The use of a single epiphyte lichen species *Hypogymnia physodes* as an indicator of air quality in northern Ontario

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Declaration

This thesis is an original composition. It is a record of the work done by myself. It has not been previously submitted for a degree. Where the work of other authors has been used, appropriate references have been made.

December, 1988

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Abstract

It has been determined that lichens are excellent indicators of regional air quality, since they are long-lived and totally dependent on atmospheric sources for nutrients. In the summer of 1987, samples of the epiphytic lichen, *Hypogymnia physodes* (L.) Nyl. were collected from 46 sites in northwestern Ontario. Twenty-eight of these sites were sampled around the city of Thunder Bay. Samples were also collected from 6 sites around each of the northwestern Ontario communities of Kenora, Ignace and Wawa. Morphological observations of the lichens were made before sampling. Chemical analyses were carried out and levels of Al, As, Cd, Cu, Fe, Hg, Mg, Pb, S and Zn were determined for each sample by atomic emission spectrometry.

Overall levels of elements were low in relation to levels reported in other literature. The ranges of concentrations (ppm) of elements in *H. physodes* sampled around Thunder Bay were as follows: Al: 185 - 706; As: 0.9 - 7.1; Cd: 0.2 - 1.2; Cu: 0.8 - 6.9; Fe: 114 - 691; Hg: 0.6 - 5.8; Mg: 69 - 393; Pb: 3.9 - 48; S: 42 - 434; Zn: 7 - 92. The area to the south and southwest of Thunder Bay had the highest levels of most elements. The area to the west had the lowest levels. The Kenora, Ignace and Wawa areas had low levels of most elements relative to Thunder Bay results.

Levels of contaminants indicated an inverse relationship existed between levels of pollutants and the distance from the pollution source. A number of morphological observations correlated significantly with levels of certain elements, suggesting possible indicator value.

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Introduction

As the numbers of past studies indicate, air quality assessment is a growing field of interest. Air pollution has increased proportionately with increased industrial activity since the turn of the century. These are mainly in the form of gases, heavy metals, and particulates. Air pollutants can be removed from the atmosphere and impact on all ecosystems by wet and dry depostion processes; they may be absorbed into plants and soil or subjected to various biochemical action (Treshow, 1970; Wotton, Sawatsky, McEachern & Jones, 1985).

Heavy metal accumulation in forest ecosystems can reach levels at which plant damage and death is possible (Anon, 1981). It is therefore important that air quality assessment techniques be continually researched and upgraded. Many of these techniques are of a mechanical nature and because of this, are typically highly technical and expensive. The use of living organisms however, as monitors and indicators of air quality, is much less technical and of relatively little expense (Skorepa and Vitt, 1976).

1.1 Purposes of Study

The following study endeavoured to, firstly, develop a standardized and relatively simple sampling method for air quality assessment that can be used throughout northern Ontario, based upon a single ubiquitous epiphytic lichen species. The second purpose of this study was to gain baseline information of pollution levels in the study area of northwestern

Ontario for use in present and future comparisons.

1.2 Bioindicators of Air Pollution

Living organisms can be used as indicators of local or regional air pollution if they are exposed to the contaminants in any uniform or comparable way (Pilegaard, Rasmussen & Gydesen, 1979). Plants are a desirable organism, suited to the recognition and evaluation of air pollutants because plants of the same species react in a relatively similar fashion, are bound to their location and are exposed to controllable and measureable environmental conditions (Schonbeck and Van Haut, 1971). Jones and Heck (1980) suggest that plants are valuable as bioindicators because a) they show relatively high sensitivity to air pollutants, b) they show a large amount of genetic variability in sensitivity, c) they exhibit foliar symptoms of injury characteristic of exposure to a particular pollutant and d) they are immobile.

The feasability of using lichens as biological indicators of air quality was first suggested by Nylander (1866) and has since been firmly established (Barkman, 1958; Pearson and Skye, 1965; Gilbert, 1965; Rao and LeBlanc, 1967; Ferry, Baddeley & Hawksworth, 1973; Stringer and Stringer, 1974; Hawksworth and Rose, 1976; Skye, 1979; Nieboer and Richardson, 1981; Sigal and Nash, 1983; Kershaw, 1985). Lichens are recommended for use as bioindicators mainly because they are extremely sensitive to air pollutants. This sensitivity is a result of highly efficient accumulation mechanisms in relation to usually very dilute substances in the air or in rainwater, upon which lichens are totally dependent for nutrition (Margot, 1973). Lichens are also recommended as bioindicators because they are long-lived, small and easy to handle (Leblanc and Rao, 1973). There is often a good deal of uniformity in the genetic make-up of certain lichen species due to vegetative reproduction (Skye, 1979).

Lichens have been historically used as pollution monitors in one of three ways (Hale, 1979). The first is to sample an individual lichen species, measure actual pollutants accumulated in the thallus and then deduce the presence, location and distance of pollution sources. The second is to identify and map all or some lichen species present around a pollution source and in this way measure effect, intensity and distribution of pollution. The third and last method is to transplant healthy lichen thalli into a polluted area and measure actual thallus deterioration over time. Of the three methods given by Hale (1979), method two is probably the most complex. This is because a complete inventory of lichen cover requires a high degree of knowledge and specialization. The use of a single species as a bioindicator is much simpler, easier and more efficient.

1.3 Single-Species Bioindicators

Criterion for choosing which lichen species to use as an indicator are suggested by Hawksworth & Rose (1976). The most reliable and useful species:

1./ would be expected to occur in the area to be studied were it not for pollution,

2./ still occur in adjacent areas in healthy populations,

3./ are known to be affected by the pollutants concerned,

4./ are characteristic of open habitats,

5./ show a range of sensitivities,

6./ are easily recognized in the field.

Skye (1968) states that the species chosen should not be overly sensitive to pollution so that it can be sampled close to the source.

When considering using a particular lichen species as a bioindicator of air pollution, it is important to note that interspecies calibration is possible. Folkeson (1979) measured heavy metal levels within several different lichen and moss species and determined how levels within each species related to the others.

1.4 Lichen Species Sampled - *Hypogymnia physodes*

In the following single-species study, the lichen *Hypogymnia physodes* (L.) Nyl. was used exclusively (also called *Parmelia physodes* (L.) Ach.) (See plate 1.) This usually epiphytic and foliose lichen is a circumpolar arctic and temperate species growing principally among mosses on bark, but may also be found on twigs of trees and shrubs, on old wood and occasionally on soil and rocks throughout northwestern Ontario (as well as most of Canada, the United States, Europe and Asia) (Thomson, 1979).

Plate 1: Photograph of H. physodes showing typical growth forms

H. physodes is described as having an adnate or loosely attached light-mineral-grey thallus, six to twelve centimetres broad, with hollow lobes appearing inflated and with its lower surface smooth to wrinkled and irregularly lacerated and perforated (Hale, 1979). Apothecia are very rare and rhizinae are lacking altogether (Duncan, 1970). Labriform (or lip-shaped) soralia with soredia are found on the lower side of the raised tip of the peripheral lobes (Margot, 1973).

1.5 *H. physodes* as a Bioindicator

The lichen species *H. physodes* has inherent characteristics well-suited for use as a single-species bioindicator. Not only does it meet the above criteria, but it also has several other advantages. It is reasonably large and usually plentiful enough for growth analysis (Peterson and Douglas, 1977). It is relatively tolerant of pollutants and is thus available for sampling in many areas (Gailey, Smith, Rintail & Lloyd, 1985). It is capable of withstanding long periods of low humidity (Pilegaard, 1979). (Lichen species less resistant to low humidity can have their metabolism greatly, if not completely retarded, resulting in less pollutant uptake.) Because *H. physodes* lacks rhizinae, relatively small amounts of pollutants would be absorbed from the substrate. And lastly, the lichen has a large surface area with many depressions and binding sites which provide potential receptor sites for collecting atmospheric pollution by impaction, sedimentation and filtration (Gailey *et al.*, 1985).

1.6 Sensitivity / Resistance to Pollutants

H. physodes has been well documented as a lichen which is relatively resistant to air pollution damage. Margot (1973) and Skorepa and Vitt (1976) called the lichen "slightly sensitive", while Skye (1979), Holopainen (1983) and Macher and Steubing (1983) refer to this lichen as relatively resistant to air pollution or "toxitolerant". Kauppi and Mikkonen (1980), in one of the first studies to examine the potential of *H. physodes* as a single-species bioindicator, suggest that because the lichen is a resilient species, it is capable of surviving in areas close to a source of pollution (and thus enabling varying degrees of pollution to be ascertained). Rao and Leblanc (1967) found the lichen to be one of the first to appear as distance increased from the lichen deserts of heavily polluted areas.

Skye (1968) found *H. physodes* to be one of several species which penetrated farthest into the industrialized Stockholm area. Workers in Europe agree that one of the most pollution resistant epiphytic foliose lichens is *H. physodes* (Gilbert, 1973). In another study, the lichen was found among the five most resistant epiphytic species (Farkas, Lokos & Verseghy, 1985).

DeWit (1976) accords certain lichen species sensitivity values from 0 to 12 (with 0 being very resistant and 12 being very sensitive). On this scale, *H. physodes* was given a value of four. In a different scale, it is placed in sensitivity class B, where class A is most tolerant of pollution and class H is least tolerant (DeWit, 1976).

DeWit (1976) also states that *H. physodes* is given a 4 on a qualitative zone scale of 0 to 10. Only three other species appeared on trees in polluted areas before *H. physodes*. As Skye (1968) suggests, it is appropriate for a bioindicator species to be neither too sensitive to pollutants, nor too resistant, and this lichen species is neither.

1.7 Sulphur Pollution

Many interesting morphological effects of sulphur dioxide and trioxide pollution upon *H. physodes* have been noted in the past. The thallus lobes and apical tips of the lichen become darkened upon first exposure, and later become bleached and whitened (Skye, 1968). O'Hare (1974), Turk and Wirth (1975) and O'Hare and Williams (1975) also found that S pollution caused chlorophyll degradation which lead to eventual total bleaching of the thallus. High concentrations over a short term appear to do little damage however (Gilbert, 1970). Schonbeck and Van Haut (1971) found that injuries to the lichen appear on the thallus as decayed tissue. This decay caused discolouration and sometimes was spread over the entire lichen.

A study by Margot (1973) examined the effects of sulphur dioxide and sulphate on the soredia of *H. physodes*. The resultant mortality rate was directly related to pollutant concentration. It was in fact the algal cells within the soredia that died, and an increased toxic effect was noted as the relative humidity increased.

In 1980, Kauppi and Mikkonen examined the reactions of *H. physodes* to sulphur dioxide and compared the results with an analysis of total epiphytic lichen flora on pines of the same region. They concluded that "a clear picture of the nature and spread of air pollution may still be obtained from morphological examinations and various measured parameters" (such as pH, chlorophyll contents and metal contents) of a single lichen species. The external appearance of the lichen in their study varied between polluted and unpolluted sites. Healthy thalli are smooth, greyish green in colour with long lobes, while pollution damage lead to the appearance of surface cracks, a grainy wrinkled appearance, loss of lobes and colour changes to sooty black and black brown. In contrast to this, a study of *H. physodes* near a sulphuric acid factory found yellowish and reddish lobe margin colour aberrations along with stunted growth (Kauppi & Mikkonen, 1980).

1.8 Heavy Metal Pollution

Whereas pollutants such as sulphur dioxides usually cause visible damage to lichens in general and to *H. physodes* in particular, heavy metals (such as Fe, Zn and Cd, among others) tend to do little if any visible damage. They merely accumulate within the lichen and this accumulation can be to astonishing levels (Hale, 1983). Measuring this accumulation is not easy however. Rarely do pollution sources emit heavy metals alone; usually high levels of sulphur dioxide or hydrogen fluoride are released in addition to particulate metal-containing pollutants (Hawksworth and Rose, 1976). As a result, the effects of metals in isolation can be difficult to assess.

H. physodes was found to be a useful indicator of heavy metal deposition in the cases of Cd, Cr, Cu, Ni, Zn, and V but not Fe or Mn (Pilegaard *et al.*, 1979). Pilegaard (1979) also studied how *H. physodes* and a moss, *Dicranoweisia cirrata* compared in terms of metal accumulation. The most accumulated metal was Cu and Zn was the least. Amounts of all accumulated metal ions in the transplanted epiphytes were linearly correlated with fallout from the atmosphere, and, as expected, metal content was inversely related to distance from the source. The bryophyte accumulated metals slightly faster than the lichen, but it was determined that seven months was too short a time for equilibrium between fallout metals from the atmosphere and metal content in sampled epiphytes.

H. physodes has been analyzed for metal levels in relation to eight other mosses and lichens (Folkeson, 1979). Such metals as Fe, Zn, Cu, Pb, Ni and Cd levels were measured and it was found that concentrations can vary considerably between species (see Table 30 for results). Metal levels for *H. physodes* compare quite favourably to the grand averages of the table. The author points out some discrepancies between his results for *H. physodes* and results found by Steinnes (1977). The latter found that *Hylocomnium splendens* contains only 81, 40, 48, and 30 percent of the concentrations of Cu, Zn, Pb and Cd respectively of those in *H. physodes*. In Folkesons study however, *H. splendens* contained 138, 69, 204 and 120 percent of the concentrations of Cu, Zn, Pb, and Cd respectively, of those found in *H. physodes*. The difference suggested by Folkeson is that the previous study was done with lichen taken from birch bark as opposed to pine bark. This could have resulted in different metal concentrations in the bark, different stem-flow characteristics and exposure and therefore, divergent results.

A study done in the Athabasca oil sands region attempted to determine the Al, S, Ti and V contents of three different lichens including *H. physodes* (Addison and Puckett, 1980). Accumulation of the metals was related to both gaseous and particulate emissions for all metals. No qualitative estimates of thallus condition were attempted for *H. physodes* since "changes in lichen morphology and colouration with plant degradation were too subtle to quantify".

Kauppi and Mikkonen (1980) determined Fe content as part of a larger study on *H. physodes*. Extremely high Fe concentrations were found in the lichens at all sites studied, testifying to a widespread distribution of Fe dust from the point source. The levels were highest close around the factory, but even the lowest values recorded (7 mg/g) were much greater than the background levels of 0.6 to 1.7 mg/g (Laaksovirta and Olkkonen, 1977).

Another heavy metal often analyzed for in lichen sampling is Pb. A study of Pb levels near a highway in Finland showed that heavy use of the highway caused high Pb levels in lichens nearby (as a result of leaded gasoline emissions) (Hale, 1983). Even three hundred metres from the highway, 308 ppm were found, as opposed to only 14 to 31 ppm in unpolluted areas.

Mercury is another heavy metal known to spread effectively in the air, and for which *H. physodes* has proven to be a useful indicator. Lodenius (1981) found very high levels (i.e. 36 ppm) of Hg in lichen samples near a chlor-alkali works at Aetsa, Kuusankoski and Oulu, Finland, and this level dropped sharply with increasing distance from the factories. Similar results were found in moss sampled by Barclay-Estrup and Rinne (1979) near a kraft mill and chlor-alkali plant in Marathon, Ontario.

In a short paper by Laaksorvirta and Olkkonen (1983), samples of *H. physodes* were analyzed for K, Ti, V, Fe and Zn. Element contents were found to give a good idea of the distribution of air pollutants. Correlations with patterns of prevailing winds were strong.

Also in 1983, Lodenius and Kumpulainen sampled *H. physodes* and analyzed it for Cd, Zn and Fe contents. Mean Cd and Zn contents of the lichens in the polluted area were significantly higher than those of the control samples. Contents of Fe in the polluted area were only slightly higher however, than Fe contents of control lichens.

Farkas *et al.* (1985) used transplanted samples of the lichen in order to determine the concentrations of Pb, Cd, Mn and Zn. Results showed that Pb values varied between 0 and 271 ppm while the control sites had 54 ppm. Samples near roads accumulated more Pb than those farther away. Cadmium concentrations varied between 0.1 and 3.6 ppm, compared with a quite high control value of 1.6 ppm. Manganese content ranged from 5 to 111 ppm with a control value of 22 ppm. Zinc results were inconclusive, as only preliminary information was obtained.

One of the most recent studies done using *H. physodes* was carried out in the vicinity of a Danish steel plant in order to determine if heavy metal pollution had decreased as a result of new furnaces (Vestergaard, Stephansen, Rasmussen and Pilegaard, 1986). Lichen samples were analyzed for levels of Cd, Cr, Cu, Fe, Mn, Pb and Zn. The results showed that there has been little reduction in heavy metal pollution (see Table 30 for levels obtained).

Methods

Methods

This section will deal with the methods employed during this study, including field and laboratory methods, as well as statistical methods. The field work was carried out during the summer months of 1987 and the laboratory and statistical work in the fall and winter of 1987/88.

2.1 Description of Study Areas

Four sample areas in Northwestern Ontario, Canada were used in this study. The major location was in the Thunder Bay area. Three secondary locations were also done: Kenora, Ignace and Wawa. These are small one-industry towns of the Northwestern Ontario region.

2.1.1 Thunder Bay Area

The main study area was centred about the city of Thunder Bay (population - 112,487 (Anon, 1987)), on the north of shore of Lake Superior (see Figure 1). This area lies between 88 and 90 degrees west longitude and between 48 and 49 degrees north latitude. The Thunder Bay area generally has an altitude of 183 - 500 metres above sea level (Wong, 1974).

The area is relatively remote from large urban or industrial centres. Major industries include 4 pulp and paper mills, 5 sawmills, 2 waferboard mills, 1 rail car assembly plant and 1 shipbuilding and drydocking facility (Anon, 1987). "Thunder Bay itself contains no real metallurgical industries and the nearest city of comparable size is more than 250 km. distant to the southwest" (Duluth, Minnesota) (Rinne, 1977). The next closest large urban area is the city of Winnipeg and this is approximately 700 km. to the west-northwest of Thunder Bay.

Two major forest regions are present in the main study area (Rowe, 1972). The Superior section of the Boreal forest region constitutes the major portion of the area north and east of Thunder Bay. Characteristic conifer species include black spruce (*Picea mariana*), white spruce (*P. glauca*), balsam fir (*Abies balsamea*), jack pine (*Pinus banksiana*), and tamarack (*Larix laricina*). Broadleaf species such as trembling aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*), and white birch (*Betula papyrifera*) are also common to the area. The areas west and south of Thunder Bay are made up of the Quetico section of the Great Lakes-St. Lawrence forest region (Rowe, 1972). Major tree species here include white pine (*Pinus strobus*) and red pine (*P. resinosa*), as well as a transitional mixture of the boreal species trembling aspen, white birch, jack pine, balsam fir, white spruce and black spruce.

Prevailing winds in the Thunder Bay area are from the west as can be seen from the wind distribution figure (see Figure 2) (Wong, 1974). The nearness of Lake Superior has a distinct affect in modifying the climate of the area, with local influences including increased snowfall and warmer temperatures in the winter, and fog and cool temperatures in the summer.

2.1.2 Secondary Areas

Kenora is a small resource-oriented town (population - 9,574 (Anon, 1988)), near the Ontario / Manitoba border (see Figure 1). This area lies between 93.5 and 94.5 degrees west longitude and 49 and 50 degrees north latitude and has an elevation of approximately 340 metres above sea level. Aside from a sulphite pulp mill, this area is largely free of major pollution sources. The nearest large urban area is Winnipeg, located approximately 230 km. to the west. Prevailing winds tend to be from the west-southwest (Anon, 1982a).

The Kenora area lies roughly on the dividing line between the Great Lakes-St. Lawrence forest region (Quetico section) and the Boreal forest region (Lower English River section) (Rowe, 1972). This is composed mainly of black spruce and jack pine, with mixtures of white spruce, balsam fir, trembling aspen and white birch.

The Ignace area is also near the dividing line between two forest regions, these being the Great Lakes-St. Lawrence forest region (Quetico section) and the Boreal forest (Lower English River section) (Rowe, 1972). The forest is composed of mixed stands of trembling aspen, balsam poplar and white spruce, along with a scattering of balsam fir, white spruce, jack pine and white birch.

Ignace itself is a small town with a population of only 2,345 (Anon, 1988) which lies between 91 and 92 degrees west longitude and between 49 and 50 degrees north latitude (see Figure 1). Local industry is limited, and the closest large urban area is Thunder Bay (180 km. southeast). Elevation here is approximately 470 metres above sea level. Prevailing winds again tend to be from the west-southwest (Anon, 1982).

Wawa is a small town of population 4,503 (Anon, 1988) located near the eastern shores of Lake Superior between 47.5 and 48.5 degrees north latitude and between 84 and 85 degrees west longitude (see Figure 1). The major local industry is an iron-sintering plant established in 1939 (Rao and Leblanc, 1967). The closest large urban areas are Sault Ste. Marie (190 km. south) and Thunder Bay (310 km. west-northwest). Prevailing winds here tend to come in off the lake from a southwesterly direction (Anon, 1982a). Elevation in the area is about 210 metres above sea level (Rao and Leblanc, 1967).

The Wawa area lies in the Algoma section of the Great Lakes-St. Lawrence forest region (Rowe, 1972). Characteristic trees include a mixture of white spruce, balsam fir, *Acer saccharum* (sugar maple), and *Thuja occidentalis* (eastern white cedar). Trembling aspen, white birch, and jack pine have formed prominent stands after fires have burned through.

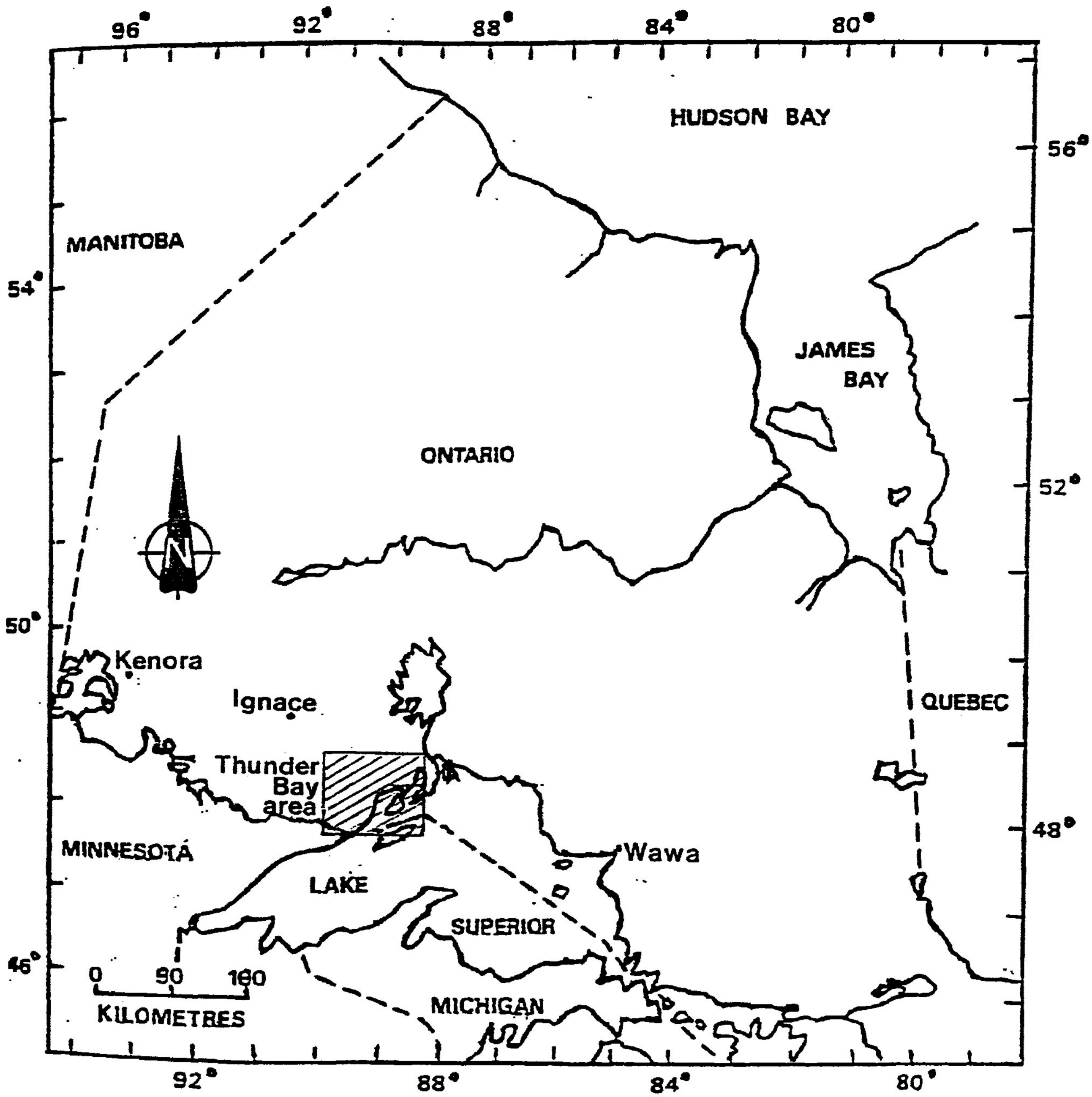

Figure 1 : Locations of primary and secondary study areas in Northwestern Ontario

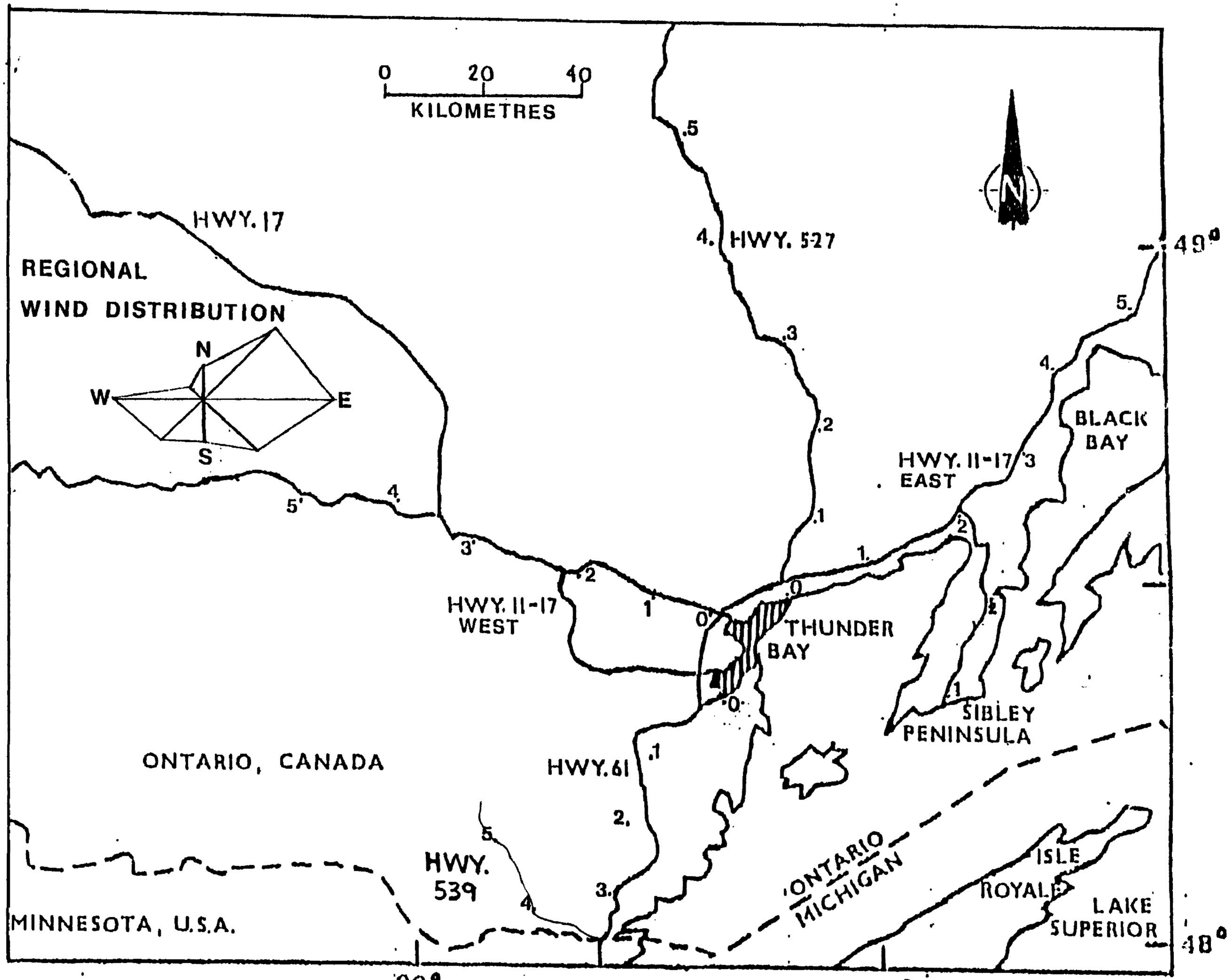

Figure 2: Primary study area sampling locations

2.2 Selection of Study Sites

2.2.1 Primary Study Area: Thunder Bay Sampling Locations

Four major routes were chosen for the main Thunder Bay sampling area, including Highway 527 north of Thunder Bay, Highway 11/17 east of Thunder Bay (including Pass Lake Road), Highway 11/17 west of Thunder Bay, and Highway 61 southwest of Thunder Bay (see Figure 2). These effectively covered all major directions except southeast (which could not be done because of Lake Superior) and were also selected for comparative purposes as these are the same routes used by Rinne and Barclay-Estrup (1980). In addition to these sites, three extra sites were selected within the urban area of Thunder Bay in order to give some idea of pollutant levels within the city itself. The first was on the northeastern side of the city, in Centennial Park. The second was close to the centre of the city and was in a wooded region of the Lakehead University campus. The third was on the southeastern slope of Mount McKay (which is located on the southwestern edge of the city). (More precise sample location descriptions for all sites can be found in Appendix A.)

On each of the major routes, six sites were selected at about 15 km. intervals. The first site or grove was at the edge of the city and was called site 0. (Highway 11/17 East and Highway 527 North shared the same site 0.) The second was about 15 km. from the first and was called site 1. The third was about 15 km. from the last site and was called site 2. This continued until the last site (site number 5) was done approximately 75 km. from the starting point. Variability was allowed at each site if necessary, because there was not always a suitable stand of trees at exactly the 15 km. interval. (See Appendix A for exact locations of sites.)

In order to determine if there were any differences in results between jack pine and white birch lichens, three sites had both jack pine and white birch groves sampled.

2.2.2 Secondary Sampling Locations: Kenora, Ignace, Wawa

The secondary sites of Kenora, Ignace, and Wawa were sampled in much the same way as the Thunder Bay area. The main difference was that only one route was done, running as close as possible to the prevailing downwind direction. As a result, the Kenora study was done along Highway 11/17, which runs east and slightly north of the town. Six sites were selected here. The Ignace site was done along Highway 599 in a generally northeast direction. Six sites were also selected here. The Wawa site should have been chosen in a northeast direction as well. Unfortunately, due to a lack of driveable roads in that direction, no transect could be run. However, two sites were completed east of town, along Highway 101, at 10 km. intervals. Because the road turned south after 20 km., no further sites were done on this road. Instead, two sites were chosen at 15 km. intervals along Highway 17 west. This road runs north and slightly east from Wawa for 30 km. before turning west. A last site done here was along Highway 519, about 9 km. east of Highway 17 (and approximately 50 km. north of Wawa in a straight line direction). In this way, an attempt was made to provide a reasonable estimation of the regional air quality.

2.3 Field Sampling Techniques

2.3.1 Preliminary Study

Before beginning the major areas of sampling, preliminary work was done in order to determine and refine sampling techniques and methodology involved. Six groves of trees were selected in the Thunder Bay area. These groves were either black spruce, jack pine or white birch. These species of trees were chosen for testing because they are common and known to have generally good epiphyte cover, because they are from dry and wet habitats, and because they include coniferous and deciduous trees.

Site description data collected at each site included:

a/ Major species - all major species of shrubs and trees growing on the site were noted.

b/ Slope - the degree and angle of the slope of the land was estimated.

c/ Canopy cover - the amount of canopy cover overhead was estimated as either closed (greater than 80% of the sky covered), semi-open (between 20 and 80% covered) and open (less than 20% covered).

Within each of the six groves, five living trees (all of the same species and all within 25 m of each other) were selected; each was at least 30 m from the nearest road (and preferably 50 m in order to avoid excessive road pollutant contamination), was of minimum 10 cm diameter at one metre height, and had a relatively good cover of *H. physodes*. On each tree, the following was done:

a/ Four quadrats were demarcated with flagging tape: the upper north side (between 100 and 150 cm from the ground), the lower north side (between 50 and 100 cm from the ground), and the upper south side and the lower south side at the same levels as the north side quadrats.

b/ Diameter at one meters height was measured and recorded in order to give some idea as to the size (and therefore the age) of the tree required for development of sufficient lichen cover.

c/ Inclination of the tree was estimated (degree and direction).

