

# Summary of Monitoring and Experimental Research

## Experimental Lakes Area

Updated December 2007

### **Joint DFO and EC involvement:**

Under a 2007 agreement between DFO Science and Environment Canada (EC) Science and Technology, a growing research involvement at the ELA by EC scientists from the National Water Research Institute, the Meteorological Service of Canada, and other EC research components is anticipated. Under this agreement, EC contributes half of the baseline support costs for the ELA facility and EC researchers have equal access with DFO researchers to the ELA facilities. In addition to these two primary user groups, a number of partner agencies also participate in ELA research.

### **DFO Programs supported at the site:**

The major [on-site programs](#) are coordinated and carried out by the Ecosystem Research Section of the Environmental Science Division, Fisheries and Oceans Canada (DFO), Central and Arctic Region. Members of the Habitat Impacts Section also participate in many of these core programs. These two sections conduct experimental ecosystem research as part of Departmental programs on freshwater fish habitat, protection of aquatic ecosystems, and related issues. Currently, the impacts of cage aquaculture are a primary focus. Traditionally, ELA studies have examined the food chain effects of stressors such as excess nutrients, acidification, water level changes, heavy metals, endocrine disruptors and organic toxicants in lakes, wetlands, and their watersheds. These DFO sections have also conducted experimental studies of greenhouse gases, eutrophication and biomanipulation. The Ecosystems Research section operates the field station in cooperation with DFO Real Property, which maintains the physical facilities. The Ecosystem Research section conducts the long-term, ecological research program used for quantifying natural reference and climate change parameters, and operates the meteorological station and the hydrological stations. This section also encompasses an analytical chemistry group, which operates water chemistry laboratories on site and at the Freshwater Institute.

### **EC Programs supported at the site:**

In 2007, EC aquatic scientists began pilot studies jointly with DFO researchers to gain better understanding of the impacts of brominated fire retardants (BFRs) in aquatic systems. In addition, some EC atmospheric and hydrometric scientists began to work with long-term ELA data sets and collect some new data at the ELA.

### **Other Agency programs utilizing the site:**

Numerous other agencies utilize the site in cooperation and partnership with DFO personnel and programs. In 2006, these included:

#### **Meteorological Service of Canada (MSC - EC)**

- provide equipment and support for meteorological station, and air quality and precipitation monitoring. Data are contributed to national and international programs (eg. CLIMATE, CAPMoN).

#### **Lake of the Woods Control Board**

- utilize streamflow and meteorological data for water management.

#### **Ecological Monitoring Coordinating Office (EC)**

- provide research support and utilize monitoring information from the ELA as an Ecological Science Cooperative within their [Ecological Monitoring and Assessment Network \(EMAN\)](#)

#### **Canada Centre for Inland Waters (EC)**

- conduct joint research on cage aquaculture.

#### **Natural Resources Canada**

- operate a seismic monitoring station
- fund research on climate change

#### **Ontario Ministry of Environment**

- contribute collaborative support and expertise for various studies of aquatic and terrestrial ecosystems.
- share data sets of common interest
- participate on Management Board and monitor compliance with environmental regulations

#### **Ontario Ministry of Natural Resources**

- utilize meteorological data for forest fire protection and wild rice management.
- exchange information on fish habitat, lake morphometry, etc.
- participate on Management Board, exercise jurisdictional authority over the waters and lands in the area, and provide liaison with the general public while providing the land and water base for all field studies.

#### **Ontario Parks (OMNR)**

- permit and support monitoring and other research activities within designated parks (Winnange Lake and Eagle-Dogtooth) intersecting the ELA

#### **University of Manitoba**

- participate as major partner in an ELA Research Unit
- train graduate students in zoology, botany, geography, microbiology, engineering, entomology, and environmental studies through cooperative programs with DFO researchers as adjunct faculty.
- administer ELA Graduate and Undergraduate Fellowship Funds
- several faculty members carry out cooperative research with DFO personnel and contribute expertise to DFO studies.

