AQUATIC ECOLOGY DIVISION

Accomplishments and Future Directions

National Water Research Institute

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AQUATIC ECOLOGY DIVISION (July 1981)

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RATIONALE

The mandate of Environment Canada is to preserve and to restore environmental quality. Governed by that mandate, its primary objective is to foster harmony between society and the environment for the benefit of present and future generations of Canadians. To achieve this objective the Department undertakes to:

1. Conserve and enhance Canada's renewable resources for sustained economic and social benefit.
2. Protect the environment from the adverse impact of human activities.
3. Facilitate the adaptation of human activities to the environment.
4. Safeguard and foster public understanding and enjoyment of Canada's natural and historic heritage.

Urbanization, industrialization, intensive use of commercial fertilizers in agriculture and long range atmospheric transport of pollutants from Canada and abroad have a profound adverse effect on the overall water quality and ecology of Canadian water resources. One result is excessive growth of algae and aquatic weeds impairing recreational value of lakes and streams, affecting particularly beaches, and causing serious problems in municipal water supplies when used for drinking purposes (off-flavour, toxicity and coloration due to algae and bacterial metabolites, clogging of filters, etc.). Periodic depletion of dissolved oxygen below levels required by fish impair sport and commercial fisheries. All of these problems are caused by excessive nutrient enrichment of water bodies. The quality of lakes and streams is also adversely affected by input of sulphur and nitrous oxides from atmospheric

precipitation (acidification), resulting in low pH values and decrease of lake productivity below optimum level, water corrosiveness, elimination of fish stocks and unsuitability of water for any use. Acid rain adversely affects ecologically sensitive areas of Canadian wetlands with respect to its wildlife component. Hydro and thermal plant developments also have a negative effect if not designed properly.

The Aquatic Ecology Division was formed in 1979 as one of five research divisions of the National Water Research Institute to tackle the above mentioned problems, namely to carry out field and laboratory experimental research on nutrient pathways, availability, dynamics and loading, algal and macrophyte ecology and physiology, lakes and wetlands ecology, paleoenvironmental history, geochemical processes in eutrophic and acid lakes, lake sediments, and on conservation of wetland areas of the Canadian north. In general, it is involved in the solution of the problems associated with environmental degradation of recreational and aesthetic values of Canadian waters.

The Aquatic Ecology Division has a highly qualified staff of 32-36 scientists, researchers and technicians, covering over ten scientific disciplines and areas (see Annex 1). Most of the projects address the high priority areas of the Inland Waters Directorate.

AQUATIC ECOLOGY DIVISION'S OBJECTIVES

Through experimental applied research on representative water bodies in selected areas, to solve the problems of environmental

degradation, mainly eutrophication and acidification. In particular, to advance knowledge in nutrient pathways, availability, dynamics and loading (both open water, nearshore areas and sediment water interface); in algal and macrophyte ecology and physiology; in wetlands ecology; in geochemical processes in eutrophic and acidified lakes; in ecological changes resulting from artificial impoundments. To advance and communicate scientific knowledge for the use of planners, engineers and managers in order to ensure maximum degree of conservation of Canadian water resources and their ecologically acceptable management.

ORGANIZATION, CURRENT ACTIVITIES*

The Aquatic Ecology Division is organized in three multidisciplinary sections (projects):

The Nutrients Pathways Section is concerned with the aquatic cycling of phosphorus, carbon, nitrogen, iron and oxygen. The emphasis is on assaying biologically available phosphorus in the water and sediment; the effect of various nutrients on algal growth using enclosures (limnocorrals) and radioactive and stable isotope techniques; the structure of organic compounds in lake water and their role in the aquatic environment. Current research at NWRI stresses the need for effective water quality standards associated with nutrient loadings and the resulting range of lakes from oligotrophic to hypertrophic. Several experimental sites are used to obtain a better

* For details see 1981/82 Study Forecasts in Appendix 2.

understanding of the complex interrelated processes of nutrient availability and uptake, algal growth, nutrient regeneration, the roles of dissolved and colloidal organic substances, zooplankton grazing, and lake restoration techniques.

The mandate of the Great Lakes Section is to investigate and report on biogeochemical processes in the Great Lakes especially those which affect the trophic status of the Canadian Great Lakes. The major thrust of the research is to understand the mechanisms by which phosphorus is eliminated from the lakes and the methods by which it is regenerated from the sediments. The effect of phosphorus on the amount of organic carbon in a lake and the vertical fluxes of carbon form another major study. Organic carbon, which can cause severe oxygen problems in the lakes, is also being studied.

