Michigan Sea Grant Annual Report 1973-74

MICHU-Q-74-001

introduction

The Great Lakes are caught in the forces of change. A decade of expanding environmental awareness, coupled with rapid expansion of shoreland communities, has fostered a wide range of serious problems. Higher than normal lake water levels have triggered bluff erosion, flooded lowlands, and caused ice damage to docks and marinas. Many serious issues confront the agencies and individuals responsible for the development, management and protection of the Great Lakes coastal zone resources. During 1973-74 Michigan Sea Grant continued to assist in the resolution of these problems through its research, education and advisory service programs.

Michigan Sea Grant Advisory Services has expanded its effectiveness by joining with Michigan State University's Cooperative Extension Service. Extension Directors in each of the coastal counties are now part of Sea Grant's communications network. On-site problems of community planning, coastal area zoning and erosion protection are identified and relayed to Sea Grant resource specialists and researchers. Available information is located and sent back to the field. Two Sea Grant field representatives are stationed in the upper part of Michigan's lower peninsula to provide additional back-up assistance for that rapidly expanding region. In the past year advisory services staff have held workshops for property owners and contractors on erosion protection. Conferences have been held to address problems of shoreland planning and management. Agents have carried out an information exchange with charter boat operators in Michigan and Oregon. The officials of the Grand Traverse Bay region have joined with the Sea Grant funded Coastal Zone Laboratory to utilize the decision model WALRUS III.

Closely linked to the public education activities of Advisory Services is the educational project on underwater technology, which provided a series of public lectures on recreational diving safety techniques. Sea Grant personnel are also involved in many of the water related courses offered at the University of Michigan, and students benefit by working on Sea Grant research projects.

Sea Grant research is directly integrated with Advisory Services, particularly through the Coastal Zone Laboratory and through the decision simulations. These simulations provide real-life experiences in the give and take of the decision-making process and highlight the implications these decisions have upon community development and environmental quality. The WALRUS III model is directly linked to the predictive ecosystem and physical models so that the results of shoreland development decisions can be understood in terms of changes in the contiguous aquatic ecosystems.

Research information must be generated continuously in order to fully understand the dimensions of change in the Great Lakes. Sea Grant works closely with both the state and federal agencies responsible for management of Great Lakes resources. Although most of Sea Grant's monitoring is aimed at providing data for the ecosystems process research, field monitoring information is coordinated with that of other research agencies. Part of Sea Grant's efforts will enhance the often poorly understood interrelationships of the Great Lakes ecosystem. In this regard both long and short range application of Sea Grant work is important. Michigan Sea Grant through research, education, and advisory service activities will continue to contribute to the development, effective use, and prudent management of the Great Lakes resources.

Director, Michigan Sea Grant Program

ecosystem and physical modeling

Data collected in the Michigan Sea Grant Field Projects provide information with which to create and verify computer models of physical, chemical, and biological conditions of aquatic ecosystems as they respond to the addition or removal of environmental stresses. Models aid in analyzing the effectiveness of various management strategies for coping with water quality problems, and they provide a projection of future conditions in the ecosystem as environmental stresses from land and water use change over time. Future changes that might occur in the ecosystem are included in the model to shed light on problems that may arise from changes in the surrounding watershed.

A biological production model can be synthesized from a number of scientific theories and is a system of simultaneous, first order, nonlinear differential equations. Once it has been built, it must be tested in the field under existing conditions before it can be used to predict future conditions. The Michigan Sea Grant Program has had an extensive field monitoring program in Grand Traverse Bay since 1970, in Saginaw Bay beginning this year, and may have one in Lake Michigan in the near future.

GRAND TRAVERSE BAY

The model for biological production in Grand Traverse Bay has been developed and verified with field data. It has been used to evaluate water quality in Grand Traverse Bay in relation to various levels of residential and industrial growth and to alternate sewage disposal systems. The effects of improvements in the Traverse City sewage plant have been projected by the models and monitored through the field program. The model predicted relatively small decreases in phytoplankton as a result of high levels of phosphorus removal. As nutrient inputs to the bay increase, the species composition of phytoplankton is predicted to shift from diatoms to blue-green forms. This will lower the quality of Grand Traverse Bay for domestic water supplies, hinder recreational use, and will adversely affect the food base of the Lake Michigan fishery.

The model has projected the expected levels of water quality variables of interest: dissolved and particulate phosphorus, particulate and dissolved organic nitrogen, ammonia, nitrate, silicon, total algae, total zooplankton, and primary production. Changes due to transport by water movements, growth, nutrient cycling, decomposition, biological uptake, exchange from Lake Michigan, and direct input from the Boardman River have been integrated into the model. Seasonal variations of these variables have agreed well with field data.

Effects of water circulation on water quality are coupled through the biological production model. Water circulation patterns are modeled and tested from circulation data obtained in the field.

Projections from the model have been presented at an open public meeting,and researchers and field agents continue to work with planning agents in Traverse City with data from the modeling project.

SAGINAW BAY

Saginaw Bay is the primary sink for a wide range of industrial and municipal wastes. It is one of the most heavily polluted regions of the Great Lakes, with water quality similar to Lake Erie or Green Bay. Because of excessive levels of turbidity and plankton, taste and odor problems occur in drinking water sources, and rapid siltation occurs in the shipping channel as well as in fish and waterfowl habitats.

Field monitoring and modeling studies were initiated to predict biological production and turbidity in Saginaw Bay. This work was expanded in response to needs expressed by

citizens and planners at an area meeting. The model accounts for natural chemical and biological mechanisms, pollutant inputs to the bay, and physical transport and circulation. The model calculates spatial and temporal variations of chlorophyll, zooplankton, primary production, phosphorus, nitrogen and silicon. It has been tested against observed chloride profiles in the bay, and verification against field data of the other variables will take place during the coming year.

The model of circulation driven by winds and oscillations of Lake Huron was developed and partially verified. This model is coupled with a model for diffusion of conservative contaminants such as chlorides. Both of the models have given results in agreement with previous qualitative estimates of circulation and diffusion patterns. Extensive analyses of the interactions of Saginaw Bay and Lake Huron have been made using data furnished by the U.S. Lake Survey Center.

In addition to the numerical models, an attempt has been made to simulate the evolution of the thermal structure of lakes under the action of winds, solar heating, and nocturnal cooling. This work was motivated by researchers who have noted strong thermal effects on biological systems. Accurate representations of the thermal structure will be important to the aquatic ecosystem models.

LAKE MICHIGAN

The water quality and fish resources of Lake Michigan have been deteriorating since 1940. Populations of undesirable algal species have increased, and high nutrient conditions have degraded water quality. Mathematical models for nutrients, plankton, and alewives can be used to define optimum management strategies for the Lake Michigan fishery. A species level model for the lower food web has been developed and partially verified. This will be combined with a numerical model of alewife population. Estimates made of predation on alewife by coho and chinook salmon and by lake trout will help fishery managers determine the impact on the alewife population of different stocking policies for sport species. In addition a comprehensive study of the smelt population is being conducted. The fisheries-related modeling was initiated in response to the needs of Michigan Department of Natural Resources, Fisheries Division, and is carried out in close cooperation with this agency. Much time this year has been spent assessing the adequacy of the modeling approach and in developing a balanced, overall model.

ecosystem processes and field research

The Ecosystem Processes and Field Research Project combines several sub-projects in varied scientific disciplines, assembled for the purpose of studying and understanding large-lake ecosystems in both their natural and stressed processes.

Several years of data collection activity in Grand Traverse Bay, Lake Michigan has resulted in a representative, working knowledge of water circulation, geochemical and biochemical pathways, and biological production in the bay. Limnological monitoring and process studies have been coordinated with the Ecosystems Modeling Project through this period of field research. This has provided the modeling group with needed information for loading and validating the biological production model of Grand Traverse Bay.

During fiscal 1974, the Ecosystem Processes and Field Research group continued limnological monitoring of Grand Traverse Bay and began an investigation into the structure and functions of the Saginaw Bay, Lake Huron aquatic ecosystems.