#### **University of Alberta**

- conduct studies on mercury and reservoir effects, and train graduate students

- jointly train graduate student

#### **University of Guelph**

- conduct joint studies on and cage aquaculture

#### **Université de Montréal**

- conduct joint research on ecosystemic mercury linkages

#### **Queen's University**

- Conduct paleolimnological coring studies and train graduate students

#### **Trent University**

- conduct joint research on ecosystemic mercury linkages and train graduate students

#### **University of Toronto**

- conduct joint research on ecosystemic mercury linkages and train graduate students

#### **University of Waterloo**

- conduct joint research on reservoir flooding impacts and train graduate students

#### **York University**

- conduct joint research on cyanobacteria, and train graduate students

#### **Hydro Québec**

- provide funding for selenium-mercury interaction studies

#### **Manitoba Hydro**

- provide funding for reservoir effect and climatic change studies

#### **Flett Research**

- conduct contractual analyses of mercury

#### **Limnotech Consultants**

- conduct contractual fish population studies

#### **University of Maryland, Chesapeake Biological Laboratory**

- conduct joint research on ecosystemic mercury linkages

#### **University of Wisconsin**

- conduct joint research on ecosystemic mercury linkages

### **Smithsonian Environmental Research Center**

- conduct joint research on ecosystemic mercury linkages

### **U.S. Geological Survey**

- conduct joint research on ecosystemic mercury linkages

### **U.S. Environmental Protection Agency**

- fund joint research on ecosystemic mercury linkages

### **Tetra Tech Inc.**

- conduct joint research on ecosystemic mercury linkages

### **Electric Power Research Institute**

- fund joint research on ecosystemic mercury linkages

### **Northern Ontario Aquaculture Association and Meeker Aquaculture**

- fund joint research on cage aquaculture impacts

Historically, dozens of external agencies have utilized the ELA facility in various ways. In addition to those above, the list includes Energy, Mines and Resources, the Canadian Forestry Service, the National Research Council, Alberta Oil Sands Environmental Research Program, Lamont Doherty Geological Observatory (Columbia University), Wood's Hole Oceanographic Institution, World Wildlife Fund, Ontario Hydro, and the Universities of Laval, McGill, Ottawa, Western Ontario, Winnipeg, British Columbia, Arizona State, Columbia, Cornell, Minnesota-Duluth, Purdue, New Hampshire, Texas, Amsterdam, Bristol, Minnesota-Duluth, Texas-Arlington, and Kyoto. Visitors have come from Canada, U.S.A., U.K., Netherlands, Sweden, Norway, Denmark, Switzerland, Germany, France, Austria, Italy, Spain, Russia, Poland, Hungary, Czechoslovakia, Turkey, Japan, China, Thailand, New Zealand, Australia, South Africa, Chile, and other countries.

### **Types of Research conducted over the history of the facility:**

The primary research function of the ELA has been to provide a unique facility for carrying out long-term, multidisciplinary, ecosystem-scale, experimental studies. While the emphasis has always been on aquatic ecosystems, wetland and upland ecosystems have also been studied. Historically, research centred on two major study areas: eutrophication and acidification. In more recent years, the focus switched to studies of reservoir effects (mercury and greenhouse gases), hormonal mimics, habitat disruption, and climate change effects. The newest study is looking at impacts of cage aquaculture. This research has involved meteorology, hydrology, geochemistry, water chemistry, physiology, microbiology, botany and zoology, all working cooperatively. Other studies have examined forest fire effects, radioisotopes and heavy metals, logging practices, biomanipulation and cropping. More than 1100 publications now document this research. An [online listing and a bibliographic database](#) are available for download.

### **Nature, Quality and Length of Record of Meteorological Data:**

A Class 'A' reporting meteorological station ([Rawson Lake](#)) was set up in June, 1969, with the assistance of the forerunners of today's Meteorological Service of Canada (MSC)). The site is operated as a part of the ELA Hydrometeorological program. The site has been serviced routinely, twice daily, in all subsequent years without interruption of the data set. Basic meteorological data are collected and reported monthly to MSC. Records include wind speed and direction, maximum and minimum air temperature, daily and hourly rainfall, daily snow water equivalents, snow depths, bright sunshine duration, pan evaporation and relative humidity for the open water season. Quarterly inspections by MSC and continuity in our own ELA staff have assured consistent data of a high standard. Records are published regularly in DFO data reports, and are contributed to MSC. This station now has

Beaty has managed this site for the entire period of record.

**Nature, Quality and Length of Record of Hydrological Data:**

An extensive hydrometric data collection network has been maintained at the ELA since 1969. Of the 58 lakes and watersheds controlled by the ELA, approximately half have some hydrological records, ranging in duration from 3 to 39 years. Since 1969, close to 50 hydrometric stations have been operated over different time periods, with some having up to 39 years of continuous record. In 2007, about 20 hydrometric stations, including lake outflow recording weirs, recording lake level stations, lake staff gauges, and wetland water table recording wells, were operated. In addition, ELA staff have assisted with the design and implementation of a hydrometric network at the Coldwater Lakes study site near Atikokan, Ontario. The ELA monitoring program was assisted by Water Survey of Canada (WSC) from 1969 to March 31, 1985, and since then has been operated independently by ELA Hydrometeorology. Records and procedures meet or exceed those normally set by WSC and are therefore of a high quality. Records are published in DFO data reports.