Over the years, much information on nutrient concentrations in the Great Lakes has been collected. This information, as it relates to the temporal changes in nutrient concentration which have occurred in time, particularly since the introduction of the ban of phosphates in detergents, are presently being organized, with trends being established.

The Ecological Impact Section carries out research on the ecology of Canada's waters with emphasis upon three major areas: 1) acidification, 2) wetlands conservation and 3) macrophyte infestation. In the areas of acidification research, studies on acidification have emphasized changes in lake chemistry and ecology due to human action as evidenced in the sedimentary record. Particular studies include the effect of acidification on organic matter cycling in lakes, the sulfur cycle and the paleolimnology

with emphasis upon biota that indicate the acid status of lakes including ostracodes and diatoms. Another study being carried out is on the release of nutrients and metals of ecological importance from lake sediments by acidification. Supporting studies include lead-210 chronology and new statistical methods of data analysis. The major wetlands study has been of the ecology of the Hudson/James Bay coast of Ontario with emphasis upon salt marshes. In addition, sediment contaminant studies have been carried out on Second Marsh on the Lake Ontario shoreline.

Macrophyte studies are focussed on Myriophyllum spicatum (Eurasian watermilfoil) and other aquatic weed infestations of major Canadian water bodies, which adversely affect recreational activities and the tourist industry. The research is concentrated on the long-term impact of macrophyte harvesting, the physiological responses of aquatic weeds to mechanical and chemical control, and the survival and spreading of exotic aquatic plants in Canada.

MAJOR ACCOMPLISHMENTS IN THE PAST DECADE (1970-1980)

Aquatic Ecology Division staff have made a number of original discoveries and break-through findings in the past decade, which have had a significant impact on federal and provincial policy making and water management strategies and implications. The following is a list of the ones that are most significant.

1. Nutrient Pathways

- Developed the model most widely cited in recent text books for phosphate movements between the biologically important forms in lakewaters.
- Improved the method for primary production measurements; currently this seems to be the generally accepted method.
- Conducted a series of radiotracer (^{32}P, ^{14}C) experiments in lake enclosures with different levels of phosphate and nitrate loading. This illustrated the role of phosphate exchange with the sediments as well as net internal loading of phosphate from the sediments.
- Turnover time values in lakes like Lake Erie and Ontario were compared to smaller lakes. The importance of physical processes in the large lakes seemed to reduce the demand for phosphate, and at the same time, it seemed that for lakes of a similar trophic state that the large lakes had fewer bacteria than small lakes.
- Iron was shown to be an important trace metal that occasionally does regulate algal growth. Generally there are adequate quantitites of iron in the water to sustain microbial growth; however, most of the iron is not in a form available to algal utilization. The algae excrete strong chelators of iron that make iron available and the chelators can also act as antibiotics. The enrichment of a lake with available iron could be expected occasionally to stimulate algal productivity.
- The distribution of organic compounds from a pulp mill effluent in the adjacent receiving waters and sediments was determined. The persistence of dehydroabietic acid in the sediments was estimated.

- 7-Ketodehydroabietic acid was identified for the first time as an aquatic pollutant.
- Estimates of methane production and oxidation rates were made indirectly from methane concentration profiles.
- A ^{15}N stable isotope technique was developed using emission spectrophotometry to rapidly measure aquatic nitrogen reactions. This has been widely used both by D.O.E. personnel and by neighboring universities.
- Nitrogen fixation by Aphanizomenon flos-aquae was studied. Temporal variability of rates was very high, moderate ammonium concentrations were not inhibitory, the C_2H_2:N_2 ratio was about 6 ± 1, and high oxygen concentrations may inhibit nitrogen fixation by this alga.
- Phenomena of algal bloom collapses in eutrophic prairie lakes and their ecological impact (summer fish kills) was investigated, its mechanism described and predictive model was developed.
- Factors controlling winter anoxia in prairie lakes (winter kill) were identified and predictive models developed.
- Identification and description of bioavailable forms of phosphorus in lake sediments was made for the first time. Methods were developed for splitting sediment P into apatite-P, organic P and non-apatite inorganic P (NAIP); the latter was highly correlated with bio-available P.
- The formation and stability of diagenetic phosphate minerals have been studied and their role in regulating the P concentrations in both the pore waters and the hypolimnatic waters assessed.
- The Mossbauer-based available P program, after five years of concentrated effort, has placed the interactions of amorphous iron

compounds, and in particular, of the phosphate-binding forms, on a quantitative basis.

