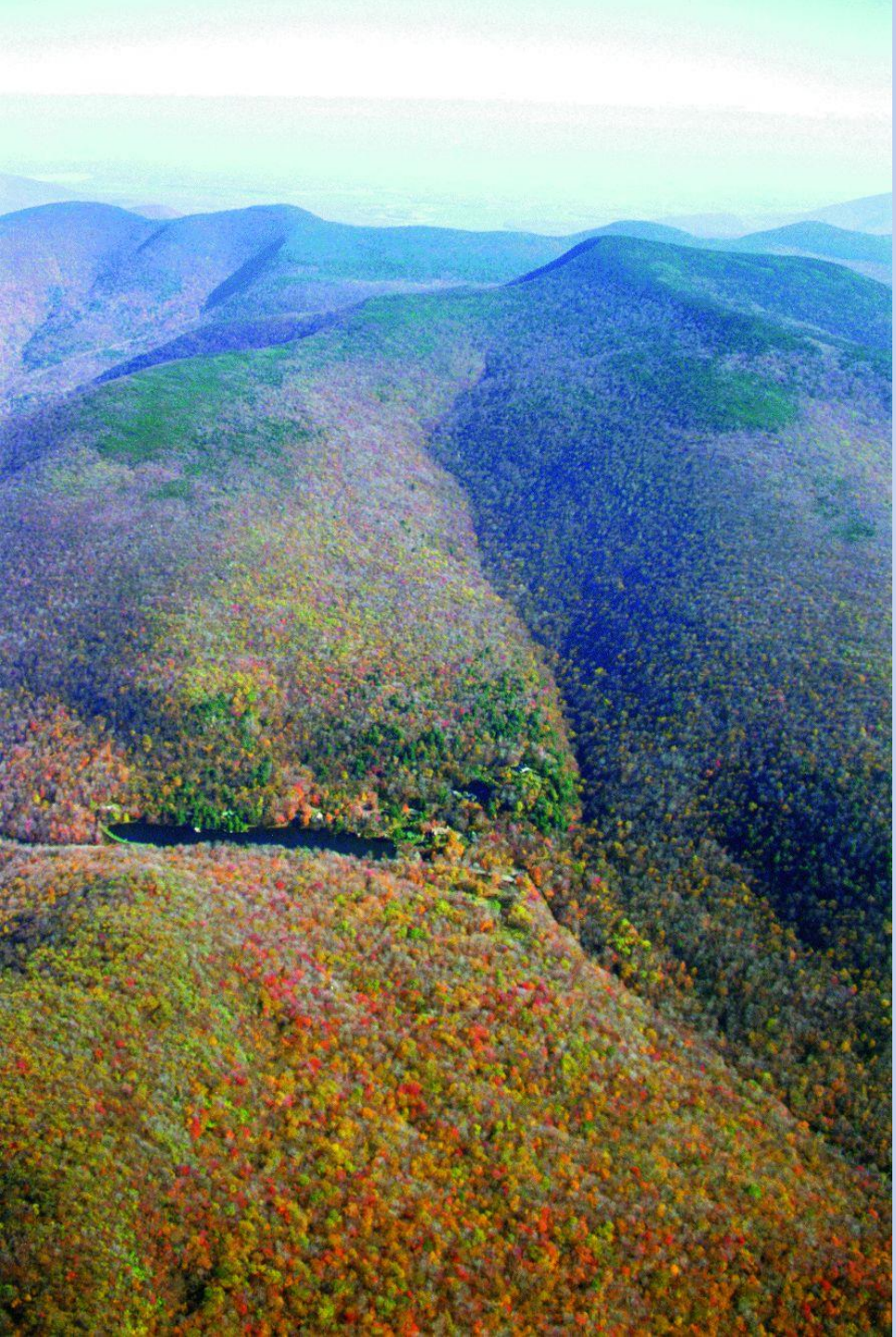


Catskill Trends

Mike McHale, Doug Burns, Jason Siemion,
Mike Antidormi, Greg Lawrence
U.S. Geological Survey, Troy NY

USGS
science for a changing world

New York City's Water Supply System

Catskill/Delaware Watersheds

Oneonta
Gilboa
ALBANY COUNTY
Delhi
DELAWARE COUNTY
Schoharie Reservoir
Schoharie Tunnel
Catskill Aqueduct
GREENE COUNTY
COLUMBIA COUNTY
NEW YORK
MASSACHUSETTS
Hunter
Cannonsville Reservoir
Walton
Pepacton Reservoir
Downsville
Phoenicia
Ashokan Reservoir
Esopus Creek
Kingston
Deposit
West Branch Delaware
East Branch Delaware
West Delaware Tunnel
East Delaware Tunnel
Hudson River
DUTCHESS COUNTY
CONNECTICUT
Neversink Reservoir
Rondout Reservoir
ULSTER COUNTY
Catskill Aqueduct
Liberty
Neversink Tunnel
Poughkeepsie
Delaware Aqueduct
Delaware River
SULLIVAN COUNTY
Ellenville
100 Miles
75 Miles
Neversink River
PUTNAM COUNTY
ORANGE COUNTY
West Branch Reservoir
New Croton Reservoir
PENNSYLVANIA
50 Miles
ROCKLAND COUNTY
Hudson River
WESTCHESTER COUNTY
CONNECTICUT
Kensico Reservoir
25 Miles (from City Hall)
NEW YORK
NEW JERSEY
New Croton Aqueduct
White Plains
Hillview Reservoir
Jerome Park Reservoir
Long Island Sound
Bronx
Manhattan
Queens
NASSAU COUNTY
Brooklyn
Staten Island
New York Bay
Atlantic Ocean

Croton Watershed

Boyds Corner Reservoir
Lake Gleneida
Middle Branch Reservoir
Lake Oscaud
Bog Brook Reservoir
East Branch Reservoir
Kirk Lake
Croton Falls Reservoir
Diverting Reservoir
Amawalk Reservoir
Titicus Reservoir
Cross River Reservoir
Muscoot Reservoir

DEP
New York City Department of Environmental Protection

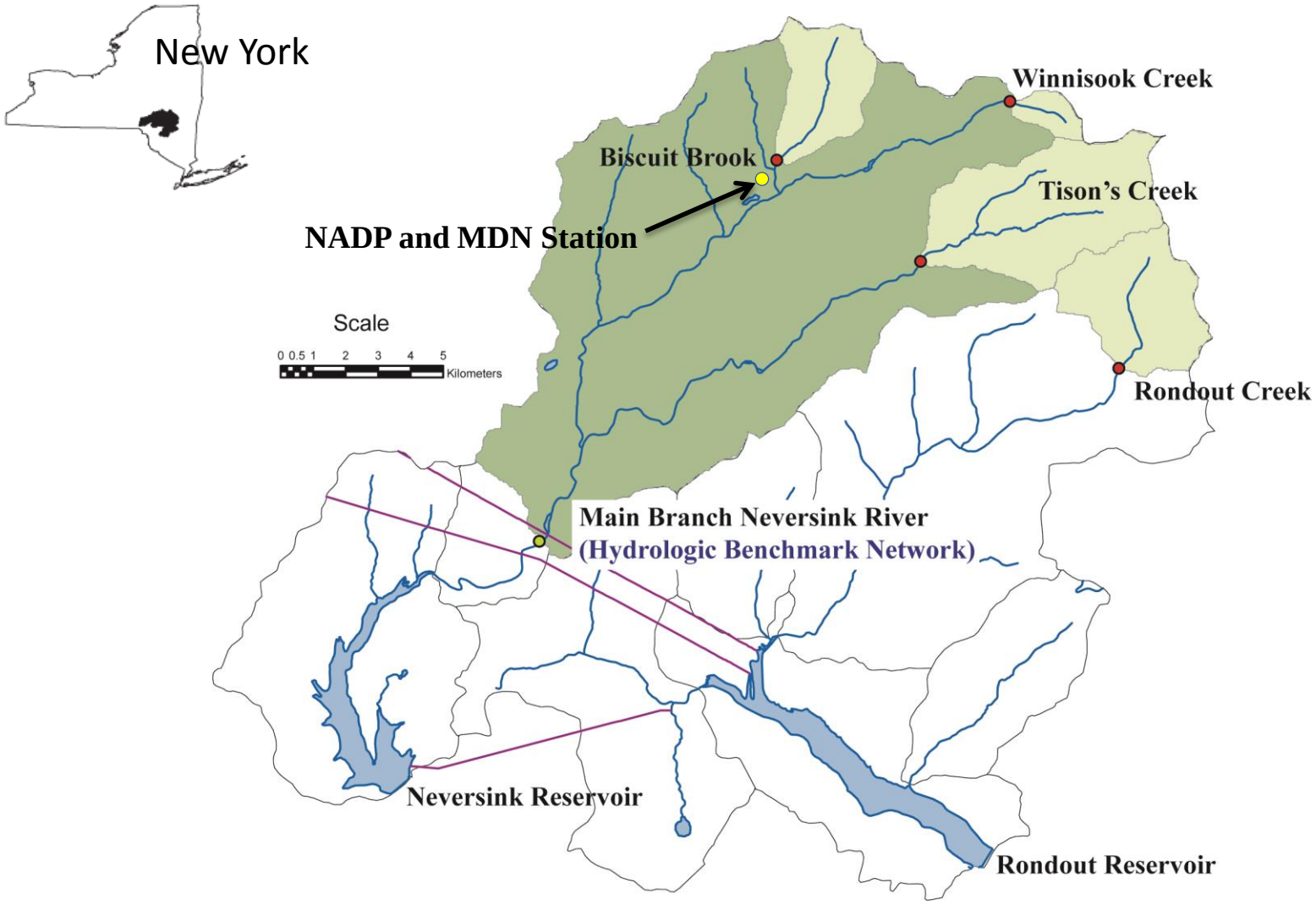
2008 NEW YORK CITY WATER TUNNELS AND DISTRIBUTION AREAS

Hillview Reservoir
NY City Line
Jerome Park Reservoir
Hudson River
New Croton Aqueduct
Bronx
Long Island Sound
City Tunnel 3 Stage 1 Manhattan Section
East River
Manhattan
City Tunnel 1
City Tunnel 2
Queens
Richmond Tunnel
Brooklyn
Staten Island
Lower New York Bay

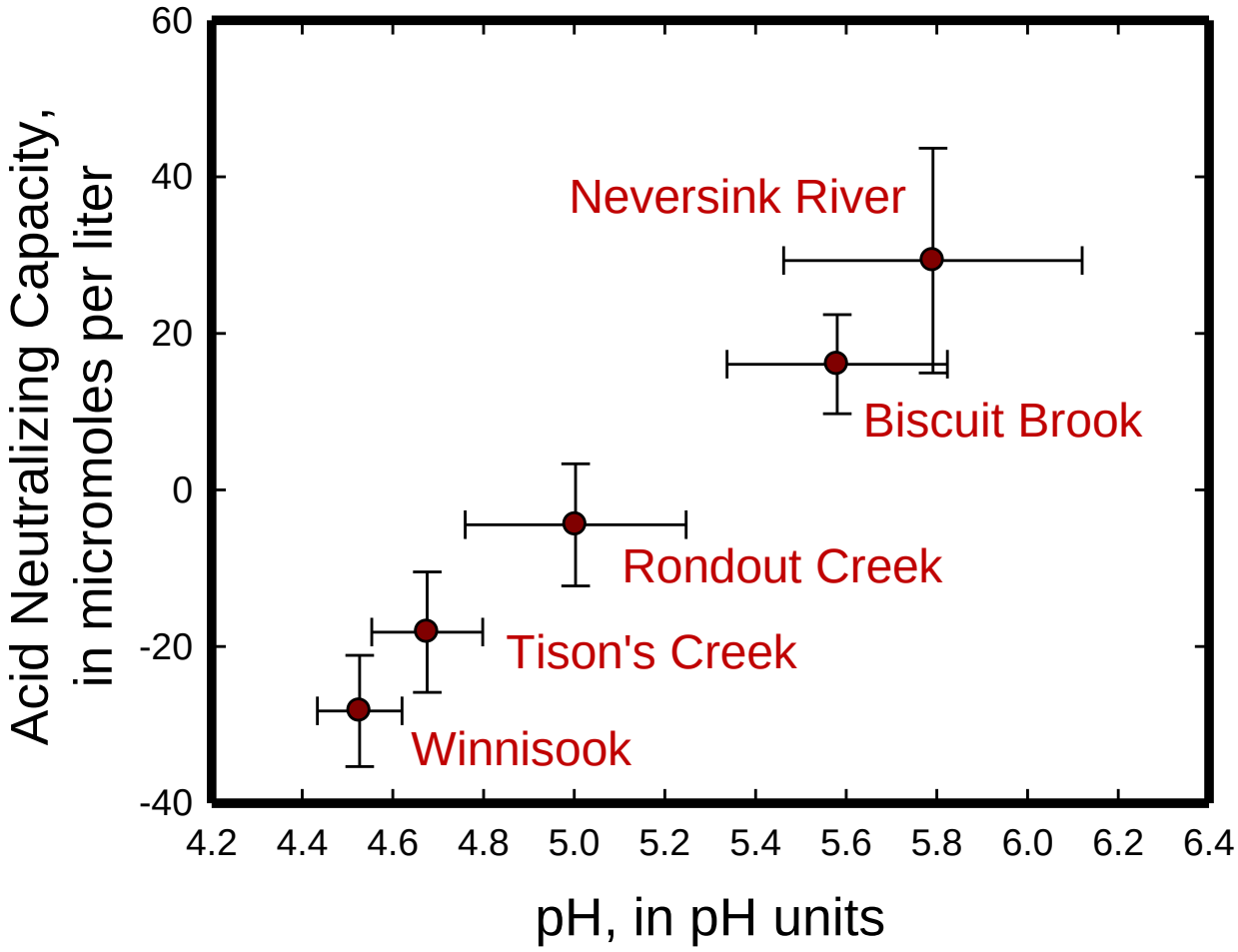
Catskill / Delaware water service area
Croton water service area (when in full operation)
Groundwater service area (when in operation)

