SAMPLING DEPOSITION-SENSITIVE LAKES IN THE MT. JEFFERSON AND COLUMBIA WILDERNESS AREAS

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Air Quality Division
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By

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EXECUTIVE SUMMARY

Six lakes were sampled in the northern Oregon Cascades in September 1999, five lakes in the Mt. Jefferson Wilderness and one lake in the Columbia Wilderness. The lakes were intentionally selected to identify dilute systems based on field measurements of conductivity. Samples of both the lake water and surface sediments were collected. The water samples were analyzed for major ion chemistry at the USDA Forest and Range Experimental Station in Fort Collins, CO. The surface sediment samples were analyzed for diatom community composition. The purpose of the sampling was to: (1) characterize the lakes with respect to current sensitivity to damage from atmospheric inputs from major industrial and metropolitan sources and (2) add to the diatom calibration set for the Cascades to increase the precision and accuracy of future reconstructions of lake chemistry made on the basis of changes in downcore diatom assemblages.

The results of the water chemistry identified two important issues: (1) some of the samples lakes were extraordinarily dilute and would thus serve as excellent long-term monitoring sites for a Cascade monitoring network; and (2) the one lake sampled in the Columbia Wilderness, Warren Lake, had unusual water chemistry that suggested inputs from atmospheric sources. The specific conductance of Scout Lake was 1.7 *u*S/cm, a value similar to commercial grade distilled water. The major ion chemistry of Scout Lake was so low that one would expect to be able to observe a change in the quality of atmospheric deposition relatively quickly.

Warren Lake, located adjacent to the Columbia Gorge at an elevation of 3732 feet, exhibited concentrations of fluoride, ammonium, potassium, and sulfate that appeared to be elevated relative the other sample lakes and to other Oregon Cascade lakes sampled in previous studies. The absolute concentrations of the ions in Warren Lake were low, but the presence of measurable amounts of fluoride is significant in that we are unaware of natural watershed sources of fluoride in the area. That information combined with the elevated levels of the other three ions listed above indicates that the chemistry of Warren Lake has been altered by atmospheric sources. However, this is based on only one water quality sample and further sampling is recommended to verify the values reported here.

The diatom assemblages found in the sediments of the six study lakes were typical of assemblages previously identified in Cascade lakes. The diatom results will be added to the Cascade Diatom Calibration Set to improve the predictive capability of the equations linking water chemistry to diatom species. This will aid future paleolimnological studies of Cascade lakes.

INTRODUCTION

Lakes have been shown to be among the most sensitive receptors of atmospheric deposition of sulfur, nitrogen, trace metals, and trace organics. Responses include acidification (from nitrate and sulfate), eutrophication (from nitrogen in N-deficient waters), and accumulation of trace contaminants in the sediment and biota. By sampling lake water and sediments, it is possible to establish background conditions for lakes that have not been impacted by atmospheric deposition or to determine the degree and rate of change for those systems that have been impacted.

Emissions of atmospheric contaminants in the Pacific Northwest historically have been low compared to emissions in the eastern United States. Nevertheless, there is concern that increasing populations could generate emissions that might damage sensitive resources. One of the ways to protect sensitive resources from levels of atmospheric emissions that could damage them is to provide high quality information regarding the current status of theses resources. The purpose of this project was to aid in this overall effort by collecting water quality data on lakes downwind of the Portland Metropolitan area and developing quantitative baseline conditions or providing documentation of the early effects of atmospheric deposition. This report summarizes the findings of sampling six lakes in the Mt. Jefferson Wilderness and Columbia Wilderness in September 1999.

METHODS

Six lakes were selected for sampling in the northern Oregon Cascades. The criteria for lake selection included location within a USDA-Forest Service designated wilderness and the likelihood that it would be a "sensitive resource" based on its hydrogeomorphic setting. Of the six lakes that were sampled as part of this effort, five were located in the Mt. Jefferson Wilderness and one was located in the Columbia Wilderness.

The lakes were accessed on foot in September 1999. *In-situ* measurements were recorded with an YSI Model 85 multi-parameter meter calibrated according to the manufacturer's specifications. The site location was recorded using a Garmin 45XL global positioning system.

A short sediment core (generally about 20 cm) was collected at the deepest site in each lake using a Mini-Glew gravity corer. The sediments were extruded on shore and 0.5-cm samples of the top and bottom of the cores were placed in whirl pacs. The surficial sediment samples were digested in nitric acid and 300 diatom valves were identified and counted per lake. Dr. Roger Sweets, University of Indianapolis, performed the diatom taxonomy.

Water samples were collected from the surface of each lake and placed in new 1-L Nalgene bottles that had been rinsed three times in the lake water. The samples were kept cool and transported out of the wilderness for overnight shipping to the USDA Forest and Range Experiment Station, Ft. Collins, CO. The samples were analyzed for major ions and acid-base chemistry related parameters using methods described in their laboratory procedures manual.

RESULTS

1. Field

The field data are summarized in Tables 1 through 6. The study lakes were shallow with maximum depths ranging from 2.5m to 7.0 m. The transparency values of all lakes were high, at least greater than the maximum depth in any given lake. In general, the lakes were well mixed. Only Davey Lake exhibited a temperature difference from top to bottom of more than 2 degrees C. The measured dissolved oxygen values were less than saturation in most cases. This is likely an artifact and the actual values for dissolved oxygen were probably close to 100 percent.

2. Water Chemistry

The water chemistry of the study lakes showed that these are highly dilute systems with specific conductance values ranging from 1.7 to 8.3 uS/cm (Table 7, Figures 1 and 2). As a point of reference, most commercially distilled water is considered acceptable at values of about 2 uS/cm. The dominant cation in these lakes was sodium, which reflects input from both marine aerosols and weathering reactions. Concentrations of calcium and magnesium were similar and potassium concentrations were generally much lower than for the other base cations. Ammonium was present in all lakes and was surprisingly high in Warren Lake, which is located in the Columbia Wilderness. pH values for the study lakes ranged from 5.76 in Scout Lake to 6.43 in Cleo Lake (Appendix A).

