The University of Michigan
SEA GRANT PROGRAM

ANNUAL REPORT 1972-73

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THE UNIVERSITY OF MICHIGAN

Sea Grant Program Annual Report

July 1, 1972–June 30, 1973

INTRODUCTION

Michigan has over 3,200 miles of Great Lake's shoreline, with more coastal length than any other state in the mainland United States. The importance of the Great Lakes to Michigan and, indeed, the entire Midwest is well-known. The many industrial, commercial, recreational, and aesthetic uses of the lakes require that considerable attention be given to the wise utilization and protection of these inland seas. The creation of the Michigan Sea Grant Program at The University of Michigan in 1969 marked a new era in the utilization of university resources to obtain a better understanding of the Great Lakes and the way in which they are influenced by and, in turn, influence man's activities.

A major objective of the Michigan Sea Grant Program continues to be the use of available university expertise to provide information and methodology to planners and managers about critical issues and uses of the Great Lakes.

The approach has been to establish an integrated and coordinated program to identify major issues, structure the research necessary to address these problems, and to use the results to aid in developing rational and practical solutions.

During 1972-73, the Michigan Sea Grant Program approached completion of the integrated pilot program in Grand Traverse Bay. This program provided a true laboratory situation in which a multidisciplinary research team could devise and test methodologies to aid resource managers in assessing various future impacts. Ecosystem models, created to predict the consequences of possible future growth patterns in the region, have been constructed. The results obtained indicate that the basic critical mechanisms have been appropriately modeled. Regional agencies and groups, assisted by Sea Grant Advisory Services, are now applying these models to critical resource issues in the region.

The models will continue to be applied in the Grand Traverse Bay region by incorporating them into the WALRUS gaming simulation. In this manner, officials and citizens can explore firsthand the various ways in which the region could grow and develop. The ecosystem models will be utilized to articulate the consequences of various regional issues: sewer expansion, waste management policies, marine transportation impacts, recreational development and impact, environmental–economic tradeoffs, and a variety of other problems. During 1972-73, the project goal was shifted to test WALRUS in actual operational planning conditions with the Grand Traverse Regional Planning Commission.

The Grand Traverse Bay project has been successful in terms of staff involvement in and integration of multidisciplinary projects. This has been reflected during the past year by the creation of the Saginaw Bay research program. This effort was designed at the request of and in cooperation with state officials who wished to utilize the Sea Grant team to analyze pollution and water-quality management issues in Saginaw Bay. Saginaw Bay is a more highly stressed natural system than Grand Traverse Bay. The pollution loadings and commercial uses of this bay are several times greater than those of Grand Traverse Bay.

Also during the past year, the integrated modeling research was applied to a problem area in Lake Michigan. In cooperation with the Michigan Department of Natural Resources (DNR), a cooperative project was begun to develop a food-web and fishery management model for the important salmon sport fishing in Lake Michigan. The experience gained in developing the Grand Traverse Bay ecosystem modle is being used directly to develop a resource management tool for another resource problem. The model developed in this project will be utilized by fishery managers in the DNR to explore the effects of lake water-quality levels and different planting and catch programs.

In the area of coastal management and engineering, the program has strengthened and expanded its cooperative relationship with the state government. During 1973, Governor William Milliken designated The University of Michigan, through its Sea Grant Program, as the state's Coastal Zone Laboratory. This new program has opened a new stage in state–university relations for the study of natural resource and environmental problems.

As an initial effort, under the Coastal Zone Laboratory program, the Michigan Sea Grant Program has received

direct state funding to develop and implement a demonstration program in engineering design, construction, and monitoring of innovative, low-cost erosion protective concepts for Michigan's endangered shorelands. Fifteen test sites are currently in use.

The Coastal Laboratory is also assisting the state in providing information and research dealing with the state's Shorelands Management Plan, soon to be implemented in Michigan. This program also assists local units of government in responding to the requirements of the Shorelands Management Plan.

A new program in urban coastal problems was initiated with the City of Chicago to study the impacts of construction of offshore islands. The city is embarking on a long-range program to create a large-scale urban, waterfront, recreational system along the 30-mile lake shore. The system will be centered on a series of large islands to be constructed in Lake Michigan. Fill material will be used from the new subway and deep-storm runoff tunnel projects. The city has given the Michigan Sea Grant Program a grant to begin identifying and analyzing the many issues associated with this pioneering effort.

Michigan Sea Grant Advisory Services have expanded into new areas of assistance to citizens of the Great Lakes water-oriented community and have provided a wide range of activities during the year. This included assembly and dissemination of information, from both Sea Grant and other sources, to state and local agencies and groups. A new advisory program oriented toward the sport and charter fishing industry in the Great Lakes was a highlight of the Advisory Services program. Advisory Services continued to function with several groups in the Grand Traverse Bay region in connection with other activities related to land-use problems and utilization of gaming techniques.

In recognition of the Sea Grant role, a joint resolution was passed by the 1972 Michigan Legislature commending the Michigan Sea Grant Program on its activities and service to the state.

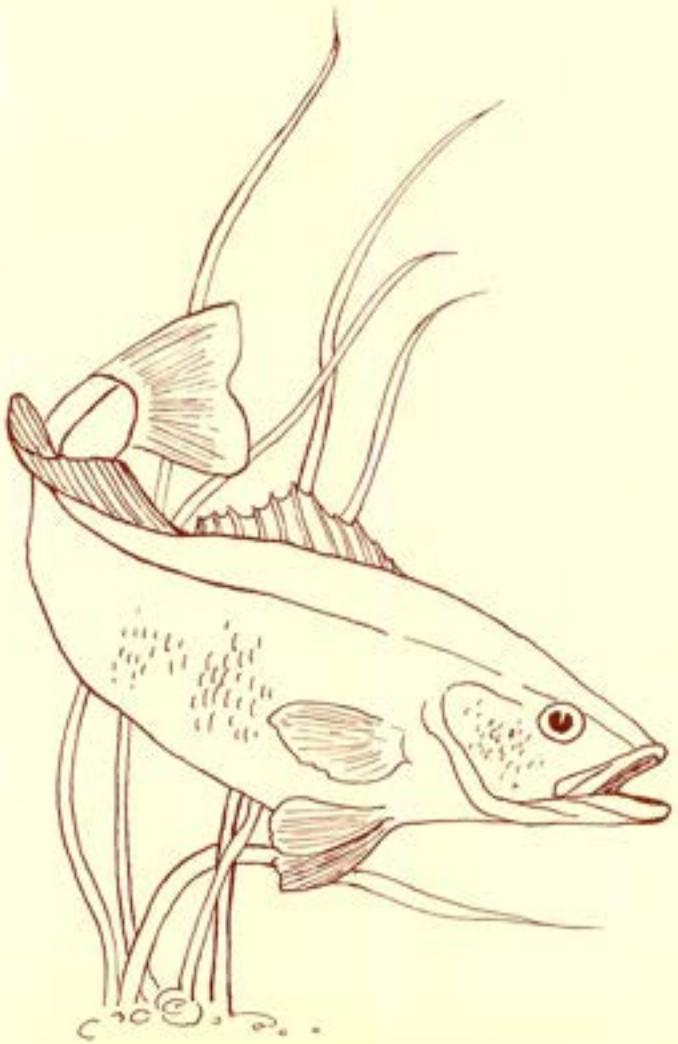
In the coming two-year period, the Michigan Sea Grant Program will be initiating a comprehensive research design project to structure an ecosystem modeling and coastal zone management program for Lake Michigan. Coordination with various agencies and other universities will be necessary to determine how best to apply the Sea Grant modeling and management methodology to a total lake system.

The following report briefly describes the individual research efforts that are part of the Michigan Sea Grant Program, and the sections represent the major areas of program activity, as related to resource issues under investigation. As in any research undertaking, it is the quality of individual research that gives real value to the coordinated efforts of the program. The Michigan Sea Grant Program is fortunate to have a team dedicated to the Sea Grant charge.

John M. Armstrong

Director,
Michigan Sea Grant Program

ADVISORY SERVICES



INFORMATION AND ADVISORY SERVICES

R. Stephen Schneider

Michigan, with its 3,200 miles of Great Lakes shoreline, has a large number of citizens whose lives are significantly affected, in one way or another, by the Great Lakes. The goal of Michigan Sea Grant Advisory Services is to reach these people with knowledge and experience which can be of real help in their water-related problems. Although Michigan lacks many of the traditional resource-based industries which affect coastal areas, residents benefit from varied recreational use of the Great Lakes waters and shores. Much of the work of Michigan Sea Grant Advisory Services involves various facets of Great Lakes recreational use.

After a serious decline during the first half of the century, Great Lakes sport fishing, once again, has become of prime importance to the state. The successful reintroduction of the lake trout and the newly introduced coho, chinook, and Atlantic salmon have brought about this change. Decimated by the sea lamprey in the 1930's and 1940's, the lake trout and the newly introduced salmon have made a remarkable impact on the economics of the state, following the development of a successful lamprey control program. Sea Grant Advisory Services personnel have worked with sport fishermen to help organize interest groups in the state in order to better effect information transferral. Work is underway to reflect the interstate nature of the Great Lakes fishery by organizing groups of fishermen from the four states which border on Lake Michigan. Information on fishery management problems, the economics of the sport fishery, and the continuing problem of lamprey control has been disseminated by Sea Grant agents to these groups.

The growth in numbers of sport fishermen has led to an associated rise in the number of charterboat fishermen who serve the sportmen. Sea Grant Advisory Services agents have participated in and sponsored workshops and conferences for charterboat captains to discuss topics similar to those presented to sports fishermen. In particular, the problem of fishery management in relation to commercial and sport fishing has become of great importance. In the fall of 1973, Advisory Services will cosponsor a conference addressing this problem and present the program to the state's lawmakers. Legislation on commercial and sport fishing is expected to result. In the belief that an exchange of ideas on all aspects of charter fishing would be beneficial, Michigan Sea Grant, with backing from two tackle companies, is planning a two-part exchange of west coast and Great Lakes charter skippers. West coast charter skippers will come to the Great Lakes to both fish and crew out of several ports and on several boats. In the spring of 1974, Great Lakes charter skippers will do the same on the west coast. Distribution of the results should be helpful to all those working in the area of charter fishing.

The number of commercial fishermen in Michigan waters of the Great Lakes has been declining over the past several decades, and now stands at 160. Of this number, many are "part-timers." The total number will see further decline as the state implements its program of changeover from gill nets to impoundment gear. A Sea Grant Advisory Service specialist is investigating methods to minimize the difficulties involved in a complete gear changeover.

On the other hand, the number of sport divers has been steadily on the increase in the Great Lakes for the past decade, and a further increase is expected. The physical dangers of diving have been emphasized, along with accident prevention measures, in a number of Sea Grant advisory activities. Advisory service agents have lectured to and held workshops with sport diving groups throughout the state to emphasize diving safety. The Michigan State Police Water Safety and Underwater Recovery Unit, the U. S. Coast Guard, and shoreline county sheriffs have been made aware of the existence of the Sea Grant hyperbaric chamber and its location in Ann Arbor. Helicopter ambulance landing pads were designated, and arrangements were made with University Hospital to oversee medical treatment of diving victims. A brochure describing diving emergency procedures and the chamber was distributed to diving clubs and gear sales outlets throughout the state. In the 1972 season, six severe diving accident victims were successfully treated in the hyperbaric chamber because of this service. During the summer of 1973, students from throughout the country will take part in three one-week diver training courses staffed by personnel from the Sea Grant Underwater Operations group.

The fate of Michigan's shoreline is extremely important to the state. Sea Grant has served in an advisory capacity to the state in the preparation of a shoreline management plan, by both preparing information for inclusion in the plan and reviewing the completed document. On the citizens' level, a Sea Grant specialist has helped citizens organize and direct the activities of a model Shorelands Coordinating Committee, along with a model shorelands zoning ordinance. Such activities are pursued in the belief that only through such efforts can citizens intelligently guide the future of their shoreland areas. On the national level, Sea Grant conducted a workshop on the interface of the landscape architect with coastal zone planning, at the annual meeting of the American Society of Landscape Architects.

WALRUS, the gaming simulation, was developed by Michigan Sea Grant as a tool to help planners at all levels of government fully understand the complexity of the

nning task. Advisory Services has organized sessions of LRUS for resource planners and managers from the fed- to the township level. Participants agreed that the use WALRUS was beneficial in gaining new understanding of complex nature of planning problems. Slides, cassette es, and a videotape were used to give a broad range of zens an understanding of the uses of gaming simulation.

Of Michigan's 3,200 miles of shoreline, 500 miles are hly erodible. This condition, aggravated by extremely h water, has caused much suffering and economic loss to oreland property owners. Many houses have fallen into Great Lakes; others had to be moved to new locations; d great amounts of time, effort, and money have been sted in misguided efforts to protect against shoreland sion. Michigan Sea Grant Advisory Services, in cooperan with the Michigan State University Cooperative Exten- n Service, the Michigan Department of Natural Re- urces, the U. S. Army Corps of Engineers, and the Soil nservation Service planned and held a series of six work- ops dealing with proper construction methods for erosion otection devices. Printed materials detailing construction ethods were prepared and distributed to concerned citi- ns and contractors.

Michigan Sea Grant Advisory Services and the national ffice of Sea Grant hosted a workshop on erosion and ooding problems on the Great Lakes in which federal and tate resource people participated.

Sea Grant personnel have given talks to various groups hroughout the state, and numerous seminars have been onducted on Great Lakes' problem areas. Michigan Sea Grant joined with Wisconsin Sea Grant in their Educational Telephone Network, both receiving and giving seminars.

Conferences also have been used to reach specific groups f people. Sea Grant and the Lake Michigan Federation co- osted a conference on the 1972 amendments to the Na- ional Environmental Protection Act. Local and federal ad- inistrators discussed the effects of the amendments on eir activities.

A conference entitled "Report to the People" is conducted annually by Advisory Services in Traverse City to give the residents an up-to-date overview of Sea Grant research activities and their effect on the area. This program brings about requests for further public contact in specific areas of research.

In the planning stage is the development of Great Lakes Information Centers throughout the state. These centers will stock publications related to the Great Lakes for dissemination to citizens in their area and assist in bringing local problems to the attention of Sea Grant Advisory Services.

The use of various media has aided the Michigan Office of Information and Advisory Services to broadly disseminate information of the Sea Grant Program and its research.

Television was utilized primarily in Traverse City, the pilot project area, to inform citizens of program findings. Television has proven particularly effective in the area of shoreland planning and management. A one-half hour televised panel discussion on this topic, involving the Director of the Planning Commission, a Sea Grant planner, and a representative of a citizens group,received widespread acclaim from citizens for its presentation of many difficult problems in this field.

Radio and newspaper coverage, and distribution of Sea Grant publications has helped a large number of people become aware of the Sea Grant Program and the type of help it offers. Magazine articles on water-related problems have been used to heighten public awareness and understanding of Great Lakes problems.

The use of media coverage of Sea Grant activities will continue and is a relatively low-cost method of informing large numbers of people about general problems and solutions.

But a person-to-person transfer of information is the most effective method of disseminating specific answers to specific problems. Because of this, Michigan Sea Grant is in the process of expanding the number of agents working throughout the state and plans to establish permanent off-campus field offices in various parts of Michigan.

ECOSYSTEM MODELING

MATHEMATICAL MODELING OF BIOLOGICAL PRODUCTION

Raymond P. Canale

The main responsibility of this project is the development of predictive mathematical models of biological production. This requires the synthesis of results of a number of other Michigan Sea Grant projects (e.g., the field measurement, circulation, and hydrology projects) into a single descriptive framework on the environment. Subsequent to verification, the models are intended to be used to predict the water quality which results from different pollution control schemes and alternate patterns of land use. This predictive capability should facilitate the adaptation of national water-quality control programs by managers.

This project is developing mathematical models of biological production in Grand Traverse Bay, Saginaw Bay, Lake Michigan, and the three Muskegon Lakes (Muskegon, White, and Mona).

During the 1971-72 report period, computer software was written and a promising preliminary biological production model for Grand Traverse Bay was developed. During the 1972-73 report period, this preliminary model was carefully verified using actual field data and applied to a number of problems of interest to administrators in Traverse City.

The Grand Traverse Bay model can be used to calculate the spatial and temporal distribution of dissolved and particulate phosphorus, particulate nitrogen, dissolved organic nitrogen, ammonia, nitrate, silica, total algae, total zooplankton, and primary productivity. The assumed interactions among these variables and the influence of physical factors in the model are illustrated in figure 1. The seasonal

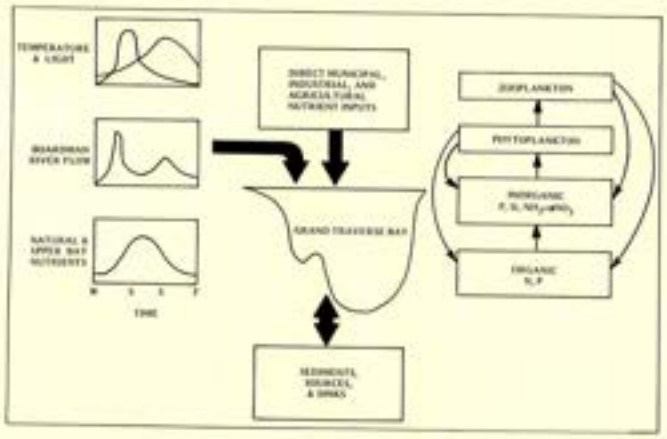


Figure 1

dynamics of each of these variables can be determined at a number of locations within the bay by the integration of mass continuity equations which account for changes due to *transport by water movements, growth, decomposition, biological uptake, exchange from Lake Michigan,* and *direct input from the Boardman River.* The basic equations which comprise the model are developed by taking mass balances for the various model constituents about uniform cells. A system of cells, coupled by advective and dispersive flows, simulates the effects of water circulation; while sources and sinks within a cell represent the effects of chemical and biological reaction. A material balance equation of the i^{th} chemical or biological species about the j^{th} volume element can be written:

$$V_j\,(dC_{ij}/dt) = J_{ij}A_j + V_jS_{ij} + W_{ij}$$

where C_{ij} is the concentration of species i in segment j; V_j is the volume of segment j; J_{ij} is the net flux of species i into segment j; A_j is the interfacial area of the j^{th} segment; S_{ij} is the summation of sources and sinks of species i in segment j which are associated with various biological, chemical, and physical reactions; W_{ij} represents the direct input of species i into segment j; and t is time.

Similar equations have been written for each water-quality variable of interest. This has resulted in a system of 48 nonlinear, nonhomogeneous, ordinary differential equations which represents the continuity of eight water-quality variables at six locations within the bay. These equations have been integrated by a variable order and step-size predictor-corrector scheme. The results of this integration for the southern shore of the bay's west arm are shown in figure 2. The seasonal variation of these water-quality measures, as calculated by the model, agrees well with field observations in a similar location.

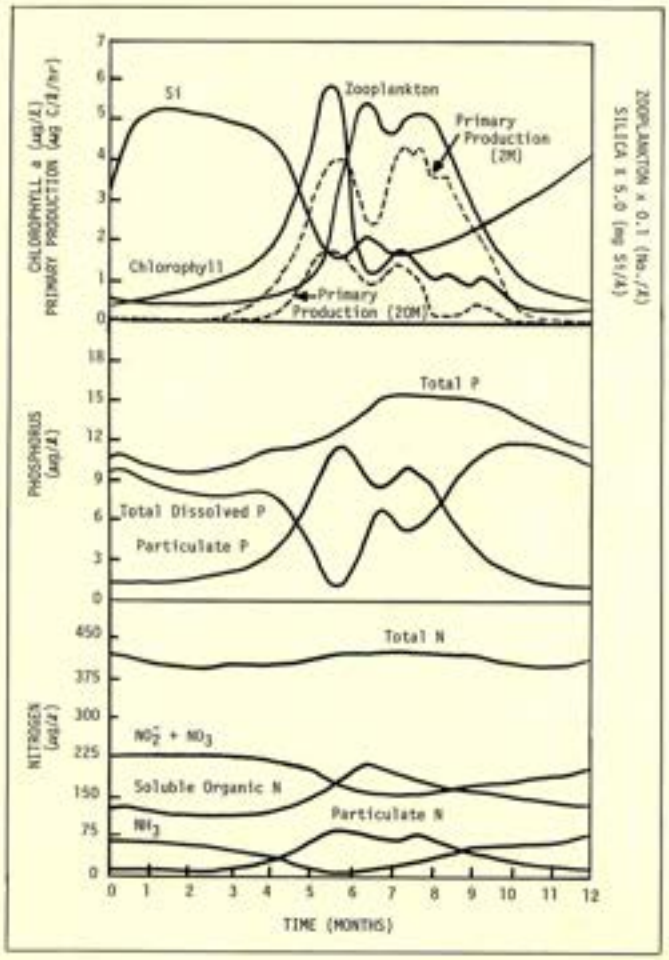


Figure 2

Since the model is capable of similating present conditions accurately, it is possible to make preliminary predictions of future conditions in the bay with the model, using alternate levels of nutrient input. Some results of predictions are shown in figure 3. Three cases are compared with present conditions in this figure. The first example assumes stable population, industrial and agricultural activity, and a 90 percent decrease in phosphorus inputs due to more stringent control. The second and third examples assume an increase in residential population from 22,000 to 88,000 – a twofold increase in the recreational and industrial activity—and a stable agricultural production. The effects on pollution of this expansion is examined under conditions with 80 percent phosphorus removal and without phosphorus input controls. The loading data for these test runs was supplied by Dr. R. L. Patterson.

