Acidification over TIME

The Long Term Response of Adirondack Surface Waters (TIME) to Reductions in Acidic Deposition

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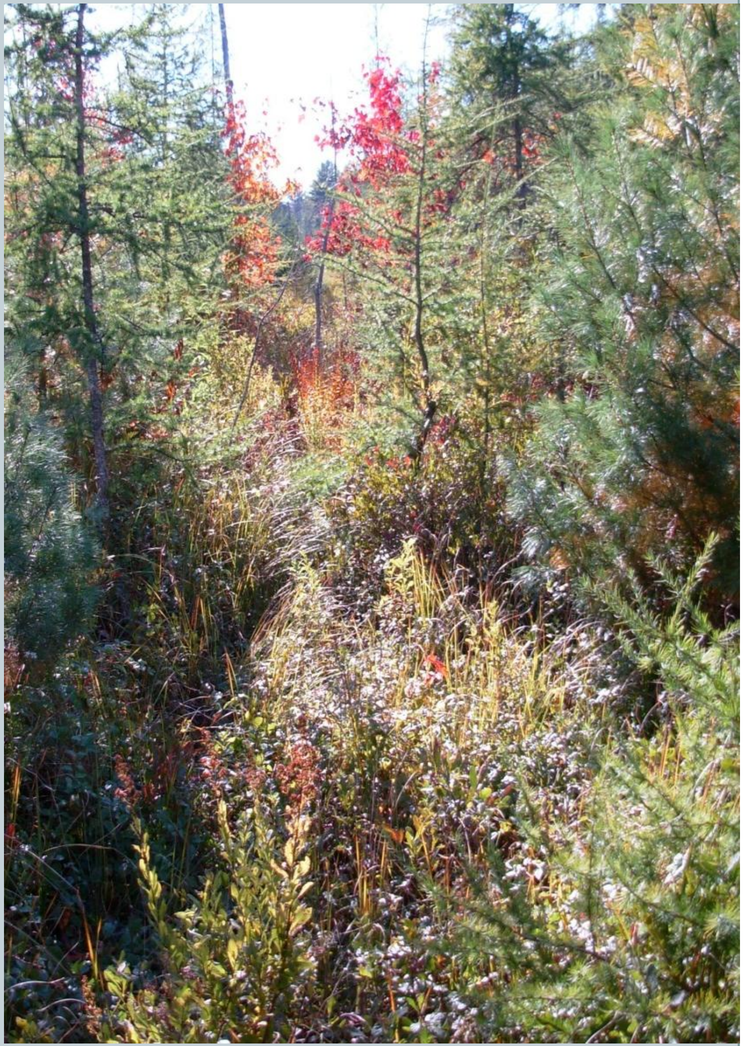
Presentation Outline

- Objective
- Methods
- Wet Deposition Trends
- Regional Lake Trends
- Factors Regulating Lake Response
- Conclusions



Objective

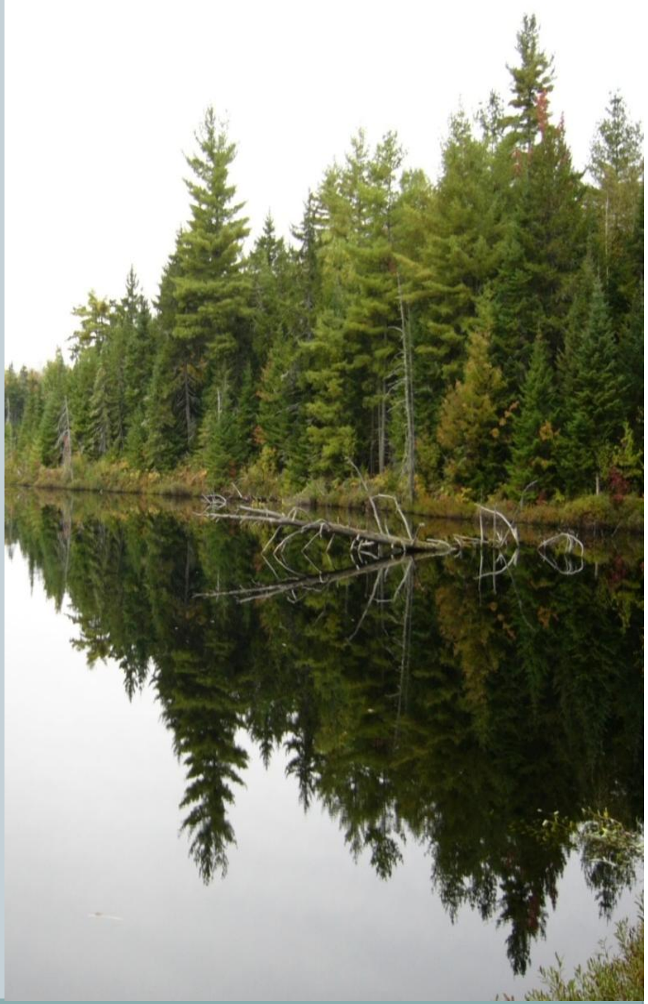
- Title IV of 1990 CAAA
  - Acid Rain Program
    - to decrease SO_2 emissions
- NO_x Budget Program for NO_x emissions
- Decreases in SO_4^{2-} and NO_3^- deposition
- What is response of sensitive ecosystems to these changes?