NYCDEP/BCOA/AJ 4/09

Catskill LTM Network



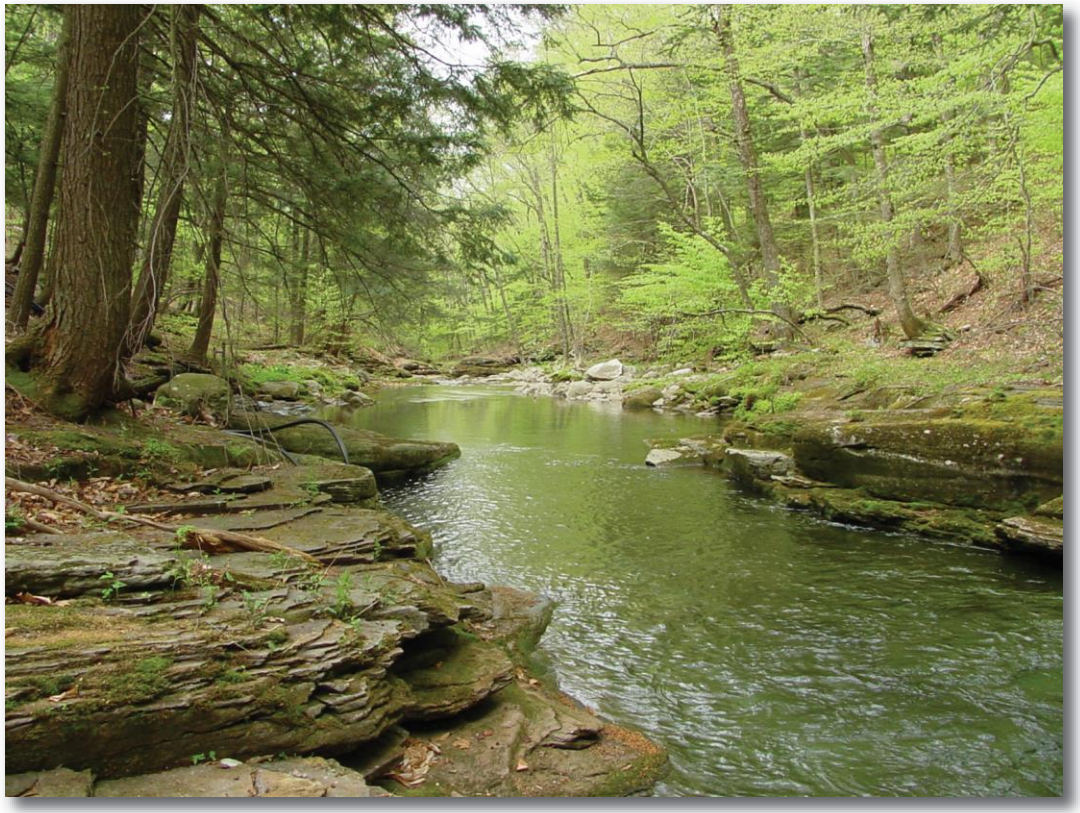
Mean Acidity 1991-2014



Catskill Sampling

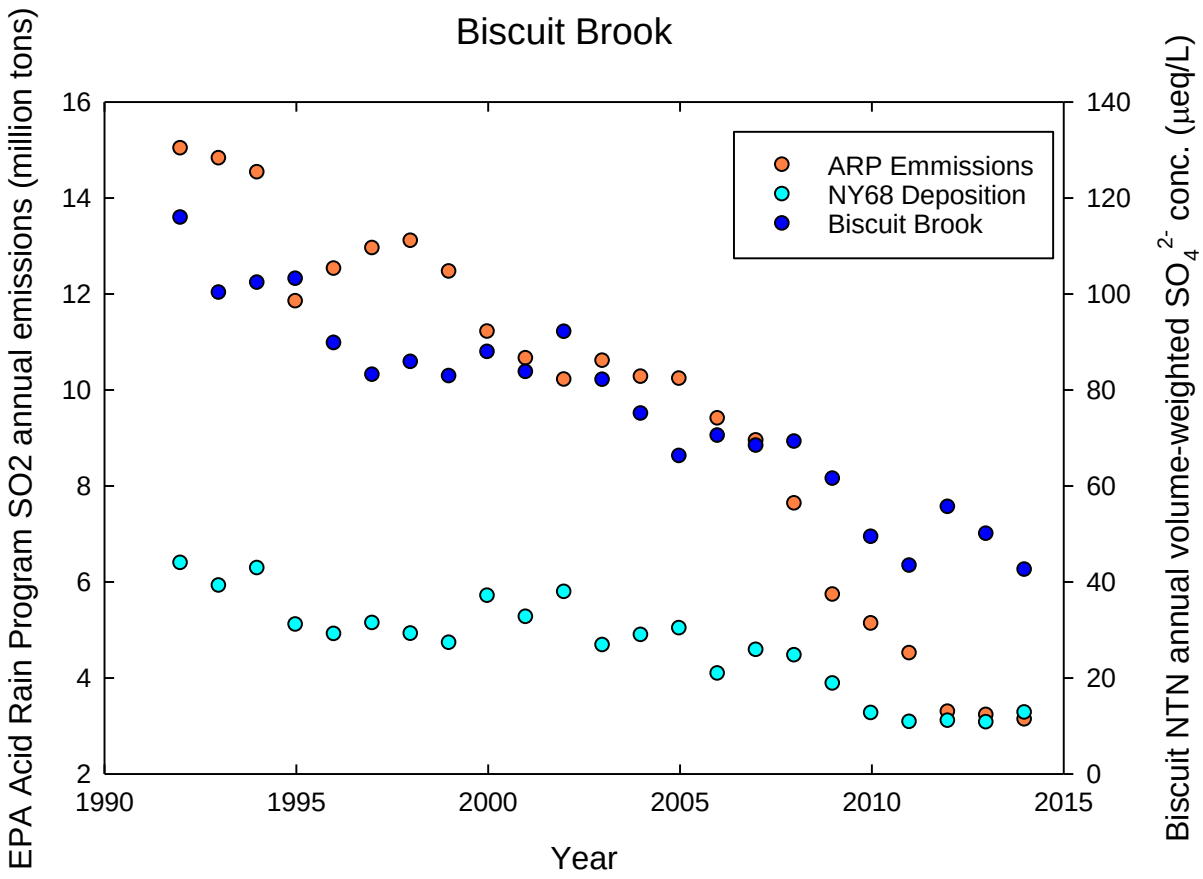
- Water sampling at 5 streams in the Catskill Mountains
- Monthly sampling plus storms
  - ~ 35 samples per year
- Winnisook soils were sampled in 1993 (Javier Ruiz) and 2012 (McHale).
- Fall Brook Soils were sampled in 2001 (Lawrence) and 2011 (Lawrence and others).
- There is an NADP site at Biscuit Brook

Winnisook Watershed (WN) on the slopes of Slide Mountain in the headwaters of the Neversink River basin

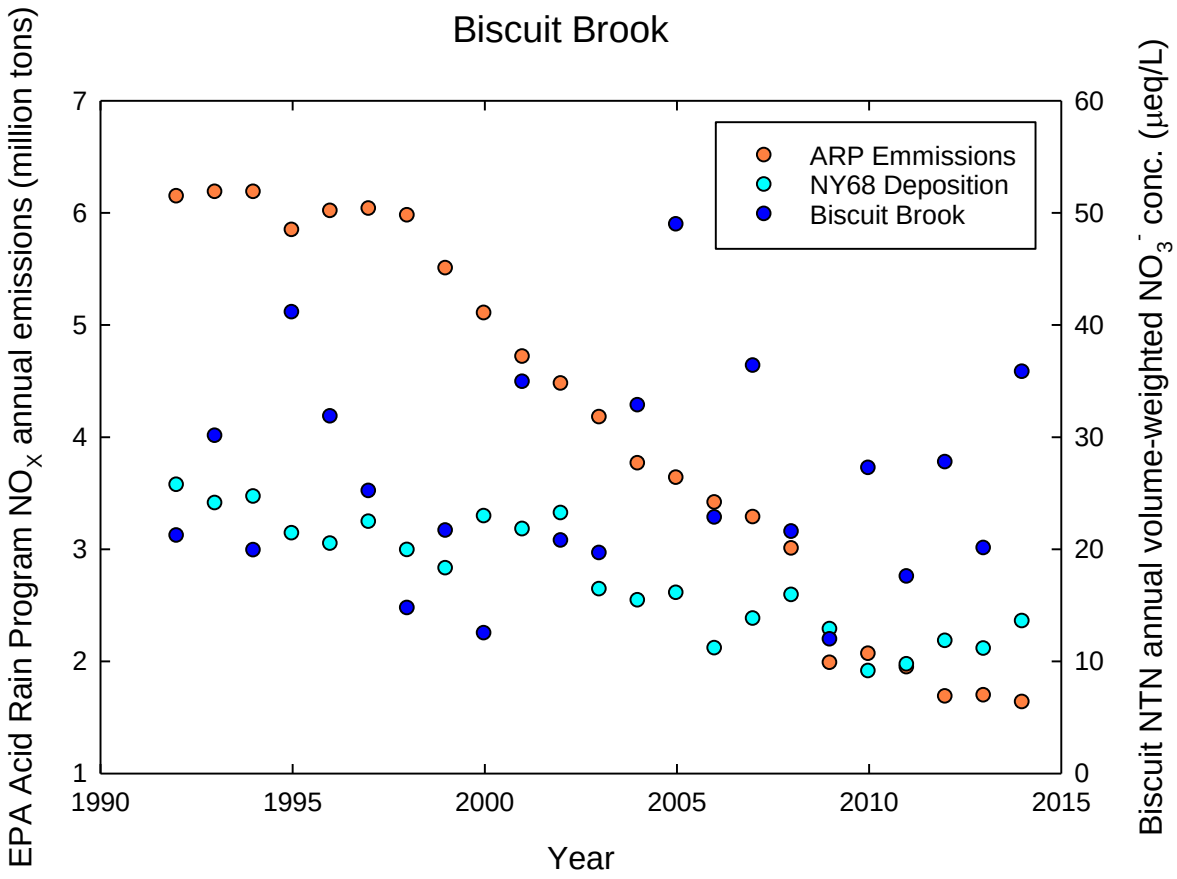


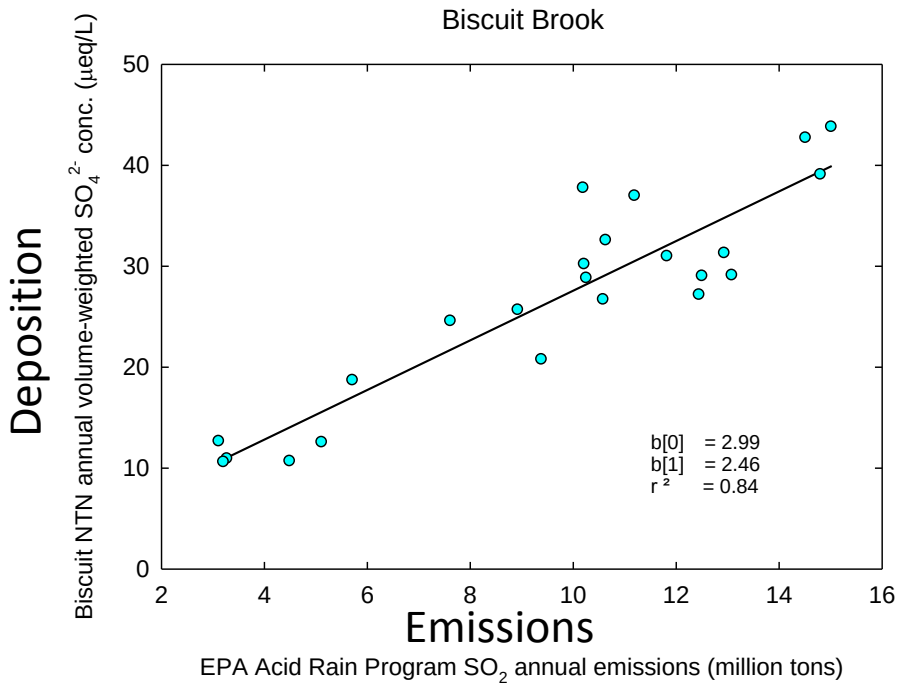
Rondout Creek above Peekamoose (RC)

