Source Contribution to $PM_{2.5}$ and Visibility Impairment in Two Class I Areas Using Positive Matrix Factorization

Keith Rose
EPA, Region 10
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Introduction

- PMF was used to analyze IMPROVE data from 1991-95 and 2000-03 time periods for Mt. Rainier and Yosemite National Park Class I Areas
- PMF identified six source profiles and the time-dependent contributions of these sources to $PM_{2.5}$ concentrations in these Class I Areas
- PMF source concentrations were converted to light extinction to determine the visibility impairment due to each source

The PMF Model

- PMF is a form of factor analysis with non-negative factor elements
- PMF looks for co-variation of species over time to identify source profiles and source time-dependent contributions which best fit the data
- PMF uses data uncertainty to “weight” the data (i.e. greater uncertainty = less weight)

The PMF Model (continued)

- PMF works best with a large (>300) number of samples and several metal tracer species
- The appropriate number of sources can be determined by analyzing the data first with another model (UNMIX), or comparing source profiles with previously identified profiles
- The model was run in the “robust” mode in the “heuristically-computed” error mode

Data Selection

- IMPROVE data from 1991-95 and 2000-03
- Species with a substantial number (>50%) of values below the MDLs were eliminated
- Data reported as “0” were replaced by ½ MDL
- Species used in this analysis included: Ca, Cu, EC1-2, Fe, K, H, Na, Pb, OC2-4, NO3, S, SO4, Si and Z
- Number of samples used: Mt. Rainier – 476/435 and Yosemite – 473/421

Determining the Number of Sources

- Used the UNMIX model to identify the number of sources and source profiles for Mt. Rainier
- Compared PMF source profiles with identified source profiles from Seattle and Columbia Gorge
- Examined “goodness of fit” of linear regression between measured and calculated source concentrations

Sources and Average Percent Contribution to $PM_{2.5}$ Concentrations at Mt. Rainier

(1998-2001 data)

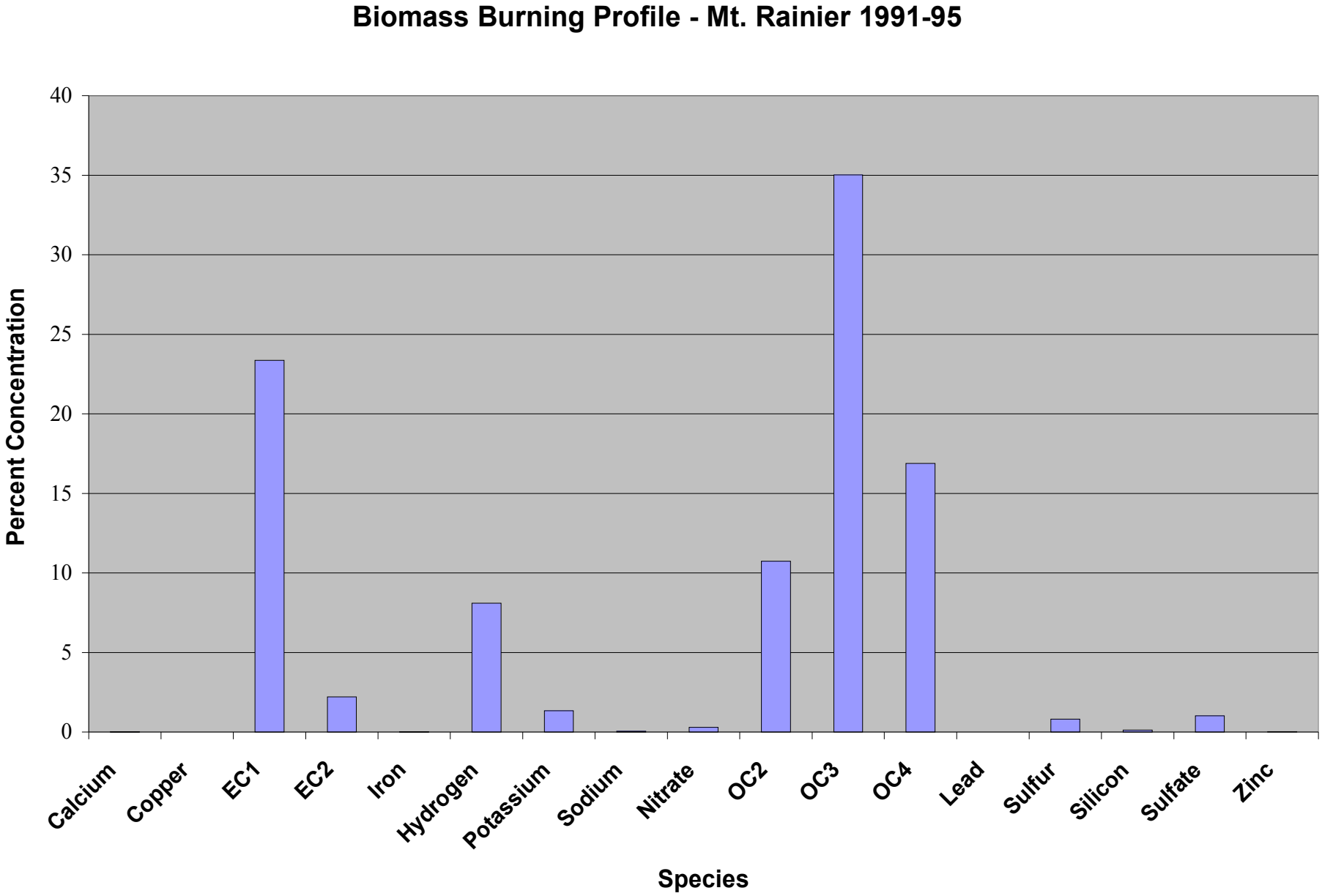
Source	PMF	UNMIX
Biomass	38.9	43.1
Sulfate	31.6	31.1
Nitrate	8.6	11.5
Mobile	4.8	4.7
Soil	9.4	5.7
Marine	6.7	4.0

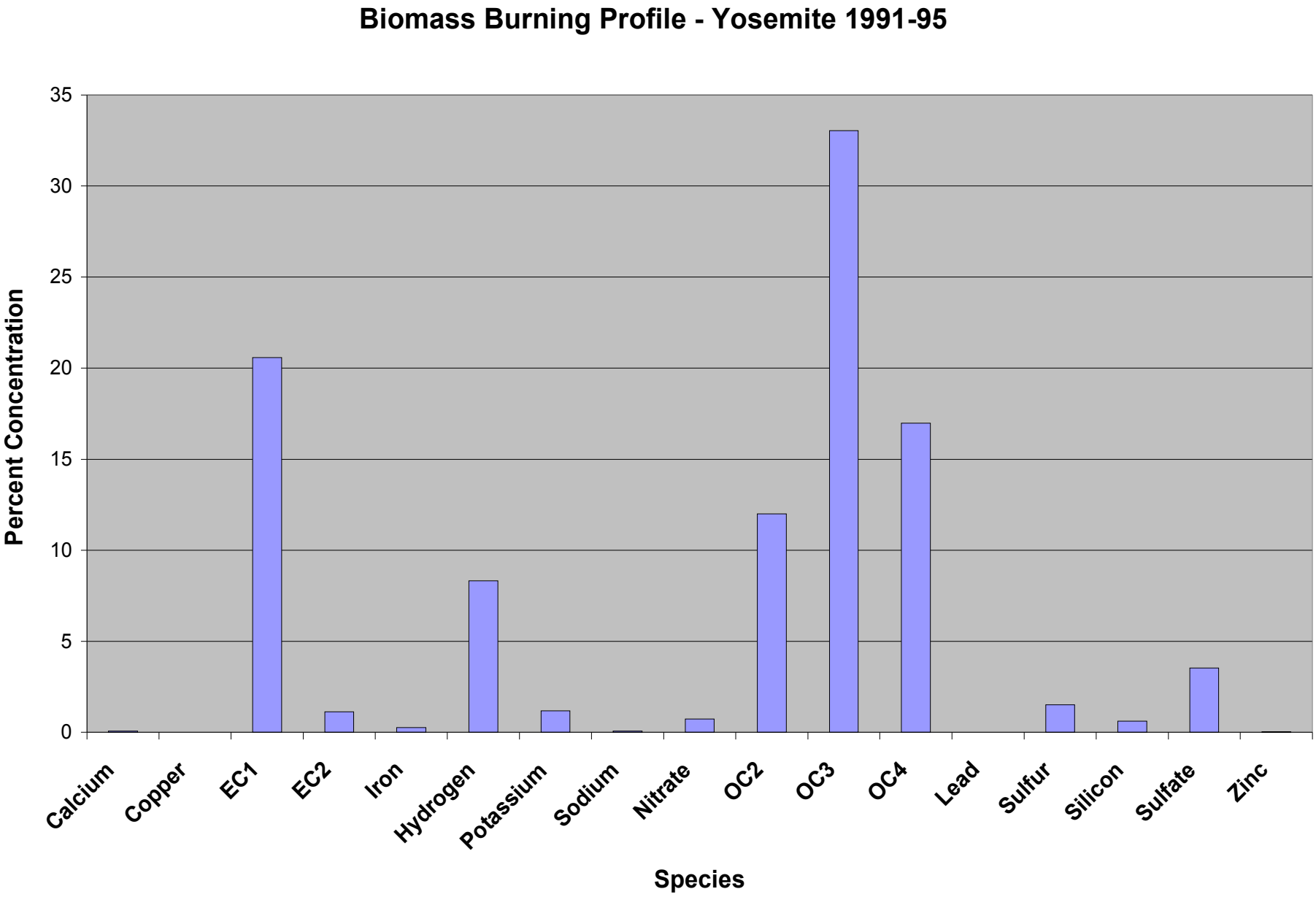
Definition of Sources

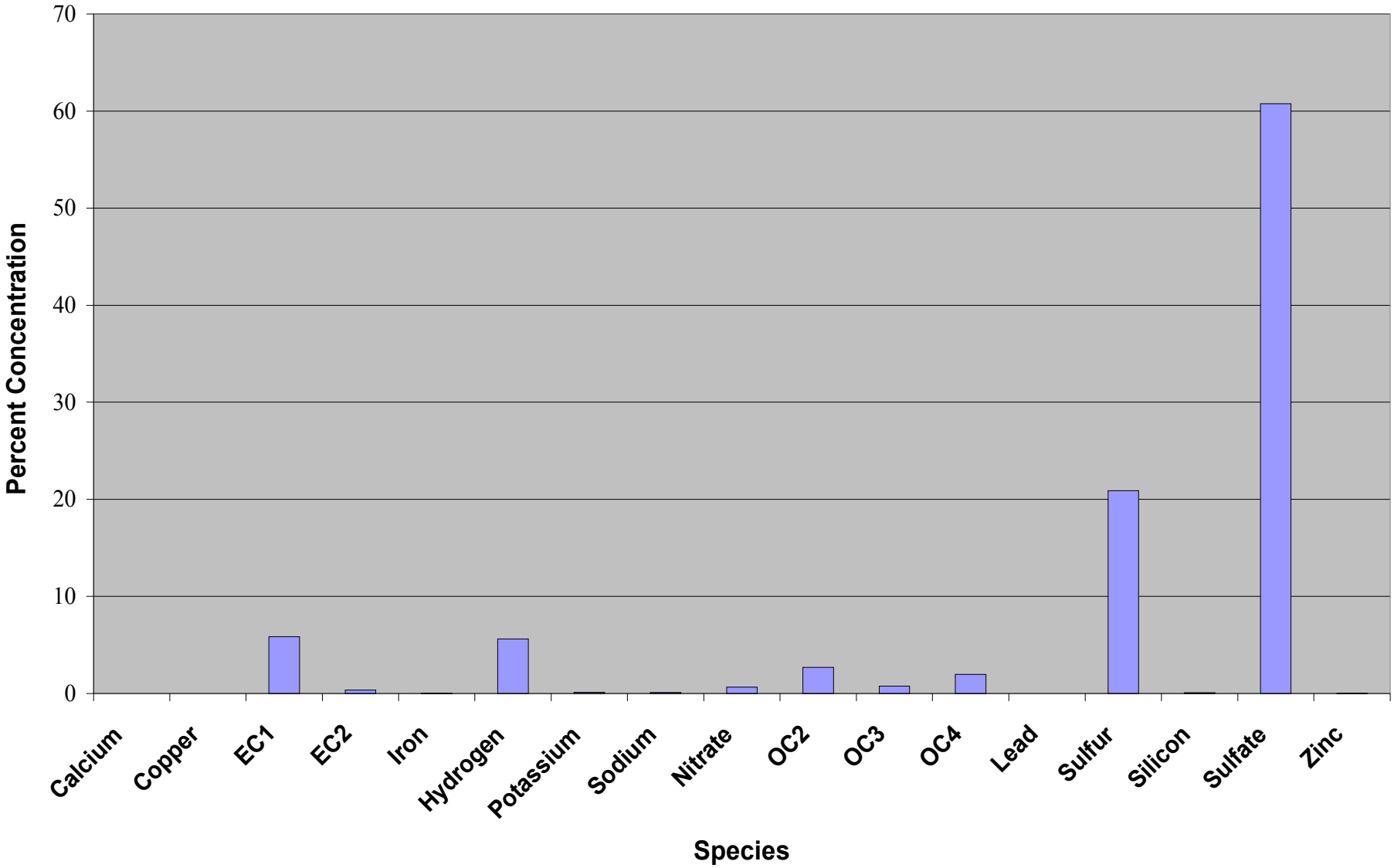
- Biomass = wood stoves/fireplaces, agricultural burning, wildfires, prescribed burning
- Mobile = on-road and off-road gasoline and diesel powered mobile vehicles
- Secondary sulfate = diesel fuel, home heating fuel, pulp mills, oil refineries
- Secondary nitrate = oil refineries, commercial boilers, power plants, on and off-road mobile sources (50-66%?)

