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Working Copy*

LICHENS AND AIR QUALITY
IN
VOYAGEURS NATIONAL PARK

Final Report
Chemical Analysis Supplement

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PREFACE

When the report on Voyageurs National Park (Wetmore, 1983) was submitted the chemical analyses of lichens from the park was not available. These data are presented in this supplemental report and are based on collections made at four localities in the park in June, 1983.

CHEMICAL ANALYSIS

An important method of assessing the effects of air quality is by examining the elemental content of the lichens (Nieboer et al, 1972, 1977, 1978; Erdman & Gough, 1977; Puckett & Finegan, 1980; Nash et al, 1981). Elevated but sublethal levels of sulfur or other elements might indicate incipient damaging conditions.

METHODS

Lichen samples of several species were collected in plastic bags at various localities in different parts of the park for laboratory analysis. Species collected and the substrates were Cladonia rangiferina (soil), Evernia mesomorpha (trees), Hypogymnia physodes (trees), Parmelia flaventior (trees), Parmelia sulcata (trees and rocks) and Umbilicaria muehlenbergii (rocks). These species were selected because they are relatively easy to clean and other authors have used them and so there is some information in the literature for comparison. Two separate collections of P. sulcata were made at Kettle Falls to compare elemental levels in the same lichen from the different substrates.

The four localities were selected to represent the geographical extremes of the park. The Rainy Lake City locality is the nearest one to International Falls and is at the northwest corner of the park. Kettle Falls is at the northeast corner of the park, the Sand Point Lake locality is at the southern end of Sand Point Lake and near the southeast

corner of the park. The Blue Fin Bay locality is on Kabetogama Lake and represents the southwest edge of the park. Ten to 20 grams of each species were collected at each site.

Lichens were air dried and cleaned of all bark and soil under a dissecting microscope but thalli were not washed. Three samples of each collection were submitted for analysis. Analysis was done for sulfur and multi-element analysis by the Research Analytical Laboratory at the University of Minnesota. In the sulfur analysis a ground and pelleted 100-150 mg sample was prepared for total sulfur by dry combustion and measurement of evolved sulfur dioxide on a LECO Sulfur Determinator, model no. SC-132, by infra red absorption. Multi-element determination for Ca, Mg, Na, K, P, Fe, Mn, Al, Cu, Zn, Cd, Cr, Ni, Pb, and boron were determined simultaneously by Inductively Coupled Plasma (ICP) Atomic Emission Spectrometry. For the ICP one gram of dried plant material was dry ashed in a 20 ml high form silica crucible at 485 degrees Centigrade for 10-12 hrs. Crucibles were covered during the ashing as a precaution against contamination. The dry ash was boiled in 2N HCl to improve the recovery of Fe, Al and Cr and followed by transfer of the supernatant to 7 ml plastic disposable tubes for direct determination by ICP.

RESULTS AND DISCUSSION

Table 1 gives the results of the elemental analyses for all replicates arranged by species. Table 2 gives the means and standard deviations for each set of replicates. In cases when values were obtained at or below the detection limits

these values have been adjusted before statistical analysis. If only one value is below the detection limit the value is included at 0.7 of the detection limit. If more than one reading is below the detection limit no statistical analysis has been done on that element at that locality. All of the levels found in the Voyageurs lichens are within typical limits. From these tables it can be seen that there is no consistent correlation between element levels and location in the park. Although any one species may have significantly higher levels of an element at one locality, other species may have higher levels at another locality so there is no overall correlation between high element levels and any one locality. The sulfur levels in lichens tested range from 260 to 1610 ppm for all samples and these values are near background levels as cited by Solberg (1967) Erdman & Gough (1977), Nieboer et al (1977) and Puckett & Finegan (1980). Levels may be as low as 200-300 in the arctic (Tomassini et al, 1976) while levels in polluted areas are 4300-5200 ppm (Seaward, 1973) or higher. The sulfur levels at Rainy Lake City are highest in two species but relatively low in the other species.

Different species may accumulate different amounts of elements and this is evident when comparing sulfur levels of the different species. Cladonia rangiferina has the lowest levels and Umbilicaria meuhlenbergii has the highest levels. Even when taking these differences into account there is no clear trend in accumulated levels of sulfur.

SUMMARY

There seem to be no important differences or correlations between collections sites and the chemical levels. There appears to be no reason to suspect man made air pollution in the park based on these chemical analyses. All levels are within normal ranges and there are no localities with significantly higher levels of elements characteristic of air pollution.