Within each quadrat on the tree, the following was done:

a/ Major species of epiphytes were recorded. This included any species which covered at least 6% of the quadrat area (i.e. Braun-Blanquet cover value of at least 2 - see below).

b/ Braun-Blanquet cover values (<1% cover = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5) were assigned for crustose, foliose, fruticose, bryophyte and *H. physodes* lichen cover.

c/ General morphological descriptions of *H. physodes* was done, including:

1. colour aberrations (any discolourations from the typical mineral grey colour of *H. physodes*) (see Plates 2,3,4 and 5 for examples)
2. overall health (estimated as poor, poor to fair, fair, fair to good, or good). This is a subjective method based on the general appearance of all of the *H. physodes* on the tree. It is comparative in that visual comparisons are made between sites.
3. amount of branching (estimated as either few, some or many - see Plates 6,7 and 8 for examples). This is a subjective method as well, based on visual comparisons made between sites.
4. size of lichens - estimated as small (less than 2 cm in greatest diameter), medium (2 to 4 cm greatest diameter), and/or large (greater than 4 cm greatest diameter) -- it should be noted that if all lichen thalli were of small size, then only small was checked. If, for example, there was a variety of both small and medium-sized thalli, then both small and medium were checked, and so on.
5. presence or absence of soredia and apothecia on the lichen thalli present.

After this information was noted (see sample data sheet on page 30), a

Plate 2: Photograph of <u>H. physodes</u> showing assorted discolourations

Plate 3: Photograph of <u>H. physodes</u> showing yellow discolourations (circled area)

Plate 4: Photograph of H. physodes showing black discolouration (circled area)

Plate 5: Photograph of H. physodes showing white discolouration (circled area)

Plate 6: Photograph of H. physodes showing "few" branchings (circled areas)

Plate 7: Photograph of H. physodes showing "some" branchings (circled areas)

Plate 8: Photograph of H. physodes showing "many" branchings (circled areas)

Sample Data Sheet

Site Location -

Tree Species - Tree # - DOM - Incl. -

Site Description - Major species -

Slope -

Canopy - closed (>80%) / semi-open / open (< 20%)

Miscellaneous -

Epiphytes

Upper North - Major Epiphytes -

B.B.* - crustose - foliose - fruticose - bryo.-

B.B.* - <u>H. physodes</u> -

colour aberrations

health -

size - small (<2 cm.)/medium (2-4 cm.)/large (>4 cm.)

branching - few / some / many

soredia - apothecia -

Lower North - Major Epiphytes -

B.B.* - crustose - foliose - fruticose - bryo. -

B.B.* - <u>H. physodes</u> -

colour aberrations

health -

size - small (<2 cm.)/medium (2-4 cm.)/large (>4 cm.)

branching - few / some / many

soredia - apothecia -

*B.B. = Braun Blanquet Cover Scale:

<1% = + 1-5% = 1 6-25% = 2 26-50% = 3 51-75% = 4 76-100%=5

sample of *H. physodes* was hand-gathered from the appropriate quadrat and placed in a pre-labelled plastic bag. Hands were kept as clean and uncontaminated as possible. As little substrate material as was practical was removed with the lichen. Upon returning the samples to the lab, they were weighed in order to determine approximate undried amounts of lichen collected.

2.3.2 Major Study

After the results of the preliminary study had been assessed, the following refinements were made to the methods used in the main study:

a/ Only the north sides of the trees were sampled. Upper north and lower north lichen samples were bulked into the same bag, because of the small amounts of lichens in each quadrat, and because of the small amounts in particular on the south side.

b/ If it was decided that after doing 5 trees, insufficient lichen material had been collected, then further trees would be sampled until a minimum of 3.0 g undried material was obtained. The number of extra trees collected from was noted.

c/ Only jack pine and white birch trees were sampled. Black spruce was often found to have an insufficient quantity of lichen for sampling.

All lichen samples were frozen as soon as possible following collection. While sampling in the Thunder Bay area, this involved a delay of approximately 2-4 hours from the time of collection to the time of refrigeration. While sampling in the secondary areas, this increased to between 6 and 36 hours.

2.4 Method of Chemical Analysis

2.4.1 Sample Preparation

The lichens were removed from the freezer and the following steps were followed with each sample in order to prepare the lichens for chemical analysis:

a/ Sampled material was cleaned by hand of as much substrate material, foreign lichens and other assorted debris as possible in order to obtain approximately 3 g fresh weight. This included removing any obviously dead *H. physodes* from the live material.

b/ The 3 g of lichen was oven-dried at 105 degrees Celsius for 24 hours (Allen, Grimshaw, Parkinson, and Quarmby,1974).

c/ From this dried material, 1 g was weighed out and placed within a 30 ml acid washed porcelain crucible. The rest was placed in a clean plastic bag for pH measurements.

2.4.2 Elemental Analysis

Chemical analyses procedures were derived from a handbook published by the Ontario Ministry of the Environment (Anon,1983). The initial lichen digestion involved ashing the lichen at 500 degrees Celsius for 3 hours and then adding an *aqua regia* acid mixture over low heat to dissolve the ash. This procedure resulted in a liquid digest which contained a fine powdery residue at the bottom. This was centrifuged at 2400 rpm for approximately 30 seconds and the liquid portion poured off into an acid-washed 150 ml flask and made up to 50 ml with double-distilled water. The residue was rinsed into a teflon crucible with double-distilled water and further digested with 4 ml. of a 3:1 mixture of hydrofluoric to nitric acid. (This latter procedure was completed at the recommendation of the Lakehead University Instrument Laboratory technicians in order to determine the composition of the residue.) After digesting overnight (approximately 16 to 20 hours), 2 ml of *aqua regia* was added and the crucible placed over low heat. The crucible was then heated to dryness (approximately 2 hours) in order to drive off the hydrofluoric acid. Once dry, 5 ml of concentrated hydrochloric acid was added and brought to a slow boil over low heat. This was then poured into an acid-washed 150 ml flask and the crucible rinsed several times into the flask with double distilled water. The flask was brought up to 50 ml volume.

Both the liquid and (the now digested) residue portions of the original digestion were analyzed using the Jarrell-Ash ICP Atomic Emission

Spectrometer located in the of Lakehead University Instrument Laboratory. The residue turned out to be a mixture of mainly Al, Si and Ti, with significant levels of As and Fe. It was thus decided that this residue could not be centrifuged off and ignored because of the important As and Fe content. In order to obtain more complete digestion and, upon the recommendation of lab technicians (A. Raitsakas and R. Chuchman, Chemistry Department, Lakehead University), the temperature and duration of heating was raised to 650 degrees Celsius for 4 hours.

While higher temperatures can result in the volatilization loss of certain elements (e.g. Cd, Hg), most losses occur once temperatures go above 300 to 400 degrees Celsius. The differences in elemental losses between 500 degrees and 650 degrees Celsius would not be significant and the results would be comparable, as long as consistency in methodology was maintained (B. Kronberg, personal communication). In order to further correlate the revised method with the accepted Ministry of the Environment method, a Pearson correlation statistical analysis was done on results obtained. Results of this test can be found in Table 7.

The combination of 650 degrees Celsius and 4 hour still resulted in a small amount of powdery residue left over after the initial digestion. As a result, the residue had to be digested separately for each sample using the hydrofluoric/nitric acid technique discussed above.

The final revised methodology then, from start to finish, was as follows. A one gram sample of dried lichen was placed in a muffle furnace at a temperature of 150 degrees Celsius. The temperature was then raised to 300 degrees Celsius for 1 hour and then raised to 650 degrees Celsius and held for 4 hours.

Before and after ashing, the crucible and its contents were weighed on an Oertling precision pan balance to the nearest milligram. After weighing the ashed lichen, the crucible was placed under a fume hood and the following chemical work done. Three ml. of *aqua regia* (3:1 concentrated hydrochloric : nitric acid) was added and the sample digested on a hot plate at moderate heat for 20 minutes. The digest was then transferred to a 15 ml test tube, the crucible was rinsed with double distilled water and this was poured into the test tube as well. The test tube was then centrifuged for 30 seconds in order to force the solid residue to the bottom of the test tube. The liquid portion was poured off into a 150 ml acid washed flask. The solid portion was washed into an acid washed teflon crucible with a minimum of double distilled water. One ml. of concentrated nitric acid and 3 ml of concentrated hydrofluoric acid was added to the teflon crucibles. This mixture was allowed to sit overnight (approximately 16 to 20 hours). The solid portion was partially digested by then. In order to digest the remainder, 2 ml of aqua regia was added and the crucible placed over low heat. The crucible was then heated to dryness (approximately 2 hours) in order to drive off the hydrofluoric acid.
Once dry, 5 ml of concentrated hydrochloric acid was added and brought to a slow boil over low heat. This was then poured into the 150 ml flask previously mentioned and the teflon crucible rinsed several times into the flask with double distilled water. The flask was brought up to 100 ml

total volume and the top covered with a square of paraffin to prevent evaporation and contamination.

The flasks contents were analyzed for the following elements (heavy metals - Cd, Cu, Fe, Mg, Hg, Pb, and Zn; metalloids - Al, As, S) with the Jarrell-Ash ICP atomic emission spectrometer. Blanks of the digestion (i.e. complete digestion without any lichen material) were analyzed as well in order to determine the purity of the acids used and the results subtracted from lichen results for better accuracy.

2.5 Method of pH Analysis

Lichen samples were first ground into powder form in a Wiley mill. Next, the best ratio of water to lichen needed to be determined. The best was considered the one which gave the most consistent results. One centimeter of ground lichen sample was placed in the bottom of a clean 50 ml beaker. To this was added an equal amount of distilled water (i.e. water was added until the mixtured reached the 2 cm mark on the beaker), in order to obtain a one to one ratio of lichen to water. Other ratios used were 2:1 and 3:1, and these ratios were used on 3 different samples. Each sample was allowed to stand for one hour in order to allow the H^+ ions to go fully into solution. Results obtained showed that all three ratios produced acceptable and comparable results. However, the 2 to 1 ratio of water to lichen was chosen because it was the least extreme of the three and because it produced a quantity of sample easily measured.

The next step was to complete the pH measurements upon the remaining samples. A Fisher Acumet pH meter was used. Each sample was measured by dipping the electrode into the lichen/distilled water mixture and swirling the mixture slightly, until a standardized reading appeared on the meter. This was recorded, and the electrode was rinsed thoroughly with distilled water before beginning the next sample. After all samples were completed, the pH results were converted to u eq/L H^+ for more accurate comparisons.

2.6 Statistical Methods

Once the numbers and results had been produced, analyses were run on the data in order to determine relationships and differences of significance. All relevant means and totals were calculated by hand. Graphs and charts were produced using the Macintosh micocomputers at Lakehead University. Using the Microvax computer system also at the university, the SPSS package was employed, including Pearson Correlation Co-efficients and paired T-tests.

Results

Results

The results of the field studies and chemical and mathematical analyses are presented in the following section. The order followed will be similar to that followed in the methods. Therefore, this section will begin with preliminary study results, followed by major study results. This latter portion includes site description data, lichen morphological description data, pH data and elemental data distribution patterns. Following this will be a summary of statistical results, including white birch / jack pine comparisons, distance / ppm correlations (overall and by study area), inter-element correlations and lastly, morphological data correlations. Tables and Figures are presented sequentially at the end of the written results.

3.1 Preliminary Study Results - Thunder Bay

The first ten sites were done differently in that four quadrats were sampled on each tree - upper north, lower north, upper south and lower south (see methodology for complete description). Amounts of *H. physodes* varied greatly between these quadrat types. Table 1 demonstrates that the lower north quadrat had the highest lichen cover with a mean weight of just over three grams per quadrat. The upper north quadrat had half as much mean weight as lower north.

The south side in general had very little lichen cover, with a mean of approximately one quarter of a gram per quadrat. Of the three tree species sampled, black spruce consistently had the least amounts of *H. physodes* cover, while white birch tended to have the most. There was a small amount of variation between trees and sites.

3.2 Major Study Results

3.2.1 Site Descriptions

Complete site description tables can be found in Appendix A. Table 2 contains a summary of means of diameters and means of inclinations for each site. There is a large amount of variation from site to site, with diameters varying from a low of 16.0 cm to a high of 34.5 cm. Group means are reasonably consistent at about 25 cm. A large amount of variation also exists within inclination results, with a low of 0.0 degrees and a high of 8.0 degrees. Means, however, varied only from 0.7 to 2.4 degrees.

3.2.2 Morphological Descriptions

Complete morphological data is available in Appendix B. Summaries of morphological data for lower north quadrats for all sites can be seen in Table 4 and that for upper north quadrats in Table 3.

H. physodes was the most common epiphyte in both upper and lower north quadrats, with apresence mean of 23.2 and 26.8 respectively for all sites. It most often grew in association with *P. sulcata* and *E. mesomorpha*.

Braun-Blanquet cover scale results show that crustose species had the highest mean cover, with foliose and fruticose species following closely. Epiphyte cover was better in lower north quadrats for all three epiphyte types. Bryophytes were found very infrequently in both upper and lower north quadrats. Braun-Blanquet cover scale results for *H. physodes* show a large amount of variation, especially in the upper north quadrats. Lower north figures however, show that secondary sites (i.e. Kenora, Ignace, Wawa) have greater cover than Thunder Bay sites.

Colour aberration results indicate that black discolouration is by far the commonest, with white and pink discolourations being a distant second and third most common respectively. No one site location appears to have significantly more total colour aberration than another.

Health of lichen specimens varied greatly from location to location, but the overall trend was for the fair category to have the most presence. There appears to be no real difference between upper and lower north results.

The number of large thalli present showed that secondary sites had far fewer large thalli. The 11/17 East locations had the highest amount. Branching results showed that 'some branching' was the most common. Secondary areas Kenora and Ignace had the most 'few branching' sites. However, these sites were done using mostly jack pine trees.

Soredia were present on lichens at most sites, while apothecia were not found to be present at any sites.

3.2.3 pH Data

Table 5 shows acidity levels in both pH and milliequivalents per litre of hydrogen for all sample sites. There are no obvious relationships between acidity and increasing distance from pollution source. Lichens sampled from jack pine had generally lower pH's and acidities than those sampled from white birch.

3.2.4 Elemental Data

3.2.4.1 Results of Revised versus Accepted Chemical Analysis Method

A Pearson Correlation Co-efficient test was run on the elemental results obtained for the two sites which were analyzed using the two methods. Table 6 shows that the results obtained correlated very strongly. Al results were the most different between the two methods and this showed in the correlation results. When Al values were included in the analysis, the correlation was significant at the $p \leq .01$ level. When Al was excluded, the results of the two methods correlated very significantly (i.e. at the $p \leq .001$ level).

3.2.4.2 Elemental Data Distribution Patterns

Tables 7 and 8 contain the results of the chemical analyses performed on the *H. physodes* samples collected. The graphs which follow these tables (Figures 3 to 22) illustrate the data. (Local site results and Sibley results could not be included in these figures because the 15 km distance intervals were not followed.) The results will be presented in order of apparent degree of pollution from lowest to highest.

3.2.4.3.1 Kenora

Al levels varied here from 181 ppm (site 4) to 356 ppm (site 2). There appears to be an overall drop in ppm as distance from the town increases (see Figure 4). As levels ranged from a high of 3.5 ppm at site 1 to a low of 1.6 ppm at site four. From the graph, (see Figure 6), an overall drop in ppm level can be seen despite some minor variation. Cd levels ranged from a high of 0.39 ppm at site 1 to a low of 0.19 ppm at site two. Again despite some variation, an overall decrease in ppm level can be seen in Figure 8. Cu levels show a more distinct drop as distance increases (see Figure 10). Levels here range from 0.9 ppm (site 5) to1.5 ppm (site 1). Levels of Fe at Kenora sites follow patterns similar to other elements in having a small overall decrease in ppm as distance increases, despite some minor variation (see Figure 12). Fe contents run from 116 ppm (site 4) to 192 ppm (site 2). Hg levels ranged from 1.00 ppm at site 1 to 2.02 ppm at site 2. Levels here seem to peak at site 2 and then steadily drop away (see Figure 14). Mg content did not show a similar trend (see Figure 16). It varied from 97 ppm at site 3 to 153 ppm at site two. Pb levels drop sharply from site 0 (20.1 ppm) to site 2 (6.5 ppm) and then level off (see Figure 18). S levels again show some variation from site 0 to site 5, with an overall decrease visible (see Figure 20). The highest amount is at site 1 (116 ppm) while the lowest is at site 3 (59 ppm). Zn levels show no overall decreases, with a high level recorded at site 5 (16.6 ppm) and a low at site 3 (8.2 ppm). Levels here drop from site 0 to site 2 and then rise again to site 5 (see Figure 22).

3.2.4.2.2 Ignace

Overall elemental levels in the Ignace region were slightly higher than those in the Kenora region. Al levels at Ignace ranged from a high of 381 ppm (site 0) to a low of 214 ppm (site 5). A drop in concentration with increasing distance can be seen in Figure 4. As levels too, show a drop with increasing distance (see Figure 6). Levels vary from 4.1 ppm (site 2) to 2.2 ppm (site 4). Cd levels (see Figure 8) showed no drop with increasing distance, with a high level reached at site 3 (0.46 ppm) and a low reached at site 1 (0.07 ppm) (see Figure 8). Cu levels are unusual at Ignace, in having a high of 14 ppm at site 0. This is the highest level of Cu for any site studied. Cu levels at Ignace also show a well-defined decrease as distance from pollution source increases (see Figure 10). Fe levels range from 156 ppm (site 2) to 260 ppm (site 0). Figure 12 shows how levels again drop (with some minor variations) as distance increases. Hg levels show an overall decrease in ppm (see Figure 14). Levels range from 1.75 ppm (site 0) to 1.27 ppm (site 1 and 4). Mg content reached a high of 143 ppm (site 1) and a low of 84 ppm (site 4). Figure 16 indicates an overall drop in ppm. Pb content in the Ignace area ranged from 8.4 ppm at site 0 to 4.8 ppm at site 5. Figure 18 demonstrates a clear and gradual drop in Pb levels from site 0 to 5. S levels varied from a high of 120 ppm (site 1) to a low of 45 ppm (site 5). Figure 20 shows how S levels again decrease overall as distance increases. Zn content at Ignace parallels that found in Kenora by dropping from site 0 to 2 and then rising again to site 5 (see Figure 22). The highest Zn level is found at site 5 (15.0 ppm) and the lowest is at site 3 (11.6 ppm).

3.2.4.2.3 Wawa

Levels here were generally higher than at Ignace and Kenora. Several observations on this region must be made clear however. Firstly, much of the area around Wawa is a lichen desert, as was found by Rao and Leblanc

(1967). This is a result of a history of heavy local pollution. Therefore, no lichen samples could be obtained in areas closest to Wawa. *H. physodes* was one of the first lichens to reappear in more distant locations however.

The second note of importance is that the sites sampled (unlike most of the other areas, and as was already explained in the methods) were not at 15 km. intervals downwind from the emissions source. Therefore, direct comparisons with other sample areas are difficult. Wawa data has been included in the graphs for comparative purposes. (They have been ordered according to increasing distance -- site 1 = 10.2 km from emission source, site 3 = 16.2 km, site 2 = 20.1 km, site 4 = 34.1 km, site 5 = 46.7 km.)

Levels of elements can be seen in Table 8. Al levels ranged from 96 ppm (site 1) to 357 ppm (site 2). As levels were also highest at site 2 (3.0 ppm) and lowest at site 1 (0.7 ppm). Cd levels varied only slightly at most sites. Site 5 had the lowest value (0.17 ppm). Cu levels ranged from 1.8 ppm (site 2) to 0.4 ppm (site 5). Fe levels peaked at site 3 (515 ppm) and were lowest at site 5 (115 ppm). Hg content was highest at site 2 (1.8 ppm) and lowest at site 4 (1.1 ppm). Site 2 also had the highest Mg levels (184 ppm). Site 1 had the lowest (58 ppm). Pb levels peaked at site 4 (14.2 ppm) and were lowest at site 5 (2.3 ppm). S deposition was similar to that of Fe. Highest values were attained at site 3 (156 ppm) and lowest at site 5 (33 ppm). Zn levels were highest at site 2 (30 ppm) and lowest at site 5 (4 ppm).

3.2.4.2.4 Highway 11/17 West - Thunder Bay

This area had the lowest mean levels of pollutants of any of the Thunder Bay sites studied. Most of the elements in the area did not seem to drop significantly from site 0 to site 5 (see Figures 3 through 23 - odd numbers). Al levels were highest at site 5 (337 ppm) and lowest at site 2 (204 ppm). No drop in level with increasing distance was obvious (see Figure 3). As ranged from 1.6 ppm at site 4 to 3.1 ppm at site 0 and had a slight drop as distance increased (see Figure 5). Cd displayed a minimum of variation, with a high of 0.55 ppm at site 1 and a low of 0.28 ppm at site 5 (Figure 7). Cu levels were highest at site 3 (4.2 ppm) and lowest at site 1 (1.7 ppm). Figure 9 shows how Cu showed no decrease in concentration as distance from emission source increased. Levels of Fe were highest at site 1 (363 ppm) and lowest at site 2 (230 ppm). A small drop in levels can be seen in Figure 11. Hg levels showed minimal variation with a high of 1.32 ppm (site 1) and a low of 1.06 ppm (site 5) (Figure 13). Mg also had only minor variation, ranging from 125 ppm (site 4) to 167 ppm (site 5) (see Figure 15). Pb levels had greater variety, with a low of 5.8 ppm (site 2) and a high of 47.8 ppm (site 0). A steep decrease in concentration from site 0 is evident in Figure 17. S ranged from 88.1 ppm (site 5) to 114.7 ppm (site 2). Only minor variation can be seen in Figure 19. Zn levels were highest at site 2 (28.6 ppm) and lowest at site 4 (13.0 ppm) and again showed only a minor overall decrease with increasing distance (Figure 21). Means suggest that sites 0 and 5 were the most severely impacted by pollutants.

3.2.4.2.5 Highway 11/17 East - Thunder Bay

This region was impacted by pollutants at approximately the same levels as the previous region. In much the same way, there were few obvious trends between distance interval and level of contaminant. Al levels were highest at site 4 (337 ppm) and lowest at site 5 (189 ppm). No clear decrease in Al content can be seen (Figure 3). Similarly, no obvious decrease exists for As (Figure 5). Levels of As were highest at site 4 (3.0 ppm) and lowest at site 5 (0.9 ppm). Cd levels ranged from 0.24 ppm at site 4 to 0.44 ppm at site 1 (Figure 7). Site 1 also had the highest Cu level (2.3 ppm) and site 4 had the lowest (0.9 ppm). Again, there is no strong decrease in content as distance from the source increases (see Figure 9). Fe ranged from 339 ppm (site 0) to 145 ppm (site 5). A slight decrease in level can be seen here (Figure 11). Hg content was highest at site 0 as well (1.6 ppm) and lowest at site 3 (0.8 ppm) and showed only minor variation with distance (Figure 13). Mg levels were highest at site 4 (219 ppm) and lowest at site 3 (82 ppm) (Figure 15). Pb levels ranged from 27.3 ppm (site 0) to 5.6 ppm (site 4). An overall decrease in concentration between site 0 and 5 is evident (see Figure 17). S levels were also highest at site 0 (134.6 ppm) and lowest at site 4 (41.5 ppm) but no relationship with distance was obvious (see Figure 19). Zn followed a similar pattern with a high of 29.1 ppm and a low of 7.3 ppm (Figure 21). Means suggest that site 0 is the most polluted site in this region, while site 5 is the least.

Sibley sites had relatively low levels of most contaminants compared with other sites to the east. Of the two Sibley sites, the one closer to the end of the peninsula had the greater levels.

3.2.4.2.6 Local Sites - Thunder Bay

The three local sites (done within the city of Thunder Bay) were similar to Wawa data in not following the 15 km distance interval pattern. As a result, they have been placed into one group. Mean levels of elements rank this group as third-most polluted. Levels of Al were highest at Lakehead University (L.U.) (507 ppm) and lowest at Centennial Park (191 ppm). For all elements except Pb, S and Zn, the L.U. site had the highest levels, and Centennial Park had the lowest. As values ranged from 1.7 ppm to 5.4 ppm. Cd levels peaked at 0.6 ppm and were lowest at 0.28 ppm. Cu levels varied from 1.4 ppm to 2.4 ppm. Levels of Fe ranged from 264 ppm to 440 ppm. Hg contents ranged from 1.4 ppm to 2.0 ppm, while Mg levels varied between 94 and 137 ppm. Pb levels were highest at L.U. again (24.6 ppm) but were lowest at the Mt. McKay site (11.9 ppm). S content was highest at the Mt. McKay site (126 ppm) and lowest at both of the other sites (77 ppm). Mt. McKay also had the highest Zn level (29.1 ppm), while L.U. had the lowest (12.4 ppm).

3.2.4.2.7 Highway 527 North - Thunder Bay

This area had the second-highest level of pollutants. The figures indicate that most contaminant levels peaked at site 3 (see Figures 3 to

21 – odd numbers). Means also suggest that site 3 is the most severely impacted while sites 0 and 5 are the least. Al levels ranged from 278 ppm (site 0) to 649 ppm (site 3). As peaked at site 3 (6.7 ppm) and was lowest at site 0 (1.6 ppm). Cd was highest at site 3 as well (0.76 ppm) and lowest at site 0 also (0.32 ppm). Levels of Cu again peaked at site 3 (3.3 ppm) and were also lowest at site 1 (1.9 ppm). Fe ranged from 192 ppm (site 5) to 460 ppm (site 3). Hg levels were highest at site 4 (2.0 ppm) and lowest at site 0 (1.1 ppm). Mg content ranged from 131 ppm (site 2) to 192 ppm (site 4). Pb levels were highest at site 0 (20.5 ppm) and lowest at site 4 (11.8 ppm). S was one of two elements to peak at site 1 (157 ppm) and it was lowest at site 4 (44 ppm). Zn followed a similar pattern, peaking at site 1 (26.2 ppm) and it was lowest at site 4 as well (7.1 ppm).

3.2.4.2.8 Highway 61 South – Thunder Bay

This area had the highest mean levels of contaminants. From the figures, it is clear that this area had the steepest drop in pollutant content as distance increased from the emissions sources. Of all sites examined in this study, site 0 in this region had the highest levels of 9 out of the 10 elements . (Pb was higher at site 0, 11/17 West). Al ranged from 706 ppm (site 0) to 185 ppm (site 5). As levels were highest at site 0 (7.1 ppm) and lowest at site 2 (1.6 ppm). Levels of Cd ranged from 0.33 ppm (site 4) to 1.2 ppm (site 0). Cu varied between 7.0 ppm (site 0) and 1.3 ppm (site 4). Fe levels ranged from 691 ppm (site 0) to 191 ppm (site

2). Hg levels went from 5.85 pm (site 0) to 0.64 ppm (site 3). Mg levels ranged from 393 ppm (site 0) to 69 ppm (site 4). Highest levels of Pb were at site 0 (27.2 ppm) and lowest levels were at site 4 (3.9 ppm). S levels again peaked at site 0 (434.8 ppm) and were lowest at site 5 (47.6 ppm). Zn levels too, were highest at site 0 (236.5 ppm) but were lowest at site 4 (11.5 ppm).

3.3 White Birch / Jack Pine Comparison

White birch and jack pine trees were the two selected as *H. physodes* sample species. In total, 33 sites were completed using white birch as the epiphyte substrate, and 15 sites were done using jack pine. This imbalance in favour of white birch was a result of its greater presence and accessibility at the sampling interval.

Both jack pine and white birch were sampled on three sites and results are compared in Table 9. In two of three cases, jack pine lichens accumulated more pollutants than white birch lichens. In all three cases, however, white birch and jack pine results were positively correlated and this correlation was very significant ($p \leq 0.001$). T-test results seen beneath Table 9 indicate that no significant difference exists between jack pine and white birch results ($p \geq 0.05$).

Tables 10 to 19 provide an individual breakdown of each element as arranged by tree species. Thunder Bay local sites and Sibley sites are not included because the distances here were not comparable to the other sites (i.e. not at the 15 km intervals). This should not affect results. Mean values for jack pine are generally higher than those for white birch for Al, As, Cd, Cu, and Fe, and generally lower for Hg, Mg, Pb, S and Zn.

Acidity results of lichens on jack pine were higher than those on white birch (see Table 5). The mean jack pine lichen acidity was 100.05 ueq/L H+ compared to only 70.69 ueq/L H+ for white birch lichens.

A Pearson correlation analysis failed to show any significant correlation between S content and acidity of the lichen ($r = 0.155$).

3.4 Distance / ppm Correlations

The results of the Pearson correlation analysis in Table 20 indicates that, when results from all areas are taken together, distances correlated negatively with pollutant levels for all elements. All of these correlations are significant except for Cd and Mg. The correlations are significant at the $p \leq 0.05$ level for Al, As, Cu, Hg and Zn and at the $p \leq 0.01$ for Fe, Pb, S.

3.4.1 Distance / ppm and inter-element Relationships by Site

Tables 21 to 27 show how the ppm results for each element from each individual direction or area sampled correlates with distance from pollution source and with each other. (Local sites and Sibley sites were not done because the distances were not comparable to the other areas.)

The order followed here will be the same as was followed in the discussion of distribution patterns (i.e. least impacted to most impacted).

3.4.1.1 Kenora

For the Kenora area sites (see Table 21), only one significant correlation was obtained between distance and ppm. This was a negative correlation between Fe and distance ($p \leq 0.05$). All other elements except Hg and Zn had negative but insignificant correlations (even though some were numerically high). As before, most elements correlated positively with each other. Several of these correlations are significant at a variety of levels, with Al and As having the only very significant correlation ($p \leq 0.001$).

3.4.1.2 Ignace

Ignace results (see Table 22) show that all elements except Cd and Zn are negatively correlated with distance. Al, As, Cu ($p \leq 0.01$), and Pb and S ($p \leq 0.05$) are all significantly correlated with distance. Correlations between elements are mainly positive, with several being significant. Al and As are again the most significantly correlated ($p \leq 0.001$).

3.4.1.3 Wawa

Results from Wawa (see Table 23) show most elements had poor correlations with distance. Most are negative and all are insignificant. Correlations between elements are mostly positive, with S and Zn showing the most correlations with other elements. Here again, Al and As have a very significant and positive correlation ($p \leq 0.001$).

3.4.1.4 Highway 11/17 West - Thunder Bay

Highway 11/17 West sites (Table 24) correlate poorly with distance, with only Hg showing a negative and significant ($p \leq 0.05$) correlation. Other significant correlations, ($p \leq 0.05$), occur between certain elements; Al correlates positively with Zn and negatively with S, and Fe correlates positively with As and Pb.

3.4.1.5 Highway 11/17 East - Thunder Bay

Highway 11/17 East ppm results (see Table 25) correlate negatively with distance for all results except Mg. However, only Cu, Fe and Pb results have a significant correlation at the $p \leq 0.05$ level. Most of the elements correlate positively with the other elements, with a number of these being significant. The most significant of these are between Al and As ($p \leq 0.01$), and between Pb and Cu, and S and Zn ($p \leq 0.001$).

3.4.1.6 Highway 527 North - Thunder Bay

Highway 527 North sites (see Table 26) had the weakest correlations with distance. Only four elements (Fe, Pb, S, Zn) had a negative correlation and none of these were significant. The rest were positive correlations without being significant. A number of elements did have significant correlations with other elements however. The most significant were positive and between Al and As, Fe and Cu, and S and Zn ($p \leq 0.001$).

3.4.1.7 Highway 61 South - Thunder Bay

Highway 61 South (Table 27) has the strongest correlations, with all elements correlating negatively and significantly with distance. Cd and Cu were the only two to show a very significant correlation ($p \leq 0.001$). All elements are significantly and positively correlated with all other elements. Most of these correlations are numerically high as well as very significant.

3.5 Morphological Data / ppm Correlations

Table 28 shows the results of a Pearson Correlation test between morphological data and ppm contents of each element for upper north results. White colour aberrations correlated positively and significantly with Cu and S contents ($p \leq 0.05$). Pink aberrations correlated positively and significantly with Fe contents ($p \leq 0.05$), and significantly with Pb results ($p \leq 0.01$). Yellow aberrations correlated positively and significantly with Hg, S and Zn contents ($p \leq 0.01$).

Branching data showed a number of both positive and negative correlations with Cd, Cu, Fe, Mg, Pb and Zn contents.

Results of correlation analysis for lower north ppm and morphological data can be seen in Table 29. Unlike upper north results, there are several negative and significant correlations ($p \leq 0.05$) between Braun-Blanquet values of *H. physodes* and Cd, Fe, Pb and Zn contents.

Colour aberrations again show a number of significant correlations. Black correlated positively and significantly with Al and Pb ($p \leq 0.05$). White correlated significantly with Cu only ($p \leq 0.05$). Brown correlated positively with Mg and Zn significantly ($p \leq 0.05$), while pink correlated positively and very significantly with Pb content ($p \leq 0.001$).

Numbers of large thalli correlated negatively and significantly with Cu ($p \leq 0.05$) and also correlated positively and significantly with Mg ($p \leq 0.05$). Branching results again show a variety of both positive and negative significant correlations.