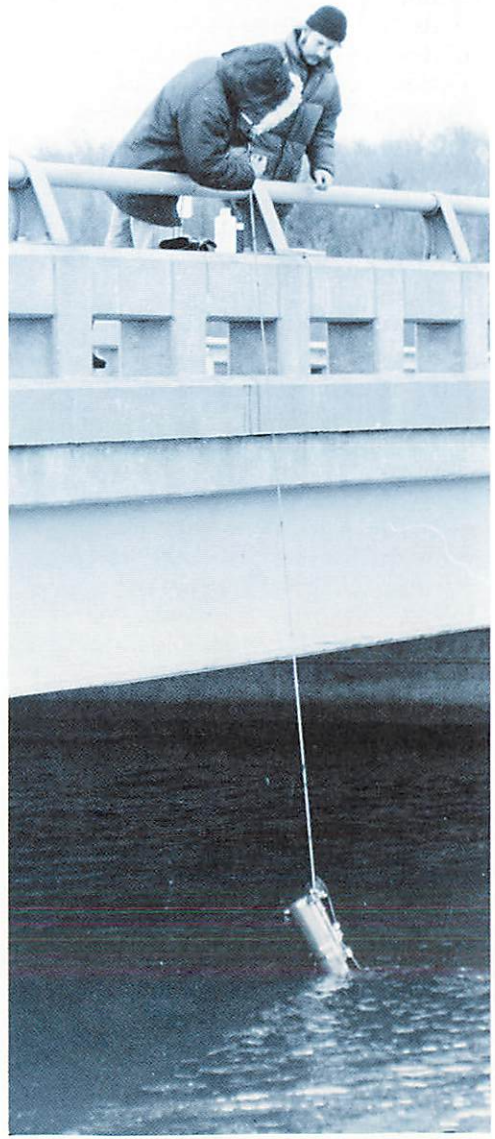
The implementation of our research efforts in Saginaw Bay were prompted by discussions with officials of the Michigan Department of Natural Resources concerned by the degraded water quality of Saginaw Bay. Michigan Sea Grant assistance was requested in developing an ecosystem approach on which to base future management decisions.

GRAND TRAVERSE BAY

Monitoring of water chemistry and biological indicators continued on a weekly basis at eight stations in the lower west arm of Grand Traverse Bay and at two stations on the Boardman River between July and December of 1973. Limnological parameters measured at these bay stations included temperature profiles, water transparency, chlorophyll-*a*, and zooplankton composition and abundance.

The R/V *Sea Grant I* was used as a sampling platform. Water samples were processed at a bayside laboratory in preparation for further analysis in the Ann Arbor laboratory. Measured parameters included chloride, ammonia, nitrate, nitrite, total and total dissolved phosphorus, silica, temperature and transparency.

Sampling of the entire bay was carried out in October 1973 and in May 1974. Two cruises sampled



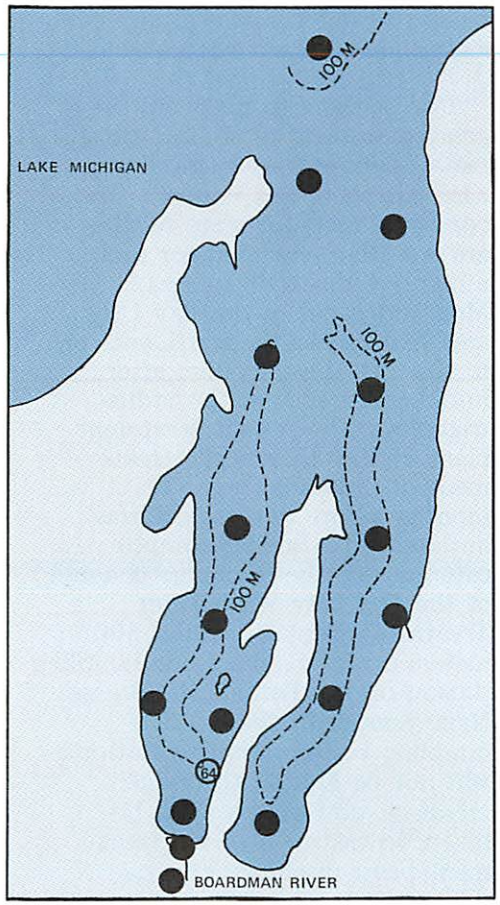
stations which were selected for the monitoring program in Grand Traverse Bay in 1970. Limnological parameters measured on these two surveys included the above parameters and additional measurements for alkalinity, specific conductance, *in situ* primary production (radio-carbon uptake), chlorophyll-*a*, and light penetration.

During August 1973 a five-day limnological time study was carried out at Station 64, a station which had been sampled on a weekly basis. Frequent samples (at three hour intervals) of routinely measured limnological parameters were obtained in a vertical profile from the R/V *Sea Grant I*, anchored on station. The information obtained from this time study documented short-term diurnal and weather-induced changes of bay chemistry and biology.

The results of this study have been applied toward the determination of confidence limits on the data previously collected in Grand Traverse Bay. It will provide a basis for selecting appropriate sampling intervals for future monitoring programs in Grand Traverse Bay and possibly other areas of the Great Lakes.

A scientific paper based on this study was presented at the 17th Conference on Great Lakes Research held at Hamilton, Ontario.

Weekly sampling of the lower Boardman River showed the effects of phosphorus removal at the Traverse City Wastewater Treatment Plant.



Grand Traverse Bay Sampling Stations

Phosphorus data obtained from sampling stations above and below the Traverse City Wastewater Treatment Plant showed the sensitivity of river phosphorus loading to the operational phosphorus removal system of the treatment plant.

Circulation measurements for the verification of the numerical model were completed with a set of drogue measurements in the east arm of the bay in July 1973.

SAGINAW BAY

In August, 1973 a bi-weekly sampling program was initiated on twenty different tributaries of Saginaw Bay. This was a first step toward understanding the Saginaw Bay aquatic system. Parameters measured included dissolved oxygen, specific conductance, temperature, turbidity, alkalinity, nutrient chemistry, trace metals, total suspended solids, chlorophyll-*a*, and coliform bacteria. Discharge data was provided by the U.S. Geological Survey and Michigan Sea Grant's Hydrology Project. During the winter months it was decided to sample only the rivers in the immediate Bay City-Saginaw area, as ice hampered our sampling procedures elsewhere. The rivers in this area accounted for 85% of the surface discharge into Saginaw Bay.

The Saginaw River and its tributaries directly influence the aquatic processes in the lower basin of Saginaw Bay and parameters measured vary greatly over time. For example, one would expect less suspended sediment during the winter months than during the spring thaw. Therefore, the average results are biased to a particular season.

Elevated levels of phosphorus, chloride, conductivity, turbidity, total suspended solids and coliform bacteria were found regularly at several stations in the Bay City-Saginaw area.

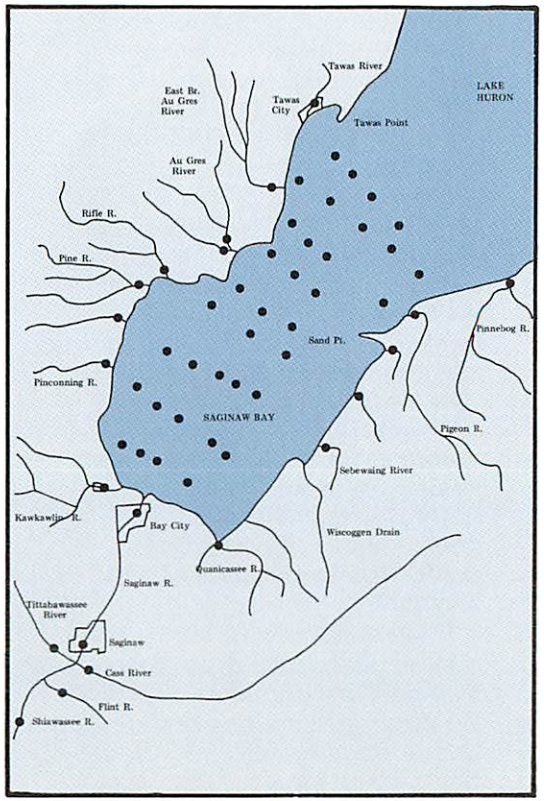
Dissolved phosphorus levels were continuously higher in the Saginaw River as compared to other rivers sampled. Dissolved oxygen remained between 40% and 90% saturation, with a mean of 58% for the entire fiscal year.