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Table 1 Mineral Levels in Lichens of Voyageurs National Park
Values in ppm of thallus

| Species | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S | Locality |
|-----------------------|------|------|-------|-----|------|------|------|-------|------|-----|-----|------|------|-----|------|------|-----------------|
| <i>C. rangiferina</i> | 526 | 1378 | 899 | 309 | 280 | 298 | 42.8 | 42.0 | 13.9 | 1.2 | 0.8 | 1.6 | 1.2 | 0.7 | 0.1 | 260 | Rainy Lake City |
| <i>C. rangiferina</i> | 433 | 1158 | 757 | 269 | 248 | 265 | 35.3 | 33.3 | 12.3 | 1.1 | 0.9 | 1.2 | 0.9 | 0.7 | 0.1 | 310 | Rainy Lake City |
| <i>C. rangiferina</i> | 531 | 1336 | 856 | 313 | 303 | 339 | 38.8 | 42.1 | 15.0 | 1.2 | 1.1 | 2.8 | 0.9 | 2.4 | 0.1 | 300 | Rainy Lake City |
| <i>C. rangiferina</i> | 510 | 1587 | 643 | 339 | 413 | 719 | 30.1 | 36.9 | 17.0 | 1.6 | 0.9 | 4.1 | 1.4 | 0.9 | 0.1 | 370 | Sand Point Lake |
| <i>C. rangiferina</i> | 769 | 2166 | 844 | 428 | 472 | 859 | 38.3 | 45.3 | 21.2 | 1.9 | 1.3 | 4.2 | 1.4 | 1.1 | 0.1 | 470 | Sand Point Lake |
| <i>C. rangiferina</i> | 600 | 1768 | 706 | 366 | 372 | 652 | 29.3 | 39.5 | 17.8 | 1.6 | 1.0 | 2.6 | 1.3 | 1.0 | 0.1 | 400 | Sand Point Lake |
| <i>C. rangiferina</i> | 874 | 1840 | 838 | 457 | 362 | 410 | 27.7 | 43.7 | 16.0 | 1.6 | 0.8 | 2.7 | 1.8 | 1.0 | <.04 | 260 | Blue Fin Bay |
| <i>C. rangiferina</i> | 854 | 1893 | 816 | 447 | 401 | 490 | 25.3 | 28.0 | 15.1 | 1.6 | 0.6 | 3.1 | 1.5 | 0.7 | 0.1 | 350 | Blue Fin Bay |
| <i>C. rangiferina</i> | 762 | 1582 | 751 | 399 | 315 | 373 | 24.2 | 36.3 | 14.1 | 1.5 | 0.7 | 1.5 | 1.8 | 0.6 | 0.1 | 270 | Blue Fin Bay |
| <i>C. rangiferina</i> | 404 | 1327 | 574 | 247 | 223 | 274 | 19.9 | 64.1 | 12.4 | 1.2 | 0.7 | 3.7 | <0.3 | 0.3 | 0.1 | 330 | Kettle Falls |
| <i>C. rangiferina</i> | 444 | 1396 | 590 | 261 | 209 | 262 | 17.2 | 72.0 | 12.7 | 1.1 | 0.6 | 3.5 | <0.3 | 0.2 | 0.1 | 400 | Kettle Falls |
| <i>C. rangiferina</i> | 460 | 1497 | 600 | 265 | 205 | 255 | 19.2 | 68.8 | 13.2 | 1.5 | 0.6 | 4.2 | 0.4 | 0.2 | 0.1 | 380 | Kettle Falls |
| <i>E. mesomorpha</i> | 774 | 2656 | 1550 | 416 | 619 | 717 | 70.8 | 33.9 | 30.8 | 2.5 | 2.0 | 6.9 | 1.5 | 1.5 | 0.3 | 1170 | Rainy Lake City |
| <i>E. mesomorpha</i> | 669 | 2481 | 1339 | 410 | 653 | 1788 | 45.4 | 48.1 | 31.9 | 4.0 | 2.3 | 8.7 | 18.1 | 1.2 | 0.2 | 1230 | Rainy Lake City |