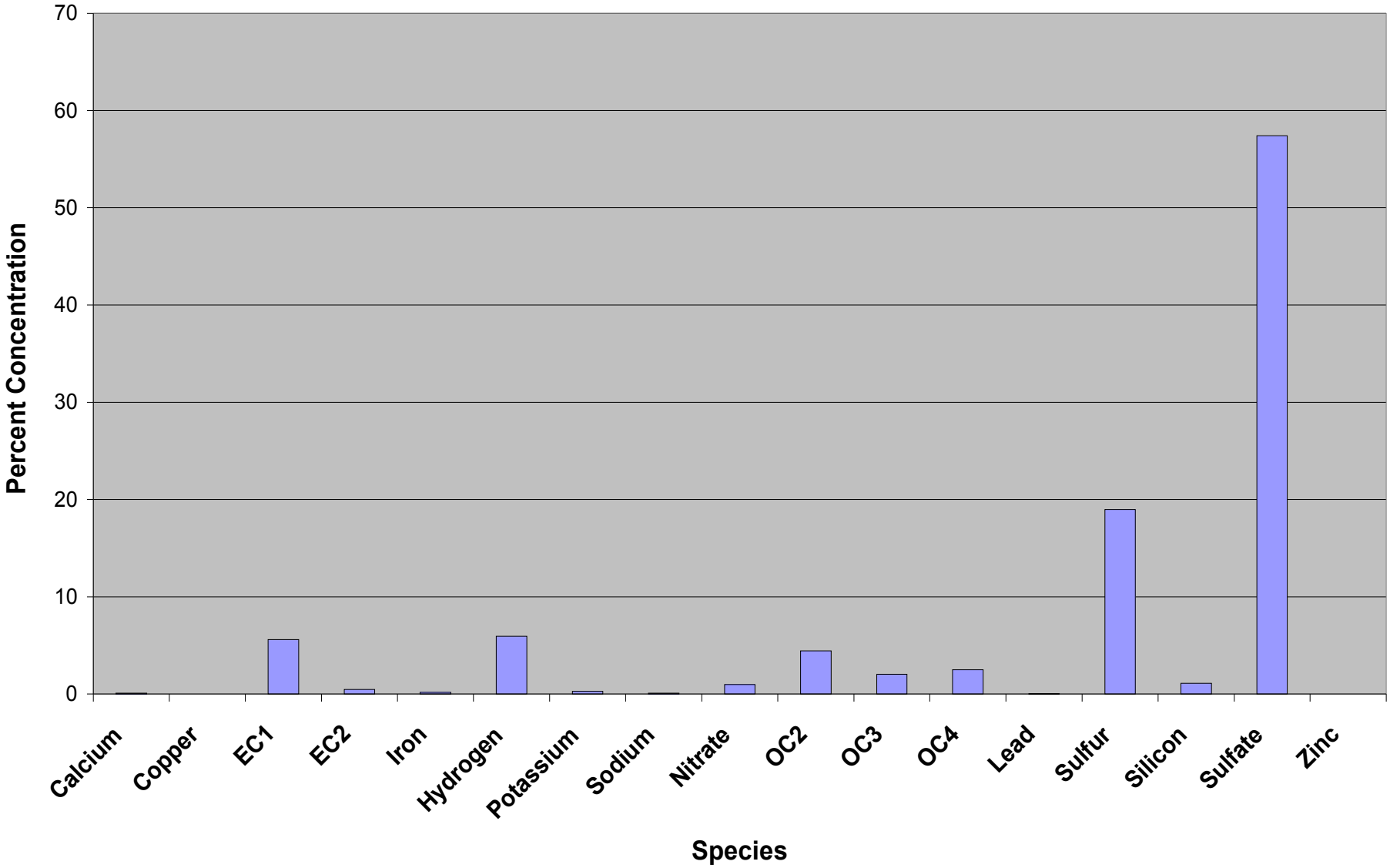
Results

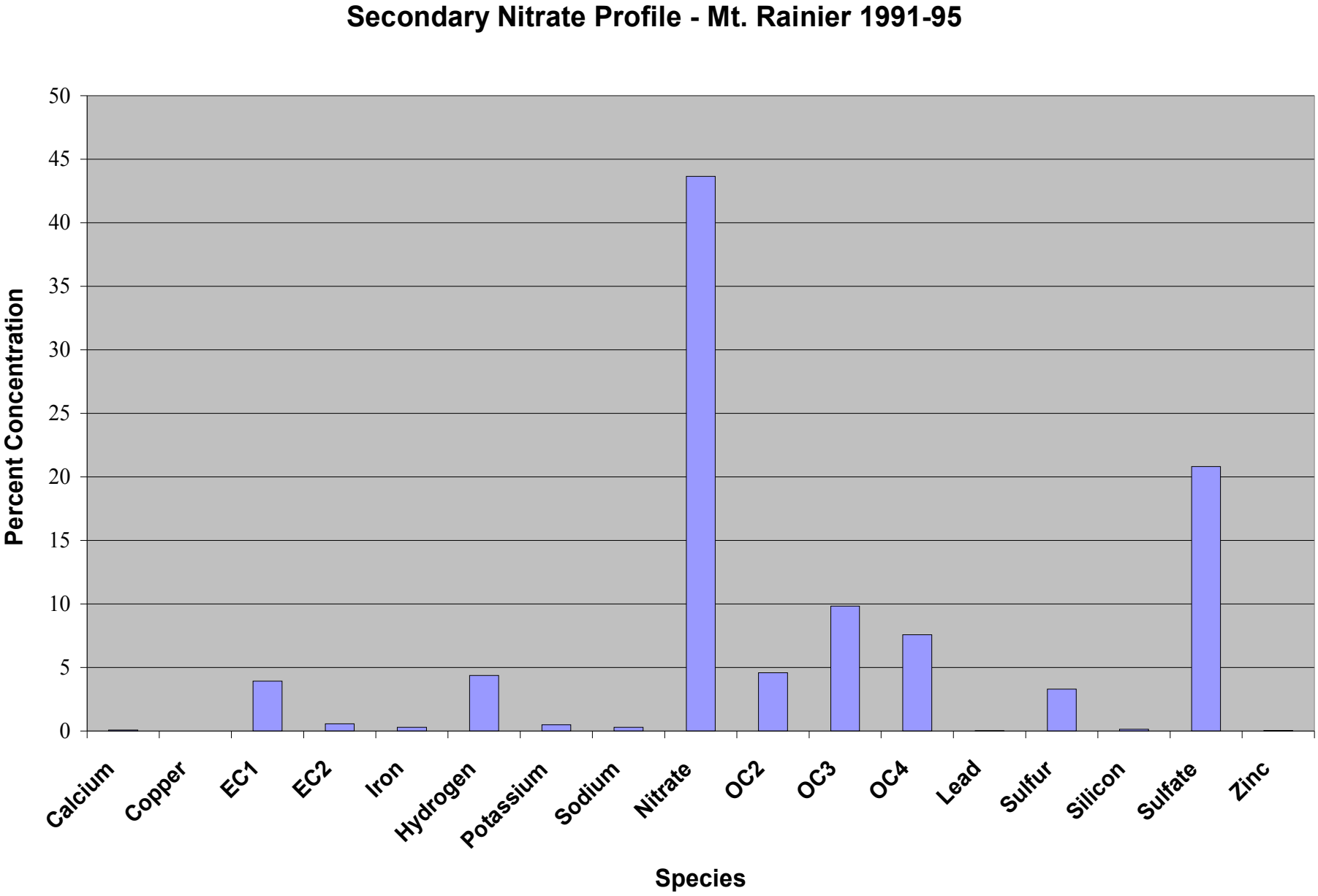
- Mt. Rainier and Yosemite source profiles
- Time-dependent concentrations for each source
- Average source light extinction (Bext)
- Light extinction by source for 1991-95 and 2000-03 time periods
- 20% worst vs. 20% best days for 2002

