

**MODELING AND MAPPING DISTRIBUTIONS OF COMMON  
BRYOPHYTES ACROSS NEW BRUNSWICK USING A LIDAR-DERIVED  
DEPTH-TO-WATER INDEX**

by

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BSc. Environment and Natural Resources, University of New Brunswick, 2013

A Thesis Submitted in Partial Fulfillment of  
the Requirements for the Degree of

**Master of Science in Forestry**

in the Graduate Academic Unit of  
Forestry and Environmental Management

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This thesis is accepted by the  
Dean of Graduate Studies

THE UNIVERSITY OF NEW BRUNSWICK

February 2016

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## Abstract

Plant species distribution is known to vary along environmental gradients. This project uses a cartographic depth-to-water (DTW) index to model the potential distributions of six common mosses and one leafy liverwort in New Brunswick at a landscape scale. Species composition and relative abundance of bryophytes were measured along transects traversing the landscape, from wetlands to uplands. Frequency of occurrence patterns were quantified using regression models. Species were found to sort along the moisture gradient; *Bazzania trilobata*, *Dicranum polysetum*, *Polytrichum commune*, *Hylocomium splendens*, and *Pleurozium schreberi* had greater probabilities of occurrence in well-drained forested areas, whereas hydrophytic mosses such as *Sphagnum fuscum* and *Sphagnum girgensohnii* were predominantly in low lying wet areas. The results support the prediction that wetness-related changes in distributions of bryophytes can be modeled using the depth-to-water index in combination with other environmental variables such as forest type. This research contributes to existing knowledge regarding bryophyte species' responses to environmental factors.

## **Acknowledgements**

I would like to thank my supervising professor, Dr. Paul A. Arp, for his support, both financial and moral, throughout this project. I am also grateful to the Natural Sciences and Engineering Research Council of Canada (NSERC) for the Canada Graduate Scholarship I received.

The staff at the UNB Forest Watershed Research Centre was immensely accommodating in providing assistance with field sampling, equipment, and ArcGIS. A big thank you to Jae Ogilvie, who processed the LiDAR-derived wet areas maps utilized for this project. I would also like to thank Matthew Bolton, Benno Künzig, and Friedrich Johan Wüthrich for their hard work and assistance with field sampling.

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## CHAPTER 1 – INTRODUCTION

Environmental factors, such as soil moisture, nutrients, light, and temperature, change regularly through time and space, providing opportunities for growth and life for some plants, while simultaneously imposing constraints on survival for others (Whittaker, 1975; Cronk and Fennessy, 2001). Gradual changes in abiotic factors through space are known as environmental gradients. Habitats and plant communities intergrade along environmental gradients (Whittaker, 1967). For example, plant species composition generally changes along soil moisture gradients, from species adapted to relatively dry conditions (mesic/xeric) to those adapted to wet conditions (hydrophytic). Environmental gradient analysis is used to better understand the variation of vegetation across the landscape, and species distribution models relate field observations to environmental predictor variables.

Certain environmental variables can be modelled and mapped as data layers within a geographic information system (GIS), and used as proxies for gradient analyses. Water availability is frequently seen as the major resource gradient for plants (Cronk and Fennessy, 2001). It is possible to approximate soil wetness at 1m resolution with a cartographic depth-to-water index, which is created using digital elevation models (DEMs) derived from airborne Light Detection and Ranging (LiDAR) data. This hydrological index provides an indicator of drainage patterns and gradual changes in soil moisture from poorly drained areas (wetlands) to well drained areas (uplands/ridge tops) (Murphy *et al.*, 2011).

Plants are typically well adjusted to specific ranges along soil moisture gradients, and species composition can often be related to characteristics of the soil moisture regime (Haines-Young *et al.*, 1993). While this phenomenon has mostly been studied for vascular plants, bryophytes have also been found to follow this pattern (Lichvar *et al.*, 2009; Gillrich *et al.*, 2010). Water availability is considered to be the major limiting factor for bryophyte growth (Glime, 2013a). Given that bryophytes rely on water available at (or above) the soil surface, mapping soil moisture regimes across landscapes could be a useful method for capturing geospatial distributions of bryophytes, particularly those common species which have widespread distributions and are known to grow primarily within a given range of environmental conditions. Previous studies have found associations between soil moisture, groundwater depth, and variations in bryophyte species composition (Busby *et al.*, 1978; Clymo, 1984; Muotka and Virtanen, 1995; Bragazza and Gerdol, 1996; Hall *et al.*, 2001; Fritz *et al.*, 2009; Gillrich *et al.*, 2010). Bryophytes may be as effective as vascular plants at indicating soil moisture levels, and at times appear more responsive to environmental influences along the upland nutrient/moisture gradient than vascular species (Carleton, 1990).

High-resolution vegetation mapping has become increasingly important for environmental research, monitoring, and impact assessment (Jenkins and Frazier, 2010). Predictive vegetation mapping of bryophytes is still a largely unexplored domain. Animals and vascular plants tend to be the focus of most studies; the distributions of bryophytes are still imperfectly known and simple mapping of presence or absence of species is still lacking for most countries (Vanderpoorten and Engels, 2002). Where bryophyte-environment relationships have been previously studied, the focus tends to be either at a

micro-scale, or at continental scale. This research differs in perspective by looking at bryophyte distributions at a landscape scale.

Multiple processes act together to influence bryophyte occurrence, however little is known about the relative importance of different environmental factors across diverse landscapes (Michel *et al.*, 2010). This research will contribute to current knowledge and understanding of the complex relationships between the geospatial distributions of bryophytes and environmental gradients. Species-habitat models can be used for many aspects of resource management and conservation planning including biodiversity assessment, reserve design, habitat management and restoration, or ecosystem modeling (Franklin, 2009). Predictive modelling of species distributions has contributed to addressing various issues in ecology, biogeography, conservation biology and climate change research (Guisan and Thuiller, 2005).

### **Research Question**

How reliably can wetness related changes in composition and distribution of bryophytes be modelled and mapped using a LiDAR-derived cartographic depth-to-water index?

### **Prediction**

Given that spatial patterns of bryophyte species are known to be influenced by moisture levels, it is predicted that hydric species will be primarily found where the depth-to-water is near the surface (within 1 meter), and that mesic/xeric species will be found in the more well-drained upland areas where the depth of the water table is greater (further from the surface).

## **Objectives**

The objectives of this research are to:

- 1) Record the presence and relative abundance of common species of bryophytes along predicted soil wetness gradients within a selection of study sites with LiDAR coverage in New Brunswick, Canada;
- 2) Quantify whether bryophyte species show a response to soil wetness as modeled by way of the LiDAR-derived cartographic depth-to-water index; and
- 3) Use the modelled species response curves to map the spatial distribution of common bryophyte species across the landscape (from wetlands to uplands) at 1m resolution.

## CHAPTER 2 – BACKGROUND

The analysis of species-environment relationships is a central issue in ecology. Species distribution models (SDMs) relate field observations to environmental predictor variables, based on various hypotheses as to how environmental variables control the distribution of species and communities (Guisan and Zimmermann, 2000). Species exhibit a range of response curves along primary environmental gradients. Whittaker (1967) found that plant species populations tend to be distributed along complex-gradients in the form of bell-shaped curves, with their densities tapering on each side of the population optima. More recent studies similarly support the occurrence of unimodal response curves for plants (Austin, 2005), and skewed asymmetric response curves are also frequent (Rydgren *et al.*, 2003; Austin, 2007). Bell-shaped curves have been postulated for species relative abundances, while thresholds and linear relationships have been used more often for species presence-absence patterns (Guisan and Thuiller, 2005; Austin, 2007). A suitable underlying theory for modeling individual species is Ramensky and Gleason's principle of individuality (Gleason, 1926), in which each species is expected to possess individual moisture, nutrient, and sunlight preferences. The theory is summarized succinctly by Whittaker (1975) as follows:

Each species is distributed in its own way, according to its own genetic, physiological, and life-cycle characteristics and its way of relating to both physical environment and interactions with other species; hence no two species are alike in distribution. The broad overlap and scattered centers of species populations along a gradient imply that most communities intergrade continuously along environmental gradients rather than forming distinct, clearly separated zones. (Whittaker, 1975, p. 115)

Plants are always responding to multiple environmental and biotic gradients, which means that each species will have a different environmental response curve for every environmental factor and each curve will differ in form (Kent, 2012). Modelling species response curves along primary environmental gradients can help explain species distribution over the regional landscape (Carleton, 1990).

### **Bryophyte Ecology**

Bryophytes are the plant group of interest in this study; they are small non-vascular plants found throughout the world, collectively comprising the second largest group of land plants after flowering plants (Schofield, 2001). The phylum known as Bryophyta includes the classes Musci (mosses), Hepaticae (liverworts), and Anthocerotae (hornworts). Bryophytes can be found colonizing all soil types, as well as the surfaces of rocks, tree trunks, roots, and coarse woody debris (Schofield, 2001). Mosses inhabit a wide diversity of habitats, including both nutrient-rich and nutrient-deficient habitats such as forests, wetlands, heath barrens, and cliffs (Belland, 2010). While small in size and often overlooked, bryophytes nevertheless have important ecological functions, such as nutrient cycling, water absorption, and retention of topsoil (Glime, 2013b). Mosses also contribute to the production of humus through their slow decomposition (Longton, 1992); this has the effect of enhancing water and nutrient retention within soils. The presence of certain species can convey information about abiotic attributes of forest ecosystems, such as moisture levels, nutrient availability, pH, or levels of heavy metals (LaPaix *et al.*, 2009).

Overall, our knowledge of bryophyte physiology is limited. One common assumption that is now known to be erroneous is that all bryophytes obtain water and nutrients solely from the surface of their leaves (Glime, 2013a). Mosses absorb moisture and nutrients over the

surface of the whole plant, mainly from the atmosphere but also in part from the substrate they are anchored to, if they have parts penetrating the substrate. Unlike most other plants, mosses have no roots. Instead, the majority of moss species possess rhizoids, which serve primarily for anchorage of the plant, but may also provide functions of conduction much like roots or root hairs (Glime, 2013a), wherever they are located on the plant (often they are on the stems, and don't reach the substrate). Bryophytes are only physiologically active when hydrated; they enter a state of dormancy during dry periods, resuming normal metabolism once water is available again (Gillrich *et al.*, 2010). The transition between fully hydrated and desiccated is fairly quick and does not appear to cause some bryophytes very much water stress (Proctor *et al.*, 2007).

Bryophytes obtain moisture and nutrients from numerous sources, including surface water, ground water, stem flow, dew, humidity, mist, fog, and precipitation (Longton, 1992). Bryophytes have the potential to reflect long term hydrology patterns because of their colonial, sessile lifestyle, and slow growth rates (Fritz *et al.*, 2009). While anoxic conditions present in hydric soils are deadly for most vascular plants, they do not appear to have much controlling influence on bryophytes (Gillrich *et al.*, 2010), because no plant parts penetrate to anoxic depth. There are many unknowns surrounding bryophytes and their ecology; the absence of a particular bryophyte species in a given location is difficult to interpret (Frego, 2007).

