

EFFECTS OF ATMOSPHERIC ACID DEPOSITION
ON WATERSHED/LAKE ECOSYSTEMS OF ISLE ROYALE
AND MICHIGAN'S UPPER PENINSULA

Robert Stottlemeyer
Department of Biological Sciences
Michigan Technological University
Houghton, MI 49931

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Contributors were

Darcy Rutkowski
David Hanson, Jr.

Introduction

There are five major objectives within the National Acid Precipitation Assessment Program (NAPAP) relating to the question of deposition effects on aquatic systems. Three of these relate to the ongoing study of Isle Royale and the Upper Peninsula of Michigan. They are as follows:

What is the extent of "sensitive" and "acidic" lakes, streams, groundwaters, and wetlands in the United States.

What factors control the susceptibility of surface and groundwaters to acidic deposition and how can these factors be used to predict future aquatic acidification or recovery under different deposition rates.

What are the relationships between surface water acidification and biological processes, biological populations, and aquatic communities, and how can these relationships be used to predict ecological changes.

In addition within NAPAP's Terrestrial Effects Program there are four additional major objectives of which three have a direct bearing on national parks, and are considered objectives for the ongoing Isle Royale/Upper Peninsula research. These are the following:

Does acidic deposition affect the structure and function of watersheds and the resulting outputs to aquatic systems.

Are soils affected by acidic deposition and, if so, what is the degree of current and expected damage.

Does acidic deposition affect forest productivity and, if so, what is the degree of current and expected damage.

The National Park Service's obligation within Interior's NAPAP commitments is 1) to conduct acid rain monitoring and research activities to develop a sound technical basis for management decisions on cultural resources, land and water management, 2) provide the basis for remedying adverse impacts of acid deposition on NPS resources, and 3) carry out research and meet deadlines as established by appropriate Task Groups within the National Acid Precipitation Assessment Program.

To this end in February 1984 Project Descriptors were prepared for the four NPS watershed ecosystem effects

studies underway. The deliverables for the Isle Royale/Upper Peninsula studies are as follows:

Snowpack dynamics and nutrient content in small watershed ecosystems of the Lake Superior Basin.

Input/output mineral and nutrient budgets for moderately buffered and "sensitive" lake/watershed ecosystems.

Comparison of anion mobility in boreal forest and northern hardwood forests of Isle Royale National Park.

Primary productivity and standing crop in sensitive and less sensitive lakes, Isle Royale National Park and Michigan's Upper Peninsula.

This report first summarizes progress made during 1985 on the Core Requirements. The Core Requirements are those revised and drafted at SEKI in January 1986 (Appendix A). The core requirements that have been completed (see last year's progress report and Appendix B herein) are not repeated here. Only those on which there was work initiated during 1985 or otherwise have yet to be completed are addressed here. Where appropriate some indication of methodology, data sets generated (frequency and intensity), and future plans are provided. This section is followed by a discussion of research progress in 1985 on additional topics including some indication of funding source, whether the project is continuing or completed, and future plans for it. This section is followed by a listing of present leverage projects which relate in some manner to the objectives of this NAPAP project. Finally, there is a listing of publications produced this year which directly relate to this research program.

Status of Core Requirements

II(1a). Location of NADP collector at each site standardized with bulk collectors.

NADP station M97, operated during period of ISRO occupation (May - October) since 1980, is now located in Wallace Lake Watershed which is co-terminus with Sumner Watershed. The station began operation in June 1985. Data are collected according to NADP protocol. Bulk collectors are used during winter and are collected monthly January - April. During fall access is impossible. Bulk collectors are still used at sensitive Trout Lake, on the Upper Peninsula. These are collected every two weeks during summer, monthly during

winter. Both the ISRO site and the Trout Lake site are equipped with a continuous recording raingage.

We have ran several correlations of chemistry quality for bulk versus event precipitation samples collected during the winter season, and find very good agreements during presence of snowpack. We also have split NADP samples from station M99 for four years now comparing CAL results to those from our lab. Also we operate an event collector at Pictured Rocks following the NADP protocol. The NADP station M99 is 60 km from Trout Lake, the Pictured Rocks event station is 110 km.

Field and laboratory data are kept updated on both laboratory micro and university mainframe files.

Future plans are to complete instrumentation of Trout Lake site this spring using event collector provided by state grant with samples analyzed in our laboratory. NADP protocol will be used except that cations will continue to be analyzed by IC methods rather than AA. The automated weather station there will also be completed this spring.

II(2). Dry Deposition.