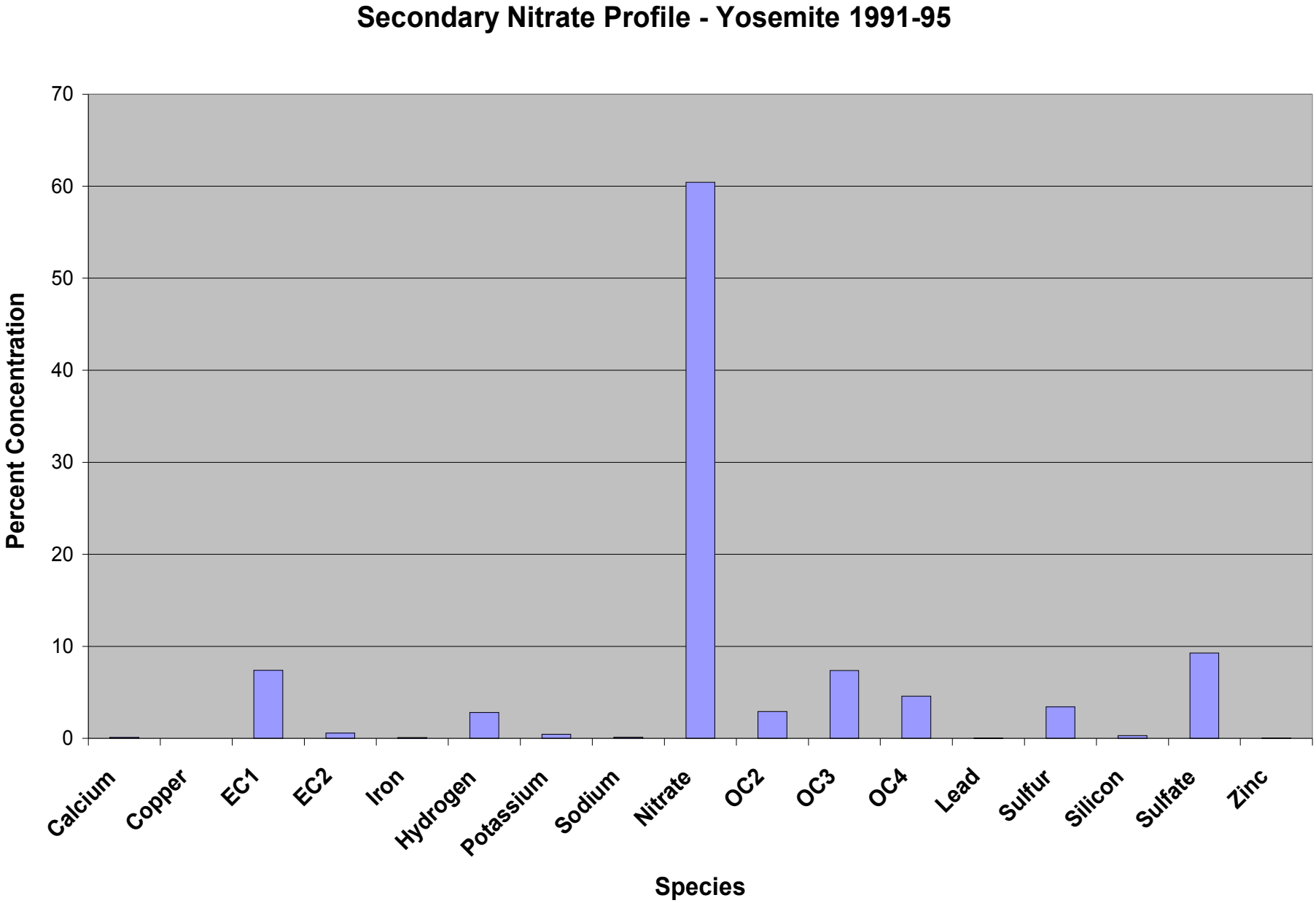

Biomass Burning Profile - Mt. Rainier 1991-95
Percent Concentration
40
35
30
25
20
15
10
5
0
Calcium
Copper
EC1
EC2
Iron
Hydrogen
Potassium
Sodium
Nitrate
OC2
OC3
OC4
Lead
Sulfur
Silicon
Sulfate
Zinc
Species

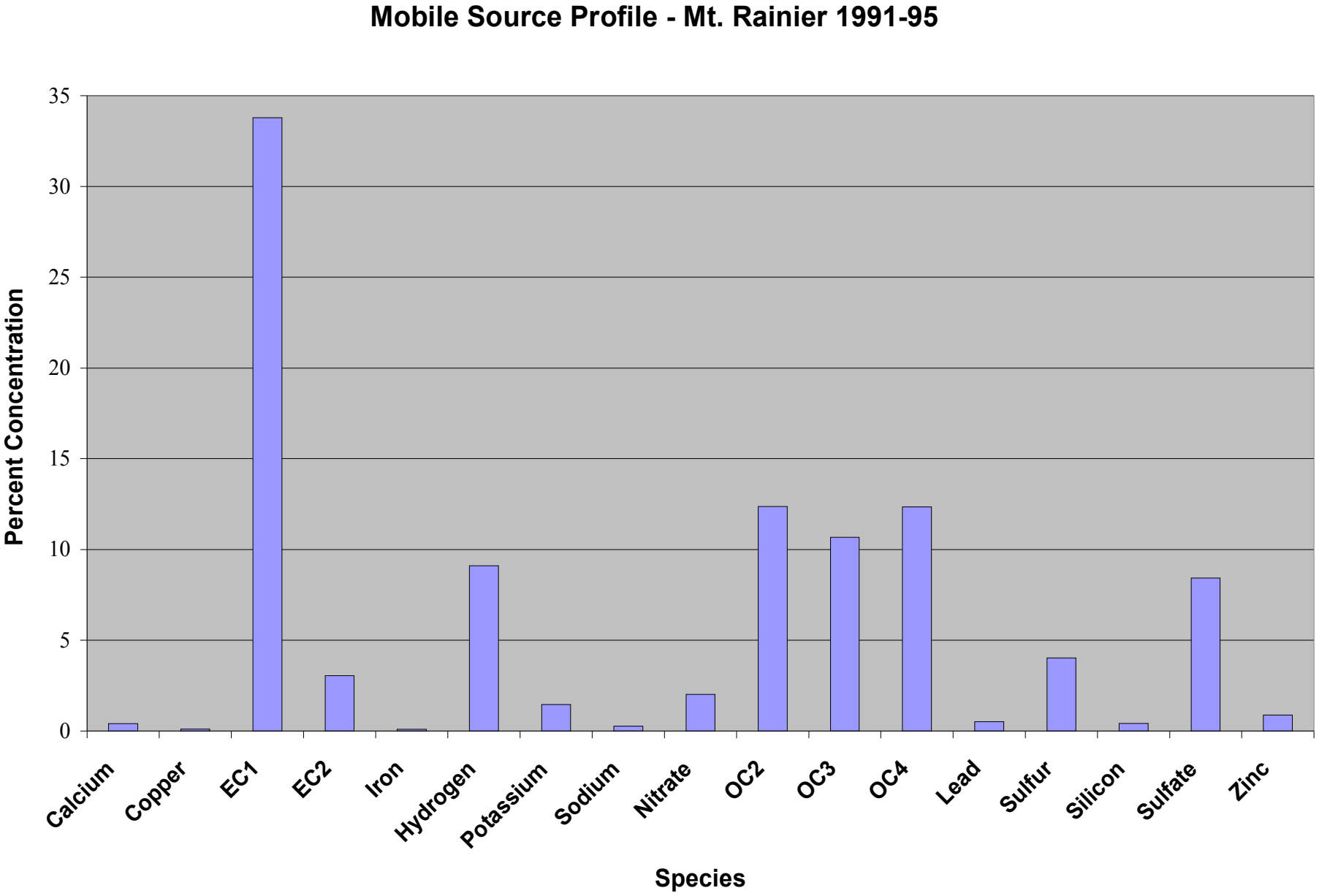

Biomass Burning Profile - Yosemite 1991-95
Percent Concentration
35
30
25
20
15
10
5
0
Calcium
Copper
EC1
EC2
Iron
Hydrogen
Potassium
Sodium
Nitrate
OC2
OC3
OC4
Lead
Sulfur
Silicon
Sulfate
Zinc
Species

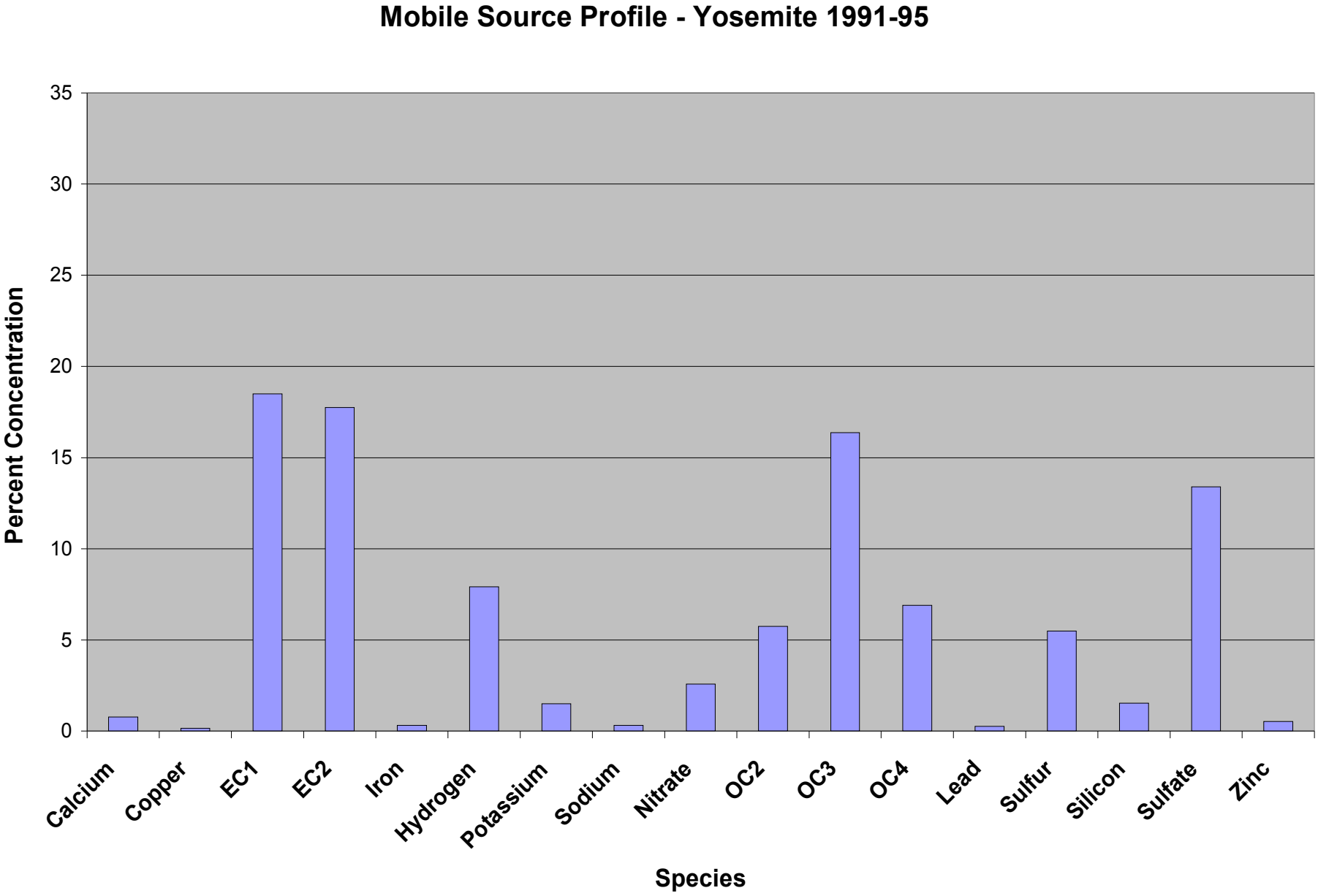

Secondary Sulfate Profile - Mt. Rainier 1991-95
Percent Concentration
70
60
50
40
30
20
10
0
Calcium
Copper
EC1
EC2
Iron
Hydrogen
Potassium
Sodium
Nitrate
OC2
OC3
OC4
Lead
Sulfur
Silicon
Sulfate
Zinc
Species