The anions show that bicarbonate was the dominant anion in most lakes, although chloride was greater in two of the six lakes. Sulfate concentrations were generally less than 3 µeq/L, although Warren Lake again exhibited the highest concentration at 8.1 µeq/L. Another surprising finding is the presence of fluoride in measurable quantities. Again, Warren Lake had

Table 1. Field data sheet for Warren Lake, Columbia Wilderness.

Lake:	Warren	**Project:**	Mt. Jefferson Lakes
Longitude: **Latitude:**	45 38 52.8 dms 121 43 40.2 dms	**Location:**	Columbia Wilderness
Date:	9-20-99	**Max. Depth:**	2.5
Time:	1420	**Secchi Transparency:**	on bottom
Conditions:	sunny, clear		

Depth (m)	**Temperature (°C)**	**DO (% sat)**	**DO (mg/L)**	**Conductivity (µS)**	**Sp. Cond. (µS/cm)**
0	17.7	87	8.41	6	
0.5	17.4	86	8.14	6	
1	16.6	84	8.12	6	
1.5	16.3	85	8.31	5.9	
2	16.1	83	8.28	5.8	
2.5	16.1	80	7.85	5.8	

Notes:

Core:
Photos: 1-4
Crew: J. Bischoff, B. Eilers

Table 2. Field data sheet for Claggett Lake, Mt. Jefferson Wilderness.

Lake:	Claggett	**Project:**	Mt. Jefferson Lakes
Longitude: **Latitude:**	44 45 17.2 dms 121 52 29.2 dms	**Location:**	Mt. Jefferson Wilderness
Date:	9-21-99	**Max. Depth:**	6 m
Time:	1530	**Secchi Transparency:**	on bottom
Conditions:	clear, sunny		

Depth (m)	**Temperature (°C)**	**DO (% sat)**	**DO (mg/L)**	**Conductivity (µS)**	**Sp. Cond. (µS/cm)**
0	17.1	75	7.45	2.5	
0.5	17.1	80	7.63	2.4	
1	16.7	77	7.41	2.4	
1.5	16.2	76	7.46	2.4	
2	15.8	78	7.66	2.4	
2.5	15.7	74	7.41	2.4	
3	15.7	73	7.37	2.4	
3.5	15.7	73	7.22	2.4	
4	15.6	70	7.12	2.4	
6	15.6	65	6.55	2.4	

Notes:

Core:	core length, 21 cm
Photos:	9-12
Crew:	J. Bischoff, B. Eilers

Table 3. Field data sheet for Davey Lake, Mt. Jefferson Wilderness.

Lake:	Davey	**Project:**	Mt. Jefferson Lakes
Longitude: **Latitude:**	44 46 06 dms 121 48 34.8 dms	**Location:**	Mt. Jefferson Wilderness
Date:	09-21-99	**Max. Depth:**	4.0
Time:	1035	**Secchi Transparency:**	on bottom
Conditions:	clear, sunny		

Depth (m)	**Temperature (°C)**	**DO (% sat)**	**DO (mg/L)**	**Conductivity (µS)**	**Sp. Cond. (µS/cm)**
0	17.1	78	7.61	-	
0.5	14.9	78	7.88	2.9	
1	14.7	77	7.85	2.9	
1.5	14.7	77	7.74	2.9	
2	14.7	73	7.39	2.9	
2.5	14.6	69	7.06	3.0	
3	14.6	76	7.70	2.9	
3.5	14.6	73	7.42	2.9	
4	14.6	75	7.59	2.9	

Notes:

Core:	core length of 22 cm
Photos:	4-8
Crew:	J. Bischoff, B. Eilers

Table 4. Field data sheet for Scout Lake, Mt. Jefferson Wilderness.

Lake:	Scout	**Project:**	Mt. Jefferson Lakes
Longitude: **Latitude:**	44 42 34.5 dms 121 48 37.4 dms	**Location:**	Mt. Jefferson Wilderness
Date:	09-22-99	**Max. Depth:**	7.6 m
Time:	1255	**Secchi Transparency:**	on bottom
Conditions:	clear, sunny, windy		

Depth (m)	Temperature (°C)	DO (% sat)	DO (mg/L)	Conductivity (µS)	Sp. Cond. (µS/cm)
0	13.9	84	8.56	1.6	
1	13.6	82	8.52	1.5	
2	13.5	81	8.5	1.5	
3	13.3	80	8.34	1.5	
4	13.1	80	8.43	1.5	
5	13.1	80	8.3	1.5	
6	13.0	78	8.17	1.5	
7	13.0	79	8.25	1.5	
8	13.1	79	8.25	1.5	

Notes:

Core:	core length 18 cm
Photos:	12-16
Crew:	J. Bischoff, B. Eilers

Table 5. Field data sheet for Cleo Lake, Mt. Jefferson Wilderness.

Lake: Cleo	**Project:** Mt. Jefferson Lakes
Longitude: 44 32 54.0 dms **Latitude:** 121 55 05.5 dms	**Location:** Mt. Jefferson Wilderness
Date: 09-24-99	**Max. Depth:** 3.05 m
Time: 1200	**Secchi Transparency:** on bottom
Conditions: clear, sunny, cool	

Depth (m)	**Temperature (°C)**	**DO (% sat)**	**DO (mg/L)**	**Conductivity (µS)**	**Sp. Cond. (µS/cm)**
0	16.5	75	7.32		6.6
0.5	16.3	73	7.2		6.6
1	16.2	72	7.1		6.6
1.5	16.2	70	6.87		6.7
2	16.1	69	6.86		6.6
2.5	16.1	68	6.78		6.6
3	16.1	66	6.52		6.6

Notes:

Core:	core length 25 cm
Photos:	20-24
Crew:	J. Bischoff, B. Eilers

Table 6. Field data sheet for Turpentine Lake, Mt. Jefferson Wilderness.