The predicted level of phytoplankton chlorophyll-a at present conditions with 90 percent phosphorus removal is only slightly lower than the populations observed now in the bay. These results reflect the fact that the major source of nutrients to the lower part of the bay's west arm is the upper bay, rather than the Boardman River. However, as the river loads increase fourfold, these inputs become more significant and result in approximately twofold increases in the peak plankton populations. This nonlinear relation between cultural nutrient inputs and plankton populations is an unanticipated result, as suggested by the model, and is expected to be a unique characteristic for a given natural water body.

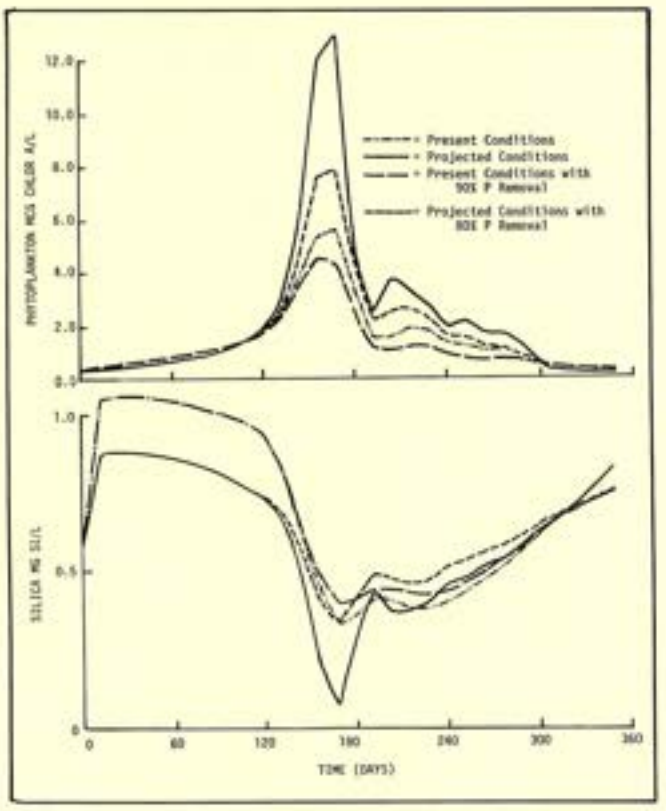


Figure 3

Figure 3 also shows the expected seasonal pattern of silica. It is interesting to note that at the highest loading the silica becomes growth limiting for diatoms resulting in high residual phosphorus levels. This situation, of course, would not persist in the bay. Rather, the silica limitation would lead to a shift in the species composition of the phytoplankton from diatoms to greens. Similar species changes due to silica limitation have been reported in lower Lake Michigan.

The results shown here have been presented at the 16th International Conference on Great Lakes Research and will be published in the proceedings of the conference. A report describing all the details of the model development is in press.

During this report period, an effort has been made to initiate the development of models similar to the Grand Traverse Bay model in Saginaw Bay and in the Muskegon Lakes. Although the computer software is nearly complete for these systems, meaningful results must await completion of the chemical, biological, and circulation field work.

FOOD CHAIN AND FISHERY MODELING

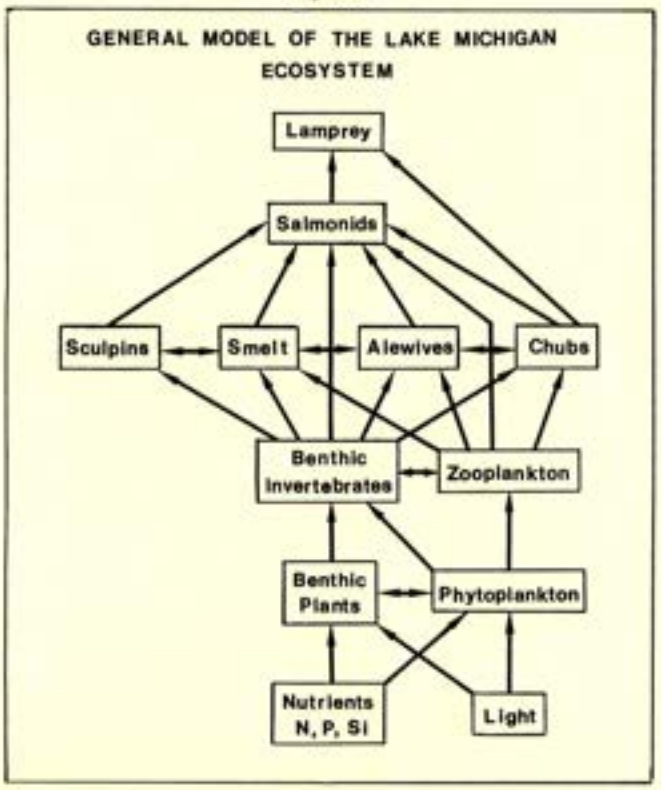
Raymond P. Canale and Richard L. Patterson

Development of a mathematical fishery model has been undertaken which links nutrients, phytoplankton, zooplankton, alewives, and salmon and trout populations as they presently exist, or might conceivably exist, in Lake Michigan waters. In progress is a project to develop models of alewife and alewife predator populations on the upper trophic levels of the food chain being carried out by Dr. Patterson. This can be coupled with a model being developed by Dr. Canale on the lower part of the food chain, from the nutrient level to the zooplankton level. The goal of this project is to develop a tool which can be used by fisheries managers to establish optimum stocking policies and determine the potential of the fishery. This project is of direct interest to the Michigan Department of Natural Resources, since the optimization of the Lake Michigan fisheries, in terms of economic and recreational values, is one of their stated goals.

Since the behavior and stability of the fishes is probably sensitive to organism interactions on the same trophic level, as well as to interactions at different trophic levels, a relatively complicated system description is required in the model. Models have been postulated of alewife and plankton growth and mortality, based upon discussions with experts and a detailed review of relevant literature. Efforts have been directed toward identifying the important fish and plankton species in the Lake Michigan fisheries food web and quantifying species interactions.

The forage fishery for salmon and trout occupies a central link in the food chain (Fig. 1) and consists mainly of alewives. The continuation of successful salmon and trout fisheries depends upon the maintenance of the alewife forage fishery, and the alewife fishery has shown extreme and sometimes costly fluctuations in the past fifteen years. Therefore, the major effort to data has been to model the alewife population and its food supply ir. Lake Michigan. Results of the population dynamics studies will provide the Michigan DNR with estimates of the dynamic change in alewife biomass in Lake Michigan and yield of the alewife fishery available to salmon and trout predators and to human harvesting. When these dynamics are supplied to an economic optimization model of the fishery (see Fig. 2), a trade-off of the utilization of the forage fishery can be analyzed subject to the dynamic constraints of the fisheries.

Figure 1.



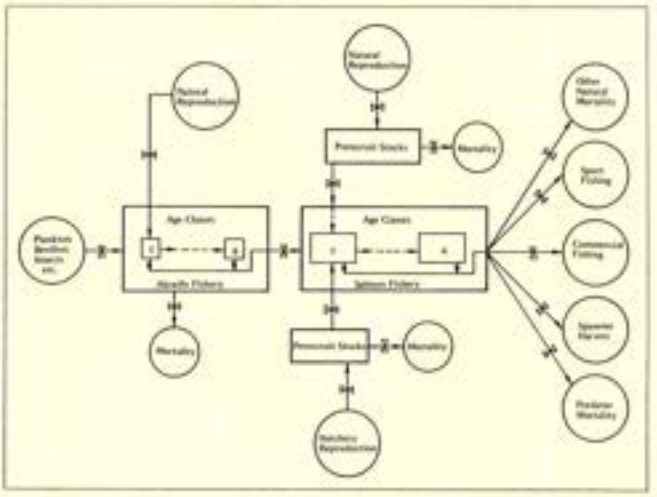


Figure 2. Process Flow Chart of Alewife–Salmon Production System.

During the next year, it is anticipated that the individual organism behaviors will be specified, the computer software for this system will be completed, and the initial model verification will begin.

INTERACTIVE DISPLAY OF WATER RESEARCH DATA

Richard L. Phillips

The intent of this project was to develop generalized, interactive display procedures which could be used for rapid, pictorial representations of water resource data. This aids the resource manager and planner in rapidly assembling, condensing, and displaying important environmental parameters upon which water resource management strategies rely. The DRAW System and the CKSUR System provide a graphical or three-dimensional representation of information in a data file.

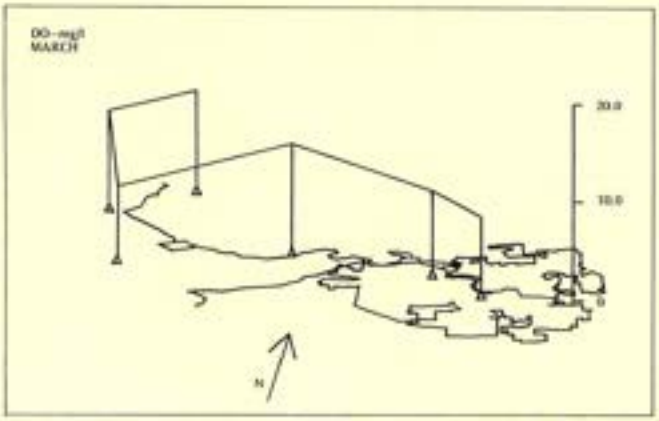
Specifically, for the Michigan Sea Grant Program, these systems can be applied to the WALRUS program to enbance user-computer communication for simulation of results of certain courses of action on watershed management.

In the case of Grand Traverse Bay, where considerable data is available, these procedures allow rapid scanning, searching for important correlations, and deduction of facts which might otherwise be unnoticed.

It is possible to display the temporal or spacial variation of selected variables which are predicted by the water circulation and biological production models.

The DRAW procedure allows an investigator to display raw or processed data, contained in a file, in the form of a graph. Alternatively, the DRAW procedure can be used with a simulation program in order to display computed results directly in graphical form.

The DRAW System is a series of subroutines which allows a programmer easy access to the complete interactive graphics library at The University of Michigan. With this system, a programmer with little or no graphics experience can produce high-quality, report-ready graphs on a Computek graphics terminal. Moreover, the user can add lines or points to the graph as he desires. Also, an edited graph may be redrawn at any time. Finally, the user has the capability of generating the CalComp hard copy of the currently visible graph.



Perspective of Huron River Drainage Basin Showing D.O. Variations

The DRAW System is designed for future expansion, without having to modify the current program. The system is flexible in that it can operate on data stored in a file which can be quickly and inexpensively updated; the DRAW System is independent of any file or file structure.

The CKSUR procedure was developed to permit an analyst to view data, either raw or calculated, in the form of a three-dimensional surface representation. Thus, it is possible to examine the behavior of two dependent variables as the independent variable is changed. A time varying spatial simulation study would be an ideal program for application of CKSUR.

CKSUR was written to allow the user to view water resource (or general) data where more than one dependent variable is of interest. For example, one may wish to display the time variation of dissolved oxygen at several locations in a body of water. With CKSUR, all three variables may be viewed concurrently. A special feature of CKSUR is that hidden line processing and elimination is performed automatically. Thus, when viewing a surface, those portions of it which would not be "visible" to the observer are eliminated. In turn, this eliminates confusion in interpreting the graph.

The user of CKSUR has a wide range of options available to him, and by controlling them can produce the optimum display for his particular program.

STOCHASTIC MODELING

Edward D. Rothman

From experiments designed to study the effects of several nutrients (phosphate, nitrate, and silica) on the production of phytoplankton, several new models were developed

These new models are modifications of Michaelis-Menten kinetic equations describing the growth rate for chlorophyll, an instrumental variable for the concentration of phytoplankton. The growth rates in the new model are now functions of the "usable" levels of phosphate as opposed to the measured levels of soluble phosphate. Results specific to the experiment indicate that only 10% of measured levels of phosphate are used by the phytoplankton species, found in the sample, in the production of chlorophyll.

Preliminary work, based on species counts, was begun to study the effect of several vitamins, chelating agents, and trace metals on the distribution of phytoplankton by species.

A detailed report on "Responses of phosphorus-limited Lake Michigan phytoplankton to factorial enrichments of nitrogen and phosphorus" is now in press in *Limnology and Oceanography*.

Algal Growth Due to Cultural Nutrient Enrichment

WATER CIRCULATION MODELING

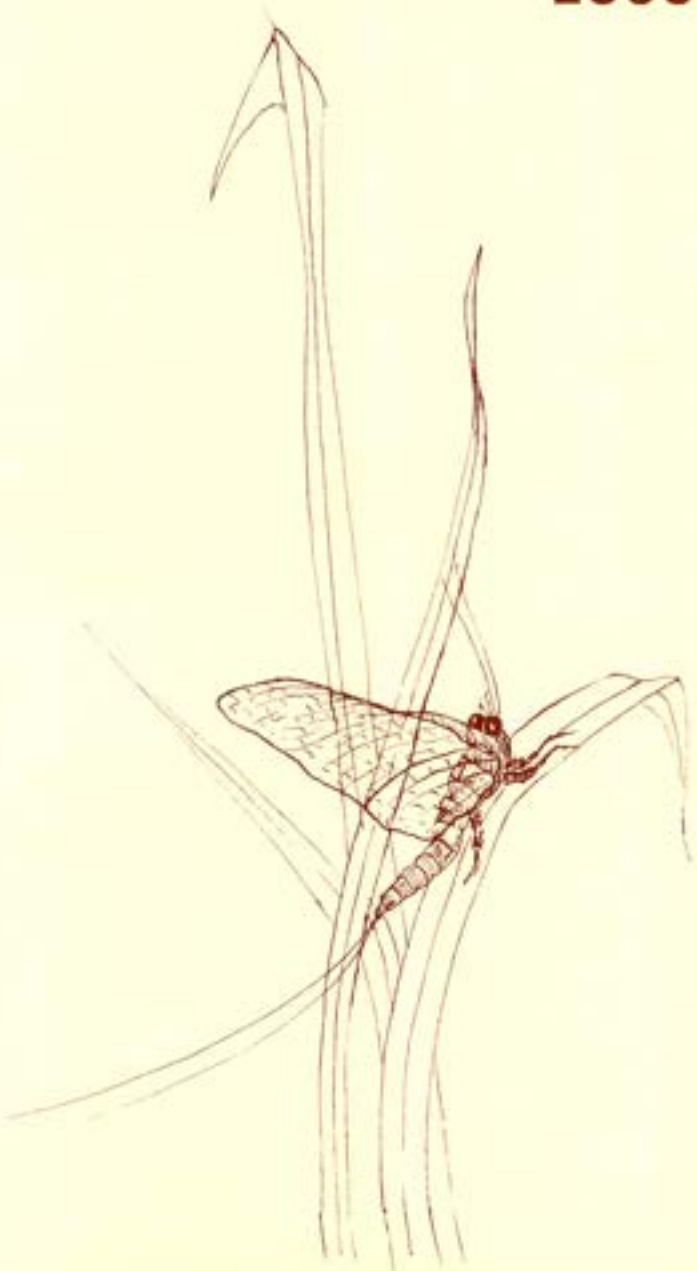
Albert W. Green

During the second year of this project, the modeling effort was expanded beyond the Grand Traverse Bay region, and the preliminary work for a dynamic model of Saginaw Bay has been completed. As a result of constructive suggestions by participants in the 1973 site visit, a new numerical model was developed which will be applied to Saginaw Bay. The new numerical technique will allow simulation of long-term dynamic response of the bay to various climatological and lake conditions. Eventually, this model will be expanded to include simulation of advective diffusion of contaminants from specified sources on the bay. By increasing the time and spatial scale of the model, it will also be possible to furnish biological models with circulation and diffusion information which more closely conforms to the field sampling intervals with which they were compared previously. The biological system models eventually will be incorporated within the dynamic model; and, as an output, the response of the ecosystem for a given input as it evolves in space and time will be plotted.

It has become apparent that the biosystem models must include effects of the thermal stratification. Consequently, studies have been initiated of models which simulate the seasonal evolution of the summer thermocline in lakes. The current two-level thermocline model will be expanded and adapted to a multilevel model of lake circulation and thermodynamics. The preliminary results of the two-level model have been realistically encouraging. Thanks to the cooperation of other investigators and agencies, arrangements have been made to obtain critical field data which will be used in setting boundary conditions and validation of the numerical models. In June 1973, the U. S. Lake Survey placed a recorder at water level at Point Au Gres in response to a request from this project. Data from that station and a permanent station at the mouth of the Saginaw River will be correlated with Lake Huron oscillations in order to evaluate the effects of lake motions on the recorded levels in the bay. Professor D. J. Portman has made available long-term micrometeorological records to aid in estimating wind stresses over the bay. Dow Chemical Company has provided the results of chloride ion distribution measurements, taken twice each summer for almost thirty years. These data will be used in evaluating the advective diffusion model.

Early in the fall of 1973, the response of Saginaw Bay to typical wind forcing conditions will be simulated to aid in advising the field investigators on critical measurements necessary for calibration of various later models.

ECOSYSTEM PROCESSES AND FIELD RESEARCH



NUTRIENT CHEMISTRY

Herbert E. Allen

During FY 1972-73, the Nutrient Chemistry Project has continued analyses of water samples for Sea Grant projects. Parameters which can be routinely analyzed now include nitrate, nitrite, ammonia, total and dissolved phosphorus, chloride, silica, iron, chemical oxygen demand (COD), and total organic carbon (TOC). All analyses are automated, including COD; and work on the automation of TOC analyses is continuing.

As of April 1973, our Technicon Auto Analyzer was expanded from a two-channel to a three-channel system. Equipment currently on order will complete a four-channel system, in which four parameters may be analyzed simultaneously. This has greatly increased capacity for handling large numbers of samples and has decreased turnaround. Acquisition of a second automated sampler also permits greater flexibility and efficiency.

Four-channel Technicon Auto Analyzer

During the year approximately 1,000 samples from Grand Traverse Bay, 200 samples from tributaries to the bay, and 140 well and ground water samples in the bay have been analyzed. While processing these samples, refinement of procedures and assessment of new methods and new types of samples continue.

The utilizability by organisms of organic phosphorus fractions in lake water has been investigated. From enzyme assays it has been demonstrated that free RNA and DNA are negligible, as are phosphatase-hydrolyzable compounds. As much as 30% of the organic phosphorus, however, is hydrolyzable by phytase, which suggests that phytic acid may be present in significant quantities. Further investigations will attempt to estimate the uptake rates of different naturally occurring organic phosphorus fractions by utilization of molecular gel chromatography and algae bioassays.

This knowledge will be useful in studies concerned with algae productivity in natural waters.

WELL WATER SURVEY AND ANALYSIS

Richard L. Patterson

An intensive analysis has been completed of ground water quality and economic factors affected by sewage disposal and water supply alternatives in several townships in or near Traverse City. A set of chemical measurements were statistically analyzed and models for nitrate—N in ground water were developed on the basis of land use, soil, and well characteristics for the same area. Analyses were completed of construction costs for community versus individual household sewage disposal and water supply systems, and of the relationship between land use and well quality. An analysis was done of the trade-offs between costs of waste water collection systems and the ecological benefits measured in terms of well water quality. A detailed discussion of the results of this project is presented in the Ph.D. thesis of R. Rajagopal.

This information was utilized by local groups in planning for future growth of sewer systems in the Grand Traverse Bay region. The development of regional sewers and water systems in the region is a controversial issue, and the results of this subproposal may be an important element in the planning activities underway.

BIOLOGICAL PRODUCTION

Dean E. Arnold, David C. Chandler
and Jim J. Sygo

The biological production project continued to supply biological, chemical, and some physical data.

The intensive sampling of the west arm of Grand Traverse Bay, implemented last May, proved to be an important step toward confirmation of the mathematical model derived for the bay. The sampling scheme involved a total of 20 cruises. Seventeen cruises were made on the R/V *Sea Grant I* and each cruise consisted of 27 water-chemistry stations and 4 biological production stations (Fig. 1): the 4 biological stations are a subset of the original 16 stations used from 1970 to 1972 (Fig. 2). The remaining 3 surveys, which were more extensive, sampled 27 water-chemistry stations and all 16 original stations and served as a monitor for past data. The cruises were tentatively scheduled twice a month from July 1972 until June 1973. The 3 survey cruises required the use of the 50-foot R/V *Mysis* in August and May and the 114-foot R/V *Inland Seas* in October. Due to unseasonably warm weather this past winter in the Traverse City area, no samples were taken between 10 December 1972 and 22 March 1973. Ice formations were not strong enough to support the snowmobile–sled sampling system and yet created conditions too treacherous for the use of the R/V *Sea Grant I*.