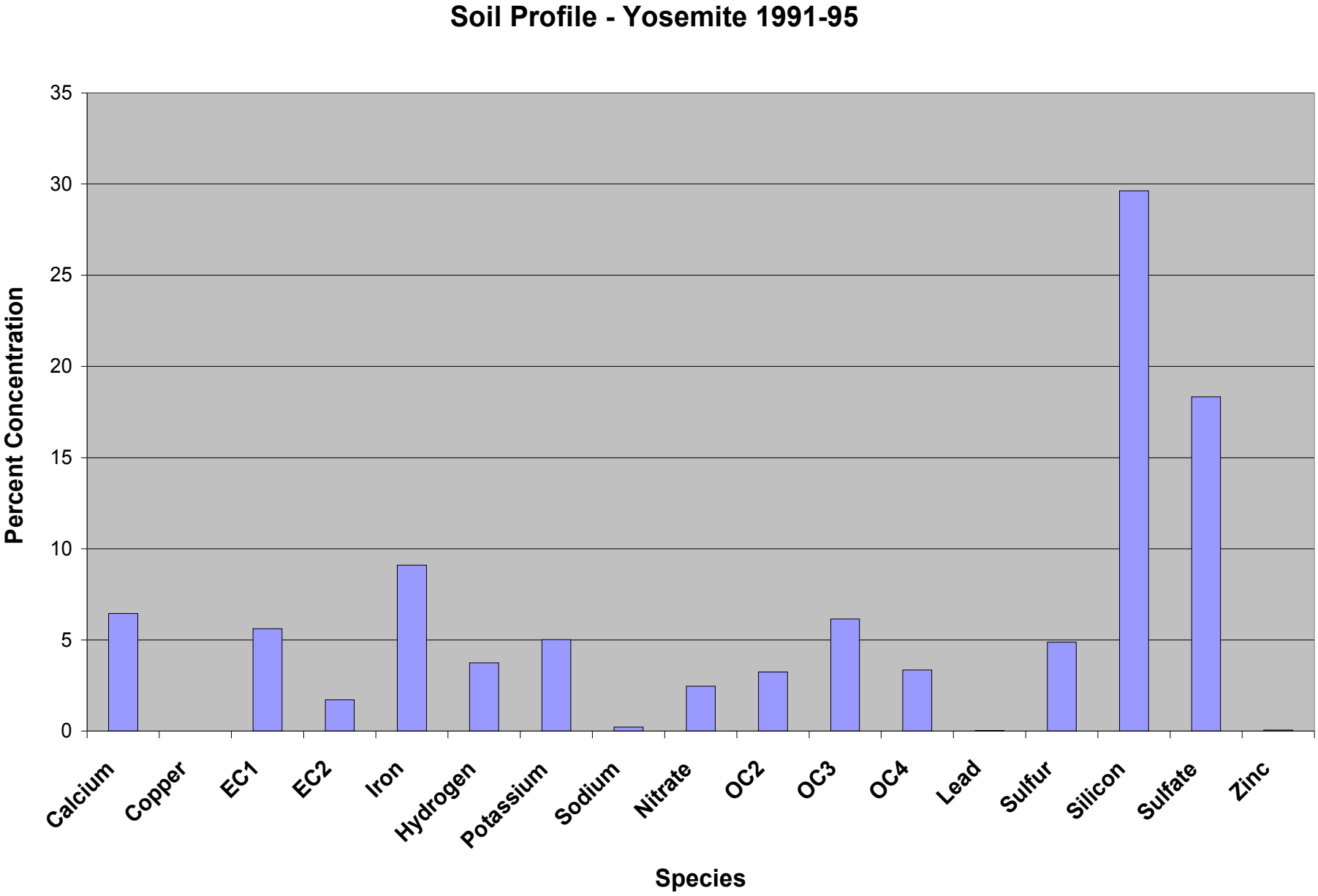

Secondary Sulfate Profile - Yosemite 1991-95
Percent Concentration
70
60
50
40
30
20
10
0
Calcium
Copper
EC1
EC2
Iron
Hydrogen
Potassium
Sodium
Nitrate
OC2
OC3
OC4
Lead
Sulfur
Silicon
Sulfate
Zinc
Species


Secondary Nitrate Profile - Mt. Rainier 1991-95
Percent Concentration
50
45
40
35
30
25
20
15
10
5
0
Calcium
Copper
EC1
EC2
Iron
Hydrogen
Potassium
Sodium
Nitrate
OC2
OC3
OC4
Lead
Sulfur
Silicon
Sulfate
Zinc
Species

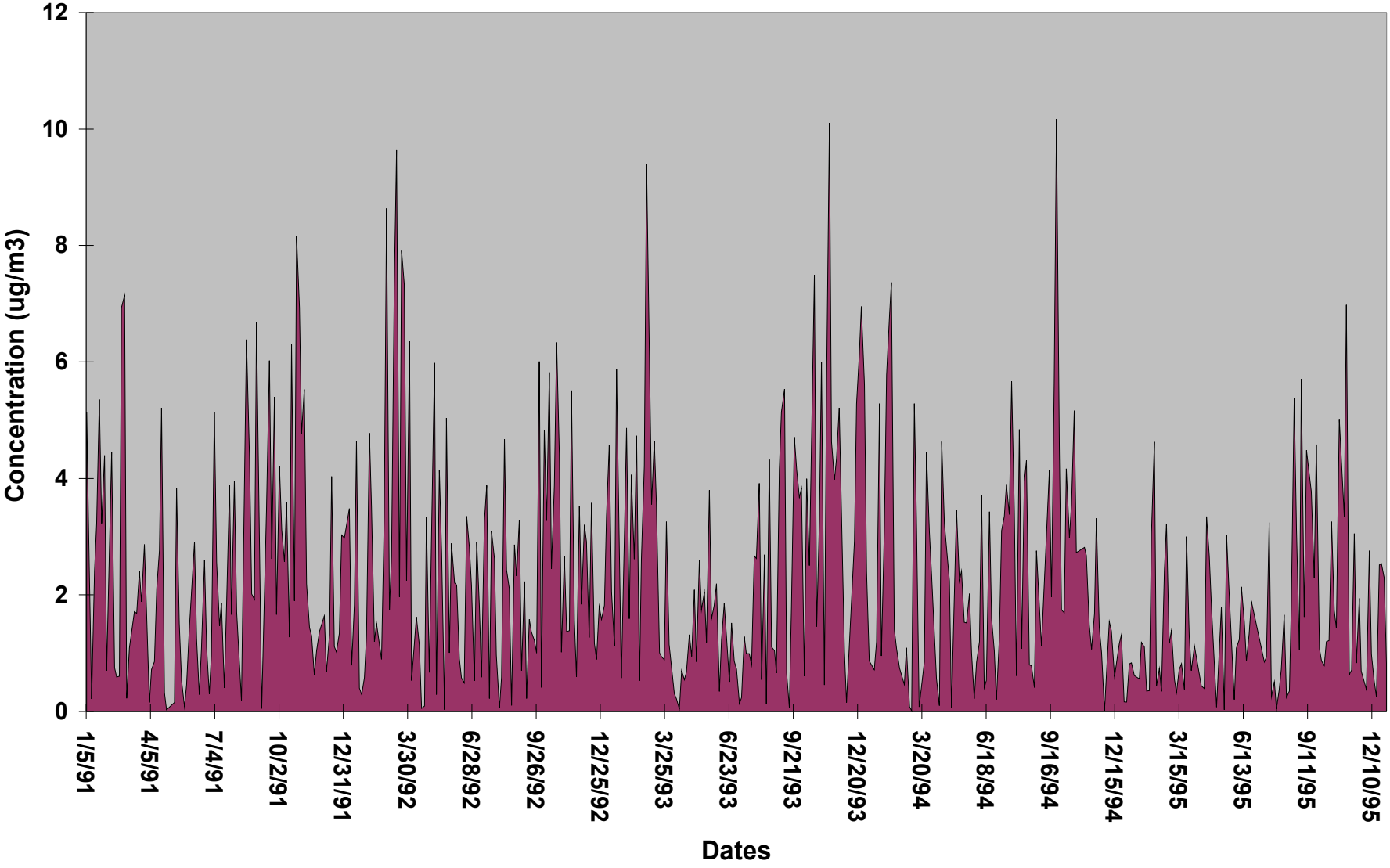

Secondary Nitrate Profile - Yosemite 1991-95
Percent Concentration
70
60
50
40
30
20
10
0
Calcium
Copper
EC1
EC2
Iron
Hydrogen
Potassium
Sodium
Nitrate
OC2
OC3
OC4
Lead
Sulfur
Silicon
Sulfate
Zinc
Species


Mobile Source Profile - Mt. Rainier 1991-95
Percent Concentration
35
30
25
20
15
10
5
0
Calcium
Copper
EC1
EC2
Iron
Hydrogen
Potassium
Sodium
Nitrate
OC2
OC3
OC4
Lead
Sulfur
Silicon
Sulfate
Zinc
Species

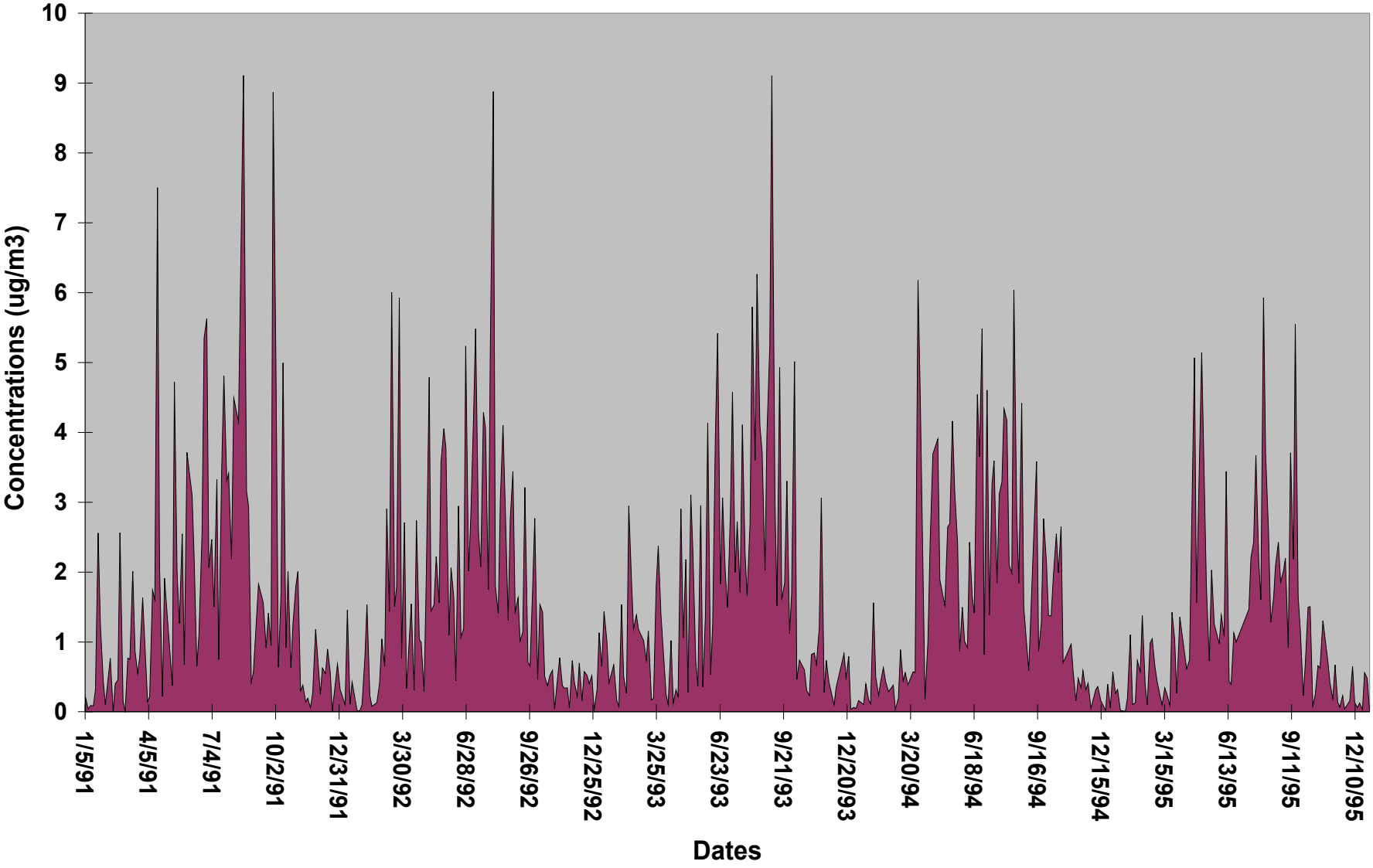

Mobile Source Profile - Yosemite 1991-95
Percent Concentration
35
30
25
20
15
10
5
0
Calcium
Copper
EC1
EC2
Iron
Hydrogen
Potassium
Sodium
Nitrate
OC2
OC3
OC4
Lead
Sulfur
Silicon
Sulfate
Zinc
Species


Soil Profile - Yosemite 1991-95
Percent Concentration
35
30
25
20
15
10
5
0
Calcium
Copper
EC1
EC2
Iron
Hydrogen
Potassium
Sodium
Nitrate
OC2
OC3
OC4
Lead
Sulfur
Silicon
Sulfate
Zinc
Species

