

PREFACE

This report tells the story of Adirondack acid rain research and places it in its historical and scientific contexts. It is a joint project of the authors and the staff of the Adirondack Lakes Survey Corporation (ALSC). Its scientific core is the data that the Adirondack Long-Term Monitoring (ALTM) program has been gathering since 1982, and its direct antecedent was the ALSC's 1990 summary of Adirondack lake chemistry, the *Interpretive Analysis of Fish Communities and Water Chemistry, 1984-1987*.*

The systematic monitoring of Adirondack lakes began with the creation of the Adirondack Long-Term Monitoring Program in 1982. The ALTM program was initiated by Syracuse University, the U.S. Environmental Protection Agency (EPA), the New York State Department of Environmental Conservation (NYSDEC), and the Empire State Electric Energy Research Corporation (ESEERCO); its primary purpose was to make monthly measurements of the chemistry of 17 lakes in the southwestern Adirondacks and to track their responses to changes in atmospheric deposition.

The first chemical surveys of Adirondack lakes were done by the NYSDEC in the early 1970s. They were significantly expanded in 1984 when the newly created ALSC undertook a landmark survey of the chemistry and fisheries of 1469 Adirondack lakes. The survey was completed in 1987; a summary and analysis of the data intended for a general scientific audience, the *Interpretive Analysis*, was published in 1990.

The *Interpretive Analysis* was the first book-length analysis of lake acidification in the United States. Its major findings were that lake acidification from atmospheric deposition was widespread in the Adirondacks, that some types of lakes were more sensitive to acidification than others, and that some fish population losses had occurred as a result of acidification.

These findings, together with the passage of the 1990 Clean Air Act Amendments, led to a major expansion of the ALTM program in 1992. The monitoring program was extended to 52 lakes across the Adirondacks; in addition the ALSC, with support from the NYSDEC and ESEERCO, took responsibility for the field and laboratory work.

A further expansion of Adirondack lake monitoring occurred in 1997 when the ALSC began a cooperative effort of annual summer sampling of 43 Adirondack lakes as part of the EPA's Temporally Integrated Monitoring of Ecosystems (TIME) project. The TIME and ALTM work continues with support from the New York State Energy Research and Development Authority (NYSERDA), the NYSDEC, and the EPA.

Cumulatively, the monitoring and research conducted by the ALSC and others have created a unique and extremely important scientific record: 23 years of continuous data documenting the effects of acid deposition on what is both the largest acid-sensitive region in New York State and probably the most severely acid-affected ecological system in North America.

The databases produced by the ALSC and the ALTM program have been critical for policy as well as science. In 1997, the Adirondack region was prominent in the proposed Acid Deposition Control Act introduced in the

*Baker, J.P. et al., *Adirondack Lakes Survey: An Interpretive Analysis of Fish Communities and Water Chemistry, 1984-1987*.

105th Congress; the environmental protection targets in this act were based on ALSC data. In a report to Congress in 2000, the U.S. General Accounting Office cited trend results from the ALTM program to support a call for greater reductions in atmospheric deposition. In 2001, a major summary of acidification effects in the northeastern United States in *BioScience* used ALSC results. In 2003, the EPA's report on the *Response of Surface Water Chemistry to the Clean Air Act Amendments of 1990* cited ALTM lake data and concluded that the ALTM and TIME monitoring sites were "core research locations that will provide essential information for a number of present and future research questions faced by EPA. Their long-term data serve as the foundation for other ecological research to be conducted using these locations and their data. Without such data, our ability to ask the right questions is reduced, and our ability to base the answers to these questions on actual data is seriously compromised."

Planning for this report began in 1998, when the ALSC received a grant from the EPA's Office of Air and Radiation Acid Rain Division to summarize the Adirondack long-term monitoring research findings and make the results available for environmental decision-making and policy development. The goals were to make the data from the monitoring program widely available and to describe the results and value of Adirondack long-term monitoring. The first goal was accomplished in 2001 with the development of the ALSC website, www.adirondacklakessurvey.org (p. x). The website, which went online in March 2001, currently publishes updated monthly and annual data of all chemistries collected in 52 lakes, as well as summaries and data from the original 1984-1987 ALSC lakes survey.

This report, which was begun in 2002 and finished in 2005, addresses the second goal. It describes our current knowledge of the chemistry and ecology of acid deposition, and documents, with some pride, the role that Adirondack research has played in the development of that knowledge. It is intended for a varied audience: students, researchers, policy analysts, decision makers, and the general public. Its primary focus (Chapters 5-10) is on recent results and recent trends in deposition and chemistry but also includes substantial introductory material (Chapters 1-2) and a history of Adirondack research from the beginnings to the *Interpretive Analysis of 1990* (Chapters 3-4).

