

**LONG-TERM STUDY OF BOREAL
WATERSHED/LAKE ECOSYSTEMS, MICHIGAN; FRASER
EXPERIMENTAL FOREST, CO; AND ALASKA**

Robert Stottlemeyer, Research Scientist¹
David Toczydlowski, Research Scientist²

1. Biological Resources Division
U. S. Geological Survey
240 W. Prospect Rd.
Fort Collins, CO 80526

2. Department of Biological Sciences
Michigan Technological University
Houghton, MI 49931

1998 ANNUAL REPORT AND 1999 WORK PLAN
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Introduction

This report summarizes research completed during FY 1998, and outlines research objectives and a study plan for FY 1999. The study sites considered in this research report are the Wallace Lake Watershed, Isle Royale National Park (ISRO), Michigan; the Calumet Watershed, Michigan's Upper Peninsula; watersheds of the U.S. Forest Service Fraser Experimental Forest, Colorado; and the treeline Fishgut Watershed, Noatak National Preserve, Alaska. The sites are predominantly boreal ecosystems. All are located at major ecotones (northern hardwoods-boreal, subalpine-alpine, taiga-tundra). While the research objectives differ somewhat among sites, the conceptual approach is similar. Much of the work is common among sites, or is planned to be such. The research emphasis has been and continues to be on terrestrial processes. An assessment of the literature suggests for terrestrial ecosystems that the study of processes in an ecosystem context likely will give the earliest statistical indication of incipient change due to stress, and a better quantification of the magnitude of response.

1999 Research Objectives/Hypotheses

MICHIGAN SITES

Calumet Watershed: Current hypotheses: 1) Snowpack accumulation of anthropogenic ions is a significant fraction of annual inputs, but high solute retention until spring melt and peak stream runoff does not occur due to periodic thaws and unfrozen soils; and 2) the pattern of snowmelt, and especially the occurrence of initial small melts, largely determines the snowpack solute pathway to streams and therefore the potential for streamwater solute "pulses". This FY, we will continue routine monitoring of this watershed, and no new research questions will be addressed. For procedures used in this study, see previous publications on this site.

Wallace Lake Watershed: This year we will continue the routine watershed monitoring and implement the recently approved research on global change (GC). Our overall research objective is to combine the long-term boreal watershed monitoring and research with new studies of change in soil and soil water chemistry and root/mycorrhizae chemistry and biomass to better understand the mechanisms regulating ecosystem carbon (C) and inorganic nitrogen (N) availability and their response to GC. Factors affecting the quantity of below-ground C affect the soil biota which regulate ecosystem N availability and in turn ecosystem production and biodiversity. The primary objectives are to 1) quantify the relation between forest floor and soil temperature, moisture, and N availability with production of dissolved organic carbon (DOC) and dissolved organic nitrogen (DON), 2) quantify below-ground CO₂ efflux, and mycorrhizae and small root production with change in soil temperature, moisture, and N availability, 3) correlate terrestrial DOC and DON production to export in aquatic ecosystems, and 4) use the long-term watershed chemical monitoring datasets with mixing models and piezometer results to determine seasonal change in watershed hydrologic flowpaths - a major factor regulating DOC and DON export to the aquatic ecosystem. This 5 year study will also be conducted in the Fishgut Watershed in the Noatak National Preserve, Alaska, located at the northern extent of the boreal biome. The sampling strategy, nested hierarchical, will incorporate data on vegetation, air and soil temperature, soil moisture, precipitation, and soil water ions, DOC, and DON from a network of small plots in each watershed to develop predictive relations between vegetation, climate, and soil DOC and DON production. Using split plots, we will intensively study processes by which GC and increased N availability alter DOC and DON production. Finally, by merging climate data from an extensive site network in each watershed with vegetation, topographic information (aspect, elevation), chemical and hydrologic results from flow-proportion soil piezometers and watershed-level mixing models, we will predict watershed DOC and DON export and compare results to actual fluxes.

FRASER EXPERIMENTAL FOREST

This FY we will continue the monitoring of surface water chemistry in nine gauged watersheds located in both alpine and subalpine watersheds. In addition, we will conduct a series of short term studies to fill in database gaps in preparation for starting a monograph in FY 2000 summarizing the long-term biogeochemical studies in the Forest. No new longer-term studies are planned at present unless outstanding research proposals are funded. An emphasis this year will also be publication of completed research datasets as indicated in the section below, Anticipated Accomplishments in FY99.