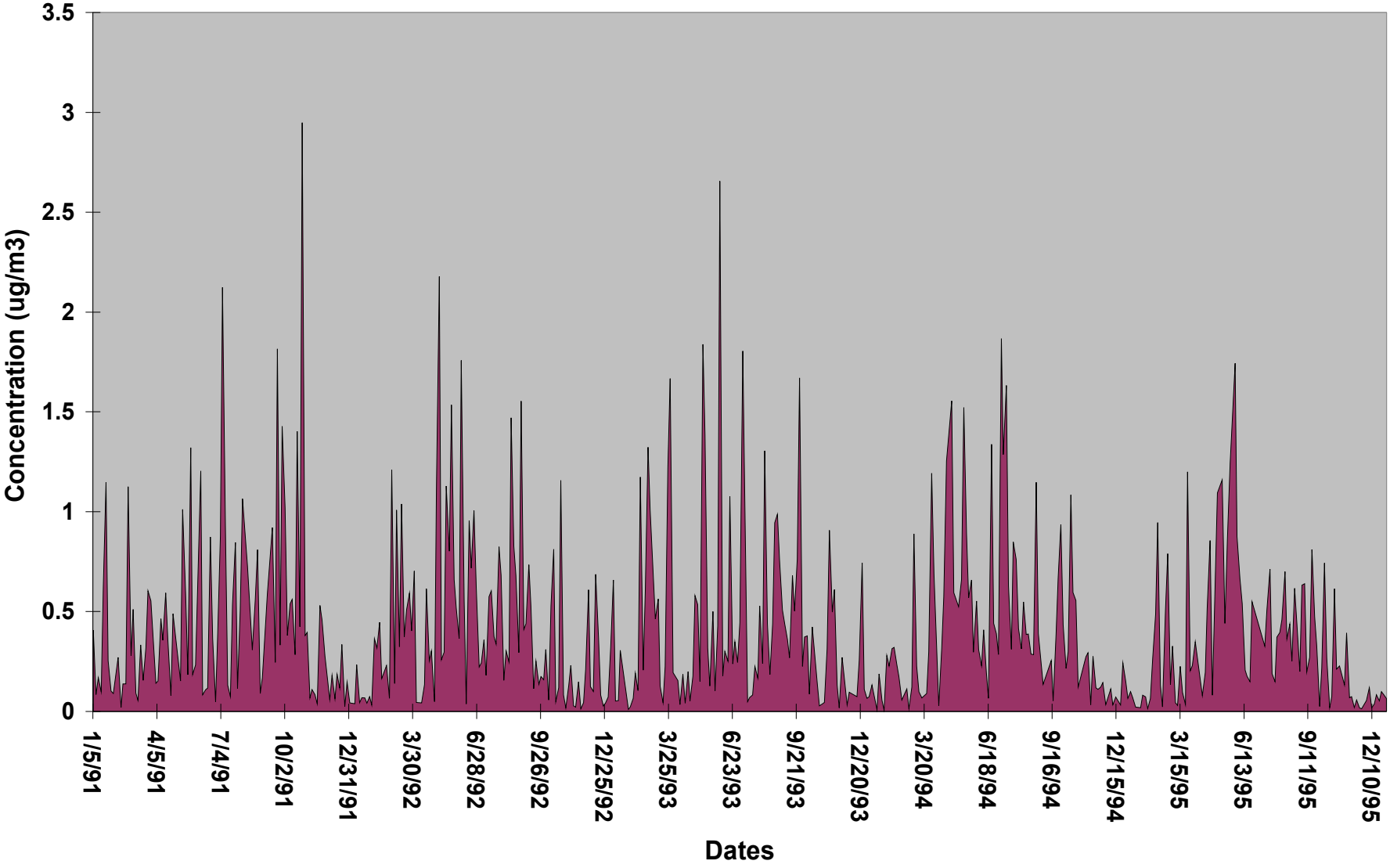
Biomass Source Trend - Mt. Rainier 1991-95



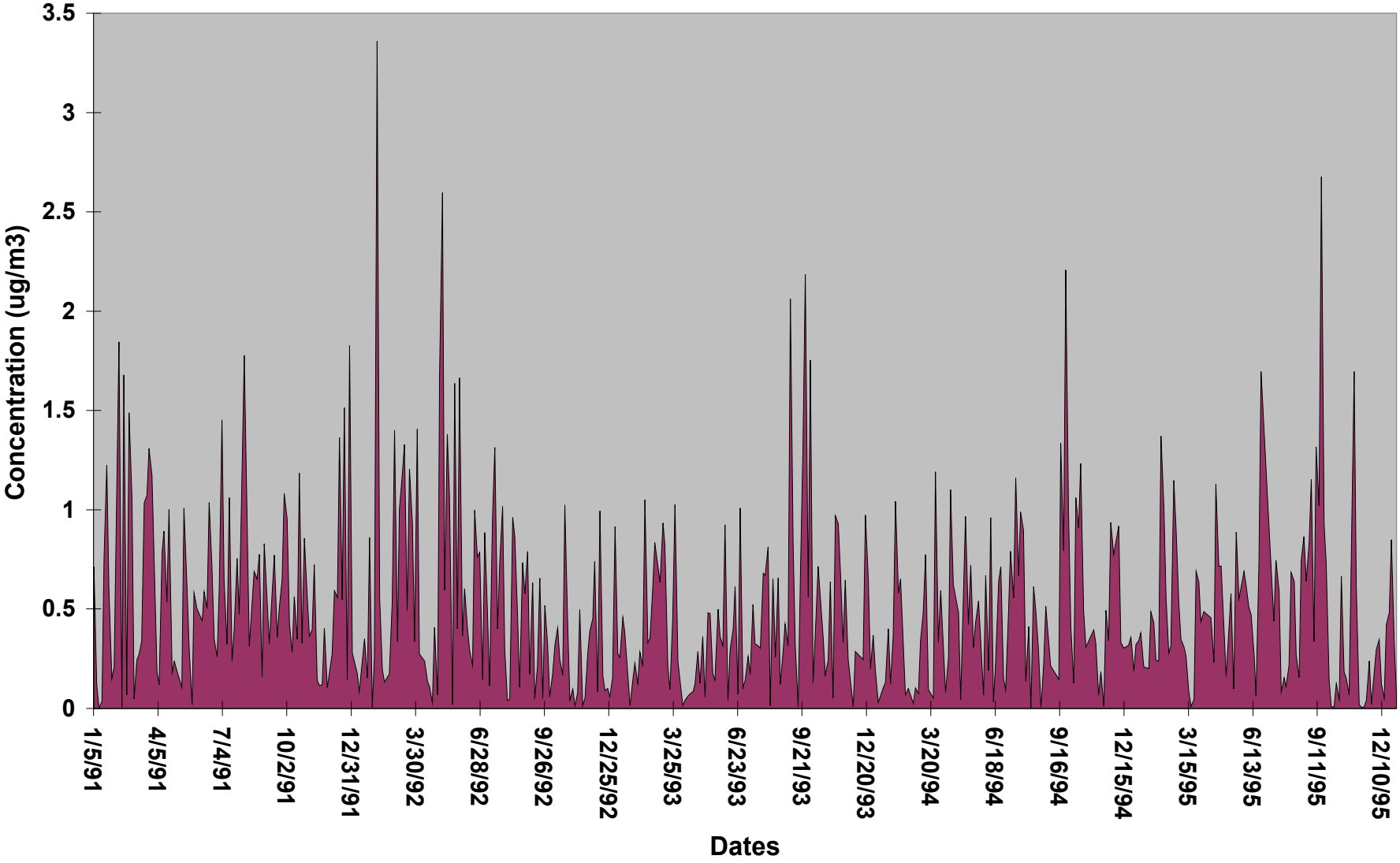
Secondary Sulfate Trend - Mt. Rainier 1991-95



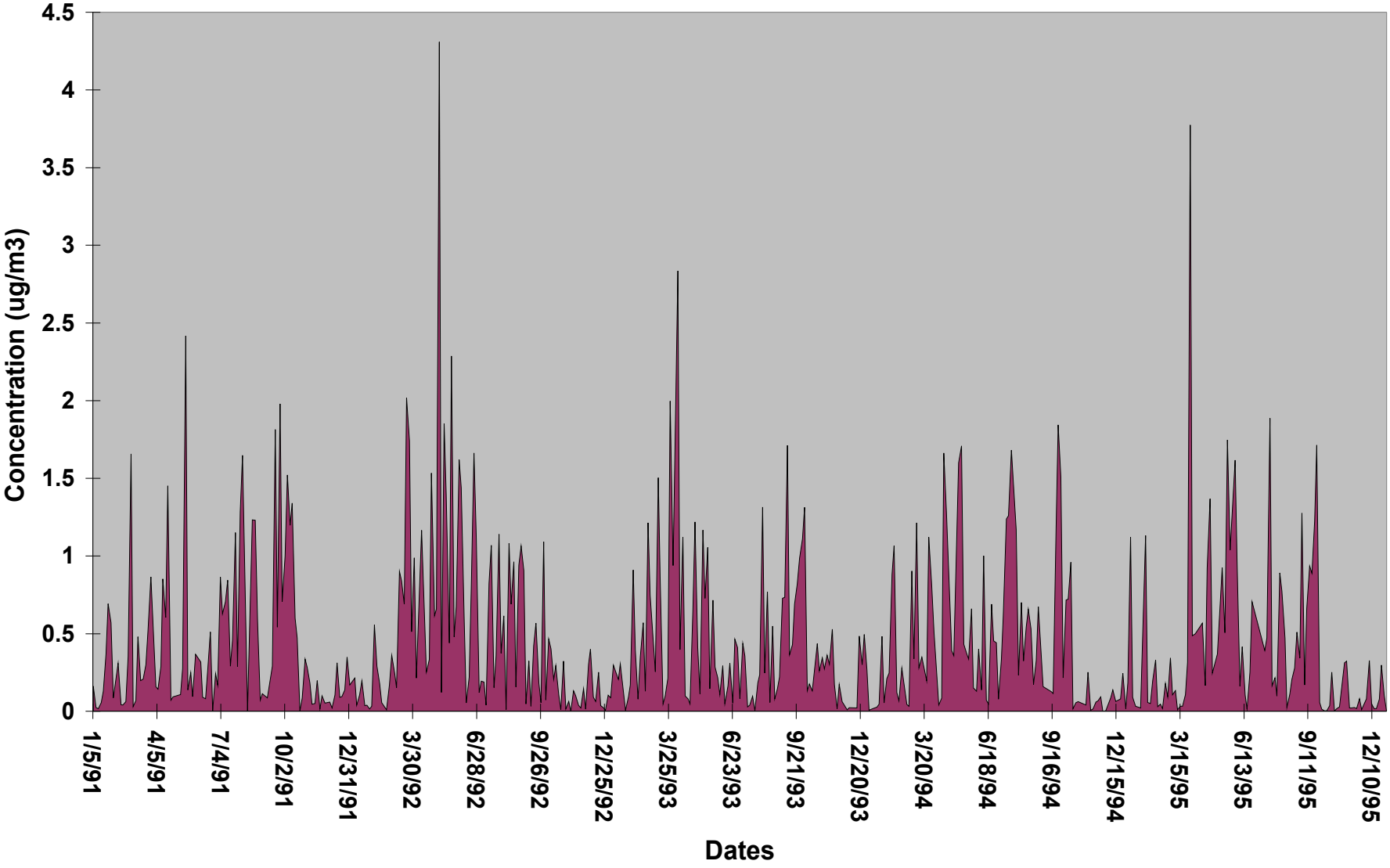
Secondary Nitrate Trend - Mt. Rainier 1991-95