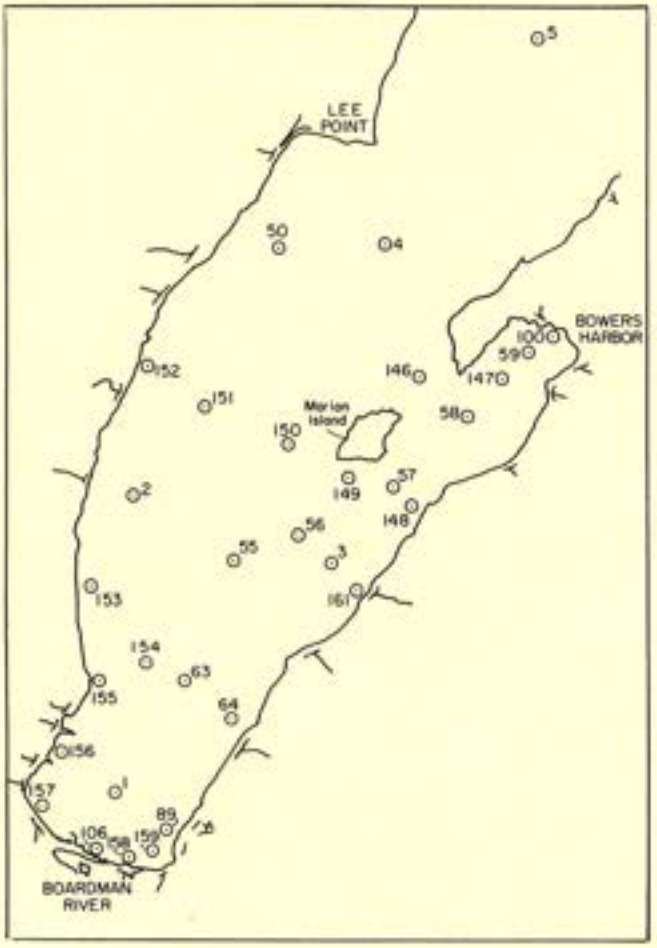


Figure 1. Sampling Stations, Lower West Arm of Grand Traverse Bay.

Van Dorn-type water sampling bottle, modified to close 1 meter off the lake bottom. Shown in use aboard R/V Sea Grant I.

Analyses and measurements conducted by project personnel at all stations included: temperature profiles, secchi disc transparency, alkalinity, conductivity, and chlorophyll-a. Water samples for nutrient chemistry were also taken, filtered, and frozen for all stations. The nutrient chemistry analysis was performed under the Sea Grant project of Herbert Allen. On the biological stations, the following parameters were also collected and analyzed: carbon fixation (*in situ* using radiocarbon tracer techniques), bottom fauna identification and abundance, zooplankton identification and abundance, phytoplankton identification and abundance, dissolved oxygen, and relative irradiance profiles. Incident sunlight was recorded at a shore station located in Traverse City.

In March 1973, a decision was reached to further intensify the sampling program in the lower west arm of the bay. A total of 10 stations were selected to be sampled once a week. Eight bay stations were selected and two river stations, one above and one below Boardman Lake. The 8 bay stations are located in 8 different segments of a 20-segment model used in the west arm of the bay (Fig. 3). This new sampling program provided a more intensified study for the verification of various models in the extreme lower west arm of Grand Traverse Bay, where most potential problems now exist.

As in the previous 2 years, carbon uptake was again measured at 2, 10, and 20 meters from the surface. Carbon uptake rates again range from zero to slightly above 10 mgC/M^3/hr. The mean primary production at Grand Traverse Bay stations continued in the same general pattern as that of the previous year. The geographical trends have remained similar with few exceptions. Carbon uptake again appears to decrease when leaving the influence of populated areas, or going from south to north in the bay. The west arm tends to show a greater variability with respect to carbon uptake, as compared to the east arm and the shoal area near the mouth of Grand Traverse Bay which exhibits consistent production. This variation may be a result of the increased nutrient-loading, true of the west arm of the bay, and the various circulation patterns therein.

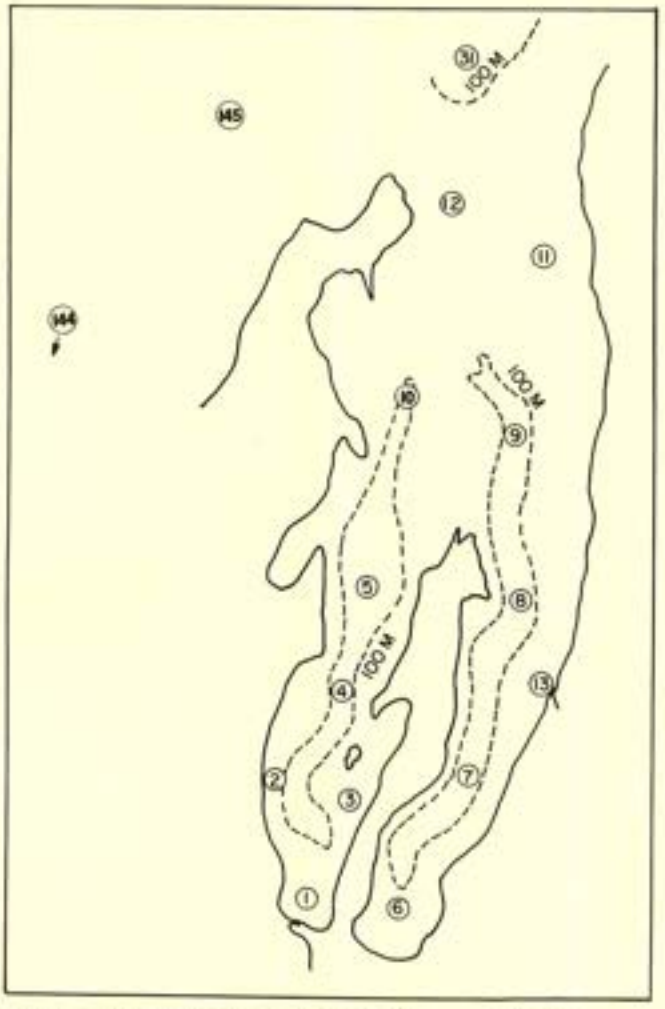


Figure 2. Sixteen Original Monitoring Stations and Depth Contours, Grand Traverse Bay and Adjacent Lake Michigan.

More noticeably this year than in past years, is the possibility of light inhibition at the 2 meter depth. On clear, sunny days the production level has decreased consistently at the 2 meter level. In July 1973 a 5-day intensive survey will be conducted in the west arm during which one station will be monitored 24 hours a day, using the R/V *Sea Grant I* as a work platform. The intentions of this study are to validate our sampling techniques and procedures and to study possible diurnal effects in the west arm of the bay. In this study we intend to take a closer look at the possibility of light inhibition by measuring carbon uptake above and below the 2 meter level.

Last May chlorophyll-a samples were added to the list of parameters to measure. To date, all chlorophyll-a analysis has been completed for water stations and biological stations. The values range from 0.03-5.5 μg/l. At biological stations there appears to be a general correlation between carbon uptake and chlorophyll-a.

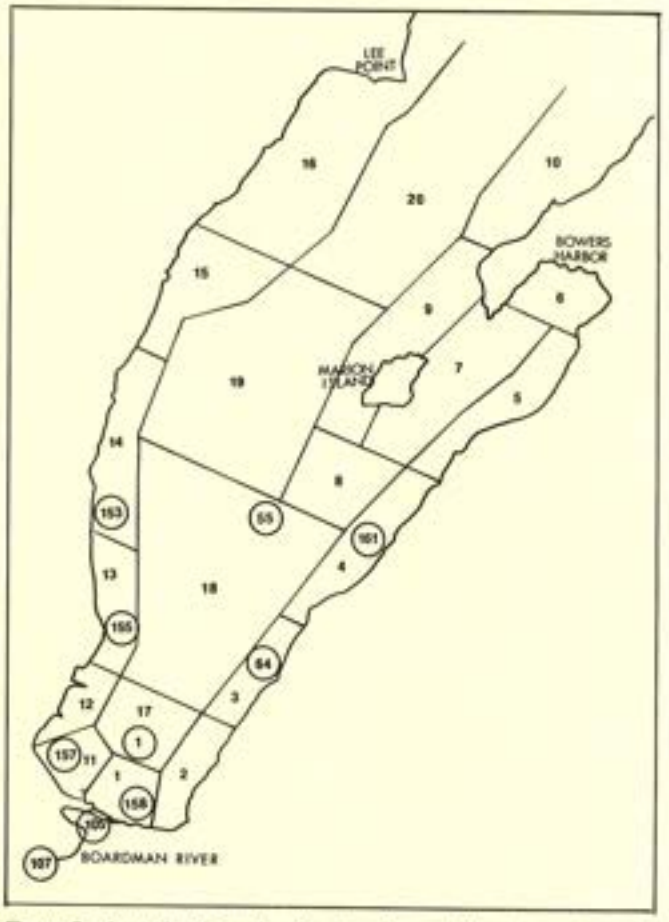


Figure 3. Intensive Sampling Stations, Lower West Arm. Stations are shown with respect to biological production model.

As of 30 June 1973, the project had collected well over 20,000 samples and measurements from Grand Traverse Bay. All of the light, temperature, dissolved oxygen, alkalinity, conductivity, transparency, primary production, nutrient, and chlorophyll-a data have been completed and placed on shared computer files for use by other Sea Grant projects. About 70% of the zooplankton and 85% of the benthos samples have been examined for numbers and major group identification. More detailed identification will await additional funds and personnel. All 1973 phytoplankton samples have been mounted on slides, but identification awaits employment of trained personnel to count these samples.

An extensive report on the biological production project in Grand Traverse Bay is now being prepared.

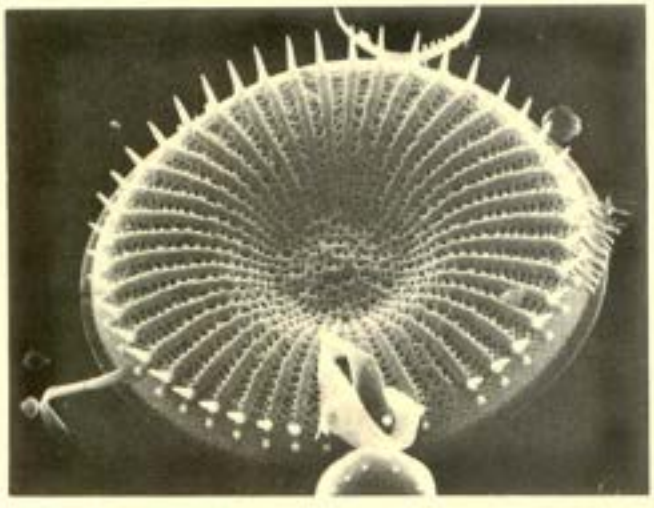
PHYTOPLANKTON DYNAMICS

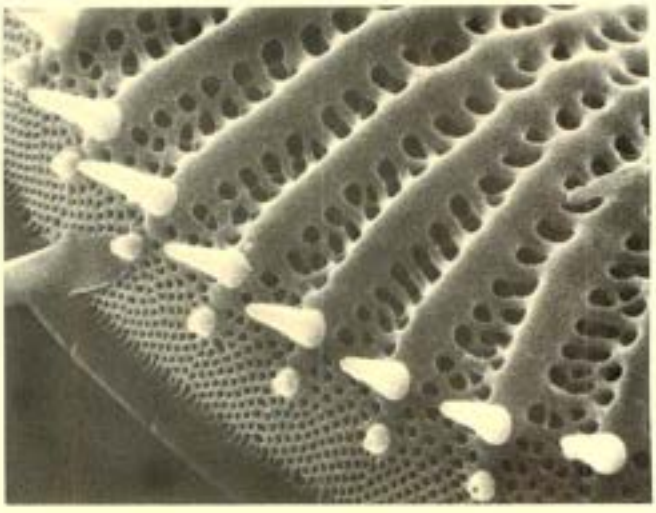
Eugene F. Stoermer

Major emphasis has shifted from survey assessment of algal population changes in the entire Grand Traverse Bay to higher density sampling of a restricted area in the west arm. Sampling at a limited number of master stations in the rest of the bay was continued to detect long-term variations in population abundance and composition. In addition, project personnel have participated in sample preparation of materials from Muskegon and Saginaw Bay projects. The major effort has continued to be support of biological productivity model development. In addition, the data generated in Grand Traverse Bay has been used, in conjunction with data developed through separately funded projects, to develop a more generalized qualitative assessment of the trends in primary producer communities in the entire Lake Michigan basin. In this regard the work in Grand Traverse Bay has been quite valuable; since it has furnished a previously lacking detailed assessment of the populations present and their seasonal and yearly variation in an area that has not, as yet, been grossly affected by pollution. Such preliminary information is viewed as being essential to the eventual development of a realistic model of the entire Lake Michigan system.

In general, results to date indicate that Grand Traverse Bay is representative of the most stable part of the Lake Michigan system. Although seasonal trends in abundance and population succession in Grand Traverse Bay are similar to those found in the southern basin of the lake proper, both the changes in total population density and the changes in population frequency are much less pronounced in the bay. Perhaps the most striking difference is in the lateral homogeneity with respect to phytoplankton abundance and assemblage composition. In Grand Traverse Bay, certain populations tend to dominate the phytoplankton flora at all stations during any particular sampling period. On the other hand, in the southern basin of the lake, the populations which dominate the near-shore zone are essentially absent from the mid-lake zone, particularly during the spring phytoplankton maximum. In terms of total assemblage abundance, lateral differences in Grand Traverse Bay appear to be, at maximum, approximately a factor of 10 for any given local region. In the southern basin of the lake, on the other hand, lateral variations are usually on the order of a factor of 10 and in many instances are on the order of a factor of 100. In general, these differences appear to be directly related to nutrient input rate; and the nutrient controlling productivity level is phosphorus. Particularly during the spring phytoplankton maximum, constraints on circulation imposed by the thermal bar phenomenon appear to have significant effects on the lateral distribution of phytoplankton assemblage density and composition. On the basis of results, it also appears that, due to present levels of phosphorus pollution, the entire lake is approaching a boundary condition with respect to the availability of silica—an essential nutrient for the previously dominant diatom component of the phytoplankton. Evidence of increasing relative abundance of green and blue-green algae during the summer stagnation is most pronounced in the southern basin of the lake; but a similar trend has also been noted in recent samples from Grand Traverse Bay.

Magnification of Stephanodiscus transilvanicus





Stephanodiscus transilvanicus magnified approximately 7000 X

A summary of these trends was presented to the Four State Conference on Pollution of Lake Michigan held in spring 1973. Data from several projects, including the Sea Grant Traverse Bay project, were combined in an attempt to give an overview of present trends in phytoplankton composition and abundance in Lake Michigan; particularly as related to current and proposed limitations on the discharge of phosphorus into Lake Michigan and its tributary waters.

Personnel from this project have also participated in laboratory experiments on the growth rates of natural phytoplankton assemblages from Grand Traverse Bay under differing nutrient conditions. A report on these results is in preparation.

A preliminary summarization of transparency trends in southern Lake Michigan has been completed. A paper reporting these results was read at the 16th Conference on Great Lakes Research and has been accepted for publication in the proceedings of that conference.

EXCHANGE OF ELEMENTS AT WATER–SEDIMENT INTERFACE

Edward Callender

The purpose of this study was to determine the role of bottom sediments in the Grand Traverse Bay ecosystem. Environmentally stressed systems, such as Green Bay and the western basin of Lake Erie, are strongly influenced by the sediments whose effect is readily seen in the widespread hypolimnetic oxygen depletion that occurs during late summer. Hypolimnetic oxygen in Grand Traverse Bay never goes below 75 percent saturation, except in the waters directly under the influence of the Boardman River, where values below 50 percent saturation are rare. Thus, one would not expect to see the massive exchange of elements, such as iron and phosphorus, across the water-sediment interface. The simplified model for phosphorus in the lower west arm of Grand Traverse Bay has been used to evaluate several assumptions concerning the role of sediments as input/output to the overall ecosystem model of Grand Traverse Bay.

Several cores taken from the lower west arm of Grand Traverse Bay were carefully analyzed for several elements including iron, manganese, several forms of phosphorus, copper, zinc, nickle, cadmium, chromium, calcium, magnesium, and potassium. The sample interval consisted of 1 cm-slices to a depth of 6 cm and 2-cm slices to a depth of 20 cm in the core. Several chemical extraction procedures were used to evaluate the percentage of inorganic, organic, and ferric hydroxide-bound phosphorus in the sediment.

The simplified model for estimating the mass transport of any chemical species in sediment pore fluid employs Fick's first and second laws of diffusion, which assume a linear concentration gradient. The flux for any chemical species between sediment and overlying water can be calculated by

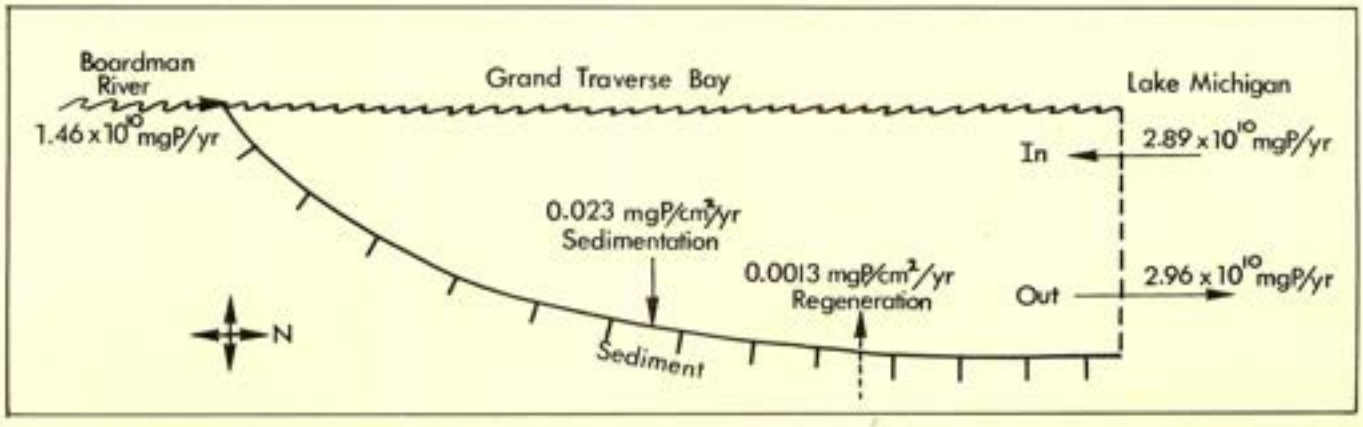
$$J_i = D(dc/dx)$$

where D is the diffusion coefficient and dc/dx is the linear concentration gradient. Considering interstitial phosphorus *(P)* in the lower west arm of Grand Traverse Bay, D is approximately 0.5×10^{-6} cm^2/sec and dc/dx is 0.080 ppm P/cm. Therefore, the flux of phosphate ions (J_{PO_4}) to the sediment surface is calculated as 4×10^{-14} g/cm^2/sec. Considering the surface area of the lower west arm of Grand Traverse Bay and integrating over one year's time, the annual mass transport of phosphate regenerated from the sediment is calculated as 7.3×10^5 g/yr. The phosphate input of the Boardman River to the lower west arm of Grand Traverse Bay is calculated as 1.5×10^7 g/yr. A comparison of these two phosphate fluxes (sediment regeneration and Boardman River input) shows that the Boardman River contributes 20 times more phosphate to the lower west arm of Grand Traverse Bay, than regeneration by surficial sediment.

If one assumes a steady state situation, then the phosphate input from the Boardman River is deposited in the surficial sediment of Grand Traverse Bay. Therefore, the sedimentation rate of P to surficial sediments of the lower west arm is 2.5×10^{-2} mg/cm^2/yr. The bulk sedimentation rate for surficial sediment in Grand Traverse Bay is between 1 and 10 mm/yr. The concentration of P in the upper 5 cm of sediment from the lower west arm of Grand Traverse Bay is 550 ppm by weight. Assuming a sediment particle density of 2.6 g/cm^3 and a sedimentation rate for these sediments as 3 mm/yr, the sedimentation rate of P in surficial sediment is calculated as 0.045 mg P/cm^2/yr.

With the above data for the mean phosphate concentration of water exchange across an imaginary boundary at the head of the west arm of Grand Traverse Bay, a gross phosphate budget can be calculated for the lower west arm. The flux of phosphate from the Boardman River to the lower west arm is 1.46×10^{10} mg P/yr. The flux of phosphate from Lake Michigan into the lower west arm is 2.89×10^{10} mg P/yr, and the flux of phosphate from the lower west arm to Lake Michigan is 2.96×10^{10} mg P/yr. Using our assumed steady state model, the flux out of the lower west arm should equal the flux in plus the flux of the Boardman River. Clearly, this is not the case using the above estimates. Therefore, approximately 1.4×10^{10} mg P must be lost to the surficial sediments each year. If this mass of phosphorus was deposited over the entire lower

Figure 1. Phosphorus Flux In and Out of the Lower West Arm of Grand Traverse Bay.



west arm of Grand Traverse Bay, then a calculated sedimentation rate would be 0.023 mg $P/cm^2/yr$. Since 0.0013 mg $P/cm^2/yr$ is regenerated from the sediments, the net sedimentation rate of phosphorus in the lower west arm of Grand Traverse Bay is 0.022 mg $P/cm^2/yr$. Thus we have calculated sedimentation rates for phosphorus using two independent methods; bulk sedimentation rate and sedimentary phosphorus concentration (0.04 mg $P/cm^2/yr$), and a steady state model for phosphate flux in and out of the lower west arm (0.02 mg $P/cm^2/yr$). A summary of the phosphorus budget is presented in figure 1.