ALAKSAN NATIONAL PARKS

This year we will implement the recently funded global change research in the Fishgut Watershed, Noatak National Preserve. The objectives and methodology of this research are the same as described above for Wallace Lake, the paired watershed site. We continue to assist Denali National Park in its monitoring of the Rock Creek watershed, and this year will initiate some terrestrial process studies at Rock Creek to better explain change in stream water chemical signatures. Support for this research comes from the National Park Service.

1998 Research Highlights

MICHIGAN SITES

By the end of FY 98, we completed 16 yrs of precipitation and streamwater chemistry on the two ISRO watersheds, 19 yrs of intensive precipitation, snowpack, snowmelt, and streamwater chemistry at the Calumet watershed, and 12 yrs of intensive forest litter and soil solution monitoring during snowmelt at Calumet.

Wallace Lake Watershed: The major effort this year was to summarize and publish the long-term watershed-level dataset, and the recently completed studies on the relation of climate to the nitrogen cycle (see FY 98 publications below). The Lake Superior basin receives moderate atmospheric H^+ , NH_4^+ , NO_3^- , and SO_4^{2-} inputs. In recent decades, regional temperatures have increased and precipitation amounts declined. At Wallace, precipitation averages 75 cm with 40% occurring in winter. Canopy interception ranges from 20 to 35% of incident precipitation. Snowpack depths are sufficient to keep soils unfrozen except beneath spruce where high interception reduces snowpack depth. Unfrozen soils and mid-winter thaws reduce snowpack peak water equivalent (PWE) and ion content. Streamflow is dominated by snowmelt, and averages 68% of precipitation input. Since 1982, precipitation H^+ and SO_4^{2-} concentrations decline. Throughfall H^+ and NO_3^- flux are reduced relative to precipitation input, but SO_4^{2-} increases. Relative to throughfall, soil water base cation (C_B), HCO_3^- , and SO_4^{2-} flux increase while H^+ , NH_4^+ , and NO_3^- decrease. Ninety percent of precipitation enters forest soils where soil processes significantly modify its chemistry. Soil inorganic N pools are >5 times precipitation input, and peak in spring and early summer. Soil net N mineralization occurs throughout the year, and peaks in May - June. Net N mineralization rates decline as soil temperature increases. Soil gross mineralization rates are about 25 times net mineralization, and increase with soil temperature, CO_2 efflux, and moisture. Microbial N immobilization is greatest beneath alder, and increases with soil temperature. Soil net and gross N mineralization rates are not correlated. Soil respiration rates increase with temperature. During snowmelt, streamwater acid neutralization capacity declines $>475 \mu\text{eq l}^{-1}$, 98% from dilution. Watershed C_B output exceeds input 17 times. The watershed retains $>99\%$ H^+ inputs, and 75% of NO_3^- and NH_4^+ inputs. SO_4^{2-} output exceeds input by 1.2 times. The Wallace boreal forest has an aboveground living biomass of 108 t ha^{-1} , comparable to interior Alaskan taiga. C_B uptake is about 90 and N $39 \text{ kg ha}^{-1} \text{ yr}^{-1}$. Presently, there is little net change in total aboveground biomass with time.

FRASER EXPERIMENTAL FOREST

We completed 16 yrs of continuous monitoring of precipitation and streamwater chemistry for the six primary watersheds. In addition, we have on average 12 yrs of streamwater chemistry for four alpine catchments, 12 yrs of comparison data for precipitation chemistry with elevation, 12 yrs of monthly snowpack chemistry along an elevation gradient, 6 yrs of intensive snowpack/snowmelt chemistry along an elevation and aspect gradient, a unique 10 yr data set on change in soil solution chemistry with depth following paired plot clearcutting, and a decade of snowpack chemistry in a separate experiment with paired plots following clearcutting.