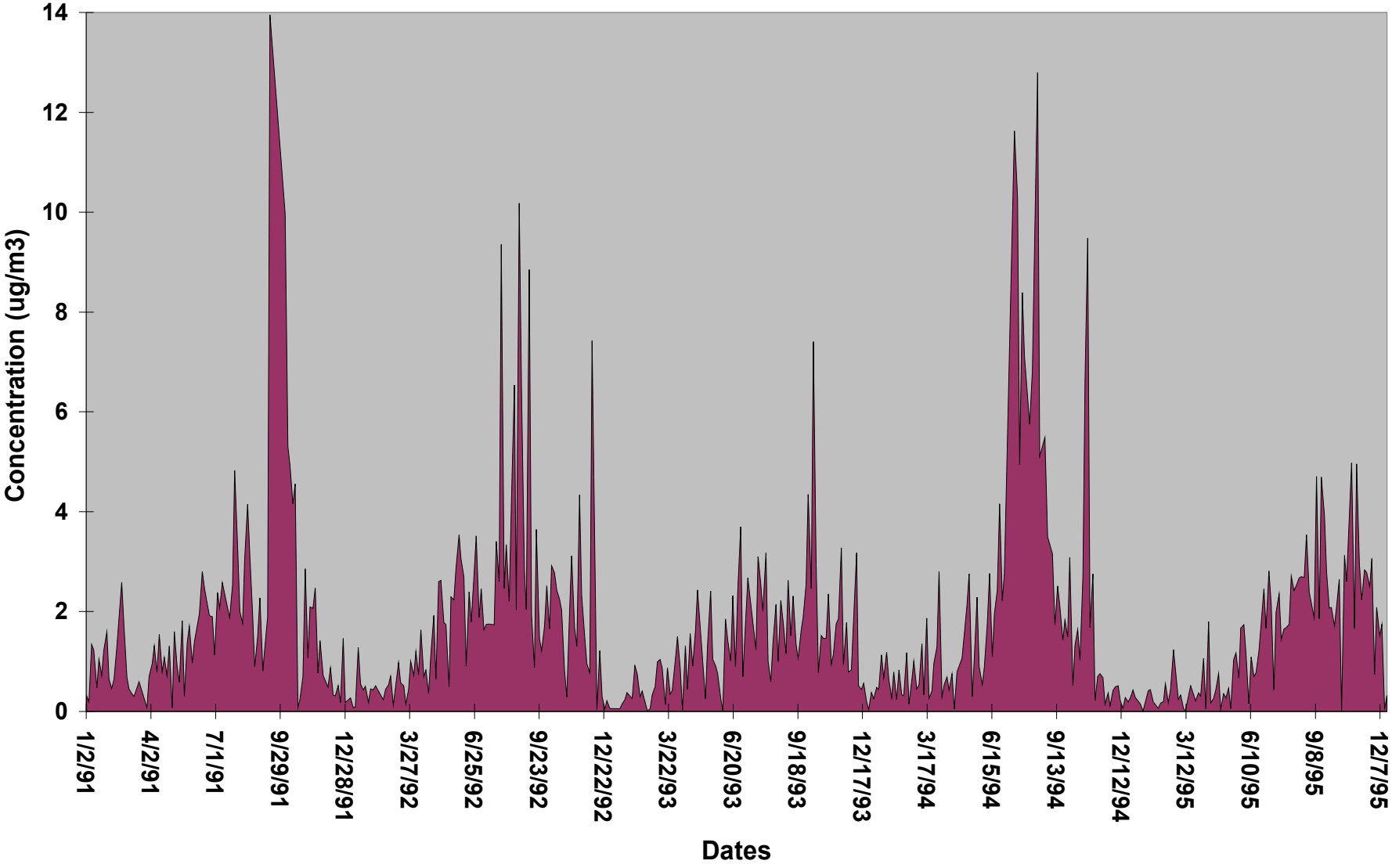
Mobile Source Trend - Mt. Rainier 1991-95