| <i>E. mesomorpha</i> | 678 | 2561 | 1364 | 410 | 626 | 750 | 60.9 | 31.0 | 31.8 | 2.6 | 2.0 | 7.8 | 1.9 | 1.3 | 0.2 | 1180 | Rainy Lake City |
| <i>E. mesomorpha</i> | 738 | 2616 | 1616 | 409 | 540 | 633 | 61.8 | 32.1 | 31.9 | 5.1 | 2.1 | 7.1 | 24.8 | 1.0 | 0.3 | 1120 | Sand Point Lake |
| <i>E. mesomorpha</i> | 667 | 2442 | 1232 | 428 | 640 | 1765 | 50.0 | 46.4 | 30.5 | 3.9 | 2.6 | 9.7 | 12.4 | 1.3 | 0.3 | 1060 | Sand Point Lake |
| <i>E. mesomorpha</i> | 828 | 2670 | 2145 | 432 | 623 | 1799 | 52.4 | 50.0 | 31.8 | 3.2 | 2.5 | 9.2 | 6.1 | 1.2 | 0.3 | 1040 | Sand Point Lake |
| <i>E. mesomorpha</i> | 885 | 2559 | 1394 | 356 | 411 | 575 | 38.4 | 53.9 | 30.5 | 2.2 | 1.4 | 5.2 | 5.0 | 0.7 | 0.2 | 780 | Blue Fin Bay |
| <i>E. mesomorpha</i> | 729 | 2407 | 802 | 324 | 378 | 501 | 35.7 | 44.2 | 26.0 | 1.7 | 1.4 | 4.4 | 0.7 | 1.0 | 0.2 | 840 | Blue Fin Bay |
| <i>E. mesomorpha</i> | 775 | 2645 | 840 | 323 | 403 | 552 | 37.6 | 46.5 | 29.2 | 2.1 | 1.5 | 5.7 | 3.3 | 0.8 | 0.2 | 920 | Blue Fin Bay |
| <i>E. mesomorpha</i> | 573 | 2104 | 563 | 304 | 596 | 953 | 40.0 | 28.9 | 27.7 | 1.8 | 1.9 | 10.4 | 2.7 | 1.1 | 0.2 | 680 | Kettle Falls |
| <i>E. mesomorpha</i> | 568 | 2089 | 818 | 327 | 604 | 1017 | 41.8 | 36.7 | 31.3 | 1.9 | 2.3 | 7.3 | 3.8 | 1.2 | 0.2 | 770 | Kettle Falls |
| <i>E. mesomorpha</i> | 552 | 2075 | 1131 | 324 | 616 | 1026 | 42.3 | 39.3 | 32.2 | 1.8 | 2.3 | 7.0 | 2.2 | 1.3 | 0.2 | 710 | Kettle Falls |
| <i>H. physodes</i> | 691 | 2902 | 15686 | 731 | 572 | 689 | 59.6 | 125.7 | 58.3 | 3.0 | 1.4 | 16.0 | 3.1 | 1.3 | 0.6 | 530 | Rainy Lake City |
| <i>H. physodes</i> | 815 | 2976 | 14500 | 774 | 528 | 640 | 64.2 | 127.4 | 59.1 | 3.2 | 1.3 | 14.8 | 3.9 | 1.2 | 0.6 | 630 | Rainy Lake City |
| <i>H. physodes</i> | 744 | 2974 | 13309 | 728 | 526 | 624 | 63.9 | 122.3 | 58.6 | 3.1 | 1.4 | 14.6 | 2.9 | 1.1 | 0.5 | 800 | Rainy Lake City |
| <i>H. physodes</i> | 706 | 2729 | 14717 | 727 | 521 | 911 | 35.4 | 122.9 | 56.7 | 2.8 | 1.2 | 15.5 | 3.5 | 1.1 | 0.6 | 540 | Sand Point Lake |
| <i>H. physodes</i> | 770 | 2682 | 15522 | 729 | 468 | 775 | 42.9 | 120.2 | 58.9 | 2.7 | 1.0 | 15.6 | 3.4 | 1.0 | 0.6 | 590 | Sand Point Lake |
| <i>H. physodes</i> | 750 | 2647 | 15385 | 780 | 475 | 794 | 40.4 | 128.9 | 54.1 | 2.7 | 1.0 | 15.4 | 3.3 | 1.0 | 0.6 | 620 | Sand Point Lake |
| <i>H. physodes</i> | 1213 | 3398 | 12737 | 825 | 386 | 574 | 34.8 | 194.9 | 57.9 | 2.8 | 0.9 | 11.4 | 2.7 | 0.9 | 0.7 | 630 | Blue Fin Bay |
