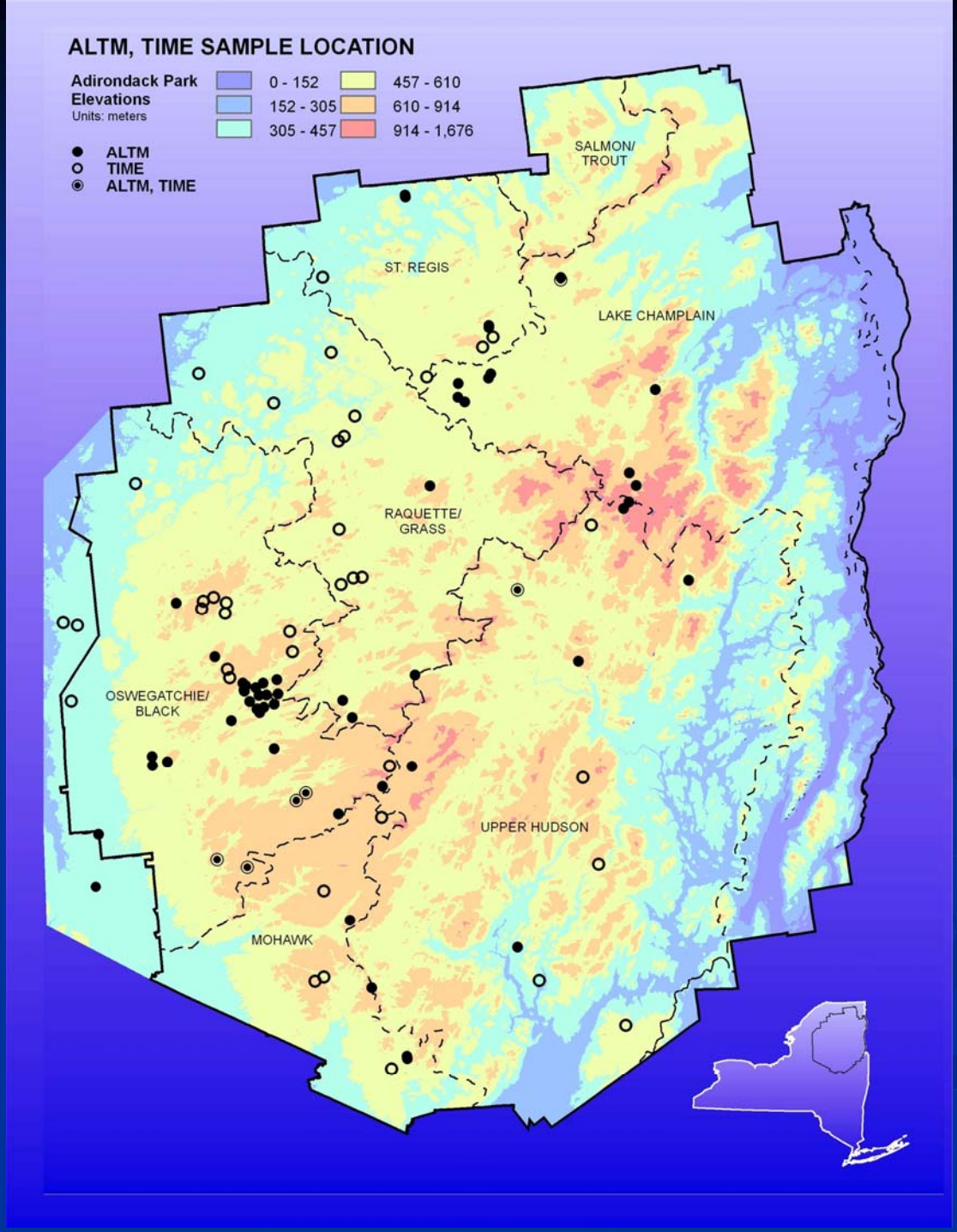
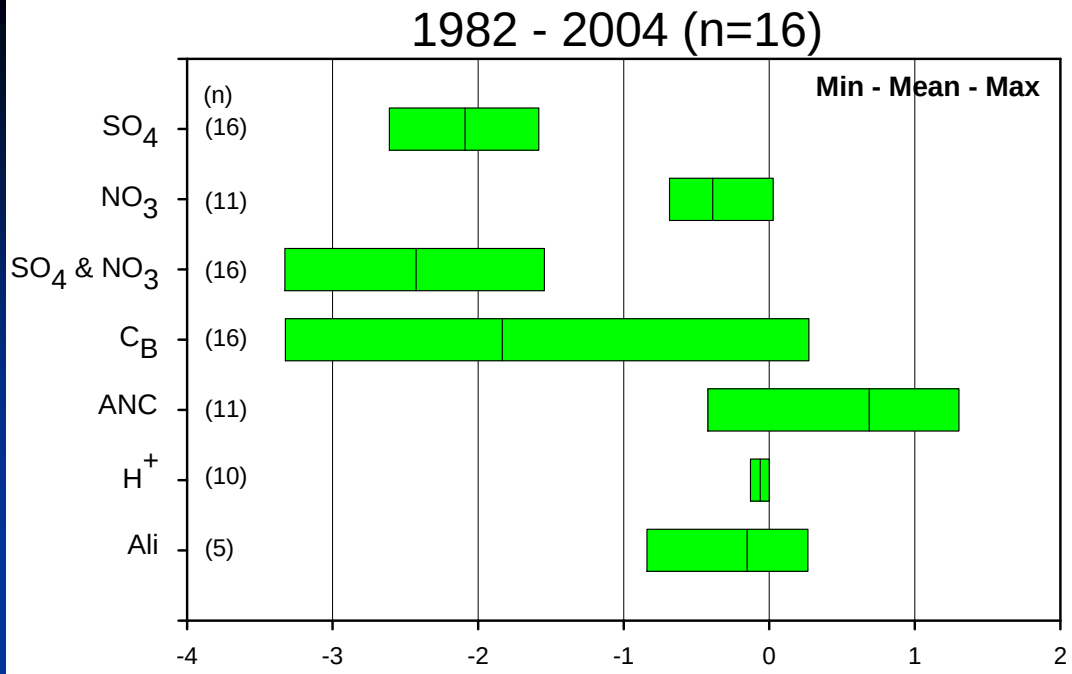
Changes in Water Quality of Adirondack Lakes