- Demonstration that colloidal organic fibrils were the major natural adhesive of microbial associations in lake waters.
- First survey of Canadian lakes for distribution of colloidal organic fibrils.
- Development of a procedure for isolating colloidal organic fibrils from lake water for future assay work on binding of trace materials.
- A controversial chlorophyll extraction procedure was modified which has distinct advantages over the standard 90% acetone procedure.
- First to suggest that bacteria and algal biomass estimates (ATP) may be obtained from size fractionation using Nuclepore filters.

2. Great Lakes Processes

- Project Hypo. This study quantified the release of nutrients from the sediments with the onset of anoxia in the Central Basin of Lake Erie. It demonstrated that the internal loading of phosphorus was greater than the external loading during the summer period. The study recommended that the external loads of phosphorus be diminished substantially so as to reduce the anoxia and thus the current internal regeneration. Based on this study, the Great Lakes Water Quality Agreement was then formulated and signed in 1972.
- Invented the <u>in situ</u> settling velocity chamber.
- Outlined the basic mathematics and physics operating on sediment traps.

- Experiments using sediment traps and radiotracer phosphorus in artificial enclosures showed the importance of phosphorus regeneration under oxic conditions in the eutrophic Bay of Quinte.
- Experiments on primary production, decomposition, and algal biomass in enriched enclosures demonstrated that primary production could be related to biomass changes only if decomposition were taken into account.
- Challenge to the conventional idea that Lake Erie's oxygen depletion became much worse since 1930 due to cultural eutrophication. This alerted water quality managers to the fact that the effect (on oxygen) of phosphorus removal programs may be less than clear cut. It was suggested that hypolimnion O_2 depends mainly on both lake depth and trophic state.
- The quantitative history of oxygen in Central Lake Erie's bottom water was the first serious study of the entire relevant data base. The study showed a trend towards increasing depletion rate of dissolved oxygen in successive summers.
- Long-term trends in P concentrations in the Great Lakes were established.
- Intensive studies were conducted on primary production, Chlorophyll *a* distribution, and nutrient/productivity interrelationships on Lakes Ontario, Erie and Huron, allowing a better assessment of the trophic status of the Great Lakes. These studies were carried out on improved methods of Chlorophyll measurements including problems inherent with *in situ* fluorometric measurements.

- Mass balance estimates for sulfur and trace metals have been prepared for Lake Erie. Also, the diagenesis of sulfur in the Great Lakes sediments has been studied intensively.
- Completed studies on modern and historical trace metal pollution in Sudbury area lakes, Lake Erie, Toronto and Hamilton Harbours; particulate and dissolved trace metals in Lake Ontario.
- It was shown that humic matter in Great Lakes sediments is primarily carbohydrate in character. This is true for all fractions of humic matter. Aromatic character is negligible, even for humic matter buried up to 400 yrs.
- First use of lipids as biological markers in Great Lakes sediments.
- The taxonomy of freshwater ostracodes and mollusca of Canada was compiled and/or published.
- Autecological data for shelled invertebrates.
- The presence of periodic anoxia in the Central Basin of Lake Erie prior to 1850 was established using paleoenvironmental techniques.

3. Environmental Impact

a) Geochemistry, Acid Lakes

- It was demonstrated that isotope ratio measurements can provide important clues on the sources and behavior of pollutant sulfur and nitrogen compounds in the aquatic environment. Variations in the

isotopic composition have also been used to delineate the principal pathways of carbon flux.

- Decomposition and the influence of acid rains on the chemistry of pollutant metals in lakes around Sudbury was described.
- Biological markers to study the effects of lake acidification on the organic carbon cycle in Precambrian Shield lakes were used.
- Development of a practical statistical procedure for the estimation of the point of change in a segmented regression model.

b) Aquatic Weeds

- Evaluated the relationship of sediment nutrients to macrophyte nutrient content and the effect of macrophyte growth on sediment nutrient concentration.
- Studies on the chemistry of subarctic acidic wetlands conducted with emphasis upon water chemistry and long-range transport of atmospheric pollutants, mainly heavy metals. Improved methods of plant and peat trace metal chemistry were developed.
- Intensive research was carried out on the Ontario shoreline of James and Hudson Bay in relation to salt marsh ecology. This work has produced a better understanding of the Hudson Bay Lowland's ecology, a major migratory bird habitat.