We have not addressed this issue. Unfortunately, there are very few data in this region which can be indexed for our use. We are attempting, with the assistance of the Air Quality Division and MWRO, to place filter samplers on ISRO using existing technology. Should this take place the filters would probably be analyzed in our laboratory which has the accepted methodology.

II(3). Meteorology. A standardized method of data collection involving an automatic recording weather station and data logger will be at each site.

Trout Lake needs some additional channels of information (radiation, wind speed and direction) which will be installed this spring. Channels will cover those meteorologic variables commonly used in evapotranspiration computations and models. We have not yet discussed the possibility of using additional channels for canopy sensing or sensing above standard meteorologic instrument heights.

Data collection frequency is as follows: precipitation - hourly, relative humidity and temperature - mean daily and max/min, solar radiation - hourly incident, wind speed and direction - hourly sector and magnitude. Data are downloaded to microcomputer and maintained on micro and mainframe files.

II(4) Vegetation Productivity and Phenology.

Most components of this have been completed (see Appendix B). However, we feel some additional research would provide more complete data on plant nutrient cycling. This should be done to take advantage of the existing vegetation plot data set. To complete this data set we will expand the number of litter fall collectors to include additional major species or forest types. This sampling will run for a period of two years. Also we will assess the contribution of dead wood (by size class) using transects and small paint marks adjacent the permanent plots. This will be initiated this summer and run the duration of this project.

Data files for this type of information have already been formatted to accommodate our existing biomass data sets. As is the case for all laboratory data sets they presently exist as hard copy and on micro computer. By this summer an additional backup of all will be on mainframe files.

II(5). Soils.

b. Soils maps will be produced for each study site. This we have not attempted with the present budget (Appendix B). Soil pits and horizon samples have been taken immediately adjacent all permanent vegetation plots and lysimeter plots. These have been fully analyzed except for buffer curves. The level of sampling required to meaningfully map soils in these three glaciated drainages is probably beyond present funding. A soils map of ISRO in toto was to be funded this year, but was dropped due to budget cuts. It is felt at this time that higher priority should be put on other study aspects such as some additional lysimeter work to better assess soil acidification properties. The soils information we now have is summarized in the 1984 progress report and a thesis. Two journal publications on the anion mobility results are in the works. Based upon their outcome and the results of the upcoming lysimeter work we may then justify doing the additional soils mapping. In the interim funding for the map of the entire park could become available eliminating use of NAPAP funds for additional watershed mapping.

c. Laboratory buffer curves. These will be done this summer in conjunction with the planned additional lysimeter research.

II(6). Surface waters.

b. Describe sources and drainage area. We have yet to complete the survey for organic debris in streams and a survey of riparian vegetation. This may be addressed this summer, but unless it can be tied into a study which will make further use of the data it will be put off until another year.

Also we feel it is important to get at least one full year's data on diurnal temperature changes in our streams. We have some partial data sets, partial due to equipment failure. Thermocouples will be used this year with the stage height data loggers.

d. Establish stream discharge records at appropriate locations for basin output analysis.

Trout Lake does not have any perennial input or output streams. Ephemeral streams are monitored on two-week basis during period of flow. These mostly are small input streams. Isle Royale sites are sampled weekly from mid April to mid November. Thereafter on a monthly basis from January to April. We sample a small first-order watershed on the mainland on a weekly basis year-round to use as a reference in detect winter season changes which might be more frequent than monthly sampling on the experimental watersheds would detect.

All usual computations, as input/output ratios, relationships between discharge and concentration, are done on data sets generally updated on an annual basis.

II(7). Critical measurements that cannot be funded under current program authorization.

See Appendix A.

Research Progress

In addition to the above core studies we are attempting to address the following NAPAP questions and objectives through ongoing and planned research:

Aquatic:

1. Acidification of a few lakes in the upper midwest is likely and probably due to acidic deposition.
2. Episodic acidification events may be more important than long-term chronic acidification in some aquatic systems.
3. There is need to evaluate historical trends in surface water alkalinity by coring lake sediments, analyzing historical chemistry, and use of biotic indicators.
4. Monitoring alkalinity and other chemical and biological parameters in representative waters throughout the US is necessary to follow future trends.

5. Bedrock, soils, hydrologic characteristics, vegetation, and climate can all affect ecosystem susceptibility.

6. Current aquatic models require significant testing and improvement to allow reliable predictions of changes in water quality as affected by acidic deposition.

Terrestrial:

1. Does acidic deposition affect the structure and function of watersheds and the resulting outputs to aquatic systems. Response to acidic inputs varies dramatically depending on vegetation, soil, bedrock, and hydrologic characteristics. Alterations in sulfur dynamics may impact nutrient availability and resulting water quality.