| <i>H. physodes</i> | 1214 | 3418 | 10583 | 848 | 362 | 508 | 28.6 | 190.9 | 56.1 | 2.7 | 0.9 | 11.5 | 3.1 | 1.0 | 0.6 | 690 | Blue Fin Bay |
| <i>H. physodes</i> | 1240 | 3445 | 11745 | 848 | 371 | 552 | 40.9 | 208.0 | 58.1 | 2.7 | 1.0 | 12.0 | 2.7 | 0.9 | 0.6 | 620 | Blue Fin Bay |
| <i>H. physodes</i> | 1012 | 3135 | 13248 | 777 | 361 | 504 | 49.1 | 241.2 | 66.9 | 2.8 | 1.2 | 11.0 | 2.5 | 0.8 | 0.7 | 750 | Kettle Falls |
| <i>H. physodes</i> | 933 | 3000 | 12790 | 755 | 350 | 478 | 37.1 | 239.5 | 68.3 | 2.9 | 1.1 | 10.9 | 2.8 | 0.7 | 0.7 | 980 | Kettle Falls |
| <i>H. physodes</i> | 910 | 2954 | 12355 | 711 | 327 | 445 | 38.5 | 225.8 | 64.7 | 2.9 | 1.1 | 10.9 | 2.4 | 0.7 | 0.6 | 600 | Kettle Falls |
| <i>P. flaventior</i> | 1550 | 3320 | 8920 | 471 | 493 | 554 | 52.4 | 76.9 | 38.6 | 2.6 | 1.7 | 9.3 | 3.5 | 1.2 | 0.4 | 830 | Rainy Lake City |
| <i>P. flaventior</i> | 1447 | 3184 | 11395 | 488 | 525 | 588 | 55.5 | 76.2 | 40.1 | 2.6 | 1.9 | 9.4 | 3.2 | 1.4 | 0.3 | 760 | Rainy Lake City |
| <i>P. flaventior</i> | 1309 | 3173 | 13267 | 457 | 547 | 632 | 58.3 | 68.0 | 40.1 | 2.6 | 2.0 | 8.5 | 3.2 | 1.3 | 0.4 | 890 | Rainy Lake City |
| <i>P. flaventior</i> | 1544 | 3221 | 2923 | 618 | 1010 | 2693 | 49.1 | 48.0 | 48.9 | 3.1 | 2.8 | 8.2 | 3.5 | 2.0 | 0.3 | 990 | Sand Point Lake |
| <i>P. flaventior</i> | 1471 | 3027 | 2734 | 592 | 951 | 1965 | 51.1 | 46.6 | 47.0 | 3.2 | 3.0 | 9.0 | 3.2 | 2.0 | 0.3 | 1020 | Sand Point Lake |
| <i>P. flaventior</i> | 1622 | 3193 | 2877 | 629 | 987 | 2021 | 48.7 | 47.7 | 48.4 | 3.4 | 3.4 | 9.0 | 3.4 | 2.1 | 0.2 | 1040 | Sand Point Lake |
| <i>P. flaventior</i> | 1368 | 2774 | 20274 | 418 | 508 | 714 | 29.7 | 48.9 | 48.7 | 2.3 | 1.1 | 14.8 | 1.7 | 1.2 | 0.4 | 830 | Blue Fin Bay |
| <i>P. flaventior</i> | 1320 | 2766 | 16166 | 417 | 555 | 803 | 34.2 | 45.2 | 51.5 | 2.2 | 1.1 | 14.8 | 1.5 | 1.3 | 0.3 | 730 | Blue Fin Bay |
| <i>P. flaventior</i> | 1334 | 2756 | 26057 | 425 | 599 | 825 | 36.2 | 53.8 | 55.4 | 2.4 | 1.0 | 16.6 | 1.4 | 1.3 | 0.5 | 800 | Blue Fin Bay |
| <i>P. flaventior</i> | 1432 | 3473 | 18471 | 419 | 422 | 621 | 39.4 | 76.2 | 51.4 | 2.7 | 2.0 | 9.7 | 1.6 | 1.2 | 0.3 | 1040 | Kettle Falls |
| <i>P. flaventior</i> | 1434 | 3427 | 16578 | 391 | 400 | 660 | 37.5 | 74.4 | 49.5 | 2.8 | 1.8 | 10.5 | 1.2 | 1.2 | 0.3 | 1130 | Kettle Falls |
| <i>P. flaventior</i> | 1461 | 3397 | 17950 | 384 | 466 | 742 | 50.7 | 58.5 | 47.6 | 2.9 | 2.1 | 11.9 | 1.7 | 1.1 | 0.3 | 1000 | Kettle Falls |