This year we continued the basic monitoring of surface water chemistry in nine gauged watersheds, the change in snowpack precipitation with elevation, and summarized our ten year study of the effect of clear cutting on subsurface flow chemistry and budgets. Our research on disturbed sites led to numerous requests to address likely impacts from disturbance in National Forests of the Rocky Mountains. Our research on the effects of vegetation manipulation on snowpack, soil water, and streamwater chemistry and flux has been underway at the Experimental Forest (FEF) since 1982. Greater than 95% of FEF snowmelt passes through watersheds as subsurface flow where soil processes significantly alter meltwater chemistry. To better understand mechanisms accounting for annual variation in watershed streamwater ion concentration and flux with snowmelt, we studied subsurface water flow, its ion concentration, and flux in conterminous forested and clear cut plots for a decade. Repetitive patterns in subsurface flow and chemistry were apparent. Control plot subsurface flow chemistry had the highest ion concentrations in late winter and fall. When shallow subsurface flow occurred, its Ca^{2+} , SO_4^{2-} , and HCO_3^- concentrations were lower and K^+ higher than deep flow. The percentage of Ca^{2+} , NO_3^- , SO_4^{2-} , and HCO_3^- flux in shallow depths was less and K^+ slightly greater than the percentage of total flow. Canopy removal increased precipitation reaching the forest floor by about 40%, increased peak snowpack water equivalent (SWE) > 35%, increased the average snowpack Ca^{2+} , NO_3^- , and NH_4^+ content, reduced the snowpack K^+ content, and increased the runoff four-fold. Clear cutting doubled the percentage of subsurface flow at shallow depths, and increased K^+ concentration in shallow subsurface flow and NO_3^- concentrations in both shallow and deep flow. The percentage change in total Ca^{2+} , SO_4^{2-} , and HCO_3^- flux in shallow depths was less than the change in water flux, while that of K^+ and NO_3^- flux was greater. Relative to the control, in the clear cut the percentage of total Ca^{2+} flux at shallow depths increased from 5% to 12%, SO_4^{2-} 5.4 to 12%, HCO_3^- from 5.6 to 8.7%, K^+ from 6 to 35%, and NO_3^- from 2.7 to 17%. The increases in Ca^{2+} and SO_4^{2-} flux were proportional to the increase in water flux, the flux of HCO_3^- increased proportionally less than water flux, and NO_3^- and K^+ were proportionally greater than water flux. Increased subsurface flow accounted for most of the increase in non-limiting nutrient loss. For limiting nutrients, loss of plant uptake and increased shallow subsurface flow accounted for the greater loss. Seasonal ion concentration patterns in streamwater and subsurface flow were similar.

ALAKSAN NATIONAL PARKS

Fishgut Watershed: This year we continued monitoring basic watershed processes, conducted an intensive study of the effect of increased temperature on net and gross nitrogen mineralization/nitrification rates and soil respiration, examined basic soil and climate variation along a chronosequence, established a gradient of climate and soil monitoring stations throughout the watershed, and began to quantify the possible role of N fixers on the watershed N budget. Most of this research directly lends itself to the objectives of the GC studies to be initiated the summer of '99.