FUTURE DIRECTIONS

The new title for the Division, Aquatic Ecology, implies its broad multidisciplinary scope with strong emphasis on biological aspects. This has not been the case in the past, when, due to the division of responsibilities with Great Lakes Biolimnology Laboratory (DFO), Aquatic Ecology Division research was biased towards geochemical and chemical-limnological processes, and primarily to the Great Lakes. Present "inherited" staff composition reflects this situation. It is the intention of the new management to rectify this and 1) ensure appropriate adjustments and/or shifts for existing disciplines, 2) re-staff vacant positions with ecological disciplines, and possibly 3) expand into new areas if additional person-years become available.

Aquatic Ecology research in the next five years will be carried out in the following areas:

- Nutrient pathways research, with particular emphasis on phosphorus bioavailability, nutrient deficiency and/or luxury uptake, interaction of nutrients with the growth of phytoplankton. Expansion to include the regenerative processes of zooplankton and microzooplankton grazing and bacterial decomposition and nutrient regeneration.
- Effect of toxic contaminants on nutrient flow, and vice versa, influence of toxicants on nutrient regime should be studied closely. This would involve a close collaboration with Environmental Contaminants Division, namely on the Great Lakes where discrepancies in level of contaminants and trophic state are visible (Lake Erie vs Lake Ontario).

- Manipulation of nutrient regime and nutrient ratios to influence phytoplankton community composition and quality.
- Unaccountable disappearance of phosphorus from some water bodies (including some Great Lakes) has to be resolved in view of possible co-precipitation with marl and/or suspended sediments adsorption.
- Economical lake restoration methods in lakes where no other corrective methods are feasible should be developed.
- More emphasis should be given to the various forms of nitrogen and its role in the aquatic environment using ^{15}N analytical approaches with the use of liquid and gas chromatography. This will help to revise conventional attitudes to N-removal from sewage effluent, which may be unnecessary in many instances.
- Mossbauer studies on $Fe(OH)_3$-adsorbed P and chemically derived NAIP should be completed within the next two years. This will be followed by a gradual shift to chemical-fractionation methods for determination of bio-available P-forms, with special emphasis on the Great Lakes.
- Redirections will be made to study nutrient availability in nearshore areas of the Great Lakes, and possibilities on chemical treatment of small bodies of water (chemical lake restoration techniques).
- Fibril research to continue. Emphasis will shift to assays for ascertaining which substances (heavy metals, toxic organics, PO_4, etc.), are bound to fibrils and how the binding affects their bioavailability.

- Shift to microbiological studies focussed on the physiological activity of bacteria (decomposition of organics, nutrient regeneration.
- In the Great Lakes processes research, the emphasis will be on Lake Ontario and Erie, the Niagara River plume and particularly nearshore areas and embayments. The overall objective will be better understanding of nearshore-offshore differences with application to water quality management, and to internal nutrient loading and its possible control.
- Continuation of investigations on sedimentation and movements of particular nutrients and contaminants in relation to the productivity cycle in Lake Ontario.
- Completion of a new O_2 profiling system and its field application.
- Develop a federal view on nearshore water quality of beaches and small harbours on the Great Lakes (relative to recommendation of the PLUARG report).
- Develop an intensive and cooperative relationship with federal-regional, provincial, and state (U.S.) agencies.
- Complete monographs on Lake Erie and Great Lakes Water Quality Atlas.
- Continue work on long-term trophic conditions and trends in the Great Lakes, in both the historic and geological sense.
- Continue work on resuspension of sediments in the Great Lakes, properties of nepheloid layer, lake bottom observations and effects on P-fluxes.
- Continue work on settling velocities of particulate P and organic C using sedimentation traps and chemical profiling data.

- Continue time-trend analyses of P in Lake Erie and Lake Ontario.
- Initiate benthological studies of the Lower Great Lakes to estimate benthic production, species composition and response of benthic community to changes in trophic level and environmental contamination.
- Continue indepth study on the geochemical cycles of metals in the Great Lakes and small lakes affected by acid rain. Establish longterm effect of metal enrichment, atmospheric transport and pH fluctuations.
- Continue Sediment Bank sampling.
- Investigate microbiological degradation of organic matter in various types of sediments. Concentrate on organic compounds of pore water. Modelling of microbially mediated diagenesis of organic matter. Relate this diagenesis to natural and anthropogenic agents of ecological change.
- Investigate the formation of humic matter in aquatic environments, including metal-humic interactions.
- Continue investigation of paleoenvironmental changes in Great Lakes using fossils.
- Research will continue in the area of acid rain with particular emphasis on the sediment chemistry and its interactions with interstitial waters.
- The statistical research will be concerned primarily with methods appropriate to the data gathering activities. As the role of statistics in environmental sciences becomes recognized by non-statisticians, statistical principles will be applied in the setting of standards.
- Studies of historical linkage between the SO_x and NO_x emissions and the development of acid stresses in limnetic environments.