There are several conclusions that can be drawn from these calculations. The regeneration of phosphorus from bottom sediment in Grand Traverse Bay is small (3%) in comparison to the phosphorus input of the Boardman River and other tributaries. Therefore, one can say that bottom sediment has little effect upon biological productivity in Grand Traverse Bay. On the other hand, significant quantities of phosphorus are accumulating in the surficial sediments of the west arm of Grand Traverse Bay, and this system should not be treated as though it were in steady state. Chemical analyses of sediment cores show that the concentration of phosphorus has nearly doubled during the time required for the upper 2 cm to accumulate.

Van Dorn water sampling apparatus.

WATER QUALITY INVESTIGATION

John J. Gannon

There were four major objectives of the Grand Traverse Bay water quality studies during this report period.

1. to conduct an intensive evaluation of the water quality of the Boardman River in and around Traverse City to determine the impact of the new treatment plant on river and bay water quality;

2. to better define the contribution from Traverse City storm water discharges by monitoring the flow and regular sampling for water quality evaluation in proportion to flow;

3. to evaluate microbial levels at bathing beaches on the bay during the summer; and

4. to evaluate water quality conditions in the Duncan H. Clinch Marina in Traverse City during the summer period of high use.

The major field effort was carried on during summer 1972 through the establishment of a temporary field station at the water treatment plant in Traverse City. Most of the chemical and bacteriological analyses were conducted at this laboratory shortly after the samples were collected. This included analyses for dissolved oxygen (D.O.), biochemical oxygen demand (BOD_5), pH, temperature, total coliform bacteria, fecal coliform bacteria, fecal streptococcal bacteria, ammonia, nitrite, nitrate, and orthophosphate. Certain additional nutrient samples were preserved and shipped to Ann Arbor for later processing. During the remainder of the year, project personnel made frequent trips to Traverse City to evaluate seasonal influence. In addition, assistance has been provided by Charles Craw, the resident Sea Grant representative in Traverse City.

All of the major objectives established for the 1972-73 study period have been accomplished; and a comprehensive report detailing each phase of the study is in preparation.

Boardman River: The Boardman River and Kidd's Creek were sampled, and discharge measurements were made on seven separate days during July and August 1972. These samples were examined for thirteen water-quality parameters on each occasion. It was observed that the lower Boardman River is, hydrologically, a very complicated area for study, since it is influenced by several upstream impoundments, by backwater from Grand Traverse Bay, and by contributions from Kidd's Creek, and from the Traverse City Wastewater Treatment Plant (Fig. 1 and 2). The general levels of flow during the summer of 1972 were above average due to excessive precipitation.

The two major sources of bacterial contamination during July and August 1972 were Kidd's Creek and the wastewater treatment plant. The bacterial concentrations which were observed in the river often exceeded the minimum standards which have been set by the Michigan Water Resources Commission for total and partial body contact use. Elevated levels of bacteria and phosphate were discharged into Grand Traverse Bay by the Boardman River.

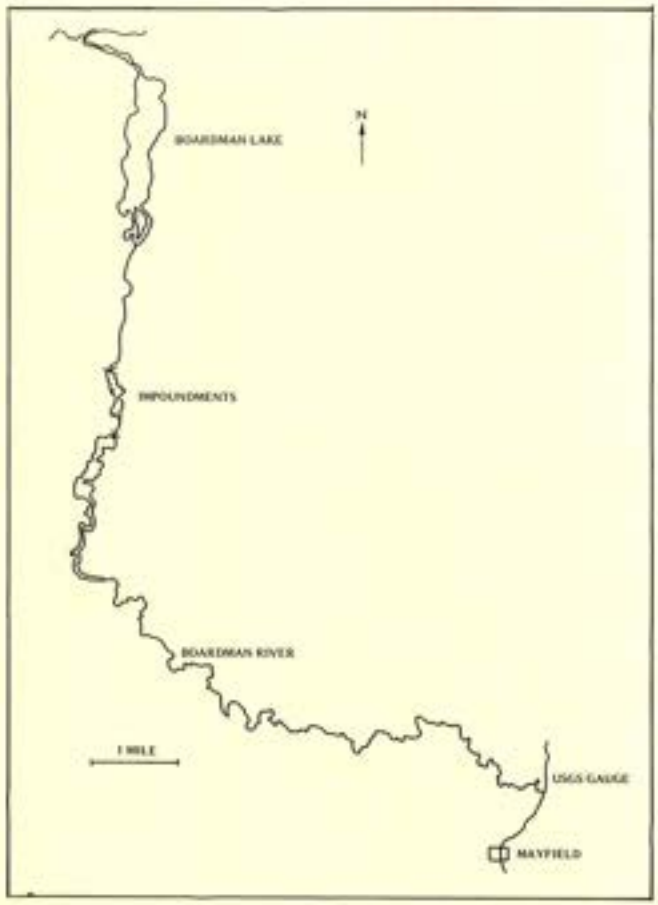


Figure 1. Boardman River Discharge Study Area, Grand Traverse County.

The recently expanded wastewater treatment plant in Traverse City initiated phosphorus reduction efforts on 15 November 1972 and had to discontinue treatment because of equipment failure during December 1972.

Since 1 January 1973, the plant reports phosphorus reduction levels on the order of 90%. A regular weekly sampling program involving five sampling stations on the Boardman River was conducted through May 1973. This information definitely shows an improvement in river water quality resulting from the increased efficiency of the wastewater treatment plant.

Traverse City Storm Water Discharge: Sampling continued during 1972-73 at the three representative Traverse City storm water systems initially selected for intensive evaluation during the summer of 1971. Sampling site A discharges into the west side of West Bay; site B discharges into the east side of West Bay at Bryant Park; and site C discharges into the west side of East Bay. The study plan consists of sampling the three sites as many times as possible during and immediately following any significant rainfall.

Four major storms occurred during July and August 1972, and sampling took place at each station at selected intervals during each storm. Twelve different water quality measures were examined for each of the samples. Highly significant levels of bacteria and nutrients were discharged into Grand Traverse Bay during each storm. It is important

to indicate that several of the storm sewers discharge into or near public bathing beaches, posing a health hazard to the bathers during wet periods.

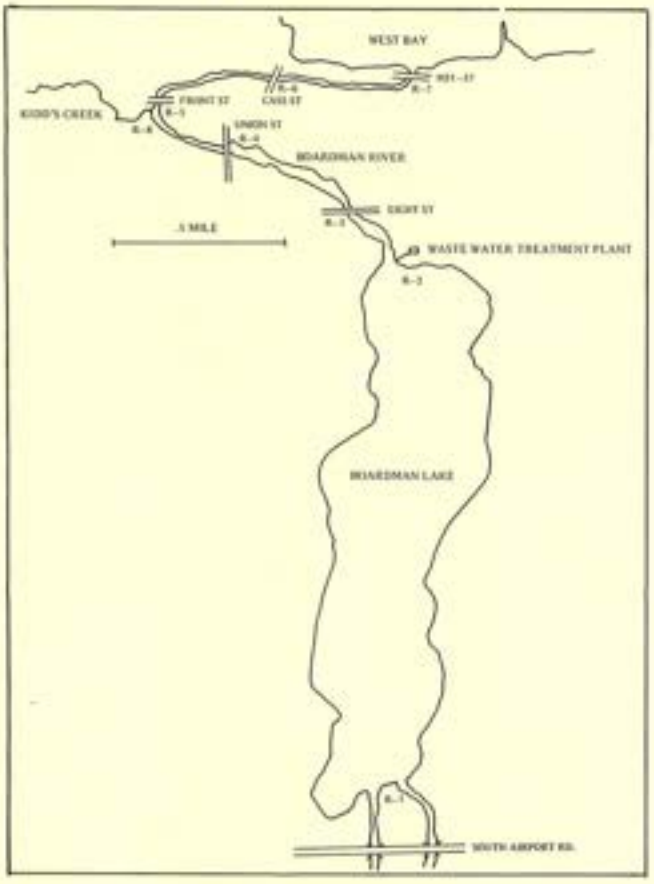


Figure 2. Study Area, Traverse City, Michigan

Organized Natural Bathing Beach Water Quality: Throughout thirteen separate sampling dates during July and August 1972, six beaches were bacteriologically evaluated in the Grand Traverse Bay area under varied climatological conditions. It was found that levels of total coliform, fecal coliform, and fecal streptococcus become considerably higher with increased precipitation. The highest counts were observed at the West End Municipal Beach, Bryant Park Beach, and East Bay Park Beach; each of which is located in close proximity to one of the major storm sewers studied.

While the overall bacterial quality of the beaches meets standards for total body contact, as determined by the Michigan Water Resources Commission, on days without precipitation, it has been observed that certain beaches do exceed these standards during periods of substantial rainfall.

An effort was made to evaluate the influence of bottom disturbance on the water quality in selected bathing areas. No significant difference could be found in terms of bacterial levels between quiesient and disturbed bottom conditions.

Duncan H. Clinch Marina: A study was conducted at the Duncan H. Clinch Marina in Traverse City in an effort to evaluate levels of total coliform, fecal coliform, and fecal

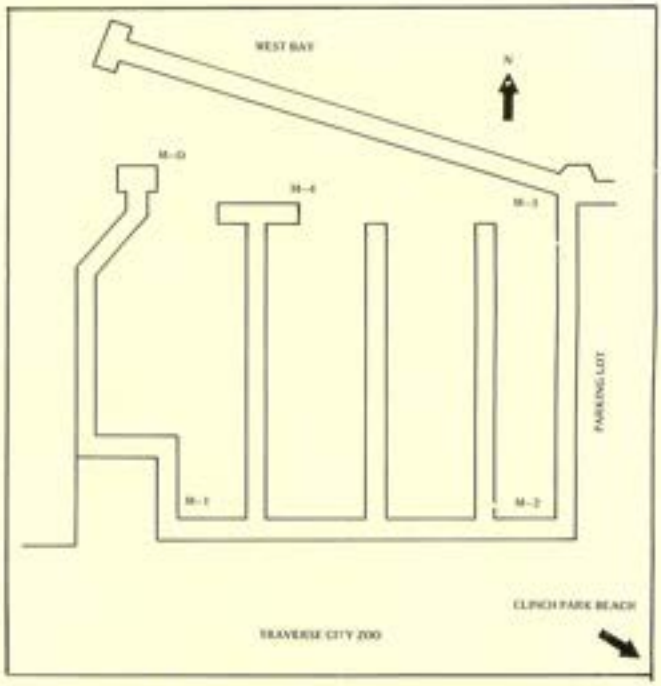


Figure 3. Duncan H. Clinch Marina Sampling Stations

streptococcal bacteria through the July and August high-use period. This marina has 100 boat slips and maintains a sanitary pump-out station. In addition, it is located adjacent to the Traverse City Zoo and close to the Clinch Park Beach.

Of the eleven separate sampling dates in which the marina was studied, intensive sampling of five separate stations, under varied climatic conditions, was made on five of these dates. Since the physical and chemical levels examined during the early sampling period were negligible, these specific examinations were suspended while the bacteriological investigations continued throughout the entire period. Due to partial isolation from West Bay, the water within the marina was not readily subject to free mixing with the open water. Two small storm sewers have been observed to discharge directly into the marina. During periods of heavy precipitation, bacterial levels within the marina have been observed to exceed the minimum levels permitted for partial body contact, as designated by the Michigan Water Resources Commission.

IMPACT ON LAKES AND RIVERS OF SEEPAGE FROM POLLUTED GROUNDWATER

John J. Gannon and Ernest F. Brater

During 1972, the Michigan Sea Grant Program was requested by local groups and the Grand Traverse Bay Regional Planning Commission to investigate the possible seepage of septic tanks and drain fields into Grand Traverse Bay. This question has considerable impact on local growth issues because it is frequently thought to be a necessitating factor in extending sewer interceptors to outlying shoreland areas in the Traverse Bay region. The extension of sewers is believed by many to be a prime inducement to growth, with possible undesirable environmental and economic impacts.

In response to this request for advisory assistance in a key issue, the project was initiated. Five major objectives were established:

1. to identify potential problems related to ground water seepage, especially to the east arm of Grand Traverse Bay.

2. to provide input for ecosystem modeling projects (possible nutrient inputs from drain fields would be evaluated with respect to their impact on biological growth in the bay, using the models);

3. to quantify the role of septic fields as general contributors to the bay pollution load (an alleged major problem in the region);

4. to study processes of ground water transport in regions bordering lakes and rivers; and

5. to develop predictive criteria.

Because of limited funds available in the middle of the fiscal year to initiate the project, work was not implemented as rapidly as desired. However, several major activities were carried out.

- A literature review was completed resulting in 53 abstracts of pertinent articles. Major categories include: (1) water, chemical and physical aspects; (2) geology, chemical and physical aspects; and (3) biological aspects. Several significant reports and articles have been located and reviewed, resulting in substantial efficiency in project planning and execution. A report of the literature review is in preparation.

- Two seminars were held in connection with the Houghton Lake study being conducted by the Michigan Water Resources Commission.

- Field techniques have been developed and equipment has been fabricated for sampling ground water at various depths.

- Sampling sites have been selected for study in the area of the east arm of Grand Traverse Bay. Permission has been received from eleven selected property owners.

- Initial sampling was started on 15 February and 5 March 1973, but had to be discontinued temporarily because of frozen ground conditions. Various depths were sampled at each location and water quality was evaluated in terms of nitrogen forms, phosphorus forms, chloride, and total and fecal coliform levels.

HYDROLOGY

Ernest F. Brater

The purpose of the hydrology project was to determine the discharge into and through Saginaw Bay. The total annual flows are first determined for the periods of record for the entire bay or for any portion of it. Further study will provide a separation between ground water and surface runoff. Information on deviations from normal flows and seasonal variations will also be developed. A hydrological model would then be developed to extend this information to the full duration of precipitation records in the region. This report covers the first portion of this work accomplished during the first year, 1972-73.

The watershed boundaries and stream gaging stations are shown in figure 1. Watershed boundaries and river locations were obtained from U. S. Geological Survey topographic maps. The total land area of the drainage basin is 8,200 square miles. The area of the bay is 1,190 square miles.

River discharge records are available at 31 gaging stations for periods ranging from 15 to 41 years. Twenty-two of these are on smaller areas within larger gaged areas. The 9 gaging stations, within which the other 22 are located, cover an area of 5,700 square miles. (These 9 are USGS numbers 1380, 1385, 1420, 1435, 1560, 1490, 1515, and 1585.)

Thirty-seven Environmental Data Service rain gages, identified and located within and adjacent to the drainage basin, are shown in figure 2. Temperature records have been obtained at 14 of these stations.

No runoff records are available on 2,500 square miles of the total 8,200 square miles. Runoff from the ungaged areas is estimated by developing relations for discharge per unit area among the various portions of the basin. Generally, estimates for any area would be made by utilizing runoff data from the nearest gaged area. In order to test the accuracy of this procedure, some comparisons were made among the gaged areas. The most useful procedure is to plot annual discharge in cfs per sq. mi. for one area against that of the other area. Examples are shown in figures 3, 4, and 5. Figure 3 shows a correlation between discharges of the Cass River at Frankenmuth and the Flint River at Flint. The least square equation relating the discharges is

$$Q_C = 1.044\ Q_F - .048$$

where Q_F and Q_C are discharges per unit area of the Flint and Cass Rivers respectively. The linear correlations coefficient, r, was 0.83, indicating a high degree of significance.

Figure 1. Stream Gages Saginaw Bay Drainage Basin
▲ = Gaging station location. 1440 = USGS No.

Figure 2. Rain Gages Saginaw Bay Drainage Basin.
⊙ = Rain gage location.

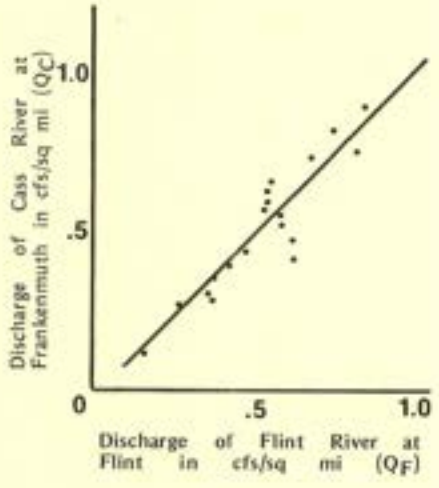


Figure 3.

This result is to be expected because they are adjacent basins having similar physical characteristics and subject to similar rainfall conditions.

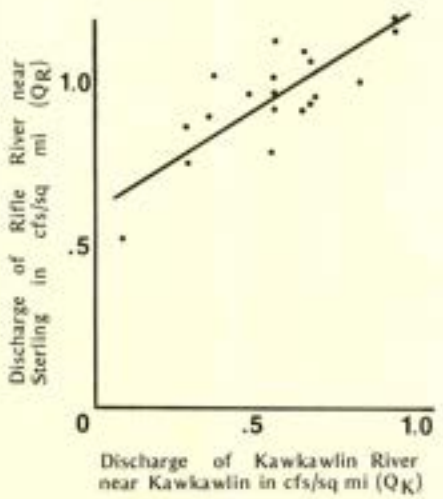


Figure 4.

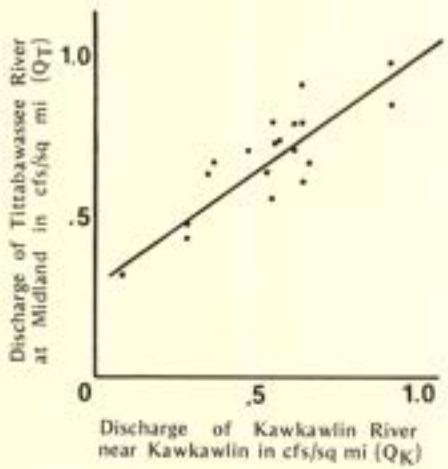


Figure 5.

Figure 4 shows a similar correlation for the Rifle River and the Kawkawlin River. The low correlation coefficient (0.50) indicates that this is a relatively poor but still significant relationship. On the other hand, when the Kawkawlin River is compared with the Tittabawassee River (Fig. 5), the relationship is much better, with the correlation coefficient being 0.67. Studies of this type provide the best basis for estimating the discharge from ungaged areas and also indicating the degree of accuracy that can be expected.

WATER CIRCULATION

Edward C. Monahan

The eulerian current measurement program in Grand Traverse Bay was essentially completed this year. A comprehensive report on this aspect of the Grand Traverse Bay work will be found in the Ph.D. dissertation of Mr. Richard Johnson, which is now is preparation.

A comparable study of Saginaw Bay, likewise involving the use of subsurface current meter moorings, will begin in July 1973 with measurements of the exchange between the inner and outer portions of the bay of Lake Huron. As was the case with the eulerian measurements from Grand Traverse Bay, these data are to be used in establishing the forcing conditions in the numerical dynamic model of the circulation being developed by our coworkers.

The study of the circulation pattern within Grand Traverse Bay, based on measurements of the trajectories of as many as twelve drogue-buoy pairs which were adrift simultaneously, is complete except for information on the circulation within the east arm of the bay. This omission will be remedied with observations during the 1973 summer. A report on the lagrangian circulation measurements, "Drogue Measurements of the Circulation in Grand Traverse Bay, Lake Michigan," appeared as a Sea Grant Technical Report. This report documents the existence of distinct gyres in the circulation pattern within the west arm of Grand Traverse Bay. Drogue calibration data, based on two tank tests, is also included in this technical report.

In preparation for a similar study of the circulation within Saginaw Bay, scheduled to begin during 1973-74, additional smaller surface buoys have been constructed for use in conjunction with our "vee" and "windowshade" drogues. The direct measurements of the circulation in Saginaw Bay will be used to verify the patterns predicted by the numerical dynamic models, as the drogue data from Grand Traverse Bay were used.

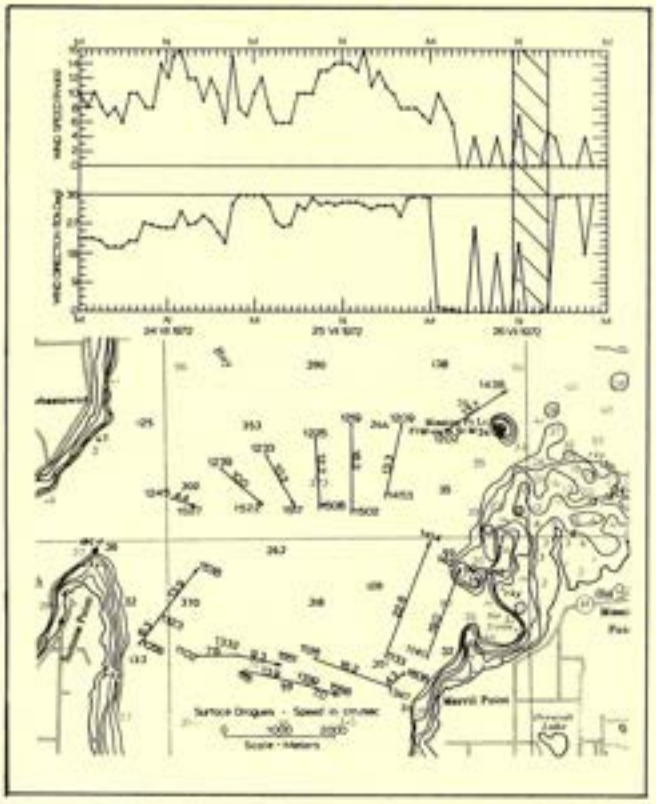


Figure 1. Trajectories of Drogues in Grand Traverse Bay, 26 July 1972. Note counterclockwise nature of flow.