Publications/Products Produced in FY 98

- Fenn, M. E., M. A. Poth, J. D. Aber, J. S. Baron, B. T. Bormann, D. W. Johnson, A. D. Lemly, S. G. McNulty, D. F. Ryan, and R. Stottlemeyer. 1998. Nitrogen excess in North American ecosystems: predisposing factors, ecosystem responses, and management strategies. *Ecol. Appl.* 8(3):706-733.
- Stottlemeyer, R. 1997. Parks and Preserves. In: *Encyclopedia of Environmental Science*, D. E. Alexander and R. W. Fairbridge, Eds., Van Nostrand Reinhold, New York, N.Y.
- Stottlemeyer, R. 1998. Conservation of coastal barrier national parks: Policy and science. In: *Abstracts of Annual Water Resources Conference*, R. Durrans and S. Nix (eds), American Water Resources Association, Herndon, VA, p. 105.
- Stottlemeyer, R. 1998. Effect of climate change on C:N pools in a boreal watershed ecosystem. Annual Progress Report to USGS Biological Resources Division Global Change Research Program, Western Great Lakes Biogeographic Area, submitted to Missouri Field Station, Univ. Missouri-Columbia, Columbia, MO, 4 p. (Research Report)
- Stottlemeyer, R., and R. Herrmann. 1998. Seasonal change in precipitation, snowpack, snowmelt, soil and stream water chemistry in a Northern Michigan Watershed. *EOS* 79(45):321.
- Stottlemeyer, R., and R. Herrmann. 1998. Long-term boreal watershed ecosystem research, Isle Royale National Park, MI. *EOS* 79(17):S128.
- Stottlemeyer, R., and R. Herrmann. 1999. Boreal ecosystem response to atmospheric nitrogen inputs and climate change. In: *Disturbance in Boreal Forest Ecosystems: Human Impacts and Natural Processes*, U.S. Forest Service Gen. Tech. Rept. (in press), 18 pages, 9 figures.
- Stottlemeyer, R., and D. Toczydlowski. 1998. Fate of atmospheric inputs in a Boreal Ecosystem: Isle Royale National Park, Michigan. Res. Rept. #74 submitted to Dr. Raymond Herrmann, Program Manager, Watershed Research Program, National Biological Service, Colorado State Univ., Ft. Collins, CO, 47 p. (research report).
- Stottlemeyer, R., and D. Toczydlowski. 1998. Long-term Study of Boreal Watershed/Lake Ecosystems, Michigan; Fraser Experimental Forest, CO; and Alaska. Res. Rept. #73 submitted to Dr. Raymond Herrmann, Program Manager, Watershed Research Program, U.S. Geologic Survey, Colorado State Univ., Ft. Collins, CO, 15 p. (research report).
- Stottlemeyer, R., and D. Toczydlowski. 1998. Long-term Study of Boreal Watershed/Lake Ecosystems, Michigan; Fraser Experimental Forest, CO; and Alaska. Five Year Research Plan for 1998-2002. Res. Rept. #76 submitted to Dr. Raymond Herrmann, Program Manager, Watershed Research Program, National Biological Service, Colorado State Univ., Ft. Collins, CO, 16 p. (research report).
- Stottlemeyer, R., and D. Toczydlowski. 1998. Nitrogen mineralization in a mature boreal forest, Isle Royale, Michigan. *J. Environ. Qual.* (in press), 29 pages, 6 figures, 3 tables.
- Stottlemeyer, R., and D. Toczydlowski. 1998. Relationships between precipitation, soil, and streamwater nitrogen, Isle Royale, Michigan. Res. Rept. #71 submitted to Dr. Raymond Herrmann, Biological Resources Division, U.S. Geological Survey, Ft. Collins, CO, 42 p.

- Stottlemeyer, R., and D. Toczydlowski. 1998. Seasonal relationships between precipitation, soil, and streamwater nitrogen, Isle Royale, Michigan. *J. Soil Sci. Soc. Amer.* (in press), 27 pages, 8 figs, 2 tables.
- Stottlemeyer, R., and D. Toczydlowski. 1998. Soil nitrogen cycling in a mature boreal forest, Isle Royale, Michigan. Res. Rept. #72 submitted to Dr. Raymond Herrmann, Program Manager, Watershed Research Program, U. S. Geological Survey, Colorado State Univ., Ft. Collins, CO, 39 p. (research report)
- Stottlemeyer, R., and D. Toczydlowski. 1998. Trends in precipitation, snowpack, snowmelt, soil and streamwater chemistry in a Northern Michigan watershed. In: *Snow Hydrology: The Integration of Physical, Chemical, and biological Systems*. J. Hardy, M. Albert, and P. Marsh (eds), Cold Regions Research and Engineering Lab. Spec. Rept. 98-10, p. 18.
- Stottlemeyer, R., and D. Toczydlowski. 1998. Trends in precipitation, snowpack, snowmelt, soil and streamwater chemistry in a Northern Michigan watershed. Res. Rept. #75 submitted to Dr. Raymond Herrmann, Program Manager, Watershed Research Program, National Biological Service, Colorado State Univ., Ft. Collins, CO, 28 p. (research report).
- Stottlemeyer, R., D. Toczydlowski, and R. Herrmann. 1998. Biogeochemistry of a mature boreal ecosystem: Isle Royale National Park, Michigan. *National Park Service Scient. Monogr. No.* (in press), 108 pages, 29 figures, 17 tables.
- Stottlemeyer, R., and C. A. Troendle. 1998. Effects of canopy removal on snowpack, soil solution, and nutrient export, Fraser Experimental Forest, CO. *Ecol. Soc. Amer. Abstracts*, p. 220.
- Stottlemeyer, R., and C. A. Troendle. 1998. Linkages between seasonal subsurface flow and streamwater chemistry, Fraser Experimental Forest, CO. Res. Rept. #78 submitted to Dr. Raymond Herrmann, Program Manager, Watershed Research Program, National Biological Service, Colorado State Univ., Ft. Collins, CO, 25 p. (research report).
- Stottlemeyer, R., and C. A. Troendle. 1998. Long-term effects of subalpine canopy removal on snowpack, soil solution, and nutrient export, Fraser Experimental Forest, CO. In: *Snow Hydrology: The Integration of Physical, Chemical, and biological Systems*. J. Hardy, M. Albert, and P. Marsh (eds), Cold Regions Research and Engineering Lab. Spec. Rept. 98-10, p. 72
- Stottlemeyer, R., and C. A. Troendle. 1998. Long-term effects of subalpine canopy removal on snowpack, soil solution, and nutrient export, Fraser Experimental Forest, CO. *Hydrol. Process.* (in press), 18 pages, 5 figures.
- Stottlemeyer, R., and C. A. Troendle. 1998. Long-term effects of subalpine canopy removal on snowpack, soil solution, and nutrient export, Fraser Experimental Forest, CO. Res. Rept. #76 submitted to Dr. Raymond Herrmann, Program Manager, Watershed Research Program, National Biological Service, Colorado State Univ., Ft. Collins, CO, 25 p. (research report).
- Suarez, F., D. Binkley, M. Kaye, and R. Stottlemeyer. 1998. Expansion of forest stands into tundra in the Noatak National Preserve, Northwest Alaska. *Ecoscience* (in press).
- Toczydlowski, D., and R. Stottlemeyer. 1998. Long-term change in soil and streamwater chemistry during snowmelt, Northern Michigan. *Ecol. Soc. Amer. Abstracts*, p. 223.