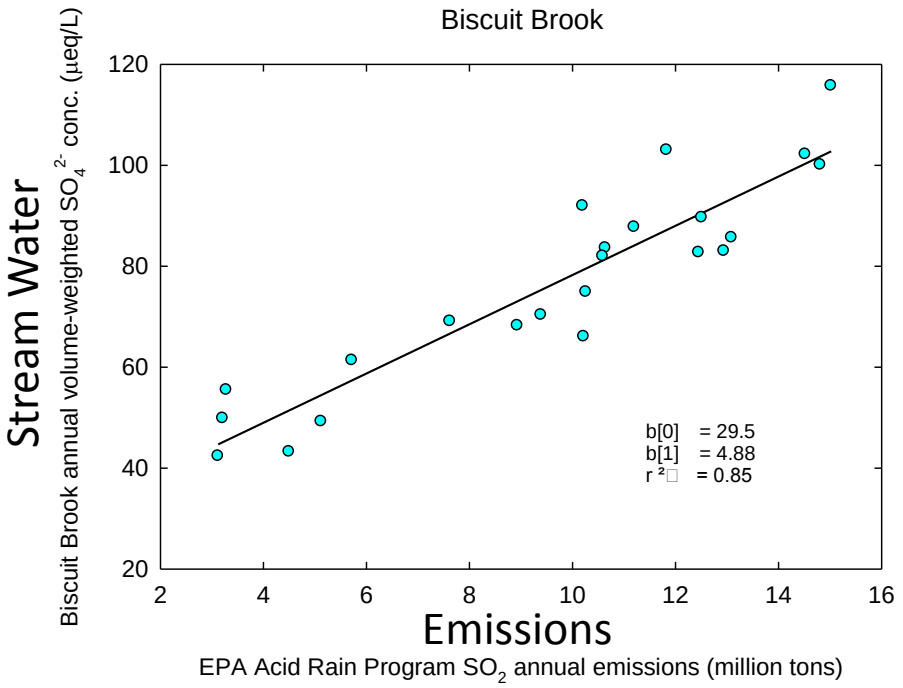
Sulfur

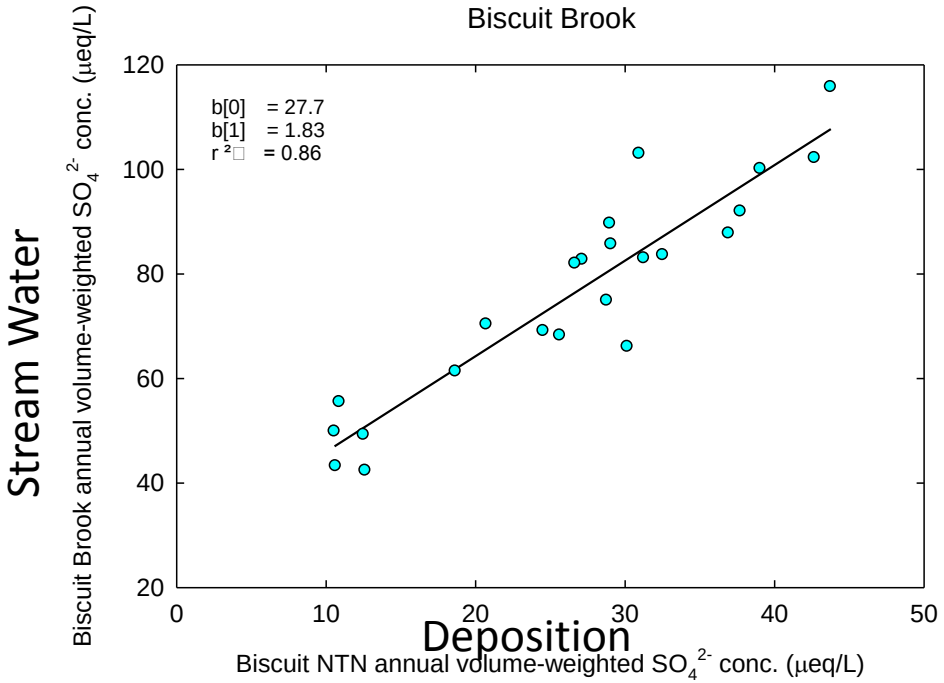

Biscuit Brook
EPA Acid Rain Program SO2 annual emissions (million tons)
Biscuit NTN annual volume-weighted SO_4^{2-} conc. (µeq/L)
Year
ARP Emmissions
NY68 Deposition
Biscuit Brook
16
14
12
10
8
6
4
2
140
120
100
80
60
40
20
0
1990
1995
2000
2005
2010
2015

Nitrogen

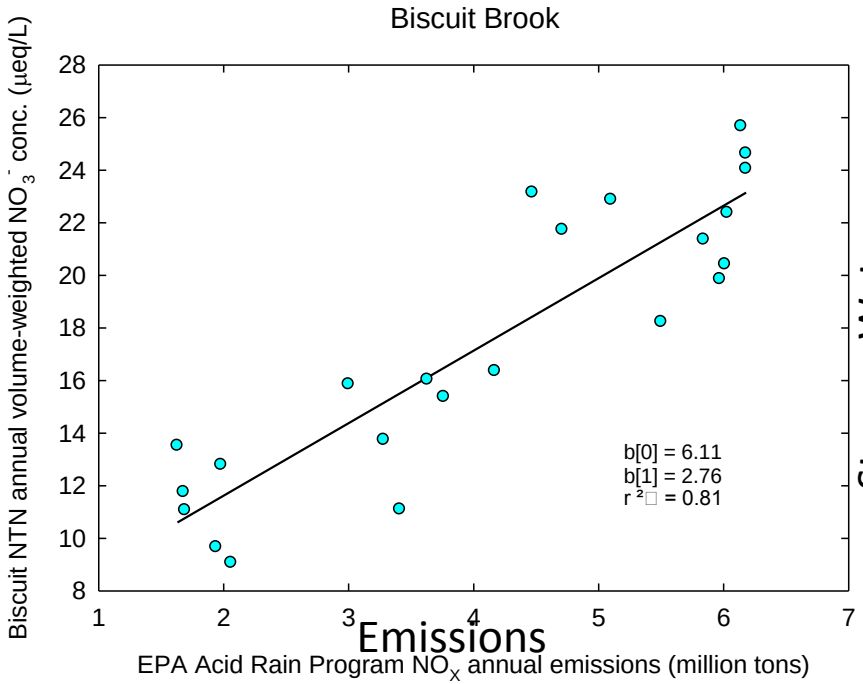

Biscuit Brook
EPA Acid Rain Program NO_X annual emissions (million tons)
Biscuit NTN annual volume-weighted NO_3^- conc. (μeq/L)
Year
ARP Emmissions
NY68 Deposition
Biscuit Brook
1
2
3
4
5
6
7
0
10
20
30
40
50
60
1990
1995
2000
2005
2010
2015

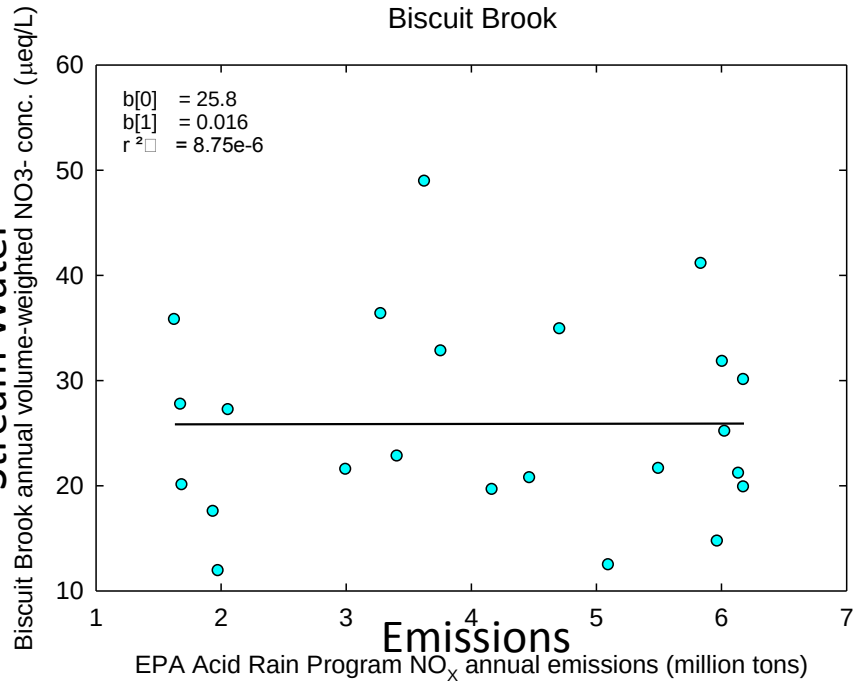

Biscuit Brook
Deposition
Biscuit NTN annual volume-weighted SO_4^{2-} conc. (μeq/L)
Emissions
EPA Acid Rain Program SO_2 annual emissions (million tons)
b[0] = 2.99
b[1] = 2.46
r² = 0.84

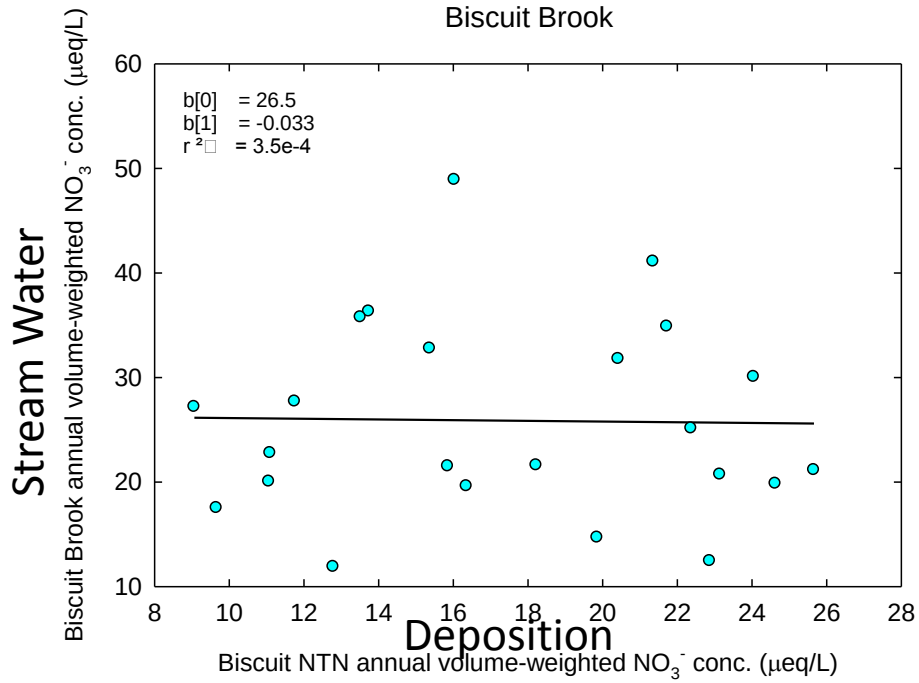

Biscuit Brook
Stream Water
Biscuit Brook annual volume-weighted SO_4^{2-} conc. (μeq/L)
Emissions
EPA Acid Rain Program SO_2 annual emissions (million tons)
b[0] = 29.5
b[1] = 4.88
r² = 0.85