The average amount of total suspended solids from the river was 39.8 mg/liter with a range of 7.5 mg/liter to 132.2 mg/liter during the last fiscal year. Specific conductance remained consistently high most of the year with an annual average of 761 micro-mhos. The only river which maintained a higher specifi' conductance was the Tittabawassee River. Chlorophyll-*a* varied remarkably during the year, depending on the season, from 0.2 μ grams/liter to 291.6 μ grams/liter with an average value of 22.6 μ grams/liter. The changes in chlorophyll-*a* have been difficult to explain through the year. The possibility of interference, caused as a result of river effluents, will be investigated to determine if fluorimetric analysis was accurate.

Iron appears to make up the greatest portion of *soluble* trace metals followed by manganese, zinc, nitrogen, and copper. The concentrations for trace metals are less than expected for such a highly industrialized area. Most industries in the Bay City area had passed their effluents on to the city sewer system after initial treatments at the industrial site. The sewage treatment plant of Bay City began treatment of industrial waste six months before our project was initiated. To further complicate matters the discharge channel of the Bay City Wastewater Treatment Plant is located 500 meters downstream of our sampling station on the Belinda St. Bridge. Next year, with the aid of a sampling vessel, sampling stations will not be limited to bridge crossings, and samples will be taken downstream of the treatment plant discharge.

In the Saginaw River total and fecal coliform bacteria counts usually exceeded the state standards for total body contact (1000 colonies/100 mls for total coliform and 100 colonies/100 mls for fecal coliform).

A preliminary sampling survey was made on Saginaw Bay in

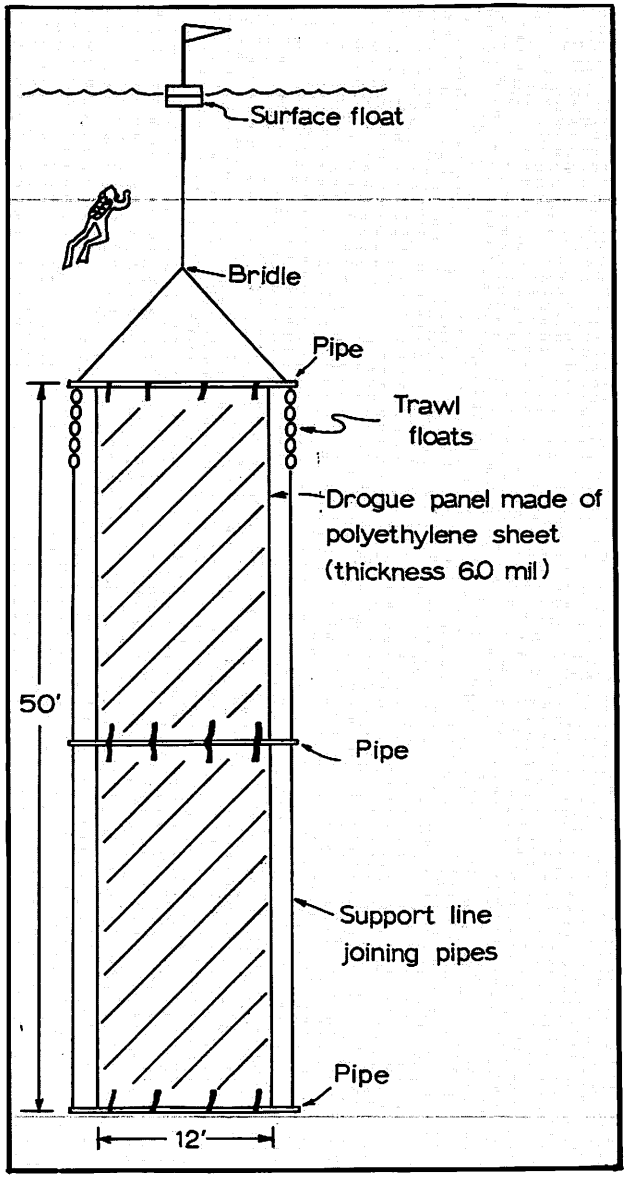


Saginaw Bay Sampling Stations

August, 1973 on board the NOAA Lake Survey R/V *Shenehon*. Thirty-six stations in Saginaw Bay were sampled at several depths for water chemistry, transparency, temperature, dissolved oxygen, chlorophyll-*a*, and surficial sediment chemistry. Ten stations were selected for sampling macrobenthos and suspended particulate material.

In general the initial survey indicated degraded water quality in the inner basin of Saginaw Bay with conditions improving towards the outer bay and Lake Huron. Degraded water along the southeast shoreline of the outer bay was evident, although more extensive sampling in this area was limited by the draft requirements of the sampling vessel. Information from this cruise aided in designing the future sampling program in Saginaw Bay.

A preliminary current measurement program was conducted in July and August 1973 in Saginaw Bay, Lake Huron, to provide insights needed in the development of a circulation model of this bay. This measurement program involved a sub-surface current meter mooring, a series of drogue measurements, and the release of 110 Michigan Mobius drifters. The Michigan Möbius drifter, a Möbius loop of Tyvek plastic "paper", with a text and postcard printed on its surface, was developed as a replacement for the drift-bottle. In the process of improving measurement methodology, a series of large sail (or "window-shade") drogues were developed. Such a drogue of 600 square feet projected area was tested successfully in Saginaw Bay.



public policy and institutional research

A POLICY PLANNING APPLICATION OF SEA GRANT RESEARCH

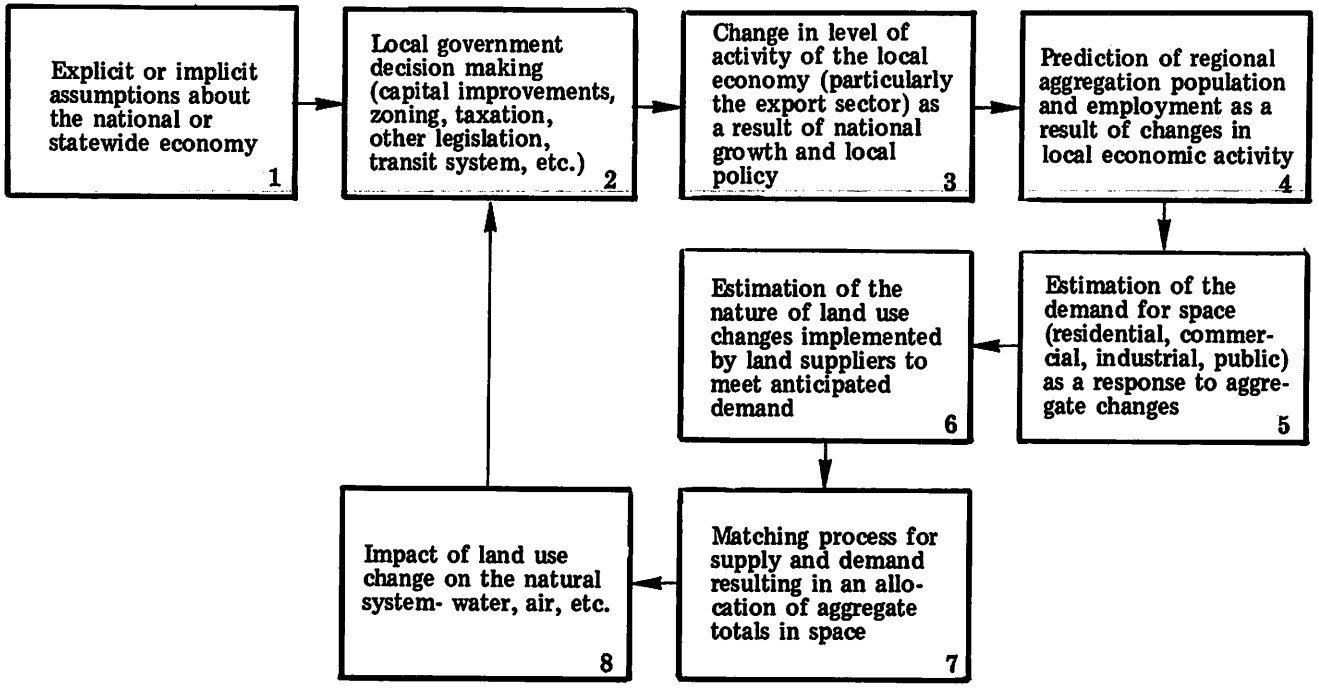
Several years ago this project developed the WALRUS I game. The use and demand for this educational device on the problems of water resources management have continued to expand during the last year including applications for the U.S. Army Corps of Engineers and for the Water Resources Administration program at the University of Birmingham in the United Kingdom. The University of Michigan Extension Gaming Service now responds to most requests for training and demonstration runs for WALRUS I. This has reduced the need of researchers to perform this service. In response to many of the criticisms and suggestions received from users over the past years, a revised version has been produced. The revision is basically a simplification and clarification of the original version.