Lake:	Turpentine	**Project:**	Mt. Jefferson Lakes
Longitude: **Latitude:**	44 32 39.6 dms 121 55 13.3	**Location:**	Mt. Jefferson Wilderness
Date:	09-24-99	**Max. Depth:**	6.25
Time:	1055	**Secchi Transparency:**	on bottom
Conditions:	sunny, cool		

Depth (m)	**Temperature (°C)**	**DO (% sat)**	**DO (mg/L)**	**Conductivity (µS)**	**Sp. Cond. (µS/cm)**
0	15.8	69	6.88		5.1
1	15.9	68	6.68		5
2	15.9	68	6.73		5
3	15.8	68	6.74		5
4	15.8	64	6.46		5
5	15.8	70	6.91		5
6	15.8	69	6.83		5
7	15.8	66	6.47		5

Notes:

Core:	core length 20 cm
Photos:	16-20
Crew:	J. Bischoff, B. Eilers

Table 7. Major ion chemistry for the six study lakes. Units for all ions are expressed in microequivalents per liter. Conductivity units are in micro-Siemens per centimeter.

Parameter	Warren	Claggett	Davey	Scout	Cleo	Turpentine
Ca	10.9	6.4	5.9	3.5	12.4	12.1
Mg	10.1	3.1	3.4	2.1	13.1	13.1
Na	44.8	12.5	12.2	6.4	18.2	19.8
K	7.4	1.8	1.1	0.7	0.8	2.3
NH4	13.9	4.4	2.6	1.4	4.2	7.1
H	0.7	1.2	0.8	1.8	0.4	0.5
HCO_3	38.2	8.8	17.3	1.8	46.7	28.6
Cl	36.8	13.9	7.5	4.2	9.1	12.8
SO4	8.1	3.5	1.7	2	0.5	2.3
F	10.5	4.5	0	0	0	1.7
C_B-C_A	27.8	6.3	13.4	6.6	34.9	32.2
Cond-meas	8.3	3	3.6	1.7	5.9	4.8
Cond-calc	10.1	3.7	3.1	1.9	5.4	5.5
%Ion diff	3.5	2.2	1	-33.4	6.8	-9.5

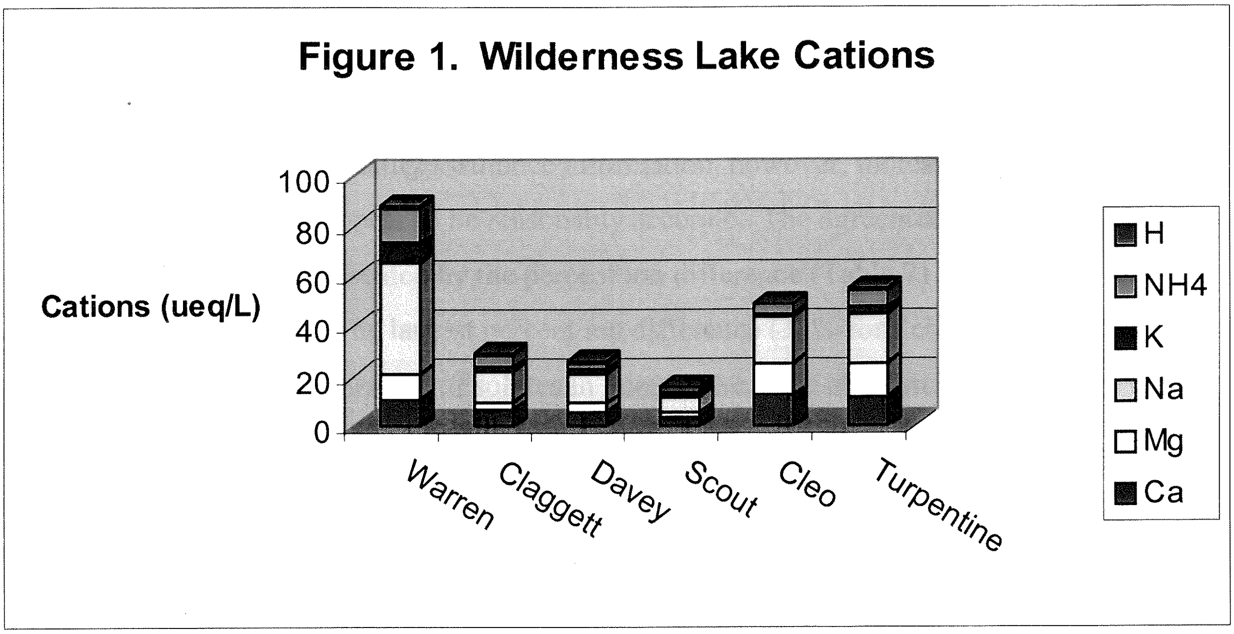

Figure 1. Cation concentrations (*u*eq/L) for the six study lakes in the Mt. Jefferson and Columbia Wildernesses based on samples collected in September 1999.