Table 1. cont.

| Species | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S | Locality |
|-------------------------|------|------|------|-----|-----|------|------|-------|------|-----|-----|------|-----|-----|-----|------|------------------|
| <i>P. sulcata</i> | 1686 | 4210 | 2671 | 548 | 480 | 537 | 30.4 | 68.4 | 87.2 | 9.0 | 3.3 | 17.4 | 2.6 | 0.6 | 0.3 | 1180 | Rainy Lake City |
| <i>P. sulcata</i> | 1569 | 4106 | 2536 | 525 | 420 | 429 | 28.7 | 66.3 | 82.7 | 5.0 | 3.0 | 17.7 | 2.1 | 0.5 | 0.3 | 1320 | Rainy Lake City |
| <i>P. sulcata</i> | 1596 | 4154 | 2847 | 539 | 479 | 482 | 31.3 | 72.6 | 85.4 | 4.6 | 3.2 | 15.3 | 1.6 | 0.7 | 0.3 | 1300 | Rainy Lake City |
| <i>P. sulcata</i> | 1340 | 3178 | 2154 | 428 | 397 | 562 | 37.2 | 68.4 | 61.9 | 3.1 | 2.3 | 15.5 | 1.8 | 0.7 | 0.3 | 720 | Sand Point Lake |
| <i>P. sulcata</i> | 1418 | 3260 | 2277 | 410 | 374 | 531 | 20.3 | 63.5 | 67.8 | 3.1 | 2.6 | 13.0 | 2.2 | 0.8 | 0.2 | 770 | Sand Point Lake |
| <i>P. sulcata</i> | 1426 | 3287 | 2471 | 434 | 416 | 592 | 34.3 | 63.2 | 69.6 | 3.3 | 2.9 | 16.5 | 1.9 | 0.8 | 0.3 | 810 | Sand Point Lake |
| <i>P. sulcata</i> | 1804 | 3457 | 2932 | 515 | 292 | 376 | 27.6 | 102.1 | 68.6 | 2.9 | 2.1 | 8.4 | 1.9 | 0.6 | 0.2 | 870 | Blue Fin Bay |
| <i>P. sulcata</i> | 1858 | 3458 | 3043 | 511 | 285 | 364 | 42.2 | 104.6 | 69.2 | 2.9 | 1.9 | 8.5 | 2.0 | 0.6 | 0.2 | 750 | Blue Fin Bay |
| <i>P. sulcata</i> | 1807 | 3406 | 3028 | 506 | 282 | 375 | 33.2 | 104.3 | 69.4 | 2.8 | 2.0 | 8.8 | 2.1 | 0.5 | 0.3 | 880 | Blue Fin Bay |
| <i>P. sulcata</i> | 1201 | 3103 | 1710 | 428 | 535 | 675 | 40.8 | 42.2 | 71.7 | 7.3 | 1.0 | 19.7 | 3.4 | 1.2 | 0.4 | 700 | Kettle Falls RK* |
| <i>P. sulcata</i> | 1215 | 3152 | 1754 | 419 | 543 | 673 | 32.5 | 43.9 | 73.9 | 6.6 | 1.1 | 21.2 | 4.0 | 0.9 | 0.3 | 690 | Kettle Falls RK* |
| <i>P. sulcata</i> | 1332 | 3264 | 1767 | 438 | 553 | 671 | 32.1 | 45.0 | 74.6 | 6.3 | 1.1 | 18.9 | 3.9 | 0.9 | 0.4 | 670 | Kettle Falls RK* |
| <i>P. sulcata</i> | 1473 | 3323 | 2796 | 451 | 407 | 521 | 28.2 | 135.2 | 78.7 | 3.3 | 2.7 | 11.9 | 2.3 | 0.7 | 0.3 | 800 | Kettle Falls TR* |
| <i>P. sulcata</i> | 1422 | 3254 | 2760 | 429 | 367 | 452 | 31.7 | 126.3 | 71.8 | 3.1 | 2.5 | 10.0 | 2.2 | 0.6 | 0.3 | 810 | Kettle Falls TR* |
| <i>P. sulcata</i> | 1487 | 3358 | 2738 | 447 | 365 | 442 | 32.6 | 126.3 | 73.8 | 3.2 | 2.7 | 9.4 | 1.7 | 0.7 | 0.3 | 800 | Kettle Falls TR* |
| <i>U. muehlenbergii</i> | 687 | 2427 | 502 | 287 | 835 | 1087 | 41.9 | 11.9 | 23.6 | 2.7 | 0.7 | 7.4 | 2.7 | 1.1 | 0.2 | 1160 | Rainy Lake City |
| <i>U. muehlenbergii</i> | 783 | 2476 | 494 | 299 | 891 | 1141 | 46.0 | 11.7 | 20.9 | 2.9 | 0.7 | 9.1 | 2.6 | 1.2 | 0.2 | 1270 | Rainy Lake City |
| <i>U. muehlenbergii</i> | 845 | 2414 | 481 | 291 | 774 | 979 | 42.1 | 11.3 | 26.5 | 2.8 | 0.7 | 10.7 | 2.7 | 1.0 | 0.1 | 1100 | Rainy Lake City |
| <i>U. muehlenbergii</i> | 959 | 2408 | 307 | 289 | 571 | 926 | 37.4 | 20.7 | 26.1 | 2.5 | 0.8 | 11.5 | 2.5 | 1.1 | 0.1 | 1270 | Sand Point Lake |
| <i>U. muehlenbergii</i> | 1122 | 2804 | 519 | 357 | 826 | 1507 | 45.1 | 26.5 | 35.3 | 3.3 | 1.0 | 21.6 | 2.8 | 1.3 | 0.2 | 1590 | Sand Point Lake |
| <i>U. muehlenbergii</i> | 1086 | 2560 | 553 | 342 | 818 | 1400 | 47.7 | 27.4 | 35.0 | 3.3 | 0.9 | 21.7 | 3.0 | 1.2 | 0.3 | 1300 | Sand Point Lake |
| <i>U. muehlenbergii</i> | 896 | 2525 | 217 | 326 | 704 | 1033 | 50.1 | 12.7 | 20.5 | 2.6 | 0.7 | 11.7 | 2.1 | 1.4 | 0.3 | 1530 | Blue Fin Bay |
| <i>U. muehlenbergii</i> | 872 | 2586 | 240 | 325 | 668 | 942 | 45.1 | 12.2 | 23.6 | 4.8 | 1.0 | 8.4 | 2.9 | 1.2 | 0.2 | 1610 | Blue Fin Bay |
| <i>U. muehlenbergii</i> | 780 | 2426 | 237 | 322 | 807 | 1144 | 48.6 | 13.3 | 20.4 | 2.7 | 0.7 | 11.3 | 2.6 | 1.6 | 0.2 | 1460 | Blue Fin Bay |
| <i>U. muehlenbergii</i> | 973 | 2344 | 244 | 284 | 504 | 765 | 49.4 | 10.8 | 22.4 | 2.6 | 0.8 | 13.0 | 1.3 | 0.9 | 0.2 | 1280 | Kettle Falls |
| <i>U. muehlenbergii</i> | 838 | 2323 | 270 | 259 | 588 | 870 | 54.1 | 10.6 | 23.0 | 2.6 | 0.7 | 14.9 | 1.7 | 0.9 | 0.2 | 1260 | Kettle Falls |
| <i>U. muehlenbergii</i> | 814 | 2107 | 246 | 257 | 508 | 805 | 68.6 | 9.7 | 19.9 | 2.4 | 0.7 | 11.8 | 1.6 | 0.9 | 0.2 | 1360 | Kettle Falls |