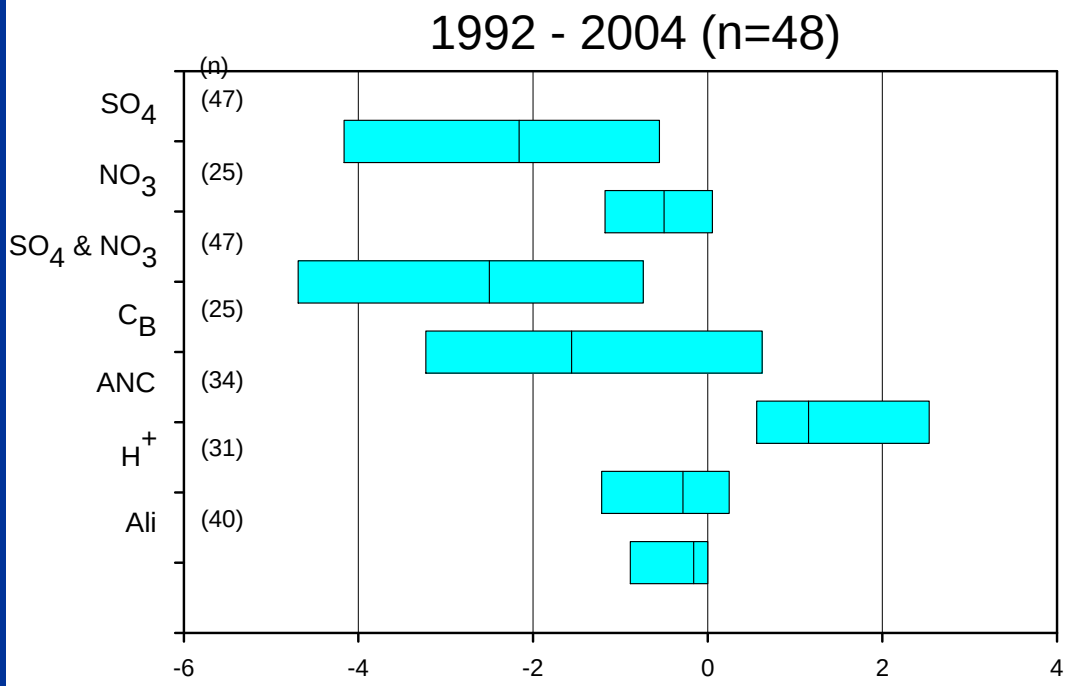
Karen Roy
New York State Department of Environmental Conservation
Ray Brook , NY 12977

James Dukett, Sue Capone, Nathan Houck and Phil Snyder
Adirondack Lakes Survey Corporation
Ray Brook, NY 12977

New York State Energy Research and Development Authority
Environmental Monitoring, Evaluation and Protection in New York: Linking Science and Policy, Albany, NY
November 15-16, 2007


ALTM, TIME SAMPLE LOCATION
Adirondack Park Elevations
Units: meters
0 - 152
152 - 305
305 - 457
457 - 610
610 - 914
914 - 1,676
ALTM
TIME
ALTM, TIME
SALMON/ TROUT
ST. REGIS
LAKE CHAMPLAIN
RAQUETTE/ GRASS
OSWEGATCHIE/ BLACK
UPPER HUDSON
MOHAWK


1982 - 2004 (n=16)
Min - Mean - Max
(n)
SO4
(16)
NO3
(11)
SO4 & NO3
(16)
CB
(16)
ANC
(11)
H+
(10)
Ali
(5)
-4
-3
-2
-1
0
1
2


1992 - 2004 (n=48)
(n)
SO4
(47)
NO3
(25)
SO4 & NO3
(47)
CB
(25)
ANC
(34)
H+
(31)
Ali
(40)
-6
-4
-2
0
2
4
Change in Lake Chemistry
(μeq/L-yr)

Trends in 48 Adirondack LTM Lakes
1992 - 2006

Mean rates of change determined by SKT (p <0.05)