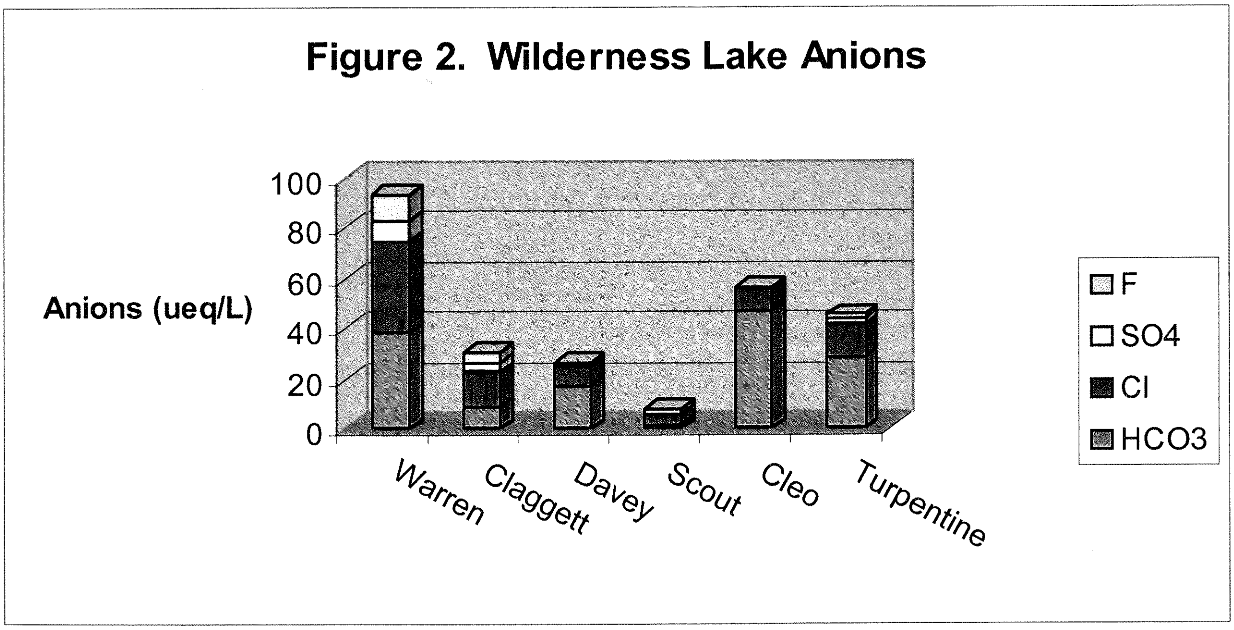

Figure 2. Anion concentrations (μeq/L) for the six study lakes in the Mt. Jefferson and Columbia Wildernesses based on samples collected in September 1999.

the highest value with a concentration of 10.5 µeq/L Nitrate was generally not present in quantities above the detection limit (Appendix A).

The quality of the analytical results is always a concern when dealing with such dilute systems. A review of the quality assurance information, however, indicates that the data are internally consistent and appear to be reasonably accurate. The agreement between sums of anions and cations as represented by the percent ion difference (Table 7) shows that the agreement is acceptable. The largest percent ion difference (33% for Scout Lake) is the result of extraordinarily low concentration of solutes in Scout Lake. The absolute ion difference in Scout Lake is only 7.9 µeq/L, much of which may be accounted for by the uncertainty in the ANC titration near zero. The calculated ANC for Scout Lake is 6.6 µeq/L compared to a measure ANC of 1.8 µeq/L (Table 7). Agreement between calculated and measured conductivity (Figure 3) and measured versus calculated ANC (Figure 4) is also acceptable.

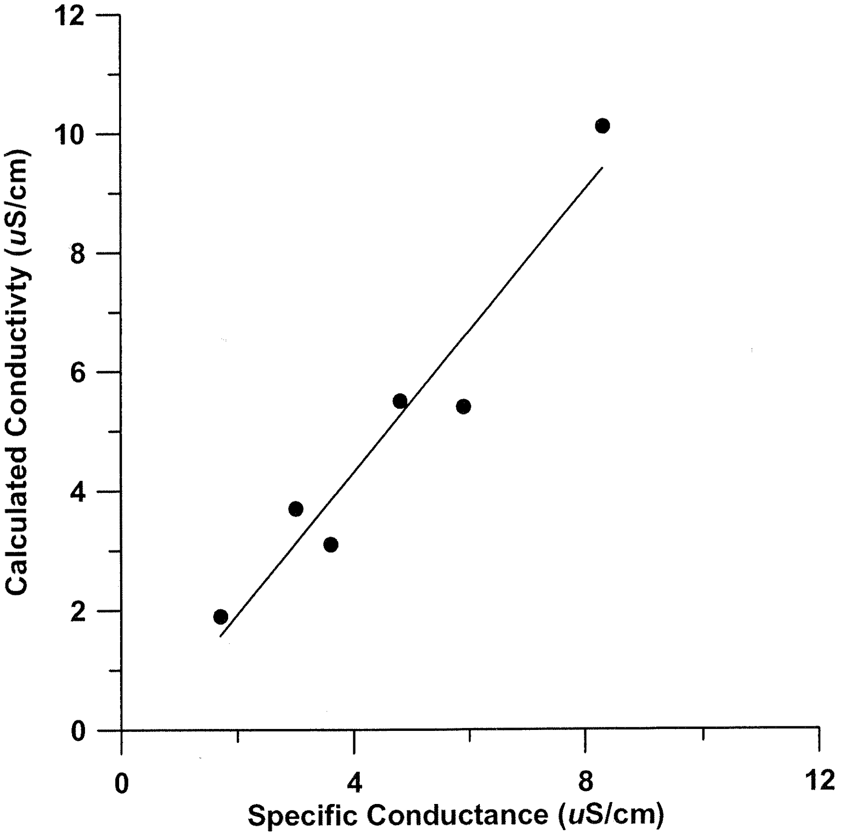

Figure 3. Calculated conductivity (*u*S/cm) versus measured conductivity for the six study lakes sampled in September 1999. The data are fitted to a linear least-squares model.

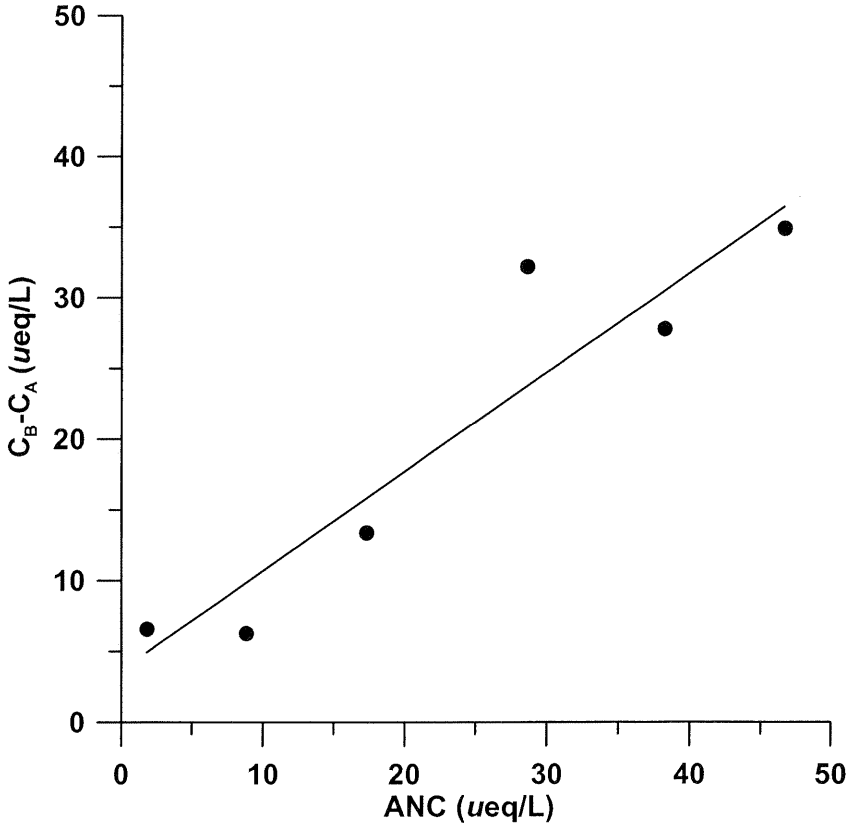

Figure 4. Calculated alkalinity (C_B-C_A) versus measured acid neutralizing capacity (ANC, µeq/L) for the six study lakes sampled in September 1999. The data are fitted to a linear least-squares model.