Biscuit Brook
Stream Water
Biscuit Brook annual volume-weighted SO_4^{2-} conc. (μeq/L)
Deposition
Biscuit NTN annual volume-weighted SO_4^{2-} conc. (μeq/L)
b[0] = 27.7
b[1] = 1.83
r² = 0.86

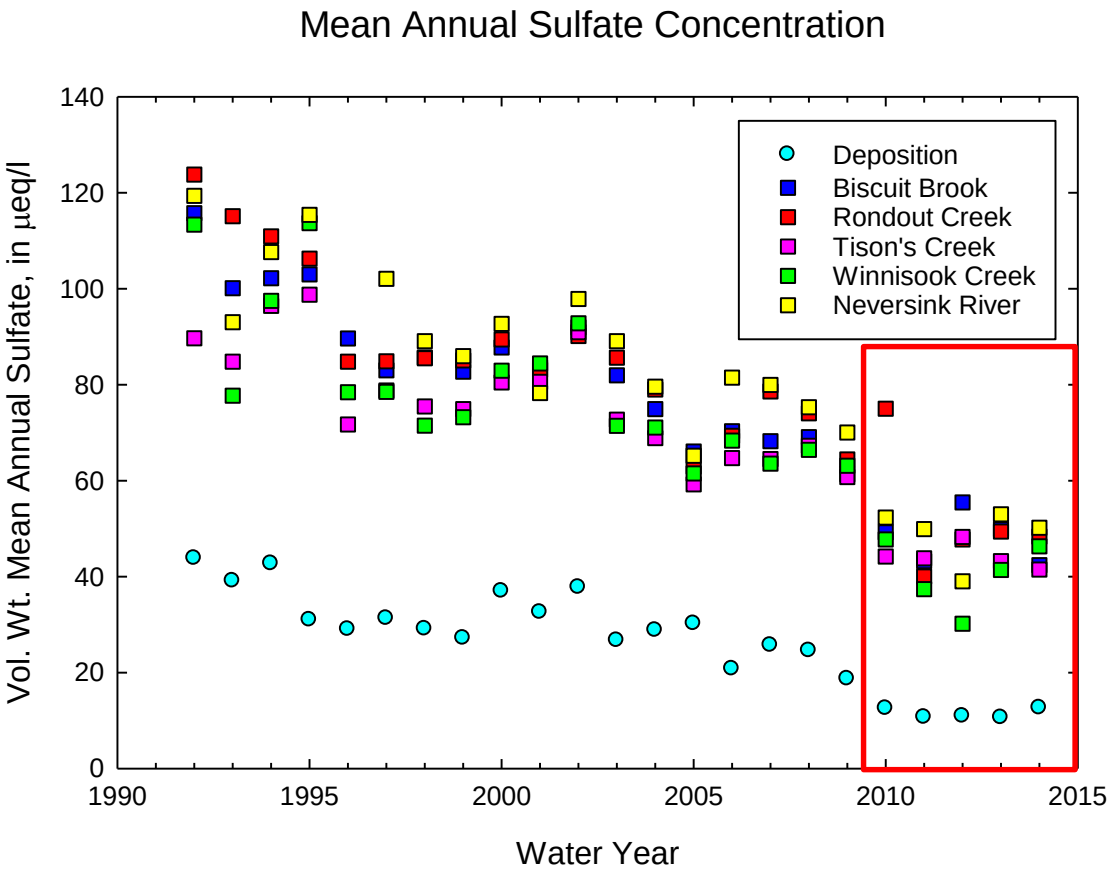
Sulfur

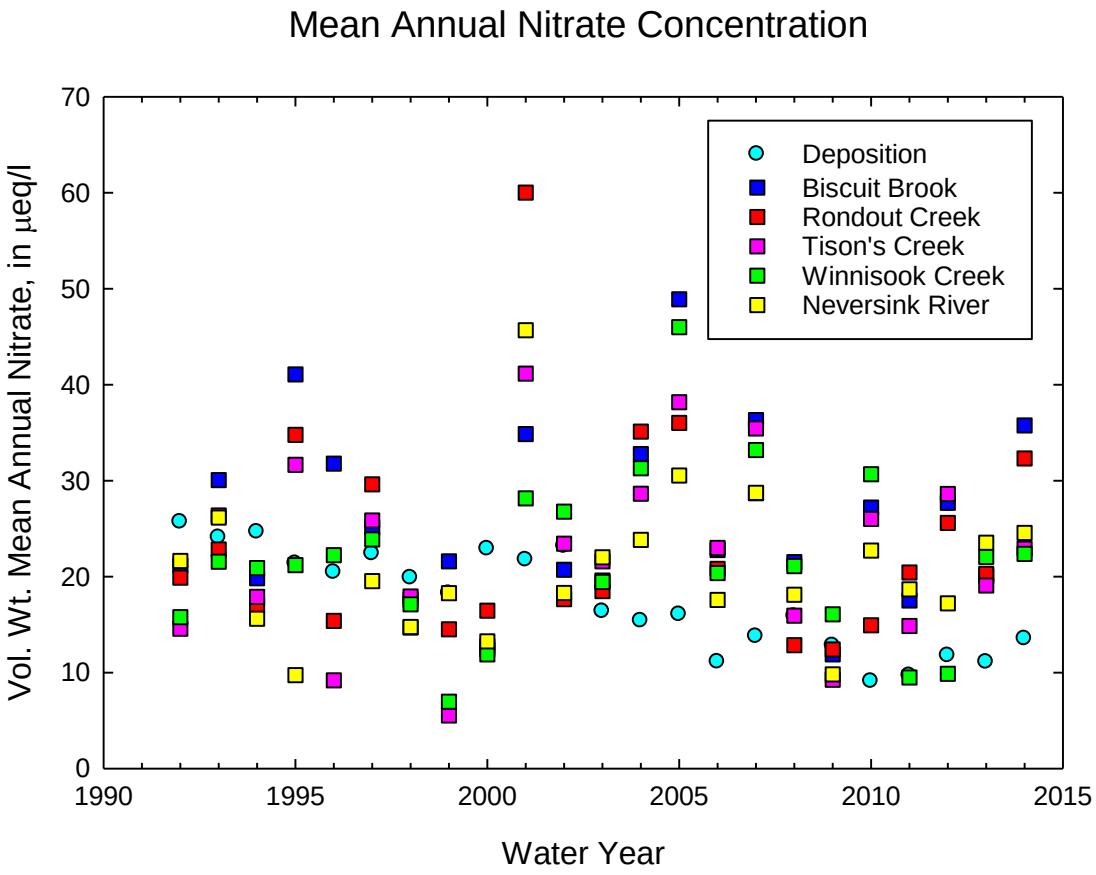

Biscuit Brook
Deposition
Biscuit NTN annual volume-weighted NO3- conc. (μeq/L)
Emissions
EPA Acid Rain Program NOX annual emissions (million tons)
b[0] = 6.11
b[1] = 2.76
r ² = 0.81


Biscuit Brook
Stream Water
Biscuit Brook annual volume-weighted NO3- conc. (μeq/L)
Emissions
EPA Acid Rain Program NOX annual emissions (million tons)
b[0] = 25.8
b[1] = 0.016
r ² = 8.75e-6


Biscuit Brook
Stream Water
Biscuit Brook annual volume-weighted NO3- conc. (μeq/L)
Deposition
Biscuit NTN annual volume-weighted NO3- conc. (μeq/L)
b[0] = 26.5
b[1] = -0.033
r ² = 3.5e-4

Nitrogen


Mean Annual Sulfate Concentration
Vol. Wt. Mean Annual Sulfate, in µeq/l
Water Year
0
20
40
60
80
100
120
140
1990
1995
2000
2005
2010
2015
Deposition
Biscuit Brook
Rondout Creek
Tison's Creek
Winnisook Creek
Neversink River


Mean Annual Nitrate Concentration
Vol. Wt. Mean Annual Nitrate, in µeq/l
Water Year
0
10
20
30
40
50
60
70
1990
1995
2000
2005
2010
2015
Deposition
Biscuit Brook
Rondout Creek
Tison's Creek
Winnisook Creek
Neversink River