Figure 2. Drogue Being Retrieved.

A paper, "Current Measurements in Grand Traverse Bay," was presented at the 77th Annual Meeting of the Michigan Academy of Science, Arts, and Letters, in April 1973.

The development of new instruments and new techniques of measurement has continued throughout this year. Extensive field tests of The Univeristy of Michigan omega navigational radio buoy–drogue system were recently conducted, the winter testing being done at the Virginia Institute of Marine Science, Gloucester Point. The results of those tests, and a comprehensive evaluation of the omega buoy, will be found in the Ph.D. dissertation of Mr. Edwardo D. Michelena, which is in preparation. A motion picture, "A Tow Tank Study of the Behavior of Four Drogue Types," was presented at the 16th Conference on Great Lakes Research in April.

In an attempt to complement the drogue circulation data with even more economically obtained information, Mr. G. Thomas Kaye and Mr. Donald L. McCown, under the supervision of Professor Monahan, have conducted a series of small tank evaluation tests on various surface drifters, including drift bottles, vertical drift envelopes, and horizontal drift cards. As a result of these tests, several hundred drift-drums were produced. These drift-drums are made of fluorescent plastic-coated paper and include a return postcard requesting information as to where and when the drifter was found. These drift-drums are being used in an intercomparison test being conducted from May to June 1973 in Woods Hole, Massachusetts, as part of the Sea Grant sponsored Oceanography Field Practicum course. If the results of this test are encouraging, these drift-drums will be used as part of the circulation study of Saginaw Bay. At present an evaluation is being made as to the possible use of rare-earth salts, combined with neutron activation analysis, in determining effective residence time of water in the bay.

ENVIRONMENTAL IMPACTS OF COOLING TOWERS

Dennis G. Baker and Edward Ryznar

The purpose of this project is a "before and after" analysis of the meteorological effects of two different methods of heat dissipation from nuclear power plants. Government and industry studies have indicated that atmospheric changes may occur, but their type and magnitude are uncertain. The project was established in 1972 at the request and encouragement of the Michigan Department of Agriculture, the Michigan Department of Natural Resources, and the Governor's Council on Environmental Quality, and is supported substantially by the power industry.

The plants chosen for the study are located on the southeastern shore of Lake Michigan. The Palisades Nuclear Plant will utilize large, mechanical, draft cooling towers located on the Lake Michigan shore, which discharge moist plumes into the atmosphere. The Cook Nuclear Plant will incorporate once-through cooling and, subsequently, discharge heated water into coastal waters of the lake. The data obtained will be used in the Coastal Zone Management Project, the Gaming Simulation Project, and the processes models. However, this research will have considerable significance for many other areas in the nation where either cooling method is being considered for nuclear electric production facilities.

During the past year, equipment for continuous meteorological sensoring has been obtained and employed at 26 inland sites. This includes equipment for measuring and recording temperature, relative humidity, and precipitation. In addition, instruments for recording solar radiation, atmospheric radiation, wind velocity, and visibility were installed at 4 sites. Sample schedules were designed and data processing and collecting was initiated. The programs for processing precipitation have been completed. It is hoped that at least two to three years of preoperational data will be obtained and combined with existing climatological records for use with three to four years of data after the cooling systems begin operation.

In addition, a predictive fog model is being designed which is general enough to consider moisture added to the air by the cooling systems. This possible increase in relative humidity and/or fog at ground level would be a problem for nearby freeway traffic and fruit growers. Records of past fog density and fog type for the area have been analyzed.

The results of this work will be watched closely by state and federal agencies, as well as by the utility industry. This project is typical of the cooperative arrangements with lake-related industry that characterize the Sea Grant charge of better understanding the marine and Great Lakes environment and man's use of them.

Color-coded Temperature Contour Map of Discharge Plume.

PUBLIC POLICY AND INSTITUTIONAL RESEARCH

PUBLIC POLICY AND INSTITUTIONAL INTERACTION

Jonathan W. Bulkley

Several activities of this project were accomplished during the past year.

- An in depth study was made of the institutional arrangements which are currently available under Michigan law for units of local government to provide comprehensive environmental services: especially, water supply, wastewater collection, treatment, and disposal; and solid waste collection and disposal.

- A study was made of the existing institutional arrangements within the Grand Traverse Bay watershed to identify a set of alternative institutional arrangements which would have been considered by the citizens during the project activities.

- A preliminary report was prepared, based upon the two studies cited above, and distributed to a number of officials and citizens in the Grand Traverse Bay area in February 1973. It identified five different types of basic institutional arrangements which could be utilized to provide the necessary environmental service; especially, wastewater collection, treatment, and disposal. The alternatives identified and discussed were: state utility, regional government, sewage authority, county service, and intergovernmental service agreements. All of these alternatives are relevant to the Traverse Bay watershed because two or more counties are involved in the provision of the desired service.

- The analysis of the Great Lakes questionnaire was continued based upon 300 responses received. The results were presented at the 16th International Conference on Great Lakes Research.

- The political simulation model has been applied to ongoing, unresolved issues regarding sewage systems for Elmwood Township. Additional modifications to the model are being investigated to enable its use in conjunction with exploratory studies of environmental impacts.

One of the primary tasks undertaken during this year concerned the identification of a range of alternative institutional arrangements for wastewater service in the Traverse Bay region.

The Traverse City sewage treatment plant has been expanded and its treatment level upgraded. However, state and federal funds have not been provided to enable interceptor sewers to be constructed to bring the sewage from separate, but so far contiguous political jurisdictions to the Traverse City sewage treatment plant.

Given the existence of an expanded and upgraded wastewater treatment plant at Traverse City, questions arise as to how and under what conditions growth will take place in the region, and what the likely impacts of such growth will be on the environmental quality of Grand Traverse Bay. On the other hand, the very existence of the expanded and upgraded wastewater treatment plant, together with a network of interceptor sewers, may be a primary force contributing to corridor or strip development radiating outward from Traverse City along the shoreline of the bay. On the other hand, the expanded capacity of Traverse City may suggest high-density development in the existing city, through vigorous development of housing and light industry which could be served by the existing facility. The physical and biological models developed by Sea Grant should provide extremely useful insights into the impact of alternative growth patterns upon environmental quality—primarily water quality—in Grand Traverse Bay.

From the public policy and institutional interaction perspective, the primary concern is the institutional form that will be utilized to provide the basic services of water supply sewage treatment, and solid waste disposal in the Grand Traverse Bay region. In theory, numerous methods exist whereby such services may be provided. It should be clear that three counties, Grand Traverse, Leelanau, and Antrim all meet in the immediate area of Traverse City; and all three counties have shorelines and drainage basins discharging into Grand Traverse Bay. Consequently, one may initiate the study for appropriate institutional arrangements for provision of the basic services of water, sewage treatment, and solid waste by examining institutional mechanisms which may provide such service in a multicounty situation. Existing legislation could be utilized to implement different wastewater collection and treatment systems in a multicounty situation.

The sanctions and authorities necessary for comprehensive water-quality management are:

1. The ability to evaluate and implement a wide range of alternatives.
2. The ability to integrate related water and land uses.
3. The ability to articulate private and local governmental decisions to increase efficiency.
4. The opportunities for affected parties to influence decisions.

The reality of the political environment in any given geographical area may dominate the outcome in terms of institutional arrangements for comprehensive wastewater management. Public attitudes, which may not be receptive to the extreme case of consolidation, may be supportive of other effective, but more limited, forms of regional governance.

A second primary task has been the additional analysis of the data collected from shoreline units of government

throughout the Great Lakes Basin. The maintenance and improvement of water quality ultimately requires that the various governmental units responsible for quality be able to perceive the nature of factors influencing water and shoreline quality, and the cause and effect relationship among these factors. A questionnaire survey conducted among 650 governmental units in the Great Lakes area has identified the levels of water quality in the respective areas, the perceived factors contributing to the destruction of water resources, and possible solutions to the problem of deteriorating water quality.

One-way frequency distributions, based on the 300 responses to the questionnaires, indicate that the water quality is medium or lower in 92 percent of the cases, while it is low or very low in 35 percent of the cases. Inadequate municipal sewage treatment and inadequate industrial effluent treatment were identified as to the most common factors causing the destruction of water resources. The primary agencies responsible for the maintenance of water quality in the local areas were reported to be the state agencies.

Analysis of two variable relationships have been made with a view to link the chain of causal factors influencing water quality in the Great Lakes. Water quality is found to vary with the type of land use and population density; decreasing with the increasing degree of industrialization and decreasing with increasing population density. A causal sequence model in which population density appears as the intervening variable between land use and water quality is proposed, and this seems to correlate with the data.

This research effort has demonstrated that a survey questionaire, directed toward units of government with jurisdiction over shoreline areas of the Great Lakes, may produce data which is useful in understanding attitudes toward resource utilization. Inadequate municipal and industrial waste treatment facilities are perceived to be the most important issues related to destruction of the water resources of the Great Lakes. One may observe that this finding places increased importance upon the implementation of advanced techniques for wastewater treatment throughout the Great Lakes Basin. The data also indicates that the land–water interface is a resource which has limited public access for vital and recreational purposes. The partitioning of the responses according to type of governmental unit, namely, township, county, and city, indicates that the different levels of government tend to have different perceptions regarding solutions to water-quality problems in the Great Lakes Basin. However, all units of government, regardless of level, ranked the creation of new agencies as lowest in priority for a solution to water quality problems. The cross-tabulation and partial correlation analysis demonstrated that in any land-use pattern, population density significantly affects water quality. However, the effect of land use on water quality is significant in the high population density areas and where industrial use is predominant. A first extension to this development would be to explore the relationship between population density and water quality, and to determine why high population density implies poor water quality. Analysis may be continued in this manner to obtain comprehensive models of water-quality relationships, and alternative causal inference models may be evaluated using partial correlation analysis.

Finally, the political simulation model has been used to investigate ongoing, unresolved issues in the Grand Traverse Bay region. While the focus of this effort was completely observational, it is interesting to record the fact that local pressure was brought to bear privately to have the project terminated. However, the data was collected and the computer model has been run. The results from the political simulation model are congruent with what subsequently transpired.

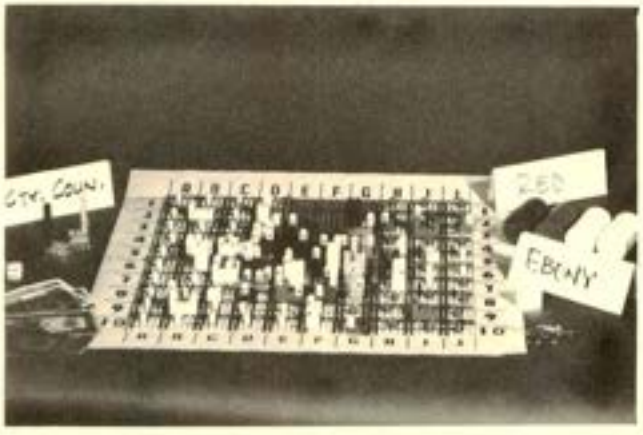
Documentation is being prepared describing the political simulation model and the application of the model; the Great Lakes Survey questionnaire; and the extension of the political simulation model to be used in conjunction with an environmental impact estimator.

GAMING SIMULATION

Allan G. Feldt and David Moses

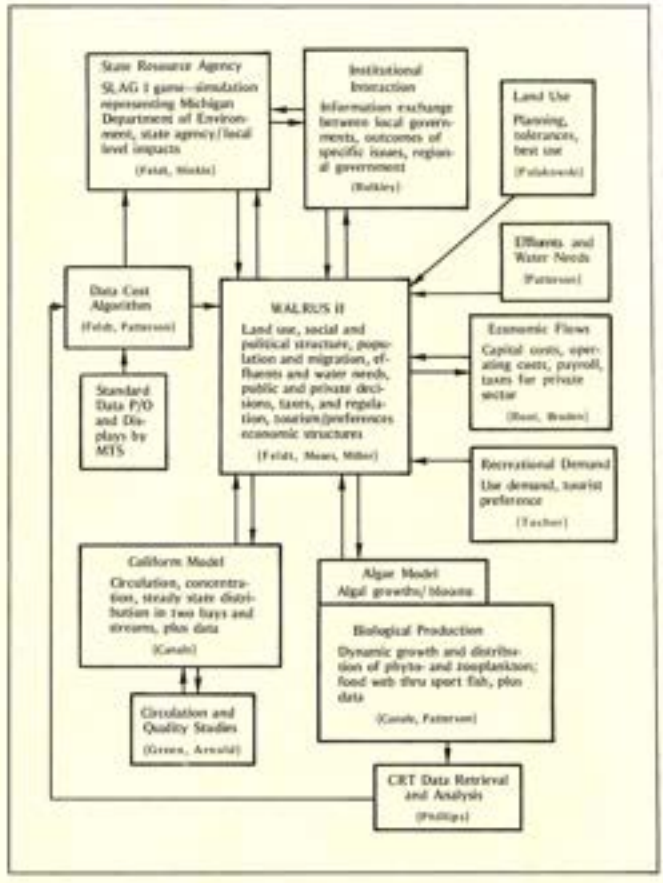
Past effort resulted in a gaming simulation model, WALRUS I, the utility and acceptance of which was substantially in excess of original expectations. This model has been used by over thirty different institutions outside The University of Michigan and in at least three foreign countries (Australia, Italy, and the United Kingdom). Further development of more sophisticated versions of the gaming simulation models has been hampered considerably by the success of our first product due to continuing requests for information, modifications, and demonstrations of WALRUS I.

A series of working meetings were held with several other Sea Grant projects in order to integrate their data and project efforts as closely as possible with the design of the more sophisticated WALRUS II. As a result of these meetings, substantial progress was made on the basic components and basic programming requirements for the model; but substantial difficulties were encountered in arriving at a satisfactory level of aggregation appropriate to problems of sensitivity and detail required in the model. These problems of level of aggregation resulted in the decision to force the development of the model into a more detailed and more sensitive format, immediately providing a level of sophistication and operational potential considerably beyond that originally intended for the WALRUS II version. This more sensitive and detailed version was subsequently called WALRUS III to keep distinct the varying levels of sophistication of the model in its different forms.



Gaming board and playing pieces used in WALRUS I

At this new, higher level of detail and sophistication, many of the artificially created problems of data handling and coding encountered in WALRUS II disappeared. At the same time, some new problems arose which were more directly reflective of real world problems of data acquisition and handling. In resolving these problems for WALRUS III, the same problems are being resolved for real world planners and decision makers.



WALRUS II in Traverse City

The major components of WALRUS III which have been worked on during the year are the following:

- A land-use inventory, sensitive from 0.25 acres of some commercial land uses to about 200 acres of some agricultural uses, including 54 different types of land use, has been developed for the 84 square-mile region surrounding the lower east and west arms of Grand Traverse Bay. Each of these 54 land-use types has associated with it a series of demographic, economic, social, political, and effluent characteristics developed in part through the cooperation of Drs. Braden and Patterson of the Sea Grant Program. This area includes all of Traverse City and Garfield Townships, a substantial portion of East Bay Township; and parts of Elmwood, Peninsula, and Acme Townships.

- An adaptation of the steady state model developed by Dr. Canale was made to cover both the east and west arms of Traverse Bay as well as the Boardman River and several inland lakes. At present, this model will handle loadings from 8 different effluent parameters and will generate steady state concentrations of these effluents for each of the 64 segments representing the water system of the region.

- A series of economic and demographic algorithms, providing what are expected to be realistic behaviors for these land-use types, have been embedded in a computer program which is currently being tested and put into operational form.

• Integration of some form of ground water model and of a preliminary version of Dr. Canale's dynamic modeling program is underway. It is expected that these two models will also be successfully integrated with the land-use types described above, providing additional information on probable effects of changes in land use on overall water quality.

• Due to a reduction of funds, no further effort will be made to add more components to WALRUS III during the next year. Rather, project efforts will now concentrate on trying to complete and make available to local authorities those components of WALRUS III already substantially completed. At the same time, a revised version of WALRUS I will be published, incorporating some of the criticisms and suggested changes received over the past two years. In addition, a computer-assisted version of the game will be developed, incorporating many of the concepts developed for WALRUS II, as well as some elements from WALRUS I and WALRUS III.

ENVIRONMENTAL DECISION MAKERS

F. Jerome Hinkle

In order to provide continuity with the previous work on this project by Professor Donald Michael and Mr. Robert Ross, the objectives of this year's work were basically determined by two factors:

1. the need to construct a summary result that offered an impact on research already completed in the area of use, quality, and flow of information in environmental policy-making agencies, and

2. the need to further relate regional systems and state-level decision making, as provided by the Gaming Simulation project of Feldt and Moses.

The principal effort has been to build a gaming simulation device which constitutes an application of the theoretical work of Michael and Ross and furnishes a quasi-experimental device for the examination of further theories about the process of decision making in a "typical" state-level policy-making agency. The "typical" agency, as represented in the gaming simulation, is a state environmental policy agency which basically responds as a function of:

(a) internal agency politics;
(b) interagency politics;
(c) external, interest-group pressures;
(d) moderately strong professionalism within the bureau—essential for generating analysis as an important component of the decisional process;
(e) traditional limitation of resource management problems to fish and game—agency faces pressures for institutional changes as regulatory responsibility increases rapidly; and
(f) common structural properties—reduction and specialization of function into divisions/departments, oversight by a "citizen" resources commission, budget/fiscal flows.

The Role of Theory

A search was undertaken to find algorithms that could be useful for representing the role of the state policy-making apparatus (for environmental affairs) in the projected WALRUS II game, which examines the dynamics of a small regional system, centered in Traverse City, Michigan. Experience with WALRUS I (and many simulations), the work of Michael and Ross, the need for quickly available results, and the basic difficulties in simulating the behavior of complex organizations suggested use of a gaming simulation device to represent a policy-making agency at the state level. Hopefully, this would complete a simple management system in WALRUS II/III which would then focus on local/regional government, as relating to the functions of a state natural resources department.

A gaming simulation of such an agency was desired which would include some of the cooperative and conflictive aspects of interest group politics, as well as the making of decisions based on actual information. Earlier Michael and Ross

work had detailed some of the problems of quality, credibility of source and flows of technical information in the Michigan agencies, whose responsibilities bear on environmental quality. These types of problems have rarely been addressed in policy-type gaming simulations, where outcomes are excessively a function of the operation of a pluralist political system. Decisions in government have both technical and political components and recent public policy analysis often weights more heavily the technical component over the political, as if the purity of "rational" action must combat the "emotion" of politics.

This suggests, then, that neither politics nor rationality be ignored when the "arena" is simulated. When traditional agency bounds are being expanded rapidly, and the demand for more understanding of complex social and biological phenomena accompany these changes in organizational goals; it is essential that the linkages between planning and analysis of politics and public accountability be portrayed. The mechanisms for formulating discrete politics/action derive from the dilemmas presented by basically conflicting forms of logic and propriety. No perfect information exists: there is always a severe compression of any time scale; constituencies and clients clamor for benefits; and public agencies possess, at a minimum, all the faults of their human components.

Action

Simulating this complex situation is formidable. Rather than promote single causal mechanisms examined at considerable depth, a number of highly simplified causal mechanisms have been selected, which all contribute differentially across discrete decisions, to some political/technical outcome. Extensive searching for a gaming framework yielded an imaginative structure, "Policy Negotiations," first developed by Professor Frederick Goodman of The University of Michigan. This has further evolved into "Policy Plan," adapted by Larry Coppard and his colleagues at the Environmental Simulation Laboratory (ESL) in the School of Natural Resources at The University of Michigan. Data-based application of this framework to a specific policy problem has resulted in "Housing Plan," done under a Ford Foundation grant by Coppard and the ESL. Goodman's general delineation of the framework provides quite a powerful device for examining the processes of public decision making and has led to some very imaginative adaptations by Coppard and the ESL in the areas of public housing, drug abuse, and wastewater management. With extensive modification, these efforts afford points of departure for further study of the process of decision making in public agencies.

A significant proportion of the effort so far has been in familiarization with basic statewide environmental issues/problems and their resolution. A look at resource management agency functions and actions has been enhanced by participant observation in the formulation of legislation and administrative rule-making, and by examination of the nature of the information (facts and data) utilized by contenders in making policies. This has served to identify the important process variables to be represented in the gaming simulation, as well as a set of issues that have appropriate generality beyond the experience of the Michigan Department of Natural Resources. However, we did not intend to dramatize only policy-making problems in Michigan (as a case study would), but to build a quasi-experimental device usable for theory testing on a particular class of problems in public policy making. It should also have great educational value in familiarizing students and the lay public in the operation of a state environmental policy agency.

