Bryophytes encountered by the Wildlands League along the Cat River system in north west Ontario July, 2002

Prepared for the Wildlands League

Jennifer Doubt
Devonian Botanic Garden
University of Alberta
Edmonton, Alberta
T6G 2E1

SUMMARY

Bryophytes (small plants, including mosses, liverworts, and hornworts), though small in stature, comprise a significant proportion of biomass in the boreal forest and are integral to ecosystem function. This report documents bryophytes encountered by a Wildlands League (a chapter of the Canadian Parks and Wilderness Society) expedition along a remote stretch of the Cat River through Ontario's north west boreal forest, about 500km north west of Thunder Bay. This region would be affected by proposed changes to forestry legislation which would allow cutting of previously protected forests. Bryophytes were collected in an ad-hoc manner as permitted by the logistics of the trip. The following findings were made:

- **101 moss and 17 liverwort species were collected**, demonstrating high species diversity. This number is quite high, considering the time available for sampling and the size of regional and provincial species pools. The list would certainly be significantly expanded by further attention to the area.

- Most species encountered on the expedition occur widely throughout the province, but **two species, *Tetraplodon mnioides* and *Pohlia sphagnicola*, are considered to be northern species in Ontario**.

- **Three species tracked by the Ontario Natural Heritage Information Centre were encountered: *Pohlia sphagnicola, Sphagnum contortum, Tetraplodon mnioides*.** Seven species were ranked 'S3' or higher, meaning that they are classified as by the Natural Heritage Information Centre as 'rare to uncommon'.

- Very few collecting records of any species, regardless of rarity, exist for the area surveyed on this trip. The information gathered therefore **contributes significantly to understanding of the flora of the area, and of species distribution in Ontario.**

- Although rocky shoreline coniferous forests were most accessible and therefore were most frequently sampled, significant species and high richness was distributed among several habitat types and demonstrated no bias for frequently sampled habitat types. Instead, **sites atypically rich in microhabitats contributed significantly to the diversity captured on this trip, and should be targeted in future surveys**.

- Intensive sampling of individual sites may have contributed to the discovery of significant species and high richness.

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INTRODUCTION

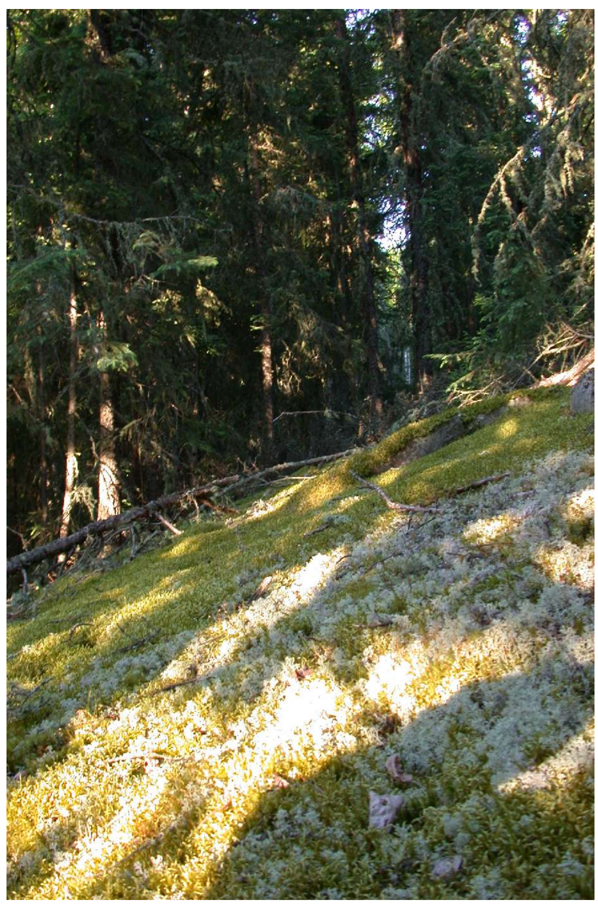
Bryophytes are small plants

Mosses, liverworts and hornworts are collectively known as 'bryophytes' or 'non-vascular plants'. To a lay-person they are generally distinguished as small (less than 15 cm tall), green plants. Bryophytes owe their characteristically diminutive stature to several factors (Figure 1) that help to define them as a group:

1. The term 'non-vascular' refers to the fact that many bryophyte species have poorly-developed vascular (water conducting) systems. Instead of transporting water and nutrients internally between roots and shoots like many other (i.e.vascular) land plants, bryophytes absorb moisture (and associated nutrients) directly through their stems and leaves from their immediate environment. Not only does a poor water conducting system make it impossible for bryophytes to distribute and maintain food and water throughout a large and complex plant, but it also diminishes the structural support available to build a large plant in the first place. While some bryophyte species have poor conducting tissue, it can be quite well developed in others. Non-vascular plants are therefore not well defined by their lack of vasculature alone.

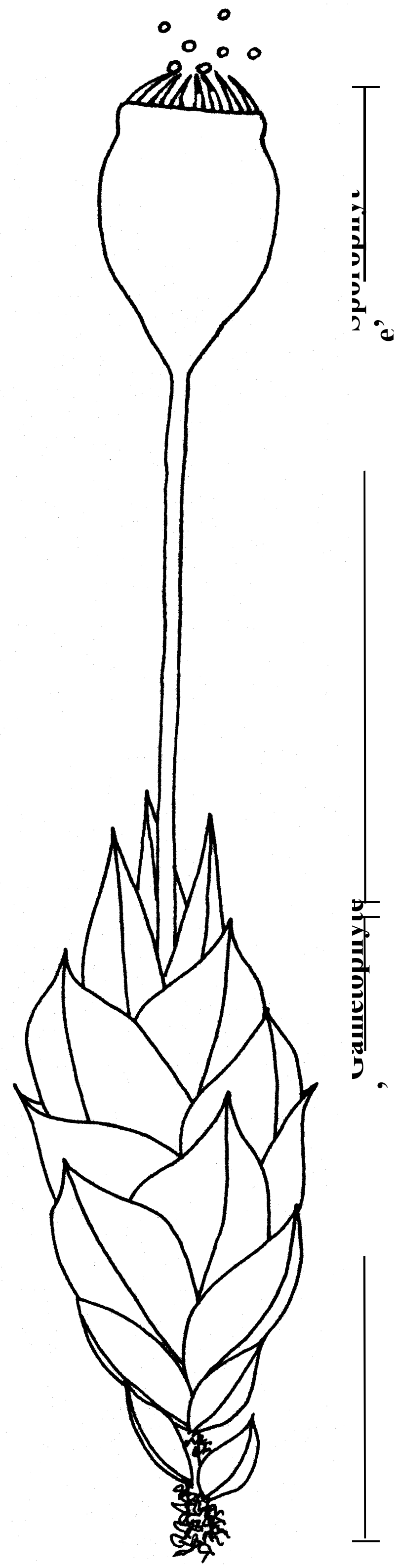
2. Unlike most other land plants, bryophytes produce swimming sperm. In some cases the egg and sperm occur in different parts of the plant, or on different plants altogether. A continuous water film through which swimming bryophyte sperm could travel to fertilize bryophyte eggs is only likely to occur if the plants are small.

3. Upon fertilization, bryophytes develop a structure called a 'sporophyte' (Figure 1) that produces spores. The sporophyte is attached to and dependent on the leafy 'gametophyte' throughout it's existence, and is therefore limited in size by the size of this supporting plant (Figure 1).



Bryophytes (and lichens) carpet many boreal coniferous forests.