Bryophytes are described as being non-vascular because the vascular tissue they possess is not as advanced or complex as that of vascular plants. Bryophytes gain water in their cells either through external (ectohydric) capillary movement along the surface of the plant, through internal (endohydric) transport within a central cylinder, or both

(mixohydric) (Glime, 2013a). Most mosses are primarily ectohydric and so have no specialized vascular tissue (Skre *et al.*, 1983), however they may have abundant rhizoids over their surface; these are not used for substrate penetration or attachment. *Sphagnum* spp., *Pleurozium schreberi* and *Hylocomium splendens* are examples of ectohydric mosses (Skre *et al.*, 1983; Crum, 2001). Endohydric mosses possess a primitive form of vascular tissue that is utilized for internal water transportation (Longton, 1992; Glime, 2013a). Endohydric bryophytes have a well-developed basal rhizoid system and tend to grow on loose substrate such as soil or humus (not usually on rocks or bark) (Chopra and Kumra, 2005). The soil is an important source of water for this group of mosses. *Polytrichum commune* is an endohydric moss, and as a result, the species is able to avoid moisture stress more than ectohydric taxa (Skre *et al.*, 1983). Mixohydric mosses employ both strategies; they have a rudimentary internal conducting system, allowing them to take up water via rhizoids in the soil, as well as from the plant surface (Longton, 1992). *Dicranum polysetum* is an example of a mixohydric moss (Crum, 2001).

Bryophytes produce neither flowers nor seeds; they reproduce sexually by producing tiny wind-transported spores (Medina *et al.*, 2011). It has traditionally been assumed that bryophytes possess no major dispersal restrictions (Medina *et al.*, 2011), however it is now known that despite their ability to produce large numbers of spores, many bryophyte species have limited to very limited geographic distributions; these can be explained by narrow ecological niches, age of taxa, local extinction or past disturbances (Frahm, 2008). The spores of bryophytes vary in size, although in general they are small, typically between 10-20  $\mu\text{m}$  in diameter (Crum, 2001; Frahm, 2008). This small size is suitable for wind dispersal, however most bryophytes probably only disperse the majority of their

spores within about 2 metres (Glime, 2014), and more typically, they fall within <1 meter (Crum, 2001; Glime, 2014). All that is needed to accomplish long-distance dispersal is for a few spores to go further (Glime, 2014). While wind is the most common dispersal mechanism, animal and water dispersal also occur, as well as vegetative reproduction (Schofield, 2001). Vegetative propagation is believed to play a vital role for bryophyte dispersal and expansion of established colonies (Medina *et al.*, 2011).

### ***Candidate Focal Species***

There are 381 species of bryophytes found in the maritime provinces (New Brunswick, Nova Scotia, and Prince Edward Island) (Ireland and Hanes, 1982), and at least 322 species in New Brunswick (Belland, 2010). The general range of bryophyte species distributions throughout New Brunswick has been documented by county (Ireland and Hanes, 1982; Belland, 2010). Thirteen candidate focal species were selected for this study by their commonness and likelihood of responding to soil moisture regimes, based on published habitat descriptions (Table 1).

**Table 1. Soil moisture and nutrient associations of 13 common New Brunswick bryophyte species.**

| Species                          | Common Name           | Soil Moisture Regime | Soil Nutrient Regime |
|----------------------------------|-----------------------|----------------------|----------------------|
| <i>Aulacomnium palustre</i>      | ribbed bog moss       | Wet/Moist            | Medium               |
| <i>Bazzania trilobata</i>        | bazzania              | Moist/Fresh          | Not Available        |
| <i>Climacium dendroides</i>      | tree moss             | Wet/Moist            | Rich                 |
| <i>Dicranum polysetum</i>        | wavy dicranum         | Wet/Moist            | Poor/Medium          |
| <i>Hylocomium splendens</i>      | stair-step moss       | Wet/Moist/Fresh      | Poor                 |
| <i>Pleurozium schreberi</i>      | Schreber's moss       | Moist/Fresh/Dry      | Poor/Medium          |
| <i>Polytrichum commune</i>       | common haircap moss   | Moist/Fresh/Dry      | Poor/Medium          |
| <i>Ptilium crista-castrensis</i> | plume moss            | Moist/Fresh/Dry      | Poor                 |
| <i>Rhytidiadelphus loreus</i>    | lanky moss            | Moist/Fresh          | Poor/Med/Rich        |
| <i>Sphagnum fuscum</i>           | brown bog sphagnum    | Wet                  | Poor                 |
| <i>Sphagnum girgensohnii</i>     | common green sphagnum | Wet/Moist            | Poor/Medium          |
| <i>Sphagnum squarrosum</i>       | prickly sphagnum      | Wet                  | Rich                 |
| <i>Sphagnum wulfianum</i>        | brittle-stem sphagnum | Wet/Moist            | Medium               |

Sources: (Ireland and Hanes, 1982; Ringius and Sims, 1997; Gillich *et al.*, 2010; Neily *et al.*, 2010)

None of these species are considered rare, endangered, or endemic to New Brunswick. The feather mosses (*Hylocomium splendens*, *Pleurozium schreberi*, and *Ptilium crista-castrensis*) do well in shaded and well drained habitats (Busby *et al.*, 1978). These species are often found in association with tall turf-forming mosses such as *Dicranum* spp. (Longton, 1992). Habitat descriptions for *H. splendens* describe the species as being commonly found on humus in coniferous forests (Conard and Redfearn, 1979; Ireland and Hanes, 1982). Poorly drained wetlands, as well as wet microsites in forested wetlands, are home to extensive carpets of shade-tolerant species of *Sphagnum*, such as *S. wulfianum* and *S. girgensohnii* (Rydin *et al.*, 2006).

Bryophytes are commonly used as indicator species in site classification schemes in Canada; examples include provincial guides for Nova Scotia (*Nova Scotia Forest Ecosystem Classification* (Neily *et al.*, 2010)), Ontario (*Field Guide to Forest Ecosystem Classification for the Clay Belt* (Jones *et al.*, 1983)), and Canada wide (*Indicator Plant Species in Canadian Forests* (Ringius and Sims, 1997)). The New Brunswick Ecological Land Classification System (New Brunswick Department of Natural Resources, 2007a) helps classify forest land based on soil moisture and nutrient regime and associated plant species composition; while it focuses mainly on vascular plants, bryophytes (*Sphagnum* mosses) are part of the vegetation type keys.

### ***Factors Affecting Distribution Patterns***

The global geographic range of most bryophyte species is very large (for example, *Pleurozium schreberi* is found throughout the entire northern hemisphere) (Mcknight *et al.*, 2013). Some species are found throughout extensive regions of the continent (i.e. northeastern North America), but with disjunct distributions that make them locally rare in certain regions and abundant in others. Climatic variables are important factors influencing the range of bryophytes at regional and global scales (Belland, 2005), and many studies have found links between bryophyte distributions and precipitation patterns (Gignac *et al.*, 1991; Hill and Dominguez Lozano, 1994; Asada *et al.*, 2003; Bates *et al.*, 2004; Belland, 2005).

At the landscape scale, the spatial distribution of bryophytes is regulated by another complex set of environmental factors, including soil moisture regimes, temperature, nutrients, substrata, slope, climate, forest cover, and vegetation type (Bates, 1995; Vanderpoorten *et al.*, 2005; Callaghan and Ashton, 2008; Michel *et al.*, 2010).

Topographic features such as slope can also influence vegetation through snow movement, water flow, erosion, and deposition of organic materials (Lassueur *et al.*, 2006).

### *Water Relations*

The water-table gradient is considered as a complex-gradient, because both shortages and excessive amounts of water can limit plant survival (Bragazza and Gerdol, 1996). Some plant species strongly sort along the upland-to-wetland gradient, particularly those species which have a narrow tolerance to fluctuations in the water table (Maltby and Barker, 2009). Hydrophytic bryophytes such as *Sphagnum* mosses are found in abundance in wetland types such as fens and bogs, where water is found at or near the surface for much of the year (Gillrich *et al.*, 2010). Research focused solely on *Sphagnum* species in bog habitats has confirmed associations between species distribution and water table depth (Busby *et al.*, 1978; Bragazza and Gerdol, 1996; Schofield, 2001; Dwire *et al.*, 2006). Other bryophytes, such as *Hylocomium splendens* and *Pleurozium schreberi*, are found primarily in well-drained upland sites along the same gradient (Lichvar *et al.*, 2009).

In wetlands, peat moss (*Sphagnum* spp.) distribution patterns are distinctly different between hummocks and hollows (Rydin *et al.*, 2006; Lichvar *et al.*, 2009). This creates a vertical zonation of species along microtopographic gradients which can be partially explained by differences in species response to desiccation (Wagner and Titus, 1984). Hummock-forming *Sphagnum* species tend to be less tolerant of desiccation than their counterparts found growing in hollows (Gillrich *et al.*, 2010), and are capable of modifying the hydrology at a micro scale by wicking water up from the water table in order to stay hydrated (Clymo, 1984; Rydin *et al.*, 2006). Busby *et al.* (1978) found that

seasonal variation in bryophyte growth rates was correlated with depth from the (bryophyte) canopy surface to the ground water table.

Mesic/xeric species may also be found in wetlands, occupying drier microsites (Stringer and Stringer, 1973). Feather mosses (*Pleurozium schreberi*, *Hylocomium splendens*, *Ptilium crista-castrensis*, as well as the liverwort *Bazzania trilobata*) can be found in bogs and fens, where they are typically restricted to dry microsites such as hummock tops (Gillrich *et al.*, 2010). *Hylocomium splendens* and *Pleurozium schreberi* sometimes co-occur on wetland hummocks; in a survey analyzing the presence of bryophytes on microtopographic positions within the landscape, Lichvar, Laursen, Seppelt, et al. (2009) found upland bryophyte species such as these mixed in with wetland bryophytes and vascular plants on hummock tops within wetlands.

In well-drained areas, other sources of moisture such as precipitation are likely more important than soil water for bryophyte growth/distribution. Feather mosses, including *Pleurozium schreberi* and *Hylocomium splendens*, grow in carpets in the boreal understory and are primarily wetted by precipitation; they are not known to be able to access water from the water table as *Sphagnum* species do (Longton, 1992). As such, the depth of the water table plays a less direct role for bryophytes in forests than it does in wetlands, particularly if it is far below the surface and inaccessible as a source of water for bryophytes (which do not possess roots capable of reaching low-lying water table depths as vascular plants do).

### *Biotic Interactions*

A multitude of biotic interactions such as competition or dispersal limitations act together to influence establishment and growth; as a result, bryophytes will not automatically be present in all suitable habitat found within their range (Cleavitt, 2005; Gillrich *et al.*, 2010). Species life history patterns, range and frequency of propagule dispersal (Chopra and Kumra, 2005), disturbance and gap regeneration (Frego, 1994), or chance occurrences of colonization and extinction also play a role in spatial distributions (Kenkel, 1987; Fenton *et al.*, 2003; Kent, 2012).

Canopy can indirectly affect the spatial distribution of mosses by altering levels of light, temperature, moisture, and nutrient supply at the forest floor (Longton, 1992; Michel *et al.*, 2010). There are differences in bryophyte species composition and abundance between coniferous and deciduous stand types (Carleton, 1990). Coniferous forests typically contain a continuous understory of bryophytes and lichens, while deciduous forests have sparse bryophyte occurrence (Lichvar *et al.*, 2009). Forests dominated by mixed broadleaf-conifer or conifers with few shrubs only, have many fallen branches and twigs that provide satisfactory substrates for some bryophytes, without the limitation from thick leaf litter. In a boreal woodland study, spruce canopy was found to be the strongest environmental predictor of bryophyte abundance patterns (Frego and Carleton, 1995). Although conifers continuously shed needles throughout the year, the shape and size of the needles allows them to work their way in between moss shoots, unlike deciduous leaf litter, which is shed profusely in annual pulses and tends to bury and shade out bryophytes on the forest floor (Longton, 1992). Although bryophytes are often unable to occupy the constantly changing leaf substrate of deciduous forests, they can still be found on elevated

substrates where the wind continually blows away leaf litter, such as on mounds, rotting logs, or rocks (Sveinbjörnsson and Oechel, 1992; Glime, 2007a).