Modifications

The Gaming Simulation project went beyond its expected accomplishments by defining and building much of WALRUS III (as opposed to just WALRUS II); and the original mandate was to test the products of that work as actual planning tools in a real/future-time sense. However, site review has called for a redefinition of purpose; and consequently, WALRUS III will have no experimental test by installation in Traverse City, Michigan for public access and utilization. Some of the most promising features of the work related directly to the NOAA call for relevance in research-visualizing tasks from real-world problems and to the building and validating of methodologies for use in public service. This change in emphasis materially reduces the value of the output from the Environmental Decision Makers project, since there is no longer a need for the state/regional/local management system linkage. However, assessment of the realities of state government will attest to its cruciality as a problem.

ECONOMIC IMPACT ANALYSIS

Patricia L. Braden

All research efforts undertaken during the previous fiscal year were focused on three task areas: regional economics, industrial water quality decisions, and an extension of Delphi procedures and methodology. Emphasis was placed on coordinating research output with other Michigan Sea Grant projects.

Regional Economics: The objective of pursuing research on regional economics was to develop a general regional economic model that could be used to assess the economic consequences of various regional development strategies. It was to be evaluated in terms of its usefulness to Grand Traverse Bay planners for both water resources management and investment cost review. The model that was actually developed was used as the formal basis for economic transactions in the WALRUS III simulation on water and land resource utilization; as well as being the vehicle for forecasting capital investments and operating costs of the various economic sectors at different levels of effluent control. To estimate the parameters of the equations, a substantial data base on each economic sector was gathered from secondary data sources. The formal transaction equations were developed after subjective appraisal of the parameters, using an earlier assessment of the socioeconomic development in the Grand Traverse Bay area as a guide (Michigan Sea Grant Technical Report No. 8).

Since it has been incorporated into the WALRUS III simulation, the regional economic model will be used directly for assessing alternative water resource management strategies and for illustrating the impact of the lack of effluent controls on regional growth and the development of commerce. The audience addressed by the simulation includes legislators, economic planners, resource managers, and citizens of the Grand Traverse Bay area. Thus, the incorporation of the regional economic model into the simulation allows the potential for far greater impact on policy and practice than similar models, delivered solely in academic journals.

Industrial Water Quality Decisions: It has long been recognized that economic activities are strongly affected by the perception of costs and prices and by attitudes toward public works programs. That is, knowing the perceptions of economic conditions is often more important to predicting economic consequences than simply knowing the facts of economic conditions.

During the past year, a survey was fielded to 500 business executives whose companies operated in pollution-prone industries along the eastern shoreline of Lake Michigan. The survey was designed to identify companies' real progress towards integrating environmental concerns into the functional operations of business; to obtain a better understanding of the attitudes and perceptions of water quality problems; and to determine the information needs of the business community, as well as the sources of water quality information used by members of the business community. The results of this behavioral study were compared by industry, by company size, and by the amount of effluent discharge measured by the Michigan Water Resources Commission. An extensive technical report of the results will be published on environmental information use in industrial decision making. In general, however, the results indicated that industry executives were more sensitive to environmental concerns than expected; the companies were more optimistic than expected about instituting successful control measures requiring only modest investment and were also less concerned about government controls than about arbitrary enforcement procedures.

Extension of Delphi Procedures and Methodology: The third task area was the application of subjective judgments to the appraisal of alternative public policies. This was carried out jointly with Professor Edgar M. Pessemier of the Purdue University Krannert School of Industrial Administration. The project combined techniques of both the Delphi methodology and weighted preference selections to develop a feasible alternative to the adversary procedure endorced in current guidelines for economic impact statements.

An extensive working report was received from Professor Pessemier on his efforts to structure appropriate field procedures and analytical methodologies. This framework will serve as a guideline for operationalizing the current year's field work on public policy choice and for analyzing the results in a field test of the procedure. Subsequently, endorsement will be sought from the Michigan State Department of Commerce Economic Impact Unit, which is in the process of establishing the required procedure for economic impact statements on state-funded projects. Efforts are already being planned to train members of the State Department of Natural Resources staff to apply the techniques and interpret the results.

In addition to the specific task areas addressed above, an extensive library is being maintained of publications and reports related to water resources management and control; and requests have been answered for information on regional economics and water resources management, which have come from residents of Michigan, state and local legislators, environmental planners, businessmen, and academic researchers.

COASTAL ZONE AND SHORELANDS RESEARCH

COASTAL ZONE AND SHORELANDS MANAGEMENT

John M. Armstrong and Peter C. Ryner

During 1972-73, development of coastal zone management research capabilities continued, with emphasis on assisting state and local government groups. In continuation of past project objectives, some effort was devoted to collecting and analyzing legislation, studies, reports, and management efforts throughout the United States, in order to provide a sound basis for development of Great Lakes coastal resource management policy. The importance of this effort continues to increase as interest in coastal zone management in Michigan accelerates. Numerous state and federal legislative actions have more than doubled the level of public involvement in coastal management efforts during the last year. Through continuing review, increasing assistance has been provided to the agencies and private citizen groups in clarifying the evolution of this new area of public concern.

As reflected in various publications and in advice to public groups, efforts to develop management concepts for the Great Lakes coastal problems, as well as for other coastal areas, have begun to relate extensively to the advisory service objectives of the program. As efforts progress toward implementing the Coastal Zone Laboratory program, designed to serve the Great Lakes coastal community, this capability will be of critical importance. At present, assistance is being provided to state agencies developing a state-level management plan, as requested under P.A. 245, 1970. In addition, concepts are being developed for implementation of the federal coastal zone management program at all levels of government. Work is also underway on the mechanics of establishing a workable interface between coastal zone management efforts and other public programs, such as land-use planning and water-quality improvement.

The major field study in the Grand Traverse Bay region continued to develop various possible management strategies to deal with the specific problems in that area. A report, detailing specific management strategies, was presented jointly by project staff and the State of Michigan Water Resources Commission to the Grand Traverse Bay Coordinating Committee, which has members from twelve townships and three counties, and was created with Sea Grant assistance and encouragement. This report was supported by a written set of recommendations, several charts and maps, and two volumes reviewing the coastal zone management issues facing the citizens of the area in the coming years.

As skills, concepts, and information develop, increasing contributions are made to the Sea Grant Advisory Services program. During the latter part of FY 1972-73, 25 percent of the project efforts were directed toward advisory services activities. Identification of critical public issues, analysis of information needs for resolution of shoreland problems, and identification of topics needing further research were the major activities for this advisory services effort; and it is expected that this effort will be expanded during the coming year.

Publications: In an attempt to develop a method of presenting resource management and techno-economic information to shoreland user groups, two publications in the *A Time of Choice* series were directed toward the problems and opportunities of the Grand Traverse Bay region. These well-received publications excited interest in coastal management and called attention to ways of increasing the use and enjoyment of valuable shorelands. Several groups in the Traverse Bay region have used these reports in planning activities, and requests have come from other areas, indicating a need for this type of material on regional, state, and national levels.

The booklet, *Water Zoning*, calls attention to serious conflicts emerging in the distribution process in many shoreland areas around the state of Michigan and across the nation. The booklet is a direct result of field work which revealed the seriousness of conflicting uses of the surface of various water areas. Recommended solutions and suggestions for obtaining further information are included.

Numerous requests have been received for the booklet, *The Structure of Management and Planning for the Coastal Zone*, describing the nature of coastal zone management. Technical Report No. 20, detailing all existing management programs, with emphasis on ten state coastal management programs, was again reprinted and has been requested by individuals in every coastal state and in several foreign countries.

Grand Traverse Bay Shorelands Pilot Project: A pilot project was undertaken to establish a locally administered shorelands plan. The project was carried out with the cooperation of the Water Resources Commission, and a detailed report of findings and recommendations was presented to the people of Traverse City and the water resources commissioners. Citizens in the area have continued this effort, and requests are received for information from various Michigan Sea Grant projects. In terms of internal significance, the pilot project revealed several areas where improvement or modification of techniques and concepts is needed. However, of satisfaction is the conclusion that the basic approach was sound, that it has applicability throughout the Great Lakes coastal zone, and that it has provided a

strong basis for developing the citizen's future ability to deal with coastal problems. As a result of this project, several possible state-level citizen aid strategies are being designed. A citizen's handbook for coastal problems is in preparation.

The Grand Traverse Bay Shorelands Coordinating Committee, originally formulated under Sea Grant guidelines, has been restructured, and its role in examining shorelands development has been strengthened. The committee will serve as an information center for the many continuing resource planning efforts in the Traverse Bay region. Coastal zone project staff will provide an integration of these various shoreland issues in the region. A report dealing with the synthesis of these plans is being prepared and will be provided to the members of the coordinating committee.

Work With Citizen Groups: Various citizen groups cooperated in discussions on coastal problems and on improvement or expanded use of various management tools. This major effort continues, combining field research, concept development, and advisory services; and it leads toward increased skills for both the project and Great Lakes shoreland citizens. The important effort to increase citizen awareness of coastal problems in the Great Lakes has been encouraging.

The Coastal Zone Project was also involved in a key shoreland use controversy in Traverse City. Development of a parcel of public shoreland by private interests generated a major conflict involving the issue of public trust and the use of shoreland resources. Coastal zone project members provided technical input to the groups involved in this issue, in terms of defining and clarifying the key factors characterizing the situation.

Another project relates to the current issue of sewer service in the shoreline township of Elmwood on Traverse Bay. A plan for utilization of the Traverse City wastewater treatment plant as a regional facility has caused considerable controversy over the need for this plan and the impact on coastal waters and induced growth on shorelands. The coastal project, along with other Sea Grant projects, works with various units of government and with private groups to clarify issues, translate past research findings, and provide an objective source of information on the subject. The experience of direct involvement in a real and critical issue has provided considerable practical experience for the entire Sea Grant Program.

Michigan Shorelands Plan Critique: At the request of the Michigan Department of Natural Resources, a detailed critique was prepared on the preliminary shoreland management plan called for in the Shorelands Protection and Management Act of 1970 (P. A. 245). It is hoped that eventually other such review and analysis can be provided to courts, the legislature, executive agencies, and various private interest groups.

Model Zoning Ordinance: A model zoning ordinance was developed which is intended as a model to help communities meet the requirements of P. A. 245, 1970. This ordinance has been conveyed to the state where it, along with other models, is being used to construct the official guidelines for local communities to protect identified critical environmental and erosion areas.

During the coming year, efforts will be expanded in advisory work with the state government on refining and extending the state's coastal plan. Work is planned with communities outside the Traverse Bay region, and several have indicated a desire to receive Sea Grant assistance in preparing for implementation of the state's coastal management regulations.

Equipment placement of large rock. It will later be covered with asphalt mastic.

Resource Planning Game: Development was initiated on a coastal resource planning game designed to reflect the policy issues of rural recreational shorelands areas. Refinement of the initial project will lead to a type of policy game which is different from those currently being constructed and which will have a general application for all shorelands areas.

Urban Coastal Zone: Under a grant from the city of Chicago, a program has been initiated to aid Chicago in implementing its extensive lakefront plan. The construction of offshore islands along the 30-mile Chicago shoreline will be a central element of the program. Coastal zone project staff are identifying the hundreds of issues and questions that must be answered, including environmental impacts, lake effects, and recreational patterns.

SHORE EROSION

Ernest F. Brater

One of the principal objectives of the Shore Erosion Project was to provide information on the rate of bluff recession at selected sites on the Michigan shoreline. Although the damage due to erosion in Michigan is in the millions of dollars, during recent history, the bluff recession rates have not been measured at a sufficient number of locations to eliminate the special conditions which might exist at individual locations. Furthermore, while it is obvious that erosion rates are related to lake levels, no dependable quantitative data had been obtained. These studies are providing an approximate estimate of bluff recession rates for various lake elevations. Information is also being obtained on the effect of major man-made structures. In the future, these results will be refined by studying the effect of major storms; taking into account their frequency, direction, intensity and duration.

Two sites were selected along the southerly shore of Lake Michigan. This is probably one of the most severaly devastated areas in Michigan. The Allegan site extends from north of Holland, 38 miles south to a point about 3 miles south of South Haven. Most of this site is in Allegan County. The Berrien site covers Berrien County from the northern boundary of the county to a point about 12 miles north of the Michigan-Indiana line and is approximately 30 miles long.

The rate of bluff recession was determined by measuring the distance to the edge of the bluff from selected reference points and baselines on aerial photographs. Most of the measuring points are 0.5 miles apart, but are spaced more closely near inlets. There are 87 measuring points in the Allegan site. Photographs were available for the years 1950, 1955, 1960, 1967, and 1970; and measurements have been completed through 1967 and partially completed for 1970. At the Berrien site, 53 measuring points were used. Measurements have been completed through 1960 at all points.

The effect of lake elevation on bluff recession rates can be illustrated by the following data from the Allegan site. In 1950-55, when the average lake elevation was 579.1 feet, the average rate of bluff recession for the 87 observation points was 6.4 feet per year; whereas, in 1955-60, when the lake elevation was 577.7 feet, the rate was 2.2 feet per year. It is not desirable to infer too much about the exact relation between lake levels and bluff recession rates on the basis of evidence collected without a complete analysis of other factors. However, present data indicate that there is an increase in average bluff recession rates of between 3 and 4 feet per year for each foot of increase in lake level.

This analysis will continue in 1973 and will include the high lake levels which now exist. As previously mentioned, other factors, such as frequency of intense storms, will be taken into account.

In the future, the types and density of man-made structures will be determined at the various measuring points; as has been done for population density along the shore area. It is expected that structures and rate of use will have considerable bearing on local recession rates. The data collected to date show that the interruption of littoral drift by jetties causes accelerated erosion on the downdrift side.

In the spring of 1973, a cooperative project was initiated with the Michigan Department of Natural Resources to design, implement, and test various shoreline protection concepts. This project, funded by the Michigan Legislature, will attempt to test new techniques in shore protection that might be applied in many areas of Michigan's endangered shoreline. Fifteen sites have been selected on Lakes Michigan, Huron, and Superior.

This effort is the first, formal research activity under the Coastal Zone and Shorelands Laboratory program at The University of Michigan, initiated earlier this year by Governor William G. Milliken. This effort will be carried out jointly with the Sea Grant Coastal Zone Management Project.

RECREATION BEHAVIOR

Ross S. Tocher

In general, recreationists are a diverse cross section of a region's population. The visitors to Lake Huron's shoreline recreation sites are no exception. The 1972-73 study concentrated on environmental preferences, motivations, attitudes towards shoreline resources and shoreline quality, and personal concerns for the quality of the recreational experience of a shoreline visit.

Information was obtained by means of approximately 244 responses to a 20-minute, self-administered questionnaire. The survey model used was basically stratified random, but an attempt was made to get representation from all identifiable major groups of shoreline users.

The Sample: The largest percentage (30.4% of respondents) were "regular seasonal visitors" campers or renters. Most were between 21 and 35 years old, with students, housewives, and professionals, in that order, most represented. The majority of the respondents live in or near larger towns or cities within Michigan, earned between $10,000 and $15,000, and had attended school through the twelfth grade. Over 80% of the respondents drove in excess of 100 miles to the site where they were interviewed, and close to 77% of those interviewed indicated they were return visitors to the area. Camping and swimming/sunbathing were their most favored recreational activities.

Recreation

1. Reasons for Choosing Area: Respondents were asked to rank the relative importance of six reasons for their choice of the area as a recreation site. By weighting the results according to ranking, the following rank-ordering of the six reasons was obtained for the sample.

1. "Enjoy the peace and tranquility of the area; quiet, restful surroundings"
2. "Escape from city environment,"
3. "Opportunity to explore,"
4. "Opportunity to experience sights, sounds, smells of nature,"
5. "Good experience for children, family,"
6. "Satisfying experience for husband and wife."

When considered with the fact that the majority of recreationists were from urban areas, the results suggest a causal relationship between the environmental quality of the visitor's home area and recreational preferences. This is particularly true of reason 1 above.

2. Recreation Motivations: The questionnaire included 36 motivational statements (e.g., "To get away from the noise back home," "To look at the natural scenery"). Respondents were asked to rate the importance of each statement as a reason for their activity at the time of the interview, based on a nine-point scale from "not important" to "extremely important."

For analysis purposes, similar statements were grouped together and weighted, as before, for each respondent category. The results showed rest, relaxation, and the enjoyment of natural scenery as the major conscious reasons people are drawn to the Lake Huron shoreline. This further suggests a strong relationship between one's home environment and recreation preferences. Clearly, one of the values of a shoreline lies in its promise of tranquility and relaxation away from the stress of day-to-day urban life.

Threats to Enjoyment

1. Threats to Recreational Value of the Area: Respondents were presented with a list of 18 environmental and social "threats" and asked to indicate the seriousness of the threat from "no problem" to "very serious." The threats rated most serious were

1. Lake Pollution
2. Shore Erosion
3. Littering
4. Commercial Development
5. Overcrowding
6. Stream Pollution

Although it is not known if respondents were thinking of pollution as a potential future threat or as an existing detriment to their enjoyment of the area, it is apparent that the perceived recreational value of the shoreline will be correlated to the extent to which these problems are seen to increase.

2. Personal and Property Security: One three-part question explored respondent's feelings and behavior on the question of security. It was found that, although only 6% had ever personally experienced a threat to their security while visiting a recreation site along the shoreline, 66% worry about their personal and property security at such times. Of the total sample, 36% of the respondents said they had means of protecting themselves and their friends from threats by others. Of that 36% (68 people), 12 listed their means of protection as a gun.

A second three-part security-related question was asked only of those respondents who either own or rent property in the area. It was found that fully 40% of the respondents to this question had had their property in the area robbed or vandalized. With respect to trespassing, 33% reported that many people trespass on their property, and 42% objected to "non-malicious trespassing."

Attitudes Toward Land Use

Response to a series of four questions determined attitudes toward shoreline land use. In the first question, 72% of the respondents said they would favor "land-use controls imposed by the state to restrict and control development of this area." It is significant that so many endorsed this strongly-worded statement.

These results are interesting in light of the difficulty being encountered by the state in its land-use efforts.

The second question, addressed to those who favored controls, asked them to rank the three categories of land use that should be subjected to the strictest controls. As before, responses were weighted to arrive at the following index of desired control from highest to lowest:

1. Industry
2. High Density Residence
3. Commercial
4. Public Recreation
5. Private Recreation
6. Low Density Residence
7. Med. Density Residence
8. Agriculture

In response to the third question, respondents said industry should be controlled because of pollution.

The final land-use question concerned level of development preferred in the area of the Lake Huron shoreline where the respondent was interviewed. Over 83% of the respondents preferred "modest" or "rustic" (only essential sanitary facilities) development levels.

These expressed preferences correspond with the results from other parts of the survey which indicate that, along Lake Huron, the primary recreation experience lies in resting and enjoying natural surroundings, and a temporary reprieve from the social and physical stress of their day-to-day life.

Importance of Wildlife and Wildlife Habitat

The motivational parts of the survey have indicated that the natural or semi-natural aspects of the Lake Huron shoreline are valued highly by visitors and residents. Wildlife and wildlife habitats are important components of natural environments, and the responses to several questions included expressed a favorable attitude. This favorable attitude toward wildlife was largely independent of whether or not a person hunted.

Respondents were also asked to identify factors which are important in reducing recreational quality. They identified loss of wildlife from an extensive array of potential problems. "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. The relationship between wildlife and the recreational value of the shoreline may not be direct. Although Lake Huron's shoreline provides habitat for a diversity of wildlife, most areas that are heavily used by people do not provide superlative wildlife viewing. Furthermore, visitors to the area show little knowledge of specific wildlife problems.

Visitors to the Lake Huron shoreline appear to value wildlife very much and gain satisfaction from simply knowing birds and animals exist nearby. They perceive that shoreline quality includes a component of birds and animals as an essential ingredient of the shoreline environment.

Implications

Recreationists to Lake Huron's shoreline came for a variety of reasons and have diverse attitudes and preferences. However, all focus on the naturalness of the shoreline. These data present a clear message to those responsible at all levels for Lake Huron shoreline management: a large measure of the recreational attractiveness of the shoreline may be lost if destruction of natural and scenic amenities is allowed to continue.

WATERSHED LAND USE

Kenneth J. Polakowski

The research of the past year was focused on the development of an ecological impact submodel that is a segment of a resource analysis planning model for the determination of land-use development suitability. The primary purpose of the project is to establish a technique capable of translating ecological–esthetic criteria into land-use planning guidelines that can become part of the comprehensive planning process. The planning model, established during the earlier phases of the research project, incorporates ecological, cultural, and perceptual data to determine the development suitability of a particular land area.

Figure 1

The planning model links the ecologic impact submodel, cultural preference submodel, and the perceptual quality submodel to resolve the environmental conflict between mans' land-use activity needs and the capabilities of the ecosystem to accommodate such needs. The development suitability for each land area is expressed in terms that assess the ability of the area to maximize the user satisfaction with minimal environmental impact while maintaining the area's scenic quality. The study procedure employed a macroanalysis technique that identified potential development zones. This provided a regional context to which to apply and test the planning model on subregions that possess a high, land-use development potential. The development potential of the subregions was based on the user's preference for natural and cultural factors associated with leisure land-use development. The results of the resource/user analysis for the regions are as follows:

Degree of Potential	Area (sq mi)
very high	559
high	514
medium	482
low	501
very low	471

The potential development zones net buildable area was determined by eliminating zones that contained 50 percent of water area, 50 percent of developed land, 50 percent possessing severe soil conditions, or with 50 percent of the zone in public ownership. Thereby, the total area that possesses a developmental potential from very high to medium is approximately 20 percent of the watershed or 500 square kilometers (Fig. 1).