Several significant correlations were found to be in both upper and lower north results. White correlating with Cu appeared significantly in both quadrats ($p \leq 0.05$). Pink and Pb content correlated significantly in both quadrats ($p \leq 0.01$). Cd, Mg and Zn contents and few branching correlated negatively in both tables ($p \leq 0.05$), while Cu content and few branching correlated positively in both as well ($p \leq 0.05$). Pb and Zn levels, and some branching also correlated positively in both upper and lower north quadrats ($p \leq 0.05$).

Results Tables

Table 1: Lichen weights in grams (undried and uncleaned) as collected in the preliminary study

Site and Tree Species	Upper North	Lower North	Upper South	Lower South	Mean
Prelim. Site 1 (Jack pine)	0.86	2.29	0.39	0.70	1.06
Prelim. Site 2 (Black spruce)	0.21	1.46	< 0.01	0.06	0.44
Prelim. Site 3 (White birch)	0.89	1.83	0.30	0.43	0.86
Prelim. Site 4 (Jack pine)	0.62	2.59	0.08	0.83	1.03
Prelim. Site 5 (Black spruce)	0.22	1.82	0.26		0.57
Prelim. Site 6 (White birch)	7.61	6.16		0.42	3.55
Hwy. 527 #0 (White birch)	1.38	2.77	0.50	0.28	1.23
Hwy. 527 #1 (White birch)	1.69	2.78	0.18	0.18	1.21
Hwy. 527 #2 (Jack pine)	1.07	2.32		0.13	0.88
Hwy. 527 #3 (Jack pine)	2.23	6.07	0.37	0.28	2.24
Mean weight	1.68	3.01	0.21	0.33	1.31

Table 2: Summary of site description tree diameter means and inclinations for all sites

Site		Tree Species[a]	Diameter Mean (cm.)	Group Mean	Inclination Mean (degrees)	Group Mean
11/17 West	#0	Wb	22.9	28.1	1.0	0.7
	#1	Wb	20.6		1.0	
	#2	Jp	32.0		0.0	
	#3	Wb	31.8		1.0	
	#4	Jp	32.6		0.4	
	#5	Wb	28.9		0.8	
61 South	#0	Wb	28.2	24.4	2.4	1.5
	#1	Wb	24.3		1.0	
	#2	Jp	27.0		2.0	
	#3	Wb	24.9		2.2	
	#4	Jp	19.1		0.8	
	#5	Wb	22.7		0.8	
11/17 East	#1	Wb	22.0	24.9	2.0	1.0
	#2	Wb	31.4		1.0	
	#3	Jp	24.6		0.8	
	#4	Wb	25.3		1.2	
	#5	Wb	21.1		1.0	
527 North	#0	Wb	28.0	24.7	1.4	1.5
	#1	Wb	16.0		3.0	
	#2	Jp	21.1		3.0	
	#3	Jp	20.4		0.0	
	#4	Jp	34.5		0.8	
	#5	Wb	28.0		0.6	
Sibley	#1	Wb	22.8	26.9	1.0	2.4
	#2	Wb	27.6		1.8	
Cent. Park		Wb	32.2		2.2	
Lakehead Univ.		Wb	24.1		8.0	
Mt. McKay		Wb	27.6		1.4	
Kenora	#0	Wb	18.3	22.7	0.6	1.1
	#1	Jp	26.2		0.0	
	#2	Wb	25.5		1.2	
	#3	Jp	25.8		1.0	
	#4	Wb	22.1		1.8	
	#5	Wb	18.2		2.2	
Ignace	#0	Jp	21.9	24.4	0.6	0.8
	#1	Jp	25.9		0.4	
	#2	Jp	26.2		1.2	
	#3	Jp	27.3		0.4	
	#4	Jp	26.6		1.0	
	#5	Jp	18.6		1.0	
Wawa	#1	Wb	25.8	24.7	2.0	2.2
	#2	Wb	22.2		1.6	
	#3	Wb	26.7		2.0	
	#4	Wb	23.5		2.6	
	#5	Wb	25.2		2.8	
Grand Mean				25.1		1.4

[a] Note: Wb = white birch
Jp = jack pine

Table 3: Summary of morphological data for **upper** north quadrat listed by site locations

	Site Locations							
Description	11/17 W	61 S	11/17 E	527 N	Kenora	Ignace	Wawa	Mean
Maj. Epip.: (Total presence per site)								
P. sulcata	19	25	23	15	14	17	4	16.7
E. mesomorpha	16	16	22	18	10	21	6	15.6
H. physodes	20	28	24	25	15	26	25	23.2
C. pinastri	0	0	0	0	0	0	0	0.0
Alectoria sp.	0	0	0	3	0	6	0	1.3
Braun-Blanquet: (Mean Braun-Blanquet Cover Values per site)								
crustose	2.6	2.9	2.5	2.0	2.2	2.9	2.5	2.5
foliose	2.2	2.7	2.7	2.0	1.6	2.3	2.7	2.3
fruticose	1.6	1.5	1.7	1.2	0.8	2.0	0.7	1.4
bryophytes	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
H. physodes:								
Braun-Blanquet (Mean B-B cover values per site)	1.4	1.8	1.6	1.3	1.1	1.7	2.5	1.6
Colour aberrations (Total presence)								
brown	0	2	4	1	1	0	10	2.6
black	21	23	20	26	13	21	16	20.0
white	10	14	11	2	14	19	16	12.3
pink	7	1	4	3	2	0	4	3.0
yellow	1	1	0	3	0	0	0	0.7
orange	0	1	0	0	0	0	0	0.1
none	5	3	0	4	7	3	0	3.1
Health (Total presence)								
poor	5	0	1	1	3	4	3	2.4
poor to fair	5	6	1	3	7	11	7	5.7
fair	5	9	15	16	7	8	8	9.7
fair to good	6	8	4	4	4	3	7	5.1
good	7	6	4	5	3	1	0	3.7
Size - # of large	8	7	10	8	0	•	5	5.6
Branching (Total presence)								
few	4	5	0	7	13	20	9	8.3
some	16	15	11	17	7	5	14	12.1
many	8	10	14	6	4	2	2	6.6
Soredia - yes	27	30	25	27	22	27	25	26.1
no	3	0	0	3	2	0	0	1.1

Table 4: Summary of morphological data for **lower** north quadrats listed by site locations

Description	Site Locations 11/17 W	61 S	11/17 E	527 N	Kenora	Ignace	Wawa	Mean
Maj. Epip. (Total presence per site)								
P. sulcata	19	27	21	12	14	18	4	16.4
E. mesomorpha	22	19	18	14	18	25	5	17.3
H. physodes	30	27	25	24	28	29	25	26.8
C. pinastri	0	3	0	0	0	0	0	0.4
Alectoria sp.	0	0	0	4	0	9	0	1.8
Braun-Blanquet (Mean Braun-Blanquet Cover Values per site)								
crustose	3.0	3.3	2.9	2.8	2.5	3.2	2.8	2.9
foliose	2.6	2.8	2.8	2.1	2.7	2.7	2.6	2.6
fruticose	1.9	1.7	1.5	1.2	1.5	2.3	0.6	1.5
bryophytes	0.1	0.0	0.0	0.0	0.01	0.0	0.0	0.02
H. physodes								
Braun-Blanquet (Mean B-B cover values per site)	1.9	1.9	1.9	1.6	2.3	2.2	2.4	2.0
Colour aberrations (Total presence)								
brown	0	5	1	1	1	1	10	2.7
black	25	23	22	29	23	23	14	22.7
white	14	17	10	9	25	27	18	17.1
pink	7	1	11	5	4	0	1	4.1
yellow	1	2	0	3	0	0	1	1.0
orange	0	0	0	0	0	0	0	0.0
none	1	4	1	1	3	1	0	1.6
Health (Total presence)								
poor	0	2	1	1	7	9	0	2.8
poor to fair	9	2	8	4	8	10	6	6.7
fair	12	12	3	13	6	8	13	9.6
fair to good	4	8	5	6	7	3	4	5.3
good	5	5	8	6	2	0	2	4.0
Size - # of large	10	9	15	14	3	1	2	7.7
Branching (Total presence)								
few	5	5	0	9	17	24	8	9.7
some	17	16	14	11	12	5	15	12.8
many	8	9	11	10	1	1	2	6.0
Soredia - yes	30	30	25	30	30	30	25	28.6
no	0	0	0	0	0	0	0	0.0

Table 5: Acidity results in both pH and milliequivalents for all sites

Site	Tree Species[a]	pH	ueq/L H+	Group Means (ueq/L H+)
11/17W	#0 Wb	4.16	69.1	68.2
	#1 Wb	4.19	64.2	
	#2 Jp	4.11	77.2	
	#3 Wb	4.11	77.2	
	#4 Jp	4.19	64.2	
	#5 Wb	4.24	57.4	
61 S	#0 Wb	4.14	72.3	101.9
	#1 Wb	4.00	99.2	
	#2 Jp	3.85	141.1	
	#2 Wb	4.12	75.6	
	#3 Wb	3.84	144.3	
	#4 Jp	3.97	106.9	
	#4 Wb	4.02	95.1	
	#5 Wb	4.09	80.8	
11/17 E	#1 Wb	4.19	64.2	74.1
	#2 Wb	4.26	54.9	
	#3 Jp	3.85	141.1	
	#3 Wb	4.17	67.5	
	#4 Wb	4.36	43.6	
	#5 Wb	4.14	73.3	
527 N	#0 Wb	4.26	54.9	89.7
	#1 Wb	4.02	95.1	
	#2 Jp	3.98	104.3	
	#3 Jp	3.95	112.0	
	#4 Jp	3.94	114.6	
	#5 Wb	4.24	57.4	
Sibley	#1 Wb	4.14	72.3	62.3
	#2 Wb	4.16	69.1	
Mt. McKay	Wb	4.11	77.2	
Lakehead U.	Wb	4.45	35.4	
Cent. Park	Wb	4.24	57.4	
Kenora	#0 Wb	4.24	57.4	80.6
	#1 Jp	4.09	80.8	
	#2 Wb	4.09	80.8	
	#3 Jp	3.92	119.8	
	#4 Wb	4.24	57.4	
	#5 Wb	4.06	87.0	
Ignace	#0 Jp	4.10	78.8	87.6
	#1 Jp	3.99	101.8	
	#2 Jp	4.09	80.8	
	#3 Jp	3.92	119.8	
	#4 Jp	4.24	57.4	
	#5 Wb	4.06	87.0	
Wawa	#1 Wb	4.26	54.9	61.3
	#2 Wb	4.12	75.6	
	#3 Wb	4.14	72.3	
	#4 Wb	4.26	54.9	
	#5 Wb	4.31	48.7	
Grand Mean				78.2

Note: Wb = white birch
Jp = jack pine

Table 6: Results of Pearson correlation between data obtained with Ministry of Environment method and data obtained with modified method

Site	Co-efficient	Significance
Sibley 1 - including Al value	r = 0.714	0.010 (**)
Sibley 1 - excluding Al value	r = 0.944	0.001 (***)
Sibley 2 - including Al value	r = 0.754	0.006 (**)
Sibley 2 - excluding Al value	r = 0.921	0.001 (***)

Note: ** = significant at the $p < .01$ level
*** = significant at the $p < .001$ level

Table 7: Elemental contents of *H. physodes* in parts per million (ug/g) dry weight for primary sites

Site	Tree species	ueq/L H+	Al	As	Cd	Cu	Fe	Hg	Mg	Pb	S	Zn	Mean
11/17	#0 Wb	69.1	283	3.1	0.29	2.1	363	1.28	126	47.8	96.6	17.5	94.0
West	#1 Wb	64.2	290	3.0	0.55	1.7	268	1.32	131	12.0	94.8	28.6	83.1
	#2 Jp	77.2	204.	1.7	0.29	2.1	230	1.29	132	5.8	114.7	15.2	70.7
	#3 Wb	77.2	237	1.8	0.31	4.2	238	1.29	129	16.1	89.3	17.7	73.6
	#4 Jp	64.2	228	1.6	0.35	3.6	231	1.12	125	6.7	115.8	13.0	72.6
	#5 Wb	57.4	337	2.1	0.28	1.8	306	1.06	167	10.7	88.1	24.3	93.9
	Mean	68.2	263	2.2	0.34	2.6	273	1.23	135	16.5	99.9	19.4	81.3
61	#0 Wb	72.3	706	7.1	1.20	7.0	691	5.85	393	27.2	433.8	92.0	236.4
South	#1 Wb	99.2	402	4.2	0.82	5.0	344	2.60	290	13.4	247.8	56.3	136.7
	#2 Jp	141.1	372	2.9	0.71	4.7	271	1.85	141	6.3	164.7	22.8	98.8
	Wb	75.6	215	1.6	0.44	1.4	191	1.29	142	6.3	94.0	26.7	68.0
	#3 Wb	144.3	252	1.9	0.62	2.2	215	0.64	196	10.2	108.7	32.0	81.9
	#4 Wb	95.1	238	2.2	0.37	1.3	224	0.91	69	7.5	68.7	11.5	62.4
	Jp	106.9	321	2.6	0.33	1.6	343	1.61	110	3.9	78.9	14.8	88.0
	#5 Wb	80.8	185	1.7	0.40	1.5	198	1.25	93	5.0	47.6	14.6	54.9
	Mean	101.9	359	3.3	0.69	3.6	324	2.18	197	11.6	178.6	38.2	111.8
11/17	#1 Wb	64.2	360	2.9	0.44	2.3	338	1.61	212	27.3	134.6	29.1	110.8
East	#2 Wb	54.9	327	2.6	0.26	1.4	259	1.35	159	15.9	47.2	9.9	82.3
	#3 Wb	67.5	252	1.6	0.34	1.5	155	0.82	157	20.9	100.3	21.6	71.2
	Jp	141.1	223	1.7	0.34	1.7	169	0.91	82	6.2	108.6	12.9	60.6
	#4 Wb	43.6	377	3.0	0.24	0.9	228	1.50	219	5.6	41.5	7.3	88.4
	#5 Wb	72.3	189	0.9	0.35	1.0	145	0.95	132	8.7	59.4	13.6	55.2
	Mean	73.9	301	2.2	0.33	1.4	225	1.24	176	15.7	76.6	16.3	81.6
Sibley	#1 Wb	72.3	240	2.6	0.23	0.8	124	1.12	117	4.5	43.3	8.8	54.2
	#2 Wb	69.1	210	2.0	0.17	0.8	114	1.25	113	4.2	44.7	10.3	50.0
	Mean	70.7	225	2.3	0.20	0.8	119	1.18	115	4.4	44.0	9.6	52.1
527	#0 Wb	54.9	278	1.6	0.32	1.9	275	1.13	131	20.5	100.6	18.4	83.0
North	#1 Wb	95.1	335	3.3	0.41	2.0	266	1.73	179	14.7	156.8	26.2	98.6
	#2 Jp	104.4	528	5.6	0.71	2.9	404	1.75	131	16.1	67.0	12.1	116.9
	#3 Jp	112.0	649	6.7	0.76	3.3	459	1.77	164	19.2	77.3	13.5	139.6
	#4 Jp	114.6	429	4.8	0.46	2.0	255	2.03	192	11.8	43.9	7.1	94.9
	#5 Wb	57.4	360	3.9	0.59	2.0	192	1.74	181	13.0	59.1	14.1	82.8
	Mean	89.8	430	4.3	0.54	2.4	309	1.69	163	15.9	84.1	15.2	102.6
Mt.McKay	Wb	77.2	337	3.4	0.46	2.1	304	1.50	125	11.9	126.5	29.1	94.1
L.H. Univ.	Wb	35.4	502	5.4	0.59	2.4	440	1.98	137	24.6	77.0	12.4	120.4
Cent.Park	Wb	57.4	191	1.7	0.28	1.4	264	1.36	94	17.8	77.0	15.0	66.3
	Mean	56.0	343	3.5	0.40	1.9	336	1.60	119	18.0	93.0	19.0	93.0

Table 8: Elemental contents of *H. physodes* in parts per million (ug/g) dry weight for secondary sites

Site	Tree species	meq/L H+	Al	As	Cd	Cu	Fe	Hg	Mg	Pb	S	Zn	Mean
Kenora*0	Wb	57.4	277	2.4	0.29	1.1	171	1.07	126	20.1	74.2	15.6	68.9
*1	Jp	80.8	356	3.5	0.39	1.5	192	1.00	153	8.3	115.7	12.6	84.4
*2	Wb	80.8	243	2.2	0.19	0.9	141	2.02	97	6.5	59.5	8.2	56.0
*3	Jp	119.8	345	3.0	0.24	1.3	175	1.37	112	6.8	97.4	9.5	75.2
*4	Wb	57.4	181	1.6	0.21	1.2	116	1.18	108	7.2	61.2	12.1	49.0
*5	Wb	87.0	197	1.6	0.22	0.9	122	1.20	138	8.0	63.1	16.6	54.9
	Mean	80.6	266	2.4	0.26	1.2	153	1.31	122	9.5	78.5	12.4	64.8
Ignace*0	Jp	78.8	381	3.8	0.25	14.0	260	1.75	91	8.4	99.0	13.7	87.3
*1	Jp	101.8	346	4.1	0.07	7.7	253	1.27	143	7.8	120.0	12.8	89.6
*2	Jp	80.8	250	2.8	0.23	7.4	156	1.58	102	7.2	85.6	11.6	62.4
*3	Jp	119.8	263	2.2	0.46	6.8	197	1.58	116	5.8	99.2	12.0	70.5
*4	Jp	57.4	215	2.2	0.27	3.3	216	1.27	84	7.4	65.0	12.4	60.7
*5	Wb	87.0	214	2.2	0.29	3.1	186	1.35	96	4.8	47.0	15.0	57.0
	Mean	87.1	278	2.9	0.26	7.0	211	1.47	105	6.9	86.0	12.9	71.2
Wawa *1	Wb	54.9	96	0.7	0.33	0.8	121	1.36	58	6.0	62.9	14.9	36.3
*2	Wb	75.6	357	3.0	0.39	1.8	334	1.82	184	12.7	148.8	30.5	107.5
*3	Wb	72.3	226	1.9	0.35	1.7	515	1.46	147	7.4	155.6	27.4	108.3
*4	Wb	54.9	196	2.0	0.36	1.5	176	1.07	122	14.2	128.2	20.5	66.3
*5	Wb	48.7	272	2.6	0.17	0.5	115	1.54	67	2.3	33.4	3.9	49.9
	Mean	61.3	230	2.0	0.32	1.2	252	1.45	116	8.5	105.8	19.4	73.7

Figure 3: Aluminum content in H. physodes (primary area)

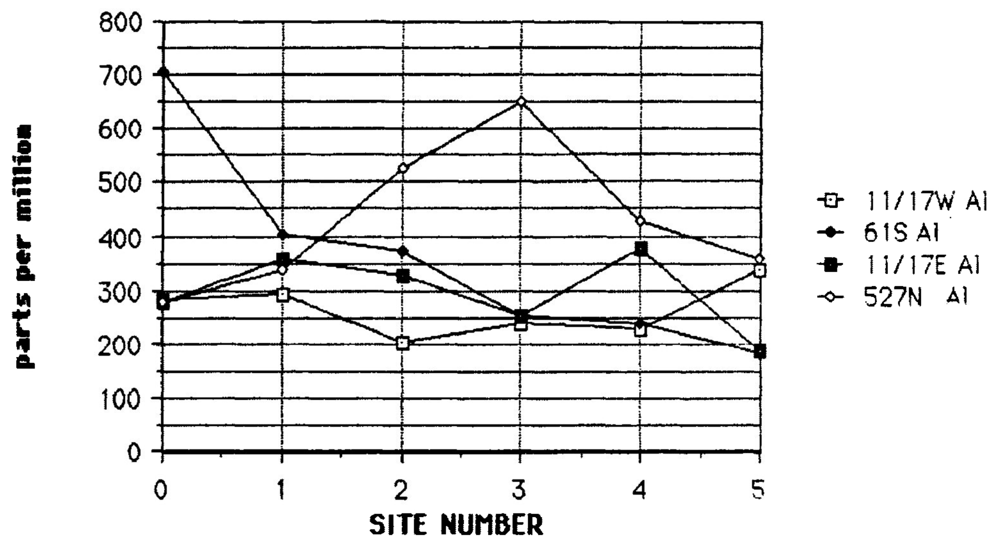

Figure 4: Aluminum content in H. physodes (secondary areas)

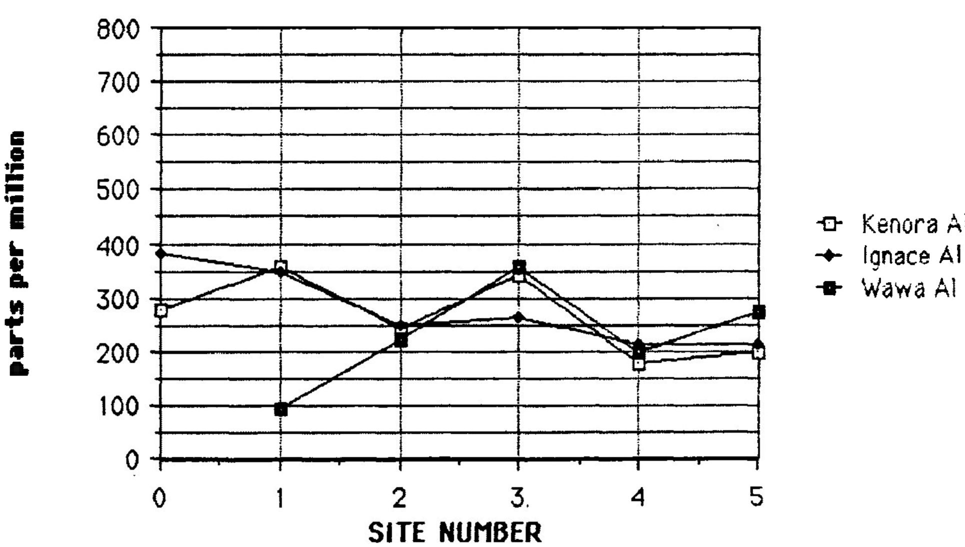

Figure 5: Arsenic content in H. physodes (primary area)

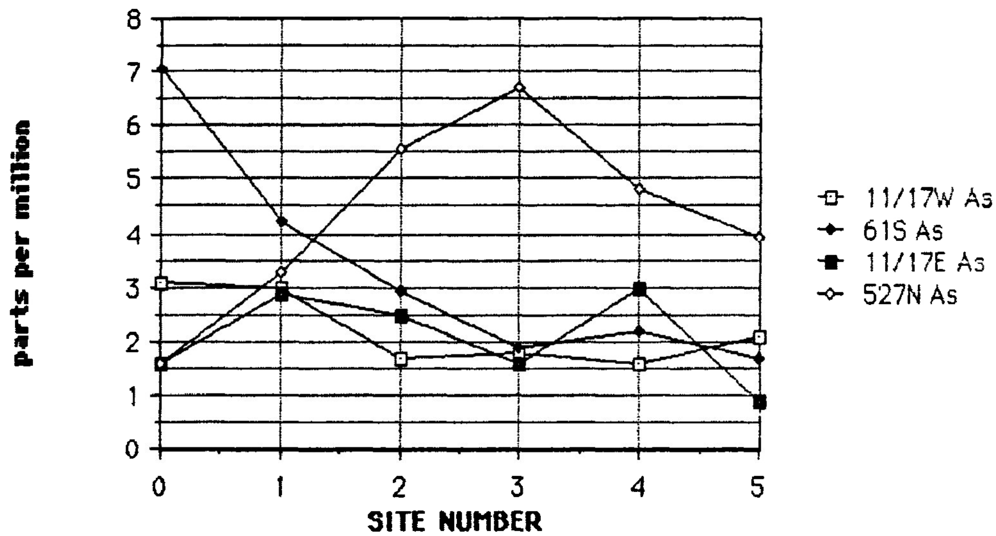

Figure 6: Arsenic content in H. physodes (secondary areas)

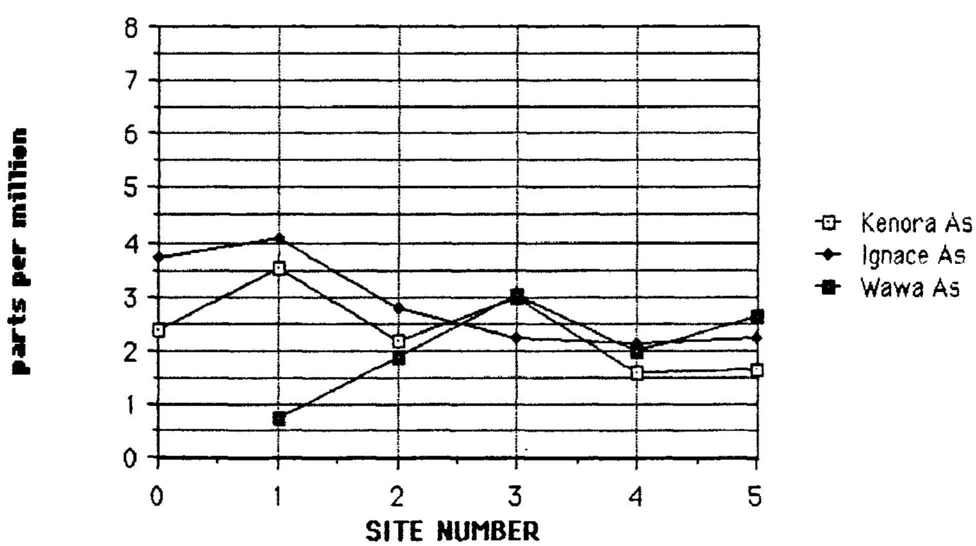

Figure 7: Cadmium content in H. physodes (primary areas)

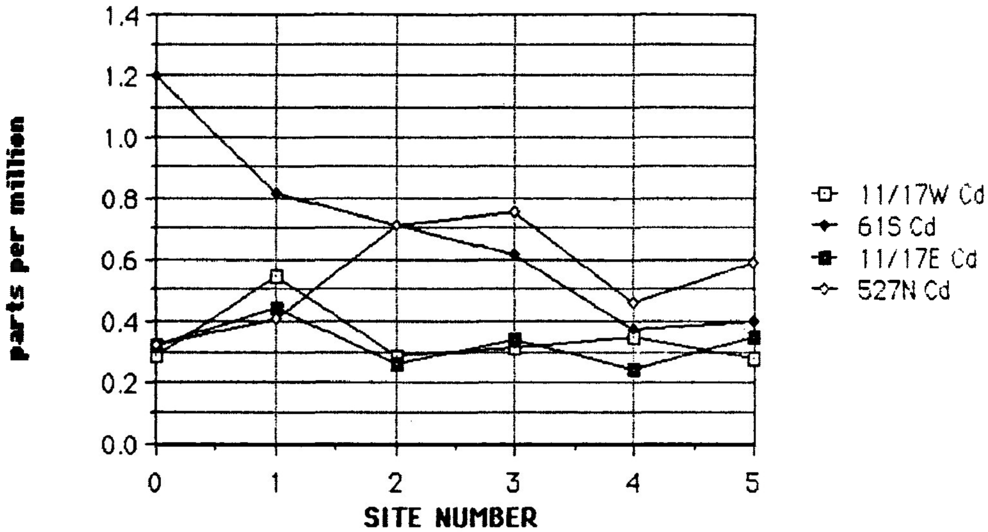

Figure 8: Cadmium content in H. physodes (secondary areas)

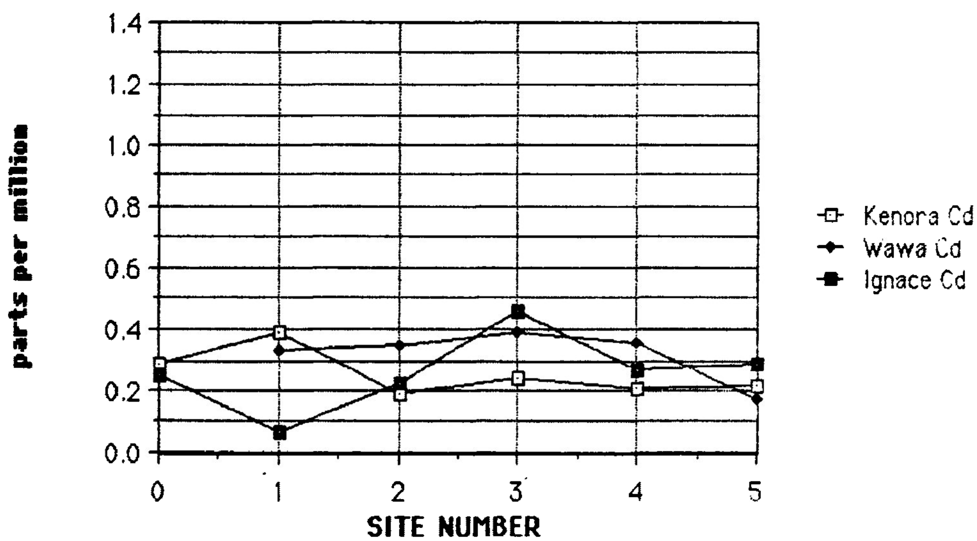

Figure 9: Copper content in H. physodes (primary areas)

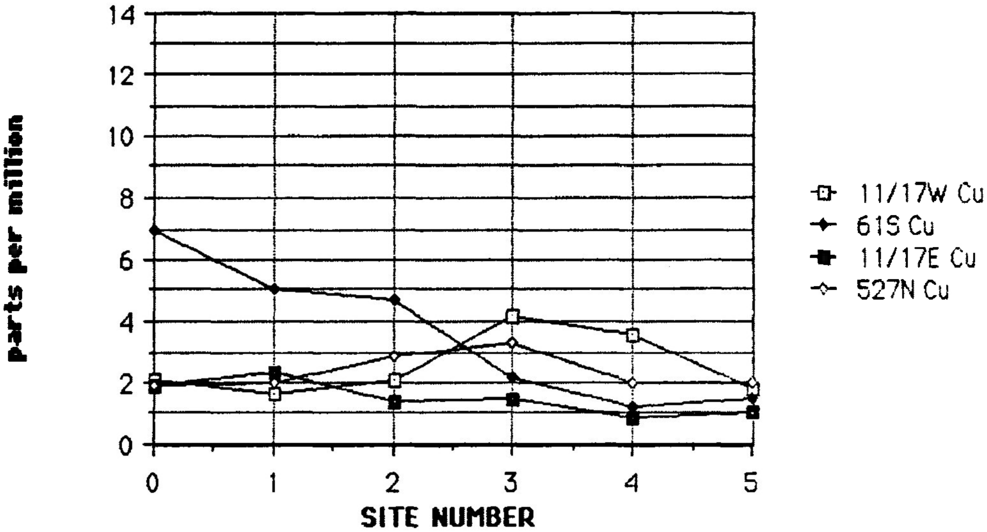

Figure 10: Copper content in H. physodes (secondary areas)

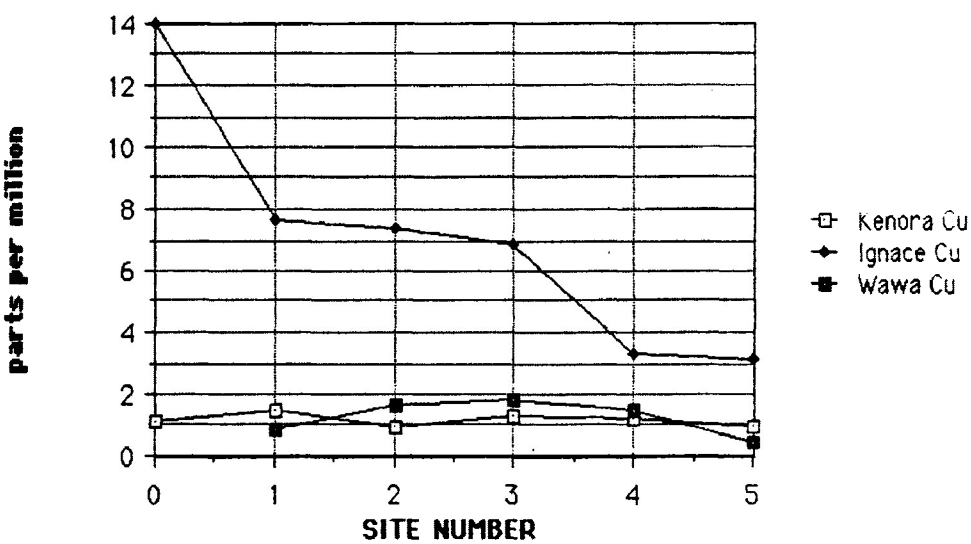

Figure 11: Iron content in H. physodes (primary areas)