Forest Floor

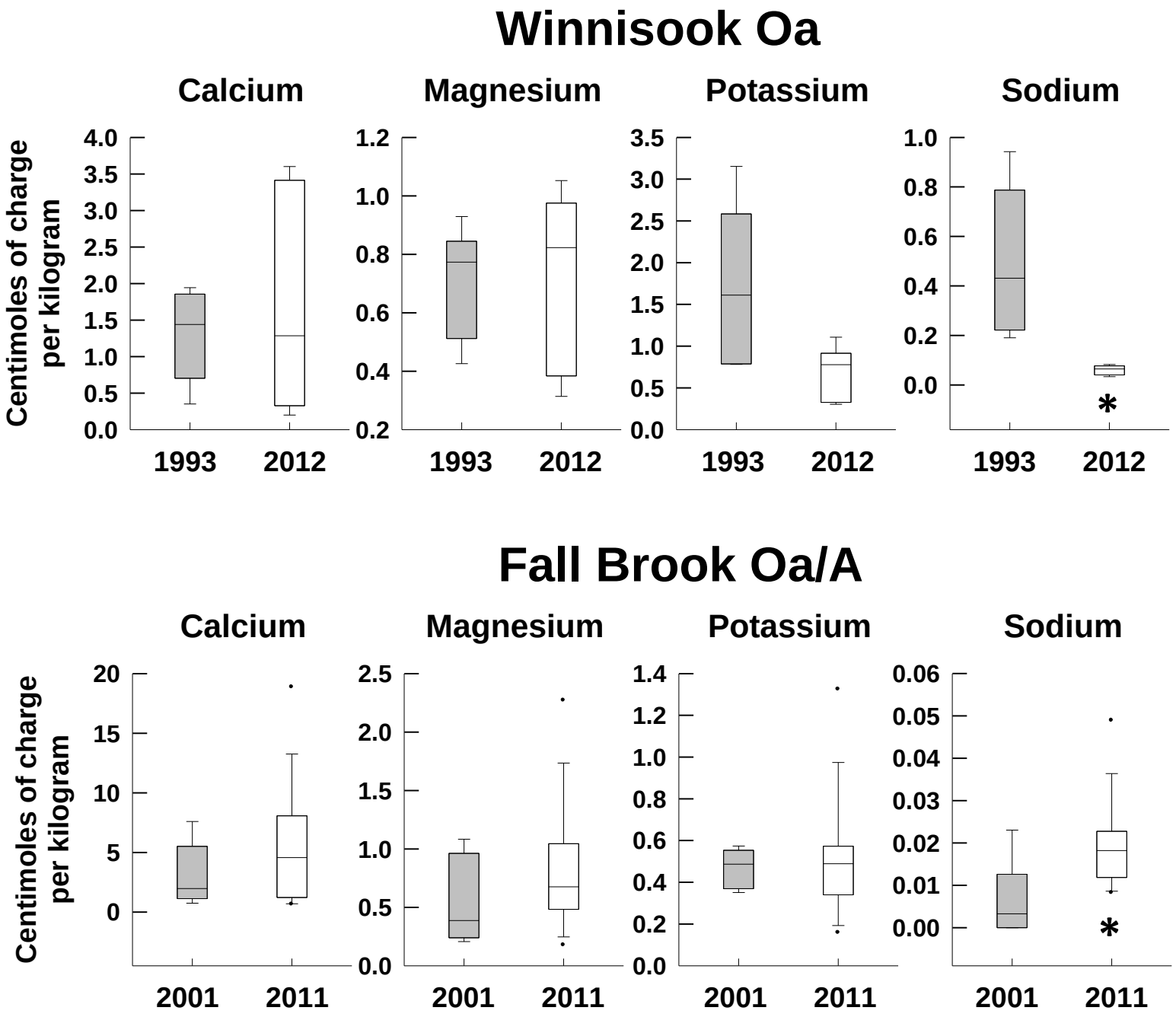
Forest Floor

Spodosol Cake

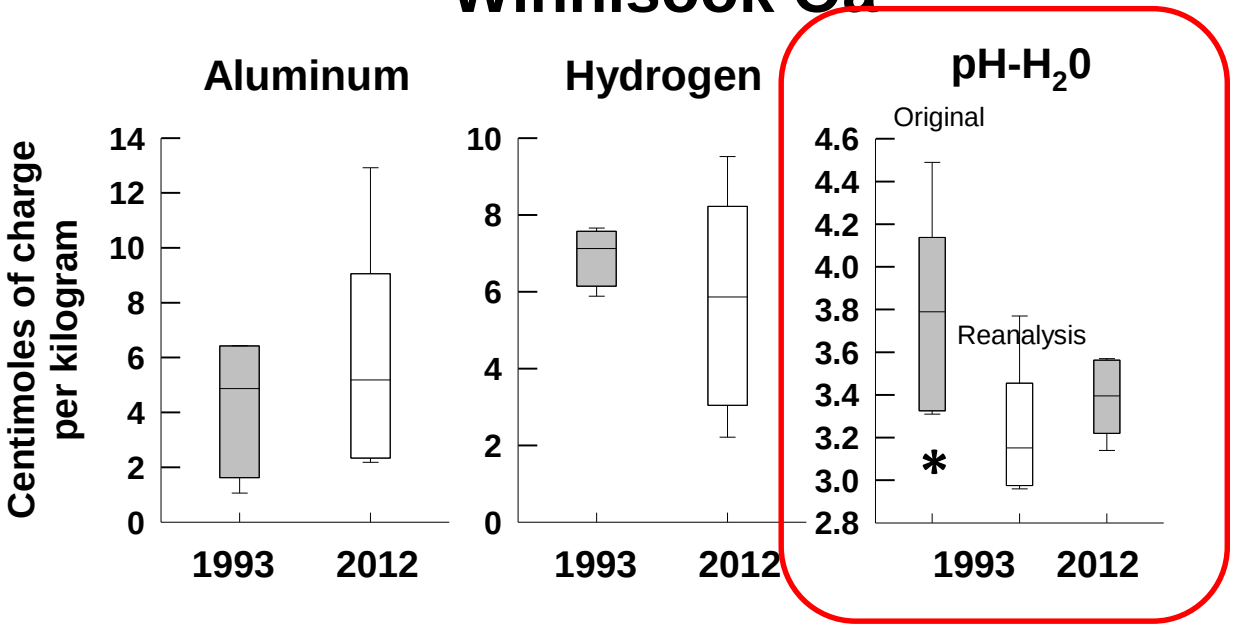
Oa

E

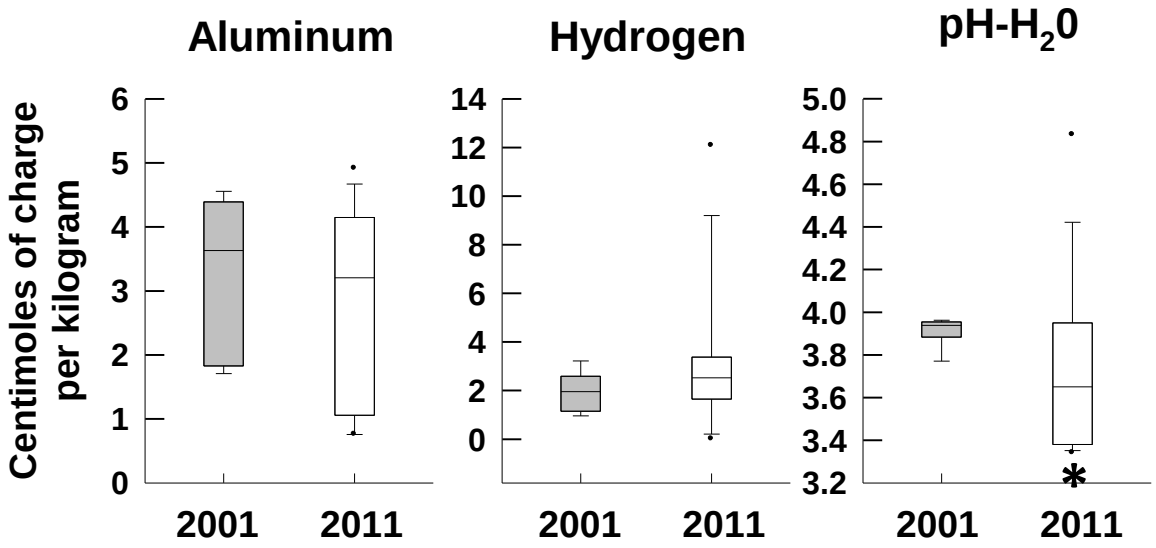
Bs


Winnisook Oa
Calcium
Magnesium
Potassium
Sodium
Centimoles of charge per kilogram
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1.2
1.0
0.8
0.6
0.4
0.2
1.0
0.8
0.6
0.4
0.2
0.0
1993
2012
Fall Brook Oa/A
Calcium
Magnesium
Potassium
Sodium
Centimoles of charge per kilogram
20
15
10
5
0
2.5
2.0
1.5
1.0
0.5
0.0
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.06
0.05
0.04
0.03
0.02
0.01
0.00
2001
2011