WALRUS II, the computer assisted version of the WALRUS I game, has also been developed including some elements from the WALRUS III simulation model. The same format as WALRUS I has been followed including the use of the Lego board land-use map, the team structure, the decisions considered, and the required time to play. However, much of the chaos and turn-around time has been reduced by the programming of the "accounting" of both natural and economic systems. The program may be accessed by terminal and the coding is available to anyone interested.

The major portion of the project effort last year was to complete and document the existing components of the WALRUS III simulation model and to provide the model in a user oriented interactive format. Briefly those components included a data bank constructed from 55 operating land use types assigned to an 84 square mile area surrounding Traverse City, a series of economic algorithms, a population-migration model, an adaptation of Professor Canale's steady-state model including chlorophyll-*a*, and a series of supporting accounting routines. The two most striking characteristics of the simulation as it currently exists are first, the highly elaborate operating characteristics of the land use types arising from the need to link with the water models; second, the omission of several components of a complete urban/environmental model (see figure) arising from funding restrictions. Components *not* included in the simulation at the end of fiscal 1974 include an operating government sector (Box 2), anything representing the supply side of the land use market (Boxes 5, 6) or impacts to natural systems other than water. Changes to land use are generated by the user or other scenerio generating devices.

There appear to be two classes of use for a device like WALRUS III. The first is to demonstrate the systemic nature and general utility of modeling and simulation efforts. WALRUS III has served this purpose well with a variety of groups over the past year.

In theory however, the methodology of simulation/modeling has a much more important potential as a tool for planning and management. Its usefulness extends beyond the most common thought of applications of projection and plan evaluation. It is also a device for organizing and retrieving data, focusing with clarity on complex systems, and identifying the underlying assumptions behind many policy arguments.



THE GENERAL URBAN ENVIRONMENTAL MODEL

In practice, simulation/modeling has rarely realized this potential. It has been our contention that the primary reason for this apparent failure is the inability or unwillingness of the academic "model builder" to work closely with the people he hopes to serve. The user must be able to understand and evaluate the conditional predictions which WALRUS III produces before he can make judgments on those predictions.

To avoid a situation in which the simulation specialist and pragmatic decision maker move in opposite directions, the staff presented a paper describing in lay terms the potential applications and limitations of the simulation to a group of planners and decision makers in the Traverse City area. Subsequently, the group jointly developed a program defining a consistent work relationship with a select group of community leaders to be implemented over the current year. The main topics of this program on the simulation included the methodology in general, particular assumptions and operations of WALRUS III, establishment of priorities for on-going development, review and evaluation of data and results produced by the model, and the design of a program for the future use of the model with several issues.

ECONOMIC IMPACT ANALYSIS

The examination of industrial water quality decisions and resolution of conflicting priorities in water and land resource utilization were major concerns of the Economic Impact Analysis Project.

A survey of nearly 500 Michigan industrial concerns located on or near the shoreline of Lake Michigan was conducted to determine the responsiveness of Michigan industry to preserving water quality (Patricia L. Braden and Francois J. Grossas. "Environmental Decision Making in Industry," TR No. 38, Michigan Sea Grant Program, June, 1974). The study concentrated on firms in "dirty" industries in order to examine the impact of recently legislated water quality standards on the companies' organizational structures and their executives' decision making.

Michigan executives revealed surprising confidence in the ability of industry to control and eventually stop pollution in a minimum of time with maximum effectiveness, and at minimum cost. Most preferred governmentally-regulated water quality standards as a means of assuring uniform enforcement. The participants indicated that decisions involving compliance with water-quality standards are made at lower levels of management by individuals with engineering backgrounds. Though lower-level managers exhibited greater concern about water quality than top management, they were likely to be given the authority to make operating decisions only, and not likely to participate in planning and control.

The managers' water-related decisions were generally made on the basis of information obtained from trade associations, trade journals, the mass media, or state agencies. Most information on water pollution control was considered to be relatively difficult to find, suggesting a need for advisory contact with management decision makers. In particular, top management requested assistance in obtaining information on legal requirements, community and legislative activities related to water quality control, cost and tax requirements, and the effectiveness of various types of water pollution control equipment.

In September of 1973, the Marine Technology Society invited Dr. Braden to present an address on the decision model being used to resolve conflicting priorities in water and land resource utilization (Patricia L. Braden, "Integrating the Interest of Competing Groups in Socio-Economic Analyses: A Suggested Approach." Washington, D.C.: Marine Technology Society, Ninth Annual Conference, September 10-13, 1973). The model, which was perfected jointly with Dr. Edgar Pessemier of the Krannert School of Industrial Administration, Purdue University, is a methodological extension of the Delphi technique. It functions effectively as a device to identify the priorities of groups in conflict and to point out alternatives which might generate solutions to issues of competing land and water uses.

The model was pretested on the problem of using nuclear power as an alternative energy source. Experts from nuclear engineering, nuclear physics, and radiological health participated in the pretest on the University of Michigan's Ann Arbor campus in order to test the reliability of the instruments prior to venturing into the field. The pretest results were very encouraging and paved the way for a field test of the model on a "live" problem.

The site chosen for study was on the Tittabawasee River in the Saginaw Bay watershed area, where a major power company had proposed to locate a twin nuclear reactor. Interest groups from nearby Midland were contacted to participate in the study. The Saginaw Valley Intervenors, the Mapleton Intervenors, and the Sierra Club represented those opposed to the new plant, while the Chamber of Commerce's "Save Our Nuclear Power Plant Committee" represented the more moderate political and economic interests in the community.

The model indicated, and observation verified, that the three groups were not irretrievably separated on the issue. Those favoring the nuclear plant did so for lack of technically feasible alternatives and with reservations about the safety and viability of nuclear power; those opposed regarded the plant as a threat to safety. A comprehensive review of the data indicated that a delay of the plant was advisable to achieve consensus while awaiting the results of further environmental and economic impact statements. The later results of these studies were substantially negative and it is our understanding that the power company is now investigating alternative sources of power for the area.