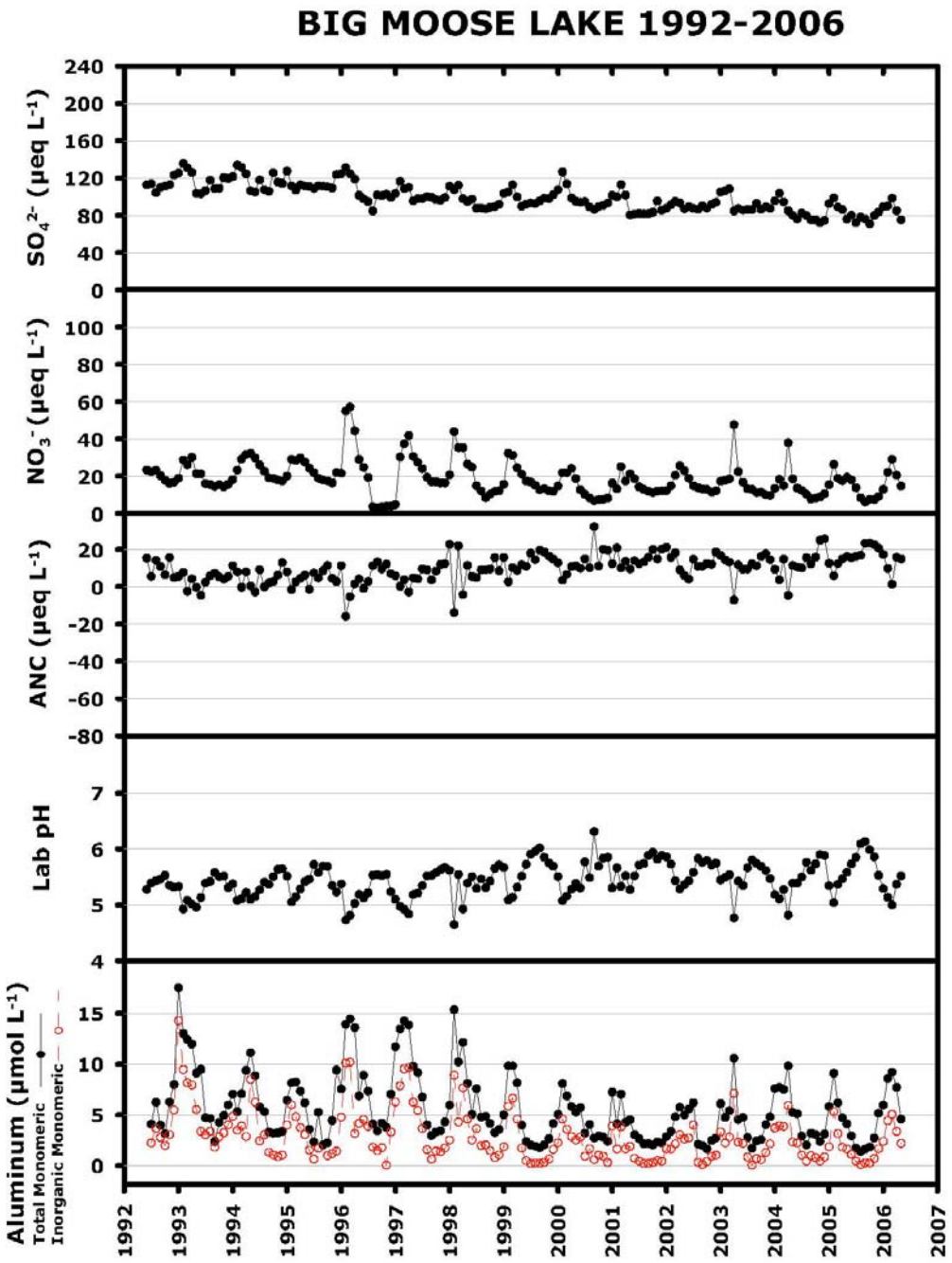
Parameter	1992-2000 Slope	1992-2004 Slope	1992-2006 Slope
Sulfate*	**-2.57**	**-2.11**	**-2.17**
Lakes (n)	44	47	47
Nitrate	**-1.03**	**-0.5**	**-0.43**
	10	21	18
ANC	**1.6**	**1.13**	**1.06**
	21	30	34
pH	**0.04**	**0.02**	**0.02**
	15	26	26
Al im	**-0.31**	**-0.16**	**-0.16**
	23	34	32
DOC	**15.7**	**9.6**	**8.4**
	3	11	15

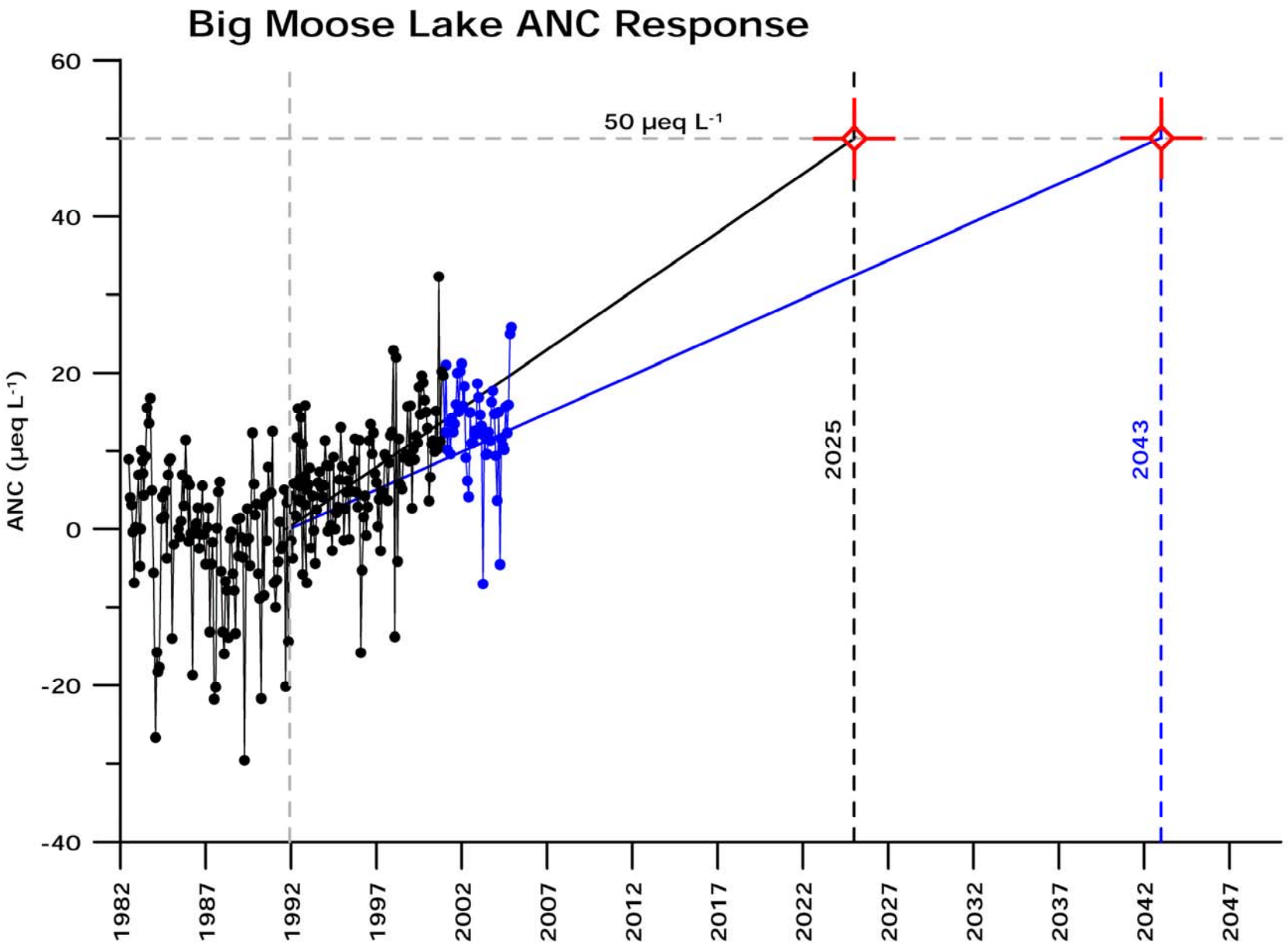
*Concentrations in ueq/L, except for Al and DOC in umol/L.