Differences in plant distributions can also be explained by competition; most plants can grow in well-drained soils, but only the best competitors are found there (Tiner, 2005). Because bryophytes are small in size and have slow growth rates, they are easily outcompeted by vascular plants. Bryophytes are generally not competitors, but in most cases are stress tolerators, thriving where other taxa are unable to survive (Glime, 2013a). Although they are not inherently shade plants (Marschall and Proctor, 2004), they are generally adapted to low light levels and able to grow in shaded habitats, which provides some release from competition. Bryophytes have the ability to make a net gain from photosynthesis even at very low light intensities (Glime, 2007b). Sometimes bryophytes are excluded from suitable habitats due to complete dominance by herbaceous vascular plants. Tussock cottongrass (*Eriophorum vaginatum*), for example, has a dense growth habit that inhibits the development of bryophytes (Lichvar *et al.*, 2009). Not all interactions with other plants are negative though. While adjacent plants compete with each other for resources and space, they can have positive interactions that benefit other individuals, such as providing shelter, raising nutrient levels, conserving moisture, soil oxygenation, or improved soil microflora and fauna (Kent, 2012). For example, Ingerpuu *et al.* (2005) found species-specific positive interactions between bryophytes and grassland vascular plants, showing that grassland vascular plants can create better microclimate (e.g. optimize temperature) for bryophytes, provided the vascular plant densities remain low. The effects of biotic interactions on individual growth and

distribution are complex with many unknowns, and are poorly documented for bryophytes overall.

### **Bryophyte-Environment Modelling**

Species distribution models (SDMs) can be used to facilitate an understanding of the variables influencing species distribution, as well as to predict the probability of species occurrence at unsampled locations by extrapolating from point observations over space (Franklin, 2009). Species distribution models have also been labeled ‘predictive vegetation mapping’ (Franklin, 1995), ‘habitat suitability modeling’ (Hirzel and Le Lay, 2008), and ‘predictive habitat distribution modeling’ (Guisan and Zimmermann, 2000), however the applications are all the same. Although predictive modelling and mapping of bryophytes is still a relatively unexplored domain, bryophyte distributions have previously been modelled across different regions and habitats, within varied landscapes (Vanderpoorten and Engels, 2002; Vanderpoorten *et al.*, 2005, 2006; Callaghan and Ashton, 2008; Safavi and Shirzadian, 2011), and strong links have been found between environmental variables and bryophyte species distributions at regional and local scales (Lee and La Roi, 1979; Vitt, 1990; Gignac *et al.*, 1991; Vanderpoorten and Engels, 2003). The response curves of bryophytes are said to be similar to those of vascular plants (Rydgren *et al.*, 2003), and have thus far been found to be primarily unimodal or monotonic along micro topographic height-above-water-table and soil moisture gradients (Økland, 1986; Carleton, 1990; Gillrich *et al.*, 2010).

There are three basic components included in a typical species distribution modelling study: 1) a data set describing the occurrence of the species of interest; 2) a data set of measured or proximate explanatory variables, and; 3) a mathematical model relating the

species data to the explanatory variables (Rushton *et al.*, 2004). The utility of the final model should be assessed using some type of verification and validation exercise.

### ***Explanatory Variables***

In terms of their influence on plants, environmental factors can be categorized as direct, indirect, or resource variables (Table 2) (Austin and Smith, 1989; Austin, 2005; Kent, 2012). For the best chance of finding cause-effect relationships, species-environment relationships should ideally be analyzed using direct and resource variables (Callaghan and Ashton, 2008). When these are unavailable, indirect data variables can replace a combination of direct and resource variables, and are more easily accessible through remote-sensing techniques or simple field measurements (Guisan *et al.*, 1999; Callaghan and Ashton, 2008).

**Table 2. Categories of environmental variables based on their influence on plants.**

| <b><i>Category</i></b>    | <b><i>Description</i></b>                                                                       |
|---------------------------|-------------------------------------------------------------------------------------------------|
| <i>Direct</i>             | Factors that have a direct influence on plant growth (i.e. temperature or soil pH)              |
| <i>Indirect</i>           | Factors that act indirectly through direct variables (i.e. elevation, geology, or habitat type) |
| <i>Resource Variables</i> | Used by plants in the course of growth (i.e. water, soil nutrients, light)                      |

Variables should be chosen based on their ecological likelihood to influence moss distributions at local scales. To allow mapping, variables must also be capable of being estimated over broad spatial extents using available GIS data layers. Many environmental variables can be modelled and mapped as data layers within a GIS, and used as proxies

for real-life gradients. Data layers can be derived from satellites, aerial imagery, or other types of remote sensing such as LiDAR.

LiDAR is a remote sensing technology in which the distance between a sensor (mounted on an aircraft) and a target surface (the ground) is obtained by determining the elapsed time between the emission of a short-duration laser pulse and the arrival of the reflection of that pulse at the sensor's receiver (Lefsky *et al.*, 2002). LiDAR data can be used to calculate precise x, y, z locations, which are then used to make digital elevation models (DEMs) (Lang *et al.*, 2013). Elevation data from LiDAR-derived DEMs provide fine-scale detail of topographic features and improved accuracy over traditional DEMs (Hudak *et al.*, 2009). These DEMs can in turn be used to create other environmental data layers, such as hydrological indices, topographic land form, aspect, slope, etc.

The hydrological index used for this project is known as the depth-to-water index. The depth-to-water index is created utilizing differences in elevation between the soil surface and adjacent open-water features, and provides an indicator of the level of soil saturation and drainage patterns in areas under consideration (Murphy *et al.*, 2011). The wet areas mapping process depicts an index of soil wetness, expressed as depth-to-water, with continuous coverage across the landscape (Murphy *et al.*, 2007). The resulting wet area maps (DTW rasters) provide an indication of the gradual changes in soil moisture from poorly-drained areas (wetlands) to well-drained areas (uplands/ridge tops). Hydrological patterns fluctuate throughout the year, meaning the groundwater level of a site is not a constant factor. The DTW index models the average water levels at a site, as well as simulates drainage classes.

### ***Spatial Scale***

Identifying the appropriate spatial scale for modelling is a challenge; patterns observed on one scale may not be apparent on another. Bryophytes are traditionally under-represented in landscape-scale studies of vegetation patterns, perhaps because it is assumed they are only sensitive to micro-scale differences in habitat components, or macro-scale variations in climate (Michel *et al.*, 2010; Medina *et al.*, 2011). Some researchers have found that bryophyte distribution is primarily influenced by macroclimatic factors (such as rainfall and temperature) (Bates *et al.*, 2004; Belland, 2005), while others assert that microenvironment features (such as light intensity, humidity, and localized temperature) are more important (Pentecost, 1998; Porley and Hodgetts, 2005). Micro-scale studies look for correlations between bryophyte occurrence and micro-scale habitat variables, such as substrate or microtopography (Frego and Carleton, 1995; Mills and Macdonald, 2004; Schmalholz and Granath, 2013).

Large-scale studies focus on enormous areas (such as entire continents, countries, or regions) and look for correlations between bryophyte species occurrence and broad-scale variables such as latitude or climate. For example, Belland (2005) found that climatic variables such as warmth of the growing season and oceanity (an index that combines annual temperature, precipitation, and evapotranspiration to quantify the influence of the sea) are important factors influencing the distribution of bryophytes in the Gulf of St. Lawrence. In another example, Bates *et al.* (2004) investigated epiphytic bryophyte-environment relationships on transects in southern Britain, and found correlations between bryophyte presence and rivers/streams, rainfall, altitude, and temperature.

The scale of study design in my thesis is neither entirely micro or macro, but instead examines bryophyte distribution at a landscape level, or meso scale. Landscape-scale studies look for patterns of bryophyte distribution that align with landscape features and site factors such as forest composition and age, moisture regime, and substrate (Batty *et al.*, 2003; Sun *et al.*, 2013). Callaghan and Ashton (2008) investigated the relationships between bryophyte distributions and environmental variables at a landscape level in north-west England, and found significant relationships with environmental predictors such as percent cover of broad-leaved woodland and total nitrogen deposition. Vanderpoorten (2002) assessed the influence of soil type, vegetation, and land use on the distribution of bryophytes at a regional scale in Belgium, and found that forest cover and soil conditions (*i.e.* loam, sand, and pebble content) were the best predictors of bryophyte species distribution. In a study on species-environment relationships of common terrestrial moss species in New Zealand, Michel *et al.* (2010) found that the environmental factors which best contributed to species distribution models were total vegetation cover, mean annual temperature and rainfall. Slope, distance to the coast, and forest type also contributed significantly to the final distribution models of that study (Michel *et al.*, 2010).

### ***Mapping***

The ultimate goal of many species-environment modeling studies is spatial inference of species occurrence across the landscape. Typically, GIS-mapped environment and landscape features are used as explanatory (predictor) variables in regression models, and then the relationships found are used to create maps. When mapping is the end goal, explanatory variables are limited to geographic data layers which are available for the area being studied; common layers include elevation, land use, forest cover, water bodies, soil

type, altitude, or annual mean precipitation. Quite often, these layers are at coarse resolution. Safavi and Shirzadian (2011) created maps for four bryophyte genera in Iran using GIS mapped environmental variables such as altitude, precipitation, temperature, and humidity. They found strong preferences for mountainous regions within three genera, as well as negative relationships between temperature and bryophyte distribution. Vanderpoorten and Engels (2002) created probabilistic models of occurrence of many species of bryophytes in Belgium using logistic regression. The occurrence of species intolerant to drought were found to be good indicators of forest cover, and were able to be predicted with a probability higher than 80% using forest cover layers in GIS (Vanderpoorten and Engels, 2002). In another example, Vanderpoorten, Sotiaux and Engels (2005) examined the impact of ecological conditions and land use on bryophyte diversity and rarity patterns using GIS layers as predictors. They found correlations between species diversity and steep slopes, woodland cover, as well as proportion of military lands (for species adapted to open habitats), and showed that patterns of bryophyte diversity can be predicted using landscape features in GIS.