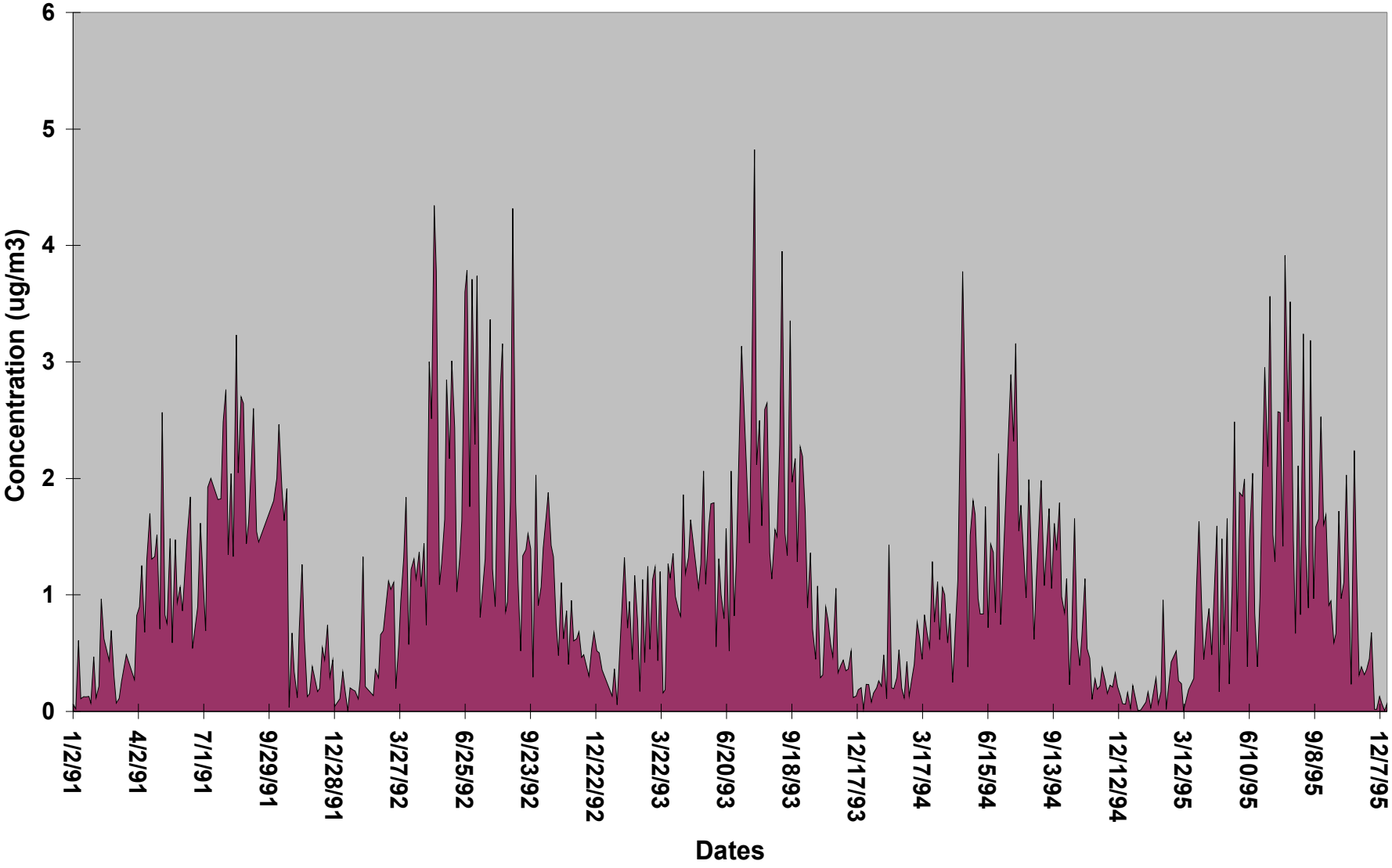


Soil Trend - Mt. Rainier 1991-95

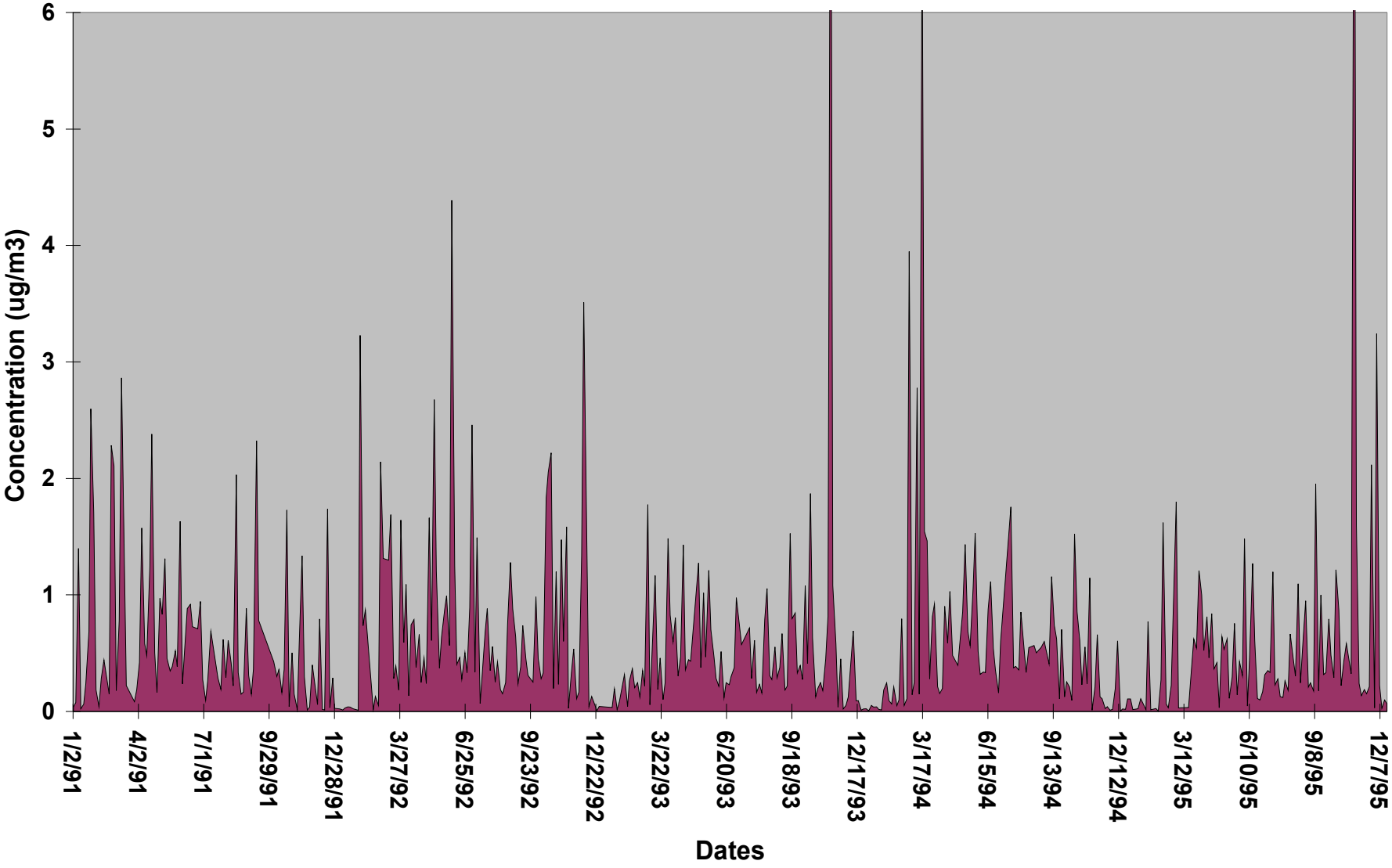


Biomass Source Trend - Yosemite 1991-95

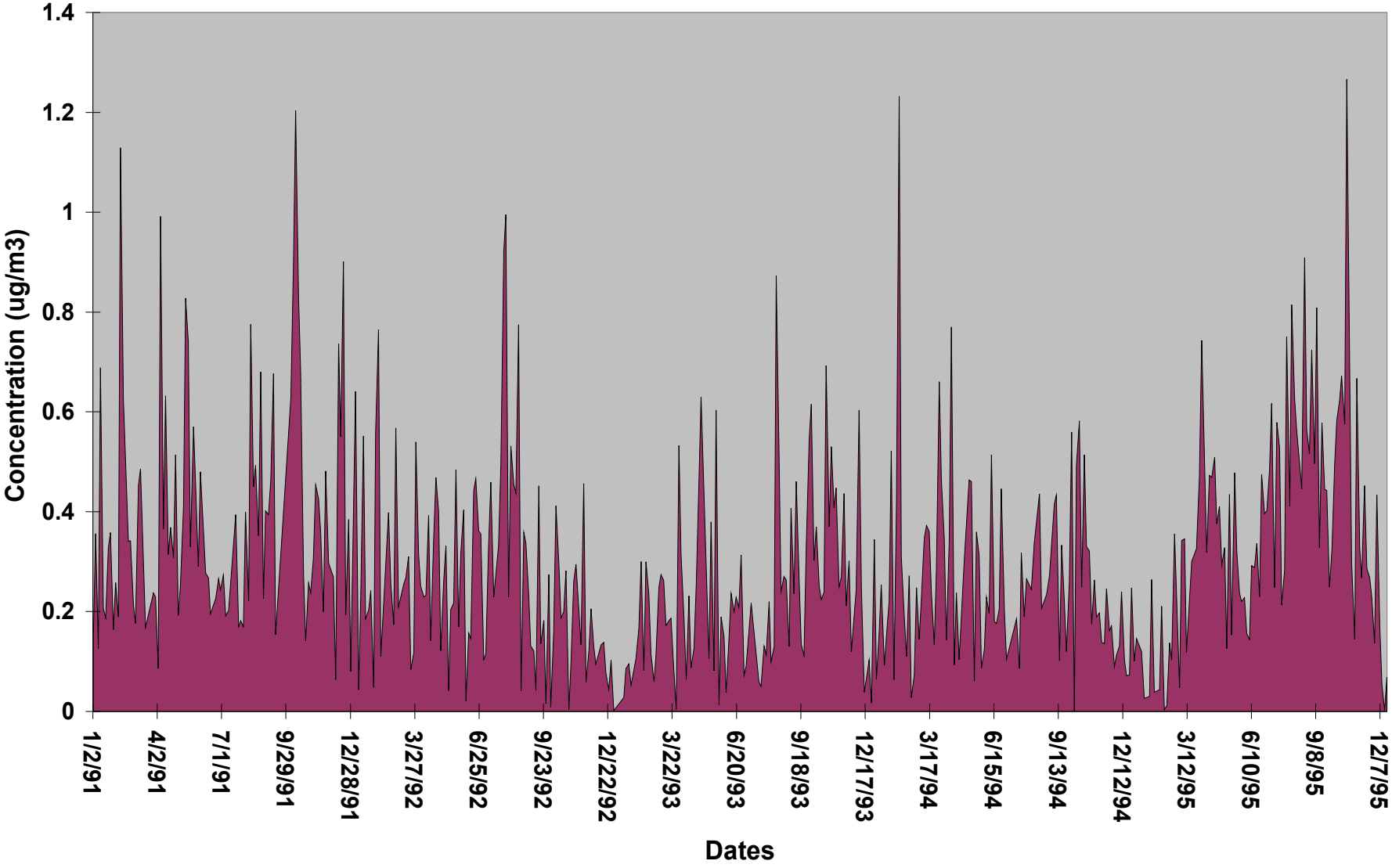



Secondary Sulfate Trend - Yosemite 1991-95
Concentration (ug/m3)
0
1
2
3
4
5
6
1/2/91
4/2/91
7/1/91
9/29/91
12/28/91
3/27/92
6/25/92
9/23/92
12/22/92
3/22/93
6/20/93
9/18/93
12/17/93
3/17/94
6/15/94
9/13/94
12/12/94
3/12/95
6/10/95
9/8/95
12/7/95
Dates

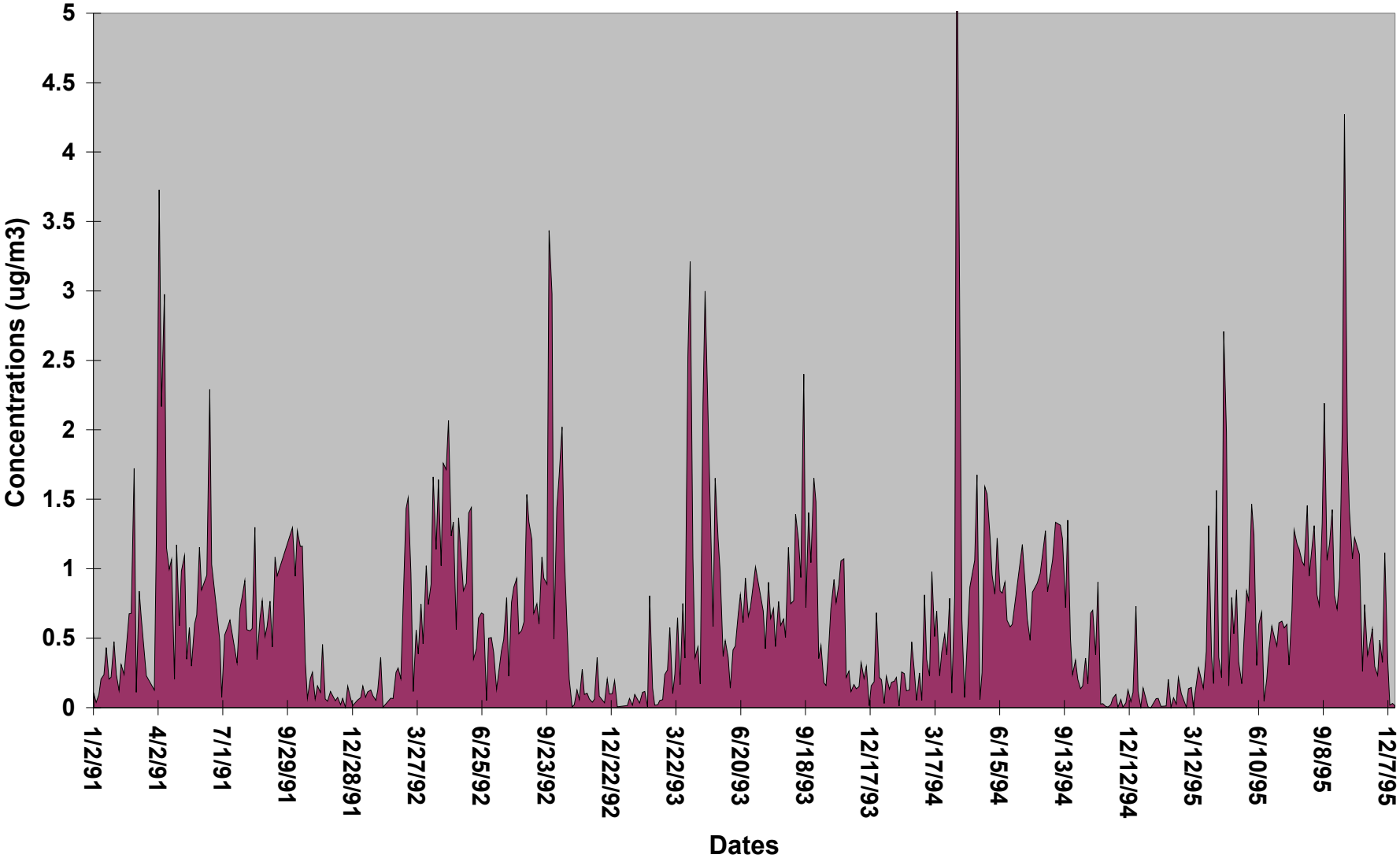
Secondary Nitrate Trend - Yosemite 1991-95