The report is a collaborative effort of the four authors. Karen Roy, the scientific manager of the ALSC research program, organized and directed the project and was responsible for its overall shape and many details of the presentation. Christopher Buerkett of the technical staff of the ALSC assembled the scientific information, prepared the bibliography, was responsible for technical editing, and arranged permission for use of copyrighted material. Jerry Jenkins, of the North America Program of the Wildlife Conservation Society, wrote the text, prepared the illustrations, and designed and produced the book. Charles Driscoll of Syracuse University, a leader in acid rain research since the 1970s and with the ALTM program since its beginning, served as a technical editor and consultant throughout.

The heart of the research described in this report comes from a series of large, interdisciplinary studies, beginning in the late 1970s and extending to the present. These studies, which have played a unique role in our understanding of acid deposition, have involved a remarkably diverse group of institutions, and sponsors. In historical order, they include:

The Integrated Lake-Watershed Acidification Study, 1977-1981 (ILWAS). Sponsor: Electric Power Research Institute (EPRI). Researchers: Peters, April, Gherini, Chen, Galloway, Schofield, Newton, Johannes, Clesceri, and Hendrey. (pp. 45-47)

The Regionalized Integrated Lake-Watershed Acidification Study, 1982-1984 (RILWAS). Sponsors: EPRI, ESEERCO. Researchers: Driscoll, Newton, Schofield, April, Peters, and Gherini. (pp. 48-54)

The first Paleoecological Investigation of Recent Lake Acidification study, 1983-1986 (PIRLA-1). Sponsors: EPRI, EPA. Researchers: Charles, Mitchell, Whitehead, Smol, and Norton. (pp. 81-83)

The second Paleoecological Investigation of Recent Lake Acidification study, 1988 (PIRLA-II). Sponsor: EPA. Researchers: Charles, Smol, Cumming, and Sullivan. (pp. 84-85)

The first Eastern Lake Survey, 1984 (ELS-1). Sponsor: EPA. Researchers: Linthurst, Landers, and Eilers. (pp. 65-67, 88-89)

The second Eastern Lake Survey, 1986 (ELS-II). Sponsor: EPA. Researchers: Herlihy, Whittier, and Sullivan. (p. 68)

The Direct/Delayed Response Project, 1984 (DDRP). Sponsor: EPA. Researchers: Church, Schnoor, Cosby, and Gherini. (p. 96)

The Episodic Response Project, 1988-1990 (ERP). Sponsor: EPA. Researchers: Wigington, Baker, Van Sickle, Simonin, and Murdoch. (pp. 109-110, 180-181)

The Integrated Forest Study, 1985-1989 (IFS). Sponsors: EPRI, ESEERCO. Researchers: Johnson, Lindberg, Mitchell, and Friedland.

The Adirondack Long-Term Monitoring Project, 1982 to present (ALTM/LTM). Sponsors: ESEERCO, NYSERDA, NYSDEC, EPA. Researchers: Driscoll, Kretser, and Roy. (pp. 197-205)

The Lake Acidification Mitigation Project, 1983-1986 (LAMP). Sponsors: EPRI, ESEERCO. Researchers: Schofield, Gloss, Driscoll, DePinto, and Young. (pp. 144-147)

The Adirondack Manipulation and Modeling Project, 1990-1995 (AMMP). Sponsors: NYSERDA, ESEERCO, National Council of the Paper Industry for Air and Stream Improvement, Inc. Researchers: Mitchell, Driscoll, and Raynal.

The Experimental Watershed Liming Study, 1989-1992 (EWLS). Sponsors: Living Lakes Inc., ESEERCO, U.S. Fish and Wildlife Service. Researchers: Driscoll, Fahey, Raynal, Leopold, Burns, and Newton. (pp. 148-150)

The Adirondack Effects Assessment Program, 1994 to present (AEAP). Sponsor: EPA. Researchers: Lawrence, Momen, Boylen, Sutherland, Nierzwicki-Bauer, and Zehr. (pp. 184-185)

The Lake Mercury Study, 1991-1993. Sponsors: ESEERCO, NYSERDA, NYSDEC. Researchers: Driscoll, Munson, Schofield, and Newton. (p. 167)

A scientific summary of this type could not have been possible without the depth and richness of the research base that is available in the Adirondacks. We have it because of the extraordinary, sustained interest and commitment of individuals who have collectively devoted years of effort to understanding the acidification problem and, we hope, its solution. To those tireless researchers, their students, and the various institutions that support them, we are greatly indebted.