Figure 1. Basic structure of a moss plant, comprised of two contrasting developmental stages: sporophyte and gametophyte. Features that contribute to the characteristically small stature of bryophytes are italicized.



'Sporophyte'

Not green at maturity; Not leafy
Depends on leafy plant (gametophyte) throughout its existence. *The size of the sporophyte is limited by the small size of the supporting leafy plant.*
Not always present

Function
Produces spores for dispersal and establishment of new plants

Origin
Results from growth of a fertilized egg in the green, leafy part of the plant

'GAMETOPHYTE'

Green, leafy plants
Not dependent on another plant (free living)
Always present

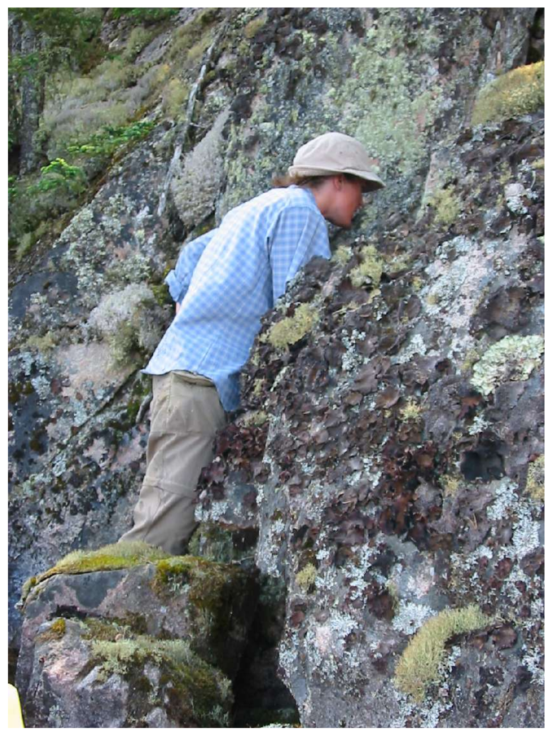
Function
Produces egg and swimming sperm for sexual reproduction. *Tall plants would prevent swimming sperm from moving through water films between male and female plant parts, which may occur on separate plants.*
Responsible for vegetative growth and reproduction. *Poor vascular tissue in many species prevents the distribution of water and nutrients internally to a large body.*

Origin
Results from the germination of a spore from the sporophyte.

Ecological importance of bryophytes

The small size of individual moss, liverwort, and hornwort plants has led many people to believe that they are ecologically unimportant. However, bryophytes actually dominate some plant communities in terms of their productivity, biomass, and/or cover, which can approach or exceed that of vascular plants (e.g. Forman 1969, La Roi & Stringer 1976, Lee & La Roi 1979, Oechel & Sveinbjornsson 1978, Slack 1988, Stringer & Stringer 1974), particularly at high latitudes and altitudes. By virtue of their abundance, in some cases, and of their mere presence in others, bryophytes are critical to ecosystem function especially in boreal habitats (e.g. Okland & Eilertsen 1993). Here are just a few examples:

<ins>Growth in harsh environments</ins> – The ability of many bryophytes to survive environmentally harsh conditions, and to avoid them by occupying sheltered microhabitats too small to accommodate most vascular plants, make them successful in environments inhospitable to almost all other organisms. For example, the extremes in temperature, solar radiation, and moisture, the anaerobic soil conditions, and the short growing seasons characteristic of arctic and alpine environments are more favourable to bryophytes than to vascular plants (Oechel & Sveinbjornsson 1978).


Bryophytes can colonize exposed, inhospitable substrates, where virtually no other plants can grow.

<ins>Plant community succession</ins> - Their tolerance for harsh environments also allows bryophytes to colonize other kinds of barren substrates, either recently disturbed (e.g. fire, flood) or newly created (e.g. gravel deposited by a river). By establishing themselves, bryophytes may stabilize soil, protect it from erosion, and insulate it from frost, making the substrate conducive to colonization by other organisms to form more mature communities (references in Longton 1992, and Slack 1988). In other cases, bryophytes insulate soils from thawing and suppress other plants. In both cases, bryophytes help to regulate plant and animal community development (Hörnberg et al. 1997).

Nutrient cycling – Non-vascular plants are often associated with nitrogen-fixing micro-organisms, which transform nitrogen into a form usable by most plants (e.g. Slack 1988, Billington & Alexander 1978). In some coniferous forests where nitrogen is a limiting nutrient, nitrogen fixation associated with bryophytes and lichens is very important for all resident organisms (Granhall & Lindberg 1978). Bryophytes also contribute significantly to the flow of energy and nutrients in boreal ecosystems through leaching and decomposition (e.g. Forman 1969, references in Slack 1988). Nutrient movement among mosses in some boreal and tundra communities can match that among vascular plants (e.g. Chapin et al. 1980, references in Slack 1988).

Moisture regime - Bryophytes also contribute significantly to the flow of moisture in boreal ecosystems (e.g. Forman 1969, references in Slack 1988). Their significant water-holding capacity (references in Slack 1988), and their ability to shield soils from moisture loss help to determine the character of plant and animal communities.

Food chains – Invertebrates such as insects commonly eat moss, and although bryophytes are thought to have low energy content (and to taste bad! (Crum 1973)), they are also sometimes used by vertebrate herbivores. Fat-rich bryophyte spores are selectively harvested by some rodents (references in Slack 1988), and moss plants may provide valuable fatty acids to several mammal (e.g. caribou, muskox) and bird (e.g. goose) species of cold environments (Prins 1982).

Shelter and nesting – Birds and small mammals collect bryophytes as nesting and bedding material. Many invertebrate species rely on bryophytes as a site for feeding, mating, and egg-laying, and fascinating details of bryophyte-invertebrate relationships are discussed by Gerson (1982). These invertebrates are, in turn, important to organisms higher in the food chain (references in Slack 1988).

Carbon sequestration – Bryophytes, especially *Sphagnum* species, are primary components of peat in many boreal and sub-arctic peatlands. The cool, anoxic conditions prevalent just below the vegetation surface in peatlands cause organic matter to accumulate rather than decompose. Carbon is said to be *sequestered* in this situation, because plants remove carbon from the atmosphere for their growth, but do not release it (Gorham 1991). Today boreal forests contain one of the largest carbon pools (200 – 500 gigatons) in the terrestrial biosphere (Dixon et al. 1994, Goulden et al. 1998). Global warming (and associated fire disturbance) and human activities have the potential to disrupt the carbon balance of these ecosystems, releasing vast amounts of carbon into the atmosphere (Goulden et al. 1998, Gorham 1991, Harden et al. 2000).

Biodiversity – Like vascular plants, bryophytes represent a substantial proportion of floral diversity, particularly in northern ecosystems (Newmaster and Bell 2002). The Ontario flora includes about 540 mosses and 130 liverwort species (Newmaster and Bell 2002, Ontario Natural Heritage Information Centre 2002).

Sphagnum (peat moss) species, such as the pinkish-red plants shown in this picture, dominate peatland habitats like bogs, where vast amounts of carbon are stored. (Jeff Heinlen photo)

Economic and cultural applications

Bryophytes, which are stunningly attractive on many scales, lend high aesthetic value to our natural and manicured landscapes. However, they are also harvested for a wide variety of economic and cultural applications. Peat, of which bryophytes are a significant component, is mined for heating and horticulture, and large volumes of moss are harvested each year for the floral and craft industries (Peck 1997). *Sphagnum* has been used traditionally and contemporarily as an absorbent in diapers and feminine hygiene products. Aboriginal people also used *Sphagnum* to extend tobacco, dress wounds, treat infection, smoke meat, and chink cabin walls (Marles et al. 2000). Traditional uses for other bryophyte species range from scrubbing pots to creating camoflage to repelling insects to refrigeration (Marles et al. 2000).