The field test of the model was highly successful and indicated that great promise exists for combining it with WALRUS III to provide a vehicle for impacting alternative water and land uses. New devices for information feedback to participating interest groups are currently being tested in Traverse City to encourage the use of WALRUS III data in resource management decisions.

coastal zone and shoreland research

COASTAL ENGINEERING AND EROSION PROTECTION

The State of Michigan has undertaken a comprehensive look at shore protection for the areas of Michigan shoreline threatened by erosion. The Sea Grant Coastal Engineering and Erosion Protection project is integrated with the Erosion Control Demonstration Program carried out for the Michigan Department of Natural Resources (DNR) by the University of Michigan Coastal Zone Laboratory. The principal objective of the Erosion Control Demonstration Program was to select, design, install, and evaluate a series of 19 demonstration sites in selected areas around the state with erosion problems. Both traditional and innovative erosion protection methods were used and evaluation considered cost, construction difficulties, durability, and reduction of erosion rates. Every site has its own special problems and these dictate variations in engineering design.

The state's project focuses on three basic methods of controlling erosion: groins, revetments, and sand fills. Groins are solid dock-like structures extending from the dry beach into the lake. Revetments consist of protection placed directly on the bank. Sand fills are used to raise the flatter portion of the beach,

causing waves to expend their energy before reaching the more vulnerable shore areas. Among the materials being tested which are new to the Great Lakes is asphalt mastic, which is similar to road asphalt except that it contains no large aggregate and has about 20 percent asphalt content. The mastic is applied as an extremely hot liquid to layers of poorly graded stone in both revetments and groins. It helps keep the structure in place and also prevents water from 'jetting through' openings between rocks, eroding the bank.

One of the major purposes of the field demonstration is to show which protection procedures hold promise for success at a reasonable cost. Only after years of monitoring the structures will this information become available and Sea Grant is helping to provide this ongoing monitoring program. A report on the Erosion Control Demonstration Program is available from the Bureau of Water Management, Michigan DNR .

A complimentary laboratory program is examining the effectiveness of certain protective measures much more rapidly and at a small fraction of the cost of a field installation. Tests conducted last year showed that shore processes, particularly bluff recession rates, were realistically demonstrated in the wave tank model and were reproducible. This model is now being used to test the effectiveness of several types of permeable walls which are being extensively installed (often combined with groin systems) by property owners along the Lake Michigan shoreline. Michigan Sea Grant and the DNR are financing this work.

A historical review of erosion at certain select sites in Michigan is being continued and expanded. Examination of old records of erosion provide a better perspective regarding the present severe erosion problems and is essential for future planning. Much use is being made of the relation between bluff recession rates and lake elevations, results determined as part of the 1972-73 Sea Grant program. For example, erosion rates can be estimated for the 29 year period 1860-1888, when the lakes were much higher than during recent years. Planners must consider the possibility of such levels being equaled or exceeded in the future.

The total erosion program described above is proving to be a very satisfactory combination of state and Sea Grant efforts. The Michigan Sea Grant Program will be integrated with a national shore erosion demonstration project since both Bill Marks of the DNR and Dr. E.F. Brater have been appointed to the advisory panel for this national program.

COASTAL ZONE AND SHORELANDS MANAGEMENT RESEARCH PROJECT

This second full year of operation under the University of Michigan Sea Grant Program was marked by a series of activities, many of which were related to the decision on the part of the federal administration to activate a federal coastal zone management program.

During the latter part of Fiscal Year 1974, the project was restructured somewhat so that research products of the project provided the maximum aid to government, industry, and citizens in responding to the requirements of the new coastal management legislation. During this year the project has also experienced a rapid increase in the number of requests for assistance and information from government, citizens, administrators, planners and industry.

Work continued on development of a coastal management concept, in cooperation with the Michigan Department of Natural Resources. Michigan Sea Grant will increasingly become an active part of the development of coastal management programs in Michigan and the Great Lakes. Specific areas in which work was begun this last year include:

- the problem of defining the boundaries of the coastal zone
- development of methodology for designating areas of critical concern
- development of design criteria of a usable coastal zone management information system
- development of local government assistance programs

In addition, work is underway on comparative evaluation of specific management techniques proposed or used in other coastal states with respect to their applicability to the specific and unique problems of the Great Lakes.

Work has progressed on the revision and updating of the earlier publication "A Description and Analysis of the Coastal Zone". This document, in the original form, has proved to be a valuable and basic reference work for researchers, planners and managers involved in coastal zone management development programs. Many requests have been received from foreign nations as well as hundreds of requests from within the U.S.

In the area of coastal management techniques two research efforts carried out during the year have been particularly productive. One project dealt with an in-depth analysis of the broad-scale effects of extending sewer services in shoreland areas of Grand Traverse Bay. This work centered on the relationships between engineering technology developments and the policy-institutional problems that can arise. A second project dealt with a comprehensive study of the Planned Unit Development concept (PUD) as a tool for shoreland use planners in the Grand Traverse Bay region. Two publications in a new series of Planning Information Bulletins have resulted from this research. Both have been widely distributed nationally and have generated interest in more information on these topics and in the bulletin series.

The single most important effort of the staff was in the development of a highly successful community workshop on zoning and planned unit development, attended by more than 70 people. Working carefully with city and regional officials and planners, a drama depicting the critical elements of PUD was developed by staff, along with a description of the zoning process and other associated materials.

In the area of shore erosion, work has continued in conjunction with the Coastal Engineering and Erosion Protection project. Researchers in the coastal management research project have been working on a project dealing with the relationship of shore erosion problems to the state's development of a general coastal management program. Primary emphasis during the past year has been on analyzing data on economic damages caused by shore erosion in various shoreland use categories such as recreation, industrial, and residential. Utilizing data from the Shore Protection Demonstration Project of the Michigan Department of Natural Resources, considerable work has been carried out in preparation for analyzing the costs and benefits of various shore protection concepts. This effort has also involved the analysis of set-back requirements (due to bluff recession rates) for local zoning of shoreland property in critical erosion areas.

A Model Zoning Ordinance completed last year by the project has not been distributed due to a continued review by the state. During the year several possible changes in the ordinance have been completed by project staff, and it is hoped that some version can be made available to the public in the near future.

Dr. Armstrong was appointed to the Michigan Shorelands Advisory Council, and now actively participates in that group's effort to guide the state on the formation of a coastal zone management plan and program.

Mr. Peter Ryner was appointed an alternate to the Michigan Environmental Review Board and has attempted to provide members of that board with technical and research support.

Significant staff time was spent in research on the issues emerging from the Sleeping Bear Dunes National Lakeshore now being structured. Cooperative efforts were carried out with members of the National Park Service, Sleeping Bear Dunes Administration and the Sleeping Bear Dunes Citizen Advisory Council.

The basic design of a Community Planning Information Center was formulated with the League of Women Voters and much groundwork for an actual Center completed.

Numerous requests for information, concepts, evaluation, and advice were received and responded to by project staff. Of particular importance

during this year was the expansion of the project advisory services from local and regional governmental units to include several state-wide groups, as mentioned above. Also, plans were made to greatly increase the technical input of staff to local planning and management efforts during the next year, as a test of methods of effectively providing university support to actual local decision situations on a day to day basis. This work represents a significant supplement to the main Sea Grant Advisory Services Project.

SHORELAND RECREATION BEHAVIOR PATTERNS

The 1973-74 research was divided into two parts. The first was a continuation of the survey of recreation visitors to and residents of the Lake Huron shorelands. The second part of the work concentrated on identification of five coastal communities where commercial fishermen and fishing villages still exist and which have potential as historic fishing areas. As part of the state-wide survey of potential fishing village sites, the general schematic concept of living history was developed. In preparation for an in-depth study during the summer season of 1974, five locations were identified. These are Big Traverse Bay and Grand Marais on Lake Superior, Fairport and Leland on Lake Michigan, and Bay Port on Lake Huron.

The 1973-74 survey research questionnaire investigated the attitude of shoreland owners. This questionnaire was administered to approximately 500 permanent and second home (vacation) residents located within the shoreland residential zone and was directed toward the problems these home owners face. In rank order, Lake Huron home owners feel recreational quality is being reduced by shoreline erosion, lake and stream pollution, trespassing on private land, vandalism, insufficient law enforcement, motorcycle rowdies, and continuous shoreline subdivision development. Other reasons, such as too little public access and lack of sufficient camping facilities, were mentioned by a few respondents. In general the opinions of home owners as to problems faced fall into two categories: (1) annoyances caused by people who are insensitive to the rights and property of private owners, and (2) changes in shoreland uses which inevitably result in greater densities of people and alteration of the natural shoreline environment.