* RK = collected from rock; TR = collected from trees

Table 2. Summary of analyses of Voyageurs Lichens
Values in ppm of thallus

| | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S | Locality |
|--|------|------|-------|-----|-----|------|------|-------|------|-----|-----|------|------|-----|------|------|--------------------|
| <u>Cladonia rangiferina</u> | | | | | | | | | | | | | | | | | |
| Mean | 497 | 1291 | 837 | 297 | 277 | 301 | 38.9 | 39.1 | 13.8 | 1.2 | 0.9 | 1.9 | 1.0 | 1.3 | 0.1 | 290 | Rainy Lake City |
| Std. dev. | 55 | 117 | 73 | 24 | 28 | 37 | 3.8 | 5.1 | 1.4 | 0.1 | 0.1 | 0.9 | 0.2 | 1.0 | <.1 | 27 | Rainy Lake City |
| Mean | 626 | 1840 | 731 | 378 | 419 | 743 | 32.6 | 40.5 | 18.7 | 1.7 | 1.0 | 3.6 | 1.4 | 1.0 | 0.1 | 413 | Sand Point Lake |
| Std. dev. | 132 | 296 | 103 | 46 | 50 | 106 | 5.0 | 4.3 | 2.2 | 0.2 | 0.2 | 0.9 | 0.1 | 0.1 | <.1 | 51 | Sand Point Lake |
| Mean | 830 | 1772 | 802 | 434 | 359 | 424 | 25.7 | 36.0 | 15.1 | 1.6 | 0.7 | 2.4 | 1.7 | 0.8 | 0.1* | 293 | Blue Fin Bay |
| Std. dev. | 60 | 166 | 45 | 31 | 43 | 60 | 1.8 | 7.9 | 1.0 | 0.1 | 0.1 | 0.8 | 0.2 | 0.2 | 0.1* | 49 | Blue Fin Bay |
| Mean | 436 | 1407 | 588 | 258 | 212 | 264 | 18.8 | 68.3 | 12.8 | 1.3 | 0.6 | 3.8 | # | 0.2 | 0.1 | 370 | Kettle Falls |
| Std. dev. | 29 | 86 | 13 | 10 | 10 | 10 | 1.4 | 4.0 | 0.4 | 0.2 | 0.1 | 0.3 | # | 0.1 | <.1 | 36 | Kettle Falls |
| <u>Evernia mesomorpha</u> | | | | | | | | | | | | | | | | | |
| Mean | 707 | 2566 | 1417 | 412 | 633 | 1085 | 59.0 | 37.7 | 31.5 | 3.0 | 2.1 | 7.8 | 7.2 | 1.3 | 0.3 | 1193 | Rainy Lake City |
| Std. dev. | 58 | 88 | 115 | 3 | 18 | 609 | 12.8 | 9.2 | 0.6 | 0.9 | 0.2 | 0.9 | 9.5 | 0.2 | <.1 | 32 | Rainy Lake City |
| Mean | 744 | 2576 | 1664 | 423 | 601 | 1399 | 54.8 | 42.9 | 31.4 | 4.1 | 2.4 | 8.7 | 14.4 | 1.2 | 0.1 | 1073 | Sand Point Lake |
| Std. dev. | 81 | 119 | 458 | 12 | 54 | 664 | 6.2 | 9.5 | 0.8 | 1.0 | 0.3 | 1.4 | 9.5 | 0.1 | <.1 | 42 | Sand Point Lake |
| Mean | 796 | 2537 | 1012 | 334 | 397 | 543 | 37.2 | 48.2 | 28.6 | 2.0 | 1.4 | 5.1 | 3.0 | 0.8 | 0.2 | 847 | Blue Fin Bay |
| Std. dev. | 80 | 121 | 331 | 19 | 17 | 38 | 1.4 | 5.1 | 2.3 | 0.2 | 0.1 | 0.7 | 2.2 | 0.1 | <.1 | 70 | Blue Fin Bay |
| Mean | 564 | 2089 | 837 | 318 | 605 | 999 | 41.4 | 35.0 | 30.4 | 1.8 | 2.2 | 8.2 | 2.9 | 1.2 | 0.2 | 720 | Kettle Falls |
| Std. dev. | 11 | 15 | 284 | 13 | 10 | 40 | 1.2 | 5.4 | 2.4 | 0.1 | 0.2 | 1.9 | 0.9 | 0.1 | <.1 | 46 | Kettle Falls |