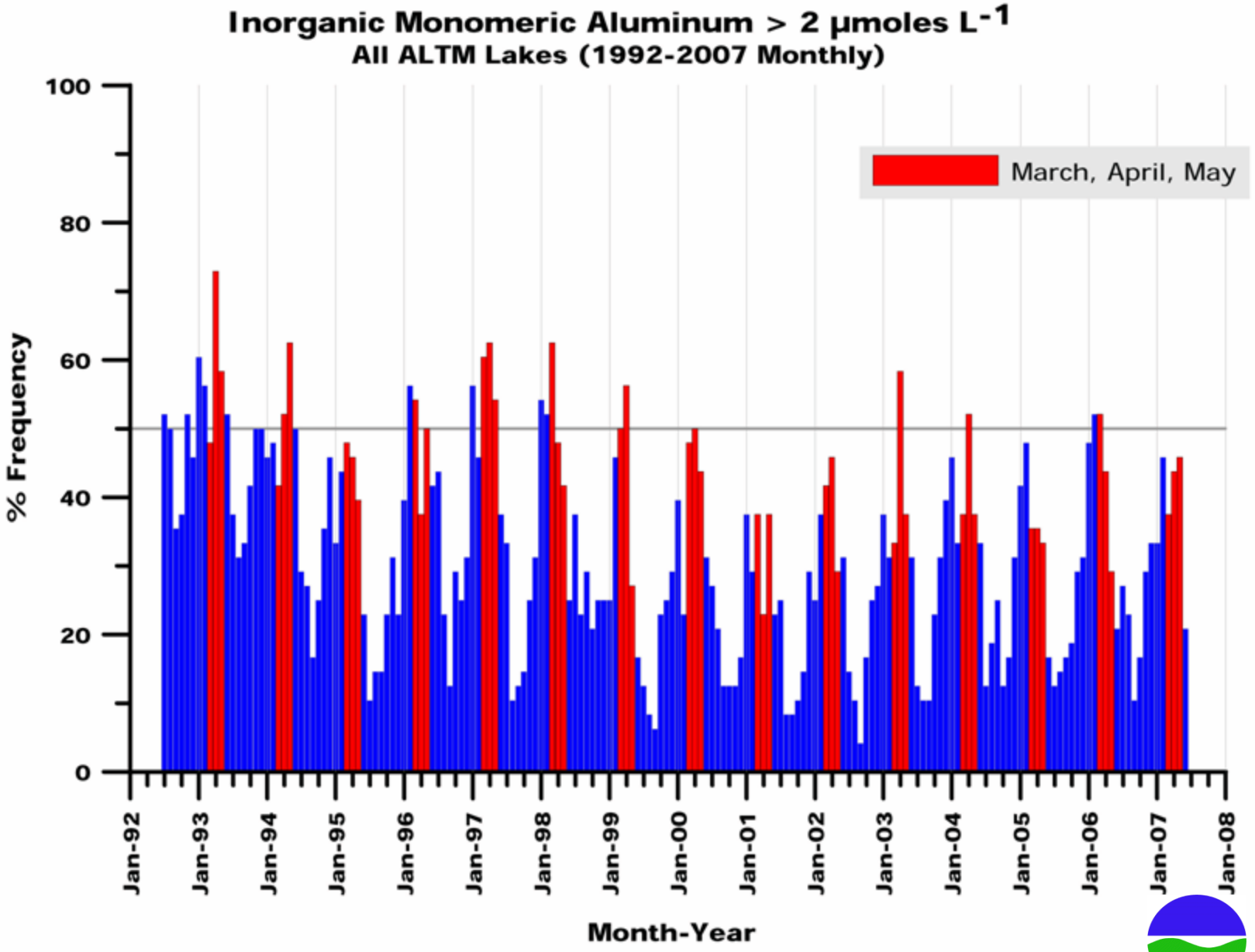
Adirondack Lakes by Classification and Study

Lake Classification	ALTM 1982 Percent	n	ALS 1984-87 Percent	n	ALTM 1992 Percent	n	TIME 1997 Percent	n
Seepage, low DOC	**0%**	0	**6%**	83	**7%**	4	**5%**	2
Seepage, high DOC	**12%**	2	**7%**	95	**6%**	3	**5%**	2
Thin till, low DOC	**41%**	7	**19%**	276	**44%**	23	**51%**	22
Thin till, high DOC	**6%**	1	**15%**	207	**8%**	4	**30%**	13
Med till, low DOC	**23%**	4	**7%**	102	**15%**	8	**2%**	1
Med till, high DOC	**0%**	0	**8%**	112	**10%**	5	**5%**	2
Thick till, low DOC	**12%**	2	**5%**	77	**6%**	3	**0%**	0
Thick till, high DOC	**0%**	0	**7%**	99	**0%**	0	**0%**	0
Carbonate	**6%**	1	**12%**	173	**4%**	2	**0%**	0
Salt-impacted	**0%**	0	**14%**	192	**0%**	0	**2%**	1
n		17		1416		52		43