- Impacts of acid rains on the cycling of trace and nutrients metals in freshwater environments.
- Improved baseline information on ecosystems susceptible to pollutant inputs.
- Microcosm research aimed at a) providing the rate data and b) predicting the response of ecosystems to specific pollutant loads.
- Field work will continue on ecology of peatlands (acidic wetlands). This will emphasize productivity, role of benthic fauna, and human inputs related to LRTAP.
- Wetlands of Canada book will be completed.
- Begin research on littoral ecology in southern Ontario wetlands and stream ecology research.
- Separate natural acidification from cultural.
- Complete evaluation of present and new control technologies for aquatic weeds.
- Assess role of aquatic macrophytes in acid lakes and impact of acid rain on macrophytes.
- Begin Cladophora research in Great Lakes.
- Continue research on littoral zone nutrient dynamics (sediment macrophyte interactions).
- Aquatic macrophyte ecological requirements of nuisance species in Canada.
- Impact of nuisance growth on nutrient chemistry and water quality, i.e., internal loading of lakes.
- Climatic interactions with macrophyte populations.

- Obtain autecological data to support the LRTAP program.
- Continue research in the use of autecological data of diatoms to decipher the use of diatoms as sensitive indicators of the effects of acid rain on aquatic systems.
- Research on the effects of climatic variability on water quality through time.

EXPANSION PROJECTIONS

1. Disciplines, Human resources

There is an acute need to supplement present disciplinary distribution by scientists/researchers with biological-ecological background. The most visible need is in algal taxonomy and zooplankton population dynamics areas, to cover food-chain and grazing aspects of ecological studies. Also, present professional to technical ratio is too high. An algal physiologist with background in algal cultures would also be very useful, as we now miss the link between the laboratory and field. In view of future trends in alternative energy resources developments, reservoir ecology and ecology of ecosystems affected by thermal effluents should become AED's expertise also, extended to the impact of peat burning for energy generation in northern areas. Electron microscopy (with the proper equipment) must remain one of the key scientific technologies in ecological research. Joint studies with other federal and provincial organizations should be encouraged to bridge disciplinary gaps. Admission

of post-doctoral fellows and visiting scientists from other organizations/universities should also be encouraged.

2. Sites

As a national organization, NWRI should be involved to some extent in research in all IWD Regions. Due to budgetary constraints, we do not anticipate any substantial increase in existing experimental sites besides the recent expansion to Quebec (macrophyte program). Short-term secondments of scientists to work in Pacific and Yukon, and Western and Northern IWD Regions should be encouraged (in cooperation with regional NWRI detachments).

3. Funding

We are realistic enough not to expect any substantial increases in funding due to the permanent restraint policy of the DOE. Present funding represents the operational minimum and any further decrease would paralyze operational capability of the Division. However, reasonable gradual increases in the A-base funding will be sought, as well as other funding routes (GLWQA, LRTAP, Aquatic weeds). Possibilities of cost-sharing joint programs with other agencies will be explored.

RELEVANCE AND LINKAGES

All AED's studies are integrated parts of the ECS Water Management Research Program and link with the Great Lakes Water Quality Agreement (Eutrophication Sub-group, Great Lakes Working Group), activities of the International Joint Commission, IWD Ontario Region and the Province of Ontario (Great Lakes Section and most of Nutrient Pathways Section projects). Macrophyte studies relate to IWD Policy Committee on Aquatic Weeds Control and closer interlink with activities of Parks Canada and Provinces of Ontario, Quebec and British Columbia. Acidification studies are part of the LRTAP Program and the wetlands ecology studies are linked to the Canadian Wildlife Service, Canadian Forestry Service and the Lands Directorate. Paleoenvironmental studies relate to the Canadian Climate Program.