**Archival Materials:**

Many samples have been archived and are currently in storage at the Freshwater Institute in Winnipeg. These include: (Personnel to contact)

**Water samples** suitable for certain chemical analyses (M. Stainton, S. Kollar/C. Baron)

**Sediment cores** preserved and/or frozen (R. Hesslein, D. Findlay, M. Paterson)

**Algal samples** preserved in Lugol's solution (D. Findlay)

**Zooplankton samples** preserved in formalin (M. Paterson, A. Salki, L. Wesson)

**Benthic Invertebrate samples**

- chironomids preserved in alcohol (C. Podemski)
- crayfish, molluscs preserved and/or frozen (C. Podemski, M. Paterson)

**Fish samples** (K. Mills, R. Hesslein, P. Blanchfield, V. Palace)

- whole fish, frozen and/or preserved
- selected organs, frozen and/or preserved
- stomach contents, preserved
- scales, otoliths, fin rays for aging

**Monitoring Activities for other agencies:**

Since 1969, the ELA program has supported other agencies and their monitoring programs. The major groups include:

- **Meteorological Service of Canada:**
  - CANSAP, precipitation chemistry sampling (discontinued)
  - CAPMoN, air and precipitation chemistry sampling
  - Climatological monitoring (CLIMATE)
  - Ozone monitoring
  - Air quality study (hi-volume, daily sampling)(discontinued)
  - National Isotopes in Precipitation study
- **Ontario Ministry of the Environment:**
  - Acidic Precipitation in Ontario Study (APIOS)(discontinued)
- **Ontario Ministry of Natural Resources:**
  - forest fire weather reporting
  - provide climatological data and meteorological data for resource development, wild rice management.
- **National Research Council:**

- Acid corrosion study on building steel (discontinued)
- **Inland Waters Directorate:**
  - provide meteorological data to the Lake of the Woods Control Board
- **Ecological Monitoring and Assessment Network (DOE):**
  - analyses of climatic variation and ecological change

### **Long-term Data Sets:**

#### Meteorology:

- 39 consecutive years (twice-daily or daily, year-round)
  - precipitation (rain and snow)
  - air temperature
  - wind speed and direction
  - bright sunshine
  - evaporation
- 35 consecutive years
  - photosynthetically available solar radiation at 10 minute to daily intervals during open-water periods.
- shorter records
  - relative humidity, snow depths

#### Hydrology:

- daily to monthly streamflow and lake level data for up to 39 consecutive years on selected basins.
- weekly to monthly stream water chemistry for up to 39 consecutive years on selected basins.

#### Air and precipitation chemistry:

- all precipitation events for 35 consecutive years for a range of chemical parameters.
- daily records on a range of air chemistry parameters for up to 29 consecutive years (CAPMoN program, MSC).
- interval sampling of wet precipitation chemistry for up to 28 consecutive years (CAPMoN & CANSAP programs, MSC; APIOS, OME)

#### Physical limnology:

- water temperatures at daily to monthly intervals and at various depth intervals over periods of up to 39 consecutive years in selected lakes.
- Secchi disk measurements of water transparency for selected lakes for up to 39 consecutive years.
- water column irradiances (photosynthetically available) at weekly to monthly intervals (open-water seasons) for up to 34 consecutive years on selected lakes. Relative attenuation values for up to 39 consecutive years.

#### Lake Water Chemistry:

- up to 39 consecutive years on selected lakes at weekly to monthly intervals and at various depth intervals. Up to 30 variables measured per sample

#### Phytoplankton populations:

- species identification and enumeration at weekly to monthly intervals and for various depth ranges in selected lakes for up to 39 consecutive years.

#### Phytoplankton production:

- measured on selected lakes for up to 39 consecutive years.
- open-water seasonal estimates using [incubator-based protocols](#) available for up to 34 consecutive years on selected lakes.

#### Periphyton populations:

- species identification and enumeration for up to 24 consecutive years in selected lakes.

#### Periphyton production:

- estimated over open-water season for up to 26 consecutive years in selected lakes.

#### Chironomid emergence:

- species identification and abundance for up to 33 consecutive years in selected lakes.

#### Zoobenthic populations:

- samples taken at weekly to monthly intervals for up to 29 consecutive years in selected lakes.