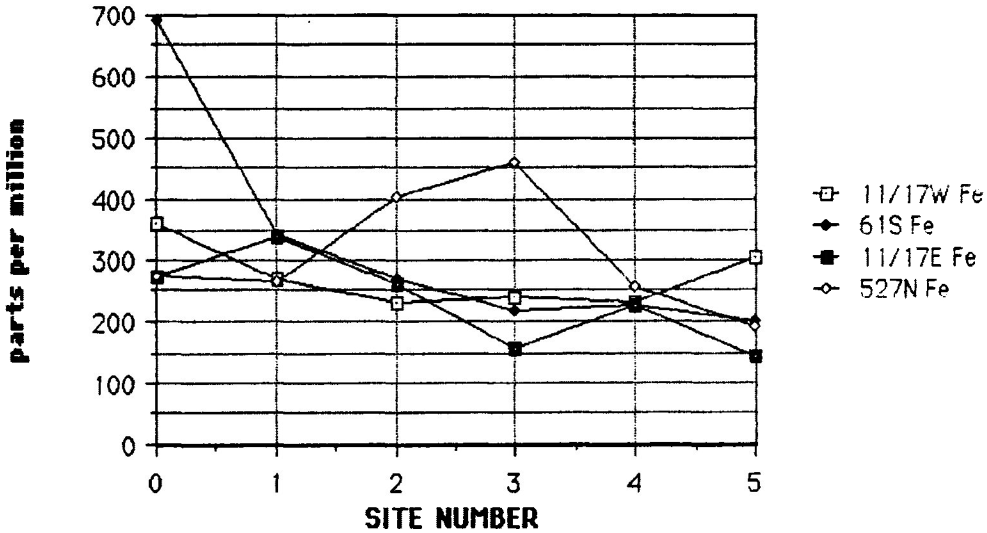

Figure 12: Iron content in H. physodes (secondary areas)

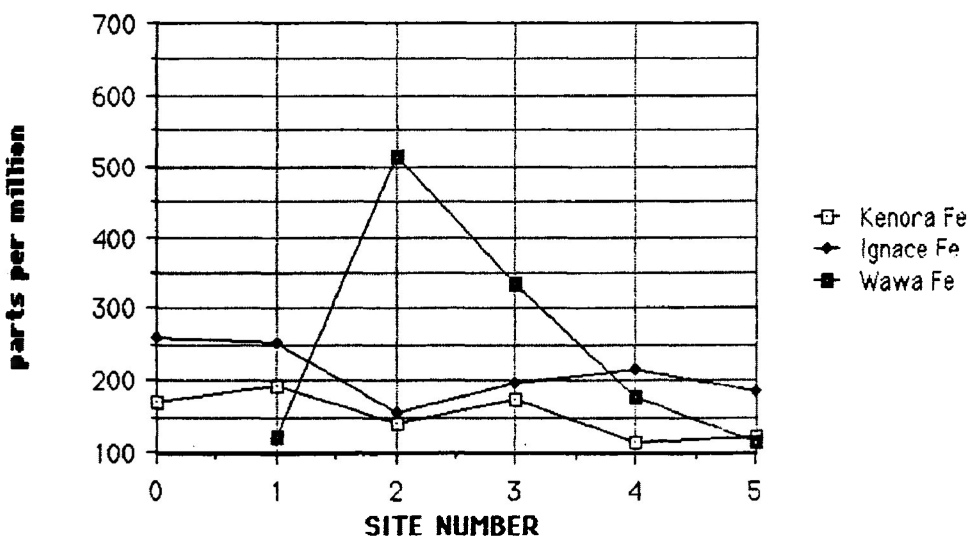

Figure 13: Mercury content in H. physodes (primary areas)

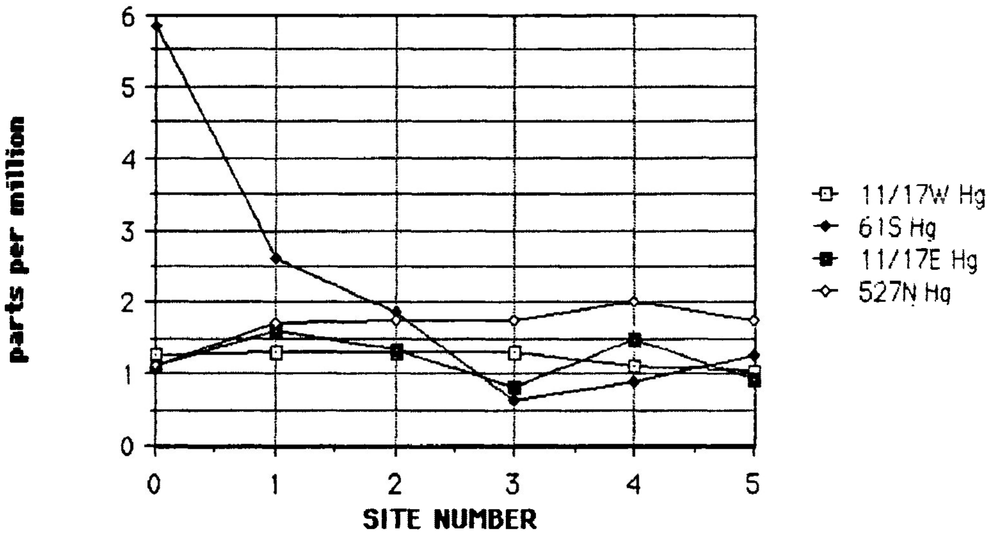

Figure 14: Mercury content in H. physodes (secondary areas)

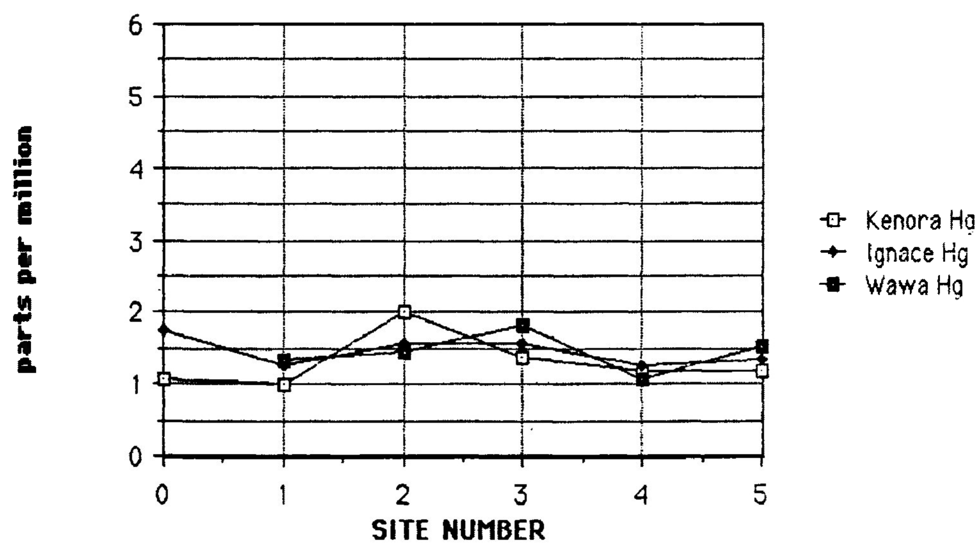

Figure 15: Magnesium content in H. physodes (primary areas)

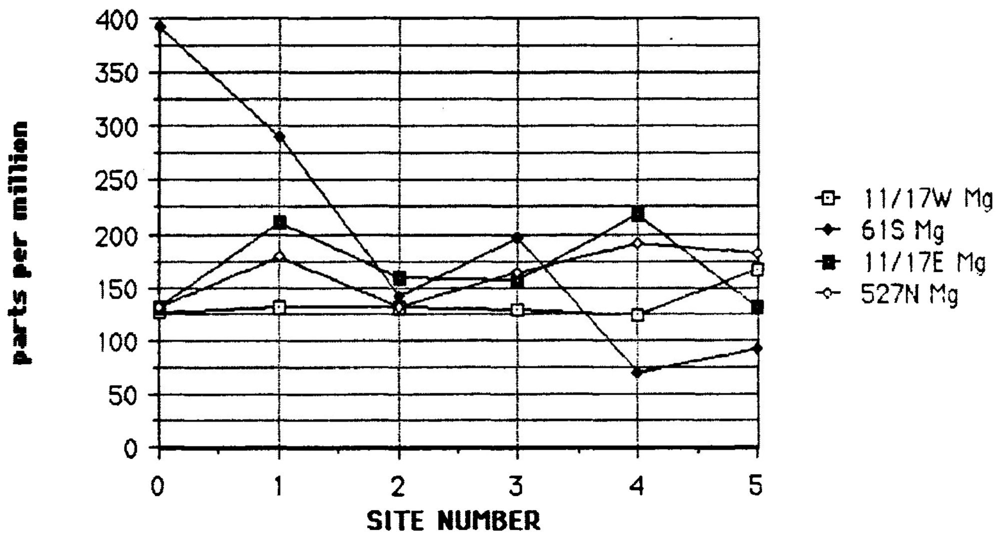

Figure 16: Magnesium content in H. physodes (secondary areas)

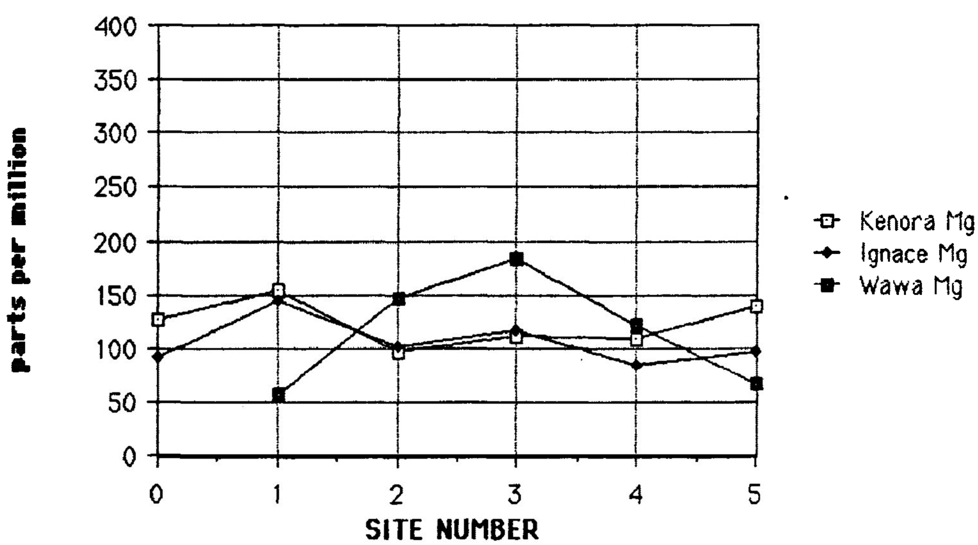

Figure 17: Lead content in H. physodes (primary areas)

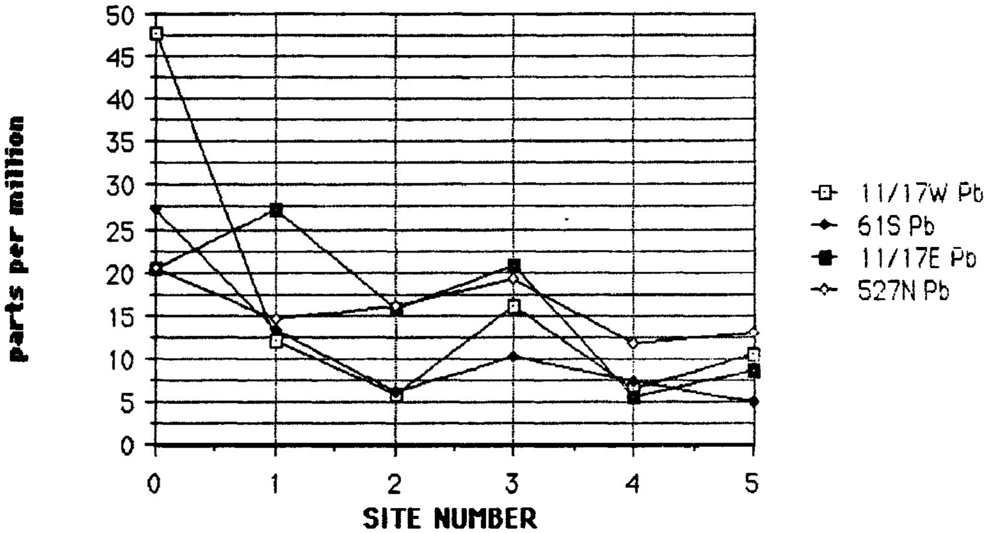

Figure 18: Lead content in H. physodes (secondary areas)

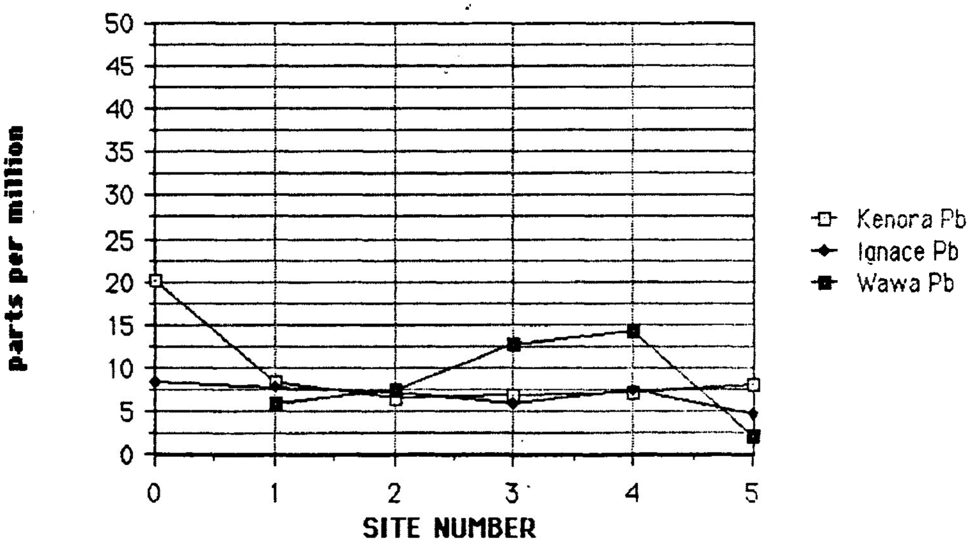

Figure 19: Sulphur content in H. physodes (primary areas)

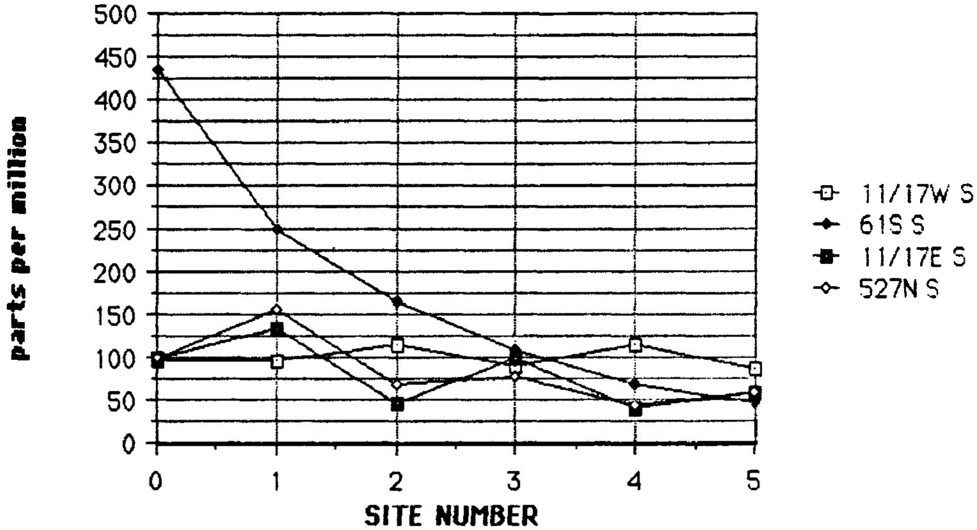

Figure 20: Sulphur content in H. physodes (secondary areas)

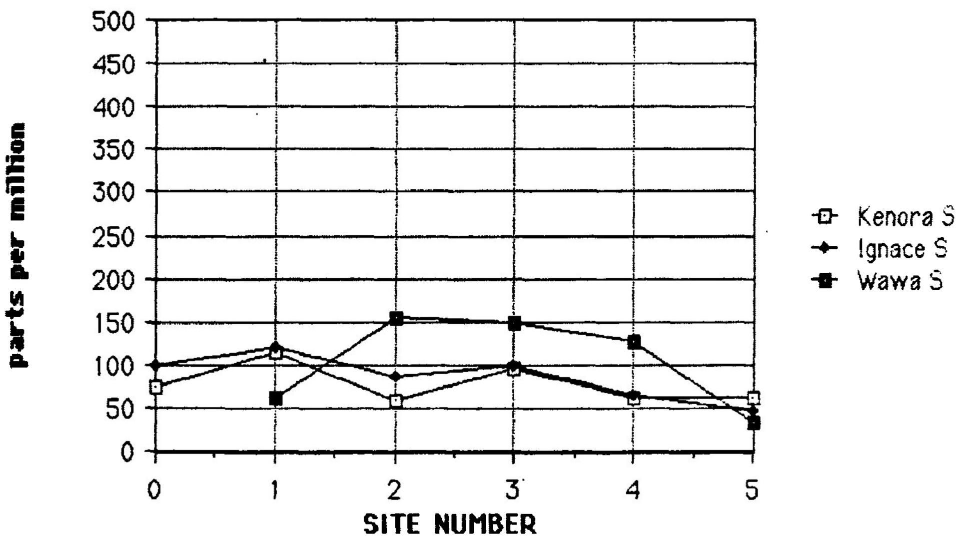

Figure 21: Zinc content in H. physodes (primary areas)

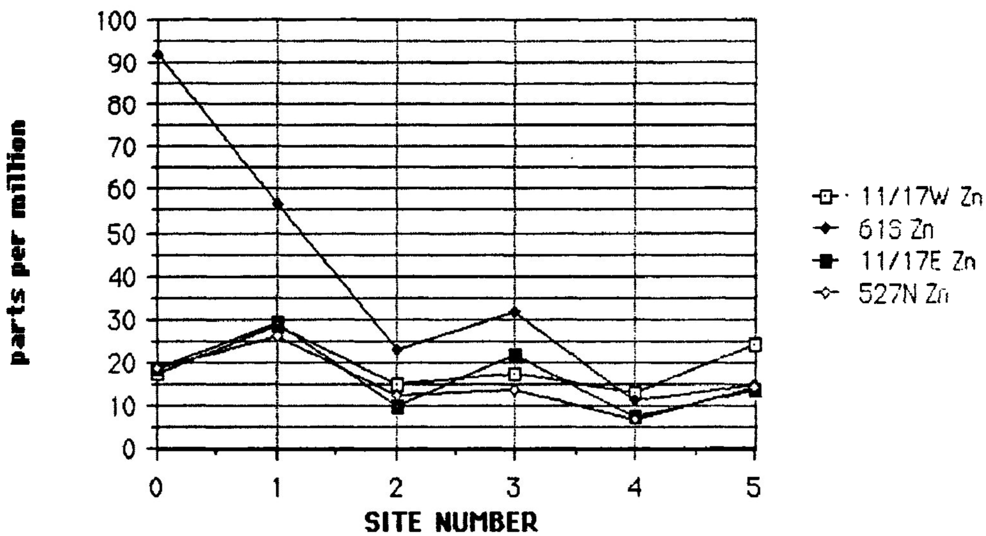

Figure 22: Zinc content in H. physodes (secondary areas)

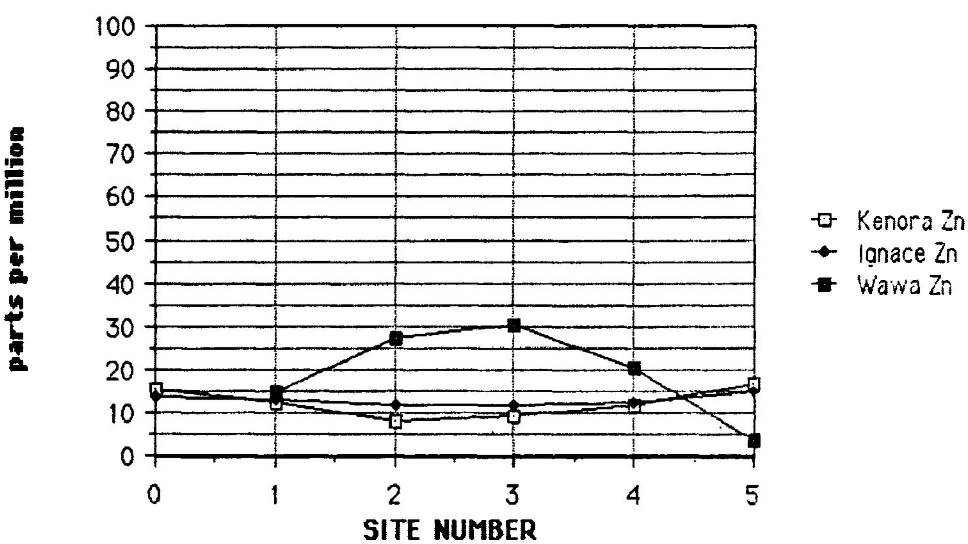

Table 9: Comparison of results (in ppm) from sites upon which both white birch and jack pine trees were sampled

Element	Site 61 South #2		Site 61 South #4		Site 11/17 East # 3	
	Wb	Jp	Wb	Jp	Wb	Jp
Aluminum	215.15	371.63	238.06	320.76	252.53	222.79
Arsenic	1.59	2.92	2.18	2.65	1.59	1.67
Cadmium	0.44	0.71	0.37	0.33	0.34	0.34
Copper	1.37	4.67	1.26	1.57	1.51	1.66
Iron	190.74	270.67	224.07	343.16	155.00	169.51
Mercury	1.29	1.85	0.91	1.61	0.82	0.91
Magnesium	141.90	141.47	68.97	110.21	157.33	81.51
Lead	6.31	6.31	7.54	3.86	20.86	6.23
Sulphur	93.97	164.68	68.69	78.92	100.27	108.56
Zinc	26.72	22.81	11.46	14.79	21.59	12.87
Mean	67.95	98.77	62.35	87.79	71.18	60.61

n = 10

	Site 61 South #2	Site 61 South #4	Site 11/17 East # 3
Pearson Correlation Test			
Correlation Coefficient (r) -	0.973	0.996	0.959
Significance Level -	(***)	(***)	(***)

(***) = significant at $p < .001$ level

	Site 61 South #2	Site 61 South #4	Site 11/17 East # 3
T-test			
T-value -	1.80	1.89	-1.29

There is no significant difference between white birch and jack pine results at $p > 0.05$ level

Table 10: Aluminum ppm by site and tree species

		Location							
Site #	Tree Species	11/17 W	61 S	11/17 E	527 N	Kenora	Ignace	Wawa	Mean
0	Wb	283	706	-	278	277	-	-	386
	Jp	-	-	-	-	-	381	-	381
	Wb	291	402	360	335	-	-	96	285
	Jp	-	-	-	-	356	346	-	351
2	Wb	-	215	326	-	243	-	357	285
	Jp	204	372	-	528	-	250	-	338
3	Wb	237	258	252	-	-	-	226	243
	Jp	228	-	223	649	345	263	-	370
4	Wb	-	185	377	-	181	-	196	235
	Jp	228	-	-	430	-	215	-	291
5	Wb	337	238	189	360	197	214	272	258
	Jp	-	321	-	-	-	-	-	321
Mean - White Birch		287	216	301	324	224	214	230	259
Mean - Jack Pine		220	346	223	535	350	291	-	328
Overall Mean		258	337	288	430	266	278	230	298

Table 11 : Arsenic ppm by site and tree species

Site #	Tree species	Location 11/17 W	61 S	11/17 E	527 N	Kenora	Ignace	Wawa	Mean
0	Wb	3.1	7.1	-	1.6	2.4	-	-	3.2
	Jp	-	-	-	-	-	3.8	-	3.8
	Wb	3.0	4.2	2.9	3.3	-	-	0.7	2.8
	Jp	-	-	-	-	3.5	4.1	-	3.8
2	Wb	-	1.6	2.5	-	2.2	-	3.0	2.3
	Jp	1.7	2.9	-	5.6	-	2.8	-	3.2
3	Wb	1.1	1.9	1.6	-	-	-	1.9	1.8
	Jp	-	-	1.7	6.7	3.0	2.2	-	3.4
4	Wb	-	1.7	3.0	-	1.6	-	2.0	2.1
	Jp	1.6	-	-	4.8	-	2.2	-	2.9
5	Wb	2.1	2.2	0.9	3.9	1.6	2.2	2.6	2.2
	Jp	-	2.6	-	-	-	-	-	2.6
Mean - White Birch		2.5	3.1	2.2	2.9	2.0	2.2	2.0	2.4
Mean - Jack Pine		1.6	2.8	1.7	5.7	3.2	3.0	-	3.0
Overall Mean		2.2	3.0	2.1	4.3	2.4	2.9	2.0	2.7

Table 12: Cadmium ppm by site and tree species

		Location							
Site #	Tree Species	11/17 W	61 S	11/17 E	527 N	Kenora	Ignace	Wawa	Mean
0	Wb	0.29	1.20	-	0.32	0.29	-	-	0.52
	Jp	-	-	-	-	-	0.25	-	0.25
	Wb	0.55	0.82	0.44	0.41	-	-	0.33	0.51
	Jp	-	-	-	-	0.39	0.07	-	0.23
2	Wb	-	0.44	0.26	-	0.19	-	0.39	0.32
	Jp	0.29	0.71	-	0.71	-	0.23	-	0.48
3	Wb	0.31	0.62	0.34	-	-	-	0.35	0.40
	Jp	-	-	0.34	0.76	0.24	0.46	-	0.45
4	Wb	-	0.40	0.24	-	0.21	-	0.36	0.30
	Jp	0.35	-	-	0.46	-	0.27	-	0.36
5	Wb	0.28	0.37	0.35	0.59	0.22	0.29	0.17	0.32
	Jp	-	0.33	-	-	-	-	-	0.33
Mean - White Birch		0.36	0.64	0.33	0.44	0.23	0.29	0.32	0.38
Mean - Jack Pine		0.32	0.52	0.34	0.64	0.28	0.26	-	0.39
Mean		0.34	0.61	0.33	0.54	0.26	0.26	0.32	0.38

Table 13: Copper ppm site and tree speciese

Site #	Tree species	Location 11/17 W	61 S	11/17 E	527 N	Kenora	Ignace	Wawa	Mean
0	Wb	2.1	7.0	-	1.9	6.1	-	-	3.0
	Jp	-	-	-	-	-	14.0	-	14.0
	Wb	1.7	5.4	2.3	2.0	-	-	0.8	2.4
	Jp	-	-	-	-	1.5	7.7	-	4.6
2	Wb	-	1.4	1.4	-	0.9	-	1.8	1.4
	Jp	2.1	4.7	-	2.9	-	7.4	-	4.3
3	Wb	4.2	2.2	1.5	-	-	-	1.7	2.4
	Jp	-	-	1.7	3.3	1.3	6.8	-	3.3
4	Wb	-	1.5	0.9	-	1.2	-	1.5	1.3
	Jp	3.6	-	-	2.0	-	3.3	-	3.0
5	Wb	1.8	1.3	1.0	2.0	0.9	3.1	1.4	1.5
	Jp	-	1.6	-	-	-	-	-	1.6
Mean - White Birch		2.4	3.1	1.4	2.0	2.3	3.1	1.2	2.2
Mean - Jack Pine		2.8	3.1	1.7	2.7	1.4	7.8	-	3.3
Overall Mean		2.6	3.1	1.5	2.4	2.0	7.0	1.2	2.8

Table 14: Iron parts ppm by site and tree species

		Location							
Site #	Tree Species	11/17 W	61 S	11/17 E	527 N	Kenora	Ignace	Wawa	Mean
0	Wb	363	691	-	275	171	-	-	375
	Jp	-	-	-	-	-	260	-	260
	Wb	268	344	338	266	-	-	121	247
	Jp	-	-	-	-	192	253	-	223
2	Wb	-	191	259	-	141	-	334	231
	Jp	230	271	-	404	-	156	-	265
3	Wb	238	215	170	-	-	-	515	284
	Jp	-	-	155	460	176	197	-	247
4	Wb	-	198	228	-	116	-	176	180
	Jp	231	-	-	256	-	217	-	234
5	Wb	306	224	145	192	122	186	115	184
	Jp	-	343	-	-	-	-	-	343
Mean - White Birch		294	311	228	245	138	186	252	236
Mean - Jack Pine		231	307	155	373	184	216	-	244
Overall Mean		273	310	216	309	153	211	252	245

Table 15: Mercury ppm by site and tree species

		Location							
Site #	Tree species	11/17 W	61 S	11/17 E	527 N	Kenora	Ignace	Wawa	Mean
0	Wb	1.28	5.85	-	1.13	1.07	-	-	2.33
	Jp	-	-	-	-	-	1.75	-	1.75
	Wb	1.32	2.60	1.61	1.73	-	-	1.36	1.72
	Jp	-	-	-	-	1.00	1.27	-	1.14
2	Wb	-	1.29	1.35	-	2.02	-	1.82	1.62
	Jp	1.29	1.85	-	1.75	-	1.58	-	1.62
3	Wb	1.29	0.64	0.91	-	-	-	1.46	1.08
	Jp	-	-	0.82	1.77	1.37	1.58	-	1.38
4	Wb	-	1.25	1.50	-	1.18	-	1.07	1.25
	Jp	1.12	-	-	2.03	-	1.27	-	1.47
5	Wb	1.06	1.61	0.95	1.74	1.20	1.35	1.54	1.35
	Jp	-	0.91	-	-	-	-	-	0.91
Mean - White Birch		1.24	2.21	1.26	1.53	1.37	1.35	1.45	1.56
Mean - Jack Pine		1.20	1.38	0.82	1.85	1.18	1.49	-	1.32
Overall Mean		1.23	2.00	1.19	1.69	1.31	1.47	1.45	1.48

Table 16: Magnesium ppm by site and tree species

		Location							
Site #	Tree Species	11/17 W	61 S	11/17 E	527 N	Kenora	Ignace	Wawa	Mean
0	Wb	126	393	-	131	126	-	-	194
	Jp	-	-	-	-	-	91	-	91
	Wb	131	290	212	179	-	-	58	174
	Jp	-	-	-	-	153	143	-	148
2	Wb	-	142	159	-	97	-	184	146
	Jp	132	141	-	131	-	102	-	126
3	Wb	129	196	157	-	-	-	147	157
	Jp	-	-	82	164	112	116	-	118
4	Wb	-	93	219	-	108	-	122	136
	Jp	125	-	-	192	-	84	-	134
5	Wb	167	69	132	181	138	96	67	121
	Jp	-	110	-	-	-	-	-	110
Mean - White Birch		169	197	176	164	117	96	116	154
Mean - Jack Pine		128	126	82	162	132	107	-	123
Overall Mean		135	179	160	163	122	105	116	144

Table 17: Lead ppm by site and tree species

Site #	Tree species	Location 11/17 W	61 S	11/17 E	527 N	Kenora	Ignace	Wawa	Mean
0	Wb	47.8	27.2	-	20.5	20.1	-	-	28.9
	Jp	-	-	-	-	-	8.4	-	8.4
	Wb	12.0	13.4	27.3	14.7	-	-	6.0	16.9
	Jp	-	-	-	-	8.3	7.8	-	8.0
2	Wb	-	6.3	15.9	-	6.5	-	12.7	9.6
	Jp	5.8	6.3	-	16.1	-	7.2	-	8.8
3	Wb	16.1	10.2	20.9	-	-	-	7.4	15.7
	Jp	-	-	6.2	19.1	6.8	5.8	-	9.5
4	Wb	-	5.0	5.6	-	7.2	-	14.2	6.0
	Jp	6.7	-	-	11.8	-	7.4	-	8.6
5	Wb	10.7	7.5	8.7	13.0	8.0	4.8	2.3	8.8
	Jp	-	3.9	-	-	-	-	-	3.9
Mean - White Birch		21.6	11.6	15.7	16.1	10.5	4.8	8.5	13.4
Mean - Jack Pine		6.2	5.1	6.2	15.7	7.6	7.3	-	8.0
Mean		16.5	10.0	14.1	15.9	9.5	6.9	8.5	12.1

Table 18: Sulphur ppm by site and tree species

Site #	Tree Species	Location 11/17 W	61 S	11/17 E	527 N	Kenora	Ignace	Wawa	Mean
0	Wb	96.6	433.8	-	100.6	74.2	-	-	176.3
	Jp	-	-	-	-	-	99.0	-	99.0
	Wb	94.8	247.8	134.6	156.8	-	-	62.9	139.4
	Jp	-	-	-	-	115.7	120.0	-	117.8
2	Wb	-	94.0	47.2	-	59.5	-	148.8	87.3
	Jp	114.7	164.7	-	67.0	-	85.6	-	108.0
3	Wb	89.3	108.7	100.3	-	-	-	155.6	113.5
	Jp	-	-	108.6	77.3	97.4	99.2	-	95.6
4	Wb	-	47.6	41.5	-	61.2	-	128.2	69.6
	Jp	115.8	-	-	43.9	-	65.0	-	74.9
5	Wb	88.1	68.7	59.4	59.1	63.1	47.0	33.4	59.7
	Jp	-	78.9	-	-	-	-	-	78.9
Mean - White Birch		92.2	156.8	76.6	105.5	64.5	47.0	106.0	107.6
Mean - Jack Pine		115.2	121.8	108.6	62.7	106.5	93.8	-	101.5
Overal Mean		99.9	155.5	81.9	84.1	78.5	86.0	106.0	98.9