Without extensive root systems, bryophytes are excellent indicators of the immediate environmental conditions in the microsites they occupy. Through changes in their abundance, richness, or species composition, bryophytes can be used to detect environmental change (e.g. Stephenson et al. 1995 (acidification), Dirske & Martaki 1992, Bowden et al. 1994 (nutrient enrichment), LeBlanc et al. 1974, Hallingbäck 1992 (pollution), Engelmann & Weaks 1985 (mining), Forbes 1994 (mechanical human disturbance)). The value of bryophytes for indicating habitat condition such as old-growth and ecosystem health has also been investigated by several groups (e.g. Crites & Dale 1998, Rambo & Muir 1998). La Roi & Stringer (1976) contend that "ecologically and geographically meaningful classifications of boreal coniferous forests can be based on the bryophyte component alone". Bryophytes also make good collectors of atmospheric pollutants (Onianwa 2001), and many authors (e.g. Lippo *et al.* 1995;

references cited in Pott & Turpin 1996 & 1998; Berg *et al.* 1996; Berlekamp *et al.* 1998; references cited in Økland *et al.* 1999) have analysed pollutant (e.g. heavy metal) content in bryophytes to examine pollution patterns on local and regional scales.

Boreal bryology

Longton (1992) writes "nowhere is the importance of mosses and lichens greater than in polar tundra and in northern forests and mires…". Although it accounts for almost half of Ontario's area, and although bryophytes comprise such an important component of boreal ecosystems, the boreal forest is bryologically under-explored (Schofield 1972). Floristic exploration – documenting the species present - has been minimal. Schofield (1972) reported that bryophyte collections from the Canadian mainland arctic and adjacent boreal forest were limited to a large number of small collections incidental to the projects of non-bryologists, and to a few unreported comprehensive collections by bryologists (people who specialize in bryophytes). Neither the studies referenced by Schofield (1972), nor most recent contributions to bryophyte floristics in boreal Canada focus on north west Ontario, although, notably, Newmaster and Bell (2002) studied patterns of diversity with respect to forestry practices near Thunder Bay, and lists assembled by Crowe (1992a,b) of mosses and liverworts of the Thunder Bay area indicate a strong history of local collecting there.

Bryophytes are quantitatively and qualitatively important in boreal ecosystems, but they are infrequently studied.

Although limited access still presents a barrier to investigation of many reaches of the boreal forest, the same barriers have delayed habitat change by human activity and development. Current proliferation of mining, forestry, and power generation in boreal forests will substantially affect bryophyte inhabitants. In view of the current interest in biodiversity and sustainability, therefore, it seems odd that efforts to capture the diversity of the relatively untouched reaches of the boreal forest have been so few. In the absence of this research, the ecoregion is often thought to be bryologically homogeneous and uninteresting to the extent that it is sometimes known as the 'boring forest'. Conservation priorities have become skewed as a result.

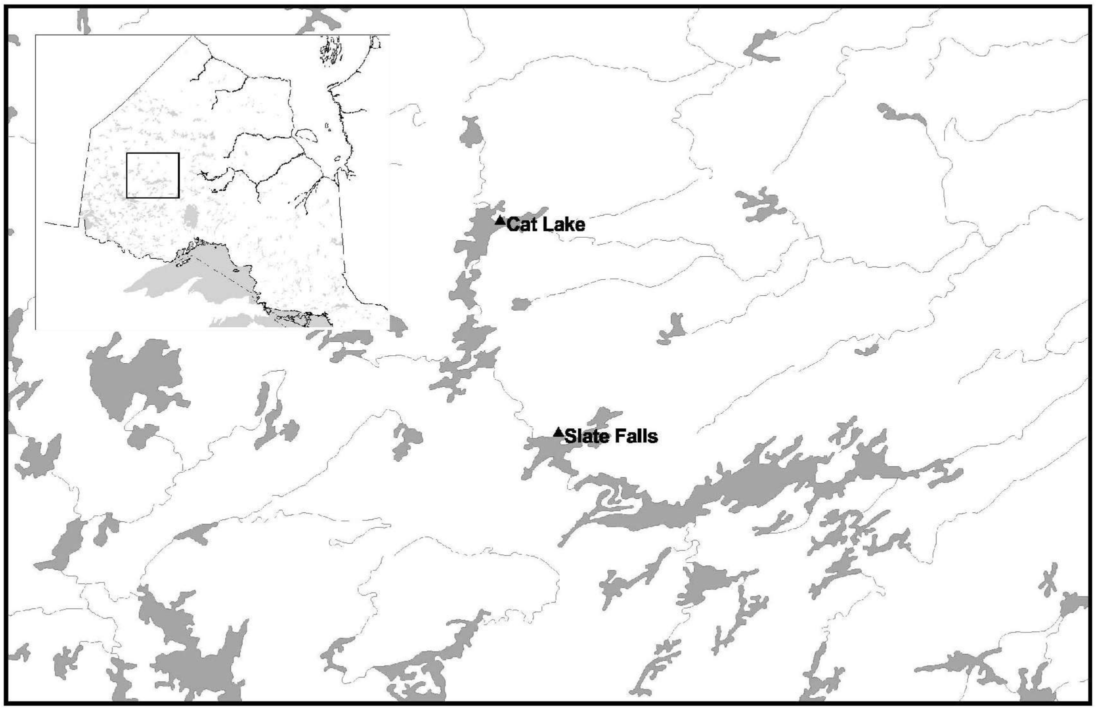
Wildlands League Cat River expedition: bryophyte component

In July, 2002, the Wildlands League (a chapter of the Canadian Parks and Wilderness Society) undertook a canoe reconnaissance of a 76 km section of the Cat River System in north west Ontario. The trip was inspired partly by proposed changes to the current 'cut line' crossing Ontario at about 51° latitude, above which logging is not currently permitted. In anticipation of imminent change, the Wildlands League initiated a series of journeys through the boreal forest to gain biological (e.g. plants, fish, birds, and forest communities) and cultural knowledge of the northern boreal forest and its ecology. This information will aid in drawing attention to the unique features of the region and aid greater public awareness of the value of the far north. This report documents the bryophytes encountered on the trip.

METHODS

Study area

The canoe route began near Pesew Falls, in the north, and ended in the community of Slate Falls, in the south (Figure 2). Precise co-ordinates for many of the collecting locations, including the start and end points of the journey, are given in Appendix 2. The river system in this region consists of island-filled lakes connected by narrow channels. Five portages were necessary. Shorelines are dominated by coniferous forest and exposed precambrian rock. Eskers and low cliffs interspersed with peat lowlands contribute topographic variability. Vegetation is generally typical of the boreal forest, and was dominated by black spruce (*Picea mariana*), aspen (*Populus tremuloides*), larch (*Larix laricina*), and jack pine (*Pinus banksiana*), with more sparse occurrences of white cedar (*Thuja occidentalis*) and white birch (*Betula papyrifera*). Local climate and drainage conditions occasionally support atypical plant communities characterized by other species. The climate of the region is described as continental, with hot summers, cold winters, and limited precipitation falling mainly during the summer (Kemp 1993).



e 2. Location of the survey (inset), and a map showing the surveyed route, which ran from north of Cat Lake, in the north, to the community of Slate Falls, in the south.