#### Zooplankton populations:

- samples taken and species identified at daily to monthly intervals for up to 39 consecutive years in selected lakes.
- species identified, enumerated and measured for selected years on selected lakes.

#### Fish Populations:

- populations monitored using mark/recapture techniques for up to 35 consecutive years on selected lakes.
- minnow populations in selected lakes monitored in detail for up to 9 consecutive years.
- movements of individual fish in selected lakes monitored using telemetry for varying periods in several different years.
- information available on age-class distributions, recruitment, condition, etc. for various species, including lake whitefish, lake trout, white sucker, northern pike, minnows.

#### **Paleoecological Studies:**

Deep-water, organic sediments in the ELA lakes are typically very fine, soft and fluid in nature (ie. "loonshit"). The sediment-water interface is visually but not physically distinct. These organic sediments are often underlain by sandy sediments from the glacial Lake Agassiz period. In several known meromictic lakes, distinct layering (varving) of the sediments occurs. Various paleoecological studies have been conducted on ELA lake sediments over the years. Researchers from the Royal Ontario Museum cored several lakes during 1969 to study pollen stratigraphy. Various personnel associated with Lamont Doherty Geological Observatory and DFO have carried out isotopic aging studies on sediments from other cores. Since 1986, freeze-cores have been taken from a large number of lakes at the ELA to examine the stratigraphy of diatoms in the sediments as a means of reconstructing

pH history. Other cores have been used to examine deposition of organic compounds, radioisotopes, and other historical aspects. Contact R. Hesslein, M. Paterson, or D. Findlay for more information.

### **Unique Site aspects and other ecosystems available for study:**

The ELA facility provides full research access to 58 small lakes and watersheds, which have been set aside exclusively for experimental ecosystem studies. This immediate area is uninhabited. Several hundred additional lakes lie within a few kilometres of the field station and its access road, and these are available for monitoring studies. The ELA offers a unique opportunity for conducting whole-ecosystem, experimental studies in a location remote from other human activities. Experimentally perturbed systems can be directly compared with adjacent natural systems. In combination with the 39-year meteorological, hydrological, chemical, and biological data records which now exist, this facilitates interpretation of experimental results and permits an improved understanding of ecosystem interactions and processes. While the site was originally selected for the study of lake ecosystems, there are a number of small stream, wetland and upland basins in the area which have been, or could be, utilized for ecosystem-scale studies. The absence of significant human habitation or development in the area is advantageous for experimental and background monitoring studies.

### **Experimental Field Studies:**

The following whole-ecosystem experimental studies have been carried out:

#### Eutrophication:

1969-1989	Epilimnetic fertilization of Lake 227 with P & N
1971-1976	Epilimnetic fertilization of Lake 304 with P, N & C
1972-1976, 1978	Hypolimnetic fertilization of Lake 302N with P, N and C
1973-1976	Epilimnetic fertilization of Lake 261 with P
1973-1980	Epilimnetic fertilization of Lake 226NE with P, N and C
1973-1980	Epilimnetic fertilization of Lake 226SW with N and C
1974-1975	Under-ice fertilization of Lake 230 with P and N
1975-1976, 1984	Epilimnetic fertilization of Lake 303 with P and N
1990-2007	Epilimnetic fertilization of Lake 227 with P
1990-1991	Epilimnetic fertilization of Lake 302N with N
1992-1993	Epilimnetic fertilization of Lake 302N with N & P

#### Radioisotopic Tracers:

1970	Radium-226 added to L227 epilimnion (gas exchange rates)
1971	Radium and barium chloride added to L261 (gas exchange)
1975	Tritium added to different thermal layers of L227 (mixing and diffusion rate studies)
1976	Tritium injected into different thermal layers of L224 to examine mixing and diffusion rates.
1976	Epilimnetic addition of selenium-75, mercury-203, zinc-65, cesium-134, iron-59 and cobalt-60 to L224 to examine fate of metals in the ecosystem.
1977	Epilimnetic addition of selenium-75, mercury-203, zinc-65, cesium-134, strontium-90, iron-59 and cobalt-60 to L226 to examine fate of metals in the ecosystem.
1978	Epilimnetic addition of phosphorus-32 to L227 (P dynamics)

1978	Tritium and radium added to L226 for tracer study
1978	Carbon-14 added to epilimnia of both basins of L226 in several additions to estimate carbon fluxes and whole-lake productivity.
1987-1992	Cadmium-109 added to epilimnion of L382 to trace pathways of metal in ecosystem.
1989	Tritium, cobalt-60 and cesium-134 injected into the hypolimnion of L226N to trace pathways of dispersion.