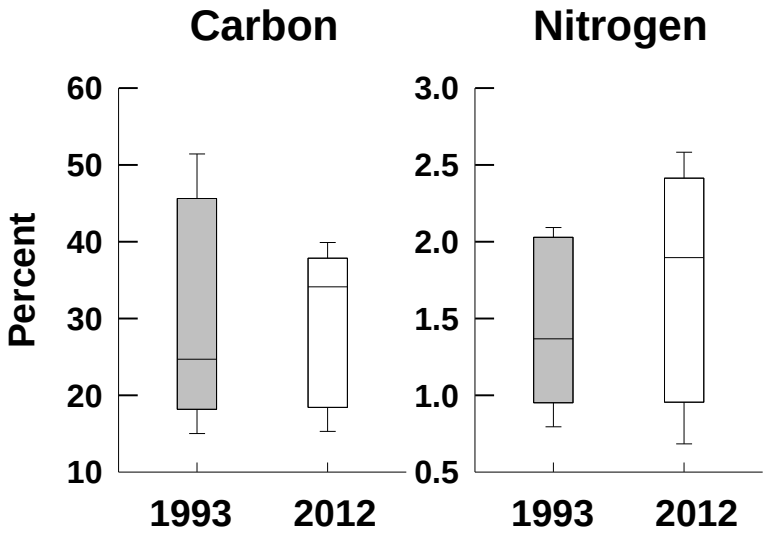
Winnisook Oa



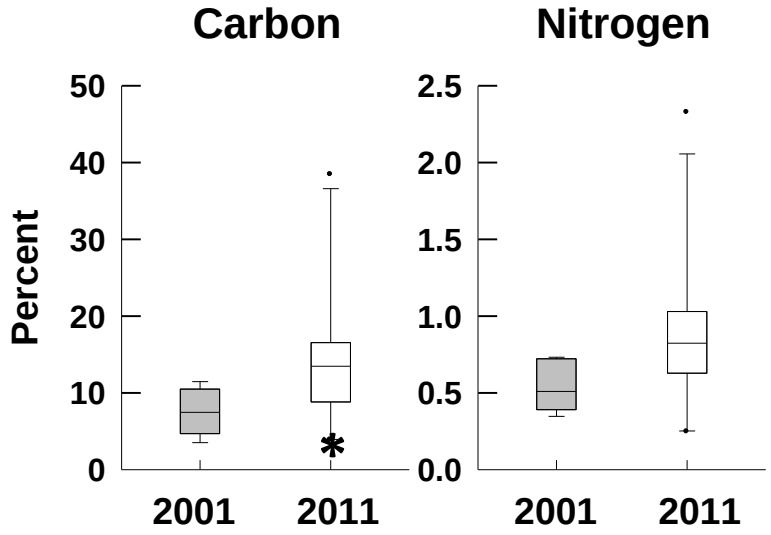
Fall Brook Oa/A



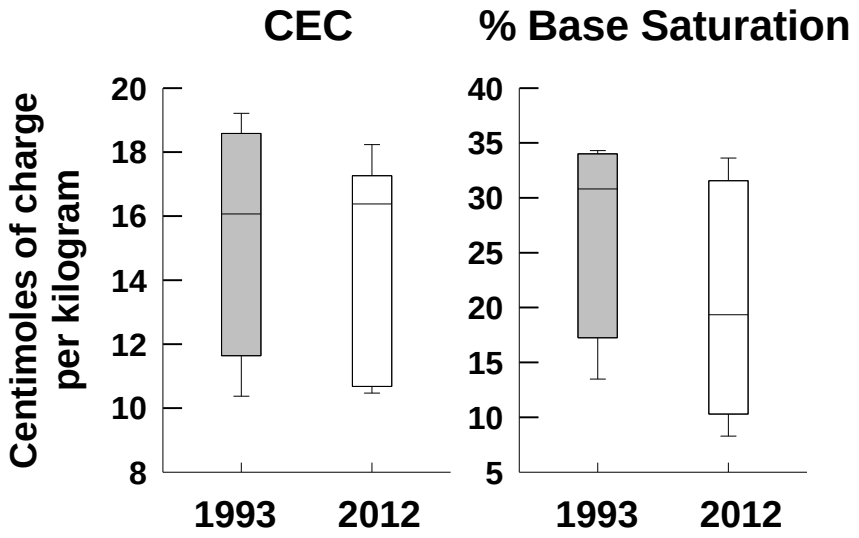
Winnisook Oa



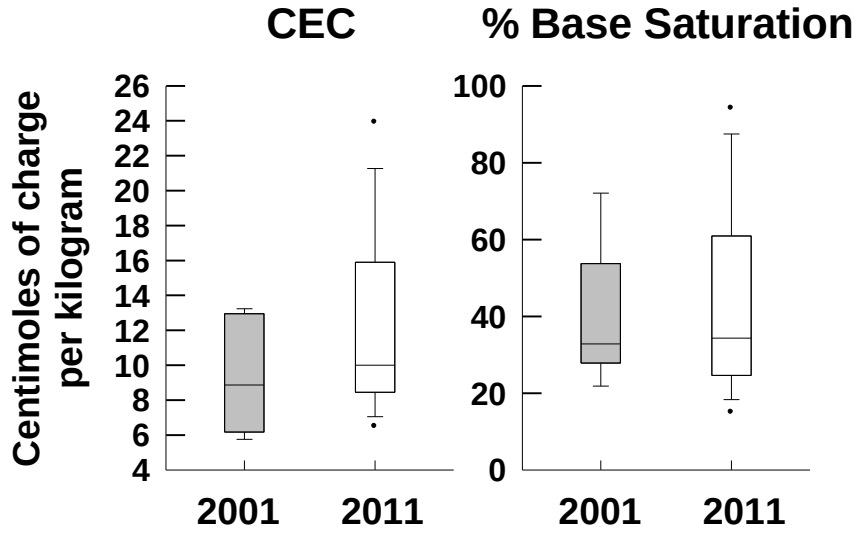
Fall Brook Oa/A



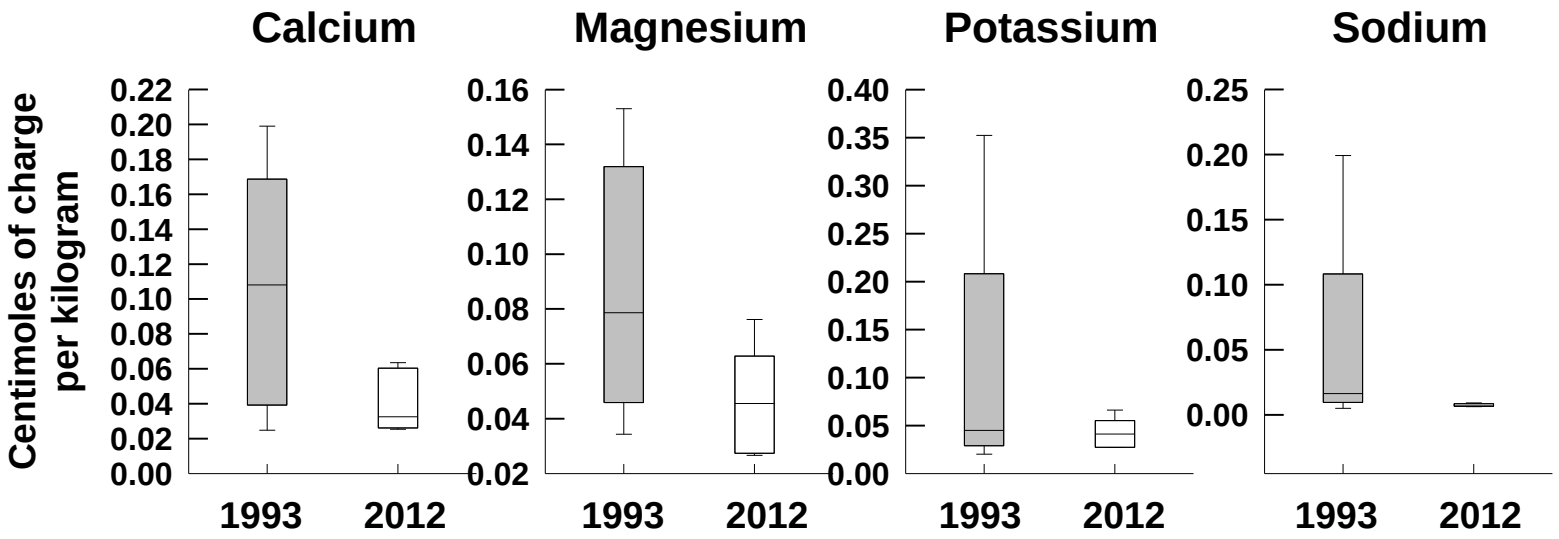
Winnisook Oa



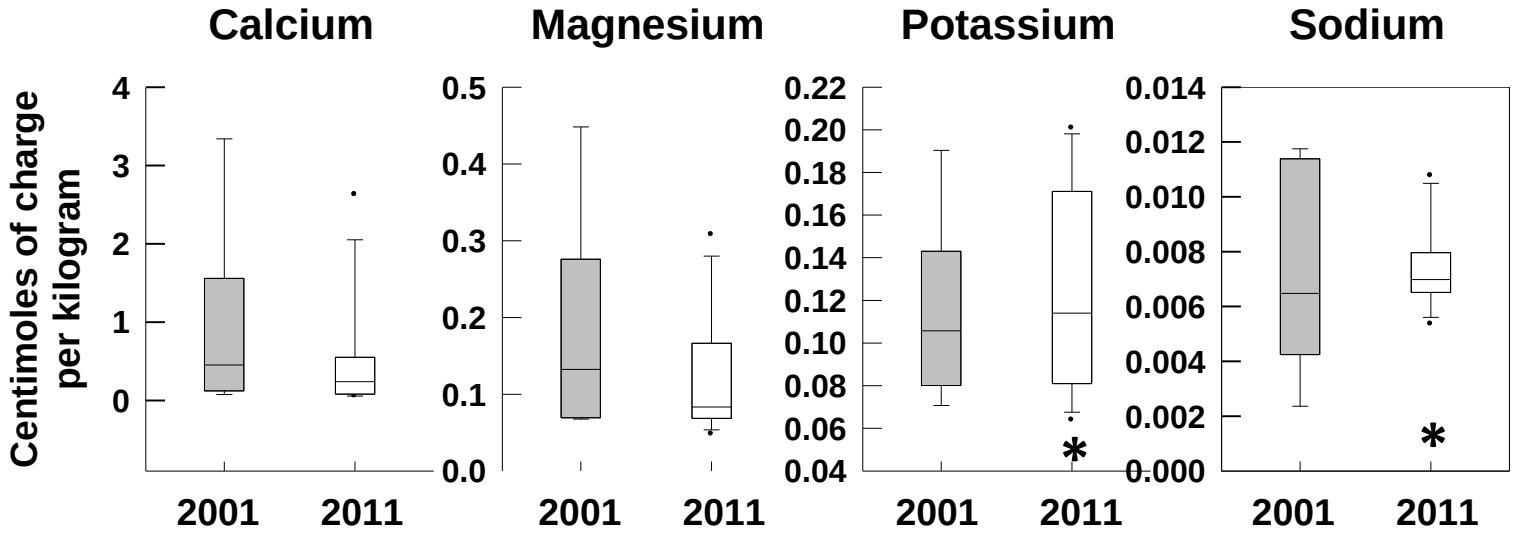
Fall Brook Oa/A



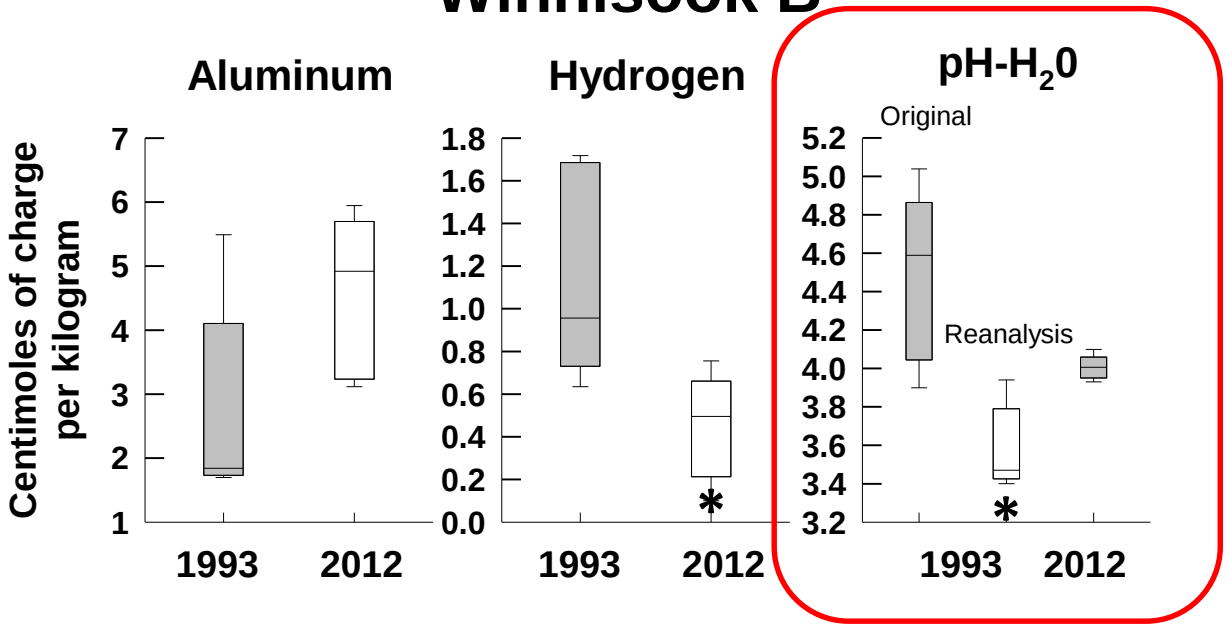
Winnisook B



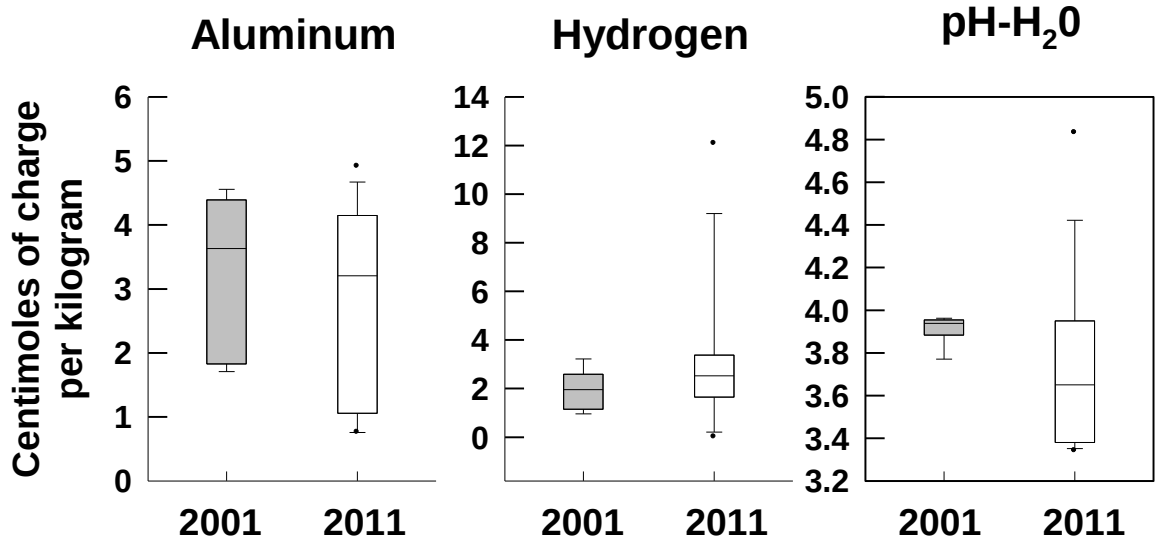
Fall Brook B



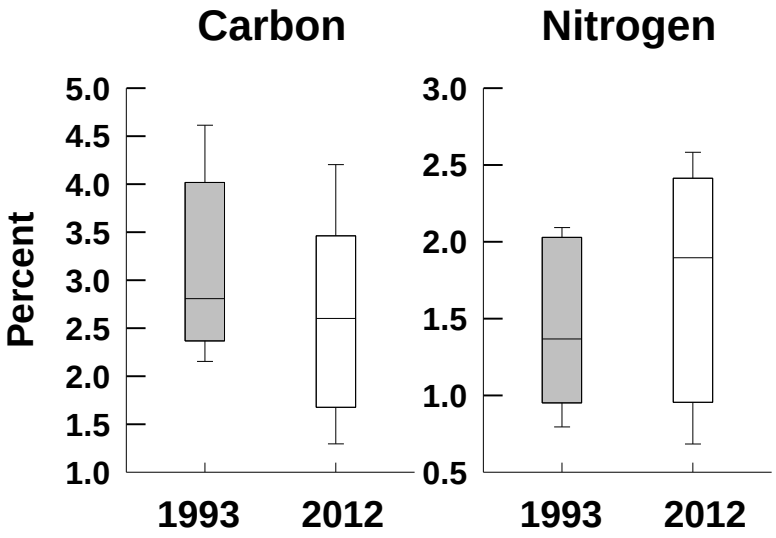
Winnisook B



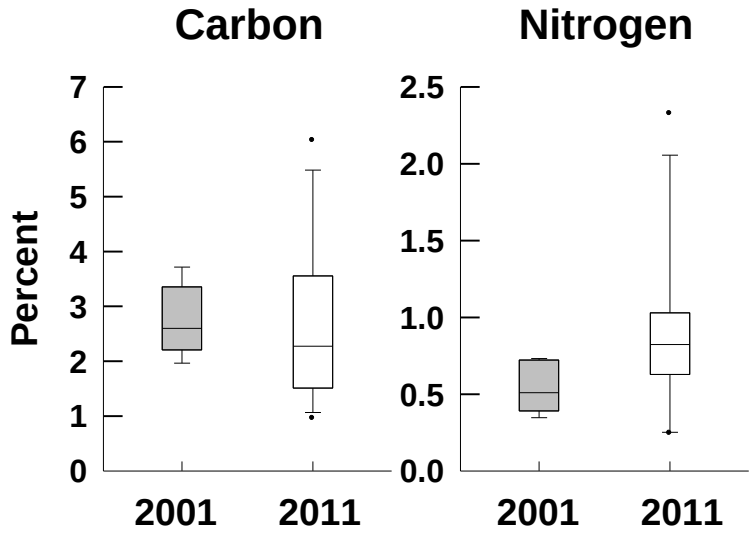
Fall Brook B



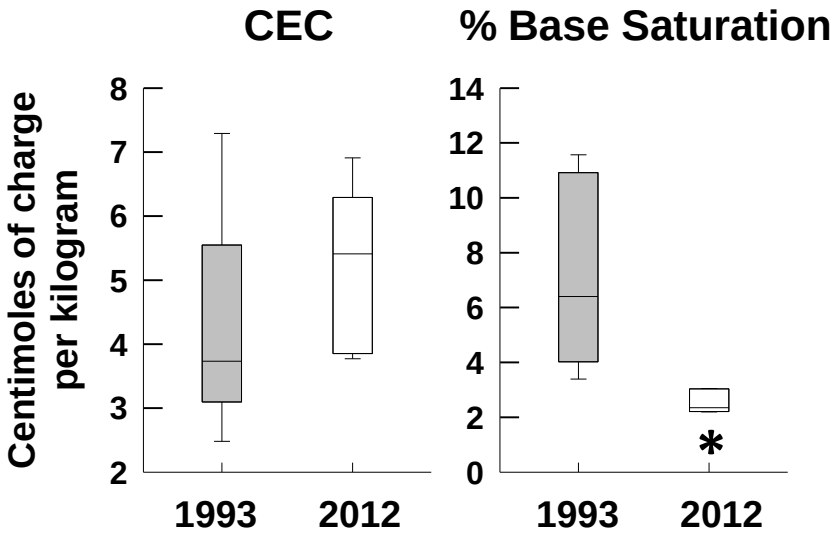
Winnisook B



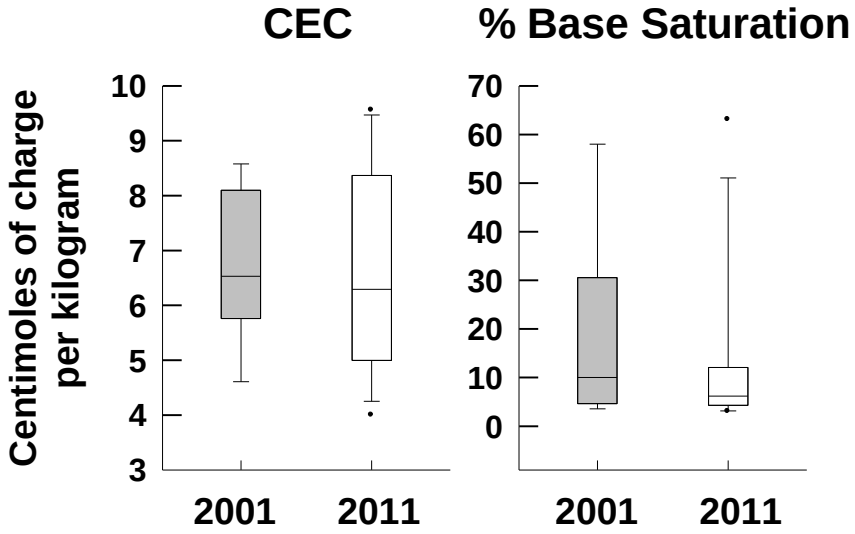
Fall Brook B



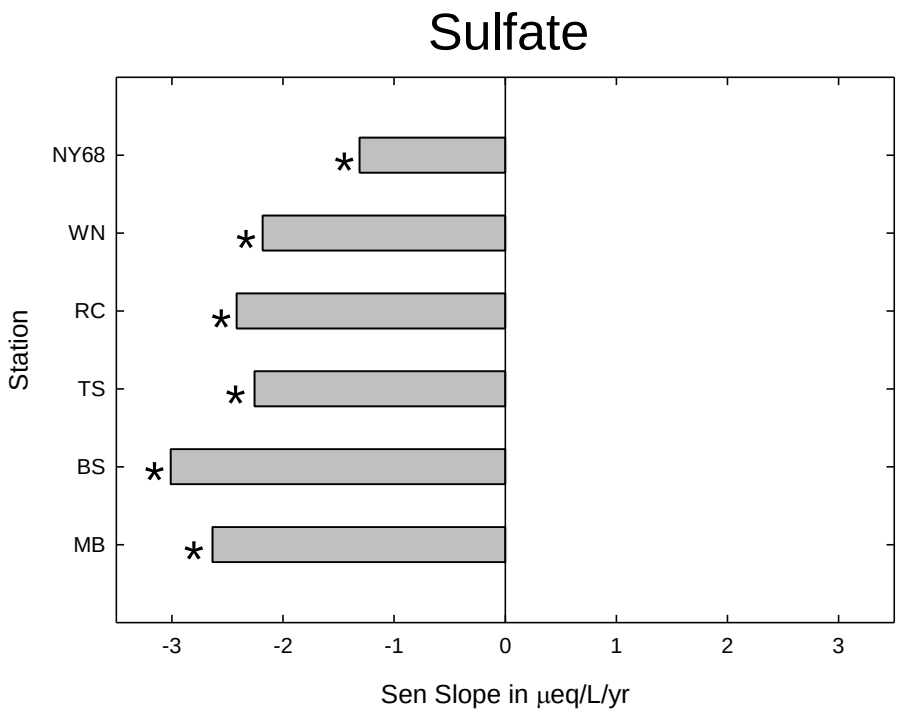