Sampling approach

Sampling was conducted largely on an ad-hoc basis, with site selection and effort devoted to each site dictated by logistical considerations such as paddling time required on a given day and the sampling of other biota. Generally, species of interest were collected along the way when time permitted, with several more concentrated efforts at individual sites. In the latter case, site boundaries were defined by the boundaries of the general habitat type. When the habitat was unmanageably large, a representative area of the habitat was sampled. Within a site, all representatives of all microhabitat types (e.g. rotten logs, hard logs, snags, tree bases, tree branches, boulders, cliff faces, crevices in rock) present were examined carefully and resident mosses and liverworts were recorded or samples were collected for later identification.

Analysis

Bryophytes were identified according to Crum and Anderson (1981), for mosses, with additional reference to Koponen (1974), Nyholm (1954), and Ireland (1969) for certain taxonomic groups, and according to Schuster (1977), for liverworts, with additional reference to Schofield (2002) where necessary. Species names were standardized to North American checklists for mosses (Anderson et al. 1990), the moss genus *Sphagnum* (Anderson 1990), and liverworts (Stottler & Crandall-Stottler 1980). Specimens will be deposited at the University of Alberta Devonian Botanic Garden.

Quantitative analyses were not possible given the inconsistent sampling approach. The value of the data gathered on this trip was determined by placing the species captured in the context of provincial and regional floras. Significant species were identified by referring to Ontario Natural Heritage Information Centre (2002) sub-national ranks, the Ontario moss atlas (Ireland and Ley 1992), and lists of mosses and liverworts of the Thunder Bay region obtained from Lakehead University (Crowe 1992a,b). Significant sites (high species diversity or significant species) were noted.

RESULTS AND DISCUSSION

Species diversity

118 bryophyte species were recorded on this trip, including 101 mosses and 17 liverworts. The number of liverwort species is significantly underrepresented due to the presence of several as yet unidentified specimens, notably *Lophozia*, *Cephalozia*, and *Cephaloziella* species, which will require additional expert attention.

Given the constraints placed on sampling, the bryophyte diversity captured on the trip is quite high, representing almost twenty percent of the provincial moss flora (Ontario Natural Heritage Information Centre 2002). Similarly, Schofield (1972) estimated that the relatively uniform bryoflora of boreal and arctic North America consisted of just over 500 mosses and 200 liverworts, and Crowe (1992a,b) lists 290 mosses and 103 liverworts for the Thunder Bay district. Given that such a large proportion of potential moss species were collected within such limiting time contraints, in what is commonly thought to be a taxonomically uninteresting ecoregion, the Cat River study area appears to support relatively high bryophyte species diversity. Concerted effort to sample all available microhabitat types along the system will undoubtedly add many more species to this preliminary list.

The high number of species discovered through this limited study may be related to several factors:

1. Habitats accessible by canoe are naturally diverse: Riparian areas such as the margins of the Cat River are subject to periodic disturbance, leading to a diverse array of habitats and substrates at varying successional stages (e.g. Kimmerer & Allen 1982). For example, gaps created by periodic disturbance by floodwater facilitate colonization by opportunistic species that would otherwise be out-competed (Kimmerer & Allen 1982).
2. Sampling was not constricted to plots, allowing for directed searches to maximize species capture in limited time.

3. Attempts were made to sample a variety of habitat types (as defined by stand moisture, dominant overstory, dominant substrate, stand age) throughout the geographic range of the study area. Inclusion of a single aspen-dominated stand, for example, accounts for nine of the species listed for the trip.
4. The study area occupies transition zones. The presence of limited white cedar, and scattered atypical plant communities reflect affinity of some areas sampled with more southern vegetation. Furthermore, La Roi and Stringer (1976) discovered floristic discontinuities in the Lake Superior region. In their study of boreal North American forest plots, the western boundaries of several eastern species and the eastern boundaries of several western species occurred in this area. The transitional position of the study area may enhance habitat variability, resulting in greater potential for species richness.

Cover of bryophytes was not measured on this trip, but many boreal plant communities support an almost continuous carpet of moss. Bryophyte richness is not generally correlated with bryophyte cover (e.g. La Roi & Stringer 1976), with a few common species generally accounting for the overwhelming majority of area covered by non-vascular plants.

Feather mosses (Knight's Plume, Stair Step) growing with *Sphagnum* species. (Natalie Cleavitt & Robert Wesley photo)

Significant species

Observations of all species found on this trip are significant in that very few species occurrence records are known from this area of the province, as indicated in the Ontario moss atlas (Ireland & Ley 1992). Similarly, only two rare non-vascular plant species (neither of which were encountered on this trip) are listed by the Ontario Natural Heritage Information Centre (2002) for all of Kenora County, in which the study area occurs.

According to the Ireland and Ley (1992) classification of Ontario mosses by provincial distribution, the greatest proportion (about 75%) of the moss species found by the Wildlands League along the Cat River system show a widespread distribution throughout Ontario (Ireland & Ley 1992, Figure 3a). About 12% (e.g. *Andreaea rupestris, Cynodontium strumiferum, Grimmia unicolor, Paraleucobryum longifolium, Racomitrium heterostichum, Rhabdoweisia crispata*) have a widespread distribution with a northern bias (Figure 3b), while approximately 10% (e.g. *Atrichum tenellum, Brachythecium acuminatum, Brotherella recurvans, Callicladium haldanianum, Ditrichum pusillum*) are widespread in the province with a bias to the south (Figure 4a). Only two species (*Pohia sphagnicola, Tetraplodon mnioides*) found on this trip, or about 2%, are not classified as widespread, and instead show a northern in distribution (Figure 4b).

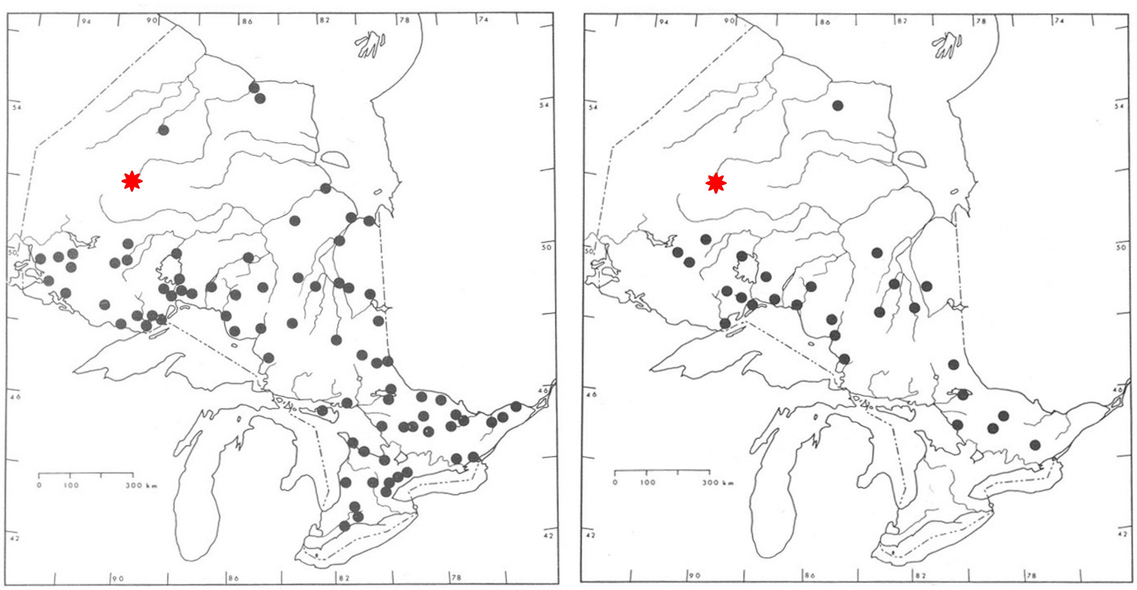


Figure 3. Approximate provincial distributions of a. *Ptilium crista-castrensis* (widespread throughout Ontario) and b. *Racomitrium heterostichum* (widespread with a bias toward the north). Illustrations from Ireland and Ley 1992. The sunburst () indicates the approximate location of the study area.