2. Are soils affected by acidic deposition and, if so, what is the degree of current and expected damage. Base cation leaching by acidic deposition or natural acidification will have less effect on nutrient export than will tree harvesting (see PIRO study below). Large changes in surface water pH may occur even when changes in soil solution pH are small (ISRO and PIRO sites). A critical information need is soil mineral weathering rates especially for eastern sites.

3. Does acidic deposition affect forest productivity and, if so, what is the degree of current and expected damage. We suspect that widespread reductions in growth rates of several forest tree species, especially conifers (spruce and fir) have occurred in the eastern US. This is especially probable in boreal forests. It is unlikely that this is due to loss of forest soil nutrients. There is a need to conduct process field (and laboratory) studies to determine direct and indirect effects of acidic deposition and trace metals on forest tree growth.

New Projects Initiated in 1985:

Phenology. Originally this was part of the core requirements. However, as an indicator of change attributable to atmospheric contaminants it apparently is of little value. Before the decision to abandon this Core Requirement we undertook such observation at Wallace and Sumner watersheds throughout spring and summer of 1985. Work on the Trout Lake watershed was limited to spring growth since the nature of the forest precludes much shrub-herbaceous growth. This study including cropping and estimating contributions due to vernal growth. Since this observation can be easily incorporated into routine stream/lake sampling, we will continue it for at least one additional year and perhaps two just to establish some record.

Lysimeters in sensitive lake/watershed. In early fall of 1985 we installed two lysimeter plots in the Legion Lake watershed, PIRO. This watershed was not one of our original watershed sites, but has been monitored since mid 1984. It is an extremely sensitive system (seepage lake) with low pH and little or no alkalinity. We think minimal study on this site will complement work on the ISRO and Trout Lake sites (see Stottlemeyer 1985). The layout design for the lysimeter plots is identical to the work already completed on ISRO. The objective here is to relate precipitation quality, currently being collected by event collector at PIRO headquarters, to canopy throughfall quality, zero and tension lysimeter soil water quality, and lake water quality. The hypothesis is that on such sensitive sites, and especially under conifers, soil leaching of potassium and soil loss of nitrate inputs is relatively more important than on less sensitive sites. This difference should be seen in water quality of the lake particularly during spring snowpack melt. This work will be continued during 1986 and into summer of 1987 with the results compared to similar designs at ISRO and Trout.

Aquatic macrophytes. This was also an initial component of the Core Requirements which, upon examination, has limited potential as an indicator of change attributable to atmospheric contaminants. However, since this work has already commenced and it does have value in assessing the successional status of lakes and especially the contribution of natural acids by macrophytes, it will be completed probably this summer.

Increased intensity of winter monitoring. One of the limiting factors in the ISRO data set has been a paucity of winter sampling. This is due to the absolute limitations on access during portions of spring and especially fall, and funding priorities. During 1985 we successfully extended the stream monitoring season through the use of automatic stream samplers. During 1986, with more commitment to travel funding, we have been able to get to the island on a monthly basis for both stream and precipitation sampling.

Continuing Projects:

Sulfate anion mobility in boreal and northern hardwood forested ecosystems. This study, initiated two years ago, is in the final stages of completion for ISRO. The focus is on sulfate ions, however a full suite of ions have also been analyzed. A thesis was recently completed, and two papers summarizing the results are in preparation. This basic concept and experimental design is being employed in the study at Legion Lake.

Snowpack ionic dynamics. This study has been underway for seven years, and probably constitutes one of the longest intensive snow quality/ionic movement records in the nation. Input and snowpack quantity and quality are measured weekly at four stations in a gaged small first-order watershed. Detailed study on a weekly basis of ionic distributions within the snowpack have been conducted for three of these years. The first year's data have been resubmitted for publication, and partial results from the data set have been presented at national meetings. We hope to summarize the seven years' data for presentation at a national meeting this summer, and follow up with partial publication early next year.

Compilation of QA/QC procedures in field and laboratory. This will include data analysis of field and laboratory QA/QC tests in addition to strategy and tactics of QA/QC (see Stottlemeyer 1986).

Detailed description of data management system. This should be completed by June 1986, and will be made available upon request by those who send samples for analyses to our laboratory.