Table 19: Zinc ppm by site and tree species

Site #	Tree species	11/17 W	61 S	11/17 E	527 N	Kenora	Ignace	Wawa	Mean
		Location							
0	Wb	17.5	92.0	-	18.4	15.6	-	-	35.9
	Jp	-	-	-	-	-	13.4	-	13.7
	Wb	28.6	56.3	29.1	26.2	-	-	14.9	31.0
	Jp	-	-	-	-	12.6	12.8	-	12.7
2	Wb	-	26.7	9.9	-	8.2	-	30.5	18.8
	Jp	15.2	22.8	-	12.1	-	11.6	-	15.4
3	Wb	17.7	32.0	21.6	-	-	-	27.4	24.7
	Jp	-	-	12.9	13.5	9.5	12.0	-	12.0
4	Wb	-	14.6	7.3	-	12.1	-	20.5	13.6
	Jp	13.0	-	-	7.1	-	12.4	-	10.8
5	Wb	24.3	11.5	13.6	14.1	16.6	15.0	3.9	14.1
	Jp	-	14.8	-	-	-	-	-	14.8
Mean - White Birch		22.0	38.8	16.3	19.6	13.1	15.0	19.4	23.0
Mean - Jack Pine		14.0	18.8	12.9	10.9	11.1	12.0	-	13.4
Overall Mean		19.4	33.8	15.7	15.2	12.4	12.9	19.4	18.4

Table 20: Pearson correlation co-efficients (r) and significance levels for relationships between distance from pollution source and element levels in *H. physodes* for **all** sites

	Distance from pollution source
Al ppm	-.344 (*)
As ppm	-.346 (*)
Cd ppm	-.182
Cu ppm	-.373 (*)
Fe ppm	-.427 (**)
Hg ppm	-.322 (*)
Mg ppm	-.248
Pb ppm	-.511 (**)
S ppm	-.484 (**)
Zn ppm	-.360 (*)

Significance Levels - (*) = significant at the $p < .05$ level
(**) = significant at the $p < .01$ level

Table 21 : Pearson Correlation Co-efficients (r) and significance levels for relationships between distances from pollution source and elemental contents - **Kenora**

	Distance	Al ppm	As ppm	Cd ppm	Cu ppm	Fe ppm	Hg ppm	Mg ppm	Pb ppm	S ppm	Zn ppm
Al ppm	-.600										
As ppm	-.613	.978 (***)	-								
Cd ppm	-.609	.706	.781 (*)								
Cu ppm	-.403	.739 (*)	.778 (*)	.777 (*)	-						
Fe ppm	-.753 (*)	.969 (**)	.956 (**)	.797 (*)	.725						
Hg ppm	.078	-.174	-.179	-.639	-.557	-.267					
Mg ppm	-.150	.352	.419	.806 (*)	.429	.427	-.754 (*)				
Pb ppm	-.644	.086	.017	.310	.005	.301	-.412	.212			
S ppm	-.420	.918 (**)	.941 (**)	.841 (*)	.882 (**)	.881 (**)	-.442	.594	-.036		
Zn ppm	.080	-.276	-.286	.271	-.132	-.130	-.727	.666	.561	-.098	-

Significance Levels - * = significant at the p< .05 level
** = significant at the p< .01 level
*** = significant at the p< .001 level

Table 22: Pearson Correlation Co-efficients (r) and levels of significance for relationships between distances from pollution source and elemental contents - **Ignace**

	Distance	Al ppm	As ppm	Cd ppm	Cu ppm	Fe ppm	Hg ppm	Mg ppm	Pb ppm	S ppm	Zn ppm
Al ppm	-.930 (**)	·									
As ppm	-.881 (**)	.920 (**)									
Cd ppm	.441	-.428	-.734 (*)								
Cu ppm	-.920 (**)	.897 (**)	.731 (*)	-.162	--						
Fe ppm	-.591	.787 (*)	.706	-.407	.545						
Hg ppm	-.539	.444	.178	.389	.779 (*)	.001	·				
Mg ppm	-.341	.394	.529	-.401	.086	.283	-.257				
Pb ppm	-.825 (*)	.704	.716	-.561	.670	.621	.234	.064			
S ppm	-.836 (*)	.793 (*)	.756 (*)	-.323	.654	.529	.273	.722	.613		
Zn ppm	.234	.062	.068	-.101	.038	.254	-.116	-.210	.345	.455	-

Level of significance - * = significant at p< .05 level
** = significant at p< .01 level
*** = significant at p< .001 level

Table 23 : Pearson Correlation Co-efficients (r) and levels of significance for relationships between distances from pollution source and elemental contents - **Wawa**

	Distance	Al ppm	As ppm	Cd ppm	Cu ppm	Fe ppm	Hg ppm	Mg ppm	Pb ppm	S ppm	Zn ppm
Al ppm	.301										
As ppm	.499	.974 (**)									
Cd ppm	-.694	-.007	-.138								
Cu ppm	-.414	.369	.254	.881 (*)							
Fe ppm	-.313	.358	.220	.503	.764						
Hg ppm	-.217	.721	.582	-.036	.152	.328					
Mg ppm	-.216	.683	.578	.687	.931 (*)	.754	.413				
Pb ppm	-.207	.225	.207	.822 (*)	.803	.245	-.177	.706			
S ppm	-.347	.343	.239	.837 (*)	.989 (**)	.815 (*)	.088	.913 (*)	.760		
Zn ppm	-.570	.318	.167	.909 (*)	.981 (**)	.778	.242	.899 (*)	.732	.958 (**)	-

Level of significance - * = significant at p< .05 level
** = significant at p< .01 level
*** = significant at p<.001 level

Table 24: Pearson Correlation Co-efficients (r) and significance levels for relationships between distances from pollution source and elemental contents - **Highway 11/17 West**

	Distance	Al ppm	As ppm	Cd ppm	Cu ppm	Fe ppm	Hg ppm	Mg ppm	Pb ppm	S ppm	Zn ppm
Al ppm	.128										
As ppm	-.728	.569									
Cd ppm	-.325	.147	.457								
Cu ppm	.346	-.549	-.600	-.251							
Fe ppm	-.388	.695	.762 (*)	-.174	-.529	-					
Hg ppm	-.838 (*)	-.392	.402	.371	-.044	-.061					
Mg ppm	.623	.707	-.099	-.257	-.401	.245	-.665				
Pb ppm	-.647	.269	.703	-.211	-.164	.842 (*)	.299	-.255			
S ppm	-.022	-.736 (*)	-.455	-.074	.112	-.486	-.017	-.470	-.330		
Zn ppm	-.093	.760 (*)	.592	.631	-.593	.294	.076	.473	-.044	-.675	

Significance Levels - * = significant at the p< .05 level
** = significant at the p< .01 level
*** = significant at the p< .001 level

Table 25: Pearson Correlation Co-efficients (r) and significance levels for relationships between distances from pollution source and elemental contents - **Highway 11/17 East**

	Distance	Al ppm	As ppm	Cd ppm	Cu ppm	Fe ppm	Hg ppm	Mg ppm	Pb ppm	S ppm	Zn ppm
Al ppm	-.351										
As ppm	-.262	.988 (***)	-								
Cd ppm	-.277	-.189	-.155								
Cu ppm	-.856 (*)	.203	.166	.725							
Fe ppm	-.785 (*)	.726	.683	.276	.721						
Hg ppm	-.301	.896 (**)	.899 (**)	.003	.249	.814 (*)					
Mg ppm	.034	.855 (*)	.892 (**)	.026	.050	.460	.792 (*)				
Pb ppm	-.783 (*)	.124	.110	.708	.955 (***)	.563	.086	.004			
S ppm	-.627	.023	.001	.863 (*)	.909 (**)	.454	.032	.066	.907 (**)		
Zn ppm	-.514	-.036	-.030	.922 (**)	.867 (*)	.380	.001	.072	.892 (**)	.983 (***)	-

Significance Levels - * = significant at the $p < .05$ level
** = significant at the $p < .01$ level
*** = significant at the $p < .001$ level

Table 26: Pearson Correlation Co-efficients (r) and significance levels for relationships between distances from pollution source and elemental contents - **Highway 527 North**

	Distance	Al ppm	As ppm	Cd ppm	Cu ppm	Fe ppm	Hg ppm	Mg ppm	Pb ppm	S ppm	Zn ppm
Al ppm	.316										
As ppm	.517	.959 (***)	-								
Cd ppm	.476	.895 (**)	.905 (**)								
Cu ppm	.048	.944 (**)	.834 (*)	.864 (*)							
Fe ppm	-.207	.858 (*)	.697	.690	.959 (***)	-					
Hg ppm	.713	.494	.709	.467	.226	.071					
Mg ppm	.650	-.046	.166	-.078	-.327	-.460	.696				
Pb ppm	-.667	.144	-.141	.021	.403	.553	-.768 (*)	-.749 (*)			
S ppm	-.710	-.389	-.462	-.442	-.200	-.061	-.380	-.083	.293		
Zn ppm	-.638	-.475	-.540	-.430	-.270	-.171	-.466	-.102	.291	.970 (***)	-

Significance Levels - * = significant at $p < .05$ level
** = significant at $p < .01$ level
*** = significant at $p < .001$ level

Table 27: Pearson Correlation Co-efficients (r) and significance levels for relationships between distances from pollution source and elemental contents - **Highway 61 South**

	Distance	Al ppm	As ppm	Cd ppm	Cu ppm	Fe ppm	Hg ppm	Mg ppm	Pb ppm	S ppm	Zn ppm
Al ppm	-.897 (**)										
As ppm	-.862 (*)	.985 (***)	·								
Cd ppm	-.960 (***)	.965 (***)	.942 (**)								
Cu ppm	-.968 (***)	.940 (**)	.916 (**)	.961 (***)	-						
Fe ppm	-.807 (*)	.977 (***)	.984 (***)	.923 (**)	.863 (*)						
Hg ppm	-.830 (*)	.969 (***)	.983 (***)	.916 (**)	.888 (**)	.987 (***)	-				
Mg ppm	-.927 (**)	.893 (**)	.908 (**)	.957 (***)	.878 (*)	.882 (**)	.865 (*)				
Pb ppm	-.780 (*)	.930 (**)	.947 (**)	.907 (**)	.794 (*)	.967 (***)	.926 (**)	.927 (**)	-		
S ppm	-.919 (**)	.988 (***)	.988 (***)	.981 (***)	.949 (**)	.967 (***)	.962 (***)	.947 (**)	.944 (**)	-	
Zn ppm	-.898 (**)	.934 (**)	.954 (**)	.958 (***)	.878 (*)	.942 (**)	.926 (**)	.988 (***)	.968 (***)	.972 (***)	-

Significance Levels - * = significant at the p< .05 level
** = significant at the p< .01 level
*** = significant at the p< .001 level

Table 28: Pearson Correlation co-efficients (r) and significance levels for relationships between morphological data at each site and ppm levels of elements - upper north

	Elements									
	Al	As	Cd	Cu	Fe	Hg	Mg	Pb	S	Zn
B.B. value of *H. physodes*	-0.194	-0.188	0.001	0.057	-0.015	-0.058	0.011	0.136	0.056	0.159
<u>Colour aber.</u>: black	0.174	0.116	0.117	-0.060	0.197	-0.143	0.037	0.238	-0.062	-0.020
white	-0.058	-0.045	-0.055	0.299 (*)	0.124	0.241	0.135	0.233	0.335 (*)	0.255
brown	-0.107	-0.151	0.079	-0.131	-0.107	-0.002	0.250	0.019	0.130	0.209
pink	0.141	0.088	0.119	-0.084	0.300 (*)	0.069	0.131	0.473 (**)	0.075	0.095
yellow	0.186	0.202	0.288	-0.113	0.249	0.297 (*)	0.275	0.125	0.372 (*)	0.353 (*)
* large thalli	0.121	0.065	0.214	-0.186	0.149	0.096	0.266	0.032	0.081	0.142
<u>Branching</u>: few	-0.064	0.088	-0.294 (*)	0.313 (*)	-0.189	-0.079	-0.352 (*)	-0.269	-0.156	-0.318 (*)
some	0.095	0.029	0.253	-0.287 (*)	0.309 (*)	0.176	0.207	0.417 (**)	0.226	0.297 (*)
many	-0.025	-0.136	0.167	-0.206	-0.019	-0.089	0.302 (*)	-0.096	-0.037	0.145

Note: Significance of correlation - (*) = significant at $p < 0.05$ level
(**) = significant at $p < 0.01$ level

Table 29: Pearson Correlation co-efficients (r) and significance levels for relationships between morphological data at each site and ppm levels of elements - lower north

	Elements									
	Al	As	Cd	Cu	Fe	Hg	Mg	Pb	S	Zn
B.B. value of *H. physodes*	-0.129	-0.086	-0.296 (*)	0.138	-0.354 (*)	-0.167	-0.260	-0.387 (*)	-0.167	-0.325 (*)
<u>Colour aber.</u>:										
black	0.288 (*)	0.267	0.020	0.056	0.220	0.001	-0.019	0.323 (*)	0.052	-0.104
white	-0.073	-0.054	-0.182	0.367 (*)	-0.071	0.084	-0.086	0.018	0.250	0.133
brown	-0.109	-0.061	0.238	-0.029	-0.036	0.066	0.285 (*)	-0.119	0.214	0.351 (*)
pink	0.170	0.085	0.034	-0.247	0.264	-0.017	0.245	0.571 (***)	0.060	0.057
yellow	-0.035	-0.084	0.177	-0.086	0.087	-0.047	0.174	0.118	0.185	0.269
* large thalli	0.223	0.096	0.246	-0.333 (*)	0.179	0.008	0.340 (*)	0.177	-0.026	0.101
<u>Branching</u>:										
few	-0.026	0.122	-0.331 (*)	0.343 (*)	-0.191	-0.091	-0.438 (**)	-0.165	-0.169	-0.376 (*)
some	0.040	-0.052	0.359 (*)	-0.215	0.223	0.134	0.324 (*)	0.293 (*)	0.294 (*)	0.443 (**)
many	-0.008	-0.111	0.067	-0.239	0.022	-0.020	0.253	-0.091	-0.084	0.036

Note: Significance of correlations - (*) = significant at $p < 0.05$ level
(**) = significant at $p < 0.01$ level

Discussion

Discussion

The following section will be a discussion of the results obtained in this study. The order followed will be similar to that followed in the Results section. Therefore, this section will begin with a discussion of site description data, followed by morphological description data, pH data, and elemental data distribution patterns. The last four sections will be discussions of the relationships between white birch / jack pine data, distance and elemental data, inter-element relationships, and relationships between elements and morphological data.

4.1 Site Descriptions

Site descriptions are summarized in Table 2. Diameter data was collected in order to determine the size (and therefore the relative age) of the tree required for development of sufficient lichen cover. From the means, it appears that approximately 25 cm diameter at one meters height provides adequate tree size and surface area for *H. physodes* growth. (Undoubtedly there were trees of smaller diameter which provided sufficient lichen cover for sampling. This figure is simply an approximation of average tree size required.)

Inclination of trees sampled was done to see if any unusual inclinations lead to adverse effects on the results. No such effect is obvious, perhaps because the mean inclinations are all relatively similar.

4.2 Morphological Descriptions

Upper and lower north morphological descriptions are summarized in Tables 3 and 4 respectively. *H. physodes* cover was only marginally higher on lower north locations, compared with upper north results. This is unexpected, given the greater difference found in the preliminary results (see Table 1). Lower north is generally a more favourable location for epiphyte growth, given its darker and damper characteristics. However, if shrub and herb layer growth was tall and thick, it was noted that lichen growth was somewhat restricted in the lower areas of the tree. This may have affected results somewhat.

H. physodes most often grew in association with *P. sulcata* and *E.*

mesomorpha. This is supported by Hale (1983), who classifies *H. physodes* in Britain as belonging to the corticolous federation of *Physodion*. Also classified in this federation and growing in close association are *P. sulcata* and *E. prunastri*.

4.3 pH Data

All lichen samples were tested for acidity (or pH) (see Table 5). It was initially theorized that perhaps lichen acidity was related to the acidity of the precipitation. Sulphur oxides and sulphates account for a large part of the acidity in precipitation (Saunders & Wood, 1973; Anon, 1982b). Therefore, a test was done to determine the strength of the relationship between acidity results and sulphur levels. The correlation between the two was positive but not significant. Therefore, the pH results cannot be related to sulphur contents in this example. This could be because northwestern Ontario is relatively remote from large sources of air pollution (Barclay-Estrup, 1986b; Anon, 1984). It was more likely that the acidity results of the lichens are a result of the acidity of their substrate. Mean lichen acidity for jack pine samples was 100.05 ueq/L H+ (pH = 4.0), as compared with only 70.69 ueq/L H+ (pH = 4.15) for lichens sampled from white birch trees. This difference can be attributed to the fact that coniferous bark is generally more acidic than deciduous bark (Barclay-Estrup, 1986a). It could also have resulted in part from different metal concentrations in the bark and different stemflow characteristics of each species (Folkeson, 1979). There was no obvious relationship between tree diameter and bark acidity.

4.4 Elemental Data Distribution Pattern

The following presents a comparison of general levels of pollutant elements in *H. physodes*, in order of apparent degree of pollution from lowest to highest.

4.4.1 Kenora

The Kenora lichens contained the lowest overall grand means of pollutants (see Table 8, Figures 4 to 22 - even numbers). Cd, Cu, Fe, S and Zn levels were the lowest of any area and levels of all other elements were among the lowest. The main source of emissions in Kenora is the Boise-Cascade Canada Ltd. sulphite pulp mill (Anon, 1978). However, S levels in sampled lichen do not indicate that emissions are a problem. This is supported by Ministry of the Environment findings, where average annual sulphation rates have dropped from 0.23 mg SO_3 / 100 cm^2 / day in 1977 to 0.07 in 1986 (Anon, 1978; Griffin, 1987).

4.4.2 Ignace

The grand pollutant mean at Ignace placed it in second lowest position in terms of overall pollutant levels (see Table 8, Figures 4 to 22 - even numbers). The only element to differ from the generally low levels is Cu. Not only were Cu levels by far the highest of any of the secondary areas, but they also far exceeded any Cu levels in the primary areas. A possible source of this Cu may be the UMEX Thierry Mine in Pickle Lake (D. Racette, personal communication). This company shipped large amounts of Cu containing ore through to the Ignace railyard from 1976 to 1982. Ignace was a transhipment point for the ore containers. Small amounts of leakage in the containers would account for the elevated Cu levels.

Rinne and Barclay-Estrup (1980) suggest that a significant part of pollutants deposited at Ignace may originate from emissions at Winnipeg, Manitoba, 400 km to the west. Such emissions could be carried great distances at high altitudes by the prevailing westerly winds.

4.4.3 Wawa

Pollutant levels at Wawa were overall low (see Table 8, Figures 4 to 22 - even numbers). However, some elements showed high levels at certain sites. In particular, site three had high levels of both Fe and S. This was an expected result, as the local emissions source, an iron sintering plant, releases high levels of both Fe and S dioxide (Rao and Leblanc, 1967). In addition, high levels of As have also been recorded in the area (Anon, 1979). Such was not discovered to be the case in lichens sampled in this study, however. This reason for this is not clear.

4.4.4 Highway 11/17 West - Thunder Bay

Concentrations of contaminants in this area are the lowest of the Thunder Bay area groups (although they are higher than any concentrations in the secondary locations) (see Table 7, Figures 3 to 21 - odd numbers). The area west of the city could be expected to show little evidence of high pollution levels because prevailing winds are from the west (see Figure 2).

The extremely high Pb levels at site O in the west area can be attributed to the proximity of two major roads. This has also been found to be an influencing factor by other researchers, as leaded gasoline combustion causes noticeable Pb emissions (Barclay-Estrup and Rinne, 1978; Takola and Olkkonen, 1981; Farkas *et al.*, 1985).

4.4.5 Highway 11/17 East - Thunder Bay

The area east of the city had low levels of most pollutants (see Table 7, Figures 3 to 21 - odd numbers. However, one would have expected to find high pollution levels here since the prevailing winds are strongly from the west. Rinne and Barclay-Estrup (1980) suggest a number of possible reasons for these low results. Winds from the west, while fairly common, may not carry much contaminant because the city is narrow in an east-west direction. Analysis of the data from the area was difficult because many of the sites were located at low elevations near the north shore of Lake Superior. This large body of water may have affected the microclimate of areas sampled. It is also possible that pollution emissions from secondary industry in certain north shore communities (e.g. Domtar Ltd. paper mill at Red Rock, 90 km. east of Thunder Bay) may be influencing the eastern portions of the sample area. This would at least partially explain the increases in Al, As, Fe, Hg and Mg levels at site four. Rinne and Barclay-Estrup (1980) also suggest that more testing of the area could produce different results. This present study does not however, produce results which disagree with their findings.

Results of the Sibley Peninsula collections can be seen in Table 7. It can be observed that, although the area is generally downwind of the city, levels of pollutants here were similar to those found at equal distances west and east of the city. Again, Rinne and Barclay-Estrup (1980) found very similar results. They suggest that the reason may be that the effects of emissions from Thunder Bay is not very great because the city extends in a northeast - southwest direction. This is supported by Ministry of the Environment findings that high pollution levels in the Thunder Bay area (in this case, sulphates and nitrates) were associated with east to northeast winds, and lowest levels with west and north winds (Anon, 1980a).

Another possible reason for the low levels at Sibley sites is that the sites sampled in this study could have been affected by the high cliffs and bluffs which lie between Thunder Bay and much of the lower end of the peninsula. This high ground could have intercepted some of the incoming pollutants.

4.4.6 Local Sites - Thunder Bay

Levels of pollutants found in lichens sampled from within the city of Thunder Bay were lower than anticipated (Table 7). The Lakehead University site showed highest levels of the three city sites, for most elements. Some contamination here was possible, as a result of the sites proximity to a large gravel parking lot and a four lane road. (All sites within the city itself are probably equally subject to contamination from major sources.) The fact that this location had the highest overall levels, followed by the Mt. McKay site and then the Centennial park site, was supported by Ministry of the Environment findings on city air quality (Anon, 1980a).

Centennial park is located on the northeastern end of the city, and as was previously mentioned, many of the large industries are located on the southwestern end. This probably accounted for the lower levels here.
By following this reasoning, the Mt. McKay site should therefore have had the highest levels, since it is located on the southwestern edge of the city. It is however, on the opposite side of the mountain from many of the major industries (e.g. Canadian Pacific kraft mill). This position could provide a degree of shelter from many of the air contaminants.

4.4.7 Highway 527 North - Thunder Bay

Overall levels of pollutants in this area were quite high (see Table 7, Figures 3 to 21 - odd numbers). This was surprising, since winds from the south are rare. Also, Rinne and Barclay-Estrup (1980) found that the area to the north of the city had among the lowest concentrations of pollutants.

Highest levels of most elements were achieved at site three, suggesting that communities east of Thunder Bay (e.g. Red Rock) may be at least partially responsible for the higher levels (in much the same way that they may be influencing the 11/17 East route). It may also be that the increasing altitude of the sites up to site three has caused increased interception of air pollutants. In a previous study, Groet (1976) was able to positively correlate altitude with Cd and Zn contents.

4.4.8 Highway 61 South - Thunder Bay

This area had the highest overall levels of pollutants (see Table 7, Figures 3 to 21 - odd numbers). Highest concentrations of all elements were discovered at site zero (except Pb, which was higher at only one other site - as previously mentioned, this was probably due to contamination from nearby roads). This indicates that the area to the southwest of Thunder Bay is being subjected to considerable pollution in relation to the other regions.

Winds blowing into the southwest are relatively uncommon, making these results unexpected. However, Rinne and Barclay-Estrup (1980) again found similar results. They found that this area had the highest amounts of all elements analyzed for, except Pb and Mn. They attributed these levels to a number of reasons. This area has a relatively high population density and a history of human activity, which helps accounts for the increased impact of air pollutants. In addition, there are a disproportionately large number of industries located in the southwest part of the city whose operations are suspected of contributing to the high levels in the area. These include the Canada Car equipment manufacturing plant, the Mission Island thermal generating station, the Valley Camp base metal handling facilities on the Kam River, the Canadian Pacific Forest Products company kraft mill (formerly called Great Lakes Forest Products), the Dow-Chemical chlor-alkali plant (closed in 1973) and the Thunder Bay International Airport (Rinne and Barclay-Estrup, 1980; Anon, 1980).

In addition to this greater industrial build-up, lichens in this area may have had higher levels because of their location on the tree. That is, lichens in all areas were sampled from the north sides of the trees. In the area to the south and southwest of Thunder Bay, this means that the lichens face the approximate direction from which contaminants are arriving. It has been established that contaminant level as well as visible damage is more prominent on the side of the tree which faces the emission source (Malhotra and Blauel, 1980).

In an overall assessment then, levels of pollutants discovered within the *H. physodes* of northwestern Ontario compare favourably with levels found in past studies. As can be seen in Table 30, levels in this report were slightly to moderately lower than levels in other studies. Many of the past studies were done around heavily industrialized areas, such as Stockholm or Budapest. In contrast, this study was in an area which is

Table 30: Range of concentrations (ppm) of contaminants discovered in *H. physodes* in past studies, compared with ranges discovered in this study

Authors	Al	As	Cd	Cu	Fe	Hg	Mg	Pb	S	Zn
Lounamaa (1965)					590-1700					59-104
Solberg (1967)									1400	
Pyatt (1973)									930	
O'Hare (1974)									570-1300	
Seaward (1974)					1100-3200					21-100
Horntvedt (1975)									650-1200	
O'Hare *et al.* (1975)									550-1000	
Olkkonen *et al.* (1975)									550-1500	
Laaksovirta *et al* (1977)					1100-21400				630-1900	180-5600
Steinnes *et al* (1977)		2.0				8.0			3000	
Swieboda *et al.* (1978)									1440	
Folkeson (1979)			0.4-1.7	10-80	290-1300			14-33		93-450
Kauppi *et al.* (1980) (in mg/g)					7-47			0.6-	1.9	

Table 30 continued ...

	Al	As	Cd	Cu	Fe	Hg	Mg	Pb	S	Zn
Lodenius (1981)						0.2-36				
Lodenius *et al.* (1983)		0.2-1.6			770-4300					65-210
Holopainen (1983) (in mg/g)									1.3-2.9	
Farkas *et al.* (1985)			0.1-3.6					0-270		17-51
Vestergaard *et al.* (1986)			0.6-0.7	2.2-5.0	1120-1700				44-76	85-100
Nuorteva *et al.* (1986) (in mg/kg)	340-620		0.4-1.2		670-1600	0.3-0.4				70-140
Wetmore (1987)	300-640		0.6-1.5	2.7-3.9	260-610		550-900	13-30	800-1060	
Pfeiffer (1988)	96-705	0.7-7.0	0.1-1.2	0.5-14.0	114-690	0.6-5.8	58-390	2-48	33-430	4-92

relatively free of heavy industry and the results bear this out.

The Ministry of the Environment lists the concentrations of certain elements which are considered excessive in vegetation samples. These are 8 ppm for As, 5 ppm Cd, 30 ppm Cu, 800 ppm Fe, 50 ppm Pb and 250 ppm for Zn (Anon, 1979). Even the highest levels obtained (at site 0, area 61 South) did not exceed these limits, supporting the contention that northwestern Ontario is relatively unpolluted. This finding is supported by other studies done in the area (Barclay-Estrup, 1986a & 1986b; Griffin, 1987).

4.5 White Birch / Jack Pine Comparison

As was stated above, a difference in lichen acidity values existed between jack pine and white birch samples. Another difference also became evident. From the results, it can be seen that *H. physodes* sampled from jack pine trees apparently collected pollutants in greater quantities than those sampled from white birch. This was most notable for Al, As, Cd, Cu, Fe and S. This difference between the two substrates did not prove to be statistically significant. Folkeson (1979) found similar differences and attributed them to differing metal concentrations in the bark, as well as differing stemflow characteristics of each tree species. However, lichens in general obtain most of their nutrients from the air, not their substrate (Hale, 1983). Others suggest that, because *H. physodes* lacks rhizinae, only an insignificant amount of metals would be absorbed from the substrate (Pilegaard, 1979).

4.6 Distance / ppm and Inter-element Relationships

When all data are grouped together, correlations between lichen pollutant contents and distance from pollution sources were negative for all elements (see Table 20). Significant correlations were obtained at $p \leq 0.05$ for Al, As, Cu, Hg, and Zn and at $p \leq 0.01$ for iron, lead and sulphur. The degree of significance is Pb > S > Fe > Cu > Zn > As > Al > Hg.

Only Mg and Cd had no significant correlation with distance. Apparently there are no significant sources of these metals in the study area. This differs from the results of Rinne and Barclay-Estrup (1980), who found that Cd levels in the Thunder Bay area did show significant correlations with distance. Perhaps when correlations are broken down by area (see below) their results can be supported. The situation with Mg is less clear, as it is often considered a nutrient element (Raven, Evert & Curtis, 1981).

The fact that Pb had the most significant correlation is similar to the findings of Rinne and Barclay-Estrup (1980) and Ruhling and Tyler (1973). They both found that the greatest regional differences in pollutant content of mosses was for Pb levels.

A greater variety of relationships between distances and pollutant concentrations were obtained when results were broken down by area, as will be seen below. In general, the higher the overall pollution levels of an area, the greater the number of significant correlations with distance there were. The order followed below will be the same as was followed in the discussion of distribution patterns (i.e. least impacted to most impacted).

Also discussed below will be the inter-element relationships found at each region. Where there is a strong positive relationship between the concentration of two or more elements, it can be concluded that the elements originated from a common source (Racette and Griffin, 1987). In this study, there were a number of significant correlations between individual elements. And, in general, where relationships between distance and concentrations were strongest and most numerous, there too were the strongest and most numerous relationships between elements.

4.6.1 Kenora

Correlations here were mostly negative (see Table 21). Only Fe had a significant correlation with distance ($p \leq 0.05$). This is evidence that the source of Fe emissions is within Kenora. (The source is not known.) The results also suggest that there is no major source of emissions in Kenora for the other pollutants. If this speculation is true, then Kenora is one of the least polluted areas in the study.

Correlations between elements at Kenora were mainly positive and a number of them were significant. Only Fe had a previous significant correlation with distance, and it further correlated significantly with Al, As, and S ($p \leq 0.01$) and Cd ($p \leq 0.05$). This suggests that, while Fe is the only element to correlate significantly with distance, reasoning suggests that the elements to which it correlates are also being emitted from the same source. But, while they are from the same source, it seems that the other elements are in levels low enough to avoid a significant correlation with distance.

S levels correlated significantly with Al, As, Cu and Fe ($p \leq 0.01$) and with Cd ($p \leq 0.05$), again suggesting that they all originate from the same source. Even though the sulphite pulp mill may not be releasing S in levels high enough to cause significant correlations with distance, the data suggest that all six elements are being emitted.

4.6.2 Ignace

Correlations between lichen pollutant content and distance from Ignace were mainly negative (only Cd and Zn correlations were positive) (see Table 22). Al, As, Cu ($p \leq 0.05$), and Pb and S ($p \leq 0.01$) levels all correlated significantly with distance, suggesting a source of emissions in the Ignace area. The transhipment of copper-containing ore in Ignace may at least partially account for these relationships.

Correlations within elements here were almost all positive and there were eight significant correlations. Most of the significant correlations between elements involve those which also had significant correlations with distance. Cu had the most striking levels in the Ignace area. Cu showed a significant positive relationship with Al and As ($p \leq 0.01$) and Hg ($p \leq 0.05$). These data suggest that these latter three elements are associated with the same source of emissions as Cu.

It is interesting to note that while Pb concentration correlated significantly with distance, there was no significant correlations with any other element. This suggests that Pb is originating at a source which emits none of the other elements. This source could easily be vehicular exhaust emissions (Farkas *et al.*, 1985).

4.6.3 Wawa

As was explained in the methods section, the sites sampled in this area did not run consistently in a downwind direction (because there were not any roads in that direction). Perhaps as a result of this, there were no significant correlations between distance and pollutant amount (see Table 23). All correlations except that with As were negative.

Sites one and two were found east of Wawa and therefore, one would have expected site one to be more severely affected than site two (given the prevailing southwesterly winds). This did not prove to be the case however. Most elements were found in greater amounts at site two. This was probably a result of the rise of land which exists one kilometre west of site one (and which therefore interposes itself between site one and Wawa). This could have intercepted a substantial amount of the eastward moving pollutants.

Sites three and four were located in a line going north of Wawa and the expected drop in concentration was observed for all pollutants except As, Cd and Pb. Site five though, was located approximately 50 km north of Wawa and was least affected by Wawa emissions. This area was considered a control in past studies (Anon, 1979). The only slightly elevated level at this site was obtained for As, perhaps a result of long range transport from Wawa emissions (where it is considered an important pollutant) (Anon, 1979).