In general home owners feel satisfied with recreational opportunities near their homes. The only additional facilities home owners desire are fishing piers, boat marinas and improved swimming beaches. As leisure home ownership expands in Michigan's northern counties, the support for increased lake access and facilities will run counter to the demands of metropolitan citizens for increased wilderness protection. Survey data indicates that while the leisure home owner and permanent resident desire to retain the wild character of the shoreline, they are very much water–recreation oriented and expect public facilities. One of the fundamental dilemmas of coastal planning will be determining how to provide urban-like services in these rural—wild coastline settings without destroying the essential characteristics which attracted people in the first place.

A second part of the 1973-74 survey research questionnaire was administered to Lake Huron shoreline visitors (non-shoreland residents). The response of this group to the question of threats to the recreational quality of the area reflected a different perspective than that of the home owner. The visitors felt shoreline erosion was less serious, unattractive private homes and development more serious, and commercial developments very serious. The visitors expressed nearly the same concern as home owners toward people-related problems of overcrowding, vandalism, motorcycle rowdies, illegal use of drugs, and insufficient law enforcement. Only 35 percent of the visitors worried about their personal security, but one-third of these were anxious enough to have some means of protecting themselves and their property. The means of protection included

guns, dogs, or other physical deterrents such as knives. Most visitors preferred to have a law enforcement officer available if needed. We are convinced that most metropolitan residents who bring guns to the coastal recreation sites do so because they also bring their urban fears with them. We feel it is only a matter of time until Michigan's public recreation areas experience the congestion-related crimes of passion now presently associated with Detroit and other large cities.

The motivational parts of the survey have indicated that the natural or semi-natural aspects of the Lake Huron shoreline are valued highly by shoreline visitors and residents. Wildlife and wildlife habitat are important components of natural environments and several questions were included in our survey to assess their significance.

Viewing wildlife, or simply knowing that wildlife exists in the area, is highly valued by shoreline users and contributed to their enjoyment of the area. "Loss of wildlife habitat and natural areas" was ranked as the third most important problem by the total sample and was ranked as the *most* important problem by respondents from the northern two-thirds of the shoreline.

The importance of wildlife to shoreline residents was further indicated by questions probing their concern for rare and endangered species and by their willingness to support government appropriations and voluntary contributions for wildlife habitat improvement. Although Lake Huron's shoreline provides habitat for a diversity of wildlife, most public recreation areas do not provide superlative wildlife viewing. There appears to be logic in classifying wetland areas and off-shore islands for protection as wildlife habitat areas. Visitor interest is sufficient to justify public ownership of such sites.

These expressed preferences correspond well with the results from other parts of the survey. Together they indicate that for most people who recreate and live along Lake Huron the primary recreation experience lies in resting and enjoying natural surroundings and the temporary reprieve from the social and physical stress of day-to-day life.

underwater

Safety of scientific personnel working underwater and in hyperbaric environments is a primary concern in the Underwater Technology Project. Data accumulated from many sources, field experimentation, and evaluation of diving equipment and procedures has been synthesized into a safety and operations code for underwater diving and hyperbaric chamber work. This is one of the few, if not the only, safety codes in the academic and scientific communities that addresses surface-supplied diving, hyperbaric chamber operation and scuba diving. The results of this research are in press in "Safety Code for Underwater Diving and Hyperbaric Chamber Operation" (MICHU-SG-74-602).

Increasing interest in polar region research and winter research in the Great Lakes area suggests that underwater scientific studies in cold weather and under ice diving will increase the next few years. The Underwater Technology Project has included research in this area of diving for several years. Specific emphasis has been placed on equipment performance, cold-water suits, under ice diving procedures, and personnel safety. Data has been accumulated from

technology

literature research, interviews, and field experience. It has also been taken into account that "sport" scuba diving in cold climates and under ice is currently experiencing an exponential growth. Consequently, the results of this work were published for both the scientific and sport diving community in "Cold Weather and Under Ice Scuba Diving" (NAUI Tech. Pub. 4). Information on surface-supplied diving will be forthcoming in future publications.

Construction of an air control-communication console for surface-supplied divers was completed, and initial tests were conducted during the summer of 1973. The results of these tests were satisfactory; however, some modifications were indicated regarding communications. The results of this work are reported in "Air Control-Communication Console for Surface-Supplied Divers" (MICHU-SG-74-204).

The Michigan Sea Grant underwater laboratory, LAKELAB, served as a base of operation for equipment evaluation and contributed significantly to the research diver training courses. This underwater laboratory, located in 30 ft. of water in Grand Traverse Bay, is unique to the U.S. waters of the Great Lakes. Air is supplied to the laboratory from a shore-based system and all activities inside the laboratory are monitored by voice communication. The facility has provided significant insights into underwater technology and education for researchers and students.

Using LAKELAB as a base of operation, Sea Grant provided diving services for the Michigan Department of Natural Resources Fisheries Division in studying the effects of pesticides on the natural reproduction of lake trout. Divers placed 16 lots of "green" eggs from Lake Michigan fish along with 16 lots of "green" hatchery eggs next to LAKE—LAB and sampled these lots on a monthly basis throughout the winter and spring. Researchers from the Marquette Fisheries Research Station planned to compare the survival of eggs incubated in Lake Michigan with those from the Marquette hatchery containing lower levels of DDT and PCB. In addition, Sea Grant divers made observations on natural spawning reefs in Lake Michigan during the winter.

Since the conception of the Underwater Technology Project, data has been compiled on scientific diving requirements and techniques. This year, nearly 800 scientific papers were reviewed in order to accumulate data on scientific diving. These findings are currently being complied into a handbook on scientific diving techniques. Since surface-supplied diving apparatus continues to demonstrate greater reliability, safety, and efficiency, research on the improvement of equipment, procedures, and training were continued this year. In addition, improved scuba diving equipment and procedures were studied for applications to scientific diving and updating the "Research Diver's Manual," of which over 4000 copies have been distributed to schools and individual divers.

Through Dr. Somers, Michigan Sea Grant continued to be represented on several national committees including the American National Institute of Standards Z-86 committee on diving equipment standards; the National Association of Underwater Instructors Board of Directors; and the American Alliance for Health, Physical Education and Recreation's Committee on Skin and Scuba Diving Instructional Standards. In addition he was appointed to the Scientific Committee of the Confederation Mondiale des Activities Subaquadeques, and he chairs the University's Diving Safety Committee, which monitors all university diving activities. Dr. Somers presented more than 20 public service lectures and three conference papers on underwater technology and education.

The Sea Grant Programs' hyperbaric chamber continues to serve the divers of Michigan, Ohio, Indiana, and Ontario for treatment of decompression sickness and air embolism.

advisory services

In its constant effort to improve two-way communications with the many individuals and groups concerned with the Great Lakes, Michigan Sea Grant has expanded the advisory field activities. In October 1973 a full-time field agent was hired to cover the state's northern counties. His work was coordinated with that of the newly established Regional Coastal Zone Laboratory office in Traverse City. In December an agreement was reached with Michigan State University to cooperate in extension work centered around Great Lakes-related problems in the state's 41 coastal counties. As a result of this agreement M.S.U. extension agents in all the coastal counties will work with Sea Grant researchers and advisory personnel to solve local problems. Sea Grant sponsored resource specialists in fish marketing and fisheries economics will be added to the M.S.U. staff in fiscal year 1974-75. Planning was begun for in-service training sessions for the coastal county agents, and methods devised for utilizing the feedback of county agents to help assign priority to advisory service or research activities.

COASTAL ZONE PLANNING AND MANAGEMENT

Interest is high throughout Michigan's 3200 miles of coastline in coastal zone planning and management, although priorities differ from area to area. Erosion is a serious and continuing problem along some 500 miles of our coastline, and citizens have been very interested in the progress of our research on low-cost erosion prevention devices. Information on this research effort has been widely distributed to individuals, groups of homeowners, and governmental agencies.