A natural and cultural inventory was completed, which included 51 variables, for three high-potential development zones in the Grand Traverse Bay watershed (A–Suttons Bay, B–Fife Lake, C–Intermediate Lake). The three zones were used to apply the ecological impact submodel (Fig. 2).

The ecologic impact was determined for each 1/25 kilometer cell (10 acres) within three high potential development zones in the Grand Traverse Bay region. The ecologic impact suitability model determined the vulnerability of the ecosystem's resources for each recreation class or combination of classes. The classification is as follows:

RECREATION ACTIVITY (DESTINATION)

a. Water-Oriented
- Swimming (beach)
- Boating (marina)
- Fishing (shore facilities)

b. Land-Oriented
- Picnic
- Field Sports
- Dining
- Observation
- Golfing
- Skiing
- Hunting

c. Water–Land Complex
- Any combination of above

RECREATION MOVEMENT (TRANSITION)

a. Mode of Circulation
- Driving
- Walking
- Riding
- Boating
- Flying
- Bus

b. Rest Nodes
- Dining
- Picnic
- Observation
- Shopping
- Wading
- Sitting
- Strolling

RECREATION LODGING (DEPARTURE)

a. Camping
   Vacation
   Transient
   Back-packer

b. Resort/Vacation
   Home Complex
   Water-oriented
   Land-oriented
   Water-Land complex
   Transient (hotel-motel)

The vulnerability for each cell's ecosystem was determined for each recreation class and ranked from very low to very high on degree of ecological impact. The following example for a vacation home complex compares the vulnerability between each 1/25 km (10 acres) within a high-potential development zone and also compares vulnerability between zones.

VACATION HOME COMPLEX ECOLOGICAL IMPACT

	Suttons Bay (acres)	Fife Lake (acres)	Intermediate Lake (acres)
Degree of Impact			
Very low	21,270	2,620	40
Low	17,390	35,800	27,400
Medium	940	2,590	11,690
High	1,230	220	2,030
Very high	420	20	90

The above data is displayed spatially on computer maps and is available for use by citizens and planners in the Grand Traverse Bay region.

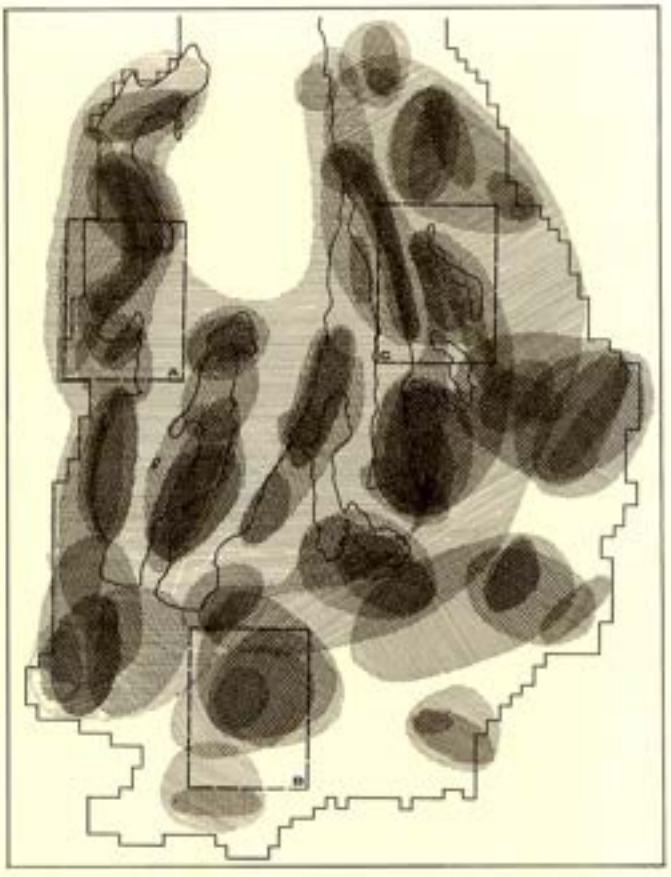


Figure 2

TECHNOLOGY ASSESSMENT

PHYSICOCHEMICAL PROCESSES IN WASTEWATER TREATMENT ALTERNATIVES

Walter J. Weber, Jr.

As national concern over water quality mounts, and as requirements for higher effluent standards become more urgent, so the need for development of advanced methods for treatment of wastewater increases. Conventional biologic treatment of sewage does not provide the quality nor the consistency of treatment necessary to achieve levels of water quality required today. A number of recent investigations, including that carried out under this Sea Grant project during 1971-72, have shown that direct physicochemical treatment by coagulation and adsorption is capable of a higher and more consistent degree of treatment of municipal and industrial wastewaters.

The activated carbon adsorption system represents a significant part of the capital and operating costs involved in physicochemical treatment of wastewater. Active carbon inventory represents the major element of capital cost, and thermal regeneration of carbon the highest operating cost. If the frequency of regeneration can be lowered, considerable savings can result in both operating costs and in costs for replacement of carbon burned or otherwise lost during regeneration.

In this work on biologically-extended physicochemical treatment, biologic activity on active carbon in expanded-bed adsorption (EBA) systems has been observed to decrease the frequency of regeneration required to maintain normal high-level performance. It is believed that the biologic growth on the carbon surface utilizes the organic waste adsorbed on the carbon surface for food, and, in so doing, partially renews the carbon surface for continued adsorption.

There are several possible explanations why active carbon, aided by biologic surface growth, works well in direct wastewater treatment. First, active carbon has a high adsorption affinity for most organic materials in wastewater; and thus functions to remove these wastes from the solution phase. This produces a very high local concentration of organic substrate on the surface of the carbon relative to that in bulk solution phase and provides an enriched substrate environment for growth of microorganisms. The rate of utilization of substrate by microorganisms is increased due to this effective increase in concentration. Further, due to the adsorptive properties of active carbon, organic waste is retained on the carbon, even if it is not immediately utilized by the microorganisms at the surface. This provides sufficient residence time for microorganisms to undergo necessary phenotypic changes in their enzymatic processes to allow them time to use even normally resistant waste as food sources.

This investigation of parameters involved in biologic growth on active carbon in EBA systems has been directed at optimization of this scheme as a waste treatment process; hopefully resulting in a significant reduction in operating costs and in capital investment. Possible cost reductions have been projected, from 8.2 cents per 1000 gallons to 6.8 cents per 1000 gallons. Thus, physicochemical treatment, which provides higher levels of treatment and superior effluent qualities, could become an economically attractive waste treatment alternative as well. Unfortunately, support for this project was terminated by the Office of Sea Grant in June 1973; thus preventing continuation of the work to its logical conclusion. Therefore, the following report covers work only partially completed.

Filtering apparatus

Organisms that develop on the active carbon surface during treatment of organic wastes have been partially identified and characterized. With this information complete, it should be possible to determine the environmental factors that influence the growth of these microorganisms. Dissolved oxygen levels, diet requirements, nutrient requirements, and factors that influence nitrogen oxidation and reduction were under study. If the effects of these environmental parameters are understood, they can be altered to fit the situation, whether the recurrence of shock or transient loads associated with the treatment of highly variable wastes or with toxic materials found in some industrial wastes.

The configuration of the microorganisms on the carbon surface, the surface phenomena associated with the *in situ* biologic regeneration of active carbon, and the mechanisms relating the surface phenomena to the configuration of microorganisms still need to be resolved completely. The surface properties of active carbon, as they relate to the mechanism of biologic regeneration (i.e., pore volume, activity, and particle size), were under study. Postulation

of a mechanism which explains the observed configuration of microorganisms and the surface renewal process was planned.

Corresponding to the mechanism, kinetic relationships were being investigated. Most of the environmental factors, such as dissolved oxygen, nutrient requirements, and dietary needs were being incorporated in the kinetic relationships. The functionality of the kinetic expressions were being procured from consideration of the limiting steps in the mechanism for biologic regeneration.

Once kinetic expressions are obtained, they can be combined into a mass balance on the carbon bed, resulting in a series of partial differential equations. From this a predictive model can be developed for the performance of the biologically active carbon EBA systems. Further, predictive models for oxygen uptake, for nutrient utilization, and for nitrogen oxidation and/or reduction can be derived. These models should be flexible enough to incorporate any adsorption kinetics expressions. Analog computing techniques might be applied to the resulting differential equations and, if necessary, digital computing techniques may also be used.

Once predictive models for biologically extended EBA systems are obtained, one can investigate the effects of time-variant inputs of waste on the effectiveness of the system and determine appropriate operating ranges for parameters such as dissolved oxygen, nutrient requirements, and hydraulic loading. This will effect the optimum *in situ* biologic regeneration of carbon in EBA systems.

The ramifications of shock loading situations on the biologic renewal of the carbon surface were under study, as were the consequences of toxicants, normally biologically resistant material, and nutrient levels on the *in situ* renewal process.

During the span of all of the experimental work, some slight sloughing of sludge from the carbon was noted, and corrective measures were developed. It was intended that the mass balance would include the sludge mass as well as gases generated by biologic activity on the carbon.

Study of the conditions, mechanisms, kinetics, and mathematical modeling involved with nitrogen oxidation and reduction in biologically extended EBA systems was also initiated.

The precise mechanism by which the bioregeneration of active carbon in EBA systems permits the remarkable sorption capacities observed is not known at present. But, on the basis of work completed, a logical preliminary scheme can be formulated.

The primary separation process is the adsorption of organic wastes from solution onto the active carbon surface. This is evidenced by observations on the relative performance of other solid media to active carbon. Crushed anthracite and sand have been tested and found to exhibit considerably less sorptive capacity. Because these media do not produce a high surface concentration of organics, they provide a growth site only for microorganisms that utilize those wastes at a concentration close to the bulk solution concentration. Active carbon, on the other hand, has a high sorption capacity, resulting in a highly enriched substrate environment on the surface. Microorganisms can use this adsorbed organic matter as a food source and thereby free the surface of the carbon for continued adsorption; thus extending the apparent capacity of the active carbon.

Since the organic matter is held on the carbon surface, the effective retention time is lengthened to days or even weeks, thus allowing sufficient time for phenotypic enzymatic adaptation which enables microorganisms to utilize the waste as a food source. Hence, some materials normally considered biologically resistant from a conventional treatment standpoint may be degraded biologically. Another important feature carbon adsorption provides is to allow storage of the waste on the surface when the loading on the EBA system exceeds the biologic demand for substrate. Many investigators have found that active carbon has the ability to adsorb industrial and municipal wastes, in particular, those that have undergone only chemical clarification and primary settling. Thus, the adsorptive properties of active carbon can provide a buffered environment for the growth of microorganisms which would reduce the effects of shock loading situations and fluctuations in waste composition. Toxic substances can also be adsorbed onto the carbon surface. This would prevent the toxic substance from participating on a wide scale in inhibitory metabolic reactions; thus reducing, by a large margin, its toxicity.

Anaerobic regeneration of carbon in EBA systems is evidenced by several phenomena. First, the sludge buildup on the active carbon is not as massive as expected for aerobic systems. Further, the sludge, once removed by vigorous aeration in EBA systems, has the appearance of anaerobic sludge. Second, an oxygen mass balance does not support a hypothesis of aerobic regeneration. This process for the renewal of active carbon is efficient from a treatment standpoint, since the E_h potential is low and the organisms require more substrate to maintain vital functions (Pasteur Effect).

The possibility of the following mechanism can be suggested for *in situ* regeneration of active carbon in EBA systems:

1. Organic matter is removed from solution by the partitioning factor of adsorption, diffusing to the carbon surface through an external boundary film separating the bulk solution and the carbon.

2. The adsorbed organic material undergoes anaerobic degradation on the carbon surface.

3. Anaerobic degradation is not complete, and low molecular weight products, such as organic acids and alcohols, are formed.

4. The low molecular-weight degradation products are not readily held by the carbon because of their inherently low energy for adsorption and,thus,exodiffuse through the external boundary film to the bulk solution.

5. Under anaerobic conditions in the bulk solution, these degradation products diffuse uneffected through a completely anaerobic boundary layer to join other non-adsorbing material in the effluent from the adsorbers, comprising the relatively low-level leakage of TOC through the adsorbers.

6. If oxygen or air is added to the expanded beds of carbon, the solution phase, as well as the outer layer of the boundary film on the carbon, can be maintained in an aerobic state. Thus, as the products of anaerobic degradation at the carbon surface diffuse through the boundary film, they encounter aerobic zones near the outside of this layer.

7. Aerobic microorganisms develop in the outer layers of the boundary film and function to oxidize the outward diffusing products of the anaerobic degradation produced at the surface.

The coagulation step in the physicochemical treatment scheme removes most of the phosphate present in wastewater. Nonetheless, it is anticipated that sufficient supplies of phosphate are carried over to the carbon to enable the microorganisms to carry out energy transfer reactions of the ADP-ATP type.

TECHNOLOGICAL IMPACTS

Raymond A. Yagle

This project continued to reflect and respond to the needs of The University of Michigan Sea Grant Program in the area of technology; primarily in assisting other projects concerned with simulation and gaming model development. More recently, a supporting role to advisory services has been initiated. Those technological developments, about which information was gathered and assessments were made in the previous fiscal year, have been carefully monitored this year, with substantial increase in efficiency of the process. Several areas have been studied in great detail and with regard to a much larger geographical area. These include vacation housing and recreational vehicles; power generation and needs; marine transportation; and other industrial expansion, as manifested by new plant construction.

The case study approach has also proved successful with the completion of a rather comprehensive report on the controversy over the Reserve Mining Company's taconite plant on Lake Superior. This study was accomplished by an extensive library search; the application of some simple economic theory; and a good deal of unbiased, but critical judgment on the part of the investigator and other experts. The chemical, physical, biological, legal, and other aspects of the various claims and counterclaims, advanced at the several hearings to date or recorded elsewhere, were studied. The impacts of this project are negative in nature and somewhat immediate in terms of attempting to determine the justification and desirability of proposed, limited regulatory action.

A second report is in preparation on the extension of the Great Lakes shipping season. For the most part, this study is based on work being done by several current research projects with other sponsorship. Evaluation and presentation of this material will be important in the area of Great Lakes resource management alternatives and to the general thrust of several Sea Grant projects. The impact of this work is more positive and long-range.

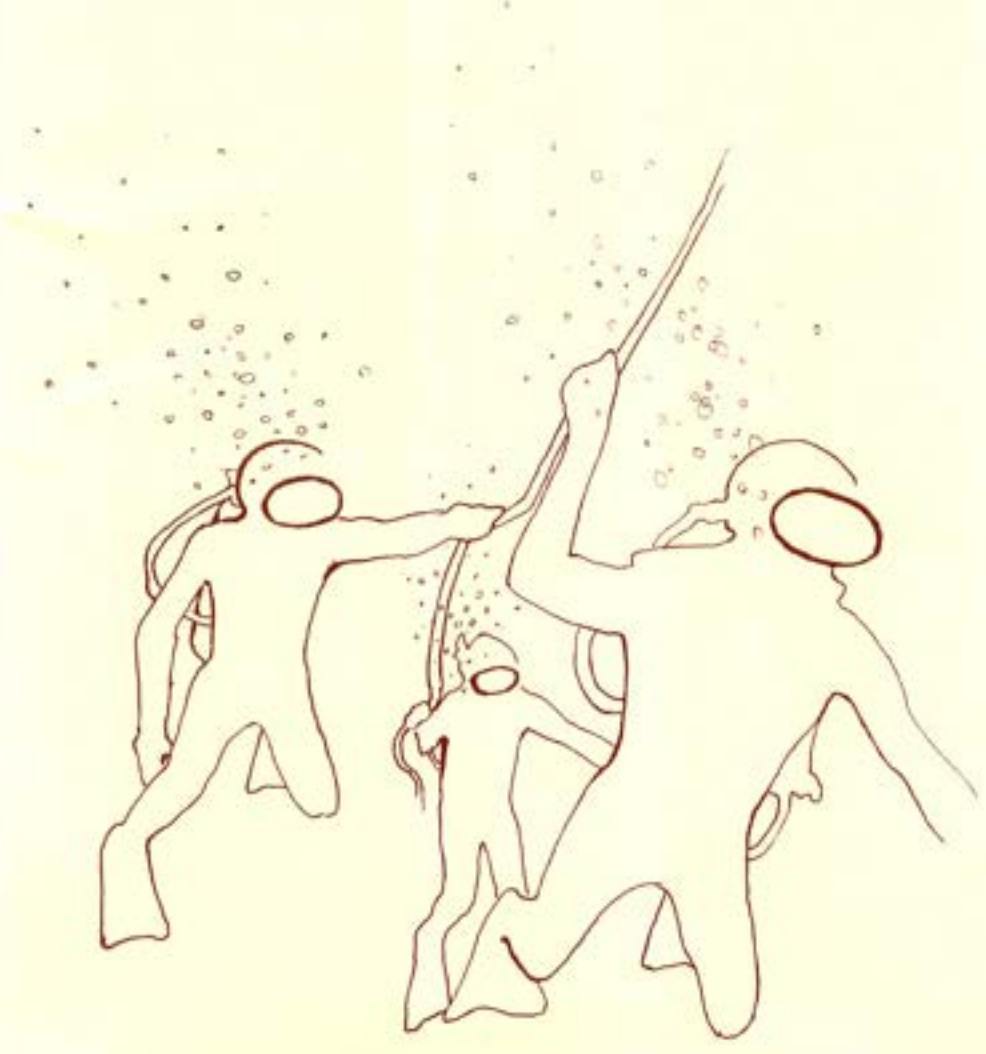
It is apparent that the shipping season, indeed, has been extended, even as the feasibility was established; and the technological, social, and economic impacts of this are sufficiently optimistic. A modified, but essentially year-round navigational season seems certain to evolve for several elements of the system. Significant effects may be found on water quality, recreational development, and coastal zone management. The effects on port requirements, ship design and shipbuilding, and especially other portions of the transportation complex can and, probably, will be extensive and profound. Accordingly, regional highway, rail, and pipeline operations are being examined with greater interest than before. The St. Lawrence Seaway has not been ignored; even though the implications of what has been learned for one system are not as profound or as optimistic for the other system, as may be imagined at first.

While no written report is being prepared on the power generation field, this activity also was handled on a broad, but objective, basis, similar to a case study. The focus had been more on the problems associated with nuclear power

plants (e.g., their siting; their cooling water requirements; and other special safety or environmental considerations, constraints, or demands) as compared with conventional fossil fuel plants. This study provided some background material for the Sea Grant project on the environmental impacts of cooling towers. The advent of the general energy shortage has given new dimension to this study. It has also required that such matters as the location, capacities, and environmental characteristics of oil refineries and of natural gas and coal distribution, storage, and processing, will be addressed in the same manner. The emphasis has remained on the expected effects on the Great Lakes. These include the need to be on the shoreline, and the validity of the reasons stipulated for this; the amount of water use for cooling or other purposes that may be required, and estimation of possible degradation of operational efficiency with lesser demand; the supply aspects and the degree of uncertainty of various transportation schemes; and similar treatment of how the finished product may be distributed. Consideration of these issues will be of importance to several Sea Grant projects.

Several brief studies have dealt with technological problems of modest scope; but with implications so basic and fundamental that they would certainly impact with the management and the future of the Great Lakes to a significant and, thus far, unrealized degree. These included a study of the aggregate shortage within the United States and a study of the concept of lakefront artificial island airports. These led in turn to further study of the disposal of dredge spoils. An examination was made of the disposal relative to the extent and nature of shore erosion processes and the method of controlling shore erosion by filling. The progression continued and it became obvious that the coupling among any collection of technological matters is just as pervasive as that among the technological, social, economic, and political aspects of any single technological matter. This lends credence to the merit of having participants from as many technological disciplines as possible consider any given problem or any proposed problem resolution. It makes clear that a problem can not be dealt with effectively in isolation or as if some predetermined scope was, in fact, a valid, unpenetrable boundary. Because of modest funding, some thought was given to depending entirely on a sort of continuing Delphi exercise in the technological impacts area; despite the shortcomings of the technique documented two years ago by a related Michigan Sea Grant project. This approach has not been implemented to date. Closer association with advisory services in responding to inquiries provides new, potential panel participants, who often suggest appropriate additional questions to be pursued.

UNDERWATER OPERATIONS



UNDERWATER OPERATIONS PROJECT

Lee H. Somers

The Underwater Operations Project provides The University of Michigan and related groups with technical assistance and supervision for underwater research activities. Major objectives of the project are to improve equipment and techniques for use in research diving; to develop research, education, and service aspects of underwater operations activity; and to provide diving services, including personnel and equipment, for other research projects. Over several years of operation the project has developed a relatively complete diving locker including self-contained and surface-supplied diving apparatus, cold water suits, a recompression chamber, air compressors, underwater cameras, and other accessory equipment.