Inter-element correlations in Wawa were mostly positive, with twelve correlations being significant. Rao and Leblanc (1967) have suggested that the two major pollutants being emitted from the iron-sintering plant in Wawa are Fe and S. This is supported by the finding in this study that, not only do these two elements have elevated local concentrations, but they are also significantly correlated with each other ($p \leq 0.05$). This implies that they are being emitted from a common source, and this source is probably the iron-sintering plant.

S is also correlated significantly with Cd and magnesium ($p \leq 0.05$), Cu and Zn ($p \leq 0.01$). This suggests that these latter elements could be secondary pollutants from the same source as S.

4.6.4 Highway 11/17 West - Thunder Bay

There was only one correlation of significance (Hg) in the western area ($p \leq 0.05$). This difference is attributable to the fact that the eastern route lies closest to the prevailing downwind direction from Thunder Bay.

The significant relationship between Hg content and distance in the western area suggests a source of Hg emissions in the Thunder Bay area. Chlor-alkali plants are well-established as sources of Hg emissions. Lodenius (1981) found levels as high as 36 ppm in *H. physodes* sampled near chlor-alkali works in Finland. The Dow Chemical chlor-alkali plant which was located on the southwest end of the city and which closed in 1973 is probably the source of emissions suggested by the significant Hg - distance correlation.

It should be noted that Hg levels in all areas sampled are slightly elevated, with means of between 1 and 2 ppm. This compares with background levels of between 0.07 and 0.48 ppm in Finland (Lodenius, 1981). These higher concentrations could be a result of the now defunct chlor-alkali plant in the Thunder Bay area. Above-normal concentrations of Hg were also found in soil samples taken near Atikokan (a community approximately 230 km. west of Thunder Bay). But, much like this study, the highest levels there were random and did not implicate point sources (Racette and Griffin, 1986). Barclay-Estrup and Rinne (1979) also found high Hg levels in feather moss sampled in northwestern Ontario. Perhaps these levels are elevated as a result of Hg spreading very effectively in the air. *H. physodes* has proven to be a good indicator of Hg air pollution (Lodenius, 1981).

The western area results yielded few inter-element relationships. Only Hg had shown a significant correlation with distance. It does not however, correlate with any other elements, indicating its source is probably not releasing any of the other pollutants in significant amounts. The elements which did correlate significantly ($p \leq 0.05$) with each other were Fe with As and Pb, Al with Zn, and Al with S. There are likely secondary sources outside of the Thunder Bay urban area, which are responsible for these pollutants. The latter elements though (Al and S), correlated negatively. This is noteworthy, as all other significant correlations were positive.

4.6.5 Highway 11/17 East - Thunder Bay

Correlations between distance and concentration for eastern results were negative for all elements except magnesium (see Tables 24 and 25). Significant negative correlations were obtained for Cu, Fe and Pb ($p \leq 0.05$). These elements therefore appear to have their source in Thunder Bay.

One would have expected the area east of Thunder Bay to show several strong relationships with the city because of its downwind direction. As was stated above, this proved to be true, with three elements correlating significantly with distance. Also supporting this were the numerous significant correlations between elements. A total of fifteen correlations of significance exist in the east area.

The most significant correlations in the east area were between Al and As, and S and Zn ($p \leq 0.001$). None of these elements correlated significantly with distance from Thunder Bay. It can be speculated then, that these pairs of pollutants are originating at some common sources outside of the city.

Those elements which did correlate significantly with distance from Thunder Bay (i.e. Cu, Pb and Fe) have a number of significant correlations with other elements. In the case of Cu and Pb, they are both significantly correlated with distance and very significantly ($p \leq 0.001$) with each other. This suggests a common source of emissions in Thunder Bay.

Cu also correlated significantly with S ($p \leq 0.05$) and Zn ($p \leq 0.01$), Fe with Hg ($p \leq 0.05$), and Pb with S and Zn ($p \leq 0.01$). Given these results, it seems that Cu and Pb are major pollutants from the same source in Thunder Bay, with S and Zn being emitted in less significant amounts from that source as well. Fe is a pollutant being released from a different source in Thunder Bay, and Hg is being released in association with Fe, albeit in lesser amounts.

4.6.6 Highway 527 North - Thunder Bay

Given the levels and unusual patterns of distribution of pollutants previously discussed for this area, it is not surprising that there were no significant correlations between distance and concentration (see Table 26). It would be interesting to resample this area to see whether similar results were again obtained.

Correlations between elements here were mainly positive (although there were more negative relationships than at any other site). A total of eleven significant correlations were obtained between elements.

As was stated above, this area had results which were unusual in that no significant correlations were evident between distance and concentration. The correlations between elements were equally unusual. Al correlated very significantly with As ($p \leq 0.001$), and significantly with Cd and Cu ($p \leq 0.01$) and Fe ($p \leq 0.05$). This suggests that a source of emissions exists for Al, As, Cd, Cu and Fe, but this source is not in Thunder Bay itself (e.g. glacial deposits). At the same time, As correlated significantly with Cd and Cu ($p \leq 0.01$) as well as Al ($p \leq 0.05$). Cd correlated significantly with Cu ($p \leq 0.05$) as well as Al and As ($p \leq 0.01$).

This again suggests an unknown common source.

Fe correlations were significant with Al ($p \leq 0.05$) and very significant with Cu ($p \leq 0.001$). This implies that Fe is being released by the same source as the above elements, but this implication is questionable given the lack of significant correlations between Fe, and As and Cd.

A last correlation worth noting here is that between S and Zn. This positive correlation is very significant ($p \leq 0.001$). Further research would be necessary to determine the common source of these two pollutants, as no definite relationship with distance from Thunder Bay was established.

4.6.7 Highway 61 South - Thunder Bay

Correlations between distance and concentration were consistently negative and significant in this area (Table 27). (Significant correlations were obtained at $p \leq 0.05$ for As, Fe, Hg, and Pb, and at $p \leq 0.01$ for Al, Mg, S and Zn, and at $p \leq 0.001$ for Cd and Cu.) This means that sources of emissions exist for all the elements in the Thunder Bay region and that the pollutants are being carried most consistently in a southwest direction. These discoveries (that the area south and southwest of Thunder Bay has the highest pollution levels and most significant correlations between distance and concentration) while unexpected, are supported by earlier findings by Rinne and Barclay-Estrup (1980).

Correlations between elements here were all positive and all significant (many were very significant). Combine this result with the fact that all elements correlated negatively and significantly with distance from Thunder Bay and it can be concluded that all pollutants are originating from a common source (or sources) and these sources are in Thunder Bay.

4.7 Relationships Between Morphological Data and Elemental Data

When considering the use of a lichen species as an indicator of pollution, it is important to consider whether there is any feature of the lichen which can be measured or gauged quickly and efficiently. Obviously, sampling a lichen is useful for measuring actual pollutant contents, but this requires a fair amount of time and knowledge (especially when the time comes for the chemical analysis of lichen material). Observations of morphological characteristics however, which visually change with increasing or decreasing pollution levels or amounts of specific pollutants, are a feature which would require little time or knowledge to employ.

In general, it has been established that the external appearance of lichens reflects the mean levels of air pollution to the extent that it is possible to trace the distribution of impurities on this basis alone, especially in the vicinity of a point source (Kauppi and Mikkonen, 1980). However, little work has been done on determining which individual morphological characteristics are the best indicators of air pollution impact. The results of correlation analyses for this study indicate that certain morphological characteristics show a strong relationship with some of the contaminant levels.

Cover values of *H. physodes* correlated negatively and significantly ($p \leq 0.05$) with levels of Cd, Fe, Pb and Zn at lower north sites (see Table 28). (This perhaps can be partially explained by the fact that there was generally more lichen material found on all lower north quadrats.) This means that as levels of these elements increase, lichen cover decreases. This could indicate that these four elements out of the ten tested, are having the most profound effect on *H. physodes* abundance and luxuriance.

Of the discolourations noted on the lichen thalli, several were discovered as having significant correlations with certain elements. Looking at Tables 28 and 29, it can be seen that Al levels correlated positively and significantly only with black discolourations at lower north quadrats ($p \leq 0.05$). (It should be noted that whenever correlations were found to be significant on lower north **or** upper north, but not both, the correlation was usually close to being significant for the other quadrat.) This could suggest that high Al levels can result in black thalli colour aberrations.

As levels did not correlate significantly with any colour aberrations. This means that, according to this study, there are no lichen thallus discolourations which would indicate high As levels. The same can be said of Cd levels, where again, no significant correlations were found with discolourations.

Cu levels correlated positively and significantly with white thallus discolourations, for both upper and lower north quadrats ($p \leq 0.05$). Again, it could be that white colour aberrations are an indication of high Cu levels.

Fe levels had only one significant relationship with discolouration, that being pink at upper north quadrats ($p \leq 0.05$). Pink might thus be considered to be an indicator of high Fe levels. However, rarely do pollutant elements occur by themselves, and, perhaps as a result, pink colour aberrations correlated significantly with Pb levels as well ($p < 0.01$). This latter correlation was more significant than that between Fe and pink discolourations and occurred at both upper and lower north quadrats. This suggests that pink is an indicator of high Pb levels and potentially an indicator of high Fe levels. However, if one were to find pink discolourations, there would be some doubt as to whether this was an indication of high Pb levels in the thallus, high Fe levels, or perhaps both high Pb and Fe levels. Chemical testing would be necessary to determine exactly what is present.

Hg levels correlated positively and significantly with yellow discolourations at upper north quadrats only ($p \leq 0.05$). This suggests the use of a yellow discolouration as an indicator of high Hg levels, but, as will be seen below, this discolouration is again not unique to this element.

Mg levels correlated significantly ($p \leq 0.05$) with brown colour aberrations for lower north quadrats only. While Mg is sometimes considered a nutrient element, brown discolourations still seem to be associated with high Mg levels within the thallus.

As has been stated above, Pb levels correlated significantly with pink discolourations in both quadrats and with black in lower north quadrats ($p \leq 0.05$). These may be a result of the fact that Pb can prevent photosynthesis, leading to discolourations in the thallus (Farkas *et al*, 1980).

High levels of S were significantly correlated with white and yellow discolourations ($p \leq 0.05$). (This was true however, for only upper north quadrats, although lower north quadrats, as was previously mentioned, show similarly high correlation co-efficients). Whitened and bleached thallus lobes is caused by chlorophyll degradation (chlorosis) resulting from sulphur dioxide pollution (Skye, 1968; Turk & Wirth, 1975; O'Hare & Williams, 1975). O'Hare (1974) found that *H. physodes* was relatively tolerant of sulphur dioxide pollution because its thallus bleached slower than other lichens'. Kauppi and Mikkonen (1980) found a variety of colour changes in their study of the effects of S pollution (from an iron and steelworks) on *H. physodes*. Lichen colour was a consistent grey-green in unpolluted areas and developed dark brown and grey brown patches closer to the iron works. In the area closest to the source of pollution, the colour changes were to sooty black and black-brown. Extreme thallus bleaching was not observed. It was noted though, that the sulphur dioxides were not the sole pollutants. An alkaline dust was also released and this is capable of neutralizing the acidic S compounds and thus serves to reduce their toxic effects (Kauppi and Mikkonen, 1980).

The yellow thallus discolourations which correlated with S levels can also be attributed to sulphur compound damage. *H. physodes* samples transplanted to points near a sulphuric acid factory developed yellow and red discolourations on lob margins (Farkas *et al*, 1985).

Zn levels correlated quite well with a number of discolourations, but only yellow in the upper north quadrats and brown in the lower north quadrats proved to be significant ($p \leq 0.05$). Here again, both colours have been associated with high concentrations of other elements. Nonetheless, high Zn levels appear to be indicated by yellow and brown discolourations.

It is obvious that colour aberrations are not altogether reliable indicators of elemental composition. Colour estimation is a subjective matter and one investigators dark yellow may be anothers light brown. For this reason alone, the value of colour aberrations as an indicator of air pollutant contamination is limited. As Addison and Puckett (1980) have stated, changes in lichen morphology and colouration with plant degradation may be too subtle to quantify. Further research is necessary before colour aberrations can become a reliable air quality assessment technique. In the meantime, colour aberrations do provide a quick, easy and reasonably informative synopsis of just how much air pollution an area is subjected to. When combined with sampling and analysis, morphological observations can be quite valuable.

The remaining morphological characteristics yielded less meaningful results. Numbers of large thalli showed no significant correlations for upper north results, perhaps because of the overall poor abundance and luxuriance of epiphyte growth in this more exposed quadrat. However, lower north results for this characteristic showed two significant correlations. The first was a negative correlation with Cu levels ($p \leq 0.05$). This suggests that high amounts of Cu cause *H. physodes* thalli to remain of small size. (It is worth noting that only one other element

(S) correlated negatively with the number of large thalli and this was far from significant. For upper north results, Cu was the only element to correlate negatively.)

The second element to correlate significantly with number of large thalli was Mg ($p \leq 0.05$). The correlation here was positive, which suggests that the more Mg in the thallus, the greater the number of large thalli. (The upper north correlation here was very close to significant.) Perhaps then, Mg is more of a beneficial nutrient element than a harmful pollutant element, as has been suggested.

The results of correlating branching figures with elemental contents yielded a number of significant correlations, but it is difficult to determine which are meaningful. Few branches correlated significantly and negatively with Cd and Zn ($p \leq 0.05$) and Mg ($p \leq 0.01$), and positively with Cu ($p \leq 0.05$). These correlations were consistent for both upper and lower north quadrats. If a pollutant element is indeed harmful to the lichen, then a positive correlation makes sense (i.e. the greater the pollutant level, the more 'few branches'). Thus, the positive correlation with Cu is understandable (especially given the previously noted negative correlation with number of large thalli). However, why few branching should correlate negatively with Cd and Zn is unclear. The negative correlation with Mg is easier to explain, given the previous positive correlation with number of large thalli and its possible nutrient element status. (Note: Few branching may have been a factor of tree species, as it was observed that jack pine lichens had fewer branches than white birch lichens.)

Some branching also correlated significantly in ways which are difficult to understand, and for a variety of different elements for upper and lower north quadrats. Pb and Zn were the only overlaps and these were both positive ($p \leq 0.05$). Cu was the only significant negative correlation ($p \leq 0.01$) and it was found in upper north results. Other significant results included a positive correlation with Fe in upper north quadrats and positive correlations with Cd, Mg, and S in lower north quadrats ($p \leq 0.05$). These are difficult to explain, because the classification of 'some' branching is to neither extreme. Further research should perhaps avoid this category and divide branching into either few or many.

The results of correlating many branching with elemental levels produced only one significant correlation ($p \leq 0.05$). This was positive and between Mg and many branches for upper north results. (The lower north correlation was large but not significant.) This suggests that the more Mg present, the more branches found in *H. physodes* and again, supports the possibility of Mg being a nutrient element.

The presence or absence of soredia was also noted in all quadrats. It was theorized that soredia may be absent near S contaminated regions (Margot, 1973). However, in all quadrats where *H. physodes* was present, soredia (in greater or lesser amounts) were also found to be present. It was discovered that presence or absence of soredia did not reveal enough information. The amount of soredia was more important, as it varied tremendously and this could have been a result of S pollution.

4.8 Suggestions for Future Research

Throughout the course of this discussion, it has been noted where future research may prove valuable. The first suggestion was to determine whether lichens growing on jack pine trees do indeed absorb more contaminants than those growing on white birch trees. This can be expanded to include not only *H. physodes*, jack pine and white birch, but any other bioindicator. Another area for future study was in the area of pH of the lichen thallus. It was theorized that acid precipitation and therefore S content may have been related to thallus pH, but no definite relationship could be determined in this study.

A third area for future research is in the area of morphological damage. It would make certain lichen species extremely valuable as a bioindicator if an easily noted morphological observation could be strongly correlated with individual contaminants. The fourth area noted was that of amounts of soredia. When using soredia as an indicator of pollution, it would be more useful to measure amounts of soredia, as opposed to presence or absence. A fifth area for future research would be to determine if similar results could be obtained by repeating this studies methods, but using a different lichen species. A good choice would be *P. sulcata*, a species similar in habitat, range and growth to *H. physodes*.

A sixth suggestion for additional research could be to do additional sampling in the Thunder Bay area in an attempt to explain some of the unusual results obtained in this study (e.g. increasing values along the 527 North route). Further research could also trace sources (e.g. soils, bark) of metals identified in the Kenora and Ignace areas.

Conclusions

There were two purposes for this study. The first was to develop a standardized and relatively simple sampling method for air quality assessment that could be used throughout northern Ontario, based upon a single ubiquitous epiphytic lichen species. This purpose has been fulfilled. *H. physodes* has been shown to be an excellent indicator of air quality. For all elements except Cd and Mg, significant correlations obtained between quantities (parts per million) and distance from emissions source. A number of morphological observations such as thallus size and discolourations have been found to correlate well with certain contaminant levels.

The second purpose was to gain baseline information of pollution levels in the study area of northwestern Ontario for use in present and future comparisons. This second aim has been achieved as well. It was discovered that the area to the southwest of Thunder Bay had the highest levels of air pollution, while the area to the west had the lowest. Levels at Kenora, Ignace and Wawa were discovered to be among the lowest for those areas studied. Northwestern Ontario, in general, was determined to be a relatively unpolluted region. A solid information base of background levels and pollutant levels has been obtained and this data has compared quite favourably with past studies.

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Appendix A

Site Descriptions and Tree Descriptions for secondary sites in the Kenora area

Site * Description

0 Stand of white birch on the south side of Highway 11/17, approximately 1.1 km. east of the tourist information centre on the eastern edge of Kenora. Canopy was open due to many windthrown trees, and slope of ground was 8 degrees north facing.

Major species - white birch, white spruce, balsam fir, mountain maple

Tree *1-Diameter at one meter-19.8 cm. Inclination-0 degrees
Tree *2-Diameter at one meter-17.6 cm. Inclination-0 degrees
Tree *3-Diameter at one meter-16.1 cm. Inclination-0 degrees
Tree *4-Diameter at one meter-20.3 cm. Inclination-3 degrees SW
Tree *5-Diameter at one meter-17.6 cm. Inclination-0 degrees
Mean 18.3 cm. 0.6 degrees

1 Stand of jack pine on the north side of Highway 11/17, approximately 15.7 km. from site number zero. Canopy was semi-open and slope of ground was nil. Many of the jack pine had dead or dying tops.

Major species - jack pine, white spruce, and trembling aspen

Tree *1-Diameter at one meter-19.6 cm. Inclination-0 degrees
Tree *2-Diameter at one meter-27.5 cm. Inclination-0 degrees
Tree *3-Diameter at one meter-30.1 cm. Inclination-0 degrees
Tree *4-Diameter at one meter-26.1 cm. Inclination-0 degrees
Tree *5-Diameter at one meter-27.8 cm. Inclination-0 degrees
Mean 26.2 cm. 0 degrees

2 Stand of jack pine on the south side of Highway 11/17, approximately 29.3 km. from site zero. This is a surviving pocket of adult trees in a burned over area (1980). Canopy was semi-open and slope of ground was nil.

Major species - jack pine, white spruce, trembling aspen, tamarack

Tree *1-Diameter at one meter-20.1 cm. Inclination-0 degrees
Tree *2-Diameter at one meter-25.6 cm. Inclination-0 degrees
Tree *3-Diameter at one meter-31.6 cm. Inclination-2 degrees S
Tree *4-Diameter at one meter-24.3 cm. Inclination-0 degrees
Tree *5-Diameter at one meter-25.8 cm. Inclination-4 degrees W
Mean 25.5 cm. 1.2 degrees

3 Stand of jack pine on the south side of Highway 11/17, approximately 43.0 km. from site zero. Canopy was open and slope of ground was nil.

Major species - jack pine, tremling aspen, tamarack

Tree *1-Diameter at one meter-28.6 cm. Inclination-0 degrees
Tree *2-Diameter at one meter-36.1 cm. Inclination-2 degrees N
Tree *3-Diameter at one meter-24.8 cm. Inclination-3 degrees N
Tree *4-Diameter at one meter-19.6 cm. Inclination-0 degrees
Tree *5-Diameter at one meter-19.7 cm. Inclination-0 degrees
Mean 25.8 cm. 1.0 degrees

4 Stand of white birch on the south side of Highway 11/17, on the shores of a small lake, approximately 58.0 km. from site zero. Canopy was semi-open and slope of ground was 2 degrees southwest facing.

Major species - white birch, white spruce, tamarack, beaked hazel

Tree *1-Diameter at one meter-21.3 cm. Inclination-2 degrees N
Tree *2-Diameter at one meter-20.1 cm. Inclination-2 degrees S
Tree *3-Diameter at one meter-30.7 cm. Inclination-3 degrees N
Tree *4-Diameter at one meter-18.6 cm. Inclination-2 degrees S
Tree *5-Diameter at one meter-19.6 cm. Inclination-0 degrees
Mean 22.1 cm. 1.8 degrees

5 Stand of white birch on the north side of Highway 11/17, approximately 74.3 km. from site zero. Canopy was semi-open and slope of ground was 2 degrees north facing.

Major species - white birch, white spruce, tamarack

Tree *1-Diameter at one meter-18.9 cm. Inclination-2 degrees E
Tree *2-Diameter at one meter-17.9 cm. Inclination-2 degrees W
Tree *3-Diameter at one meter-18.5 cm. Inclination-2 degrees SW
Tree *4-Diameter at one meter-11.3 cm. Inclination-2 degrees W
Tree *5-Diameter at one meter-24.3 cm. Inclination-3 degrees E
Mean 18.2 cm. 2.2 degrees

Site Descriptions and Tree Descriptions for secondary sites done in the Ignace area

Site # Description

0 Stand of jack pine on the west side of Highway 599, approximately 1 km. north of the intersection of Highways 17 and 599. Canopy was semi-open and slope of ground was nil.

Major species - jack pine, tamarack

Tree #1-Diameter at one meter-21.6 cm. Inclination-0 degrees
Tree #2-Diameter at one meter-21.8 cm. Inclination-0 degrees
Tree #3-Diameter at one meter-18.3 cm. Inclination-3 degrees W
Tree #4-Diameter at one meter-28.3 cm. Inclination-0 degrees
Tree #5-Diameter at one meter-19.8 cm. Inclination-0 degrees
Mean 21.9 cm. 0.6 degrees

1 Stand of jack pine on the west side of Highway 599, approximately 12.8 km. north of site zero. Canopy was semi-open and slope of ground was nil.

Major species - jack pine, white spruce, balsam fir

Tree #1-Diameter at one meter-27.8 cm. Inclination-0 degrees
Tree #2-Diameter at one meter-19.6 cm. Inclination-0 degrees
Tree #3-Diameter at one meter-23.4 cm. Inclination-2 degrees S
Tree #4-Diameter at one meter-30.1 cm. Inclination-0 degrees
Tree #5-Diameter at one meter-28.6 cm. Inclination-0 degrees
Mean 25.9 cm. 0.4 degrees

2 Stand of jack pine on the east side of Highway 599, approximately 30.4 km. north of site zero. Canopy was semi-open and slope of ground was nil.

Major species - jack pine, white spruce, balsam fir, tamarack

Tree #1-Diameter at one meter-26.9 cm. Inclination-2 degrees W
Tree #2-Diameter at one meter-31.7 cm. Inclination-0 degrees
Tree #3-Diameter at one meter-19.3 cm. Inclination-0 degrees
Tree #4-Diameter at one meter-28.4 cm. Inclination-0 degrees
Tree #5-Diameter at one meter-24.5 cm. Inclination-4 degrees W
Mean 26.2 cm. 1.2 degrees

3 Stand of jack pine on the west side of Highway 599, approximately 43.3 km. north of site zero. Canopy was semi-open and slope of ground was nil.

Major species - jack pine, white spruce, trembling aspen, balsam fir

Tree #1-Diameter at one meter-27.5 cm. Inclination-2 degrees N
Tree #2-Diameter at one meter-28.3 cm. Inclination-0 degrees
Tree #3-Diameter at one meter-21.5 cm. Inclination-0 degrees
Tree #4-Diameter at one meter-27.3 cm. Inclination-0 degrees
Tree #5-Diameter at one meter-31.8 cm. Inclination-0 degrees
Mean 27.3 cm. 0.4 degrees

4 Stand of jack pine on the east side of Highway 599, approximately 59.0 km. north of site zero. Canopy was semi-open and slope of ground was nil.

Major species - jack pine, white spruce, balsam fir

Tree *1-Diameter at one meter-25.6 cm. Inclination-0 degrees
Tree *2-Diameter at one meter-25.3 cm. Inclination-3 degrees S
Tree *3-Diameter at one meter-18.5 cm. Inclination-0 degrees
Tree *4-Diameter at one meter-34.7 cm. Inclination-2 degrees S
Tree *5-Diameter at one meter-28.9 cm. Inclination-0 degrees
Mean 26.6 cm. 1.0 degrees

5 Stand of white birch on the east side of Highway 599, approximately 73 km. north of site zero. Canopy was closed and slope of ground was nil.

Major species - white birch, trembling aspen, balsam fir

Tree *1-Diameter at one meter-10.8 cm. Inclination-0 degrees
Tree *2-Diameter at one meter-21.3 cm. Inclination-0 degrees
Tree *3-Diameter at one meter-14.6 cm. Inclination-3 degrees E
Tree *4-Diameter at one meter-21.3 cm. Inclination-0 degrees
Tree *5-Diameter at one meter-25.3 cm. Inclination-2 degrees SE
Mean 18.6 cm. 1.0 degrees

Site Descriptions and Tree Descriptions for secondary sites done in the Wawa area

Site # Description

1 Stand of white birch on the south side of Highway 101, approximately 10.2 km. east of Wawa, near Twin Lakes. Canopy was semi-open and slope of ground was nil. Most of white birch had defoliated and dying tops.

Major species - white birch, white spruce, beaked hazel, trembling aspen

Tree #1-Diameter at one meter-34.7 cm. Inclination-2 degrees N
Tree #2-Diameter at one meter-21.3 cm. Inclination-3 degrees S
Tree #3-Diameter at one meter-18.1 cm. Inclination-0 degrees
Tree #4-Diameter at one meter-23.5 cm. Inclination-0 degrees
Tree #5-Diameter at one meter-31.3 cm. Inclination-5 degrees NE
Mean 25.8 cm. 2.0 degrees

2 Stand of white birch on the south side of the intersection of Highway 101 and Hawk Junction, approximately 20.1 km. east of Wawa. Canopy was semi-open and slope of ground 7 degrees north facing.

Major species - white birch, white spruce and mountain maple

Tree #1-Diameter at one meter-25.6 cm. Inclination-3 degrees N
Tree #2-Diameter at one meter-18.5 cm. Inclination-2 degrees NW
Tree #3-Diameter at one meter-19.6 cm. Inclination-3 degrees E
Tree #4-Diameter at one meter-21.3 cm. Inclination-0 degrees
Tree #5-Diameter at one meter-26.1 cm. Inclination-0 degrees
Mean 22.2 cm. 1.6 degrees

3 Stand of white birch on the west side of Highway 17 West, 16.2 km. north of Wawa turn-off (Highway 101 intersection with Highway 17 West). Canopy was semi-open and slope of ground was nil. Most of the white birch had dead or dying tops.

Major species - white birch, white spruce, beaked hazel, tamarack

Tree #1-Diameter at one meter-31.6 cm. Inclination-2 degrees S
Tree #2-Diameter at one meter-17.5 cm. Inclination-3 degrees W
Tree #3-Diameter at one meter-27.1 cm. Inclination-2 degrees NW
Tree #4-Diameter at one meter-25.6 cm. Inclination-0 degrees
Tree #5-Diameter at one meter-31.6 cm. Inclination-3 degrees S
<u>Mean 26.7 cm. 2.0 degrees</u>

4 Stand of white birch on the west side of Highway 17 West, 34.1 km. north of Wawa turn-off. Canopy was semi-open and slope of ground was nil.

Major species - white birch, balsam fir

Tree #1-Diameter at one meter-25.1 cm. Inclination-0 degrees
Tree #2-Diameter at one meter-22.4 cm. Inclination-4 degrees S
Tree #3-Diameter at one meter-19.0 cm. Inclination-3 degrees SW
Tree #4-Diameter at one meter-24.3 cm. Inclination-0 degrees
Tree #5-Diameter at one meter-26.8 cm. Inclination-6 degrees SE
<u>Mean 23.5 cm. 2.6 degrees</u>

5 Stand of white birch on the north side of Highway 519, 8.7 km. east of the intersection of Highway 519 with Highway 17 and approximately 46.7 km. from the Wawa turn-off. Canopy was closed and slope of ground was nil.

Major species - white birch, white spruce, balsam fir

Tree #1-Diameter at one meter-34.8 cm. Inclination-3 degrees S
Tree #2-Diameter at one meter-24.7 cm. Inclination-0 degrees
Tree #3-Diameter at one meter-22.1 cm. Inclination-5 degrees E
Tree #4-Diameter at one meter-25.0 cm. Inclination-2 degrees E
Tree #5-Diameter at one meter-19.4 cm. Inclination-4 degrees SW
Mean 25.2 cm. 2.8 degrees

Site Descriptions and Tree Descriptions for primary sites done in the Thunder Bay area - route Highway 102 to Highway 11/17 West

Site # Description

0 Stand of white birch on southwest side of Highway 102, at the intersection of the highway with Paquette Rd. Canopy was open and slope of ground was 3 degrees south. Because site has major roads on two sides, lead contamination is possible.

Major species - white birch, white spruce, trembling aspen, beaked hazel

Tree #1-Diameter at one meter-25.6 cm. Inclination-0 degrees
Tree #2-Diameter at one meter-20.1 cm. Inclination-2 degrees S
Tree #3-Diameter at one meter-17.1 cm. Inclination-0 degrees
Tree #4-Diameter at one meter-27.8 cm. Inclination-3 degrees S
Tree #5-Diameter at one meter-24.1 cm. Inclination-0 degrees
Mean 22.9 cm 1.0 degrees

Stand of white birch 100 meters off of 102 on north side, 15.0 km. from site zero. Canopy was semi-open and slope of ground was 2 degrees south.

Major species - white birch, trembling aspen, willow, mountain maple, beaked hazel
Tree #1-Diameter at one meter-28.7 cm. Inclination-2 degrees S
Tree #2-Diameter at one meter-11.9 cm. Inclination-0 degrees
Tree #3-Diameter at one meter-21.5 cm. Inclination-1 degrees E
Tree #4-Diameter at one meter-19.9 cm. Inclination-2 degrees W
Tree #5-Diameter at one meter-21.1 cm. Inclination-0 degrees
Mean 20.6 cm. 1.0 degrees

2 Stand of jack pine on south side of 102, 30.1 km. from site zero. Canopy was open and slope of ground was 2 degrees north.

Major species - jack pine, trembling aspen, tag alder, mountain maple

Tree #1-Diameter at one meter-22.5 cm. Inclination-0 degrees
Tree #2-Diameter at one meter-41.3 cm. Inclination-0 degrees
Tree #3-Diameter at one meter-36.5 cm. Inclination-0 degrees
Tree #4-Diameter at one meter-30.1 cm. Inclination-0 degrees
Tree #5-Diameter at one meter-29.8 cm. Inclination-0 degrees
Mean 32.0 cm. 0 degrees

3 Stand of white birch on south side of 11/17 west, 46.5 km. from site zero. Canopy was semi-open and slope of ground was nil.

Major species - white birch, trembling aspen, mountain maple, tag alder, beaked hazel

Tree #1-Diameter at one meter-19.5 cm. Inclination-0 degrees
Tree #2-Diameter at one meter-33.5 cm. Inclination-2 degrees W
Tree #3-Diameter at one meter-33.3 cm. Inclination-0 degrees
Tree #4-Diameter at one meter-34.1 cm. Inclination-2 degrees E
Tree #5-Diameter at one meter-38.4 cm. Inclination-1 degree W
Mean 31.8 cm. 1.0 degrees

4 Stand of jack pine on north side of 11 west, 100 metres down poorly used dirt road, approximately 61.0 km. from site zero. Canopy was semi-open and slope of ground was nil.

Major species - jack pine, trembling aspen, tag alder, beaked hazel

Tree #1-Diameter at one meter-23.6 cm. Inclination-0 degrees
Tree #2-Diameter at one meter-33.4 cm. Inclination-0 degrees
Tree #3-Diameter at one meter-27.5 cm. Inclination-0 degrees
Tree #4-Diameter at one meter-38.4 cm. Inclination-0 degrees
Tree #5-Diameter at one meter-40.1 cm. Inclination-2 degrees SE
Mean 32.6 cm 0.4 degrees

5 Stand of white birch on south side of Highway 11 west, at intersection of highway with Highway 586, approximately 75.8 km. from site zero. Canopy was open and slope of ground was nil.