Projects Completed in 1985:

Four-year study of lake primary productivity and chlorophyll. This was initially a component of the Core Requirements, but research since that time has found such study is not a good indicator of ecosystem change certainly over periods of less than ten years. Due to funding limitations and the need to devote more effort to examining those components with more promise for showing change we have decided to cease this study. The results, in themselves, are valuable especially in this region. They will be summarized, analyzed and published hopefully during 1986.

About 1300 samples were analyzed directly for this project.

Projects Planned for 1986 and Beyond:

Natural nitrification and acidification, ISRO. Most watersheds on ISRO contain significant populations of *Alnus*. This is especially true for Wallace Lake and its input stream. In view of data collected on a watershed on ISRO some years ago it appears desirable to get some quantification of the nitrification/soil acidification processes in the experimental watersheds. Project initiation is contingent upon the analysis of existing

station W1 data and the evidence of nitrate it shows. The experimental design would follow that already employed by Cole and others. Lysimeters will probably be installed in 1986 with sampling beginning in late fall. This would run for one full year ending in 1987. NAPAP funding would be used.

Lake benthic cores, Legion and Trout Lakes. It does not appear beneficial to core the ISRO lakes since they clearly are not directly sensitive to anthropic acidification. However, Trout and Legion Lakes are sensitive. These are both non-colored (low organic acid) lakes and moderately deep. Before project initiation, however, we will check on the status of the EPA/University of Minnesota study of lake cores in this general region to ensure that there is no duplication of effort and that diatom calibrations exist. Our current hypothesis is that the sensitive lake/watershed systems we are studying have been acidified due to natural lake succession along the lines proposed by Gorham. This study will be initiated this spring, and be part of the NAPAP funding for this year.

Natural Mineral Weathering. It would be very desirable at some future date but before program termination to get some estimate of natural mineral weathering. At this time we have not thought through an approach as to how to do this. We are aware of the Hubbard Brook studies and other publications on this, but feel some modification of these procedures would be desirable. No action is anticipated on this for 1986.

Watershed Model Development. We have been collecting literature on the different models now developed and being developed for watersheds. There appear to be at least three different possibilities at present. It is timely to examine these to see if there are any significant data deficiencies which should be addressed before study completion. This we have begun. Obviously, this is different than model development and testing, but it is useful. It is doubtful that present funding will permit serious model development efforts. Rather we will have to attempt to adapt existing models to our needs. The present low-key effort will continue through 1986, with an attempt next winter to pull together our existing data and plug it into an existing model for testing.

Publications during 1985:

Stottlemeyer, R., K. Bick, R. A. Janke, R. M. Linn, R. O. Peterson, and D. Rutkowski. 1985. Isle Royale Biosphere Reserve: a bibliography of scientific studies. USMAB Publication Series #11, US Dept. of State, OES/ENR/MAB, Washington, D.C. 55p.

Hanson, D. and R. Stottlemeyer. 1985. Soil anion mobility in mature northern hardwood and boreal-forested watershed ecosystems, Michigan's Upper Peninsula. Ecol. Bull. 66(2):187.

Rutkowski, D., and R. Stottlemeyer. 1985. Biomass and nutrient content in northern hardwood and boreal forested watersheds, Michigan's Upper Peninsula. Ecol. Bull. 66(2):260.

Stottlemeyer, R. 1985. Monitoring and quality assurance procedures for the study of remote watershed ecosystems. Ecol. Bull. 66(2):277.

Stottlemeyer, R. 1986. Monitoring and quality assurance procedures for the study of remote watershed ecosystems. Amer. Soc. Test. Materials (in press).

Stottlemeyer, R., and D. Hanson. 1985. Comparison of sulfate mobility in soils of mature boreal and northern hardwood forested watersheds, Upper Great Lakes region. NADP Tech. Comm. Meeting, Colorado State Univ., Ft. Collins, CO, p.21.

Stottlemeyer, R. 1985. Effects of atmospheric acid deposition on lake/watershed ecosystems of Isle Royale and Michigan's Upper Peninsula. Conf. on U.S., Canadian, and Michigan Acidic Deposition Research, Conf. Summary p 18-19.

Leverage Projects

Facilities:

Boreal Research Station on Isle Royale. Initially provided by NPS principally for this project and now expanded for other research use. Essential facility for field and basic laboratory processing of samples from experimental watersheds.