A special acknowledgment goes to the Adirondack Lakes Survey Corporation staff for their continual commitment to making the Adirondack long-term monitoring effort a success. Members of the ALTM program team during the preparation of this report included Dale Bath, Linda Branch, Jeff Brown, Christopher Buerkett, Sara Burke, Mike Cantwell, Sue Capone, Paul Casson, Craig Cheeseman, Theresa Cleary, Rick Costanza, Tom Dudones, Jed Dukett, Nathan Houck, Pam Hyde, Monica Schmidt, and Phil Snyder.

We are also grateful to Walt Kretser, who along with John Holsapple, Sandra Meier, and Charley Driscoll, initiated this proposal with the EPA; to Howard Simonin, who provided substantial direction and review comments throughout many drafts; to Rona Birnbaum, Jennifer Kramer, and Tamara Saltman at EPA for their comments and patient support; to our copy editor Sally Atwater; and to a number of reviewers who provided comments and suggestions for various portions of the report along the way.

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ADIRONDACK LAKES SURVEY DATA ON THE WEB

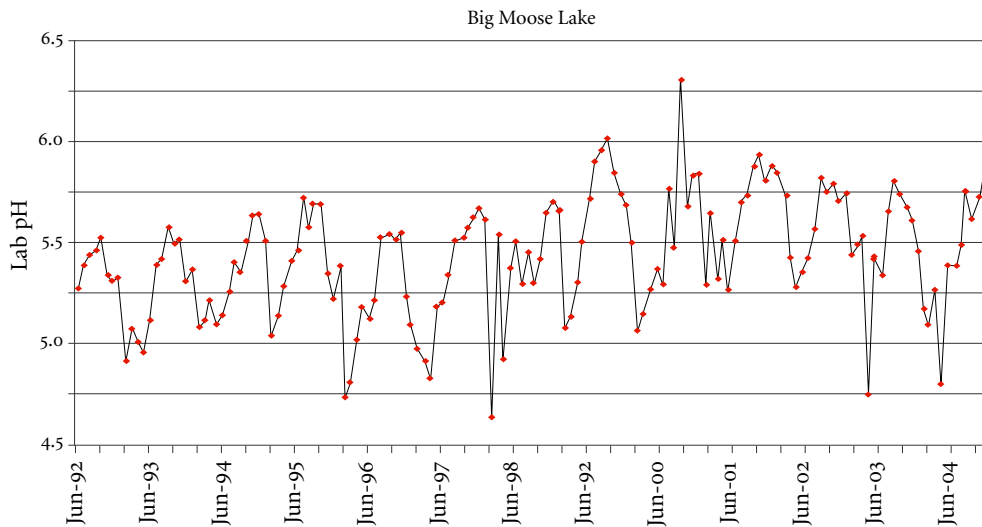
In 2001, as a part of its public outreach program, the Adirondack Lakes Survey Corporation created a website, www.adirondacklakessurvey.org. The website contains historical information about the ALSC and data from the Adirondack Lakes Survey and Adirondack Long-Term Monitoring program. The website has proved an effective way of distributing ALSC data: approximately 500 users visit the site every day, and 150 to 200 users download data from it every quarter.

Three sorts of data are available on the website: the complete 1984-1987 dataset for lakes and ponds examined by the Adirondack Lakes Survey, the 1992-2004 data from Big Moose Lake, and the complete 1992-2004 set of monthly observations and annual averages for the 52 ALTM lakes.

The Adirondack Lakes Survey data are available as a series of on-line tables that describe the morphometry, landscape features, chemistry, and fish populations of each pond visited during the survey.

The Big Moose Lake data are presented graphically: there are graphs showing the trends in chemical parameters from 1992 to the present and GIS maps showing the topography and chemistry of the watershed.

The ALTM data, which are the official scientific record of the monitoring program, are available for download as an Excel™ spreadsheet. The spreadsheet currently contains the monthly observations for 21 parameters at 52 lakes. A separate spreadsheet of annual averages is also available.



Laboratory pHs of Big Moose Lake, 1992-2004, redrawn from the ALSC website. The annual pH cycle consists of a spring minimum and a summer peak. The average pH increased in the 1990s as the Clean Air Act Amendments began to take effect (p. 2), but low snowmelt pHs still occur.