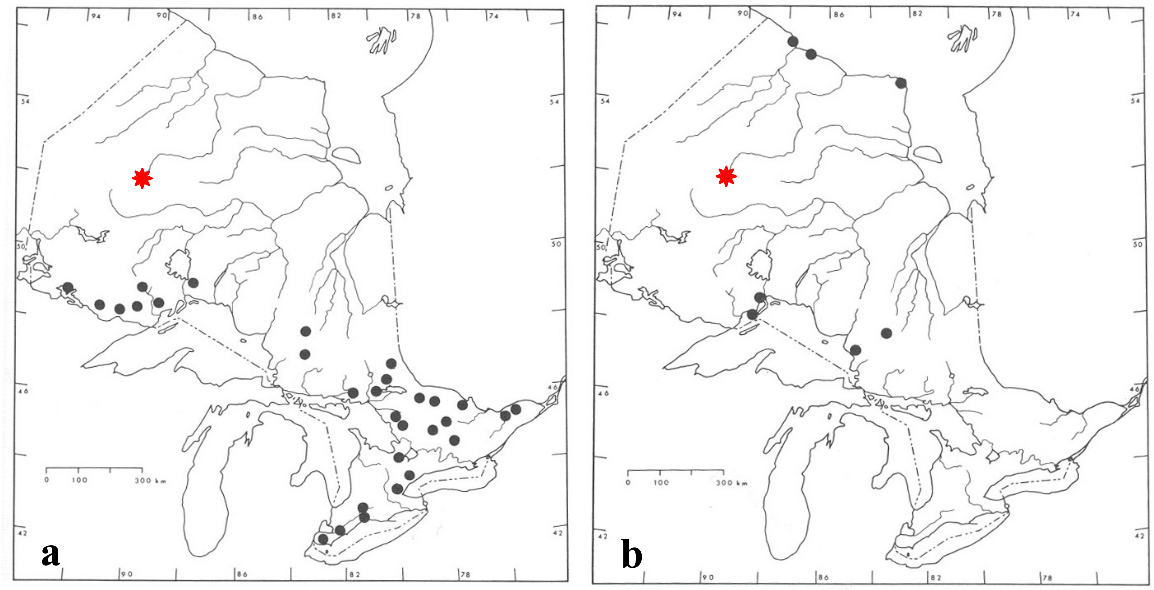


Figure 4. Approximate provincial distributions of a. *Ditrichum pusillum* (widespread in Ontario with a bias to the south) and b. *Tetraplodon mnioides* (northern distribution in Ontario). Illustrations from Ireland and Ley 1992. The sunburst () indicates the approximate location of the study area.

Seven moss species collected on this trip are ranked S3 or higher by the Ontario Natural Heritage Information Centre (Table 1, Appendix 1). No rare liverworts were found. Three of these species are tracked by the NHIC, and are discussed in greater detail below:

Pohlia sphagnicola (ranked S2) is a small (stems generally 4-30 mm tall) moss with a copper-coloured stalk supporting its spore-filled capsule. It occurs in peatlands, and is often sparsely intermixed with *Sphagnum*. *P. sphagnicola* looks superficially very similar to an extremely common species (*Pohlia nutans*) and for this reason it is likely that *P. sphagnicola* is often overlooked. Furthermore, some experts contend that *P. sphagnicola* should not be considered a species separate from *P. nutans*, so it is not always reported separately. The rarity of *P. sphagnicola* in Ontario and its reported absence from the Thunder Bay area (Appendix 1) may therefore be misrepresented. Along the Cat River system, *P. sphagnicola* was collected in a bog earmarked by the Wildlands League as a potential biodiversity 'hotspot' – a site that also supported the most rare bryophyte of the trip – *Sphagnum contortum*.

Sphagnum contortum (ranked S1) appears to be uncommon throughout North America. Like most *Sphagnum* species, *S. contortum* displays a 'capitulum' of crowded branches at the growing tips, and fascicles (bunches) of spreading and hanging branches along the stem. *Sphagnum* grows indeterminately, so that as lower portions of the plants die, the living tops continue to accumulate biomass – a feature that helps to account for the important role of *Sphagnum* in peat accumulation and carbon sequestration. According to Crum (1984), *S. contortum* is characteristic of wet, eutrophic, sedge habitats in rich fens. On the Cat River, *S. contortum* was collected from a graminoid fen area of a peatland complex earmarked by the Wildlands League in advance of the trip as a potential biodiversity 'hotspot'. It was sparsely intermixed with large amounts of another fen species, *Campylium stellatum*.

Table 1. Summary of sub-national rank designations for Ontario, as they apply to the mosses collected along the Cat River system. These provincial 'Sranks' are applied by the Natural Heritage Information Centre to set protection priorities for rare species and natural communities. Ranks are based on criteria such as total number and condition of element occurrences, population size, range extent and area of occupancy, threats, environmental specificity, and fragility. These ranks are not legal designations, but in combination with global ranks they help the NHIC and other organizations to evaluate the rarity and urgency of conservation management actions for each species.

Rank	Rarity in Ontario	Number of occurrences and other criteria
S1	Extremely rare	▪ Usually 5 or fewer occurrences in the province or very few remaining individuals ▪ often especially vulnerable to extirpation.
S2	Very rare	▪ usually between 5 and 20 occurrences in the province or with many individuals in fewer occurrences ▪ often susceptible to extirpation

S3	Rare to uncommon	▪ usually between 20 and 100 occurrences in the province; may have fewer occurrences, but with a large number of individuals in some populations ▪ may be susceptible to large-scale disturbances. ▪ most species with an S3 rank are not tracked, unless they have a high global rank.
S4	Common and apparently secure	▪ usually with more than 100 occurrences in the province.
S5	Very common and demonstrably secure	
S?	Not Ranked Yet, or if following a ranking (e.g. S3?), Rank Uncertain.	

Tetraplodon mnioides (ranked S2) grows almost exclusively on dung (usually that of carnivores or omnivores) in upland habitats, and unlike most mosses, its spores are sticky and are dispersed by insects rather than by wind or water. The temporary nature of dung substrates makes resident populations highly localized and difficult to re-locate in the field, because any population will have died and dispersed to form a new colony elsewhere within a few years. Marino (1988) reports that boreal *Tetraplodon* species produce spores for up to five years (Marino 1988). The species' purported provincial rarity (and that of the related *T. angustatus*) may reflect the its peculiar ecology rather than its actual abundance. On the Cat River system, *T. mnioides* was collected intermixed with *T. angustatus* on an upland trailside clearing. Both *T. mnioides* and *T. angustatus* are circumboreal species (Marino 1988), although the range of *T. mnioides* extends into the arctic whereas *T. angustatus* is largely restricted to boreal North America.

The most frequently recorded species along the route was *Pohlia nutans* (16 of 23 localities), followed by *Pleurozium schreberi* (10), *Plagiothecium laetum* (9), *Polytrichum juniperinum* (8), *Dicranum polysetum* (8), and *Ceratodon purpureus* (8). Most species collected were encountered just once (38) or twice (34). It should be noted, however, that the focus of sampling was detecting as many species as possible.