Research Laboratory at MTU. With this space we have been able to set up laboratory for complete chemical analyses of water samples. It has provided us the logistical support essential to use state of the art technology complete with hardware access to mainframe computation and graphic services. We also have low-cost direct access to Ionics Carbon Analyzer, fully automated radioactive tracer instrumentation, and programmable spectrophotometric equipment. As Adjunct Professor of Forestry I have direct access to an Orion Auto Analyzer and digester block for the analyses of total organics. In sum this permits us to perform a full array of chemical analyses on water, soil, and tissue samples with good quality assurance at a fraction

of the cost outsiders would pay. This has permitted this project to conduct much more intensive and far more complete chemical analyses with present funding. As part of these analyses, from project initiation we have ran all SEKI watershed samples free of charge.

In addition to our own laboratory we have direct access to the soils analyses laboratory in Forestry, and a small MTU field station at Trout Lake.

Provision for NADP site, MTU. MTU has provided us an easily accessible protected site complete with power at no cost for installation of one of our NADP stations (M99).

Coordination With NPS Science:

Provide analysis of all water samples for SEKI. Hardware investment and logistical support has also permitted us to perform routine water analyses for eleven other national parks on a regular basis at a fraction of the cost of outside providers and with documented quality assurance/quality control. The latter is rarely if ever available from most commercial labs.

Multi-park gradient analysis of anthropic inputs. This project, in its third year, is leading up to some interesting results regarding potential air contaminant impacts to parks of the Great Lakes Basin. It, in turn, has provided a regional context within to better assess the situation at ISRO and Trout Lake. It has also served well in accomplishing some of the NAPAP objectives for this region.

NPS/MTU Forestry School assessment of effect of forest harvesting on representative stream water chemistry, soil water chemistry, and forest nutrient cycling (Mroz and Stottlemeyer, Co PI's). This project also is assisting in providing some context within which to evaluate trends seen on ISRO and Trout Lake. The study design also employs the watershed ecosystem approach, and involves most of the same analyses now being conducted on NAPAP study.

University of Minnesota: effects of moose browsing on plant nutrient cycling. A final decision on funding (NSF) for this project has not yet been made. If it is funded the project will provide us with some valuable information on the effects of herbivory on nutrient cycling in ecosystems of ISRO. ISRO is one of the few experimental sites where large herbivores could be a significant natural factor in determining at least the rate of nutrient cycling, and this could be important in assessing effects of anthropic inputs.

MTU study of sulfur and heavy metals in lichens of Isle Royale. This study directly complements our work in

providing some historical evidence of past deposition rates. It is in its fourth year.

State of Michigan support for statewide gradient impact analysis. We along with Univ. of Michigan and MSU have submitted a proposal to the MERRA for a considerable increase in station density for monitoring atmospheric contaminant inputs from the Upper Peninsula to southeast Michigan. This is needed to better assess the suspected gradient of atmospheric inputs across the state. If funded it will place eight sites in operation all following the NADP protocol with samples analyzed in our laboratory at MTU.

Coordination with NPS Resource Management:

Primary productivity and aquatic nutrients, deep water station, Isle Royale National Park. A resource management specialist has developed under our supervision an approved research project which will be the first routinely collected data on open lake water quality and productivity around Isle Royale. This project will rely very heavily on our field equipment, protocols, and university analytical equipment (without cost) for completion. The study will be based out of the Boreal Research Station.

Supervisor, NADP station (M97), Isle Royale. This station is operated by Resource Management personnel, ISRO, relying upon the GLARSU for supervision.

Timeframe and Reports:

Period of study will run from April 1986 to February 1, 1987. Progress report will be issued by end of January 1987, and will be in format similar to the above.

Budget for 1986

Equipment:

Automated weather station, Trout Lake with three channels and tower	4500.00
Data loggers and stream stage height gages with thermistors (three)	7500.00
Field micro-computers	3000.00
Statistical software (SAS)	700.00
Uninterrupted Power Source (protection of microcomputer on park generator)	700.00
Balance (Mettler or equivalent)	1500.00
Van Dorn samplers (4)	1200.00
Winch (boat for samplers)	500.00

Sub total = 19,600.00

Supplies:

General lab and field supplies	3462.00
Travel for technicians to ISRO	3000.00
Equipment maintenance	1200.00

Sub total = 7,662.00

Student and Technician Wages:

Graduate student (two quarters)	4356.00
Technicians (two man years)	28906.00
Summer student (4 months)	4025.00

Sub total = 37,287.00

Student and Technician Fringe Benefits:

Graduate student (1%)	44.00
Technicians (28%)	8094.00
Summer student (18%)	725.00

Sub total = 8,863.00

Soil, plant tissue, and water analyses beyond
those normally done in our laboratory
(approximately 100 samples)

2650.00

Indirect Costs

30% of all costs except equipment or 0.30 of \$56,462	16938.00
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Total Costs = \$93,000.00