Photo: epa.gov

- Assess Recovery of Adirondack Lakes From Acidic Deposition

Methods

- Long Term Monitoring Programs
  - NADP NTN
  - NOAA's NEXRAD (WSR-88D) Doppler radar system
  - TIME
- Statistical Analysis
  - Mann Kendall Test for Annual Trends
    - Significance when $p < .05$
  - Watershed Characteristics
  - Extrapolation to regional estimates
  - Fluxes
    - Conc. * Precipitation in*.6 (runoff)= (meq/m^2-yr)



Temporally Integrated Monitoring of Ecosystems
(TIME)

- 43 Original Lakes, 42 Currently
- Statistical Weighting Factors
  - to extrapolate regional trends
- 1991-2007
- Annual Summer Sampling
- Main Focus on Sulfate Effects

Constituents Sampled:	
Acid Anions (C_A):	SO_4^{2-}
	NO_3^-
Base Cations (C_B):	Na^+
	Mg^{2+}
	K^+
	Ca^{2+}
Carbon:	DOC
	DIC
Other Parameters:	Al^{3+}
	pH
	NH_4^+

Lake ANC: Classification and Calculations

Classifications:

- To look at response variations
- Based on 2007 ANC $_G$
- Bias to sensitive lake populations
- **Calculations:**
- ANC $_G$
  - Measured TIME Value
- ANC $_{Calc}$
  - Σ Base Cations (C_B) – Σ Strong Acid Anions (C_A)

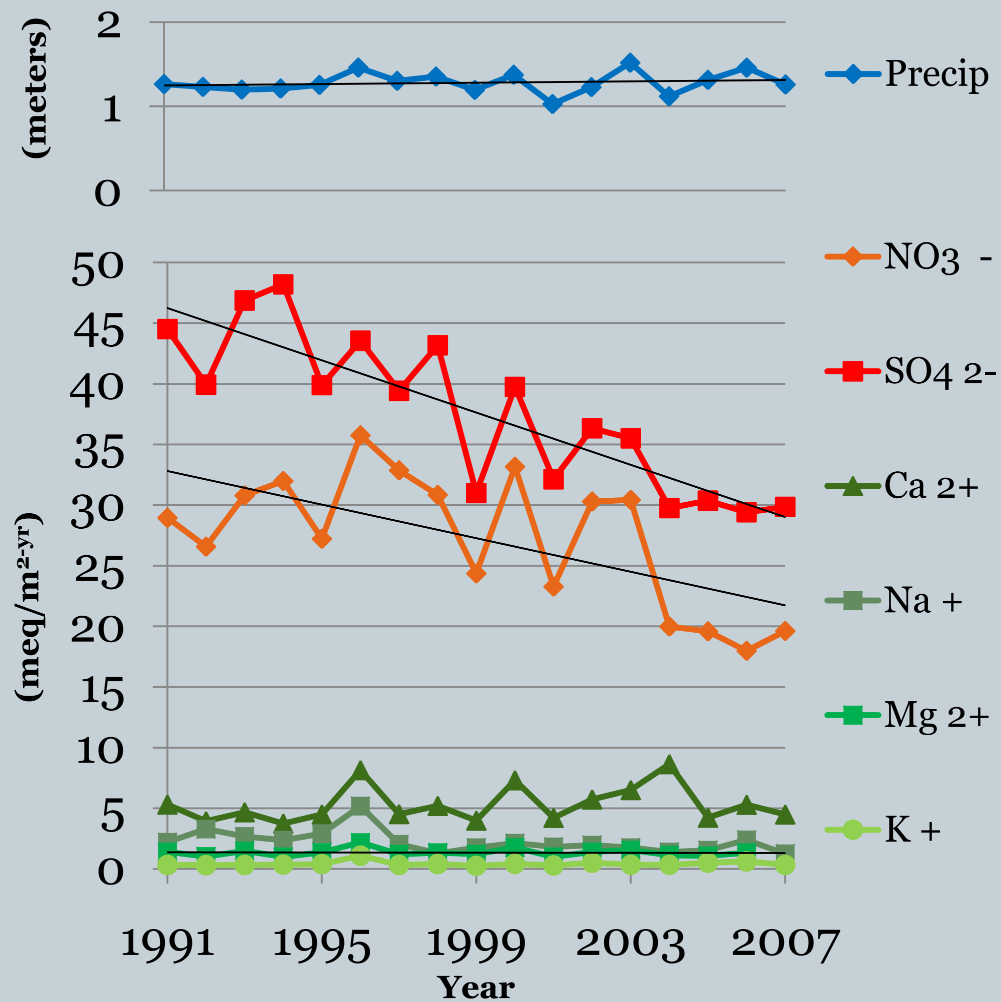
Classification	ANC Range (µeq/L)	#of Lakes
Acute Concern	< 0	6
Severe Concern	0-20	10
Elevated Concern	20-50	14
Moderate Concern	50-100	11
Low Concern	>100	1

Wet Deposition Trends

(Extrapolated from NY98 and NY20)

Trend Summaries:
(meq/m²-yr)