Most moss and liverwort species discovered on this trip were previously known for the Thunder Bay area. Notable exceptions include *Sphagnum contortum, Barbilophozia kunzeana,* and *Pohlia sphagnicola*. The frequency of moss occurrence was not ranked by Crowe (1992), but among the liverworts collected, two species collected by the Wildlands League (*Marchantia polymorpha, Mylia anomala*) are listed by Crowe (1992b) as being uncommon (5-8 locations) in the Thunder Bay district.

Significant sites

Sampling was distributed among sites according to their accessibility and abundance. Sampling effort devoted to different habitat types is outlined in Table 2.

Table 2. Distribution of sampling among habitat types, including sites that were visited and those sampled intensively (sampled until no new species were found).

General habitat type	**Number Sampled**
Rocky shoreline coniferous forest	8 sites (2 intensively)
Upland coniferous forest	2 (1)
Deciduous forest	1 (1)
Mature mixedwood	2 (1)
Untreed upland	1
Peatland	3 (1)
Shoreline cliff	4
Rapid	2

On this trip, the Wildlands League flagged certain habitats for sampling before the trip, based on their atypical character compared with the surrounding landscape or on their high potential for rare species occurrence. In view of the bias demonstrated in the bryophyte sampling effort, future explorations of non-vascular plants should also use extensive examination of all available maps and air photos in advance of the trip. This would allow researchers to identify

1) habitat types present along the route, to ensure that examples of each are visited, maximizing the number of species captured along the way. On this trip, for example, peatland sites were under-represented among sampled sites, even though pockets of peat-dominated habitat were common. Peatlands at the base of the esker sites 6 and 7, and along the portage site 22, for example, were promising sites, particularly in view of the significant species found in the one peatland that was sampled relatively intensively.
2) sites with potentially high microhabitat richness (e.g. cliffs, particularly treed and/or seepy cliffs), to flag sites with potential for high species diversity
3) sites that differ from the dominant habitat types, to flag sites with high potential to support locally rare species.

While some rich or unique sites are only identifiable on the ground (the portage at Kaskego rapids (site 12) showed high potential for vascular and non-vascular plant richness and rarity, and should be re-visited), and logistical considerations further emphasize the need for flexibility, this kind of pre-trip analysis will ensure the informed prioritization of sites as the trip proceeds.

Because most sites were not sampled exhaustively, the species richness and composition of the sites visited on the trip could not be quantitatively compared. However, two sites: a mature, moist aspen stand near Pesew Falls (site 4) and a moist, mixed forest with Maple/Yew understory (site 20) were particularly rich, with 40 and 44 bryophyte species, respectively. The apparent age of these stands (as evidenced by large tree size), frequency and variety of down woody material, scattered rock, and heterogeneous forest floor microtopography appears to have provided considerable variety in moss microhabitats (e.g. logs at different stages of decay, variety of rock types, dissection of rock surfaces, microtopographical variation, variety in canopy species), which is closely linked with high species richness. By comparison, La Roi and Stringer (1976) reported the mean richness of 60 300 m x 300 white spruce/fir stands sampled across boreal North America at 24 bryophyte species, and the mean richness for black spruce stands at 15 species.

Sites supporting significant species did not share obvious characteristics. The eight species ranked S3 or higher ('significant' species) that were discovered on this trip were distributed among eight sites. Three sites: a peatland (site 11), a dry rocky upland (site 15), and moist mixedwood forest (site 20) supported two significant species each. Sites 4 (deciduous forest), 10, 13 (rocky shoreline coniferous forest), 12 (mature mixedwood forest), and 21 (lakeshore cliff) also supported significant species. Intensive sampling appears to have resulted in the discovery of significant species: these were found in three of the four intensively sampled sites, two of which supported two significant species each. Most significant species were found in habitats other than the most frequently sampled habitat type (rocky shoreline coniferous forest, Table 2).

The most readily accessed and therefore most frequently sampled sites were characterized as rocky shoreline coniferous forest.

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Appendix 1. Species found along the Cat River System. Species' scientific names have been standardized to the North American checklist (Anderson et al. 1990). Species' common names were selected from those compiled by Glime (1989, 1990, 1991, 1992a,b, 1993 a,b, 1994 a,b,c, and unpublished database) and Glime and Zhang (1990). 'Ontario rank' refers to the sub-national threat ranking assigned by the Ontario Natural Heritage Information Centre (2002), while 'T-Bay Status' indicates membership (**y**es/**n**o) of mosses and frequency rating (**c**ommon (13 or more locations), **o**ccasional (usually related to specific habitat, 9-12 locations), **u**ncommon (5-8 locations) of liverworts in lists of bryophytes for the Thunder Bay District (Crowe 1992a,b). Presence of a species in a site (numbered 1-23) is indicated by a '1' (bold type – species collected, normal type – species observed). UTM co-ordinates and brief descriptions for the sites are given in Appendix 2. Sampling effort varied from site to site, so species richness (though tallied for each site) cannot be compared between sites.

Scientific Name	Common Name	Ontario rank	T-Bay Status	July 5		July 6			July 7				July 8				July 9			July 10			July 11			July 13
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Abietinella abietina	wiry fern moss	S5	y					**1**											1							
Amblystegium serpens	delicate willow moss	S5	y				**1**								**1**											
Andreaea rupestris	black rock moss	S4	y		**1**											**1**	**1**							**1**		
Atrichum crispum	wave-leaved crane's-bill moss	**S3**	y																				**1**			
Aulacomnium palustre	bog thread moss	S5	y	**1**							**1**					**1**		**1**					1			**1**
*Barbilophozia barbata**	common fine-split-lobe liverwort	S4?	c	**1**			**1**				**1**					**1**	**1**						**1**			
*Barbilophozia kunzeana**	mire fir lycopod moss (liverwort)	S3S4	n														**1**									
Bartramia pomiformis	common apple moss	S5	y														**1**									
*Blepharostoma trichophyllum**	common eye-lash liverwort	S5	c										**1**										**1**			
Brachythecium acuminatum	grass moss	S5	y				**1**																			
Brachythecium campestre	hill grass moss	S5	y				**1**																**1**			
Brachythecium reflexum	grass moss	S5	y				**1**																			
Brachythecium rivulare	river grass moss	S5	y																		**1**					
Brachythecium salebrosum	forest grass moss	S5	y				**1**								**1**								**1**			
Brachythecium starkei	spaced-out grass moss	**S3**	y				**1**						**1**		**1**								**1**			
Brotherella recurvans	common raphidostegium	S5	y																			**1**				