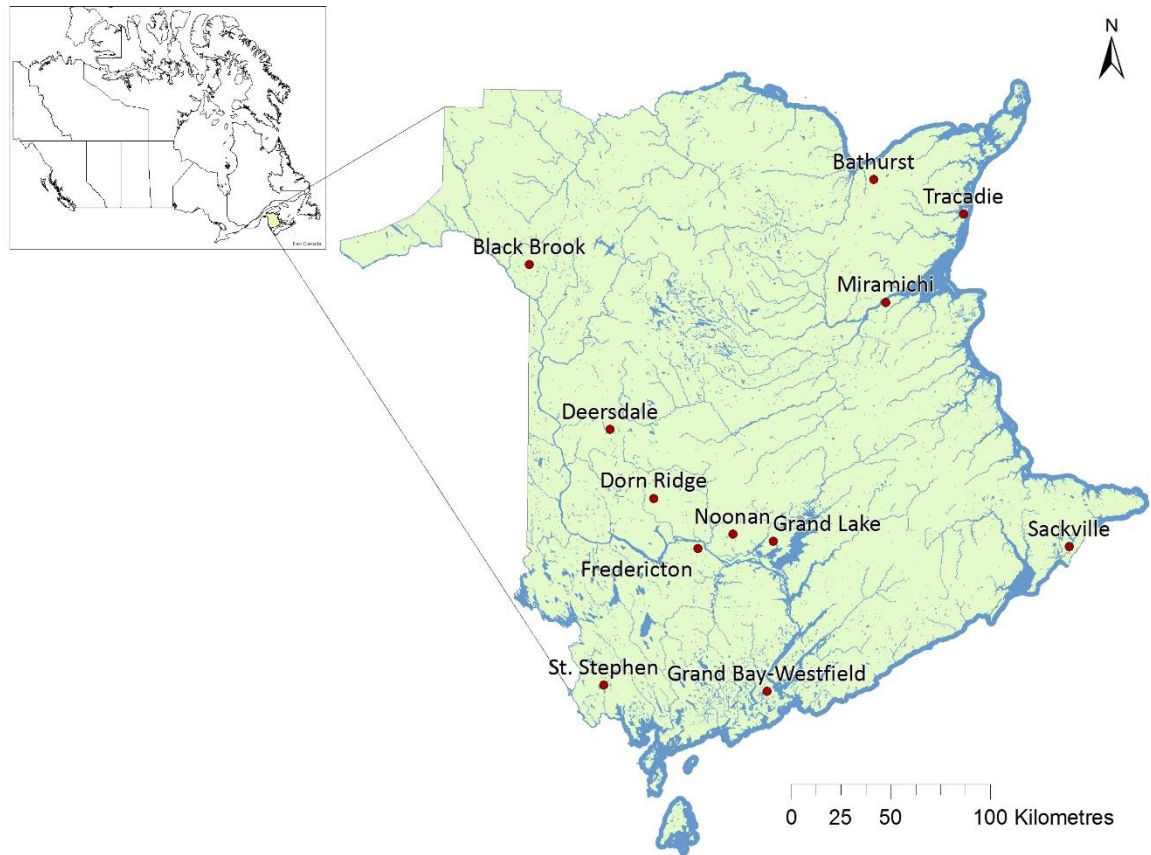
While studies focused on bryophyte-environment mapping are rare, such studies using hydrology models are even rarer; no others were found. Økland (1986) modelled response curves of bryophytes relative to a water-table gradient in Norway, however the primary focus was on rescaling ecological gradients for detrended correspondence analysis and subsequent changes in response curve shapes, not on spatial distributions. Nevertheless, he found significant relationships with water table depth for several species of *Sphagnum* (Økland, 1986). Topographic moisture indices have proven useful for modeling vascular plant species composition, richness, and distribution in a number of studies (Newell and

Peet, 1998; Franklin *et al.*, 2000; Dymond and Johnson, 2002; Kopecký and Čížková, 2010; Sass *et al.*, 2012). The DTW index has previously been used to model and map vegetation types in Alberta according to species-specific soil moisture preferences (Hiltz *et al.*, 2012). This work produced vegetation index maps (ranging from hydric to xeric) for almost 500 vascular plant species, and demonstrated that through plot-based indexing of vegetation type by soil wetness, it is possible to map variations in vegetation types along landscape-scale moisture gradients (Hiltz *et al.*, 2012). Given the evidence in the literature regarding the relationships between bryophytes and landscape scale environmental variables, utilizing a hydrological model to try to map their distributions seems feasible.

### **Study Sites**

In order to create distribution maps that are broadly applicable, an effort was made to sample from sites located across the province, spanning multiple ecosystem types. Locations for the vegetation surveys were limited to areas for which LiDAR data were already available. The acquisition of LiDAR is costly, so it is only available for areas where there are management interests for its procurement, such as for municipalities (Fredericton, Grand Lake, St. Stephen, Grand Bay-Westfield, Bathurst, Miramichi, Sackville, Tracadie, and Noonan) or forested land owned/maintained by forestry companies (Deersdale, Dorn Ridge, and Blackbrook). From this group of LiDAR areas, suitable sites were narrowed down by accessibility, ownership (only Crown lands), and level of development/fragmentation visible from satellite imagery. Efforts were made to select sites with minimal human influence and hydrologic modifications that would affect drainage. The final survey sites were located in wetlands and forested areas at 12 locations

across New Brunswick (Figure 1). For convenience, each of the study sites is named according to the nearest municipality, although in reality the sites were located well outside of developed areas.



**Figure 1. Survey locations across New Brunswick**

The province of New Brunswick is situated between boreal coniferous forests to the north and temperate deciduous forests to the south. It is an ecological transition zone that contains north-temperate mixed forest known as the Acadian Forest, which is a diverse combination of deciduous and coniferous stands with 39 native tree species. The forest is characterized by red spruce (*Picea rubens*), red maple (*Acer rubrum*), balsam fir (*Abies balsamea*), yellow birch (*Betula alleghaniensis*), and sugar maple (*Acer saccharum*) as the most dominant species, with white pine (*Pinus strobus*) and Eastern hemlock (*Tsuga canadensis*) also occurring frequently, but to a lesser degree. The boreal species black

spruce (*Picea mariana*), white spruce (*Picea glauca*), balsam poplar (*Populus balsamifera*), white birch (*Betula papyrifera*), and aspen (*Populus* spp.) are also present (Ecological Stratification Working Group, 1995).

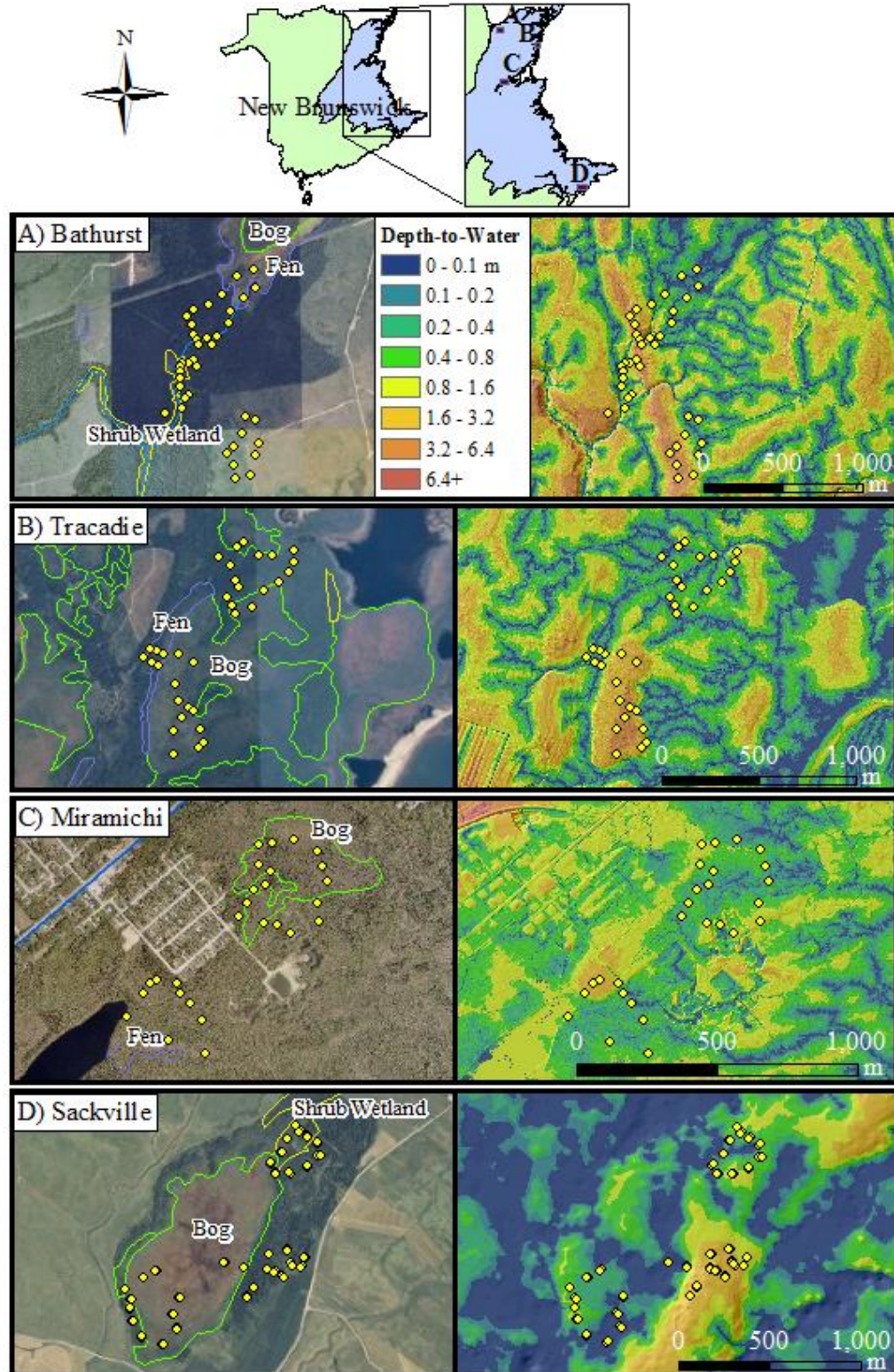
The wetlands at the sites included a mixture of bogs, fens, forested wetlands, and shrub wetlands. Bogs are peat wetlands, with a saturated water regime and closed drainage system. They are covered by ericaceous shrubs, sedges, and sphagnum moss, with black spruce and tamarack being the most common tree species (Ecological Stratification Working Group, 1995). Fens are also peatlands of a saturated water regime, however they have an open drainage system and receive water from surrounding upland areas through seepage, streams, or surface runoff. Forested wetlands are areas where the water table is at or near the surface, for example black spruce swamps (NB Department of Natural Resources, 2006). Shrub wetlands are dominated by a variety of shrubs and also include alder thickets adjacent to wetlands and along watercourses.

While there are some differences in climate from the northern portion of the province to the south, the overall climate of New Brunswick is relatively uniform (New Brunswick Department of Natural Resources, 2007b), compared to the variability in climate across the entire geographic range of the focal species. The species included in the present study have previously been recorded throughout the province (Ireland and Hanes, 1982; Bagnell *et al.*, 2014), thus it is not expected that climatic variables would have much effect on distribution across local moisture gradients. The coordinates and details for each study site are provided in APPENDIX A. The province of New Brunswick is divided into 7 ecoregions, using an ecological land classification process that follows the concept of ecological gradients. These are defined primarily by differences in major landforms,

elevation, latitude, marine influences, and broad aspect, as well as the associated changes in distributions of species and ecosystems in relation to these landscape characteristics (New Brunswick Department of Natural Resources, 2007a). The study site descriptions have been grouped by ecoregion for simplicity only; each of the focal bryophyte species can be found within any ecoregion (Ireland and Hanes, 1982).

