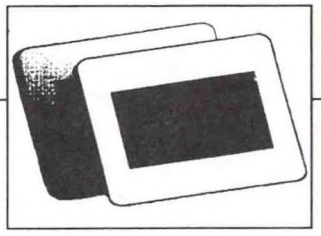

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Acronyms

AAPS	Ann Arbor Public Schools
ADCP	Acoustic Doppler Current Profiler
ARCS	Assessment and Remediation of Contaminated Sediments
ASSP	Approved Species-Specific Protocol
AVHRR	Advanced Very High Resolution Radiometer
BaP	Benzo(a)pyrene
CCIW	Canada Centre for Inland Waters
CD-ROM	Compact Disk - Read Only Memory
CER	Coordinated Ecosystem Research
CHARM	Coupled Hydrosphere Atmosphere Research Model
CILER	Cooperative Institute for Limnology and Ecosystems Research
COP	Coastal Ocean Program
CSCS	Consolidated Scientific Computing System
CTD	Conductivity, Temperature, and Depth
CZE	Capillary Zone Electrophoresis
DOC	Dissolved Organic Carbon
DOM	Dissolved Organic Matter
DON	Dissolved Organic Nitrogen
EC_{50}	Effective concentration at which 50% of worms will leave sediment)
E-MAP	EPA Mapping Program
EEO	Equal Employment Opportunity
EPA	U.S. Environmental Protection Agency
ERL	Environmental Research Laboratories
ERS	Earth Resources Satellite
FEDLINK	Federal Library and Information Network
FIBS	Field by Information Blending and Smoothing
FNOC	Fleet Numerical Oceanographic Center
FY	Fiscal Year
GOES	Geostationary Observational Environmental Satellite
GCM	General Circulation Model
GC/MS	Gas Chromatography/Mass Spectrometry
GIS	Geographic Information System
GLERL	Great Lakes Environmental Research Laboratory
GLFS	Great Lakes Forecasting System
GPS	Global Positioning System
HCBP	Hexachlorobiphenyl
HOC	Hydrophobic Organic Compound
HPLC	High Performance Liquid Chromatography
IDIDAS	Interactive Digital Image Display and Analysis System
IJC	International Joint Commission
IMSL	International Mathematics and Statistical Library
MARC	Machine-Readable Cataloging
MICIS	Midwestern Climate Information System
MOIL	Marine Operations and Instrumentation Laboratory

LAN	Local Area Network
LAVc	Local Area VAXcluster
LC50	Lethal concentration in environment resulting in 50% mortality.
LD50	Lethal dose which results in 50% mortality of population.
LORAN-C	Location Radio Navigation- Coordinates
MAR	Mississippi Atchafalaya River
MCC	Midwest Climate Center
MCSST	Multi-Channel Sea Surface Temperature
MLC	Michigan Library Consortium
MRP	Mississippi River Plume
MRP/GS	Mississippi River Plume/Gulf Shelf
MRP/IGS	Mississippi River Plume/Inner Gulf Shelf
NBS	National Bureau of Standards
NDBC	National Data Buoy Center
NECOP	Nutrient Enhanced Coastal Ocean Productivity
NESDIS	National Environmental Satellite, Data, and Information Service
NIST	National Institute of Standards and Technology
NLIN	NOAA Library and Information Network
NLSST	Non-Linear Sea Surface Temperature
NMC	National Marine Center
NOAA	National Oceanic and Atmospheric Administration
NOCN	National Ocean Communication Network
NOS	National Ocean Service
NRL	Naval Research Laboratory
NSIPS	NRL Satellite Impage Processing Systems
NSF	National Science Foundation
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research
OCLC	Online Computer Library Center
OCNMAP	Ocean Map
OSU	The Ohio State University
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PDMS	Polydimethylsiloxane
PMF	Probable Maximum Flood
POC	Particulate Organic Carbon
POM	Particulate Organic Matter
PMEL	Pacific Marine Environmental Laboratory
RAMS	Regional Atmospheric Modeling System
RNN	Regional Network Node
SAR	Synthetic Aperture Radar
SEAS	Shipboard Environmental Acquisition System
SIMS	Stable Isotope Mass Spectrometer
SPM	Suspended Particulate Material
SST	Sea Surface Temperature
TM	Thematic Mapper
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
VACM	Vector Averaging Current Meter
WLLN	Washtenaw-Livingston Library Network
XBT	Expendable Bathythermograph