Acidification:

1976-1993	Epilimnetic acidification of L223 with H <sub>2</sub> SO <sub>4</sub>
1979-1986	Epilimnetic acidification of L114 with H <sub>2</sub> SO <sub>4</sub>
1982-2000	Epilimnetic acidification of L302S with H <sub>2</sub> SO <sub>4</sub>
1982-1986	Epilimnetic acidification of L302N with HNO <sub>3</sub>
1983	Pulse acidification of L222 outflow stream (insect effects)
1983-1990	Acidification of L239 Fen with H <sub>2</sub> SO <sub>4</sub> and HNO <sub>3</sub>
1987-1989, 1994-1996	Epilimnetic acidification of L302N with HCl
1987	Pulse acidification of L225 with HCl
1990-1993	Epilimnetic acidification of L302N with HCl and NaSO <sub>4</sub>

Metals:

1984	Epilimnetic additions of aluminum to L114
1987-1991	Epilimnetic addition of cadmium to L382 (Cd toxicity)
1987	Addition of cadmium to L226 outflow stream (toxicity)
2001-2006	Addition of three stable isotopes of mercury (Hg-202, Hg-200, Hg-198) to Lake 658, its terrestrial upland drainage, and its tributary wetland (mercury loading, ecosystemic pathways)
2007	Addition of stable isotope of mercury (Hg-202) to Lake 658,(mercury loading, ecosystemic pathways)

Biomanipulations:

1969	Introduction of rainbow trout fingerlings to Lakes 303 and 304
1974	Cropping (estimated 63%) of lake whitefish population in Lake 122
1981	Cropping (estimated 40%) of lake whitefish population in Lake 305
1982	Cropping (estimated 26%) of lake whitefish in Lake 258
1983	Cropping (40 individuals; estimated 70%) of lake trout population in Lake 239
1987	Introduction of northern pike to Lake 221 (transfer from Lake 222)

1993	Introduction of northern pike to Lakes 227 and 110 (transfers from Lakes 222 and 663).
1995-1997	Removal of northern pike from Lake 227.
1996-1998	Removal of macrophytes from Lake 191.
2001	Cropping (100 individuals; estimated 20%) of lake trout population in Lake 382
2003-2007	Cage aquaculture of rainbow trout in Lake 375.

Organics:

1988-1990	Injection of lake trout and white suckers in Lake 260 with chlordane and toxaphene (toxicity studies)
2001-2003	Addition of a synthetic estrogen (EE2) to surface waters of Lake 260 (chronic physiological and population effects)

Physical Perturbations:

1993-2007	Raising of water level (seasonal) in Lake 979 and its sphagnum/black spruce bog to simulate flooding for hydro-electricity generation (methylmercury, greenhouse gases)
1995-1997	Lowering of water level in Lake 226 to simulate reservoir drawdown (impacts on fish reproduction)
1999-2003	Flooding (seasonal) of three forested upland reservoir sites (Lake 239 and 468 watersheds) to simulate edge effects of large boreal reservoirs (methylmercury and greenhouse gases)

In addition to these whole-ecosystem experiments, hundreds of smaller-scale experimental studies have been carried out in the field at the ELA. Many have utilized enclosures ranging in size from several litres volume to 10-metre diameter limnocorrals. Most are described in published papers ([listing available](#)).

**Terrestrial Research:**

Most of the ELA research to date has focused on the aquatic components of the ecosystems. The facility provides terrestrial research opportunities, particularly with respect to boreal forest studies, but these have not been a primary focus. ELA is forested with a mix of boreal species dominated by jack pine and black spruce. Forest fires and logging activities in the area during the 1970's and 1980's have resulted in a variety of stands ranging from young (27 years) to mature (130+ years). Both natural and managed regeneration are occurring in the area. Mammals, birds and other fauna are generally typical of the mid-continental, boreal forest, with some incursion of prairie species.

One SI/MAB forest biodiversity monitoring plot has been established (1998) in a mature, upland forest stand (Lake 302 upland) at the ELA. A second SI/MAB plot has been partially established (1997) in a stand (Lake 239 west) regenerating from a 1980 wildfire. A series of tiny experimental upland catchments, complete with monitoring weirs, has been established within the Lake 302 watershed. These catchments have been used for pilot-scale studies investigating nitrogen and mercury additions to upland watersheds.

**Bibliography:**

Over 1100 scientific publications have resulted from research conducted at the ELA facility over the first 39 years of operation. More than 40 articles have been published in the general public literature. A complete, downloadable [listing of these publications and a bibliographic database](#) are available elsewhere on this web site.