Mobile Source Trend - Yosemite 1991-95



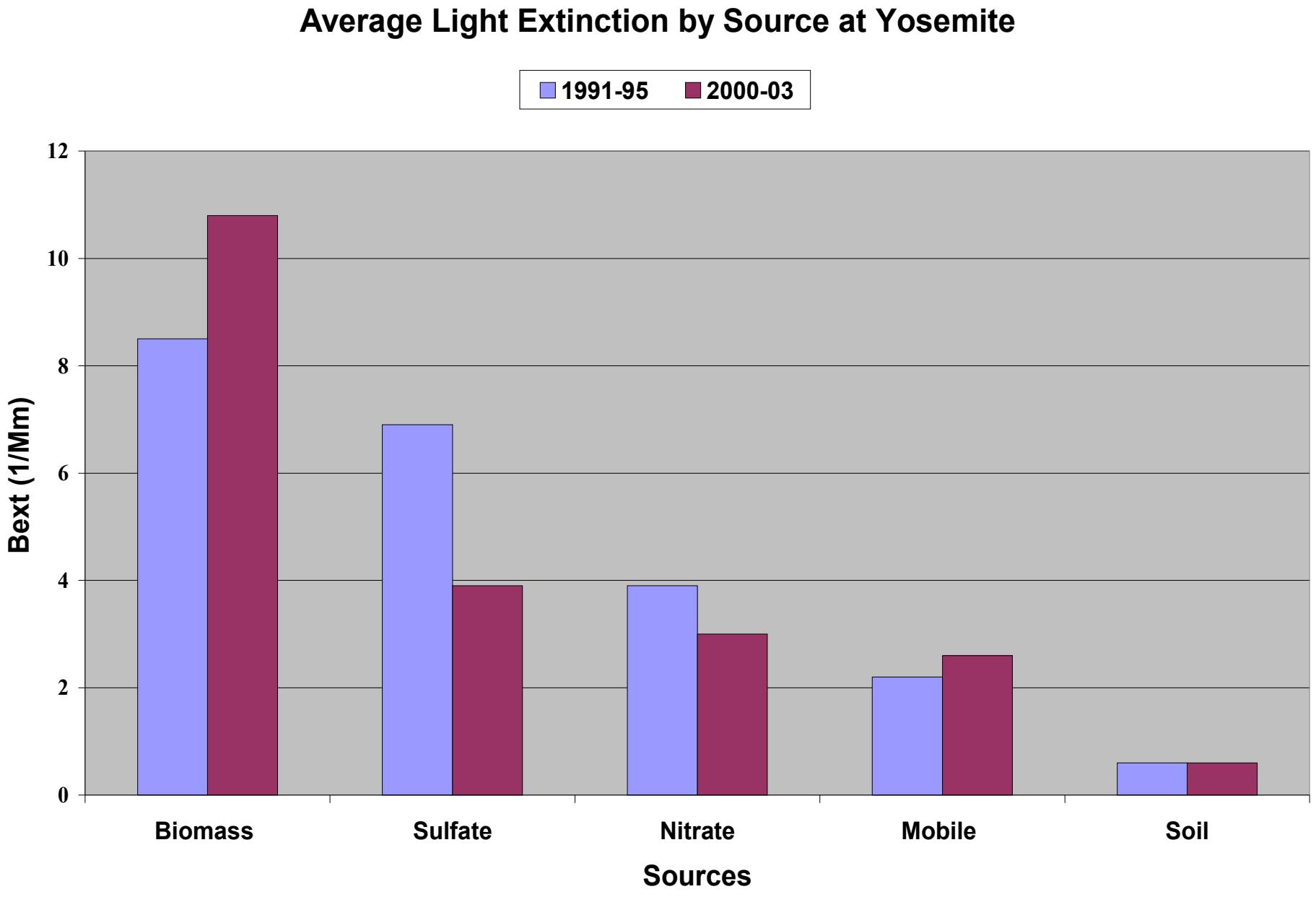
Soil Trend - Yosemite 1991-95

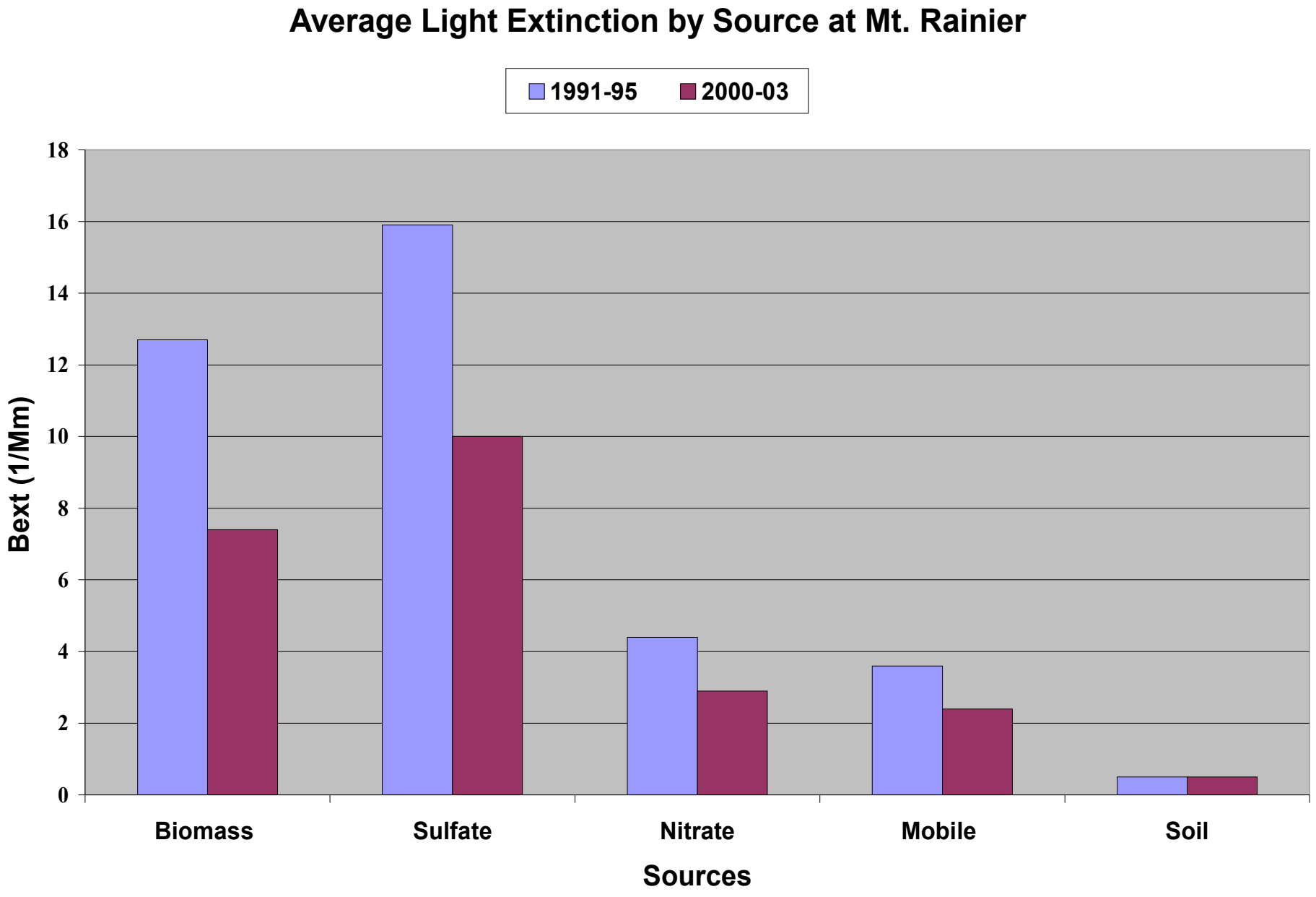


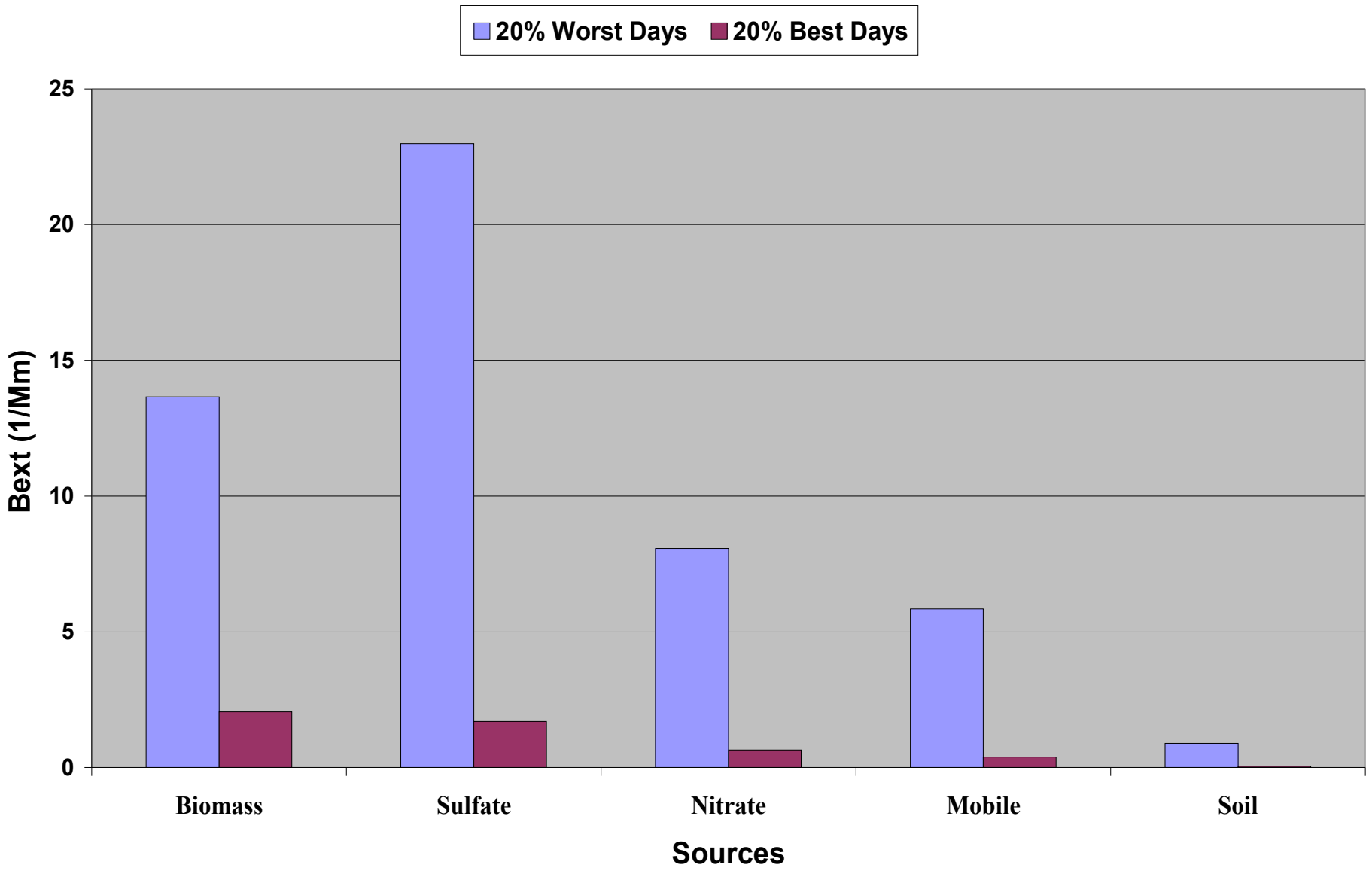
Light Extinction Calculation

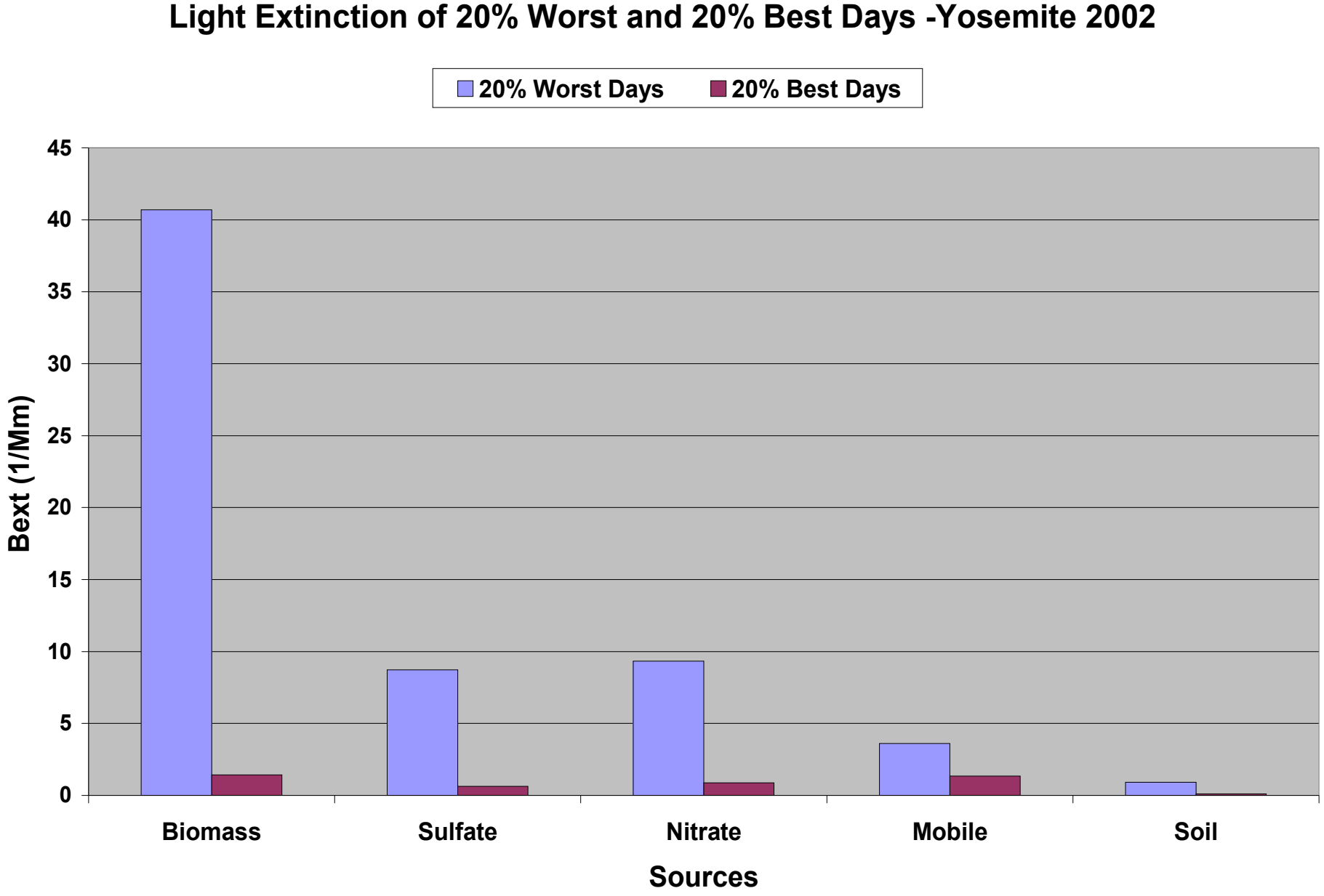
- Bext = $(3m^2/g)Ft(RH)[sulfate] + (3m^2/g)Ft(RH)[nitrate] + (4m^2/g)[OC] + (10m^2/g)[EC] + (1m^2/g)[soil]$

- Ft(RH) = annual average relative humidity factor


Average Light Extinction by Source at Yosemite
1991-95
2000-03
12
10
8
6
4
2
0
Bext (1/Mm)
Biomass
Sulfate
Nitrate
Mobile
Soil
Sources


Average Light Extinction by Source at Mt. Rainier
1991-95
2000-03
Bext (1/Mm)
18
16
14
12
10
8
6
4
2
0
Biomass
Sulfate
Nitrate
Mobile
Soil
Sources


Light Extinction of 20% Worst and 20% Best Days - Mt. Rainier 2002
20% Worst Days
20% Best Days
Bext (1/Mm)
25
20
15
10
5
0
Biomass
Sulfate
Nitrate
Mobile
Soil
Sources


Light Extinction of 20% Worst and 20% Best Days -Yosemite 2002
20% Worst Days
20% Best Days
Bext (1/Mm)
45
40
35
30
25
20
15
10
5
0
Biomass
Sulfate
Nitrate
Mobile
Soil
Sources

Conclusions

- At Mt. Rainier, the highest Bext is due to secondary sulfate and the second highest is due to biomass burning
- At Yosemite, the highest Bext is due to biomass burning and the second highest is to secondary sulfate
- At Mt. Rainier, Bext from biomass, sulfate, nitrate and mobile sources decreased between 1991-95 and 2000-03
- At Yosemite, average Bext from biomass and mobile sources increased, while secondary sulfate and nitrate sources decreased between 1991-95 and 2000-03

Conclusions (continued)

- Bext of the 20% worst days at Mt. Rainer in 2002 was due to a combination of secondary sulfate (44%) and biomass burning (27%)
- Bext of the 20% worst days at Yosemite in 2002 was dominated by biomass burning (66%)
- PMF is a valuable tool in determining source contribution to visibility impairment, and changes in visibility impairment over time in Class I Areas