3. Sediment Diatoms

The diatom community composition in the surficial sediments of the six study lakes is shown in Tables 8 through 13. The diatom communities in the six lakes are quite similar to one another and to previous Cascade lakes sampled as part of the Cascade Diatom Calibration Set (cf Eilers et al. 1998a for a description of this project). The most common diatom in the lakes is the centric genus *Aulacoseira.* Although there are subtle differences between several similar species, they are typically forms of the species *Aulacoseira distans*. Another common taxon is *Navicula tenuicephala*, a species that prefers acidic waters. The remaining diatoms are largely a mixed assemblage of epiphytic (attached to plants) and benthic (bottom) species. The common taxa in these groups of diatoms are *Cymbella, Pinnularia, and Achnanthes.*

Table 8. Diatom community composition for the surficial sediments in Warren Lake.

Full Name	Percent
Achnanthes levanderi Hust.	0.31
Achnanthes marginulata Grun.	0.62
Anomoeoneis serians var. brachysira (Bréb. ex Kütz.) Hust.	4.02
Aulacoseira distans (Ehr.) Simonsen	8.36
Aulacoseira distans var. nivalis (W. Sm.) Haworth	0.93
Aulacoseira distans var. tenella (Nygaard) R. Ross	2.48
Aulacoseira lirata (Ehr.) R. Ross	3.62
Cymbella aequalis W. Sm.	0.93
Cymbella amphicephala Naeg. ex Kütz.	0.93
Cymbella brehmii Hust.	1.15
Cymbella gaeumannii Meist.	2.17
Cymbella hebridica Grun. ex Cl.	2.79
Cymbella lunata W. Sm.	2.17
Cymbella mexicana (Ehr.) Cl.	0.31
Cymbella minuta Hilse ex Rabh.	1.86
Cymbella perpusilla A. Cl.	3.10
Eunotia meisteri Hust.	0.62
Eunotia rhomboidea Hust.	0.31
Eunotia serra Ehr.	0.31
Eunotia sudetica O. Müll.	0.31
Eunotia vanheurckii Patr.	0.31
Fragilaria brevistriata Grun.	0.31
Fragilaria exigua Grun.	2.17
Frustulia rhomboides (Ehr.) DeT.	2.17
Frustulia rhomboides var. saxonica (Rabh.) DeT.	2.17
Gomphonema gracile Ehr. emend. V. H.	0.31
Navicula leptostriata Jorgensen	3.62
Navicula mediocris Krasske	1.24
Navicula radiosa var. parva Wallace	4.33
Navicula seminulum Grun.	0.31
Navicula sp. 24 PIRLA	0.31
Navicula subminuscula Mang.	0.31
Navicula subtilissima Cl.	0.93
Navicula tenuicephala Hust.	1.86
Neidium affine (Ehr.) Pfitz.	1.86
Nitzschia fonticola Grun.	1.55
Pinnularia biceps Greg.	3.10
Pinnularia braunii (Grun.) Cl.	1.55
Pinnularia maior (Kütz.) Rabh.	0.31
Pinnularia microstauron (Ehr.) Cl.	2.48
Pinnularia termitina (Ehr.) Patr.	0.31
Surirella delicatissima var. 1 PIRLA	0.31
Tabellaria fenestrata (Lyngb.) Kütz.	0.31
Tabellaria flocculosa (Roth) Kütz.	0.62

Table 9. Diatom community composition for the surficial sediments in Claggett Lake.

Full Name	Percent
Achnanthes lapponica (Hust.) Hust.	0.32
Achnanthes levanderi Hust.	2.54
Achnanthes marginulata Grun.	5.71
Anomoeoneis serians var. brachysira (Bréb. ex Kütz.) Hust.	0.95
Aulacoseira distans (Ehr.) Simonsen	11.75
Aulacoseira distans var. nivaloides Camburn	3.17
Aulacoseira distans var. tenella (Nygaard) R. Ross	10.16
Aulacoseira lirata (Ehr.) R. Ross	0.95
Cymbella aequalis W. Sm.	0.32
Cymbella amphicephala Naeg. ex Kütz.	3.17
Cymbella brehmii Hust.	9.84
Cymbella hebridica Grun. ex Cl.	3.17
Cymbella minuta Hilse ex Rabh.	0.95
Cymbella oregonicus (Ehrenberg) Hakansson	0.63
Cymbella perpusilla A. Cl.	3.17
Eunotia maior (W. Sm.) Rabh.	0.63
Eunotia meisteri Hust.	0.32
Eunotia vanheurckii var. intermedia (Krasske ex Hust.) Patr.	0.32
Frustulia rhomboides var. saxonica (Rabh.) DeT.	4.44
Gomphonema acuminatum Ehr.	0.32
Navicula leptostriata Jorgensen	1.59
Navicula mediocris Krasske	0.32
Navicula radiosa var. parva Wallace	0.32
Navicula subtilissima Cl.	5.08
Navicula tenuicephala Hust.	11.11
Neidium affine (Ehr.) Pfitz.	0.32
Neidium iridis var. ampliatum (Ehr.) Cl.	0.63
Pinnularia bogotensis (Grunow) Cleve	0.32
Pinnularia braunii (Grun.) Cl.	5.71
Pinnularia microstauron (Ehr.) Cl.	7.94
Pinnularia subcapitata Greg.	0.32
Pinnularia sudetica (Hilse) M. Perag.	0.63
Pinnularia termitina (Ehr.) Patr.	0.32
Pinnularia viridis (Nitz.) Ehr.	1.27
Surirella minuta Bréb.	0.63
Tabellaria flocculosa (Roth) Kütz.	0.63

Table 10. Diatom community composition for the surficial sediments in Davey Lake.