| <u>Hypogymnia physodes</u> | | | | | | | | | | | | | | | | | |
| Mean | 750 | 2951 | 14498 | 744 | 542 | 651 | 62.6 | 125.1 | 58.7 | 3.1 | 1.3 | 15.1 | 3.3 | 1.2 | 0.5 | 653 | Rainy Lake City |
| Std. dev. | 62 | 42 | 1189 | 26 | 26 | 34 | 2.6 | 2.6 | 0.4 | 0.1 | 0.1 | 0.8 | 0.5 | 0.1 | 0.1 | 137 | Rainy Lake City |
| Mean | 742 | 2686 | 15208 | 745 | 488 | 827 | 39.5 | 124.0 | 56.5 | 2.7 | 1.1 | 15.5 | 3.4 | 1.0 | 0.6 | 583 | Sand Point Lake |
| Std. dev. | 33 | 41 | 431 | 30 | 29 | 74 | 3.8 | 4.4 | 2.4 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | <.1 | 40 | Sand Point Lake |
| Mean | 1222 | 3420 | 11688 | 840 | 373 | 545 | 34.8 | 197.9 | 57.3 | 2.7 | 0.9 | 11.6 | 2.8 | 1.0 | 0.6 | 647 | Blue Fin Bay |
| Std. dev. | 15 | 24 | 1078 | 13 | 12 | 34 | 6.2 | 9.0 | 1.1 | 0.1 | 0.1 | 0.3 | 0.2 | 0.1 | 0.1 | 38 | Blue Fin Bay |
| Mean | 952 | 3030 | 12797 | 748 | 346 | 476 | 41.6 | 235.5 | 66.6 | 2.9 | 1.1 | 10.9 | 2.6 | 0.7 | 0.7 | 777 | Kettle Falls |
| Std. dev. | 54 | 94 | 447 | 34 | 17 | 30 | 6.6 | 8.4 | 1.8 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 191 | Kettle Falls |
| <u>Parmelia flaventior</u> | | | | | | | | | | | | | | | | | |
| Mean | 1435 | 3226 | 11194 | 472 | 522 | 591 | 55.4 | 73.7 | 39.6 | 2.6 | 1.8 | 9.1 | 3.3 | 1.3 | 0.4 | 827 | Rainy Lake City |
| Std. dev. | 121 | 82 | 2180 | 16 | 27 | 39 | 3.0 | 5.0 | 0.8 | <.1 | 0.1 | 0.5 | 0.2 | 0.1 | 0.1 | 65 | Rainy Lake City |
| Mean | 1546 | 3147 | 2845 | 613 | 983 | 2226 | 49.6 | 47.4 | 48.1 | 3.3 | 3.0 | 8.8 | 3.4 | 2.0 | 0.3 | 1017 | Sand Point Lake |
| Std. dev. | 76 | 105 | 99 | 19 | 30 | 405 | 1.3 | 0.7 | 1.0 | 0.2 | 0.3 | 0.5 | 0.2 | <.1 | 0.1 | 25 | Sand Point Lake |
| Mean | 1341 | 2765 | 20832 | 420 | 554 | 781 | 33.3 | 49.3 | 51.9 | 2.3 | 1.1 | 15.4 | 1.5 | 1.3 | 0.4 | 787 | Blue Fin Bay |
| Std. dev. | 25 | 9 | 4969 | 4 | 46 | 59 | 3.3 | 4.3 | 3.4 | 0.1 | 0.1 | 1.0 | 0.1 | 0.1 | 0.1 | 51 | Blue Fin Bay |
| Mean | 1442 | 3432 | 17666 | 398 | 429 | 674 | 42.5 | 69.7 | 49.5 | 2.8 | 2.0 | 10.7 | 1.5 | 1.1 | 0.3 | 1057 | Kettle Falls |
| Std. dev. | 16 | 38 | 978 | 19 | 34 | 62 | 7.1 | 9.8 | 1.9 | 0.1 | 0.2 | 1.1 | 0.2 | 0.1 | <.1 | 67 | Kettle Falls |
| <u>Parmelia sulcata</u> | | | | | | | | | | | | | | | | | |
| Mean | 1617 | 4157 | 2685 | 537 | 460 | 483 | 30.2 | 69.1 | 85.1 | 6.2 | 3.2 | 16.8 | 2.1 | 0.6 | 0.3 | 1267 | Rainy Lake City |