Winnisook B

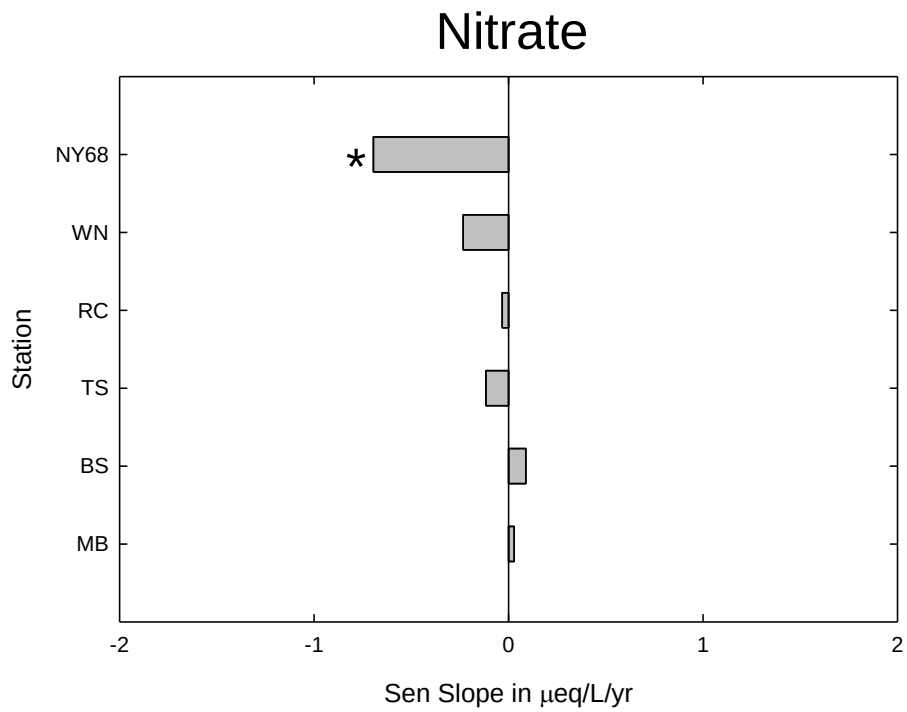


Fall Brook B

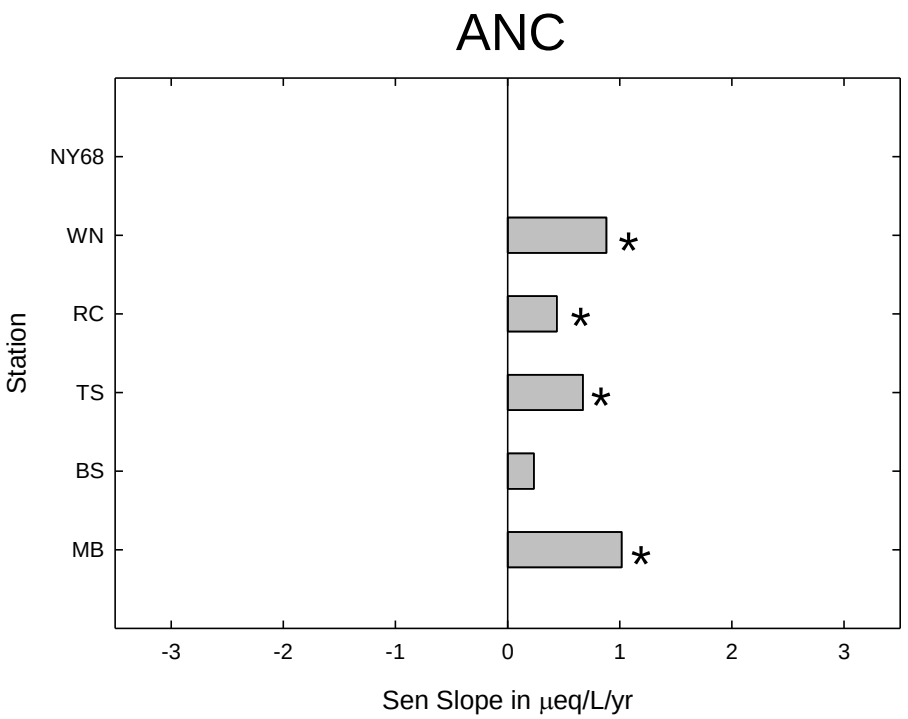


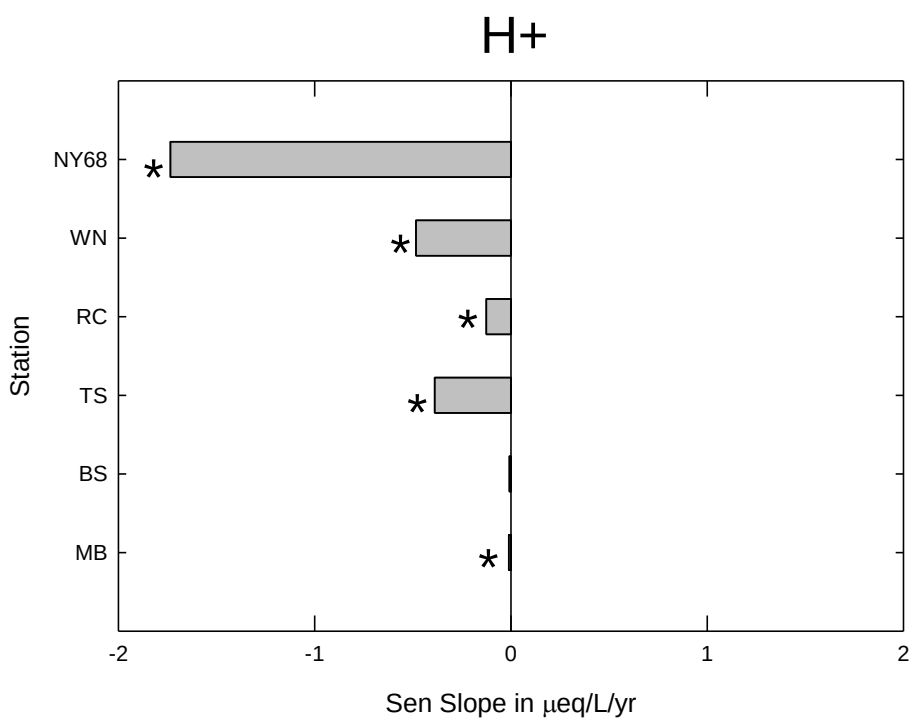
Stream Water Trends



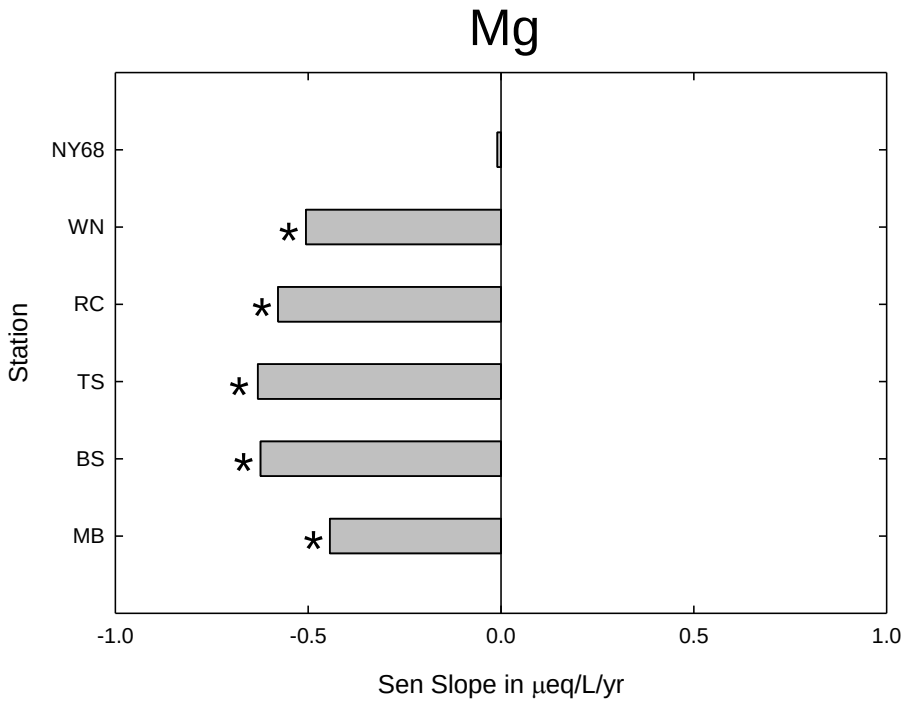


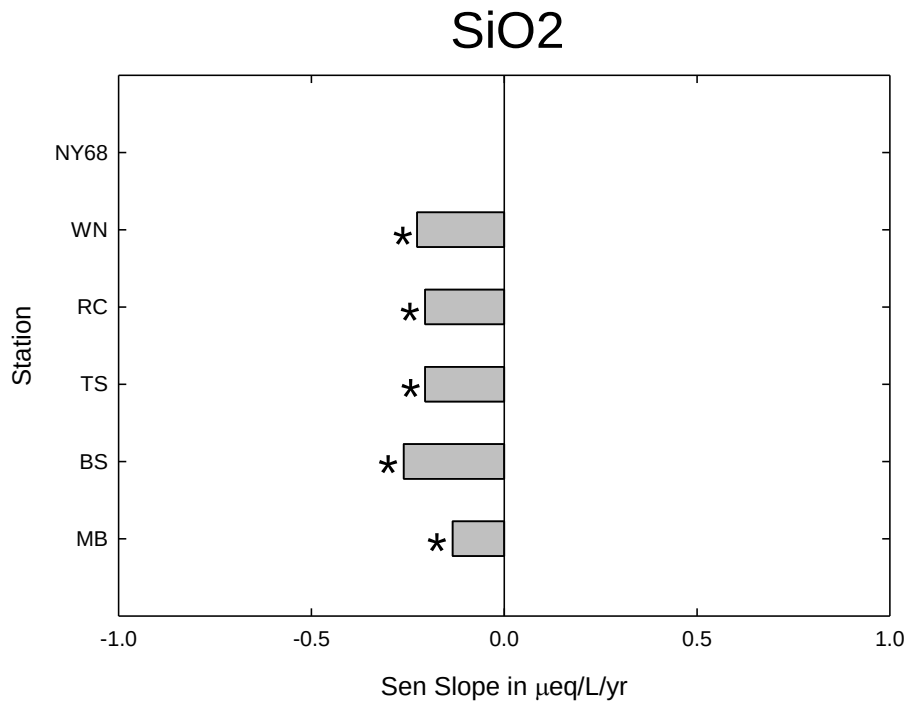
Stream Water Trends





Stream Water Trends





Base Cation- Si Correlations (r^2)

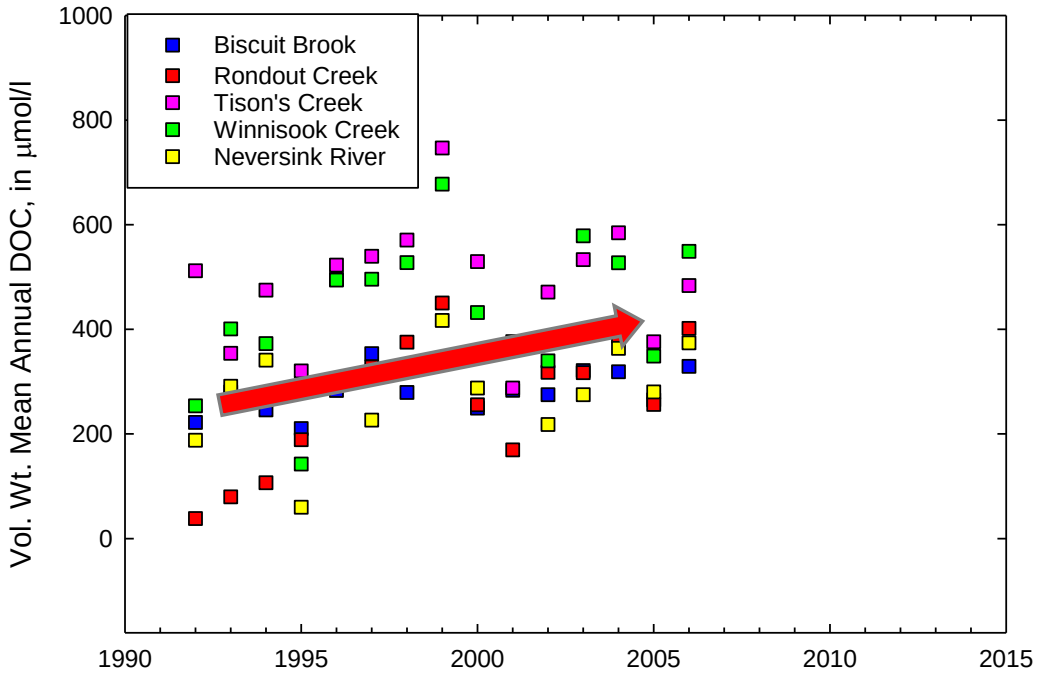
Site	Mg-Si	Ca-Si	Na-Si	K-Si
Biscuit	0.934	0.873	0.625	0.843
Rondout	0.847	0.839	0.718	0.525
Tison	0.884	0.867	0.623	0.702
Winnisook	0.863	0.633	0.497	0.637
Claryville	0.755	0.141	-0.733	0.588

Is this an indication of a decreasing weathering rate?

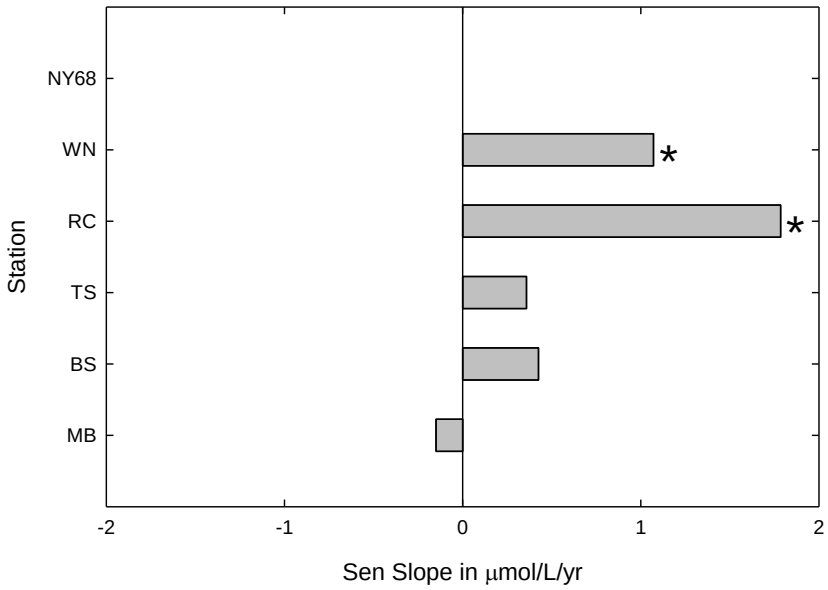
Conclusions