Major species - white birch, trembling aspen, white spruce

Tree #1-Diameter at one meter-26.1 cm. Inclination-0 degrees
Tree #2-Diameter at one meter-25.2 cm. Inclination-2 degrees W
Tree #3-Diameter at one meter-28.3 cm. Inclination-2 degrees S
Tree #4-Diameter at one meter-30.1 cm. Inclination-0 degrees
Tree #5-Diameter at one meter-34.6 cm. Inclination-0 degrees
Mean 28.9 cm. 0.8 degrees

Site Descriptions and Tree Descriptions for primary sites done in the Thunder Bay area - route Highway 11/17 East

Site * Description

0 Same as route 527 North site number 0

1 Stand of white birch behind the Shuniah Fire Hall *1, off of Coral Beach Rd approximately 13.7 km. east of the intersection of Highways 527 North and11/17 East (and 14.1 km. from site zero). Canopy was semi-open and slope of ground was nil. Herb layer was dense and high in some places.

Major species - white birch, trembling aspen, balsam fir, mountain maple

Tree *1-Diameter at one meter-26.7 cm. Inclination-2 degrees S
Tree *2-Diameter at one meter-20.5 cm. Inclination-2 degrees N
Tree *3-Diameter at one meter-21.5 cm. Inclination-3 degrees SW
Tree *4-Diameter at one meter-24.1 cm. Inclination-1 degree E
Tree *5-Diameter at one meter-17.1 cm. Inclination-2 degrees W
Mean 22.0 cm. 2.0 degrees

2 Stand of white birch on south side of highway, approximately 100 metres short of the Pass Lake Road intersection and 30.2 km. from site zero. Canopy was open and slope of ground was 2 degrees southeast facing.

Major species - white birch, white spruce, balsam fir, mountain maple, beaked hazel

Tree *1-Diameter at one meter-24.5 cm. Inclination-2 degrees W
Tree *2-Diameter at one meter-26.0 cm. Inclination-0 degrees
Tree *3-Diameter at one meter-32.4 cm. Inclination-1 degree S
Tree *4-Diameter at one meter-37.6 cm. Inclination-0 degrees
Tree *5-Diameter at one meter-36.7 cm. Inclination-3 degrees S
Mean 31.4 cm. 1.0 degrees

3 Stand of jack pine on top of 60 meter tall rocky knoll on south side of highway, approximately 3.0 km. past Pearl Lake and 44.7 km. from site zero. Canopy was open and slope of ground was 2 degrees west-facing at the top.

Major species - jack pine, mountain ash, tag alder

Tree #1-Diameter at one meter-32.1 cm. Inclination-0 degrees
Tree #2-Diameter at one meter-26.4 cm. Inclination-0 degrees
Tree #3-Diameter at one meter-27.4 cm. Inclination-2 degrees E
Tree #4-Diameter at one meter-18.7 cm. Inclination-0 degrees
Tree #5-Diameter at one meter-18.6 cm. Inclination-2 degrees E
Mean 24.6 cm. 0.8 degrees

4 Stand of white birch on west side of Dorion Fish Hatchery Road, approximately 0.8 km. north of intersection with 11/17 East and 61.8 km. from site zero. Canopy was semi-open and slope of ground was nil. Herb layer was dense and high in some places.

Major species - white birch, trembling aspen, tag alder, beaked hazel, mountain maple

Tree #1-Diameter at one meter-24.8 cm. Inclination-2 degrees NE
Tree #2-Diameter at one meter-29.7 cm. Inclination-2 degrees S
Tree #3-Diameter at one meter-27.9 cm. Inclination-0 degrees
Tree #4-Diameter at one meter-20.8 cm. Inclination-2 degrees W
Tree #5-Diameter at one meter-23.2 cm. Inclination-0 degrees
Mean 25.3 cm. 1.2 degrees

5 Stand of white birch on north side of highway, 16.0 km. from site number four and 76.8 km. from site zero. Canopy was semi-open and slope of ground was nil. The site is near an abandoned gravel pit and looks like it was cutover in recent past.

Major species - white birch, trembling aspen, white spruce, beaked hazel, pin cherry, mountain maple

Tree #1-Diameter at one meter-20.8 cm. Inclination-0 degrees
Tree #2-Diameter at one meter-15.5 cm. Inclination-2 degrees S
Tree #3-Diameter at one meter-24.8 cm. Inclination-2 degrees N
Tree #4-Diameter at one meter-26.1 cm. Inclination-1 degree E
Tree #5-Diameter at one meter-18.1 cm. Inclination-0 degrees
Mean 21.1 cm. 1.0 degrees

Site Descriptions and Tree Descriptions for auxiliary sites done in the Thunder Bay area - route Sibley Peninsula and Thunder Bay urban area

Site	Description
Sibley *1	Stand of white birch on southeast corner of Pass Lake Road intersection with Squaw Bay Road. Canopy was semi-open and slope of ground was nil. Major species - white birch, trembling aspen, white spruce, balsam fir Tree *1-Diameter at one meter-20.1 cm. Inclination-0 degrees Tree *2-Diameter at one meter-31.8 cm. Inclination-2 degrees W Tree *3-Diameter at one meter-25.1 cm. Inclination-3 degrees N Tree *4-Diameter at one meter-18.8 cm. Inclination-0 degrees Tree *5-Diameter at one meter-18.3 cm. Inclination-0 degrees <u>Mean 22.8 cm. 1.0 degrees</u>
Sibley *2	Stand of white birch on southeast side of Pass Lake Road, approximately 37.1 km. from the intersection of Pass Lake Rd. with Highway 11/17. Canopy was closed and slope of ground was 6 degrees north-facing (and as a result, the site was quite damp and cool). Major species - white birch, white cedar, balsam fir, tamarack Tree *1-Diameter at one meter-30.8 cm. Inclination-2 degrees N Tree *2-Diameter at one meter-21.8 cm. Inclination-2 degrees N Tree *3-Diameter at one meter-27.1 cm. Inclination-0 degrees Tree *4-Diameter at one meter-26.3 cm. Inclination-2 degrees NW Tree *5-Diameter at one meter-31.9 cm. Inclination-3 degrees N <u>Mean 27.6 cm. 1.8 degrees</u>

Cent. Park — Stand of white birch behind the picnic grounds on the west side of Lyon Road, approximately .4 km. from its intersection with Arundel Ave., on the southeastern side of the city of Thunder Bay. Canopy was semi-open and slope of ground was nil.

Major species - white birch, trembling aspen, balsam fir

Tree #1-Diameter at one meter-	28.9 cm.	Inclination-3 degrees W
Tree #2-Diameter at one meter-	36.1 cm.	Inclination-3 degrees SW
Tree #3-Diameter at one meter-	31.2 cm.	Inclination-2 degrees S
Tree #4-Diameter at one meter-	33.4 cm.	Inclination-3 degrees S
Tree #5-Diameter at one meter-	31.6 cm.	Inclination-0 degrees
Mean	32.2 cm.	2.2 degrees

L.H. Univ. — Stand of white birch along the bank of the McIntyre River, where the river passes alongside parking lot #5 adjacent to Lakehead University. Canopy was semi-open and slope of ground was 20 degrees west-facing. Due to the proximity of roads and parking lots, lead contamination of samples was possible here.

Major species - white birch, white spruce

Tree #1-Diameter at one meter-	23.8 cm.	Inclination-5 degrees W
Tree #2-Diameter at one meter-	19.1 cm.	Inclination-10 degrees W
Tree #3-Diameter at one meter-	28.3 cm.	Inclination-5 degrees W
Tree #4-Diameter at one meter-	25.6 cm.	Inclination-7 degrees SW
Tree #5-Diameter at one meter-	23.7 cm.	Inclination-13 degree SW
Mean	24.1 cm.	8.0 degrees

Mt. McKay	Stand of white birch on the east side of the road leading up to the lookout on the eastern slope of Mt. McKay, approximately .4 km. north of the gatehouse. Canopy was semi-open and slope of ground was 3 degrees southeast-facing.

Major species - white birch, trembling aspen, mountain maple

Tree #1-Diameter at one meter-	31.4 cm.	Inclination-0 degrees
Tree #2-Diameter at one meter-	25.6 cm.	Inclination-2 degrees SW
Tree #3-Diameter at one meter-	27.4 cm.	Inclination-3 degrees SE
Tree #4-Diameter at one meter-	23.4 cm.	Inclination-0 degrees
Tree #5-Diameter at one meter-	30.1 cm.	Inclination-2 degrees E
Mean	27.6 cm.	1.4 degrees

Site Descriptions and Tree Descriptions for primary sites done in the Thunder Bay area - route Highway 527 North

Site * Description

0 Stand of white birch on south side of Lakeshore Drive, approximately 0.7 km. southwest of its intersection with Highway 527. Canopy was open and slope ofground was 2 degrees southeast facing. The area was cutover for poplar within the past decade and mainly birch and a dense herb understorey remain.

Major species - white birch, trembling aspen, white spruce, mountain maple

Tree *1-Diameter at one meter-32.4 cm. Inclination-0 degrees
Tree *2-Diameter at one meter-23.0 cm. Inclination-2 degrees N
Tree *3-Diameter at one meter-36.6 cm. Inclination -0 degrees
Tree *4-Diameter at one meter-29.1 cm. Inclination -2 degrees E
Tree *5-Diameter at one meter-18.9 cm. Inclination -3 degrees N
Mean 28.0 cm. 1.4 degrees

1 Stand of white birch on the east side of the highway, approximately 13.7 km. north of the intersection of Highways 11/17 and 527 (and 14.9 km. from site zero). Canopy was semi-open and slope was 2 degrees northwest facing. Herb layer was dense and high.

Major species - white birch, trembling aspen, mountain maple

Tree *1-Diameter at one meter-19.8 cm. Inclination-6 degrees NW
Tree *2-Diameter at one meter-22.6 cm. Inclination-4 degrees NW
Tree *3-Diameter at one meter-11.8 cm. Inclination-3 degrees NE
Tree *4-Diameter at one meter-13.9 cm. Inclination-1 degree W
Tree *5-Diameter at one meter-12.0 cm. Inclination-1 degree N
Mean 16.0 cm 3.0 degrees

2 Stand of jack pine on the east side of the highway, approximately 29.0 km. north of 11/17 and 527 intersection (and 30.2 km from site zero). Canopy was open and slope of ground was nil.

Major species - jack pine, black spruce, *Salix spp.* (willow)

Tree #1-Diameter at one meter-18.6 cm. Inclination-0 degrees
Tree #2-Diameter at one meter-24.3 cm. Inclination-0 degrees
Tree #3-Diameter at one meter-24.0 cm. Inclination-2 degrees N
Tree #4-Diameter at one meter-19.5 cm. Inclination-1 degree N
Tree #5-Diameter at one meter-19.1 cm. Inclination-0 degrees
Mean 21.1 cm. 3.0 degrees

3 Stand of jack pine on the east side of the highway, approximately 43.2 km. north of 11/17 and 527 intersection (44.4 km. from site zero) and 100 meters back from Hicks Lake Rd. Canopy was semi-open and slope of ground was nil.

Major species - jack pine, black spruce, trembling aspen

Tree #1-Diameter at one meter-23.2 cm. Inclination-0 degrees
Tree #2-Diameter at one meter-17.8 cm. Inclination-0 degrees
Tree #3-Diameter at one meter-21.2 cm. Inclination-0 degrees
Tree #4-Diameter at one meter-17.1 cm. Inclination-0 degrees
Tree #5-Diameter at one meter-22.7 cm. Inclination-0 degrees
Mean 20.4 cm. 0 degrees

4 Stand of jack pine on the east side of the highway, approximately 60.7 km. north of 11/17 and 527 intersection (61.9 km. from site zero). Canopy was semi-open and slope of ground was nil.

Major species - jack pine, balsam fir, white spruce, mountain maple

Tree #1-Diameter at one meter-35.7 cm. Inclination-0 degrees
Tree #2-Diameter at one meter-41.2 cm. Inclination-0 degrees
Tree #3-Diameter at one meter-37.1 cm. Inclination-2 degrees E
Tree #4-Diameter at one meter-31.4 cm. Inclination-0 degrees
Tree #5-Diameter at one meter-27.1 cm. Inclination-2 degrees W
Mean 34.5 cm. 0.8 degrees

5 Stand of white birch on west side of the highway, approximately 80.0 km. north of 11/17 and 527 intersection (81.2 km. from site zero), and 3 km. beyond pipeline pumping station. Area was cutover in recent years and only pockets of trees remain. Canopy was open and slope of ground was 2 degrees north.

Major species - white birch, balsam fir, american mountain ash (*Sorbus americana*)

Tree *1-Diameter at one meter-32.8 cm. Inclination-1 degree N
Tree *2-Diameter at one meter-21.5 cm. Inclination-0 degrees
Tree *3-Diameter at one meter-31.1 cm. Inclination-0 degrees
Tree *4-Diameter at one meter-26.7 cm. Inclination-0 degrees
Tree *5-Diameter at one meter-28.1 cm. Inclination-2 degrees W
Mean 28.0 cm. 0.6 degrees

Site descriptions and Tree Descriptions for primary sites done in the Thunder Bay area - route Highway 61 Southwest

Site # Description

0 Stand of white birch on west side of Mt. McKay, 0.8 km. southwest of intersection between Mountain Rd. and .
Great Lakes Forest Products pulp and paper mill is approximately 1 km. northeast of site. Canopy was semi-open and slope of ground was 3 degrees west.

Major species - white birch, trembling aspen, tag alder

Tree #1-Diameter at one meter-41.3 cm. Inclination-3 degrees W
Tree #2-Diameter at one meter-27.3 cm. Inclination-2 degrees S
Tree #3-Diameter at one meter-25.6 cm. Inclination-3 degrees W
Tree #4-Diameter at one meter-19.6 cm. Inclination-2 degrees E
Tree #5-Diameter at one meter-27.3 cm. Inclination-2 degrees W
<u>Mean 28.2 cm. 2.4 degrees</u>

1 Stand of white birch at end of Boy Scout Camp Rd. (which branches south off of Highway 61 approximately 18 km. from site zero). Canopy was semi-open and slope of ground was 2 degrees North.

Major species - white birch, trembling aspen, mountain maple, beaked hazel

Tree #1-Diameter at one meter-28.5 cm. Inclination-2 degrees W
Tree #2-Diameter at one meter-24.3 cm. Inclination-0 degrees
Tree #3-Diameter at one meter-24.2 cm. Inclination-1 degree W
Tree #4-Diameter at one meter-23.1 cm. Inclination-2 degrees W
Tree #5-Diameter at one meter-21.3 cm. Inclination-0 degrees
<u>Mean 24.3 cm. 1.0 degrees</u>

2 Stand of white birch on north side of Cloud Lake Road, approximately 3.4 km. from intersection with Highway 61 and 32.3 km. from site zero. Canopy was semi-open and slope of ground was 2 degrees southwest.

Major species - white birch, trembling aspen, beaked hazel

Tree *1-Diameter at one meter-32.5 cm. Inclination-0 degrees
Tree *2-Diameter at one meter-22.5 cm. Inclination-2 degrees SW
Tree *3-Diameter at one meter-24.3 cm. Inclination-2 degrees W
Tree *4-Diameter at one meter-28.9 cm. Inclination-4 degrees NE
Tree *5-Diameter at one meter-26.8 cm. Inclination-2 degrees SW
Mean 27.0 cm. 2.0 degrees

3 Stand of white birch on north side of highway, 100 m. after Pine River bridge and approximately 44 km. from site zero. Site is adjacent to driveway of 'Great Lakes Nickel Ltd.'. Canopy was open and slope of ground was 3 degrees east.

Major species - white birch, trembling aspen, white spruce, mountain maple

Tree *1-Diameter at one meter-18.3 cm. Inclination-2 degrees W
Tree *2-Diameter at one meter-33.1 cm. Inclination-5 degrees W
Tree *3-Diameter at one meter-25.8 cm. Inclination-2 degrees W
Tree *4-Diameter at one meter-21.3 cm. Inclination-2 degrees S
Tree *5-Diameter at one meter-26.1 cm. Inclination-0 degrees
Mean 24.9 cm. 2.2 degrees

4 Sites 4 and 5 were completed on Highway 539 which branches west off of Highway 61 about 5 km. before the Pigeon River Border Station. Site *4 was a stand of jack pine on north side of highway, approximately 73.1 km. from site zero. Although road kilometeres put this site further away from site zero than site *5, it was actually closer in straight line distance to Thunder Bay than site *5 and was thus called *4. Canopy cover was semi-open and slope of ground was nil.

Major species - jack pine, trembling aspen, white birch, tag alder

Tree *1-Diameter at one meter 25.1 cm. Inclination-0 degrees
Tree *2-Diameter at one meter-31.3 cm. Inclination-2 degrees S
Tree *3-Diameter at one meter-18.4 cm. Inclination-0 degrees
Tree *4-Diameter at one meter-23.6 cm. Inclination-0 degrees
Tree *5-Diameter at one meter-15.1 cm. Inclination-2 degrees E
Mean 22.7 cm. 0.8 degrees

5 Site 5 was a stand of white birch on the north side of Highway 539, approximately 62.0 **road** km. from site zero. Canopy was semi-open and slope of ground was 3 degrees north.

Major species - white birch, trembling aspen, mountain maple, tag alder

Tree *1-Diameter at one meter-18.1 cm. Inclination-0 degrees
Tree *2-Diameter at one meter-26.3 cm. Inclination-2 degrees N
Tree *3-Diameter at one meter-14.5 cm. Inclination-0 degrees
Tree *4-Diameter at one meter-20.1 cm. Inclination-2 degrees W
Tree *5-Diameter at one meter-16.5 cm. Inclination-0 degrees
Mean 19.1 cm. 0.8 degrees

Appendix B

Morphological data for upper north and lower north quadrats as collected in the Kenora area

Site Location: Kenora (Hwy. 17) Site Number: 0

Tree Species: <u>Betula papyrifera</u>

Tree Number	1	2	3	4	5
<u>Upper North</u>					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps	Hp, Ps	Hp, Ps	Hp, Ps	Hp, Ps
<u>Braun-Blanquet</u>[2]					
crustose	2	2	2	2	2
foliose	2	3	4	2	2
fruticose	-	-	+	+	+
bryophyte	+	-	-	-	-
<u>H. physodes</u>					
Braun-Blanquet[2]	2	2	2	2	2
Colour aber.	black, white pink	black, white	black, white	black, white pink	black, white
Health (p, p-f, f, f-g, g)[3]	f	f	p-f	p-f	f
Size (s,m,l)[4]	s,m	s,m	s,m	s,m	s
Branching (f,s,m)[5]	s	s	f	f	f
Soredia?	yes	yes	yes	yes	yes
<u>Lower North</u>					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps	Hp, Ps	Hp, Ps	Hp, Ps	Hp, Ps
<u>Braun-Blanquet</u>[2]					
crustose	2	2	1	2	2
foliose	2	3	3	2	2
fruticose	-	-	+	+	-
bryophyte	+	-	-	-	
<u>H. physodes</u>					
Braun-Blanquet[2]	2	2	2	1	2
Colour aber.	black, white	black, white	black, white	black, white	black, white
Health (p, p-f, f, f-g, g)[3]	f	f	p-f	f	p-f
Size (s,m,l)[4]	s,m	s,m	s,m	s	s
Branching (f,s,m)[5]	s	f	f	s	f
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Kenora area

Site Location: Kenora (Hwy. 17) Site Number: 1
Tree Species: Pinus banksiana

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	none	none	none	none	Hp
Braun-Blanquet[2]					
crustose	3	2	3	2	2
foliose	-	+	-	-	1
fruticose	+	+	+	-	+
bryophyte	-	-	-		-
H. physodes					
Braun-Blanquet[2]		+			1
Colour aber.		black			none
Health (p, p-f, f, f-g, g)[3]		f			p-f
Size (s,m,l)[4]		s			s
Branching (f,s,m)[5]	-	f	-	-	f
Soredia?	no	no	no	no	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Em	Hp, Em	Hp, Em	Hp	Hp, Em
Braun-Blanquet[2]					
crustose	3	2	2	3	3
foliose	3	3	2	3	3
fruticose	2	2	3	1	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	3	3	2	3	3
Colour aber.	black, white	black, white	black, white	black, white pink	black, white pink
Health (p, p-f, f, f-g, g)[3]	f	f	p-f	p-f	p-f
Size (s,m,l)[4]	s,m	s,m,l	s,m	s,m	s,m
Branching (f,s,m)[5]	f	s	f	f	f
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Kenora area

Site Location: Kenora (Hwy. 17) Site Number: 2
Tree Species: <u>Betula papyrifera</u>

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	none	none	none	none	none
Braun-Blanquet[2]					
crustose	2	3	3	3	2
foliose	+	-	-	+	-
fruticose	-	-	+	-	-
bryophyte	-		-		
H. physodes					
Braun-Blanquet[2]	+			+	
Colour aber.	none			none	
Health (p, p-f, f, f-g, g)[3]	p			p	
Size (s,m,l)[4]	s			s	
Branching (f,s,m)[5]	f	-	-	f	-
Soredia?	yes	no	no	no	no
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp	Hp, Em	Hp	Hp, Em	Hp, Em
Braun-Blanquet[2]					
crustose	3	3	2	3	2
foliose	3	3	4	3	2
fruticose	+	2	1	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	3	3	4	3	2
Colour aber.	black, white pink	black, white	black, white pink	black, white	black, white
Health (p, p-f, f, f-g, g)[3]	p	p	p-f	p	p
Size (s,m,l)[4]	s,m	s,m	s,m,l	s,m	s,m
Branching (f,s,m)[5]	f	f	f	f	f
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Kenora area

Site Location: Kenora (Hwy. 17)   Site Number: 3
Tree Species: Pinus banksiana

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Em	Em	Hp	Hp	none
Braun-Blanquet[2]					
crustose	2	2	2	1	2
foliose	1	1	1	2	+
fruticose	1	2	+	+	+
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	1	1	1	2	1
Colour aber.	black, white	black, white	black, white	black, white	black
Health (p, p-f, f, f-g, g)[3]	p-f	p	p-f	p-f	p-f
Size (s,m,l)[4]	s	s	s,m	s,m	s
Branching (f,s,m)[5]	s	f	f	f	f
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Em	Hp, Em	Hp, Em	Hp, Em	Hp, Em
Braun-Blanquet[2]					
crustose	2	2	3	2	3
foliose	2	3	2	3	2
fruticose	3	2	2	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	3	2	3	2
Colour aber.	black, white	black, white	black, white	black, white	black, white
Health (p, p-f, f, f-g, g)[3]	p	p-f	p	p-f	p
Size (s,m,l)[4]	s,m	s,m	s,m	s,m	s,m
Branching (f,s,m)[5]	f	f	f	f	f
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*
2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5
3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good
4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)
5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Kenora area

Site Location: Kenora (Hwy. 17) Site Number: 4
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Em	Hp, Ps, Em	Em, Ps	Hp, Ps	Em, Ps
Braun-Blanquet[2]					
crustose	2	2	2	3	3
foliose	+	3	2	4	3
fruticose	2	2	2	1	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	+	2	+	2	1
Colour aber.	none	none	none	black, white	black, white
Health (p, p-f, f, f-g, g)[3]	f	f-g	f	f-g	f
Size (s,m,l)[4]	s	s,m	s	s,m	s,m
Branching (f,s,m)[5]	f	s	f	s	s
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps	Hp, Ps	Hp, Ps, Em	Hp, Ps, Em	Hp, Ps, Em
Braun-Blanquet[2]					
crustose	2	3	2	3	3
foliose	3	2	3	3	3
fruticose	1	1	1	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	2
Colour aber.	white	none	black, white	black	black
Health (p, p-f, f, f-g, g)[3]	f-g	g	f-g	f-g	f-g
Size (s,m,l)[4]	s,m	s,m	s,m,l	s,m	s,m
Branching (f,s,m)[5]	s	m	s	s	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Kenora area

Site Location: Kenora (Hwy. 17)　　　Site Number: 5

Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps, Em	Hp, Ps, Em	Ps	Hp, Ps, Em	Hp, Ps, Em
Braun-Blanquet[2]					
crustose	2	2	2	2	2
foliose	3	3	3	3	3
fruticose	2	2	1	3	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	1	2	2
Colour aber.	brown	white	white	white	none
Health (p, p-f, f, f-g, g)[3]	g	f-g	f-g	g	g
Size (s,m,l)[4]	s,m	s,m	s,m	s,m	s,m
Branching (f,s,m)[5]	m	m	s	m	m
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps, Em	Hp, Ps	Ps	Hp, Em	Hp, Ps, Em
Braun-Blanquet[2]					
crustose	3	3	3	2	3
foliose	2	2	3	2	4
fruticose	2	1	1	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	1	2	2	2
Colour aber.	none	white	white	white, brown	none
Health (p, p-f, f, f-g, g)[3]	g	f-g	f	f-g	f-g
Size (s,m,l)[4]	s,m	s,m	s	s	s,m
Branching (f,s,m)[5]	s	s	s	s	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*　　Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Ignace area

Site Location: Ignace (Hwy. 599)   Site Number: 0
Tree Species: <u>Pinus banksiana</u>

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	none	Hp	none	none	Hp, Ps, Em
Braun-Blanquet[2]					
crustose	3	3	3	3	3
foliose	-	2	+	1	2
fruticose	2	+	+	1	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]		2			2
Colour aber.		black, white			black, white
Health (p, p-f, f, f-g, g)[3]		p			p-f
Size (s,m,l)[4]		s,m			s,m
Branching (f,s,m)[5]	-	f	-	-	f
Soredia?	no	yes	no	no	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Em	Hp, Em	Hp, Ps, Em	Hp, Ps, Em	Hp, Ps, Em
Braun-Blanquet[2]					
crustose	3	3	3	4	3
foliose	2	2	3	2	3
fruticose	2	2	3	2	3
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	2
Colour aber.	black, white	black, white	black, white	black, white	black, white
Health (p, p-f, f, f-g, g)[3]	p	p	p	p	p
Size (s,m,l)[4]	s	s	s,m	s,m	s,m
Branching (f,s,m)[5]	f	f	f	f	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Ignace area

Site Location: Ignace (Hwy. 599)   Site Number: 1
Tree Species: Pinus banksiana

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps, Em, *Alectoria* spp.	Hp, Em, *Alectoria* spp.	Hp, Ps	Hp, *Alectoria* spp.	Hp, Ps *Alectoria* spp.
Braun-Blanquet[2]					
crustose	3	3	3	3	3
foliose	3	2	3	2	3
fruticose	3	2	3	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	2
Colour aber.	black, white	black	black, white	black, white	white
Health (p, p-f, f, f-g, g)[3]	p-f	f	p-f	p	f
Size (s,m,l)[4]	s,m	s,m	s,m	s	s
Branching (f,s,m)[5]	f	f	f	f	f
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps, Em, *Alectoria* spp.	Hp, Ps, *Alectoria* spp.	Hp, Ps	Hp, Ps, Em, *Alectoria* spp.	Hp, *Alectoria* spp.
Braun-Blanquet[2]					
crustose	4	4	3	3	4
foliose	3	3	3	3	3
fruticose	3	2	2	3	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	3	3	3
Colour aber.	black, white	black, white	black, white	black	black, white
Health (p, p-f, f, f-g, g)[3]	p-f	p-f	f	p-f	p-f
Size (s,m,l)[4]	s,m	s	s,m	s,m	s,m
Branching (f,s,m)[5]	f	f	f	f	f
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*
2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5
3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good
4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)
5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Ignace area

Site Location: Ignace (Hwy. 599) Site Number: 2
Tree Species: Pinus banksiana

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps, Em	Hp, Em	Hp, Em	Hp, Em, *Alectoria* spp.	Hp, Em, *Alectoria* spp.
Braun-Blanquet[2]					
crustose	3	3	3	3	4
foliose	3	3	2	3	3
fruticose	2	2	3	3	3
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	3
Colour aber.	black	none	black	white	black, white
Health (p, p-f, f, f-g, g)[3]	f	f	p-f	p-f	p-f
Size (s,m,l)[4]	s,m	s,m	s	s,m	s,m
Branching (f,s,m)[5]	f	f	f	s	f
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Em, *Alectoria* spp.	Hp, Em *Alectoria* spp.	Hp, Em	Hp, Em, Ps	Hp, Em, Ps, *Alectoria* spp.
Braun-Blanquet[2]					
crustose	4	3	3	4	3
foliose	3	3	2	3	3
fruticose	3	2	2	2	3
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	3	3	2	2	2
Colour aber.	black, white	black, white	black, white	black, white	white
Health (p, p-f, f, f-g, g)[3]	f	f-g	f	p-f	p-f
Size (s,m,l)[4]	s,m	s,m	s,m	s,m	s,m
Branching (f,s,m)[5]	f	f	f	f	f
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Ignace area

Site Location: Ignace (Hwy. 599) Site Number: 3
Tree Species: <u>Pinus banksiana</u>

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Ps, Hp, Em	Hp, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	2	2	3	3	3
foliose	2	3	1	2	3
fruticose	3	2	1	3	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	3	1	1	2
Colour aber.	black, white	black, white pink	white	black, white	black, white
Health (p, p-f, f, f-g, g)[3]	f	f	f	p-f	p-f
Size (s,m,l)[4]	s,m	s,m	s	s,m	s,m
Branching (f,s,m)[5]	s	f	f	f	f
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps, Em	Hp, Em	Hp, Em	Hp, Em, *Alectoria* spp.	Hp, Ps, Em, *Alectoria* spp.
Braun-Blanquet[2]					
crustose	3	3	4	4	4
foliose	3	2	3	3	4
fruticose	2	2	3	3	3
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	3	3	3
Colour aber.	black, white	white	white	black, white	black,white
Health (p, p-f, f, f-g, g)[3]	p-f	f	f	p-f	p-f
Size (s,m,l)[4]	s,m	s,m	s,m	s,m	s,m
Branching (f,s,m)[5]	f	f	f	s	f
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*
2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5
3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good
4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)
5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Ignace area

Site Location: Ignace (Hwy. 599) Site Number: 4
Tree Species: <u>Pinus banksiana</u>

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps, Em	Hp, Ps, Em	Hp, Em	Hp, Ps, Em	Hp, Ps, Em
Braun-Blanquet[2]					
crustose	3	3	4	3	3
foliose	3	2	2	3	3
fruticose	2	1	3	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	3	2
Colour aber.	black, white	black, white	black, white	black, white	black, white
Health (p, p-f, f, f-g, g)[3]	p-f	p	p	p-f	p-f
Size (s,m,l)[4]	s,m	s	s,m	s,m	s,m,l
Branching (f,s,m)[5]	f	f	f	s	f
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps, Em	Hp, Ps, Em	Hp, Em	Hp, Em	Hp, Em
Braun-Blanquet[2]					
crustose	3	3	4	3	2
foliose	3	3	2	2	2
fruticose	3	2	2	2	3
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	2
Colour aber.	black, white	black, white	black, white	black, white	black, white
Health (p, p-f, f, f-g, g)[3]	p	p-f	p	p	p
Size (s,m,l)[4]	s	s,m	s	s,m	s,m
Branching (f,s,m)[5]	f	s	f	f	f
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*
2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5
3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good
4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)
5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Ignace area

Site Location: Ignace (Hwy. 599)   Site Number:5

Tree Species: <u>Betula papyrifera</u>

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps, Em	Hp, Em	Hp, Ps	Hp, Ps	Ps, Em
<u>Braun-Blanquet</u>[2]					
crustose	2	2	2	2	3
foliose	3	3	2	3	2
fruticose	1	2	2	1	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	1	2	1	2	1
Colour aber.	black	none	none	black, white	black
Health (p, p-f, f, f-g, g)[3]	g	f-g	f	f-g	f-g
Size (s,m,l)[4]	s	s,m	s,m	s,m	s
Branching (f,s,m)[5]	m	m	f	s	s
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps	Hp, Ps, Em	Hp, Ps	Ps, Em	Hp, Ps, Em
<u>Braun-Blanquet</u>[2]					
crustose	3	2	2	3	3
foliose	3	3	3	3	2
fruticose	+	3	2	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	1	2
Colour aber.	brown, white	white	none	black	white
Health (p, p-f, f, f-g, g)[3]	f-g	f-g	f	f	[illegible]
Size (s,m,l)[4]	s,m,l	s,m	s,m	s	s,m
Branching (f,s,m)[5]	m	s	f	f	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Wawa area

Site Location: Wawa (Hwy. 101) Site Number: 1
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp	Hp	Hp	Hp	Hp
Braun-Blanquet[2]					
crustose	2	3	3	3	2
foliose	3	2	4	2	1
fruticose	+	-	-	-	+
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	3	2	4	2	1
Colour aber.	brown, white	black, brown	brown, white	black, white	brown, white
Health (p, p-f, f, f-g, g)[3]	f-g	p-f	f	f	p-f
Size (s,m,l)[4]	s,m,l	s,m	s,m,l	s,m	s
Branching (f,s,m)[5]	s	f	s	f	f
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp	Hp	Hp	Hp	Hp
Braun-Blanquet[2]					
crustose	2	2	3	2	3
foliose	3	2	2	2	2
fruticose	1	-	-	-	+
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	3	2	2	2	2
Colour aber.	brown, white yellow	brown, white	white	white	black, white brown
Health (p, p-f, f, f-g, g)[3]	f	f	f	p-f	f
Size (s,m,l)[4]	s,m,l	s	s,m	s,m	s,m
Branching (f,s,m)[5]	s	f	f	f	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*
2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5
3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good
4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)
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Morphological data for upper north and lower north quadrats as collected in the Wawa area