Parameter:		Graph Slope:	Mean Trend:	# Sig*
Precipitation:		+.004	+.004	2
Acid Anions:	SO_4^{2-}	-1.08	-1.04	42
	NO_3^-	-.69	-.69	21
Base Cations:	Na^+	-.1	-.08	23
	Ca^{2+}	.006	.04	2
	K^+	.002	.004	1
	Mg^{2+}	-.004	.008	0
	SUM		-.072	0

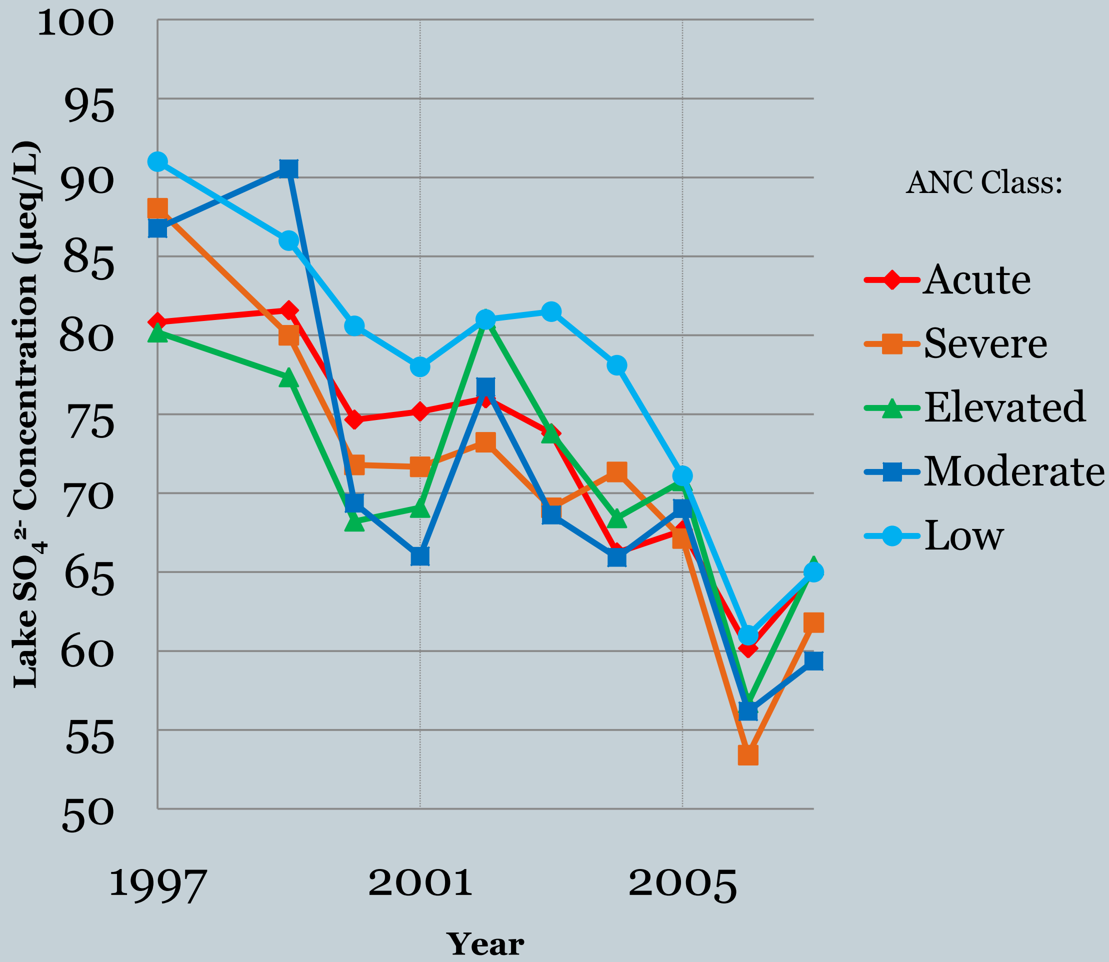


Lake Sulfate (SO_4^{2-}) Concentrations

ANC Class:	Slope: (μeq/L-yr)
Acute	-2.02
Severe	-2.63
Elevated	-1.58
Moderate	-2.86
Low	-2.61

Across all Lakes:

- 41 Decreasing Trends
- 30 Significant
- -2.12 * μeq/L-yr



Wet SO_4^{2-} v. Lake SO_4^{2-} Trends

- Poor relationship between annual wet SO_4^{2-} deposition and lake SO_4^{2-} fluxes (R^2=.055)

Measurement:	Deposition:			Lake Flux:		
Average Trend: (meq/m²-yr)	-1.04			-1.19		
Range: (meq/m²-yr)	-.33	to	-1.87	+1.31	to	-4.31
% Decreasing :	100%			85.7%		
# Significant*:	42			13		

Low R^2 may result from:

•No dry deposition

•Limited runoff estimates

•Uniform changes

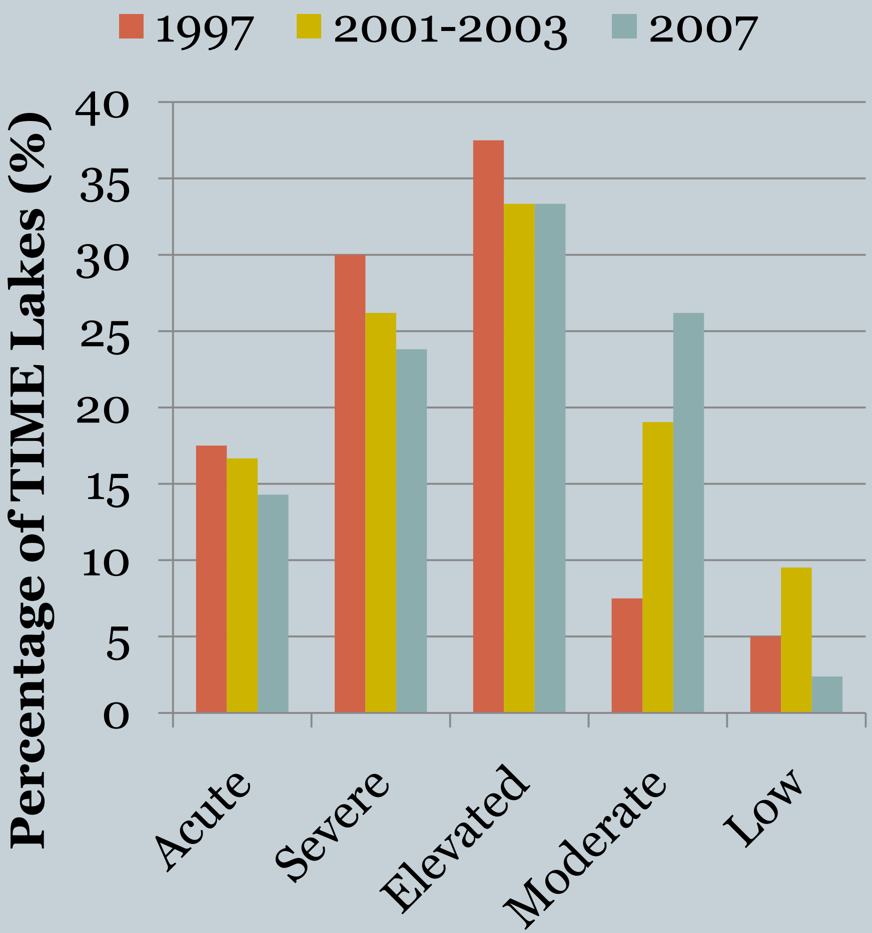
However, consistent regional decreases suggest cause and effect

So are there improvements in acid-base chemistry?

Resulting ANC Trends

Parameter:	ANC_G :			ANC_{Calc}:		
Average Trend: (μeq/L-yr)	+1.08			+2.03		
Range: (μeq/L-yr)	-1.59	to	+3.47	-.68	to	+7.43
% Increasing :	80.1%			97.6%		
# Significant*:	9			26		