Full Name	Percent
Achnanthes helvetica (Hust.) Lange-Bert.	4.09
Achnanthes levanderi Hust.	4.40
Achnanthes marginulata Grun.	3.46
Anomoeoneis serians var. brachysira (Bréb. ex Kütz.) Hust.	0.31
Anomoeoneis vitrea (Grun.) Ross	0.31
Aulacoseira distans (Ehr.) Simonsen	12.58
Aulacoseira distans var. nivalis (W. Sm.) Haworth	12.89
Aulacoseira distans var. tenella (Nygaard) R. Ross	8.81
Cymbella aequalis W. Sm.	0.94
Cymbella amphicephala Naeg. ex Kütz.	6.92
Cymbella brehmii Hust.	6.60
Cymbella gaeumannii Meist.	0.31
Cymbella hebridica Grun. ex Cl.	2.20
Cymbella minuta Hilse ex Rabh.	0.31
Cymbella oregonicus (Ehrenberg) Hakansson	0.31
Cymbella perpusilla A. Cl.	5.66
Cymbella sp. 9 PIRLA	0.31
Cymbella subaequalis Grun.	0.63
Eunotia bilunaris var. mucophila Lange-Bert. & Nörpel	0.31
Eunotia exigua (Bréb. ex Kütz.) Rabh.	0.63
Fragilaria capucina var. vaucheriae (Kütz.) Lange-Bert.	0.31
Gomphonema parvulum (Kütz.) Kütz.	1.26
Navicula leptostriata Jorgensen	2.20
Navicula mediocris Krasske	0.63
Navicula radiosa var. parva Wallace	0.94
Navicula tenuicephala Hust.	14.78
Neidium affine (Ehr.) Pfitz.	0.63
Neidium bisulcatum (Lagerst.) Cl.	0.31
Pinnularia braunii (Grun.) Cl.	2.83
Pinnularia microstauron (Ehr.) Cl.	2.20
Pinnularia viridis (Nitz.) Ehr.	0.31
Surirella delicatissima var. 1 PIRLA	0.94
Surirella minuta Bréb.	0.63

Table 11. Diatom community composition for the surficial sediments in Scout Lake.	
Full Name	Percent
Achnanthes levanderi Hust.	7.64
Achnanthes marginulata Grun.	4.14
Anomoeoneis vitrea (Grun.) Ross	0.32
Aulacoseira distans (Ehr.) Simonsen	7.32
Aulacoseira distans var. nivalis (W. Sm.) Haworth	7.96
Aulacoseira distans var. nivaloides Camburn	22.29
Aulacoseira distans var. tenella (Nygaard) R. Ross	13.06
Cymbella aequalis W. Sm.	0.64
Cymbella amphicephala Naeg. ex Kütz.	9.87
Cymbella brehmii Hust.	3.50
Cymbella lunata W. Sm.	0.32
Cymbella silesiaca Bleisch	0.32
Cymbella subaequalis Grun.	0.32
Eunotia meisteri Hust.	0.32
Eunotia minor (Kütz.) Grun.	0.32
Eunotia sp. 45 PIRLA	0.32
Eunotia spp.	0.32
Navicula leptostriata Jorgensen	0.32
Navicula seminulum Grun.	0.32
Navicula subrotundata Hust.	0.32
Navicula tenuicephala Hust.	17.83
Neidium affine (Ehr.) Pfitz.	1.27
Neidium affine var. longiceps (Greg.) Cl.	0.32
Pinnularia braunii (Grun.) Cl.	0.32
Pinnularia microstauron (Ehr.) Cl.	0.32

Table 12. Diatom community composition for the surficial sediments in Cleo Lake.

Full Name	Percent
Achnanthes levanderi Hust.	1.32
Achnanthes marginulata Grun.	3.95
Anomoeoneis serians var. brachysira (Bréb. ex Kütz.) Hust.	0.99
Aulacoseira distans (Ehr.) Simonsen	6.25
Aulacoseira distans var. nivalis (W. Sm.) Haworth	3.29
Aulacoseira distans var. nivaloides Camburn	0.33
Aulacoseira distans var. tenella (Nygaard) R. Ross	6.91
Aulacoseira lirata (Ehr.) R. Ross	0.66
Cymbella amphicephala Naeg. ex Kütz.	3.29
Cymbella brehmii Hust.	0.66
Cymbella gaeumannii Meist.	0.99
Cymbella hauckii V. H.	1.32
Cymbella hebridica Grun. ex Cl.	5.59
Cymbella lunata W. Sm.	12.17
Cymbella minuta Hilse ex Rabh.	0.99
Cymbella perpusilla A. Cl.	2.63
Eunotia exigua (Bréb. ex Kütz.) Rabh.	0.33
Fragilaria lata (Cl.-Eul.) Renberg	0.33
Frustulia rhomboides (Ehr.) DeT.	3.62
Frustulia rhomboides var. saxonica (Rabh.) DeT.	4.61
Gomphonema camburnii Metzeltin & Lange-Bertalot	1.97
Gomphonema gracile Ehr. emend. V. H.	0.99
Gomphonema parvulum (Kütz.) Kütz.	0.99
Gomphonema spp.	0.66
Navicula leptostriata Jorgensen	0.33
Navicula mediocris Krasske	0.99
Navicula radiosa var. parva Wallace	3.29
Navicula subtilissima Cl.	0.99
Navicula tenuicephala Hust.	1.32
Neidium affine (Ehr.) Pfitz.	1.32
Neidium alpinum Hust.	1.64
Neidium bisulcatum (Lagerst.) Cl.	0.66
Pinnularia abaujensis (Pant.) Ross	0.66
Pinnularia biceps Greg.	0.99
Pinnularia braunii (Grun.) Cl.	8.55
Pinnularia brevicostata Cl.	2.63
Pinnularia divergens W. Sm.	0.33
Pinnularia microstauron (Ehr.) Cl.	1.97
Pinnularia rupestris Hautz.	2.30
Stauroneis anceps fo. gracilis Rabh.	0.99
Stenopterobia intermedia (Lewis) V. H.	2.30
Surirella delicatissima Lewis	2.63
Surirella delicatissima var. 1 PIRLA	0.66
Tabellaria flocculosa (Roth) Kütz.	0.66

Table 13. Diatom community composition for the surficial sediments in Turpentine Lake.