- The Clean Air Act and its amendments have decreased emissions and deposition
- Stream sulfate concentrations have decreased significantly, nitrate concentrations have not
- At the most acidic sites stream water ANC is increasing and H+ is decreasing
- The stream water trends results may indicate a decreasing weathering rate in response to decreased acid deposition.
- There little or no signs of recovery in either Fall Brook or Winnisook soils.

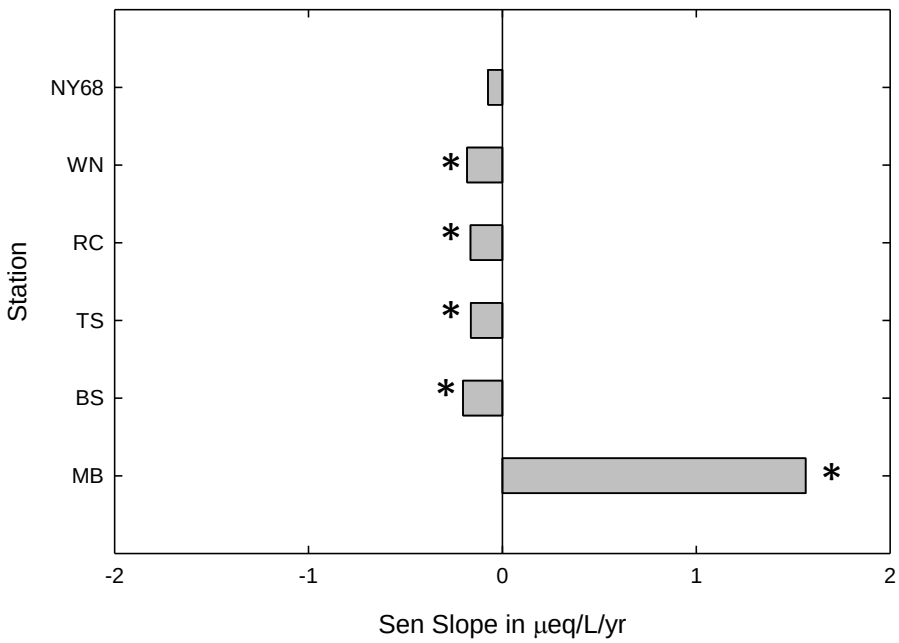
Mean Annual DOC Concentration



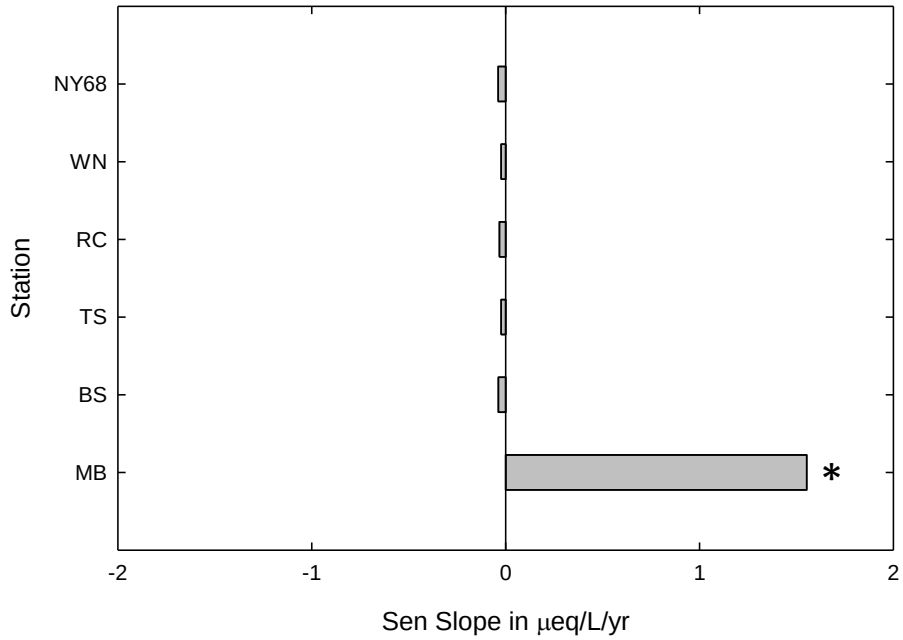
DOC



Chloride


NY68
WN
RC
TS
BS
MB
Station
*
*
*
*
-2
-1
0
1
2
Sen Slope in μeq/L/yr

Na


NY68
WN
RC
TS
BS
MB
Station
*
-2
-1
0
1
2
Sen Slope in μeq/L/yr