Deliverables in FY 99

We anticipate the following papers will be submitted for publication.

Long-term change in precipitation, snowpack, snowmelt, soil and streamwater chemistry in a Northern Michigan watershed (Calumet data). Submit to Amer. Water Resour. Assoc. J.

Seasonal change in precipitation, snowpack, snowmelt, soil and streamwater chemistry, Northern Michigan. Submit to Hydrol. Process.

Relationship between geology, land form, and surface water chemistry, Denali National Park and Preserve, Alaska. Submit to Arct. Alp. Res.

Long-term effects of subalpine canopy removal on precipitation inputs, snowpack, and snowpack chemistry, Fraser Experimental Forest. Submit to J. Hydrol.

Net and gross nitrogen mineralization and nitrification rates in young and old-growth Englemann spruce and subalpine fir, Fraser Experimental Forest, Colorado. Submit to the Soil Sci. Soc. Amer. J.

Long-term change in subalpine snowpack and snowpack ion loading with elevation, Fraser Experimental Forest, Colorado. Submit to the J. Environ. Qual.

Relationships between terrestrial nitrogen processes and streamwater export in a treeline watershed, Alaska. Submit to Soil Sci. Soc. Amer. J. A series of related papers will also be submitted on this watershed.

The nitrogen cycle and budget for an alpine-subalpine watershed in the Central Rocky Mountains. MS thesis, Utah State University (and will be submitted for publishing next year as separate papers).

Presentations at national scientific meetings. One presentation will be made at the AGU fall conference, two presentations at the Ecological Society of America, and several at regional science conferences.

Budget for 1999

Equipment:

None

Supplies:

General lab and field supplies	\$ 4,000.00
Travel for technicians	1,500.00
Supplies f/ inorganic N studies	1,525.00

Sub total \$ 7025.00

Student and Technician Costs:

Technician (1 yr)	\$35,000.00
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Sub total \$35,000.00

Sample Analyses: Most of these will be conducted at CSU/USFS Lab.

Inorganic sample analyses (our laboratory)	
245 samples @ \$25	\$ 6,125.00

SEKI inorganic sample analyses (380 samples)	9,500.00
DOC analyses (300 samples)	1,500.00

BIBE inorganic sample analyses (80 samples)	2,000.00
ROMO (Loch Vale) sample analyses (162 samples)	4,050.00

Sub total \$23,175.00

Overhead: 15% of \$65,200.00 total or \$ 9,800.00

Total Costs \$ 75,000.00