Full Name	Percent
Achnanthes levanderi Hust.	1.65
Achnanthes marginulata Grun.	3.63
Anomoeoneis serians var. brachysira (Bréb. ex Kütz.) Hust.	0.66
Aulacoseira distans (Ehr.) Simonsen	15.84
Aulacoseira distans var. nivalis (W. Sm.) Haworth	4.95
Aulacoseira lirata (Ehr.) R. Ross	0.99
Cymbella aequalis W. Sm.	1.65
Cymbella amphicephala Naeg. ex Kütz.	1.65
Cymbella brehmii Hust.	5.61
Cymbella falaisensis (Grun.) Kram. & Lange-Bert.	0.33
Cymbella gaeumannii Meist.	2.64
Cymbella hebridica Grun. ex Cl.	3.30
Cymbella lapponica Grunow	0.33
Cymbella lunata W. Sm.	0.99
Cymbella minuta Hilse ex Rabh.	1.65
Cymbella perpusilla A. Cl.	2.97
Cymbella spp.	0.33
Cymbella subaequalis Grun.	0.99
Eunotia bilunaris (Ehr.) Mills	0.33
Eunotia implicata Nörpel, Lange-Bert. & Alles	0.33
Eunotia praerupta Ehr.	0.33
Eunotia serra Ehr.	0.33
Eunotia sudetica O. Müll.	0.33
Fragilaria lata (Cl.-Eul.) Renberg	0.66
Fragilaria pinnata Ehr.	0.33
Frustulia rhomboides (Ehr.) DeT.	1.65
Frustulia rhomboides var. saxonica (Rabh.) DeT.	7.59
Gomphonema acuminatum Ehr.	0.33
Gomphonema angustatum (Kütz.) Rabh.	0.33
Navicula leptostriata Jorgensen	4.29
Navicula mediocris Krasske	0.66
Navicula subtilissima Cl.	11.22
Navicula tenuicephala Hust.	2.97
Neidium affine (Ehr.) Pfitz.	1.65
Neidium iridis (Ehr.) Cl.	0.33
Pinnularia abaujensis (Pant.) Ross	0.66
Pinnularia biceps Greg.	0.66
Pinnularia braunii (Grun.) Cl.	5.94
Pinnularia microstauron (Ehr.) Cl.	4.29
Pinnularia rupestris Hautz.	0.33
Pinnularia spp.	0.66
Pinnularia termitina (Ehr.) Patr.	0.33
Pinnularia viridis (Nitz.) Ehr.	0.33
Stenopterobia intermedia (Lewis) V. H.	0.66
Surirella delicatissima Lewis	0.99
Surirella delicatissima var. 1 PIRLA	0.33
Surirella minuta Bréb.	0.66
Tabellaria binalis (Ehr.) Grun.	0.33

The WACALIB results, which are the modeled water chemistry based on Cascade Diatom Calibration Set, show reconstructed pH values for the surface sediments that are close to the measured pH values from the water samples (Table 14). The modeled conductivity values using WACALIB (not shown) were all near zero. The principle components analysis (PCA) based on species percentage composition indicates that the six study lakes fit into the Cascade/Rainier assemblages near the center of the distribution, extending out into the Rainier lakes axis (Figure 5).

Table 14. Diatom-inferred pH computed using the Cascade Diatom Calibration Set (without the study lakes included) versus measured pH for the six study lakes.

Calibration Lake ID	Lake Name	Diatom-Inferred pH	Measured pH
50 CLAG2K	Claggett	5.95	5.91
51 CLEO2K	Cleo	6.15	6.43
52 DAVE2K	Davey	5.96	6.09
53 SCOU2K	Scout	5.92	5.76
54 TURP2K	Turpentine	6.04	6.29
55 WARR2K	Warren?	6.19	6.15

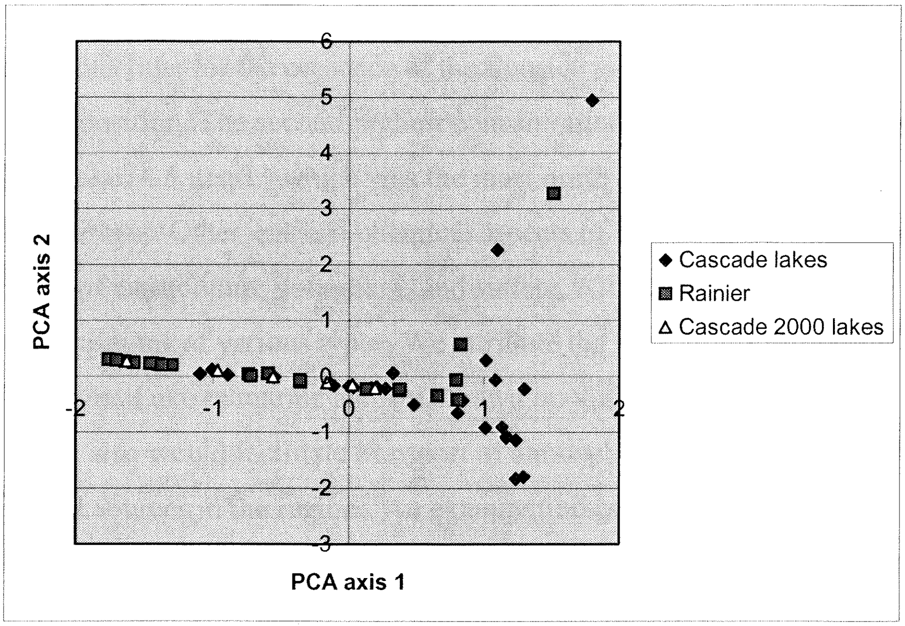

Figure 5. The six study lakes (shown as Cascade 2000 lakes) plotted against the lakes in the existing Cascade Diatom Calibration Set (CDCS). The CDCS lakes are further subdivided into two groups: those sampled near Mt. Rainier and those lakes in other areas of the Cascade Range.