Annex 1

Aquatic Ecology Division Expertise:

General: Limnology
Chemical limnology, nutrient chemistry, hydrochemistry
Sedimentology, sediment chemistry
Geochemistry (inorganic and organic biogeochemistry)
Paleolimnology (malacology, ostracodology)
Macrophyte physiology and ecology
Algal physiology and ecology
Microbial ecology
Electron microscopy
Mossbauer spectroscopy

Specific areas of research: Nutrient uptake kinetics
Liquid scintillation counting
Nitrogen fixation and denitrification
Spectrophotometry - auto analyzer
Atomic absorption spectrophotometry
Gel chromatography
U.V. oxidation of organics
Primary production
Light measurements
Biomass measurements
Natural organic compounds measurements
Enclosure experiments
^{15}N analysis by optical emission

Annex 2

AQUATIC ECOLOGY DIVISION
STUDY FORECASTS - 1981/82

ECOLOGICAL IMPACT SECTION

Study No.	Study Leader	Study Title
406	L.D. Delorme	Taxonomy, Ecology, Paleolimnology of Freshwater Ostracodes.
407	S.R. Esterby	Inference about Change in a Sequence of Variables.
408	S.R. Esterby	Statistical Analyses of Paleoecological Data.
409	S.R. Esterby	Statistical Analyses of Surveillance Data.
410	R.A. Bourbonniere	Effect of Lake Acidification on Cycling of Organic Matter in Precambrian Shield Lakes.
411	H.K.T. Wong/ J.O. Nriagu	Pb-210 Geochronolgy of Softwater Lakes.
412	J.O. Nriagu	Assessment of the Isotopic Composition of Pollutant Sulfur in Softwater Lakes of Algonquin Provincial Park, Ontario.
413	N. Arafat	Impact of Acid Rain on Nutrient and Metal Chemistry of Lake Sediments.
414	W.A. Glooschenko	Hudson/James Bay Coastal Ecology.
415	W.A. Glooschenko	Wetlands Ecology Book.
416	W.A. Glooschenko	Ecological Significance of Acidic Wetlands.
417	W.A. Glooschenko	Impact of Human Activities on Second Marsh.
418	L.D. Delorme	Paleolimnology of Acid Susceptible Lakes.
419	R.A. Bourbonniere/ J.O. Nriagu	Biogeochemical Processes in Great Lakes Sediments and their Relation to Paleoenvironmental Changes.

Study No.	Study Leader	Study Title
477A	S. Painter	Long-Term Impact of Harvesting Milfoil.
477B	S. Painter	Environmental Impact and Efficacy of Chemical Control Techniques for Milfoil Control.
477C	S. Painter	Aquatic Macrophyte Response to a Contaminated Stream.
477D	S. Painter	Acid Rain- Aquatic Macrophytes Relationships.
477E	R. Carignan	The Impact of Aquatic Macrophytes on Sediment Geochemistry.
477F (GLWQA 1320)	R.A. Bourbonniere	Sediment Bank - Great Lakes.

GREAT LAKES SECTION

420	F. Rosa	Trend Analysis of Phosphorus Concentrations in Lake Erie from 1970 to 1980, and the Dependence of Phosphorus Concentration on Settling and Resuspension in the West Basin.
421	F. Rosa	The Settling of Particulate Carbon and Phosphorus Together with Associated Contaminants in Lake Ontario (Niagara Region) and Spatial-Temporal Trends of Nutrients in Lake Ontario.
422	N.M. Burns	Lake Erie: Past, Present and Future.
423	L.L. Kalas	Shelled Macroinvertebrates as Indicators of Environmental Change.
424	H.F.H. Dobson	Lake Ontario Water Chemistry Atlas.
425	M.N. Charlton	Sedimentation and Decomposition of Material Loaded in Lake Ontario.
426	M.N. Charlton	Organic Material Production and Decomposition (Lake Erie).

Study No.	Study Leader	Study Title
427	M.N. Charlton	Development of an Oxygen Profiling System.
428	R.G. Sandilands	
451	W. Booth	

NUTRIENT PATHWAYS SECTION

430	P.G. Manning	Bioavailability of Phosphorus in Surficial Lake Sediments.
431	B.G. Brownlee	Aquatic Nitrogen Cycle.
432	B.G. Brownlee	Assimilation of Organic Compounds in a Polluted Stream.
433	B.K. Burnison	Bioavailability of Phosphorus in Lake Water.
434	B.K. Burnison	Function of High Molecular Weight "DOC" in Lake Water.
436	G.G. Leppard	Physiological Impact of Organic Fibrillar Colloids in Lake Water.
437	T.P. Murphy	Chelate Antibiosis.
438	D.R.S. Lean	Lake Ecosystem Nutrient Process Investigations.
439	D.R.S. Lean	Lake Restoration by Hypolimnetic Aeration.