DATE	POND # ^a	SO4 (mg/L)	NO3 (mg/L)	Cl (mg/L)	F (mg/L)	ANC (ueq/L)	DIC (mg/L)	DOC (mg/L)	SiO2 (mg/L)
1/Jun/92	020058	4.24	0.072	0.45	0.090	27.90	0.86	12.695	1.81
1/Jun/92	020059	4.04	0.026	1.32	0.078	31.90	0.21	9.740	1.17

A portion of the ALSC database showing the first long-term monitoring data, from June 1992, for Little Hope (020058) and Big Hope (020059) ponds. The complete spreadsheet currently contains about 5,500 records, each giving the values for 21 measurements from a particular lake on a particular date.

Links to other acid deposition websites may be found on the menu bar of the ALSC website, www.adirondacklakessurvey.org. Descriptions and locations of other intensive research programs may be found on the NYSERDA website, at www.nyserdera.org/programs/environment/EMEP/home.asp.

THE ADIRONDACK LAKES SURVEY AT WORK



Dale Bath doing a fishery survey.



Theresa Cleary analyzing samples in the lab.



Paul Casson and Sara Burke taking a Kemmerer sample.



Paul Casson sampling through the ice.

Acid Rain Is Discovered & Regulated, 1845–2003

1845 Ducros, a French pharmacist, identifies nitric acid, formed by electrical discharges, in hail from a thunderstorm and describes his observation as *pluie acide*.

1852 Angus Smith identifies sulfuric acid, produced by burning coal, in the rain of Manchester, England. In 1872 he publishes *Air and Rain: The Beginnings of a Chemical Climatology*.

1911–1913 Crowther and his colleagues show that the acidity of the rain of Manchester, England, decreases with distance from the city and that the acids in the rain can affect tree growth, soil microbes, and seedling germination.

1919 Rusnov, working in Austria, shows that acid rain has acidified forest soils.

1950–1960 Studies in Scandinavia, England, and North America show a general correlation between the acidity of precipitation and the concentration of sulfate in rural lakes, suggesting that the acids generated by burning fossil fuels are traveling a long way from their urban and industrial sources.

1963 The Hubbard Brook Experimental Forest in northern New Hampshire begins monitoring precipitation and runoff chemistry.

1970 Congress passes the Clean Air Act Amendments, regulating emissions of sulfur oxides and volatile organic compounds.

1972 Likens, Bormann, and Johnson publish an article titled “Acid Rain,” based on records from Hubbard Brook. They point out that 40% of the acidity at Hubbard Brook was associated with nitric rather than sulfuric acid, and that much of this arises from nitrogen oxides produced by automobiles and other vehicles.

1973 U.S. emissions of sulfur dioxide peak at 28.8 million metric tons and then fall by about 25% in the next 22 years as the Clean Air Act Amendments take effect. Nitrogen oxide emissions, which have not been regulated, increase in the same period.

1974 Cogbill and Likens, by reviewing earlier surveys, show that acid precipitation is occurring over much of the eastern United States.

1972–1979 Researchers in Scandinavia, England, Germany, Canada, and the United States document

reproductive failure and increased mortality in fish in acidified lakes.

1975 The first international conference on acid rain is held in Dayton, Ohio.

1976 Schofield surveys 214 Adirondack lakes for the New York State Department of Environmental Conservation and reports that half of the lakes over 2,000 feet in elevation are acidified, and many of these have no fish.

1978 A consortium of state and federal agencies and private research organizations opens the first 22 precipitation monitoring stations in the National Trends Network of the National Atmospheric Deposition Program.

1980 The U.S. Acid Precipitation Act of 1980 creates the National Acid Precipitation Assessment Program (NAPAP). In the next ten years NAPAP, at that time the largest environmental research program ever conducted, funds more than \$500 million of acid rain research, including many major Adirondack studies.

1982 The Regionalized Integrated Lake–Watershed Acidification Study (RILWAS) begins the monthly monitoring of 20 Adirondack lakes.

1984 New York State initiates a sulfur dioxide control policy, identifying the Adirondacks and Catskills as sensitive receptor areas, and issues its first mercury advisory, warning against consumption of fish from Stillwater Reservoir in the western Adirondacks.

1990 Congress passes Title IV of the Clean Air Act Amendments. This creates a “cap and trade” program that requires utilities to reduce sulfur emissions 40% below their 1980 levels and creates a market that allows utilities to buy, sell, and bank allowances. Title IV requires only a 10% reduction in nitrogen oxide emissions, and provides no cap.

1995 Phase I of the 1990 Clean Air Act Amendments takes effect, and sulfur dioxide emissions decline 14% in the next three years. Nitrogen oxide emissions, which have not been capped, only decline by 2%.

2003 A review of the effects of the Clean Air Act Amendments finds, for the first time, small but significant increases in the acid-neutralizing capacities of surface water in the upper Midwest, Adirondacks, and northern Appalachians, but only very small increases in New England.