Scientific Name	Common Name	Ontario rank	T-Bay Status	July 5		July 6			July 7				July 8				July 9			July 10			July 11			July 13
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Bryohaplocladium microphyllum	fine-leafed small plume moss	S4	y				1								1	1										
Bryum lisae var. *cuspidatum*	intermediate bryum	S5	y				1								1				1							1
Bryum pallescens		S4	y													1										1
Bryum pseudotriquetrum	marsh bryum	S5	y									1									1					
Callicladium haldanianum	haldane moss	S5	y				1												1				1			
Calliergon cordifolium	marsh spoon moss	S5	y				1																			1
Calliergon stramineum	pale spoon moss	S5	y																	1					1	
Campylium chrysophyllum	yellow-leaf fine wet moss	S5	y				1					1				1										
Campylium hispidulum	common fine wet moss	S5	y				1																			
Campylium polygamum	long-rib fine wet moss	S5	y									1														
Campylium stellatum	inclined-leaf fine wet moss	S5	y											1		1										
Ceratodon purpureus	burn moss	S5	y	1						1	1		1		1	1							1			1
Climacium dendroides	tree moss	S5	y								1	1			1	1									1	
Cynodontium alpestre	northern mosquito moss	S?	y			1											1		1					1		
Cynodontium strumiferum	goiter clipped wad	S4	y	1		1					1						1		1							
Dicranella heteromalla	silky fork moss	S5	y										1													1
Dicranum flagellare	flagella broom moss	S5	y																			1				
Dicranum fuscescens	mountain broom moss	S5	y	1									1									1	1			
Dicranum montanum	stump broom moss	S5	y																			1	1			
Dicranum ontariense	taiga broom moss	S5	y	1					1													1	1			
Dicranum polysetum	wavy broom moss	S5	y	1			1		1	1	1					1						1	1			
Dicranum scoparium	broom moss	S5	y	1			1				1		1			1							1			
Dicranum undulatum	electric eels	S5	y											1		1										
Distichium capillaceum	hair-leaved flat moss	S5	y									1														
Ditrichum pusillum	brown ditrichum	S4	y							1																1
Drepanocladus aduncus	common sickle moss	S5	y																						1	1
Eurhynchium pulchellum	beautiful beak moss	S5	y				1								1								1			
Fissidens osmunioides	bracken pocket moss	S5	y									1				1										
*Frullania eboracensis**	common frullania	S5	c																				1			

Scientific Name	Common Name	Ontario rank	T-Bay Status	July 5		July 6			July 7				July 8				July 9			July 10			July 11			July 13
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Funaria hygrometrica	common cord moss / Cinderella	S5	y												1											1
*Geocalyx graveolens**	<turpentine moss>	S5	c																				1			
Grimmia unicolor	dingy grimmia	S4	y	1																						
Hamatocaulis vernicosus	stick hook moss	S5	y											1												1
Hedwigia ciliata	Hedwig's fringe leaf moss	S5	y	1		1					1					1	1		1							
Herzogiella turfacea	flat stump moss	S5	y				1																1			
Hylocomium splendens	stair-step	S5	y	1			1																1			
Hypnum lindbergii	clay pigtail	S5	y													1										
Hypnum pallescens	stump pigtail	S5	y	1			1				1		1		1	1							1			
Hypnum pratense	flat gray moss	S5	y													1										
Isopterygiopsis pulchella	beautiful luster moss	**S3**	y													1										
*Jamesoniella autumnalis**	autumn round-leaf liverwort	S5	c				1																1			
*Lepidozia reptans**	little hands	S5	c														1						1			
Leptobryum pyriforme	pear moss	S5	y												1								1			1
Leptodictyum riparium	willow moss	S5	y													1										
*Lophocolea heterophylla**	crest liverwort	S5	c				1																1			
*Lophocolea minor**	delicate crest liverwort	S4S5	o				1																			
*Marchantia polymorpha**	common liverwort	S5	u																				1			1
Mnium spinulosum	red-mouthed mnium	S5	y																				1			
*Mylia anomala**	bog mylia	S5	u											1												
Neckera pennata	feathered neckera	S5	y								1		1		1								1			
*Nowellia curvifolia**	fist liverwort	S5	c				1																			
Oncophorus wahlenbergii	spaced-out bumpmoss	S5	y				1																1			
Orthotrichum obtusifolium	blunt-leaved bristle moss	S5	y				1																			
Orthotrichum speciosum	showy bristle moss	S5	y				1					1											1			
Paraleucobryum longifolium	long-leaved fork moss	S5	y			1	1									1	1							1		
Philonotis fontana	fountain apple moss	S5	y																1		1				1	
*Plagiochila porelloides**	little bracken moss (liverwort)	S5	c													1										
Plagiomnium cuspidatum	woodsy mnium	S5	y				1								1				1							

Scientific Name	**Common Name**	**Ontario rank**	**T-Bay Status**	**July 5**		**July 6**			**July 7**				**July 8**				**July 9**			**July 10**			**July 11**			**July 13**
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Plagiomnium drummondii	Drummond's mnium	S4S5	y				**1**																			
Plagiomnium ellipticum	marsh mnium	S5	y												**1**				**1**							
Plagiomnium medium	bow mnium	S5	y				**1**								**1**											
Plagiothecium denticulatum	denticulate plagiothecium	S5	y													**1**										
Plagiothecium laetum	shiny plagiothecium	S5	y	**1**		**1**	**1**				**1**		**1**				**1**		**1**				**1**	**1**		
Platygyrium repens	common flat-brocade moss	S5	y								**1**								**1**				**1**			
Pleurozium schreberi	big red stem	S5	y	**1**			**1**		**1**		**1**		**1**			**1**		**1**				**1**	**1**		**1**	
Pohlia cruda	opal nodding moss	S5	y																					**1**		
Pohlia nutans	copper-wire moss	S5	y	**1**	**1**	**1**				**1**	**1**		**1**	**1**		**1**	**1**	**1**	**1**	**1**		**1**	**1**	**1**		**1**
Pohlia sphagnicola	bog nodding moss	**S2***	n											**1**												
Polytrichum commune	common hair cap	S5	y	**1**							1		**1**			**1**							1	**1**		1
Polytrichum juniperinum	juniper hair cap	S5	y	1					1	**1**	1		**1**			1							**1**			**1**
Polytrichum longisetum	marsh hair cap	S4	y																				**1**		**1**	
Polytrichum piliferum	awned hair cap	S5	y	1						1	1															
Polytrichum strictum	slender hair cap	S5	y										**1**	**1**												**1**
*Ptilidium ciliare**	common hair-leaf liverwort	S5	o	**1**			**1**			**1**						**1**	**1**						**1**	**1**		
*Ptilidium pulcherrimum**	deep-split hairy-leaf liverwort	S5	c	**1**			**1**			1	**1**		**1**									**1**	**1**			
Ptilium crista-castrensis	knight's plume	S5	y				**1**			**1**			**1**									**1**	**1**		**1**	
Pylaisiella polyantha	aspen moss	S5	y				**1**					**1**			**1**				**1**				**1**			
Racomitrium heterostichum	bristly woolly moss	S4	y	**1**							**1**					1										
Rhabdoweisia crispata	toothed blackfly moss	**S3**	y																					**1**		
Rhytidiadelphus triquetrus	shaggy moss	S5	y				1																**1**			
Rhytidium rugosum	wrinkled-leaf feather moss	S4	y										**1**													
*Riccardia latifrons**		S4?	c				**1**																			
Sanionia uncinata	circleleaf moss	S5	y	**1**		**1**	**1**						**1**		**1**	**1**							**1**			
Schistidium rivulare	brook bloom moss	S5	y					**1**													**1**					
Sphagnum angustifolium	club peat moss	S5	y											**1**						**1**		**1**				**1**
Sphagnum capillifolium	pointy-leaf peat moss	S5	y													**1**						**1**				**1**
Sphagnum centrale	raked peat moss	S4	y	1																**1**						1