ANC Status of Time Lakes 1997-2007

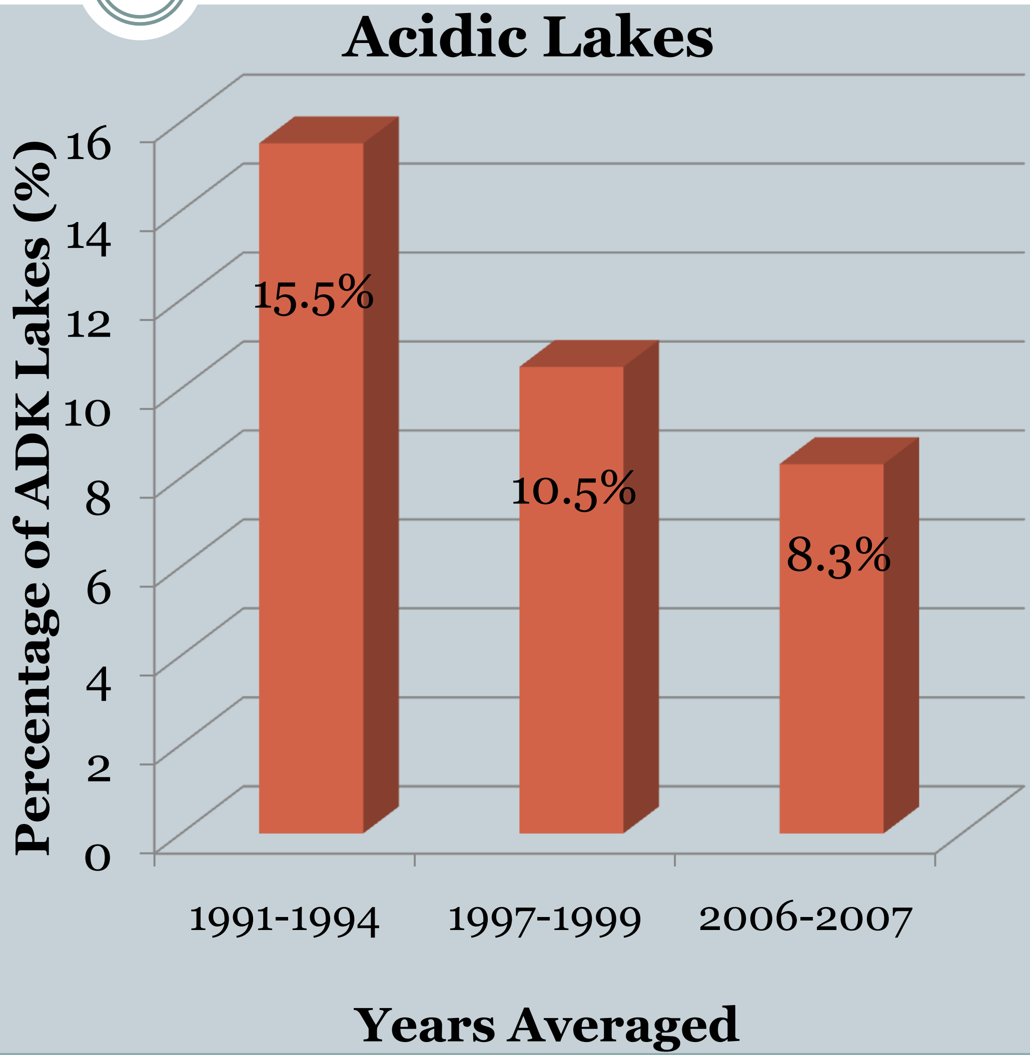


ANC Class:	% of TIME Lakes		
	1997	2002-2003	2007
Acute	17.5	16.7	14.3
Severe	30.0	26.2	23.8
Elevated	37.5	33.3	33.3
Moderate	7.5	19.0	26.2
Low	5.0	9.5	2.4

Regional Recovery

Post Title IV:

- 132 Lakes no longer acidic
  - 46.5% decrease
  - 152 Lakes Still Acidic
- Stoddard et. al (2002) 8.1%
- Trends have followed expectations

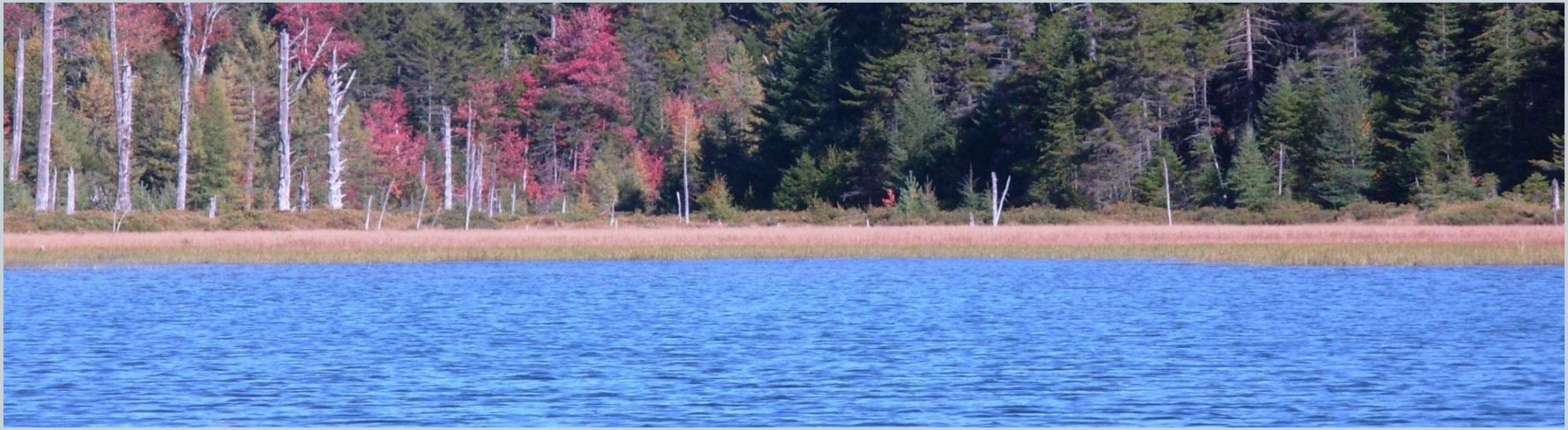


What Drives Variations in Recovery?

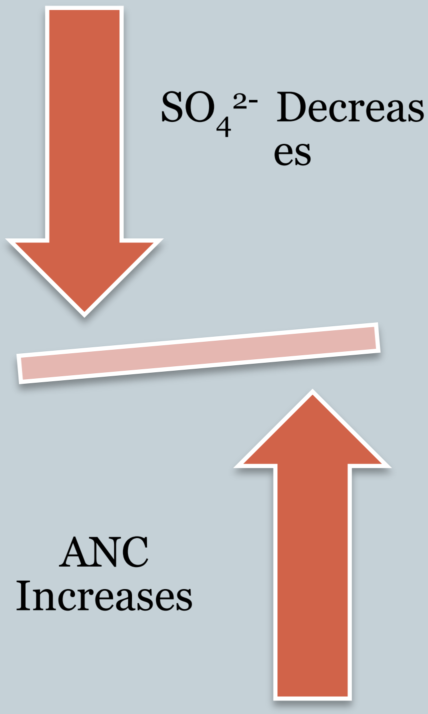
- $ANC_{Calc} = \Sigma$ Base Cations (C_B) – Σ Strong Acid Anions (C_A)