| Std. dev. | 61 | 52 | 156 | 12 | 34 | 54 | 1.4 | 3.2 | 2.3 | 2.4 | 0.2 | 1.3 | 0.5 | 0.1 | <.1 | 76 | Rainy Lake City |
| Mean | 1395 | 3242 | 2301 | 42 | 396 | 562 | 30.6 | 65.0 | 66.4 | 3.2 | 2.6 | 15.0 | 2.0 | 0.8 | 0.2 | 767 | Sand Point Lake |
| Std. dev. | 48 | 57 | 160 | 13 | 21 | 31 | 9.1 | 2.9 | 4.0 | 0.1 | 0.3 | 1.9 | 0.2 | 0.1 | <.1 | 45 | Sand Point Lake |
| Mean | 1823 | 3440 | 3001 | 511 | 286 | 372 | 34.3 | 103.6 | 69.1 | 2.9 | 2.0 | 8.6 | 2.0 | 0.6 | 0.2 | 833 | Blue Fin Bay |
| Std. dev. | 30 | 30 | 60 | 5 | 5 | 7 | 7.4 | 1.4 | 0.4 | 0.1 | 0.1 | 0.2 | 0.1 | <.1 | 0.1 | 72 | Blue Fin Bay |
| Mean | 1249 | 3173 | 1744 | 428 | 544 | 673 | 35.2 | 43.7 | 73.4 | 6.7 | 1.0 | 20.0 | 3.8 | 1.0 | 0.4 | 687 | Kettle Falls (RK)+ |
| Std. dev. | 72 | 83 | 30 | 10 | 9 | 2 | 4.9 | 1.4 | 1.5 | 0.5 | 0.1 | 1.2 | 0.3 | 0.1 | <.1 | 15 | Kettle Falls (RK)+ |
| Mean | 1461 | 3312 | 2765 | 442 | 380 | 471 | 30.8 | 129.3 | 74.8 | 3.2 | 2.6 | 10.5 | 2.1 | 0.7 | 0.3 | 803 | Kettle Falls (TR)+ |
| Std. dev. | 34 | 53 | 29 | 12 | 24 | 43 | 2.3 | 5.1 | 3.6 | 0.1 | 0.1 | 1.3 | 0.3 | 0.1 | <.1 | 6 | Kettle Falls (TR)+ |
| <u>Umbilicaria muelenbergii</u> | | | | | | | | | | | | | | | | | |
| Mean | 772 | 2439 | 492 | 292 | 833 | 1069 | 43.3 | 11.6 | 23.7 | 2.8 | 0.7 | 9.1 | 2.7 | 1.1 | 0.2 | 1177 | Rainy Lake City |
| Std. dev. | 80 | 33 | 11 | 6 | 59 | 83 | 2.3 | 0.3 | 2.8 | 0.1 | <.1 | 1.7 | 0.1 | 0.1 | <.1 | 86 | Rainy Lake City |
| Mean | 1056 | 2591 | 460 | 329 | 738 | 1278 | 43.4 | 24.9 | 32.1 | 3.0 | 0.9 | 18.3 | 2.8 | 1.2 | 0.2 | 1387 | Sand Point Lake |
| Std. dev. | 86 | 200 | 133 | 36 | 145 | 309 | 5.4 | 3.7 | 5.2 | 0.5 | 0.1 | 5.9 | 0.2 | 0.2 | 0.1 | 177 | Sand Point Lake |
| Mean | 849 | 2512 | 231 | 324 | 726 | 1040 | 48.0 | 12.7 | 21.5 | 3.4 | 0.8 | 10.5 | 2.5 | 1.4 | 0.2 | 1533 | Blue Fin Bay |
| Std. dev. | 61 | 81 | 13 | 2 | 72 | 101 | 2.5 | 0.6 | 1.9 | 1.2 | 0.2 | 1.8 | 0.4 | 0.2 | <.1 | 75 | Blue Fin Bay |
| Mean | 875 | 2258 | 253 | 267 | 533 | 813 | 57.4 | 10.4 | 21.8 | 2.5 | 0.7 | 13.2 | 1.6 | 0.9 | 0.2 | 1300 | Kettle Falls |
| Std. dev. | 86 | 131 | 15 | 15 | 47 | 53 | 10.0 | 0.6 | 1.7 | 0.1 | 0.1 | 1.6 | 0.2 | <.1 | <.1 | 53 | Kettle Falls |

* = one value at or below detection limit; included as 0.7 of detection limit; # = two values at or below detection limit;
+ RK = collected from rock; TR = collected from trees