DISCUSSION

The water chemistry results for the study lakes reveal several notable features. First, the results for Scout Lake indicate that its composition would make it an ideal long-term monitoring site to detect the effects of atmospheric emissions in northwestern Oregon on the northern Oregon Cascades. Scout Lake is one of the most dilute lakes sampled to date. It is virtually a large rain gage modified only slightly by minuscule weathering inputs. Its chemistry is highly similar to Notasha Lake in the southern Oregon Cascades (Eilers et al. 1990, 1996) and to Summit Lake in the Washington Cascades (Eilers et al. 1998b). Together, these three lakes offer the Forest Service an important opportunity for monitoring early effects of atmospheric deposition throughout much of the length of the Cascade Range.

A second noteworthy finding is the water chemistry of Warren Lake, located in the Columbia Wilderness. The results from this lake strongly suggest that there is an atmospheric signal in the area. The fluoride concentration (10.5 μeq/L) is remarkably high for lakes in the Cascades. There are no known fluorapatite deposits in the area that might explain the observed values (c.f., Eilers et al. 1989 for a discussion of lake chemistry in the West). The most likely explanation at this time for the presence of the fluoride is that it entered the lake from atmospheric deposition. The second highest concentration of fluoride among the six study lakes was Claggett Lake (4.5 μeq/L) which was the most northwesterly lake sampled in the Mt. Jefferson Wilderness. Other unusual chemical aspects of Warren Lake are the apparent elevated concentrations of ammonium, potassium, and sulfate. All of these ions can be associated with atmospheric emissions of various types. We attribute the very high concentrations of sodium and chloride in Warren Lake to marine aerosols drawn up through the Columbia Gorge. This type of weather system also would facilitate transport of atmospheric contaminants from the urban/industrial sources in the region. An examination of the measured ANC (38.2 μeq/L) compared to the sum of non-marine base cations (32.2 μeq/L) in Warren Lake indicates that there has been no substantial loss of ANC (acidification) at this time. Nevertheless, the results from the water chemistry suggest that there have been measurable inputs of atmospheric contaminants to the site. Additional sampling of this site would be useful to confirm the data presented here.

The diatom assemblages from the surficial sediments are all typical of dilute, slightly acidic lakes in the West. The diatom data from these six lakes will be added to the Cascade Diatom Calibration Set and the CANOCO analysis will be rerun to update the statistics for the calibration equations.

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APPENDIX A

Water Chemistry Data for Mt. Jefferson and Columbia Wilderness Areas

FS ID#	SAMPLE ID	NP OR NF	MILITARY TIME	SAMPLE DATE	RECEIVE DATE	pH	uE/L ANC	uS/cm Conduct.	mg/l Na
JB 01	WARREN			990920	990927	6.154	38.2	8.3	1.030
JB 02	CLAGETT LK			990921	990927	5.906	8.8	3.02	0.286
JB 03	DAVEY			990921	990927	6.094	17.3	3.63	0.280
JB 04	SCOUT LK			990922	990927	5.757	1.8	1.7	0.147
JB 05	CLEO LK			990924	990927	6.429	46.7	5.9	0.420
JB 06	TURPENTINE LK			990924	990927	6.286	28.6	4.78	0.456
WS12	MAIDU LK			991106	991110	7.13	231.5	21.24	1.603

mg/l NH4	mg/l K	mg/l Mg	mg/l Ca	mg/l F	mg/l Cl	mg/l NO3	mg/l PO4	mg/l SO4	ueq/L ANC	ueq/L pH	ueq/L Ca	ueq/L Mg
0	0.290	0.123	0.218	0.200	1.306	0.026	0	0.391	38.2	0.701	10.860	10.088
0.080	0.071	0.038	0.128	0.086	0.494	0	0	0.168	8.8	1.242	6.364	3.098
0	0.041	0.042	0.118	0	0.266	0	0	0.080	17.3	0.805	5.864	3.443
0	0.028	0.026	0.069	0	0.148	0	0	0.094	1.8	1.750	3.464	2.109
0.076	0.032	0.159	0.249	0	0.322	0	0	0.024	46.7	0.372	12.409	13.065
0.128	0.090	0.160	0.242	0.032	0.455	0	0	0.111	28.6	0.518	12.065	13.142
0	1.389	0.469	1.694	0	0.29379	0	0	0.02256	231.5	0.0741	84.530938	38.592882

ueq/L Na	ueq/L K	ueq/L NH4	ueq/L F	ueq/L CL	ueq/L NO3	ueq/L SO4	ueq/L [ANC]	SUM ANIONS	SUM CATIONS	TOTAL ION	%ION DIFF	SUM BASES	SUM ACIDS	DIFF= ALK
44.805	7.412	13.884	10.547	36.841	0.420	8.147	38.2	94.15	87.75	181.91	3.520	73.17	45.41	27.76
12.458	1.822	4.451	4.523	13.930	0	3.501	8.8	30.75	29.43	60.19	2.193	23.74	17.43	6.31
12.180	1.055	2.594	0	7.514	0	1.670	17.3	26.48	25.94	52.43	1.033	22.54	9.18	13.36
6.374	0.727	1.440	0	4.173	0	1.956	1.8	7.93	15.86	23.79	-33.351	12.67	6.13	6.55
18.249	0.817	4.203	0	9.089	0	0.510	46.7	56.30	49.11	105.41	6.815	44.54	9.60	34.94
19.814	2.308	7.123	1.677	12.834	0	2.308	28.6	45.42	54.97	100.39	-9.512	47.33	15.14	32.19
69.72667	35.5258	0	0	8.28678	0	0.46977	231.5	240.257	228.45	468.707	2.519	228.376	8.75655	219.62

ANC	FLAG	% COND	FLAG	THEOR.
	%ION	DIFF	% COND	COND
38.2	OK	21.81	OK	10.11
8.8	OK	21.57	OK	3.67
17.3	OK	-15.83	OK	3.06
1.8	OK	11.54	OK	1.90
46.7	OK	-8.29	OK	5.41
28.6	OK	14.47	OK	5.47
231.5	OK	8.01882	OK	22.943