Lake Characteristics				
Elevation (m)				
mean	546	504	570	533
median	552	502	563	532
range	479 - 661	137 - 1129	384 - 874	326 - 749
Surface area (ha)				
mean	57	16	40	36
median	21	6	16	12
range	1 - 512	0.1 - 287	1 - 512	2 - 218


BIG MOOSE LAKE 1992-2006
SO_4^{2-} (µeq L^{-1})
240
200
160
120
80
40
0
NO_3^- (µeq L^{-1})
100
80
60
40
20
0
ANC (µeq L^{-1})
20
0
-20
-40
-60
-80
Lab pH
7
6
5
4
Aluminum (µmol L^{-1})
Total Monomeric
Inorganic Monomeric
15
10
5
0
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007

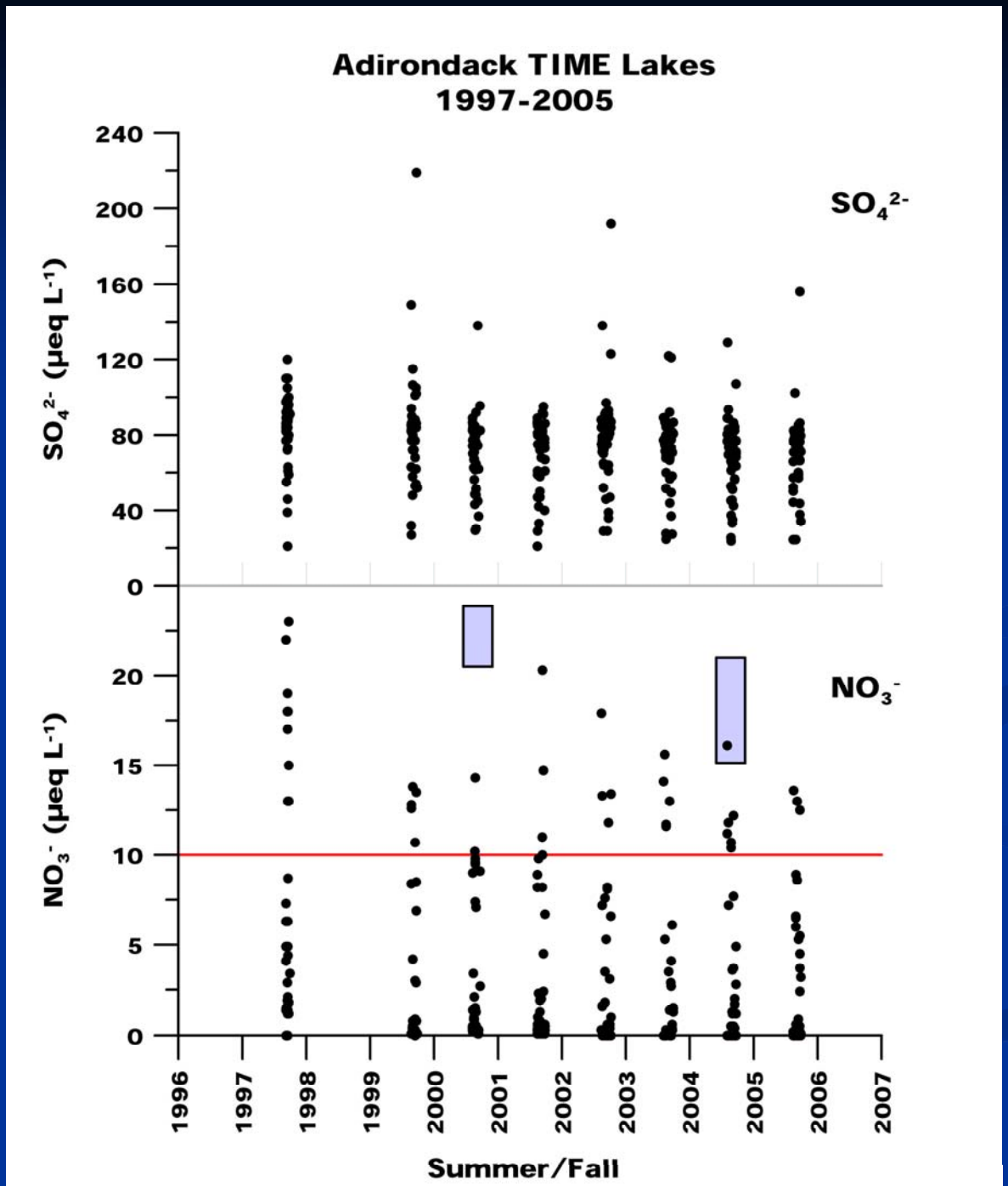

Big Moose Lake ANC Response
50 µeq L-1
2025
2043
ANC (µeq L-1)
60
40
20
0
-20
-40
1982
1987
1992
1997
2002
2007
2012
2017
2022
2027
2032
2037
2042
2047