Site Location: Wawa (Hwy. 511) Site Number: 2
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp	Hp	Hp	Hp	Hp
Braun-Blanquet[2]					
crustose	3	2	2	3	2
foliose	2	3	3	3	3
fruticose	-	-	+	+	+
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	3	4	3	3
Colour aber.	black, white	black, brown	pink, white	black	black, white
Health (p, p-f, f, f-g, g)[3]	p-f	f	p-f	f	p-f
Size (s,m,l)[4]	s,m	s,m	s,m	s,m	s,m
Branching (f,s,m)[5]	s	s	s	s	f
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp	Hp	Hp	Hp	Hp
Braun-Blanquet[2]					
crustose	3	3	3	3	2
foliose	2	2	3	2	2
fruticose	+	-	-	-	+
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	3	2	2
Colour aber.	black, white	black, white	black, white	black, white	black
Health (p, p-f, f, f-g, g)[3]	f	p-f	p-f	f	f
Size (s,m,l)[4]	s,m	s,m	s,m	s,m	s
Branching (f,s,m)[5]	s	f	s	f	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*
2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5
3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good
4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)
5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Wawa area

Site Location: Wawa (Hwy. 17) Site Number: 4
Tree Species: <u>Betula papyrifera</u>

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp	Hp	Hp, Em	Hp	Hp, Em
<u>Braun-Blanquet</u>[2]					
crustose	2	3	2	3	3
foliose	4	2	2	2	3
fruticose	+	+	2	1	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	4	2	2	2	3
Colour aber.	pink, white	black	black, white	brown	black, white
Health (p, p-f, f, f-g, g)[3]	f-g	f	f	f-g	[illegible]
Size (s,m,l)[4]	s,m	s,m	s,m,l	s	s,m
Branching (f,s,m)[5]	f	s	s	s	s
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp	Hp	Hp, Em	Hp	Hp
<u>Braun-Blanquet</u>[2]					
crustose	2	3	4	2	3
foliose	3	2	3	2	3
fruticose	+	-	2	+	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	3	2	3	2	3
Colour aber.	brown, white	white	brown, white	black	brown, white
Health (p, p-f, f, f-g, g)[3]	f	f-g	f	f	f-g
Size (s,m,l)[4]	s	s	s,m,l	s	s.m
Branching (f,s,m)[5]	f	s	s	s	m
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Wawa area

Site Location: Wawa (Hwy 519) Site Number: 5
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps, Em	Hp, Ps, Em	Hp, Ps	Hp, Em	Hp, Ps, Em
Braun-Blanquet[2]					
crustose	2	3	3	2	3
foliose	4	3	4	2	3
fruticose	2	2	1	3	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	3	2	2	2
Colour aber.	black, brown	black	black, white	black, brown	black, white
Health (p, p-f, f, f-g, g)[3]	f-g	f-g	f-g	f	f-g
Size (s,m,l)[4]	s,m,l	s,m,l	s,m	s	s,m
Branching (f,s,m)[5]	s	m	s	s	m
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps, Em	Hp, Ps	Hp, Ps, Em	Hp, Em	Hp, Ps, Em
Braun-Blanquet[2]					
crustose	3	3	3	4	3
foliose	4	3	4	3	3
fruticose	2	1	2	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	3	2	2	3	2
Colour aber.	black	black, white	black	black, brown	black, white
Health (p, p-f, f, f-g, g)[3]	g	f-g	g	f-g	f
Size (s,m,l)[4]	s,m	s	s	s,m	s
Branching (f,s,m)[5]	s	s	m	s	f
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*
2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5
3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good
4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)
5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 11/17 West Site Number: 0
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Hp, Em	Ps, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	2	1	2	2	2
foliose	2	3	3	3	3
fruticose	2	4	3	3	3
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	1	3	1	2	2
Colour aber.	black, white pink	black, white pink	none	black, white	black, white
Health (p, p-f, f, f-g, g)[3]	p	p-f	f-g	p-f	p-f
Size (s,m,l)[4]	s,m	s,m	s,m	s,m	s,m
Branching (f,s,m)[5]	f	s	m	s	s
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	2	2	2	4	2
foliose	2	2	3	2	3
fruticose	2	3	3	3	3
bryophyte	-	2	-	2	-
H. physodes					
Braun-Blanquet[2]	1	2	3	1	2
Colour aber.	black, white pink	black, white pink	black, pink	black	black, white
Health (p, p-f, f, f-g, g)[3]	p-f	p-f	f-g	p-f	p-f
Size (s,m,l)[4]	s,m	s,m	s,m,l	s	s,m
Branching (f,s,m)[5]	f	s	s	f	f
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 11/17 West Site Number: 1

Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Em	Ps, Hp, Em	Ps, Hp	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	3	4	3	2	4
foliose	3	3	3	3	3
fruticose	2	2	1	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	1	2	1	2	2
Colour aber.	pink	black, yellow	black	black	black, pink
Health (p, p-f, f, f-g, g)[3]	g	p	f-g	f-g	f-g
Size (s,m,l)[4]	m	s,m	s,m	s,m,l	s,m,l
Branching (f,s,m)[5]	s	s	m	m	s
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	3	3	3	2	4
foliose	3	4	3	3	2
fruticose	2	2	2	2	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	2
Colour aber.	white	black, yellow pink	black, white	black, pink	black
Health (p, p-f, f, f-g, g)[3]	g	p-f	f	f	[illegible]
Size (s,m,l)[4]	s,m,l	s,m	s,m	s,m,l	s,m,l
Branching (f,s,m)[5]	s	s	s	m	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 11/17 West Site Number: 2
Tree Species: Pinus banksiana

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	none	none	Em	none	none
Braun-Blanquet[2]					
crustose	3	3	3	2	2
foliose	1	-	+	1	+
fruticose	1	+	2	1	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	1	-	+	1	+
Colour aber.	black	none	black, white	black, white	none
Health (p, p-f, f, f-g, g)[3]	p		p-f	p	p
Size (s,m,l)[4]	s	-	s,m	s	s
Branching (f,s,m)[5]	f	-	s	f	f
Soredia?	yes	no	yes	yes	no
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Em	Hp, Em	Hp, Em	Hp, Em	Hp
Braun-Blanquet[2]					
crustose	3	3	3	2	3
foliose	2	2	1	2	2
fruticose	2	1	2	2	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	1	2	2
Colour aber.	black	black	black, white	black, white pink	black
Health (p, p-f, f, f-g, g)[3]	f	f	p-f	p-f	p-f
Size (s,m,l)[4]	s,m	s,m	s,m	s,m,l	s,m
Branching (f,s,m)[5]	s	m	m	s	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*
2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5
3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good
4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)
5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 11/17 West   Site Number: 3
Tree Species: <u>Betula papyrifera</u>

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp	Ps, Hp	Ps, Hp	Ps, Hp
Braun-Blanquet[2]					
crustose	2	2	2	3	3
foliose	3	4	2	3	3
fruticose	1	1	1	1	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	2
Colour aber.	black	black	pink, white	black	black, white
Health (p, p-f, f, f-g, g)[3]	g	g	p-f	g	[illegible]
Size (s,m,l)[4]	s,m,l	s,m,l	s,m,l	s,m	s,m
Branching (f,s,m)[5]	s	m	s	m	s
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp	Ps, Hp	Ps, Hp	Ps, Hp
Braun-Blanquet[2]					
crustose	3	3	4	4	4
foliose	2	4	2	3	3
fruticose	1	1	1	1	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	1	2	2
Colour aber.	black	black, white	black	white	black, white
Health (p, p-f, f, f-g, g)[3]	g	f	f	f-g	p-f
Size (s,m,l)[4]	s,l	s,m,l	s,m	s,m	s,m
Branching (f,s,m)[5]	s	m	s	m	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 11/17 West Site Number: 4
Tree Species: Pinus banksiana

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	none	Em, Hp	Em, Hp	Em	Em
Braun-Blanquet[2]					
crustose	3	4	3	3	3
foliose	-	2	1	1	1
fruticose	-	2	1	2	1
bryophyte		-	-	-	-
H. physodes					
Braun-Blanquet[2]	-	2	1	1	1
Colour aber.	none	black, white	black, pink	white	pink
Health (p, p-f, f, f-g, g)[3]		f	f	f	f
Size (s,m,l)[4]	-	s,m	s,m	s,m	s,m
Branching (f,s,m)[5]	-	s	s	s	s
Soredia?	no	yes	yes	yes	yes

Tree Number	1	2	3	4	5
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp	Em, Hp	Hp	Em, Hp	Em, Hp
Braun-Blanquet[2]					
crustose	3	4	4	3	4
foliose	2	2	2	2	2
fruticose	-	2	1	3	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	2
Colour aber.	none	black	black, pink	black, white	black, pink
Health (p, p-f, f, f-g, g)[3]	f	f	f	f	f
Size (s,m,l)[4]	s	s,m	s,m	s	s,m
Branching (f,s,m)[5]	s	s	s	f	f
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 11/17 West Site Number: 5
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp, Em	Ps, Hp	Ps, Hp	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	3	3	3	3	2
foliose	3	3	3	2	2
fruticose	1	2	1	1	3
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	1
Colour aber.	black	black	black	none	black
Health (p, p-f, f, f-g, g)[3]	g	f-g	g	g	f-g
Size (s,m,l)[4]	s,m,l	s,m,l	s,m	s,m,l	s,m
Branching (f,s,m)[5]	s	m	m	m	s
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	3	3	2	3	3
foliose	4	4	3	3	3
fruticose	2	2	2	3	3
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	3	2	2	2
Colour aber.	black	white	black, white	black	white
Health (p, p-f, f, f-g, g)[3]	g	g	f-g	g	f-g
Size (s,m,l)[4]	s,m,l	s,m,l	s,m	s,m,l	s,m
Branching (f,s,m)[5]	s	m	s	m	m
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 11/17 East   Site Number: 1
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp, Em	Ps, Hp	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	3	2	2	1	2
foliose	4	2	4	3	2
fruticose	+	1	+	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	1	1	2	1
Colour aber.	black, pink white	white	black, pink	black, white	white
Health (p, p-f, f, f-g, g)[3]	f	f	f	p	f
Size (s,m,l)[4]	s,m,l	s,m	m	m,l	m
Branching (f,s,m)[5]	s	s	s	m	s
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp	Ps, Hp	Ps, Hp	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	3	2	2	2	3
foliose	3	3	3	2	2
fruticose	+	+	+	1	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	2
Colour aber.	black, white pink	black, white pink	black	black, white pink	black, white pink
Health (p, p-f, f, f-g, g)[3]	p	f-g	g	p-f	p-f
Size (s,m,l)[4]	s,m,l	s,m,l	s,m,l	s,m	s,m,l
Branching (f,s,m)[5]	s	s	m	m	m
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 11/17 East Site Number: 2
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	2	3	3	2	4
foliose	2	2	3	3	3
fruticose	1	2	2	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	1	2	2
Colour aber.	black, white	black, brown	black	black	black, white
Health (p, p-f, f, f-g, g)[3]	p-f	f	f	f	f-g
Size (s,m,l)[4]	s,m	s,m	s,m	s,m	s,m,l
Branching (f,s,m)[5]	s	s	s	m	s
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	2	3	3	3	4
foliose	2	3	3	3	4
fruticose	1	2	2	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	3
Colour aber.	black	black, pink	black, white pink	black, white pink	black
Health (p, p-f, f, f-g, g)[3]	f	p-f	p-f	f	f-g
Size (s,m,l)[4]	s,m	s,m	s,m,l	s,m,l	s,m,l
Branching (f,s,m)[5]	s	s	s	s	m
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*
2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5
3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good
4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)
5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 11/17 East   Site Number: 3
Tree Species: <u>Pinus banksiana</u>

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Ps, Hp, Em	Hp	Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	2	3	2	3	2
foliose	3	2	2	2	2
fruticose	2	2	1	1	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	1
Colour aber.	black, brown	black, white	black	black	black
Health (p, p-f, f, f-g, g)[3]	f	f	f	f-g	f
Size (s,m,l)[4]	s,m,l	s,m	s,m	s,m	s,m
Branching (f,s,m)[5]	m	m	s	s	m
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Ps, Hp, Em	Hp, Em	Hp, Em	Hp, Em
Braun-Blanquet[2]					
crustose	3	3	3	3	2
foliose	3	3	2	2	2
fruticose	2	2	1	2	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	1
Colour aber.	black, pink	black, pink white	black, white	black, white pink	black
Health (p, p-f, f, f-g, g)[3]	f	p-f	p-f	p-f	p-f
Size (s,m,l)[4]	s,m,l	s,m,l	s,m	s	s,m
Branching (f,s,m)[5]	s	s	s	s	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 11/17 East   Site Number: 4
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Ps, Hp, Em	Ps, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	3	4	3	3	3
foliose	3	3	2	3	4
fruticose	2	2	2	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	1	1	+	2	2
Colour aber.	black, pink white	black	black	black, white	pink
Health (p, p-f, f, f-g, g)[3]	f	g	g	f-g	g
Size (s,m,l)[4]	s,m	s,m,l	s	s,m,l	s,m,l
Branching (f,s,m)[5]	m	m	m	m	m
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp	Ps, Hp
Braun-Blanquet[2]					
crustose	3	4	3	3	4
foliose	4	4	3	3	3
fruticose	2	2	2	1	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	2
Colour aber.	black, white	black	black, pink	pink	black
Health (p, p-f, f, f-g, g)[3]	f-g	g	g	g	g
Size (s,m,l)[4]	s,m	s,m,l	s,m,l	s,m,l	s,m,l
Branching (f,s,m)[5]	m	m	m	m	m
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 11/17 East   Site Number: 5
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	2	2	2	2	2
foliose	3	3	3	3	2
fruticose	2	2	2	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	3	2	1	2	1
Colour aber.	black, white	brown	black, brown	white	black
Health (p, p-f, f, f-g, g)[3]	g	f	f	f-g	f
Size (s,m,l)[4]	s,m,l	s,m,l	s,m	s,m,l	s,m
Branching (f,s,m)[5]	s	m	m	m	m
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	3	2	3	3	3
foliose	3	3	1	3	2
fruticose	2	2	2	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	1	1	2	2
Colour aber.	brown	none	black	black	black
Health (p, p-f, f, f-g, g)[3]	g	g	f-g	g	f-g
Size (s,m,l)[4]	s,m,l	s	s	s,m,l	s,m
Branching (f,s,m)[5]	s	s	s	m	m
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Mt. McKay
Tree Species: <u>Betula papyrifera</u>

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps	Hp, Ps, Em	Hp, Ps, Em	Hp, Ps	Hp, Ps, Em
Braun-Blanquet[2]					
crustose	1	+	+	1	+
foliose	4	3	2	2	2
fruticose	+	+	1	+	+
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	4	3	1	1	2
Colour aber.	none	black, white	white	white	black
Health (p, p-f, f, f-g, g)[3]	p-f	p-f	g	f-g	[illegible]
Size (s,m,l)[4]	s,m,l	s,m	s,m	s,m,l	s,m,l
Branching (f,s,m)[5]	m	m	s	m	m
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps	Hp	Hp, Ps	Hp, Ps, Em	Hp, Em
Braun-Blanquet[2]					
crustose	3	3	2	3	3
foliose	2	2	3	2	2
fruticose	+	+	+	2	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	2
Colour aber.	none	black, white brown	black	black, white	none
Health (p, p-f, f, f-g, g)[3]	p	p-f	g	f	f-g
Size (s,m,l)[4]	s,m	s	s,m,l	s,m	s,m
Branching (f,s,m)[5]	s	m	m	m	m
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Centennial Park
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	2	2	2	2	3
foliose	3	3	3	2	2
fruticose	3	3	4	3	3
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	1	2	2
Colour aber.	black, white brown	black, white	black, white yellow	black, white	black white
Health (p, p-f, f, f-g, g)[3]	f	p-f	f	f-g	p-f
Size (s,m,l)[4]	s,m,l	s,m	s,m	s,m	s,m
Branching (f,s,m)[5]	s	m	s	m	f
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	3	3	3	3	2
foliose	2	2	3	4	3
fruticose	4	3	3	2	3
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	1	2	3	2
Colour aber.	black	black, white	white	black, white	black
Health (p, p-f, f, f-g, g)[3]	f-g	f	f-g	f-g	f
Size (s,m,l)[4]	s,m	s,m,l	s,m,l	s,m,l	s,m,l
Branching (f,s,m)[5]	s	m	m	m	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Lakehead University
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp	Ps, Hp	Hp	Ps, Hp
Braun-Blanquet[2]					
crustose	2	3	2	3	3
foliose	3	2	2	2	2
fruticose	1	1	1	1	+
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	3	1	1	2	1
Colour aber.	black, white	black, white brown	black, white	black	black, white
Health (p, p-f, f, f-g, g)[3]	f	p-f	p-f	p-f	f
Size (s,m,l)[4]	s,m	s,m	s,m	s,m,l	s,m
Branching (f,s,m)[5]	s	s	s	s	m
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp	Ps, Hp, Em	Ps, Hp	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	2	3	3	3	2
foliose	4	3	2	3	2
fruticose	1	1	2	1	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	3	2	1	2	1
Colour aber.	black, white	black, white	black, white	black	black, white
Health (p, p-f, f, f-g, g)[3]	f	f	p-f	f	p-f
Size (s,m,l)[4]	s,m,l	s,m	s	s,m	s,m
Branching (f,s,m)[5]	s	s	s	f	m
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Sibley (Pass Lake Road) Site Number: 1
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp, Em	Ps, Hp	Ps, Hp, Em	Ps, Hp
Braun-Blanquet[2]					
crustose	3	3	2	4	3
foliose	2	3	3	2	3
fruticose	1	2	1	2	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	2
Colour aber.	white, black brown	black	black, white brown	black, white	white
Health (p, p-f, f, f-g, g)[3]	f-g	f-g	f	f-g	f
Size (s,m,l)[4]	s,m	s,m,l	s,m	s,m	s,m
Branching (f,s,m)[5]	s	m	s	s	s
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Em	Ps, Em	none	Ps, Hp	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	3	4	3	3	3
foliose	2	3	2	3	3
fruticose	2	2	1	1	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	1	1	1	2	3
Colour aber.	white	brown	black, white	black, white brown	black, white brown
Health (p, p-f, f, f-g, g)[3]	f	f	p-f	f-g	f-g
Size (s,m,l)[4]	s	s	s	s,m	s,m
Branching (f,s,m)[5]	f	s	s	s	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*
2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5
3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good
4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)
5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Sibley (Pass Lake Road) Site Number: 2

Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	4	4	3	3	3
foliose	3	3	4	3	4
fruticose	1	2	2	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	3	2	3
Colour aber.	white	black, white brown	black, white brown	black, white brown	black, white brown
Health (p, p-f, f, f-g, g)[3]	f	p-f	p-f	f	p-f
Size (s,m,l)[4]	s	s,m	s,m	s,m	s,m
Branching (f,s,m)[5]	s	s	s	s	s
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Em, Hp	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	4	4	3	4	4
foliose	3	3	4	3	3
fruticose	2	2	2	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	3	2	2
Colour aber.	white	black, white brown	black, white brown	black, white brown	black, white brown
Health (p, p-f, f, f-g, g)[3]	f	p-f	p-f	f	f
Size (s,m,l)[4]	s,m	s,m	s,m,l	s,m	s,m,l
Branching (f,s,m)[5]	f	s	s	s	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 527 North   Site Number: 0
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp	Hp, Em	Hp, Em, Ps	Hp, Em, Ps	Hp, Em
Braun-Blanquet[2]					
crustose	1	2	1	2	2
foliose	1	1	2	2	2
fruticose	+	1	1	2	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	1	1	1	1	2
Colour aber.	black, pink	black, white	black, white	black	black
Health (p, p-f, f, f-g, g)[3]	f	p-f	p	f	f-g
Size (s,m,l)[4]	s,m	s,m	s,m	s,m	s,m
Branching (f,s,m)[5]	s	s	s	s	s
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp, Em	Ps, Hp	Ps, Hp	Ps, Hp; Em
Braun-Blanquet[2]					
crustose	2	3	2	3	3
foliose	3	1	2	2	2
fruticose	1	1	1	1	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	1	1	1	1
Colour aber.	black	black, white pink	black, white	black, yellow	black, white yellow
Health (p, p-f, f, f-g, g)[3]	f	p	p-f	f	f
Size (s,m,l)[4]	s,m,l	s,m	s,m	s,m	s,m
Branching (f,s,m)[5]	m	f	s	m	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 527 North   Site Number: 1
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp, Em	Ps, Hp
Braun-Blanquet[2]					
crustose	+	+	2	2	1
foliose	3	2	3	4	3
fruticose	1	1	1	2	+
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	1	2	2	2	2
Colour aber.	none	black, yellow	black, yellow	black, yellow	black, brown
Health (p, p-f, f, f-g, g)[3]	f	f	f-g	g	f
Size (s,m,l)[4]	s	s,m,l	s,m,l	m,l	s,m,l
Branching (f,s,m)[5]	s	s	m	m	m
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp	Ps	Ps, Hp	Ps, Hp
Braun-Blanquet[2]					
crustose	2	3	3	2	2
foliose	3	3	2	2	2
fruticose	1	1	+	-	1
bryophyte	-	-	-		
H. physodes					
Braun-Blanquet[2]	1	2	1	2	1
Colour aber.	black, white	black, white brown	black, pink	black, white	black, yellow
Health (p, p-f, f, f-g, g)[3]	f	f	p-f	f-g	f
Size (s,m,l)[4]	s,m,l	s,m,l	s,m	l	s,m,l
Branching (f,s,m)[5]	m	m	f	m	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 527 North   Site Number: 2
Tree Species: Pinus banksiana

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Em	Em	Hp, Em	Hp, Em	Hp
Braun-Blanquet[2]					
crustose	1	3	3	3	3
foliose	2	2	2	2	1
fruticose	1	1	2	1	+
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	+	1	2	1	1
Colour aber.	black	none	black	black, pink	black, pink
Health (p, p-f, f, f-g, g)[3]	f	p-f	f-g	f	f
Size (s,m,l)[4]	s,m	s	m,l	s,m	s,m
Branching (f,s,m)[5]	f	f	s	s	f
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Em	Hp, Em	Hp, Em	Hp, Em	Hp
Braun-Blanquet[2]					
crustose	3	3	3	3	3
foliose	2	2	2	2	2
fruticose	1	1	2	1	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	1	2	2	2	1
Colour aber.	black, white	black, white pink	black	black	black
Health (p, p-f, f, f-g, g)[3]	f	p-f	f	f	f
Size (s,m,l)[4]	s,m	s,m,l	s,m	s,m	s,m
Branching (f,s,m)[5]	f	s	f	s	f
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*
2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5
3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good
4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)
5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 527 North Site Number: 3
Tree Species: <u>Pinus banksiana</u>

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Em	Hp, Em	Ps, Em, *Alectoria* spp.	Em, *Alectoria* spp.	Em
Braun-Blanquet[2]					
crustose	3	2	2	3	2
foliose	1	2	2	1	2
fruticose	1	1	3	3	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	1	2	+	+	1
Colour aber.	black	black	black	black	black
Health (p, p-f, f, f-g, g)[3]	g	g	f	p-f	f
Size (s,m,l)[4]	s,m	s,m,l	s	s	s
Branching (f,s,m)[5]	s	m	s	f	s
Soredia?	yes	yes	no	no	no
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Em	Hp, Em, *Alectoria* spp.	Hp, Em, *Alectoria* spp.	Hp, *Alectoria* spp.	Hp, Em
Braun-Blanquet[2]					
crustose	4	3	3	3	2
foliose	2	2	2	1	2
fruticose	1	1	2	2	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	1	2
Colour aber.	black	black	black, pink	black	black
Health (p, p-f, f, f-g, g)[3]	g	g	g	g	f-g
Size (s,m,l)[4]	s,m	s,m,l	s,m,l	s,m,l	s,m
Branching (f,s,m)[5]	s	s	s	m	f
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata* Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 527 North   Site Number: 4
Tree Species: Pinus banksiana

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps	Hp	Hp, Em, *Alectoria* spp.	Hp	Hp, Ps, Em
Braun-Blanquet[2]					
crustose	2	2	2	3	2
foliose	2	1	1	2	3
fruticose	1	+	3	1	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	1	1	2	1
Colour aber.	black	black	none	black	black
Health (p, p-f, f, f-g, g)[3]	f	f	f	f	f-g
Size (s,m,l)[4]	s,m	s,m	s,m	s,m	s,m,l
Branching (f,s,m)[5]	f	f	f	s	m
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps, Em	Hp	Hp, Em, *Alectoria* spp.	Hp, Ps	Hp
Braun-Blanquet[2]					
crustose	3	3	3	3	3
foliose	3	1	2	2	3
fruticose	1	+	2	1	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	1	2	2	2
Colour aber.	black, white	black	none	black, pink	black
Health (p, p-f, f, f-g, g)[3]	p-f	f	f	f	f-g
Size (s,m,l)[4]	s,m	s,m	s,m	s,m	s,m,l
Branching (f,s,m)[5]	f	f	f	s	m
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 527 North   Site Number: 5

Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps	Hp, Ps	Hp, Ps	Hp, Ps	Hp, Ps
Braun-Blanquet[2]					
crustose	3	2	2	2	2
foliose	2	3	1	3	1
fruticose	+	1	1	+	+
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	1	1	1	2	1
Colour aber.	black	black	none	black	black
Health (p, p-f, f, f-g, g)[3]	f-g	g	g	f	f
Size (s,m,l)[4]	s,m	s,m	s,m,l	s,m	s
Branching (f,s,m)[5]	s	m	s	s	s
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp, Em	Ps, Hp	Ps, Hp, Em	Ps, Hp
Braun-Blanquet[2]					
crustose	3	3	3	3	3
foliose	3	2	2	2	2
fruticose	2	2	1	2	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	2
Colour aber.	black	black	black	black	black
Health (p, p-f, f, f-g, g)[3]	g	g	f-g	f-g	f-g
Size (s,m,l)[4]	s,m,l	s,m,l	m,l	s,m	m,l
Branching (f,s,m)[5]	s	m	m	s	m
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 61 South   Site Number: 0
Tree Species: <u>Betula papyrifera</u>

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp	Ps, Hp	Ps, Hp	Hp, Em
<u>Braun-Blanquet</u>[2]					
crustose	3	4	4	3	3
foliose	2	2	3	2	2
fruticose	1	1	1	1	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	1	2	1	2
Colour aber.	yellow, white	black, white	black, white pink	black, white	orange, white
Health (p, p-f, f, f-g, g)[3]	f-g	p-f	p-g	p-f	p-f
Size (s,m,l)[4]	s,m	s, m	s,m,l	s	s,m
Branching (f,s,m)[5]	s	s	s	s	s
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps	Hp, Ps	Hp, Ps	Hp, Ps, Cp	none
<u>Braun-Blanquet</u>[2]					
crustose	3	4	4	4	3
foliose	3	2	2	2	2
fruticose	1	1	1	1	+
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	3	1	2	1	+
Colour aber.	white, black pink	black, white	black, white	black, white	none
Health (p, p-f, f, f-g, g)[3]	f-g	p	p-f	p-f	p
Size (s,m,l)[4]	s,m,l	s,m	s,m	s,m	s
Branching (f,s,m)[5]	s	s	s	s	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 61 South   Site Number: 1
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Ps, Hp	Ps, Em	Ps, Hp, Em	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	3	3	3	3	2
foliose	4	3	3	4	3
fruticose	2	3	2	3	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	1	2	1
Colour aber.	brown, white	black, white	white	brown, white black	black
Health (p, p-f, f, f-g, g)[3]	f-g	f-g	f	f	g
Size (s,m,l)[4]	s,m	s,m	s,m	s,m,l	s,m
Branching (f,s,m)[5]	m	m	s	m	m
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Em, Hp	Ps, Em, Hp	Ps, Em, Hp	Ps, Em, Hp	Ps, Em
Braun-Blanquet[2]					
crustose	3	3	4	3	4
foliose	4	2	3	4	2
fruticose	2	2	2	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	3	2	2	2	+
Colour aber.	brown, black yellow, white	black	white, brown	brown, white black	none
Health (p, p-f, f, f-g, g)[3]	f	f-g	f	f-g	f
Size (s,m,l)[4]	s,m,l	s,m	s,m	s,m	s
Branching (f,s,m)[5]	m	m	s	m	s
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 61 South   Site Number: 2
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Hp	Em, Hp	Ps, Hp	Ps, Hp
Braun-Blanquet[2]					
crustose	2	2	3	3	3
foliose	2	2	2	3	3
fruticose	+	-	2	1	1
bryophyte	-	-	-	-	
H. physodes					
Braun-Blanquet[2]	2	2	1	2	3
Colour aber.	black	black, white	black	none	black
Health (p, p-f, f, f-g, g)[3]	f	p-f	f	f-g	[illegible]
Size (s,m,l)[4]	s,m,l	s,m	s	s,m	s,m,l
Branching (f,s,m)[5]	s	s	f	f	m
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp, Em	Ps, Em	Hp, Em	Ps, Hp, Em	Hp, Em
Braun-Blanquet[2]					
crustose	3	4	3	3	3
foliose	3	2	3	3	4
fruticose	2	2	3	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	1	3	3	4
Colour aber.	black, white	black, white	black	none	black, white
Health (p, p-f, f, f-g, g)[3]	p-f	f	f	f-g	f-g
Size (s,m,l)[4]	s,m,l	s	s,m,l	s,m	s,m,l
Branching (f,s,m)[5]	m	f	s	s	m
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 61 South   Site Number: 3

Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp, Em	Ps, Hp, Em	Ps, Em	Ps, Em, Hp
Braun-Blanquet[2]					
crustose	3	3	4	2	3
foliose	3	4	3	2	2
fruticose	1	2	2	1	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	1	2	2	1	2
Colour aber.	black	white, black	black	black	black
Health (p, p-f, f, f-g, g)[3]	f	p-f	g	f-g	f
Size (s,m,l)[4]	s,m	s,m	s,m,l	s,m	s,m
Branching (f,s,m)[5]	s	f	m	m	f
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Hp, Ps, Cp	Hp, Ps, Cp	Hp, Ps, Em	Hp, Ps, Em	Hp, Ps, Em
Braun-Blanquet[2]					
crustose	3	3	3	3	4
foliose	4	3	4	2	3
fruticose	1	1	2	2	2
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	2	2	2
Colour aber.	white, yellow black	black	white, brown	white, black	black, white
Health (p, p-f, f, f-g, g)[3]	f	f-g	f-g	f	f
Size (s,m,l)[4]	s,m	s,m,l	s,m	m	s,m,l
Branching (f,s,m)[5]	s	s	s	s	f
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*

2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5

3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good

4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)

5 f = few, s = some, m = many

Morphological data for upper north and lower north quadrats as collected in the Thunder Bay area

Site Location: Highway 61 South   Site Number: 5
Tree Species: Betula papyrifera

Tree Number	1	2	3	4	5
Upper North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp, Em	Hp, Ps	Ps, Hp	Ps, Hp, Em
Braun-Blanquet[2]					
crustose	3	3	2	2	3
foliose	3	4	3	4	2
fruticose	1	2	1	1	1
bryophyte	-	-	-	-	-
H. physodes					
Braun-Blanquet[2]	2	2	3	2	2
Colour aber.	black	black	black	white, black	none
Health (p, p-f, f, f-g, g)[3]	g	g	g	f-g	g
Size (s,m,l)[4]	s,m	s,m	m,l	s,m	s,m
Branching (f,s,m)[5]	s	s	m	m	m
Soredia?	yes	yes	yes	yes	yes
Lower North					
Maj. Epiphytes (Ps, Em, Hp, Cp)[1]	Ps, Hp	Ps, Hp, Em	Ps, Hp	Ps, Hp, Em	Ps, Hp
Braun-Blanquet[2]					
crustose	3	4	2	3	3
foliose	3	3	2	3	3
fruticose	2	3	1	2	1
bryophyte	-	-	-	-	
H. physodes					
Braun-Blanquet[2]	2	1	1	2	2
Colour aber.	black	none	none	black, brown	black
Health (p, p-f, f, f-g, g)[3]	g	g	g	g	g
Size (s,m,l)[4]	s,m,l	s,m	s,m	s,m,l	s,m
Branching (f,s,m)[5]	m	s	m	m	m
Soredia?	yes	yes	yes	yes	yes

1 Ps = *Parmelia sulcata*   Cp = *Cetraria pinastri*
Em = *Evernia mesomorpha*
Hp = *Hypogymnia physodes*
2 Braun-Blanquet Cover Scale: <1% = +, 1-5% = 1, 6-25% = 2, 26-50% = 3, 51-75% = 4, 76-100% = 5
3 p = poor, p-f = poor to fair, f = fair, f-g = fair to good, g = good
4 s = small (< 2 cm.), m = medium (2-4 cm.), l = large (> 4 cm.)
5 f = few, s = some, m = many