### ***Eastern Lowlands***

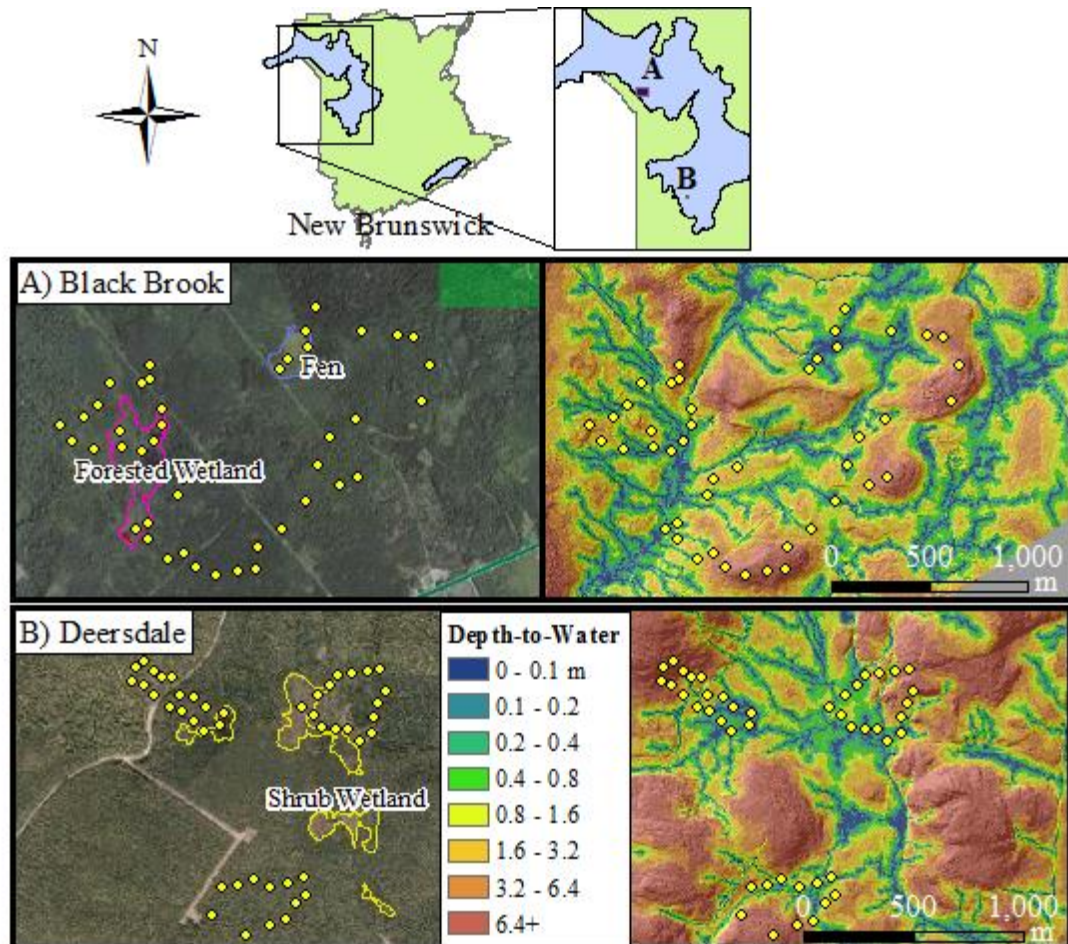
The sites within the Eastern Lowlands Ecoregion included Bathurst, Tracadie, Miramichi, and Sackville (Figure 2). This region consists of flat to gently rolling terrain, defined by the Chaleur Bay and the Northumberland Strait on the north and eastern margins, with sand dunes, salt marshes, and lagoons along the coast (NBDNR, 2007). Extensive peatlands can be found inland, some of which are commercially mined for horticulture. The underlying geology is composed of Carboniferous sedimentary rocks, such as fine, reddish siltstones, grey, quartz-rich sandstones, and coarse pebble conglomerates. The elevation ranges between 150m and sea level. The inland summer temperatures are comparable to those in the Valley Lowlands Ecoregion, while the Northumberland coastline experiences much higher summer temperatures than the rest of the province (NBDNR, 2007).



**Figure 2. Study sites in the Eastern Lowlands Ecoregion, with vegetation quadrats shown in yellow. Aerial imagery on the left, and DTW index on the right, including sites: A) Bathurst, B) Tracadie, C) Miramichi, and D) Sackville.**

### *Central Uplands*

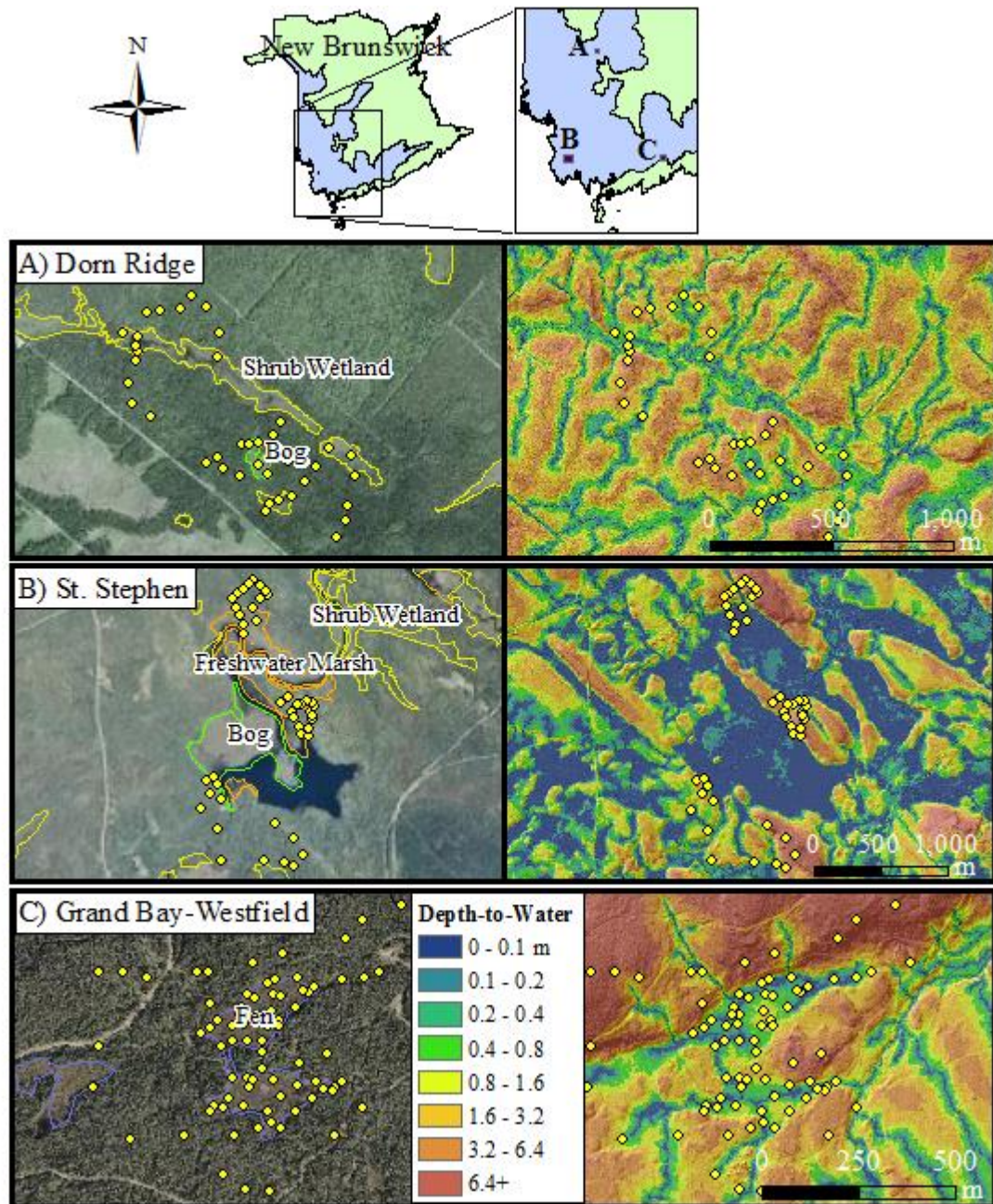
The Blackbrook and Deersdale sites were located within the Central Uplands Ecoregion (Figure 3). The bedrock composition of this area can be broadly divided into two sections: the northern section, which has steeply dipping Ordovician to Devonian metasedimentary rocks (some of which are calcareous), and a southern section, which consists of Devonian granites with minor sedimentary and volcanic rocks of varied ages (NBDNR, 2007). The region has a higher elevation than the neighboring Valley Lowlands Ecoregion, leading to a cooler climate and fairly high amounts of precipitation.



**Figure 3. Study sites in the Central Uplands Ecoregion, with vegetation quadrats shown in yellow. Aerial imagery on the left, and DTW index on the right, including sites: A) Blackbrook and B) Deersdale.**

### ***Valley Lowlands***

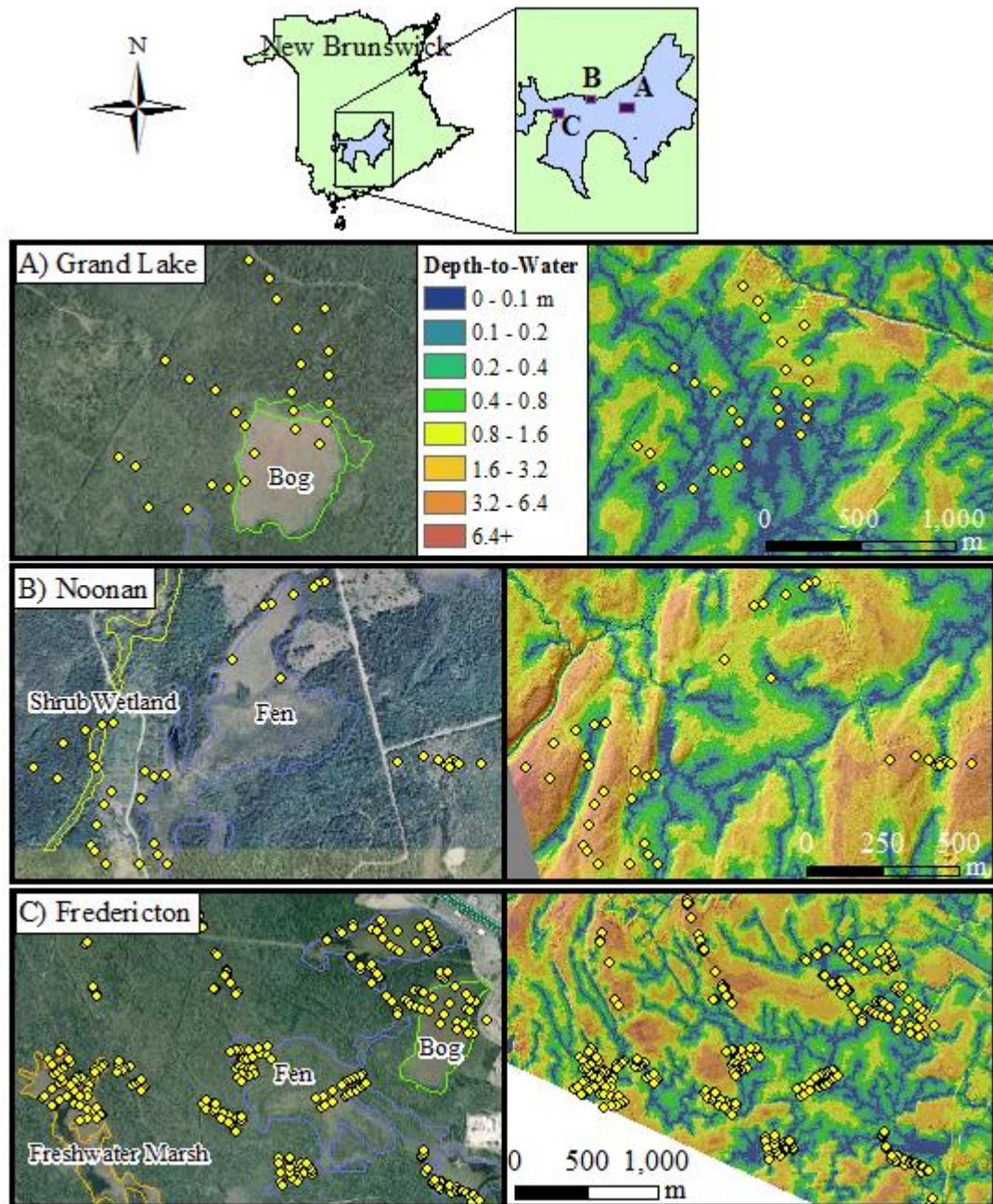
The sites located in this region included Dorn Ridge, St. Stephen, and Grand Bay-Westfield (Figure 4). The Valley Lowlands Ecoregion is most characterized by its diversity, as it stretches over a large portion of the province (NBDNR, 2007). Part of this diversity represents itself by the highly varied geology of the area: the dominant lithology contains sedimentary and metasedimentary rocks of Ordovician, Silurian, and Carboniferous ages. The highest elevation occurs at 572m on Cameron Mountain, and the lowest is 100m in a basin-like area near the ecoregion's shared border with the Grand Lake Lowlands. The Saint John River is the dominating watercourse, and is the watershed for all lesser rivers and streams in the area. The climate is continental, and sheltered from the maritime influences of the Northumberland and Fundy coasts. Summers are warmer and winters are colder than in areas closer to the coast, and the area receives less precipitation than other ecoregions in the province (NBDNR, 2007).