Workshops, seminars and conferences on various aspects of coastal zone planning and management were held with various groups throughout the year. At the request of the Grand Traverse Bay Regional Planning Commission Sea Grant held a workshop on planned unit development. It was attended by numerous city and county planning and administrative officials. In cooperation with the Great Lakes Basin Commission, Sea Grant held a workshop on Great Lakes Shoreland Management which was attended by

representatives from the governors' offices of the eight Great Lakes states. A well-attended workshop on the effects of sewer development on shoreland development was held in Traverse City at the request of the Grand Traverse Bay Regional Planning Commission. A field trip for members of the Michigan Basin Geological Society was held in order to aquaint the participants with the effect of geological formations on shoreland planning and management in the Grand Traverse Bay area. A Citizen Planning Information Center was opened in Traverse City, in cooperation with the League of Women Voters and the city library. This is considered a pilot project, to be evaluated by the League after a year's operation. The concept is being considered for implementation throughout the country. The WALRUS III gaming/simulation was demonstrated to Grand Traverse Bay area officials. WALRUS was presented at an Urban Gaming Workshop in which participants learned how to run a game and modify the game to their own specific purposes. Sea Grant was represented on the Governor's Shoreline Advisory Council, providing a broad range of information to this group which makes recommendations on shoreland planning and management to the governor. Plans were developed for a conference on the problems of flood plain development to be held in the fall of 1974 in cooperation with the Bureau of Outdoor Recreation. Plans were developed for a Great Lakes Shorelands Conference to be held in the fall of 1974, sponsored by the Michigan legislature and coordinated by Michigan Sea Grant. Newspaper articles, magazine articles, lectures, and participation on TV talk shows were utilized to further disseminate information on coastal zone planning and management.

RECREATIONAL DIVING SAFETY

Some agencies estimate that the number of recreational scuba diving participants has increased over 200% during the last 5 years. During this time interval nearly 750 scuba divers were trained at the University of Michigan. Increased activities and public visibility suggest that the Great Lakes area has followed the national trend in increased recreational diving. This increase in recreational diving activity has stimulated a tremendous demand for public education programs and professional consultation involving a relationship between various members of the diving community including instructors, equipment retailers, equipment manufacturers, and the academic community.

The Michigan Sea Grant Program annually sponsors approximately 20 public service lectures and hyperbaric chamber demonstrations at the Underwater Technology Laboratory directed toward recreational diving clubs, classes and instructors. These programs are intended to promote safe diving and educate divers in various aspects of diving physiology, decompression, diving technology and diving procedures. Demonstrations are designed to discourage "deep" recreational diving.

The advisory activities of 1973-74 have led to increased emphasis on safety education for recreational divers and the proposed formulation of new research, educational, and service programs for future years. A close working relationship has developed with the Michigan Skin Diving Council, as well as with retail diving equipment stores and instructor groups.

FISHERIES

Sea Grant Advisory Service personnel have participated in meetings of both sport fishermen and commercial fishermen throughout the year, distributing information on fisheries management plans in Michigan and delivering speeches on the topic. Field agents have been working with the Michigan Fish Producers Association (M. F.P.A.) to devise new methods of harvesting fish which are in compliance with new state regulations. The possibility of developing a new industry revolving around the harvesting of rough fish, along with the associated product development and marketing techniques, has been discussed with the M.F.P.A. and state agencies. The exciting potential of this project prompted the support of a fisheries economist and a fish marketing specialist for the next fiscal year. A conference entitled "The Great Lakes-A Great Resource" which dealt with fishery management problems was held in cooperation with the Grand Traverse Area Sports Fishing Association, the Great Lakes Fishery Advisory Committee, and the Traverse City Chamber of Commerce. It was attended by several hundred state legislators and fishermen.

A two-week workshop of charter boat operators from Michigan and Oregon was held in September, 1973 and June, 1974. The exchange, backed by the Shakespeare Company and the Wright and McGill Company, allowed those in the relatively new industry in the Great Lakes to exchange information with their well-established west coast counterparts on differences in approach to a very similar resource. Methods of dealing with clients, types of boats and equipment, methods of locating and catching fish, and support services were thoroughly discussed. The charter boat captains from both areas gathered beneficial information which they are putting into practice in their own location.

education

The importance of education in the Michigan Sea Grant Program is exemplified in several ways.

Sea Grant principal investigators are very often faculty members involved in teaching and educational activities directly related to Sea Grant objectives and goals. Each year, these faculty members teach or participate in a wide range of departmental and interdepartmental courses directly related to water resources and research problems of the program.

A unique learning experience for both graduate and undergraduate students is obtained through participation in applied research projects, and, during the past year, approximately 60 students worked directly in the field and in the laboratory on Sea Grant projects. Sea Grant research experiences play a significant role in enriching and integrating the classroom experience for many students.

In addition, new and innovative courses relating to marine resources have been encouraged and supported by the Sea Grant Program.

Again in the summer of 1973, the oceanography field practicum was conducted at Woods Hole, Massachusetts. This in-depth course enables graduate students in oceanography and related fields to carry out experimental observations on the ocean in order to become acquainted with the practical techniques currently used in marine research. Three distinct aspects of the course covered practicum exercises, lectures, and individual research projects. Among the areas covered were design and implementation of oceanographic observational programs; marine data-gathering capabilities; current techniques in physical, chemical, geological, and biological oceanography; and marine geophysics and marine meterology.

Specific educational activities sponsored by the Underwater Technology Project included Research Diver Training Courses, Hyperbaric Chamber Attendant Courses, and an Underwater Technology Course in the College of Engineering.

Two intense week-long Research Diver Training Courses trained 20 novice scuba divers in advanced scuba diving, surface-supplied diving, habitat diving, underwater research techniques, underwater work, and related topics to aid them in becoming working research divers.

The increased use of the hyperbaric chamber at the Sea Grant Underwater Technology Laboratory produced a demand for more chamber attendants and operators. Consequently, the Laboratory sponsored courses to train approximately 30 students and faculty in hyperbaric chamber operation and maintenance. The course outline is included in a text specifically prepared for this course titled "The University of Michigan Hyperbaric Chamber Attendant's Handbook" (MICHU-SG-74-601). This course is taught in cooperation with the University of Michigan Medical Center, Pulmonary Division.

An Underwater Technology Course (AOS/NA 469) was sponsored by Sea Grant as a part of the College of Engineering curriculum. This is a survey course with emphasis on manned undersea activities in oceanography and ocean engineering. Topics covered range from human performance underwater to equipment design and applications.

In addition, Michigan Sea Grant personnel train 50 to 90 students per school term in the use of self-contained diving apparatus through the Department of Physical Education. Approximately 50% of the students enrolled in these courses are science and engineering students who specify that they are seeking this training for possible future application in their professional work.

program summary

july 1973 - june 1974

ACTIVITY BUDGET SUMMARY

July 1, 1973-June 30, 1974

	NOAA Grant Funds	Matching Funds
Program Management Activities		
Program Administration	$70,000	$10,600
Publications	15,000	
Research Activities		
Ecosystem Modeling	76,000	19,500
Ecosystem Processes & Field Research	106,200	67,300
Physical Modeling & Field Research	60,000	26,600
Public Policy, Technology & Institutional Research	82,000	44,300
Coastal Zone & Shorelands Research	57,600	105,300
Underwater Operations	30,000	25,700
Advisory Services Activities	70,400	1,000
TOTAL	$ 567,200	$ 300,300