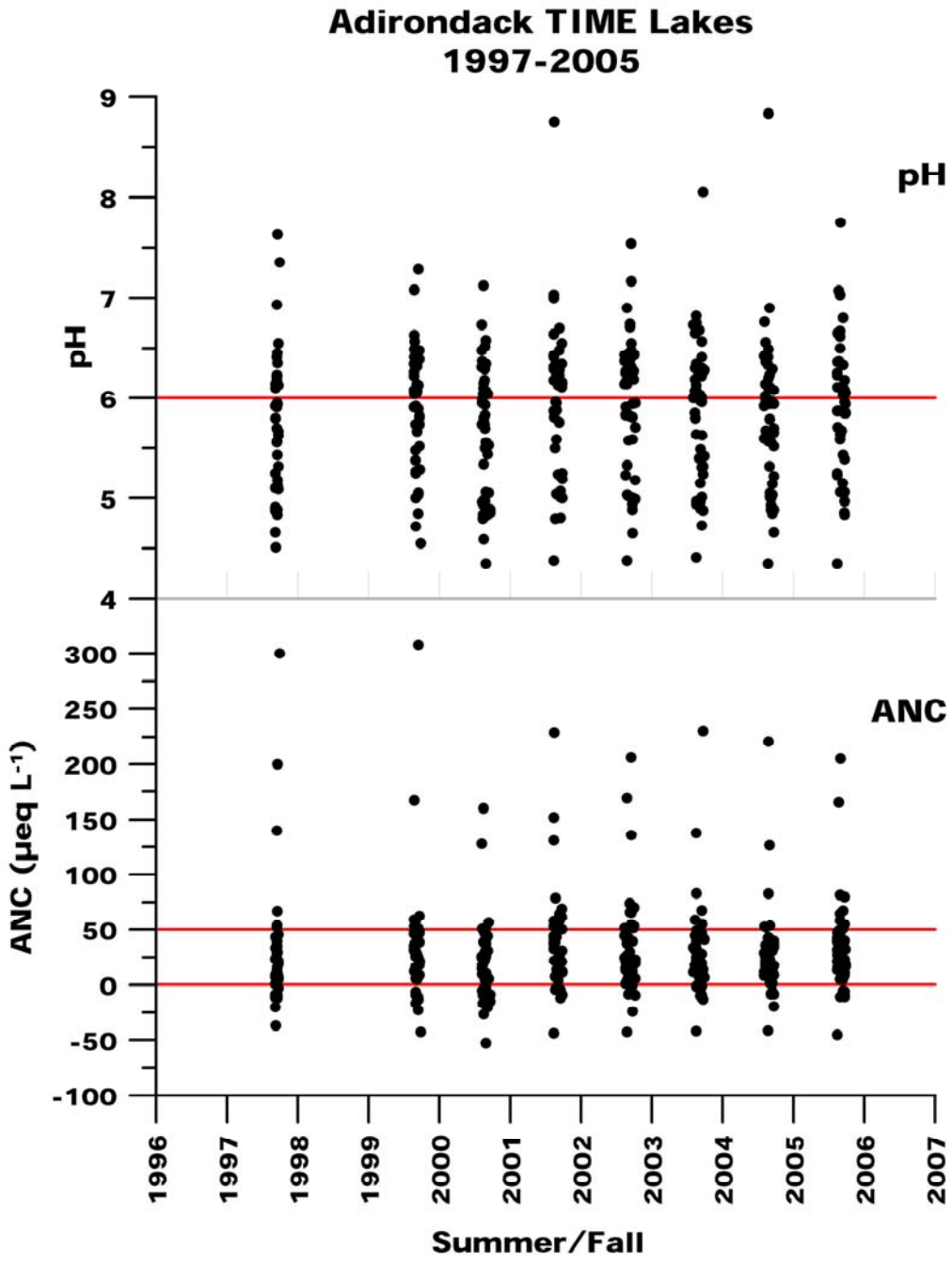

Inorganic Monomeric Aluminum > 2 µmoles L-1
All ALTM Lakes (1992-2007 Monthly)
March, April, May
% Frequency
100
80
60
40
20
0
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Month-Year