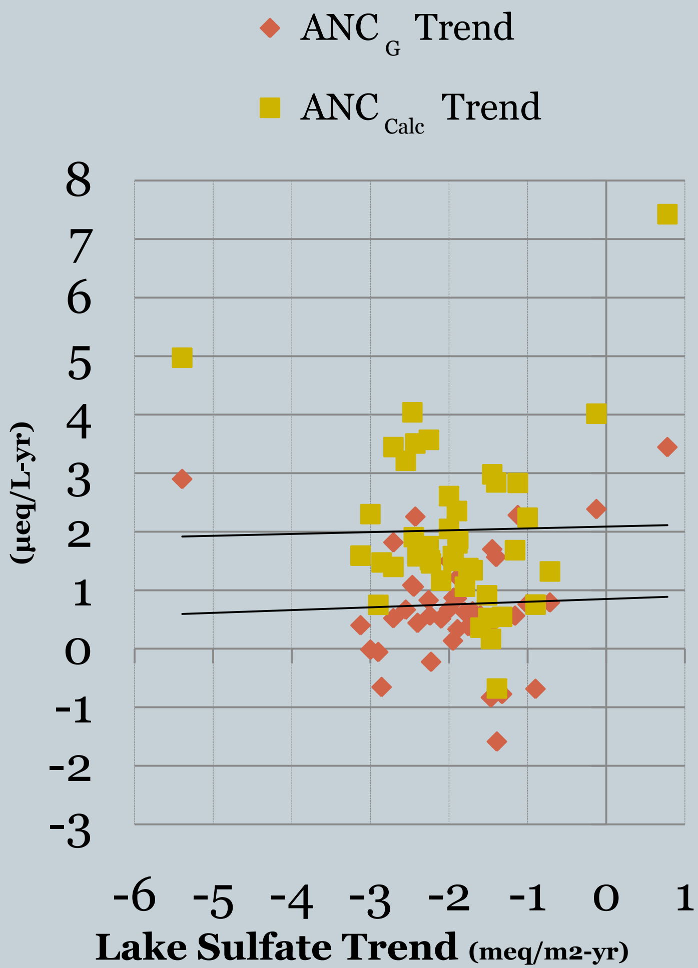
Expected greatest ANC increases with:

- Greater SO_4^{2-} decreases or Base Cation increases
- Previous reports of Base Cations trends limiting recovery



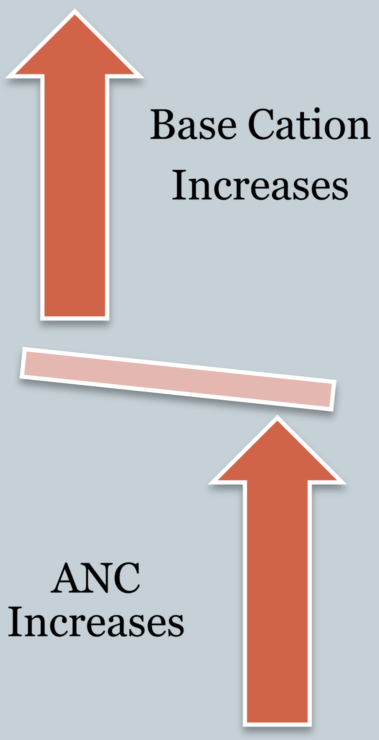
Do SO_4^{2-} Trends Drive Recovery?

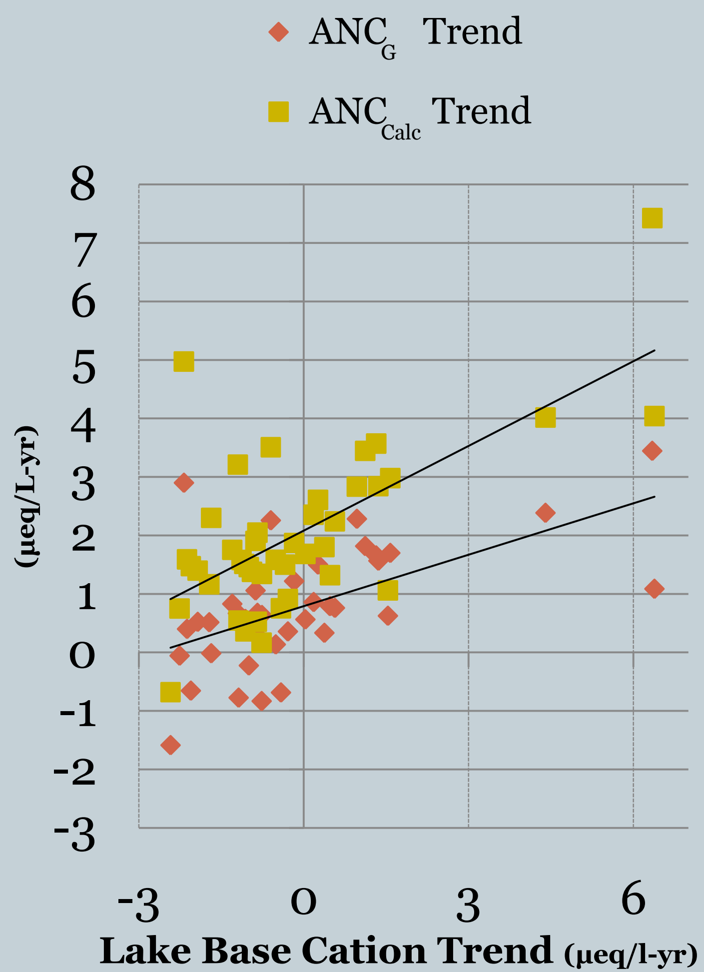




ANC:	**R^2:**	**Slope:**
Calc	.0004	.03
Gran	.002	.05

Do Base Cations Drive Recovery?