SEA GRANT PROGRAM DEVELOPMENT

PROGRAM AREA—Year Beginning July	1971	1972	1973
PROGRAM MANAGEMENT ACTIVITIES			
Program Administration and Development (Armstrong)	C	C	C
Information and Advisory Services (Schneider)	C	C	C
Education (Armstrong)	C	C	T
Technical Publications (Bozorgmanesh)		N	C
ECOSYSTEM MODELING			
Mathematical Modeling (Canale)	C	C	C
Resource System Modeling (Patterson)	C	C	C
Interactive Display of Water Research Data (Phillips)		N	T
Stochastic Modeling (Rothman)	N	C	T
Control Theory Modeling (Woodring)	C	T	
ECOSYSTEM PROCESSES AND FIELD RESEARCH			
Nutrient Chemistry (Allen)	N	C	C
Biological Production (Arnold, Chandler, Sygo)	C	C	T
Ecosystems Processes and Field Research (Kelly, Meier)			N
Evaluation of Ferromanganese (Callender)	C	T	
Water Sediment Interface (Callender)	C	C	C
Water Quality (Gannon)	C	C	C
Nutrient Enrichment and Nutrient Chemistry (Schelske)	C	T	
Phytoplankton Dynamics (Stoermer)	C	C	T
Field Operation and Services (Craw)			N
PHYSICAL MODELING AND FIELD RESEARCH			
Hydrology and Shore Erosion (Brater)	C	C	T
Impact on Lakes and Rivers of Seepage from Polluted Groundwater (Brater)		N	T
Water Circulation Models (Green)	C	C	C
Water Circulation Measurement (Monahan)	C	C	C
Power Plant Thermal Discharges (Ryznar)		N	T

PROGRAM AREA—Year Beginning July	1971	1972	1973
PUBLIC POLICY, TECHNOLOGY, AND INSTITUTIONAL RESEARCH			
Public Policy Project (Bulkley)	C	C	T
Gaming Simulation (Duke, Feldt)	N	C	C
Decision Making (Michael, Hinkle, Feldt)	C	C	T
Economic Impact Analysis (Braden)	C	C	C
Technological Impacts (Yagle)	C	C	C
COASTAL ZONE AND SHORELANDS RESEARCH			
Coastal Zone and Shorelands Management (Armstrong)	C	C	C
Shoreline Processes (Brater)	T		
Recreation Behavior (Tocher)		N	C
Watershed Land Use (Polakowski)	C	C	C
TECHNOLOGY ASSESSMENT			
Wastewater Treatment (Weber)	C	C	T
Remote Sensing–Lake Michigan (Polcyn)	C	C	T
Intra-Lake Bulk Carrier (Yagle)	T		
UNDERWATER OPERATIONS			
Underwater Operations (Somers)	C	C	C

N—New C—Continuing T—Terminated

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ORGANIZATIONS INTERACTING WITH THE MICHIGAN SEA GRANT PROGRAM

Michigan Water Resources Commission
Michigan Department of Natural Resources
Grand Traverse Bay Regional Planning Commission
Lake Survey Center - NOAA
Great Lakes Basin Commission
Grand Traverse Bay Shorelands Coordinating Committee
Environmental Protection Agency
Michigan Department of Commerce
University of Wisconsin Sea Grant Program
Great Lakes Commission
Michigan Technological University
Michigan Department of Health
Michigan Department of Agriculture
Michigan State University
Dow Chemical Company
U.S. Army Corps of Engineers--North Central District
Northwestern Michigan College
U.S. Bureau of Sport Fisheries and Wildlife Laboratory
International Great Lakes Study Group
Saginaw Valley College
Shakespeare Corporation
Grand Traverse Bay Sports Fishery Association
City of Chicago, Department of Planning and Development
Michigan Chamber of Commerce
Motor Vehicle Manufacturers Association
Lake Michigan Federation
Bureau of Outdoor Recreation
Grand River Watershed Council
City of Traverse City
Industrial Users of the Great Lakes Association

publications

Bozorgmanesh, C.K. (editor). The University of Michigan Sea Grant Program Annual Report 1972-73. January 1974.

Braden, P. and J. Grossas. Environmental Decision Making in Industry. Michigan Sea Grant Program, TR No. 38 (MICHU-SG-74-201), June 1974.

Brater, E.F., J.M. Armstrong, and M.R. McGill. Shore Erosion Engineering Demonstration Project: Post-construction Season Progress Interim Report. Coastal Zone Laboratory. February 1974.

Canale, R.P., D.F. Hineman, and S. Nachiappan. A Biological Production Model for Grand Traverse Bay. Michigan Sea Grant Program, TR No. 37 (MICHU-SG-74-200), February 1974.

Canale, R.P. 1973. Model of coliform bacteria in Grand Traverse Bay. J. Water Pol. Con. Fed. 46:2358-2371.

Canale, R.P., S. Nachiappan, D.J. Hineman, and H.E. Allen. 1973. A dynamic model for phytoplankton production in Grand Traverse Bay. Proc. 16th Conf. Great Lakes Res. pp. 21-33.

Canale, R.P., R.L. Patterson, J.J. Gannon, and W.F. Powers. 1973. Water quality models for total coliform. J. Water Pol. Con. Fed. 45:325-336.

Canale, R.P. 1973. Experimental and Mathematical Modeling Studies of Protozoan Predation on Bacteria. In: Biotechnology and Bioengineering. Vol. XV, pp. 707-728. John Wiley and Sons, Inc., New York.

Canale, R.P. and A.H. Vogel. 1974. Effects of temperature in phytoplankton growth. J. Env. Eng. Div., ASCE 100: 231-241.

Canale, R.P. and F.Y. Cheng. 1974. Oxygen utilization in bacterial-protozoan community. J. Env. Eng. Div., ASCE 100:171-186.

Monahan, E.C. and E.A. Monahan. Drogues, Drags, and Sea Anchors. Michigan Sea Grant Program, TR No. 36 (MICHU-SG-73-203), September 1973.

Monahan, E.C. and E.A. Monahan. 1973. Trends in drogue design. Limnol. and Oceanog. 18:981-985.

Monahan, E.C. and E.A. Monahan. Drift Bottles and Other Surface Current Markers. Michigan Sea Grant Program (MICHU-SG-73-104). Fall 1973.

Ryner, P.C. Planning Information Bulletin 1: Sewers and Shorelands development. Michigan Sea Grant, January 1974.

Ryner, P.C. Planning Information Bulletin 2: Planned Unit Development (PUD): tool or trap? Michigan Sea Grant, February 1974.

Schneider, R.S. Hard-water Great Lakes ice problems. Michigan Natural Resources Magazine, pp. 18-21, November-December, 1973.

Somers, L.H. 1973. Lakelab underwater habitat. Proc. 16th Conf. Great Lakes Research, pp. 1046-1049.

Somers, L.H. 1973. Cave diving equipment and procedures. In: The Complete Guide to Cave Diving. NAUI Tech. Pub. No. 3. 50 pp.

Somers, L.H. 1973. Cold Water and Under Ice Scuba Diving. NAUI Tech. Pub. No. 4. 57 pp.

Somers, L.H. 1973. Selection and training of aquanauts for hydro-lab type saturation dives. Hydro-Lab J. 2:97-103.

Vogel, A.H. and R.P. Canale. A food web model for Lake Michigan: Part 1—Justification and development of the model. Michigan Sea Grant, TR No. 40 (MICHU-SG-74-203), March 1974.

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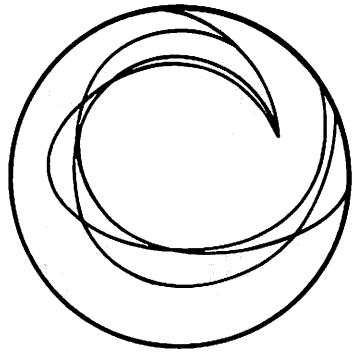

The Michigan Sea Grant Program is supported by the Office of Sea Grant, National Oceanic and Atmospheric Administration, U.S. Department of Commerce under Grant 04-4-158-23.

Edited and designed by Cheryl Bozorgmanesh

Printed by University Lithoprinters, Inc.
Ypsilanti, Michigan

Photographs courtesy of Blanchard Mills, Stuart Abbey, Michigan Tourist Council, Michigan Sea Grant Advisory Services.