**Figure 4. Study sites in the Valley Lowlands Ecoregion, with vegetation quadrats shown in yellow. Aerial imagery on the left, and DTW index on the right, including sites: A) Dorn Ridge, B) St. Stephen, and C) Grand Bay-Westfield.**

### ***Grand Lake Lowlands***

The sites located in this ecoregion included Grand Lake, Noonan, and Fredericton (Figure 5). The Grand Lake Lowlands Ecoregion in central New Brunswick is distinguished by its extensive alluvial floodplains; included are the Grand Lake basin, the Oromocto River watershed, and the floodplains surrounding the lower Saint John River (NBDNR, 2007). Sections closest to the river are characterized by seasonal flooding. The bedrock of this ecoregion is composed almost entirely of Carboniferous, non-calcareous sedimentary rocks, such as fine siltstone, sandstone, and coarse conglomerates (NBDNR, 2007). Elevation ranges from 150m, west of Fredericton to just above sea level along the floodplains of the lower Saint John River. This region has the warmest climate in New Brunswick, with the longest growing season and warmest summer temperatures (NBDNR, 2007).



**Figure 5. Study sites in the Grand Lake Lowlands Ecoregion, with vegetation quadrats shown in yellow. Aerial imagery on the left, and DTW index on the right, including sites: A) Grand Lake, B) Noonan, and C) Fredericton. The Fredericton site has more sample plots, because it was sampled in a previous year as part of a different project; it was only used for model validation, as described further in the Methods section.**

## CHAPTER 3 – DATA AND METHODS

### Data Collection

A stratified sampling strategy was employed for data collection, in an effort to represent each section of the sampled gradients. The DTW index previously described was used to define the strata (areas were divided into 8 depth-to-water (DTW) classes ranging from very wet ( $DTW < 0.1m$ ) to dry ( $DTW > 12 m$ )). The range of DTW classes represent moisture gradients from wetlands to upland environments that are increasingly dry. Transects are commonly used to survey changes in vegetation composition along an environmental gradient (Sutherland, 2006). Gradient directed transects were placed across predicted moisture gradients using ArcGIS, and an equal number of sampling points were placed within each DTW class; this resulted in 90 plots per site (see APPENDIX B for complete data set). The transects were positioned to cross through all DTW classes several times, from dry to wet and back again, and also to allow forest entry and exit from a single point (back to the vehicle). Plots were located in the field by following transect lines using a handheld GPS. Plots were at least 10 metres apart to maintain the independence of each plot. To ensure independent plots from each DTW class, samples were not taken in areas where the change in mapped DTW was slight, with narrow divisions of DTW strata very close together.

Ground flora species composition and relative abundance were recorded in 980 plots. Mosses were identified using hand lenses, and samples were brought back to the lab for identification under a microscope as needed. At each plot, a visual estimate of relative abundance was recorded for each species present (estimated visually as a percentage of

the total area within the 1m<sup>2</sup> frame quadrat) (Sutherland, 2006). Percent cover is one of the most common measures of plant abundance, and is defined as the area of ground within a quadrat that is occupied by the above-ground parts of each species when viewed from above (Bullock, 1996). A potential problem with the subjectivity of visually estimating cover is that estimates can vary systematically between investigators. To increase consistency of data collection and limit discrepancies in estimating percentages, the same 2 people measured vegetation quadrats during the entire field season. It is also important to cross-calibrate when more than one person is estimating cover, which was done by periodically assessing quadrats together and estimating cover individually until the numbers estimated by both agree. We also used templates to keep our cover estimates continually calibrated throughout the day (these consisted of cut-out squares representing 0.5%, 1%, 3%, and 5% cover). A photograph of each plot was taken for future reference and to verify the consistency of the visual estimates noted in the field should any discrepancies/errors be found during data analysis.

An effort was made to primarily sample mosses growing on the forest floor (as opposed to those growing on large boulders, for example), because bryophytes are able to colonize a wide variety of surfaces and the growth substrate can affect whether or not individuals are impacted by the local soil moisture regime (substrate was recorded using categories, including mineral soil, humus, rock, woody debris, or water). The depths of the leaf litter layer, fermented layer, and humus layer were measured. Because bryophyte species composition is known to change over microtopographic gradients (Gillrich *et al.*, 2010), mound and pit density of the immediate area was recorded using microtopography classes (Neily *et al.*, 2010).

To characterize the vegetation type of the stands surrounding each plot, tree species composition was sampled using a prism sweep method. A visual estimate of forest canopy closure as a percentage was also recorded for each plot; canopy closure can be used as a proxy for light availability at the forest floor. The tree species composition data were used to determine the vegetation type (VT) of each stand, based on the New Brunswick forest site classification (New Brunswick Department of Natural Resources, 2007a). The VT values range from 1 (predominantly ericaceous species associated with poor soil conditions) to 4 (tolerant hardwood tree species associated with rich site conditions). Each plot was assigned one of eight ecosite categories (bog, fen, freshwater marsh, shrub wetland, forested wetland, ecotone, or riparian zone) based on its location within the landscape, hydrology, and plant species composition, using the New Brunswick Department of Natural Resources (NB DNR) classification scheme. A simple binary variable of ‘wetland’ was also used, denoting 1 if the plot was located in a wetland, and 0 if not. Although the variables measured in the field were used to create the initial models, remotely-sensed data were required in order for the models/maps to be extrapolated to unsampled areas. The New Brunswick Department of Environment GIS data layers were used, consisting of forest cover and wetland polygons, created through a combination of forest inventory sampling and interpretation of DNR aerial photographs (NB Department of Natural Resources, 2006).

A series of LiDAR-derived 1 meter resolution digital elevation models were used to generate the depth-to-water maps for each site using ArcGIS (ESRI, 2009). The depth-to-water table index is created utilizing the difference in elevation between the soil surface and adjacent open-water features (such as flow channels or water pools) (Murphy *et al.*,

2011). This method provides an indicator of the level of soil saturation in the areas under consideration. An average DTW value (in meters) was interpolated at the location of each sample point.

Focus was placed on predictors that could intuitively be true variables in determining species distribution patterns, and that were also capable of being mapped at a landscape scale (Table 3).

**Table 3. Variables tested in regression models**

| <b>Variable</b>             | <b>Description</b>                                                             | <b>Units</b>               |
|-----------------------------|--------------------------------------------------------------------------------|----------------------------|
| <b>GIS-Mapped Variables</b> |                                                                                |                            |
| DTW                         | Depth-to-water (log <sub>10</sub> -transformed)                                | Log <sub>10</sub> (Metres) |
| Slope                       | DEM-derived slope (20m focal average)                                          | %                          |
| Aspect                      | DEM-derived aspect (northness/eastness)                                        | 2 Classes                  |
| Ecosite                     | Wetlands: Bog, Fen, Marsh, Forested, Riparian, Shrub, and Non-Wetlands: Upland | 7 Classes                  |
| ForestType                  | Forest Type (SW, HW, MX, Other)                                                | 4 Classes                  |
| CC                          | Canopy Closure Class (0-5)                                                     | 6 Classes                  |
| <b>Unmapped Variables</b>   |                                                                                |                            |
| VT                          | Vegetation Type (1-Poor to 4-Rich)                                             | 4 Classes                  |
| Microsite                   | Mound or pit                                                                   | 2 Classes                  |
| Soil type                   | Organic vs. Mineral soil                                                       | 2 Classes                  |
| L_Layer                     | Depth of the litter layer                                                      | cm                         |

## **Statistical Models**

Selecting an appropriate statistical model is not a straightforward task. There is no global consensus or standard for which models work best for modelling plant species responses and distributions (Austin, 2007). Species distribution modelling is an active area of research, meaning new techniques are continually created to improve upon the old. Guisan and Zimmermann (2000), as well as Franklin (2009) provide summaries of many different model types. Since plants often show non-linear responses to environmental variables, it is good practice to test for such responses and not assume straight line or quadratic functions without justification (Austin, 2007). Regression analyses are amongst the most prevalent models. Of these, generalized linear models (GLMs) are frequently used, as they provide a flexible generalization of ordinary linear regression that allows for non-normal error distributions (Guisan *et al.*, 2002), which are the norm in plant species occurrence data. Logistic regression is one type of GLM; it is one of the most established statistical frameworks for plant species distribution modeling (Franklin, 2009), and has been widely used for this purpose in ecological studies (Guisan *et al.*, 1999; Vanderpoorten and Engels, 2002; Rydgren *et al.*, 2003; Engler *et al.*, 2004; Chahouki and Chahouki, 2010; Lemke *et al.*, 2011). This study uses a combination of three types of logistic regression models; a description of each follows.