The Underwater Operations Laboratory, established with Sea Grant funds in January 1972, was maintained and expanded during 1972-73. The laboratory's recompression chamber was used for the successful treatment of air embolisms (of sport divers), carbon monoxide poisoning, and gangrene; pressure testing and calibration of oceanographic and diving apparatus; oxygen and nitrogen tolerance tests; and training of diving, engineering, and medical students. The large diving pool, housed in the same building, was improved and is utilized in equipment evaluation and diver training. The laboratory was also used for equipment evaluation and construction.

A new breathing gas control-communication panel for surface-supplied diving operations was designed and constructed by project personnel. This is a second generation gas control panel resulting from construction and evaluation of an earlier model. The unit is designed to provide two surface-supplied divers with air or mixed gas breathing media through a compact gauge-valve system. The panel is easily monitored by a diving supervisor or tender, and the diver may be switched from a primary to a secondary gas supply immediately in the event of primary supply malfunction. The tender may continuously visually monitor the gas supply gauges or rely on an automatic alarm system currently under evaluation for installation in the panel. The unit also includes redundant diver-surface communicators, a timer, and a precision pneumofathometer for continuously monitoring the diver's depth. The compactness and simplicity of this unit make it desirable over several models currently used in commercial and military diving.

The gas panel-communications panel will undergo field evaluation in August 1973. Following successful completion of field tests, a detailed technical report will be prepared with instructions for construction of similar units by other groups.

The project's underwater habitat, LAKELAB, built in the spring of 1972, was placed in Grand Traverse Bay at a depth of approximately 30 feet. Initial operation of LAKELAB included primarily field evaluation of the habitat and support equipment. During 1972-73 a habitat control van was designed and outfitted for 1973-74 operations. This van included an air supply system, work bench, operations center, and storage for project equipment. A large habitat-diver air control panel was designed and constructed to provide central control of habitat and diver air supply. This unit is designed to provide air for any of four sources, two low-pressure and two high-pressure. It has sufficient capacity for continuous habitat ventilation and supply of air to two or more divers simultaneously. The diving supervisor or tender may switch from one source to another immediately in event of an emergency. All activities in the habitat are monitored continuously by radio.

The LAKELAB facilities have been made available to any qualified scientist or research group. These facilities are used extensively in the evaluation of project equipment, training project personnel, and training research divers. Dr. Somers also worked cooperatively in Puerto Rico for one month with the Puerto Rico International Undersee Laboratory Group on habitat engineering problems, habitat operations, and diver training.

The *Research Diver's Manual*, originally published in 1971, was revised and expanded. Wide acceptance of this manual has rapidly depleted supplies and a second printing of the revised edition was required. This manual is currently being used by both sport and university diving classes and as a field manual on many diving operations. A second volume is currently being prepared.

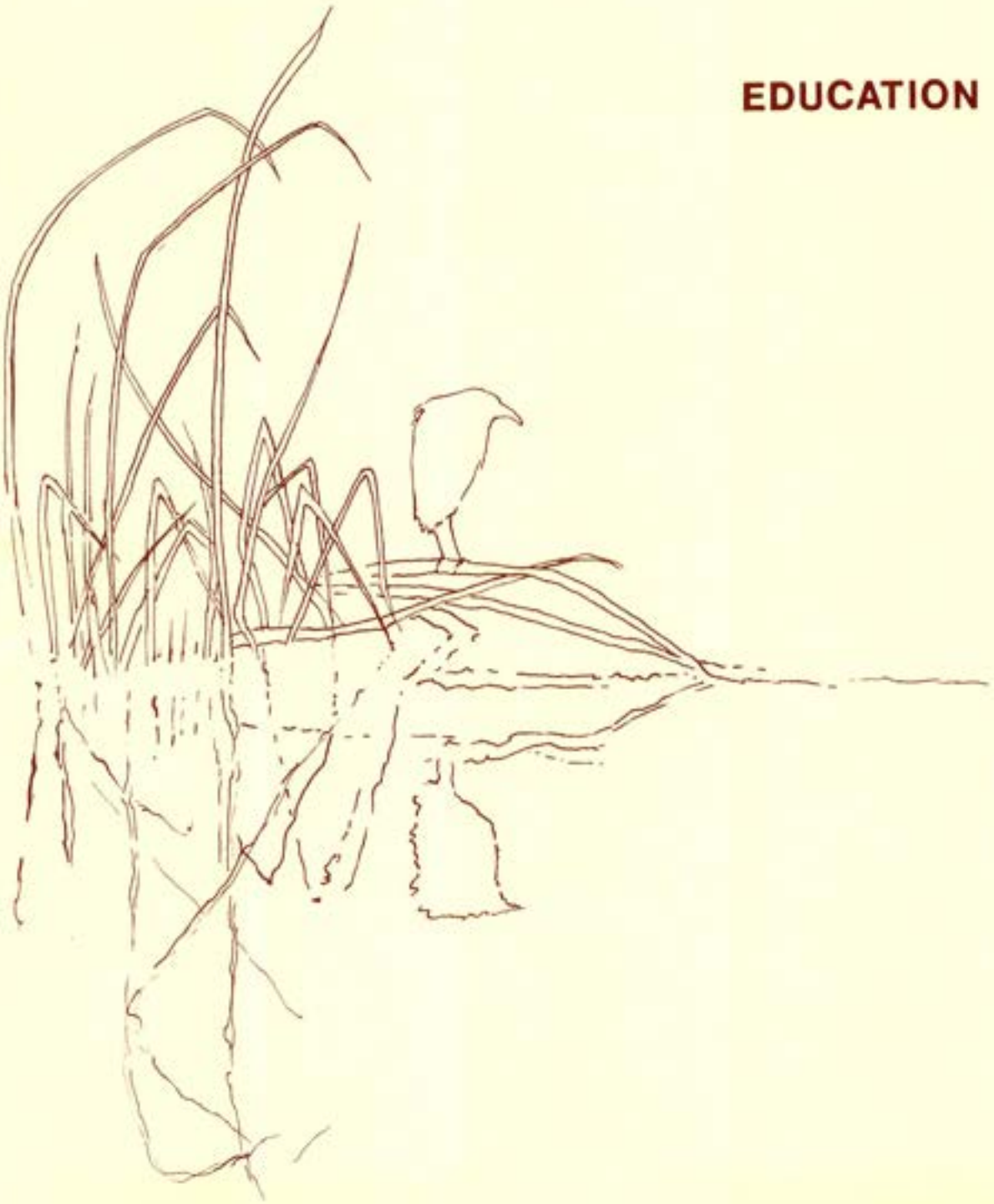
Dr. Somers is active on various local and national committies including, The University of Michigan Diving Safety Committee (chairman); Northern Area YMCA Scuba Committee; National YMCA SCUBA Program Advisory Board

(chairman); National Association of Underwater Instructors (member, Board of Directors), American Association of Health, Physical Education, and Recreation Committee on SCUBA Instruction (chairman); the American National Standards Institute, Z-86 Committee on Diving Equipment Safety Standards (chairman); and the Michigan Department of Natural Resources Aquatic Safety Committee. In addition, Dr. Somers has given approximately twenty public lectures and provided training for medical personnel in the operation of hyperbaric chambers.

Through a broad spectrum of research and educational activities, an insight has been gained into diving safety problems, diving apparatus problems, application of bell diving techniques to scientific research, diver instruction problems and related areas. This insight has established the foundations for proposing an Underwater Technology Research Center at The University of Michigan and seeking funds to continue detailed research in diver safety and education.

The LAKELAB underwater habitat being placed in Grand Traverse Bay.

EDUCATION



EDUCATION

The importance of the education dimension of the Sea Grant Program at The University of Michigan 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 varied departmental and interdepartmental courses directly related to 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 Sea Grant activities have been encouraged and supported by the Sea Grant Program.

Students retrieving plankton net during Oceanography Field Practicum at Woods Hole, Massachusetts.

The Michigan Sea Grant Program supports a course in oceanographic field methods offered at The University of Michigan Biological Station. It is oriented primarily toward undergraduate students, who are completing their sophomore year, and is designed to give them practical experience in basic instrumentation and techniques of oceanography and limnology. It is an opportunity for students to integrate their knowledge of the marine environment through class and individual projects and to better understand shipboard procedures for data collection by spending several days aboard a research vessel.

Again in the summer of 1972, 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.

A seminar course on international environmental policy was taught in the School of Natural Resources and dealt specifically with environmental problems shared by the United States and Canada. Student papers and guest lecturers dealt with a broad range of topics of interest: comparative approaches to natural resource policy and administration; Great Lakes water quality; international energy and water transfer; North American petroleum transportation networks; and international park development.

A general overview of problems in the Great Lakes was presented in a graduate seminar course in the Department of Civil Engineering. This course involved individual research topics and talks by Michigan Sea Grant project directors and outside guest lecturers and covered a variety of issues in resource management in the Great Lakes region.

The Underwater Operations Project supported two advanced training courses for research divers at the LAKELAB facility. These courses, designed for research and technical scientific personnel, included instruction in several areas: advanced scuba diving, surface-supplied diving, habitat diving, underwater work and research techniques, emergency first aid, seamanship, and related subjects. Courses were filled to capacity, and a number of applicants had to be rejected due to lack of space and equipment.

This project also supported a graduate level underwater operations course, which emphasized manned undersea activities and apparatus for use in oceanography and ocean engineering. Several students have participated in special research projects through the Underwater Operations Project. Dr. Somers served on the staff for a field course in the Caribbean and supervised the training of University divers.

A course to train hyperbaric chamber attendants was offered at the Underwater Operations Laboratory in cooperation with physicians at the UofM Medical Center. Students and faculty were trained in hyperbaric chamber operation and in assisting physicians in treatment of diving victims.

In addition to student course work, Sea Grant has encouraged and sponsored seminars by outside speakers on a variety of issues relating to resource problems in the Great Lakes. These seminars have been of interest to individuals in the state who are directly or indirectly involved in the Sea Grant Program at The University of Michigan.

Specific educational activities, designed for the general public, state and local planners, and groups with special interests were conducted through the Advisory Services Program.

Sea Grant Recipients of Advanced Degrees, 1972-73

Bottrell, Thomas (M.S.) – teaching high school science in California. Thesis: "Limnology of the Great Lakes for the Scuba Diver."

Grossas, Francois J. (M.B.A.) – Financial Analyst, Manhattan Bank, France.

Janson, Owen C. (M.S.) – Executive Secretary, Huron River Watershed Council. Thesis: "Natural Areas Legislation in Land Use Context: The Michigan Example."

N'Jock, Josue (M.S.) – continuing studies at The University of Michigan, School of Engineering.

Tolsma, Brant (M.S.) – continuing studies at The University of Michigan, School of Engineering.

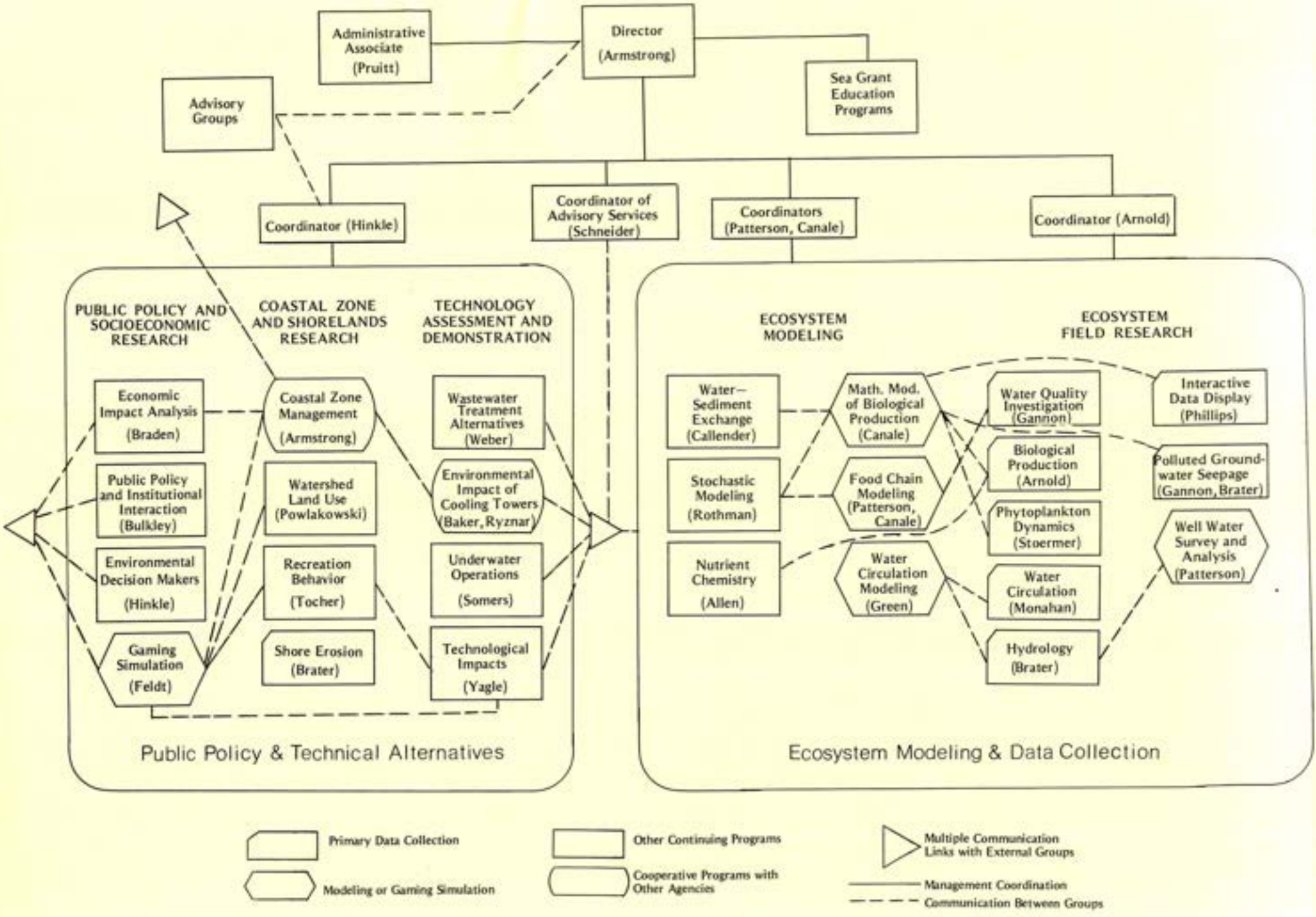
Rajapopal, Rangaswamy (Ph.D.) – Assistant Professor of Fishery and Forestry, University of Washington. Thesis: "Sewage Disposal and Water Supply Alternatives on the Basis of Water Quality and Economic Criteria."

Rossman, Ronald (Ph.D.) – Research Associate, University of Michigan Great Lakes Research Division. Thesis: "Lake Michigan Ferromanganese Nodules."

Smith, Edward B. (Ph.D.) – Numerical Analyst with United Aircraft Corporation. Thesis: "Wind Driven and Seiche Forced Water Motion in Grand Traverse Bay, Michigan."

Sea Grant sponsored advanced training course for research divers.

PROGRAM SUMMARY



Sea Grant Program Functions 1972-73

Sea Grant Program Development

PROGRAM AREA – Year Beginning July	1970	1971	1972
PROGRAM MANAGEMENT ACTIVITIES			
Program Administration and Development (Armstrong)	C	C	C
Information and Advisory Services (Schneider)	C	C	C
Education (Armstrong)	C	C	C
Technical Publications (Schnell, Pruitt)			N
Coastal Zone Feasibility Lab (Armstrong)			N
ECOSYSTEM MODELING			
Mathematical Modeling (Canale)	C	C	C
Resource System Modeling (Patterson)	N	C	C
Interactive Display of Water Research Data (Phillips)			N
Stochastic Modeling (Rothman)		N	C
Control Theory Modeling (Woodring)	C	C	T
UNDERWATER OPERATIONS			
Underwater Operations (Hough, Somers)	C	C	C
ECOSYSTEM PROCESSES AND FIELD RESEARCH			
Nutrient Chemistry (Allen)		N	C
Biological Production (Arnold)	N	C	C
Evaluation of Ferromanganese (Callender)	C	C	T
Water Sediment Interface (Callender)	C	C	C
Water Quality (Gannon)	C	C	C
Nutrient Enrichment and Nutrient Chemistry (Schelske)	C	C	T
Phytoplankton Dynamics (Stoermer)	C	C	C
Biochemistry of the Sheath of Sphaerotilus natans (Bernstein)	T		
Anaerobic Digestion and the Phosphorus Problem (Borchardt)	T		
Measurements of Chemisorption of Organic Pollutants on Sediments (Mark)	T		
Pesticides in Western Lake Erie (Hartung)	T		
Sulfur in the Great Lakes (Mancy)	T		

PROGRAM AREA – Year Beginning July	1970	1971	1972
PHYSICAL MODELING AND FIELD RESEARCH			
Hydrology and Shore Erosion (Brater)	N	C	C
Impact on Lakes and Rivers of Seepage from Polluted Groundwater (Brater)			N
Water Circulation Models (Green)	N	C	C
Water Circulation Measurement (Monahan)	N	C	C
Power Plant Thermal Discharges (Ryznar)			N
PUBLIC POLICY AND INSTITUTIONAL RESEARCH			
Public Policy Project (Bulkley)	C	C	C
Gaming Simulation (Duke, Feldt)		N	C
Decision Making (Michael, Hinkle, Feldt)	C	C	C
Economic Impact Analysis (Root, Braden)	C	C	C
Economic and Institutional Interdependencies in Choosing Water Management Strategies (Luken)	T		
COASTAL ZONE AND SHORELANDS RESEARCH			
Coastal Zone and Shorelands Management (Armstrong)	N	C	C
Shoreline Processes (Brater)	N	T	
Recreation Behavior (Tocher)			N
Watershed Land Use (Polakowski)	C	C	C
TECHNOLOGY ASSESSMENT			
Wastewater Treatment (Weber)	N	C	C
Technological Impacts (Yagle)	N	C	C
Pollutional Effects of Two-stroke Marine Gasoline Engine Exhaust (Weber)	T		
Remote Sensing – Lake Michigan (Polcyn)	C	C	C
Remote Sensing for Water Pollution Detection (Wezernak)	T		
GREAT LAKES TRANSPORTATION			
Intra–Lake Bulk Carrier (Yagle)	C	T	
St. Lawrence Seaway (Adams)	T		
Pollution Control Regulation (Woodward)	T		

N – New Project T – Terminated C – Continued Project

Sea Grant Program Budget 1972-73

Ecosystem Modeling	$ 115,096
Ecosystem Processes and Field Research	231,532
Public Policy and Institutional Research	150,447
Coastal Zone and Shorelands Research	115,165
Technology Assessment	43,112
Underwater Operations	40,000
Information and Advisory Services	107,100
Education	13,417
Program Management	92,031
Program Development	20,000
Field Operations and Support	21,500
Total	$ 949,400

Sea Grant Publications July 1972-June 1973

Grand Traverse Bay: A Time of Choice, 1. Basic Issues, Peter C. Ryner, MICHU-SG-72-101.

Grand Traverse Bay: A Time of Choice, 2. Recreation, Peter C. Ryner, MICHU-SG-72-102.

Sea Grant Program: The University of Michigan, MICHU-SG-72-103.

Water Zoning: The Control of Surface Traffic on Lakes, Streams, Rivers, and Bays, Peter C. Ryner, MICHU-SG-73-101.

Applications of Linear Integer Programming to Problems of Land Use Allocation, R. L. Patterson, MICHU-SG-72-213, TR 31.

A Hydrological Model for Estimating the Inflows To and Outflows From Grand Traverse Bay, E. R. Brater, MICHU-SG-72-214, TR 32.

Oceanography Field Practicum: 1972, Edward C. Monahan and G. Thomas Kaye, MICHU-SG-72-215, TR 33.

The Grand Traverse Bay Sport Fishery: Angular Activity, Revenue, and Economic Impact, James M. Kapetsky and James R. Ryckman, MICHU-SG-73-201, TR 34.

Drogue Measurements of the Circulation in Grand Traverse Bay of Lake Michigan, Edward C. Monahan, G. Thomas Kaye, and Eduardo D. Michelena, MICHU-SG-73-202, TR 35.

The Structure of Management and Planning for the Coastal Zone, John M. Armstrong, MICHU-SG-72-301.

The Dimensions of Coastal Zone Management, John M. Armstrong and Thomas H. Suddath (eds.), MICHU-SG-72-302.

Management and Planning Concepts for the Grand Traverse Bay Shorelands, Coastal Zone and Shoreland Management Project, March 1973.

Coastal Zone and Shoreland Management for Michigan: A Critical Analysis of "A Plan for Michigan's Shorelands" as Prepared by the Water Resources Commission and the Department of Natural Resources, John M. Armstrong and Peter C. Ryner, March 1973.

An Investigation of the Meteorological Impact of Mechanical–Draft Cooling Towers at the Palisades Nuclear Plant, Edward Ryznar and Dennis G. Baker, May 1973.

Meteorological Study of Power Plant Thermal Discharges, Dennis G. Baker and Edward Ryznar, May 1973.

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Raymond A. Yagle	Professor of Naval Architecture and Marine Engineering

Editing, Layout, and Design by Cheryl Bozorgmanesh
Drawings by Marcia Dorr

1101 North University Building
The University of Michigan
Ann Arbor, Michigan 48104