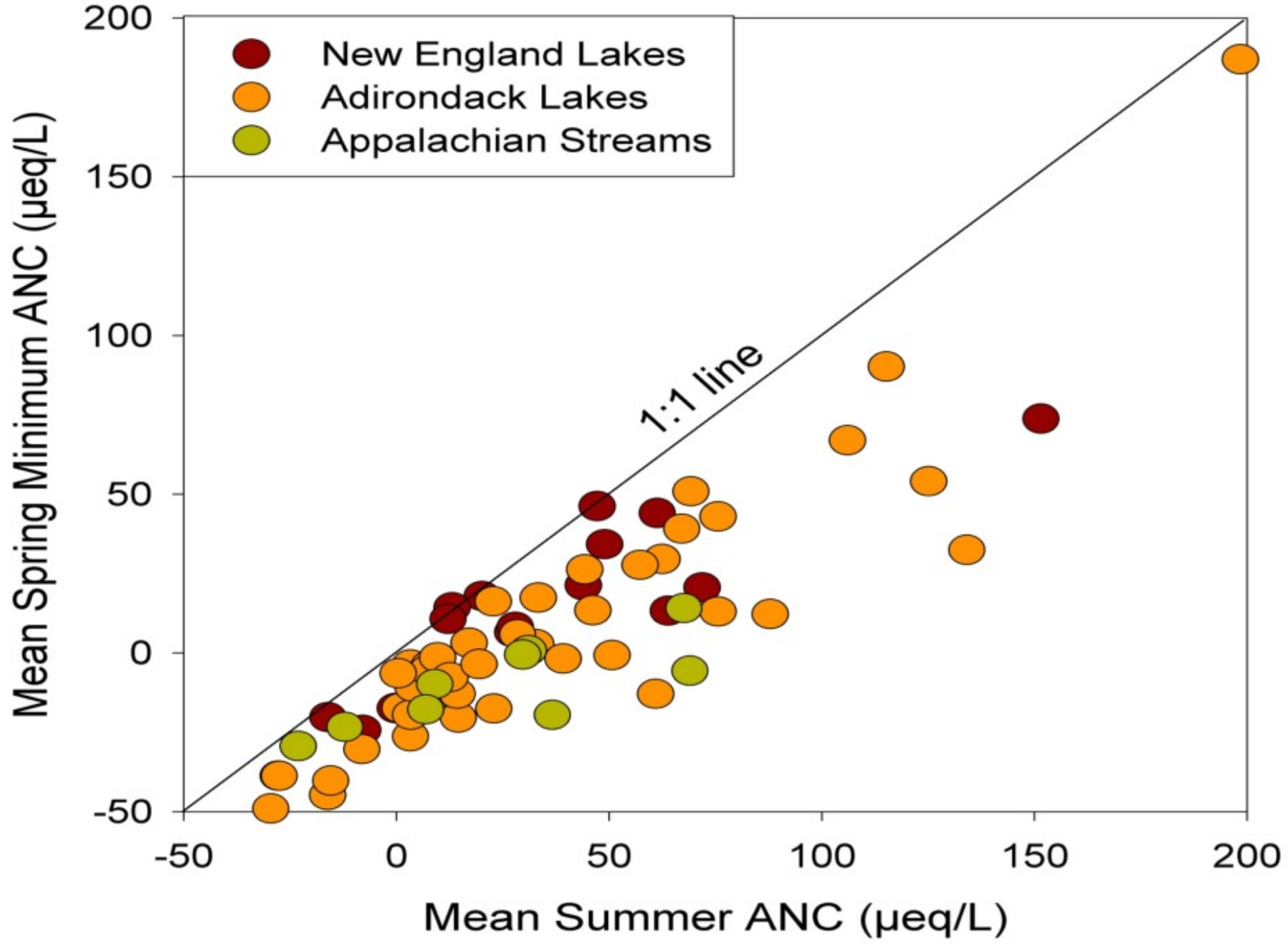
Critical Chemical Thresholds

- pH less than 6.0
- ANC less than 50 $\mu eq\ L^{-1}$
- Al_{im} greater than 2 $\mu mol\ L^{-1}$

These indicate that aquatic biota are at risk from surface water acidification because of acidic deposition (Driscoll et al. BioScience Vol. 51, 2001).


Adirondack TIME Lakes
1997-2005
SO_4^{2-}
SO_4^{2-} (µeq L^{-1})
240
200
160
120
80
40
0
NO_3^-
NO_3^- (µeq L^{-1})
20
15
10
5
0
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
Summer/Fall


Adirondack TIME Lakes
1997-2005
pH
ANC
pH
ANC (µeq L-1)
9
8
7
6
5
4
300
250
200
150
100
50
0
-50
-100
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
Summer/Fall


New England Lakes
Adirondack Lakes
Appalachian Streams
1:1 line
Mean Spring Minimum ANC (µeq/L)
Mean Summer ANC (µeq/L)
200
150
100
50
0
-50
-50
0
50
100
150
200

Arbutus Lake 050684

Lat. 43° 58' 58" N Long. 074° 14' 09" W

Lake: Arbutus Lake (also known as Arbutus Pond) lies in the Upper Hudson River watershed at an elevation of 513 m. The lake has a surface area of 48.2 ha. Archer Creek flows into the lake from the north and forms the major inlet. Seven relatively small wetlands are connected with the lake shoreline. The largest wetland is associated with a beaver meadow on Archer Creek. The lake has a triple basin profile with the deepest basin (7.9 m) at the southern end near the outlet (Fig 2). At the outlet is a V-notch weir. Weekly flow and discharge data have been collected by SUNY College of Environmental Forestry (ESF) at the site continuously since October 1990.

Arbutus Lake is classified as a medium till drainage lake, with low dissolved organic carbon. The lake is considered moderately sensitive to acidification. This is one of the original ALTM waters. It has been monitored each month at its outlet since June 1982 and sampled as part of the EMAP program in 1994. The lake and its watershed (Fig. 1) are located within Huntington Forest, a research site managed by ESF, and is one of the most intensively studied ALTM lakes (web 1).

Paleolimnological analyses: Diatom taxa were studied as part of PIRLA Phase I.

Lake chemistry 1984: Arbutus Pond (1A1-052) was sampled as part of ELS-I on 15 Oct 1984.
Field pH: 6.76 ANC: 75.2 μeqL^{-1} sulfate: 133.6 μeqL^{-1} nitrate: 0.6 μeqL^{-1} sum cations: 242.4 μeqL^{-1} sum anions: 212.1 μeqL^{-1}. Arbutus Lake was not part of the ALS survey (1984-87).

Aquatic biota: No data available.

Fisheries: The lake was stocked intermittently between 1972 and 1992. The ALSC survey on 6/27/01 found brook trout, brown bullhead, northern red belly dace and blacknose dace.

Mercury: This is an ACLP water. Mercury deposition monitoring occurs at the meteorological station.

Deposition: Within the watershed is a combined meteorological station. The station has participated as part of the National Atmospheric Deposition Program (NADP) and the National Trends Network (NTN) since 1978 (web2), and the National Mercury Deposition Network (MDN) (web 3) since 1999. Adjacent to the watershed is 38-m walk up tower with monitoring instrumentation maintained under the auspices of the Atmospheric Integrated Research Monitoring Network (AIRMoN) (web4) and a Clean Air Status and Trends Network (CASTNET) since 2002 (web5). Annual rainfall in 2004 totaled 102.90 cm with an average pH of 4.53 , wet deposition of 12.81 $kgha^{-1}$ of sulfate, and 11.63 $kgha^{-1}$ of nitrate (Table 2).

Soils: Sullivan *et al* 2005 established a soil test plot in this watershed (Fig 1).

Intensive studies: Chemical trend analyses have been conducted from 1982 through 1991, 1994, 1997, 2000 and 2004 (Mitchell *et al* 2001, Driscoll *et al* 2003) More intensive processes (e. g. nitrogen and carbon) have also been

Figure 1. Catchment

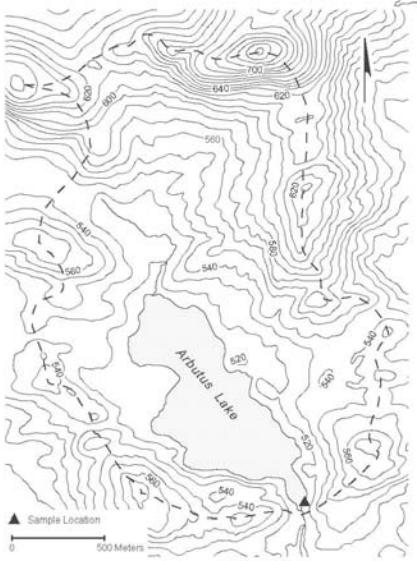


Figure 2. Bathymetry

examined. Arbutus lake is one of five watersheds where the integrated biogeochemical model (PnET-BGC) model has been applied in the Adirondack and Catskills [397].