### ***HOF Models***

Huisman-Olff-Fresco (HOF) models (Huisman *et al.*, 1993) are a type of logistic regression that allows visualization of non-linear response curves for individual species. HOF models have been used in a number of species/environment modelling studies and have been shown to be among the best techniques for characterizing species-environment

relationships (Rydgren *et al.*, 2003; Pakeman *et al.*, 2007; Peppler-Lisbach, 2008; Suchrow and Jensen, 2010; Uğurlu and Oldeland, 2012; Jansen and Oksanen, 2013; Wesuls *et al.*, 2013). They are designed to model the realized niche of species for any gradient type, while being simple and easy to interpret (Jansen and Oksanen, 2013). HOF models are parametric generalized linear models (GLMs) that consist of a set of hierarchical species response curves of increasing complexity, involving one to four model parameters (equations 1 to 5).  $M$  represents the maximum value of the response variable, which is equal to 1 for binary data.

$$\text{Model I:} \quad y = M \frac{1}{1+e^a} \quad (1)$$

$$\text{Model II:} \quad y = M \frac{1}{1+e^{a+bx}} \quad (2)$$

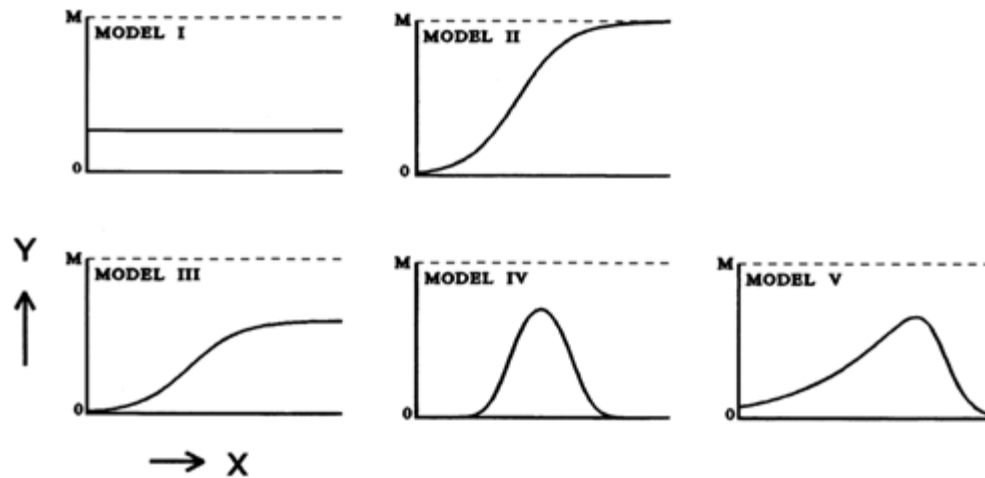
$$\text{Model III:} \quad y = M \frac{1}{1+e^{a+bx}} \frac{1}{1+e^c} \quad (3)$$

$$\text{Model IV:} \quad y = M \frac{1}{1+e^{a+bx}} \frac{1}{1+e^{c-bx}} \quad (4)$$

$$\text{Model V:} \quad y = M \frac{1}{1+e^{a+bx}} \frac{1}{1+e^{c+bx}} \quad (5)$$

A hierarchical framework following maximum likelihood methods is used to identify the most parsimonious model from the family of models (Huisman *et al.*, 1993). Model type I is a null hypothesis and means there is no significant trend along the gradient for that species (Figure 6). Models II and III are sigmoidal, and only allow for an “open-ended” response, which is quite different from the traditional Gaussian response (Huisman *et al.*, 1993). Models IV and V are unimodal. The models are descriptive and provide a visualization of the species response curves along measured and modelled environmental

gradients. As this approach utilizes only univariate models, it is an initial step in the modelling process, to be followed by more complex (multivariate) regression models.



**Figure 6. Theoretical species response models, ranked by increasing complexity. There are five model types: (I) no response, (II) sigmoidal with plateau equal to upper bound ( $M$ ), (III) sigmoidal with plateau below upper bound ( $M$ ), (IV) unimodal symmetric, and (V) unimodal skewed.**

From: Huisman, Olff, & Fresco (1993).

Binary species occurrence data (presence or absence of a species) from all 980 plots were used along with four measured/modelled environmental variables: depth-to-water (DTW), slope, canopy closure, and leaf litter depth. HOF models require continuous variables, and so it was not possible to model species response curves for categorical variables such as wetland or forest cover type, however these are indirect variables that are represented by DTW and canopy closure. The DTW and slope gradients were created using 1m resolution LiDAR DEMs, whereas canopy closure and leaf litter depth were measured at each plot in the field. These variables were chosen on the basis of availability, as well as suitability for HOF modeling. Raw mean values were calculated for each species along each gradient, with 95% confidence intervals. The modelled species response curves, optima,

and niche width were calculated with the statistical programming environment R 3.1.2 (R Core Team, 2014), using the *eHOF* package v. 1.5.7 (Jansen and Oksanen, 2013). The model parameters (a, b, c, d) were estimated by the software using non-linear maximum likelihood estimation procedures with  $\alpha=0.05$  (Oksanen and Minchin, 2002) to get the best fitting curve out of the set of models (I-V). Selection of the most adequate model type was done using the Akaike Information Criterion (AIC) (Akaike, 1974). AIC measures model goodness-of-fit and complexity, and when comparing a set of models, the model with the lowest AIC is said to describe the most parsimonious model (Burnham and Anderson, 2002), and hence the most probable species response curve.

For each gradient and species, an ecological optimum and niche width were extracted using internal functions of the *eHOF* package (Jansen and Oksanen, 2013). The optimum is defined as the gradient value where the species response is highest (greatest probability of species occurrence). The realized niche width was estimated for each species using fractions of response curve maxima to obtain central and outer range borders (Jansen and Oksanen, 2013). The outer border and central border provide a measurement of the distance from the optimum (in both directions) which is needed for the response to decline a certain amount (i.e. short distance indicates a narrow response, and a long distance indicates a broad response) (Heegaard, 2002).

The generally recommended guideline is that a minimum of 50 observations of species occurrence are required to give an accurate estimate of species response functions with logistic regression (Stockwell and Peterson, 2002; Coudon and Gégout, 2007; Franklin, 2009). Species with less than 50 observations out of 980 plots were therefore omitted from the modeling. The 7 species that had a sufficient proportion of occurrences in the data set

and were included in the analysis were: *Bazzania trilobata*, *Dicranum polysetum*, *Hylocomium splendens*, *Polytrichum commune*, *Pleurozium schreberi*, *Sphagnum fuscum*, and *Sphagnum girgensohnii*.

The fit of nonlinear regression models can be assessed with a plot of the fitted values overlaid with the observed responses. Since the observed responses in this instance are binary, they must be converted into relative frequencies before plotting. Each environmental gradient was subdivided into intervals (classes), and the fraction of observations within each defined class (relative frequency) was then calculated for each species. The relative frequencies were superimposed as points on the graphs to visualize how well the fitted curves match with observed response (represented by the relative frequency in each interval).  $R^2$  values resulting from linear regression analyses were used to quantify the relationship between observed and predicted values. The binary (presence/absence) data which were used to create the curves are also shown on the graphs, represented by '+' symbols.

### ***Logistic Regression***

Logistic regression (Hosmer and Lemeshow, 1989) is a special form of GLM that is appropriate for use when the response data are binary (such as presence/absence observations). For binomial data, a logit link function is used to describe the relationship between the response and the linear sum of the predictor variables (Hosmer *et al.*, 2013).

The logistic regression model is represented as:

$$\log\left(\frac{p_i}{1-p_i}\right) = \alpha + \beta_1 X_1 + \cdots + \beta_n X_n \quad (6)$$

where  $p$  is the probability of species occurrence,  $\alpha$  is a constant to be estimated, and  $\beta_i$  a coefficient to be estimated for each explanatory variable  $X_i$  (Hosmer *et al.*, 2013). The regression equation provides probability values of  $y$  ranging from 0 to 1, with values close to 1 representing high probability of species presence.

Logistic regression was used to test the influence of depth-to-water, slope, canopy closure, forest type, microtopography, and leaf litter depth on the likelihood of occurrence (presence/absence) of seven bryophyte species. The models were fitted using SPSS (IBM Corp., 2013). The initial set of variables was reduced using exploratory data analysis to remove variables that were highly correlated with another variable, or had no apparent relationship with the response variables. A two-step procedure was used; first, the responses to each of the predictor variables were modelled separately. Secondly, logistic models were fitted for each species by including predictor variables in order of decreasing F (and p) values. Checks were made at each stage to verify that terms already in the model remained significant ( $\alpha = 0.05$ ) as new terms were added. The significance of the model coefficients were assessed using the Wald test (Tutz, 2012). Model coefficients and their errors were checked for possible collinearity problems using the variance inflation factor (VIF) measure (Mansfield and Helms, 1982). Akaike's Information Criterion (AIC) scores were used to compare among models (Burnham and Anderson, 2002). Model goodness of fit was evaluated using the likelihood ratio test as well as two different pseudo  $R^2$  measures, Cox and Snell  $R^2$  and Nagelkerke  $R^2$  (Akaike, 1974; Cox and Snell, 1989; Nagelkerke, 1991; Hosmer *et al.*, 2013).

### ***Autologistic Regression***

Species distribution models constructed using GLMs are actually non-spatial, in the sense that predicted occurrence at a location is independent of the predictors and/or responses at neighboring locations (Lichstein *et al.*, 2002). Predictions from these models can be used to create spatial output, however the model structure (and resulting maps) does not consider explicit spatial processes such as dispersal or aggregation (Diebel *et al.*, 2010). Conventional statistical modelling on spatial data thus ignores spatial autocorrelation in the residuals, even though there is an ecological likelihood that neighbouring pixels will have dependent probabilities of use (Osborne *et al.*, 2001).

### ***Spatial Autocorrelation***

Ecological datasets often have positive autocorrelation for pairs of observations found near one another, which tend to be more similar than observations that are farther apart (Legendre, 1993; Latimer *et al.*, 2006). This phenomenon is known as spatial autocorrelation (SAC), and it complicates the analysis of spatial data. Spatial autocorrelation of observations in a model can occur when: 1) biological processes are distance-related (i.e. dispersal or species interactions), 2) non-linear relationships are erroneously modeled as linear, and 3) an important *spatial* variable is not accounted for in the statistical model (Legendre, 1993). SAC is typically present in species observation data (Lennon, 2000). Overlooking this issue can lead to violating the assumption of independence on which most statistical models are built, and to a form of pseudoreplication (Legendre, 1993; Fortin and Dale, 2005). Spatial pseudoreplication can increase the probability of rejecting the null hypothesis when it is in fact true (i.e. type I errors) (Fortin and Dale, 2005; Beale *et al.*, 2010), which in turn may result in poorly

estimated regression coefficients and the selection of unimportant explanatory variables (Lennon, 2000; Dormann *et al.*, 2007).

The Mantel test was used to determine whether the ordinary logistic model residuals captured spatial autocorrelation in the observed distributions at each site. This was done using the Pearson residuals and the function ‘mantel.rtest’ of R package *ade4* (Dray and Dufour, 2007). The spatial patterns were visualized via semivariograms using function ‘variog’ of R package *geoR* (Ribeiro Jr. and Diggle, 2001). The semivariograms describe residual spatial autocorrelation after accounting for environmental variation.