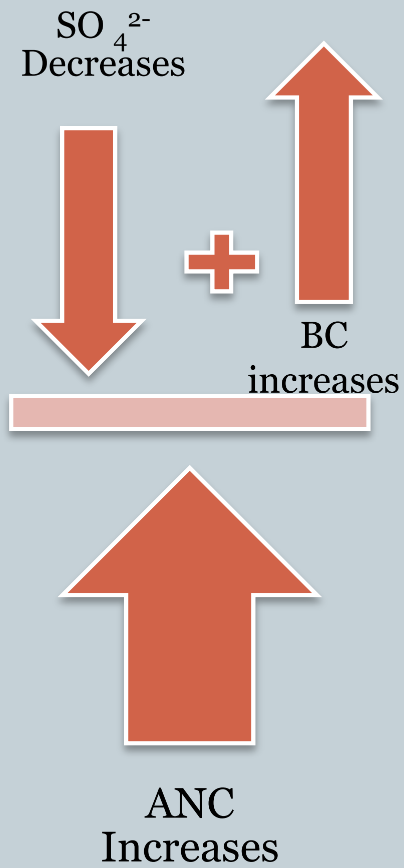


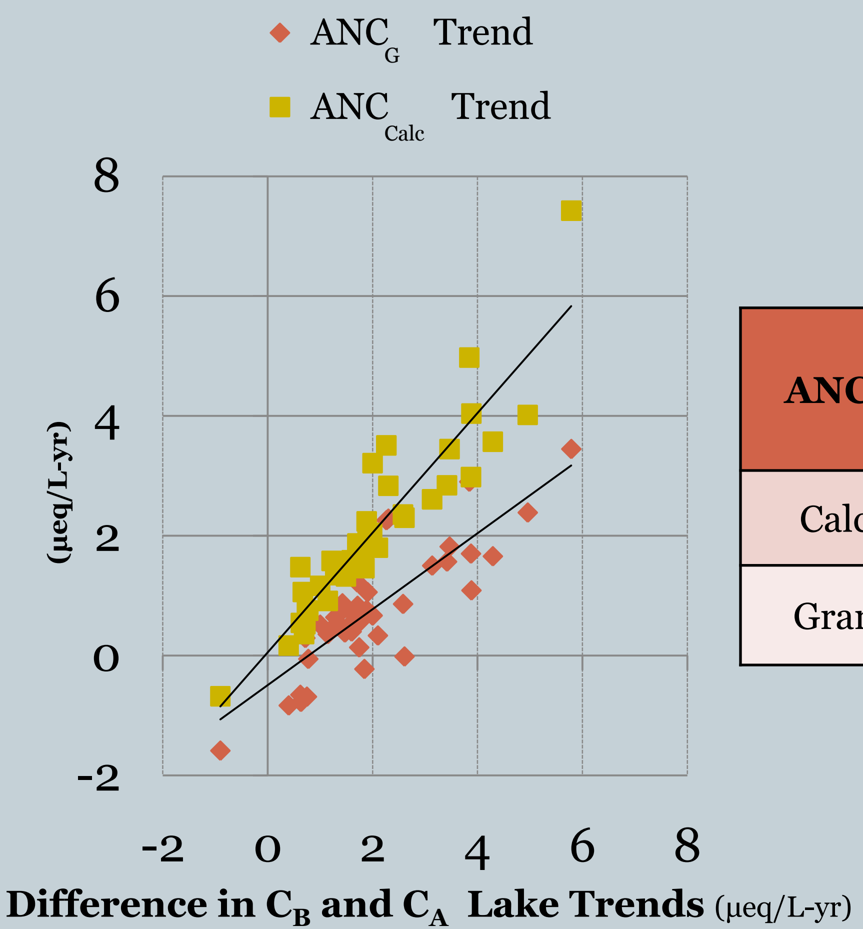


ANC:	R^2:	Slope:
Calc	.440	.48
Gran	.328	.29

Strongest Relationship to Lake Trend Difference

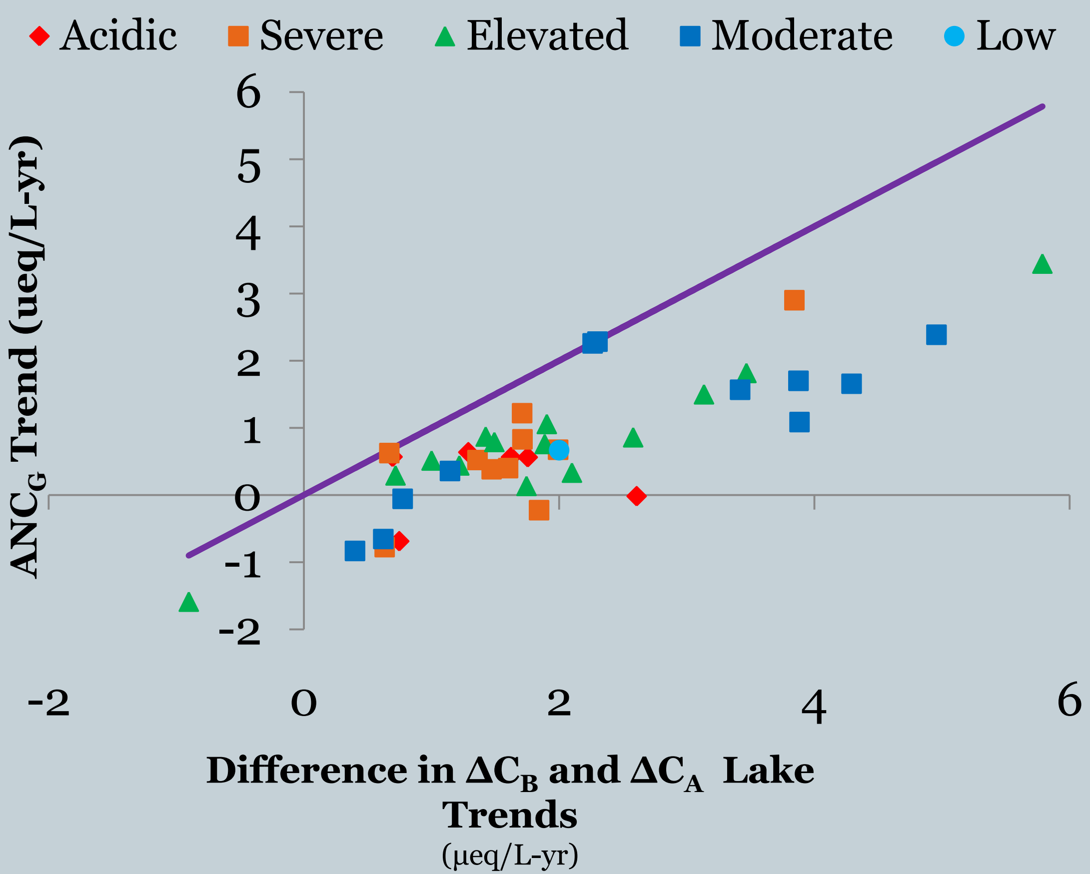
$\Delta C_B - \Delta C_A$





ANC:	R^2:	Slope:
Calc	.858	1
Gran	.700	.63

What Drives the Difference in Trends?

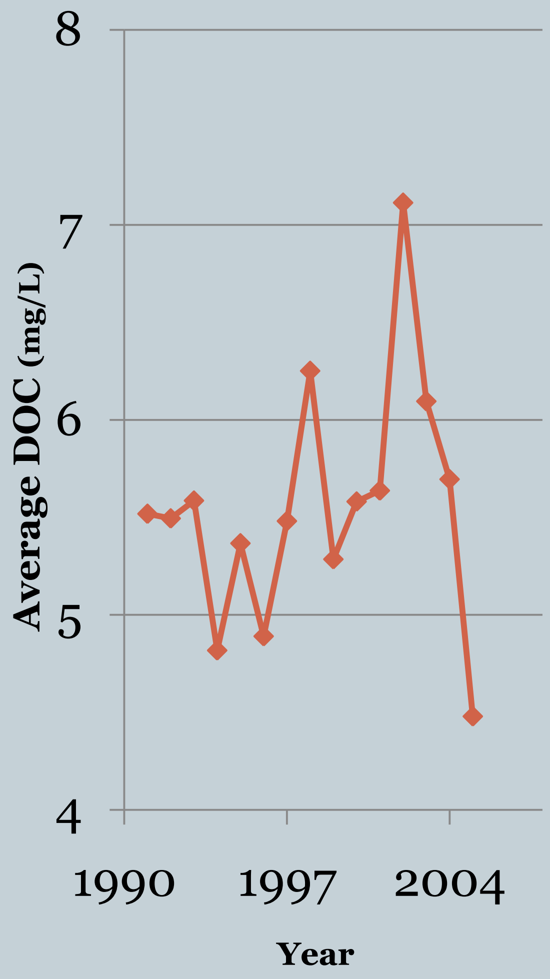


Lake Characteristic:	R^2:
Base Saturation of Soils	.016
Watershed Elevation	.054
Watershed Area	.003

- Changes Well Dispersed Among ANC Class and Lake Characterizations

Dissolved Organic Carbon (DOCs)

Parameter:	91-07:	91-07:	04-07:
Average Trend: (mg C/L-yr)	+.025	+.105	-.819
Range: (mg C/L-yr)	-.25 to +.34	-.10 to +.56	-3.6 to +.13
% Increasing :	69.0%	81.0%	9.5%
# Significant*:	4	7	0



Conclusions

- Strong decreases in wet SO4 deposition (-1.04 meq/m2-yr) and SO4 lake fluxes (-1.19 meq/m2-yr)
- Increases in ANC_G (+1.08 ueq/L-yr) and ANC_{CALC} (+2.03 ueq/L-yr)
- Substantial decreases in the number of acidic lakes (132)
- Decreases in wet SO4 deposition is weakly related to increases in ANC
- Increases in ANC strongly related to $\Delta C_B - \Delta C_A$
- Changes in ANC_{CALC} exceed $ANC_{G,}$ but limited trends in DOC

Acknowledgements

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