Watershed: The bedrock underlying this 354 ha watershed is primarily granitic gneiss with some gabbro-amphibolite. The parent material is a thin bouldery glacial till. Soil depth varies but is typically less than one meter, and is dominated by coarse, loamy, mixed, frigid Typic Haplorthods with Greenwood Mucky peats occupying valley bottom wetlands [206]. Surficial geology maps reveal 1.6 % of the watershed with exposed bedrock and the remaining 98.4% as till. To the northeast, the watershed rises to a maximum of 741 m. The watershed has 227 m of relief with an average slope of 11% [206].

Land Cover/ Use: The watershed is predominately forested. Northern hardwoods predominiate the landscape with conifers dominating the lake environs, riparian zones and high elevations. Dominant tree species include American beech, sugar maple, yellow birch, red spruce, and balsam fir [206]. Total wetland area is 17.3 ha, or 4.9 % of the watershed. The predominant wetland types are forested needle-leaved evergreen and scrub/shrub broad-leaved deciduous, 3.8% and 1.8 % of the watershed, respectively. The watershed is largely undeveloped with the exception of seasonal roads and a camp lodge *circa* XXXX on the southeastern shore of the lake.

Watershed disturbance: The 1916 fire protection source data reveals 87.9% of the watershed as virgin and second growth green timber with no slash. The watershed was not affected by either the 1950 or the 1995 blowdowns. In the winter of 1960-61, a total of 1.5 million cubic meters of timber, primarily softwoods, were removed from 162 ha in and around the watershed [206].

Table 1. Lake Chemistry

050684			1993			2004	
Parameter	Min	Max	Avg	Min	Max	Avg.	Units
SO_4^{2-}	108.26	148.24	128.93	93.69	130.54	105.52	μeqL^{-1}
NO_3^-	-0.16	23.31	7.77	0.48	19.85	6.76	μeqL^{-1}
Cl^-	7.33	12.13	9.83	8.74	13.82	10.53	μeqL^{-1}
F^-	3.84	5.11	4.66	3.58	5.26	4.52	μeqL^{-1}
ANC	44.84	81.09	68.66	50.16	77.07	64.88	μeqL^{-1}
DIC	58.28	188.99	111.56	69.94	172.34	105.80	$\mu molofCL^{-1}$
DOC	304.13	427.19	356.57	360.91	541.33	443.38	$\mu molofCL^{-1}$
SiO_2	30.62	101.36	71.79	34.12	89.71	63.59	$\mu molL^{-1}$
Ca^{2+}	126.25	189.13	154.70	117.27	150.71	137.07	μeqL^{-1}
Mg^{2+}	35.38	55.13	45.40	34.56	46.08	39.91	μeqL^{-1}
Na^+	26.10	36.10	31.14	29.14	37.84	33.24	μeqL^{-1}
K^+	6.91	9.46	7.99	5.88	7.16	6.18	μeqL^{-1}
NH_4^+	-0.61	2.61	0.79	-0.22	2.88	1.33	μeqL^{-1}
AL_TD	0.48	5.00	2.33	1.19	5.04	2.90	$\mu molL^{-1}$
AL_TM	0.19	10.27	1.86	1.15	2.59	1.74	$\mu molL^{-1}$
AL_OM	0.05	2.19	0.88	1.11	2.22	1.61	$\mu molL^{-1}$
AL_IM	0.23	8.86	1.34	0.04	0.37	0.16	$\mu molL^{-1}$
LABPH	5.91	6.87	6.49	5.85	6.64	6.32	
AIREQPH	6.47	7.08	6.80	6.50	7.09	6.83	
TRUECOLOR	15	35	25	30	45	39	PtCo
SCONDUCT	23.87	29.94	26.61	23.50	29.10	25.35	μScm^{-1}

Table 2. Precipitation NADP NY20 Newcomb

Year	1993		2004	
	Concentration	Deposition	Concentration	Deposition
Parameter	μeqL^{-1}	$kgha^{-1}$	μeqL^{-1}	$kgha^{-1}$
SO_4^{2-}	1.680	17.10	1.25	12.81
NO_3^-	1.49	15.11	1.13	11.63
Cl^-	0.09	0.96	0.07	0.73
Ca^{2+}	0.06	0.63	0.07	0.73
Mg^{2+}	0.013	0.132	0.011	0.113
Na^+	0.052	0.53	0.032	0.329
K^+	0.010	0.13	0.009	0.093
NH_4^+	0.18	1.87	0.19	1.93
Lab H^+	4.38	0.42	4.53	0.31
Conductivity	20.85		16.02	
Precipitation (cm)		101.6		102.90

Table 3. Lake Characteristics

Parameter	Value
Elevation msl	513 m
Maximum depth	7.9 m
Mean depth	2.8 m
Volume	134.3 x 10^4 m^3
Surface area	48.2 ha
Watershed surface area	354 ha
Watershed ratio	7.3
Flushing Rate (times $year^{-1}$)	2.1
Watershed	Upper Hudson
County, Town	Essex, Newcomb
USGS Quadrangle	Newcomb
Land use classification	Resource Management

Collaborators

Syracuse University C.T. Driscoll, K. Driscoll
US Geological Survey G. Lawrence
SUNY ESF M.J. Mitchell, M. Domser
US EPA ORD Corvallis S. Paulsen, J. Stoddard
SUNY Cortland C. Cirmo
SUNY Plattsburgh E. Romanowicz
NYSERDA Environmental Monitoring, Evaluation and Protection Program
NYSDEC
A. Bulger UVA