Scientific Name	Common Name	Ontario rank	T-Bay Status	July 5		July 6			July 7				July 8				July 9			July 10			July 11			July 13
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Sphagnum contortum	twisted-branch peat moss	**S1***	n											**1**												
Sphagnum fuscum	rusty peat moss	S5	y											**1**												1
Sphagnum girgensohnii	Girgensohn's peat moss	S5	y										**1**													
Sphagnum magellanicum	midway peat moss	S5	y											**1**												
Sphagnum russowii	wide-tongued peat moss	S5	y								**1**		**1**				**1**					**1**				
Sphagnum warnstorfii	Warnstorf's peat moss	S5	y											**1**						**1**						
Tetraphis pellucida	pellucid four-tooth moss	S5	y										**1**	**1**									**1**			
Tetraplodon angustatus	toothed lemming moss	**S3?**	y															**1**				**1**				
Tetraplodon mnioides	lemming moss	**S2***	y															**1**								
Thuidium delicatulum	fern moss	S5	y																**1**				**1**			
Thuidium recognitum	fern moss ('elevator moss')	S5	y				**1**																			
*Tritomaria quinquedentata**	ginkgo liverwort	S4?	o																					**1**		
Warnstorfia exannulata	marsh hook moss	S5	y													**1**										**1**
Warnstorfia fluitans	water hook moss	S5	y											**1**												
Number of species detected				23	2	7	40	2	4	9	20	8	21	14	17	31	13	5	14	5	4	14	44	10	7	21

Appendix 2. Descriptions and UTM co-ordinates for sites where bryophytes were collected along the Cat River system in July 2002. Species found at each site are listed in Appendix 1. UTM co-ordinates were recorded using various datums but are standardized here to WGS84. Most co-ordinates were measured using gps devices in the field. Co-ordinates marked with an asterisk were estimated from a map following the trip. 'Unrecorded' co-ordinates were not noted adequately in the field and could therefore not be estimated.

Site Number	Description	UTM Co-ordinates
1	Near initial drop-off point. Shoreline of gently sloping rock and shrubs clustered in hollows; small pools of water in rock depressions from splashing waves; scattered, very rotten wood. Spruce forest behind with deep, spongey moss floor.	15 U 573197 5737646
2	Enroute to Pesew Falls from drop-off point. Exposed, vertical acidic rock dropping straight into water (collected from canoe).	15 U 575875 5740375*
3	Pesew Falls, northern Cat Lake (Campsite #1). *Pinus banksiana* over *Ledum*, *Sphagnum*, rock.	15 U 575707 5740986
4	South end of Pesew Falls Portage, near to campsite #1. Bordered by portage on west, Falls on east, river on south. Mature, moist *Populus* with floor of varied microtopography (mounds and hollows), scattered rock, and logs (*Populus, Betula*) of all sizes in various stages of decay.	15 U 575875 5741250*
5	Border of Mature Aspen and swiftly flowing water below Pesew Falls. Forest floor very wet.	15 U 575875 5741250*
6	North-east Cat Lake. Unlogged section of esker 'hotspot' flagged by Wildlands League in advance of trip. Mature, dry *Pinus banksiana* over *Betula*; sparse understory of *Vaccinium*, *Ledum*, *Cypripedium acaule*, green *Pyrola, Pipsissewa, Lycopodium* (at least 2 species) over near-continuous feathermoss/*Dicranum* carpet. Lots of deadfall.	15 U 581713 5736437

Site Number	Description	UTM Co-ordinates
7	North-east Cat Lake. Logged section of esker 'hotspot' (as site 6). Open – much less shaded, with *Betula papyrifera* dominant and taller than under Pine in unlogged section. Sparse understory of *Vaccinium myrtilloides, Lycopodium, Ledum.* Puffballs common. Patchy exposed soil.	15 U 581713 5736437
8	North Cat Lake, north of village (Campsite #2). *Picea / Pleurozium* forest with scattered rock. Shoreline of dry, exposed, broken rock and moist, shaded hollows.	15 U 579704 5733421
9	Enroute from Campsite #2 to Campsite #3 (collected from canoe). Bases and branches of shoreline cedars.	unrecorded
10	South Cat Lake (Campsite #3). Sparse, spruce-dominated forest with boulders and wind-throw trees on floor. Exposed soil among roots of tip-ups and associated hollows. Shoreline denser moist spruce forest over *Ledum* and rotting logs.	15 U 577634 5721634
11	South-east Cat Lake. Peatland 'hotspot' flagged by Wildlands League in advance of trip. Bog: *Larix, Picea mariana*, ericaceous shrubs, *Vaccinium oxycoccus, Maianthemum canadense* (?)*, Sarracenia purpurea, Drosera,* with hummocky Sphagnum floor. Also briefly investigated associated open graminoid fen with pools.	15 U 581792 5722751
12	Cat Lake – Kapikik Lake. Portage around Kaskego Rapids. Moist, mature mixedwood with large trees and abundant epiphytes. Lush understory over variable floor with abundant dead wood in various stages of decay. *Moneses uniflora*, *Thuja occidentalis*, *Populus*, *Acer.*	15 U 575461 5715757
13	Campsite #4. Kapikik Lake. Wet shoreline of saturated mud and wet tree bases, rotting wood, and broken rock. *Thuja*, *Ledum*. Tip-ups with drier soil among roots.	15 U 573600 5707191

Site Number	Description	UTM Co-ordinates
14	Enroute from Campsite #4 (Kapikik Lake) to Campsite #5 (Zionz Lake). Cliff between two portages (sampled by hopping in and out of canoe) – steeply-sloping series of ledges dropping directly into water. Vertically undulating. Sparse, stunted spruce on some ledges.	15 U 579303 5704078
15	Enroute from Campsite #4 (Kapikik Lake) to Campsite #5 (Zionz Lake). Second (south) portage, and longest portage of the trip. Dry, un-treed, domed bedrock dominated by lichens. Trailside.	15 U 579250 5703500*
16	Enroute from Campsite #4 (Kapikik Lake) to Campsite #5 (Zionz Lake). South end of second (longest) portage. Blocky granite shoreline. Sloping deciduous forest.	15 U 579166 5703002
17	Enroute from Campsite #5 (Zionz Lake) to Campsite #6 (Kezik Lake). Cliff (sampled from canoe) and shoreline in narrows between Zionz and Fawcett Lakes.	15 U 581500 5692625*
18	Enroute from Campsite #5 (Zionz Lake) to Campsite #6 (Kezik Lake), within view of campsite at 'Devils Portage' between Fawcett and Kezik Lakes. Wet, unshaded, gently sloping bedrock splashed by rushing rapids.	15 U 585000 5686125*
19	Kezik Lake. Rejected Campsite. Sloping, open, mossy coniferous forest with boulders.	unrecorded
20	Kezik Lake (Campsite #6). Mossy, rocky, undulating coniferous forest. Focussed on moist lakeside mixedwood basin with very large dead-fall trees. Dead wood of varied sizes and stages of decay. *Taxus, Acer, Betula, Equisetum, Rubus.* Occasional rock. Moist rich-looking humus with patches of exposed mineral soil associated with tip-ups.	15 U 588604 5680496
21	Enroute from Campsite #6 (Kezik Lake) to Campsite #7 (Wesleyan Lake). Lakeside cliff, at entrance to narrows, south Kezik and Lake. Sampled from canoe. Many aspects, many crevices of varying sizes, many moisture levels. *Polypodium* (?).	15 U 593567 5677213

Site Number	Description	UTM Co-ordinates
22	Enroute from Campsite #6 (Kezik Lake) to Campsite #7 (Wesleyan Lake). 'Cat River Portage'. Peat-dominated with *Larix* in overstory; slightly raised and drier away from shoreline.	15 U 591875 5673750*
23	Slate Falls Airport. Peatland and roadside opposite terminal building (across tarmack). Wet, mineral-muddy roadside ditches alongside sand hummocks (young *Pinus banksiana, Epilobium angustifolium, Salix, Alnus*), interspersed with dominant bog habitat (*Sarracenia purpurea*).	15 U 595985 5665007*