After assessing the degree of spatial autocorrelation in the residuals, a method to control the SAC was implemented. One widely applied method is the autologistic approach, an extension of the logistic regression model, which accounts for SAC by including an additional term (the autocovariate) to represent the influence of neighboring observations (Augustin *et al.*, 1996). While an autocovariate can be added into many GLMs, it has most often been applied to logistic regression models (e.g. Augustin *et al.*, 1996; Luoto *et al.*, 2002; Syartinilia and Tsuyuki, 2008; Santika and Hutchinson, 2009). Autologistic models have been found to have better predictive performance than models that do not account for SAC (Hoeting *et al.*, 2000; Wintle and Bardos, 2006; Crase *et al.*, 2014), and the use of autocovariates can improve predictive performance of logistic regression models (Sanderson *et al.*, 2005; Piorecky and Prescott, 2006; Santika and Hutchinson, 2009). The autologistic is a modification of the regular logistic model from equation 6 with an additional autocovariate term:

$$\log\left(\frac{p_i}{1-p_i}\right) = \alpha + \beta_1 X_1 + \cdots + \beta_n X_n + \beta_{n+1} autocov_i \quad (7)$$

where  $\beta_{n+1}autocov_i$  at any site  $i$  may be calculated as:

$$\beta_{n+1}autocov_i = \sum_{j \in k_i} w_{ij}y_j \quad (8)$$

The autocovariate represents the weighted sum of the predicted probability of occurrence for sites within a specified neighbourhood ( $y_j$  is the response value of  $y$  at site  $j$  among site  $i$ 's set of  $k_i$  neighbours; and  $w_{ij}$  is the weight given to site  $j$ 's influence over site  $i$ ) (Augustin *et al.*, 1996).

The initial probability of occurrence maps estimated using the ordinary logistic regression were used as a starting point for fitting autologistic models, following the modified Gibbs sampler method (Augustin *et al.*, 1996; Osborne *et al.*, 2001). The ideal neighbourhood size is defined as the maximum distance at which the residuals from the logistic regression model are autocorrelated; this distance can be determined using a semivariogram of the residuals (Lichstein *et al.*, 2002). A moving window of 21 x 21 pixels was selected to calculate the sum of the probabilities within a 15m neighbourhood of each cell using the focal statistics tool in ArcGIS (ESRI, 2009). The resulting autocovariance term was incorporated into the model along with the other predictor variables, to create the first autologistic regression probability surface. This procedure was then repeated on the new probability surface, until the fitted probabilities converged (Augustin *et al.*, 1996). Augustin *et al.* (1998) found that convergence of fitted probabilities occurred at about the fifth iteration, and that probability maps with just one autologistic iteration performed better than ordinary logistic regression models. Several different neighbourhood sizes were tested and compared, and a neighbourhood size of 15m was chosen based on model AIC, predictive power, and significance of predictor variables.

### ***Model Performance***

Receiver operating characteristic (ROC) curves were calculated using SPSS and used as a measure of model accuracy. The ROC curve describes the relationship between the numbers of correct vs incorrect predicted presences. The area under the ROC curve (AUC) index measures model discriminatory ability and varies from 0.5 (no better than chance) to 1.0 (perfect discrimination) (Hanley and McNeil, 1982). Models with AUC values >0.7 are considered to have high discriminatory power (Hosmer *et al.*, 2013). Model accuracy was also evaluated using the proportional by chance accuracy rate, which is calculated by summing the squared proportion that each group (present/absent) represents of the total sample. The benchmark criterion typically used to characterize a logistic regression model as useful is a 25% improvement over the rate of accuracy achievable by chance alone (White, 2013).

### **Mapping**

Maps showing the probability of occurrence for each species across the landscape were created using ArcGIS (ESRI, 2009). Regression model results are implemented in the program by multiplying each regression coefficient with its related predictor variable. The results of logistic regressions must be transformed using the inverse link function so that the resulting probability values are on the scale of the original response variable (Guisan and Zimmermann, 2000). The inverse logistic transformation for binary logistic regression is  $p(y) = \exp(LP) / (1 + \exp(LP))$ . LP is the linear predictor fitted by logistic regression (Guisan and Zimmermann, 2000). The equation produces probability values between 0 and 1 at every cell of the GIS grid (1x1m). The resulting maps are considered

as habitat suitability maps, showing the probability of occurrence for each species across the landscape based on environmental variables.

### **Model Validation**

This study utilizes independent data for evaluation, meaning the models were calibrated with one set of data, and the fit was evaluated with totally separate data. This is recommended over the ‘resubstitution’ method, where a random subset of the data used to calibrate the models are also used to validate them, as models may over-fit to the calibration data leading to low predictive accuracy on other data sets (Araújo *et al.*, 2005). Assessing model predictions against an independent dataset is vital when researchers wish to generalize model predictions to other regions (Jewell *et al.*, 2007). The independent data set consists of vegetation surveys conducted in the UNB Woodlot in Fredericton, NB, (66° 40' 42.408" W, 45° 55' 52.062" N), during the summer of 2013. The UNB woodlot data set contains 325 quadrats, assessed using the same techniques, spanning the same range of depth-to-water values, and containing most of the wetland types (with the exception of shrub and forested wetlands) represented in the full data set; the data are provided in APPENDIX C. The sole limitation is that the *Sphagnum* species were only identified to genus, meaning that species-specific validation will not be possible for *S. fuscum* and *S. girgensohnii*.

The process involved applying the regression model results in ArcGIS in the usual way, by multiplying each regression coefficient with its related predictor variable, to create species distribution maps for the UNB woodlot area. The model predicted probabilities were then compared with the actual observed occurrences, both visually and quantitatively using the AUC method described previously.

## CHAPTER 4 – RESULTS

The frequency of occurrence varied widely among the sampled mosses. *P. schreberi* and *S. girgensohnii* were the two most common species, appearing respectively in 328 and 301 of the samples (Table 4). *D. polysetum* was also quite common, with 233 recorded observations. Several species, including *C. dendroides*, *P. crista-castrensis*, *R. triquetrus*, *S. squarrosum*, and *S. wulfianum* were locally abundant in terms of percent cover, but not relative frequency. Species with fewer than 50 observations (n=6) were not included in the modeling exercise.

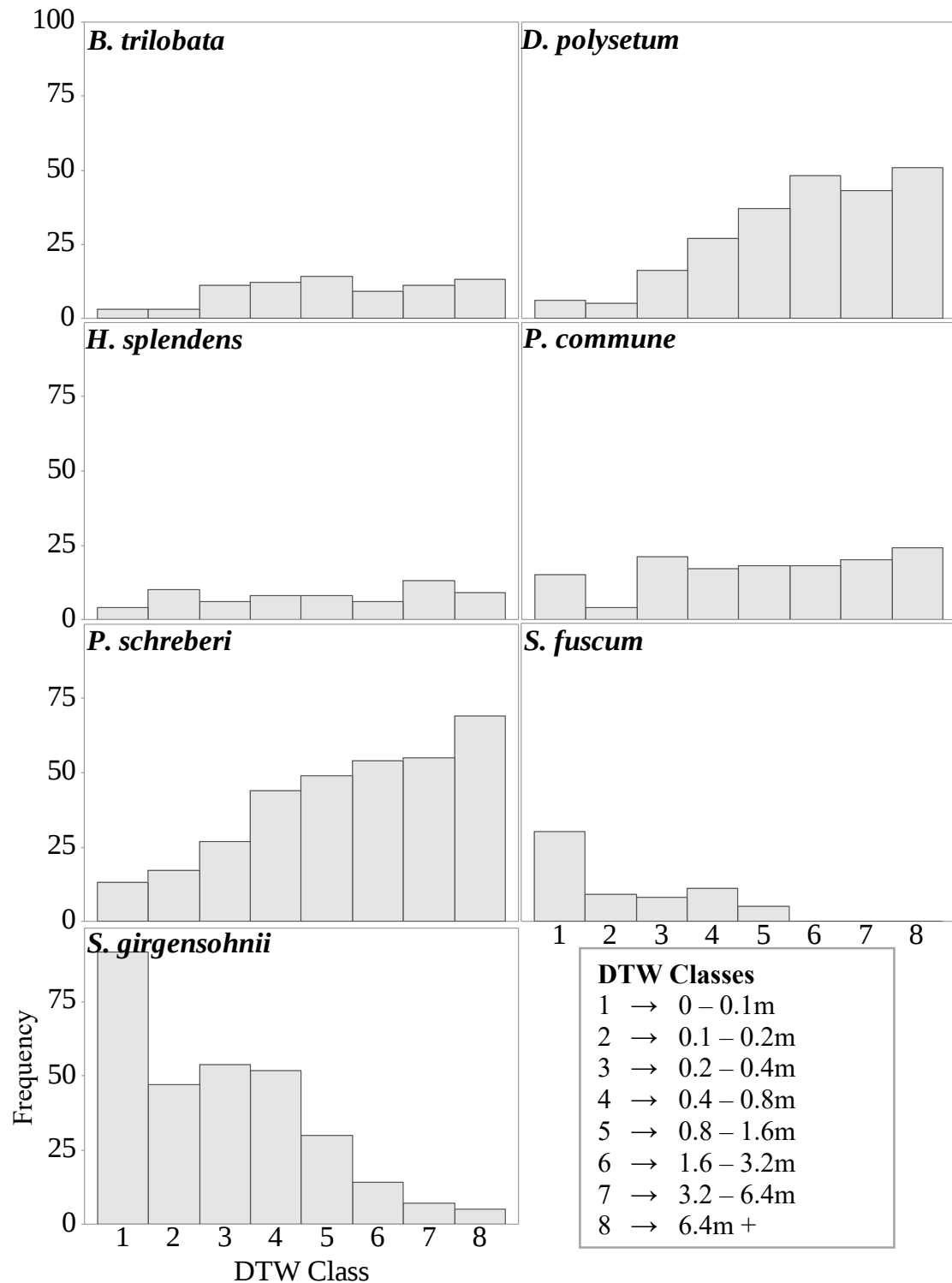
**Table 4. Total and percent frequency of occurrence, and mean percent cover (when present) of 13 bryophyte species in the data set.**

| Species                           | Common Name              | Count<br>(N=980) | %<br>Frequency | Mean<br>%<br>Cover |
|-----------------------------------|--------------------------|------------------|----------------|--------------------|
| <i>Aulacomnium palustre</i>       | ribbed bog moss          | 18               | 1.8            | 2.6                |
| <i>Bazzania trilobata</i>         | bazzania                 | 76               | 7.8            | 6.6                |
| <i>Climacium dendroides</i>       | tree moss                | 18               | 1.8            | 6.5                |
| <i>Dicranum polysetum</i>         | wavy dicranum            | 233              | 23.8           | 5.7                |
| <i>Hylocomium splendens</i>       | stair-step moss          | 64               | 6.5            | 10.0               |
| <i>Polytrichum commune</i>        | common haircap moss      | 137              | 14.0           | 10.4               |
| <i>Ptilium crista-castrensis</i>  | plume moss               | 35               | 3.6            | 3.5                |
| <i>Pleurozium schreberi</i>       | Schreber's moss          | 328              | 33.5           | 21.8               |
| <i>Rhytidiadelphus triquetrus</i> | shaggy moss              | 25               | 2.6            | 20.1               |
| <i>Sphagnum fuscum</i>            | brown bog sphagnum       | 63               | 6.4            | 49.6               |
| <i>Sphagnum girgensohnii</i>      | common green sphagnum    | 301              | 30.7           | 47.7               |
| <i>Sphagnum squarrosum</i>        | prickly sphagnum         | 24               | 2.4            | 16.4               |
| <i>Sphagnum wulfianum</i>         | brittle-stemmed sphagnum | 17               | 1.7            | 16.3               |

The seven species with greater than 50 observations were analyzed further for trends/relationships with the available explanatory variables. The sampling was stratified by DTW class. Figure 7 illustrates the frequency (count) of each species, categorized by DTW class. *D. polysetum* and *P. schreberi* show increased frequency in higher DTW

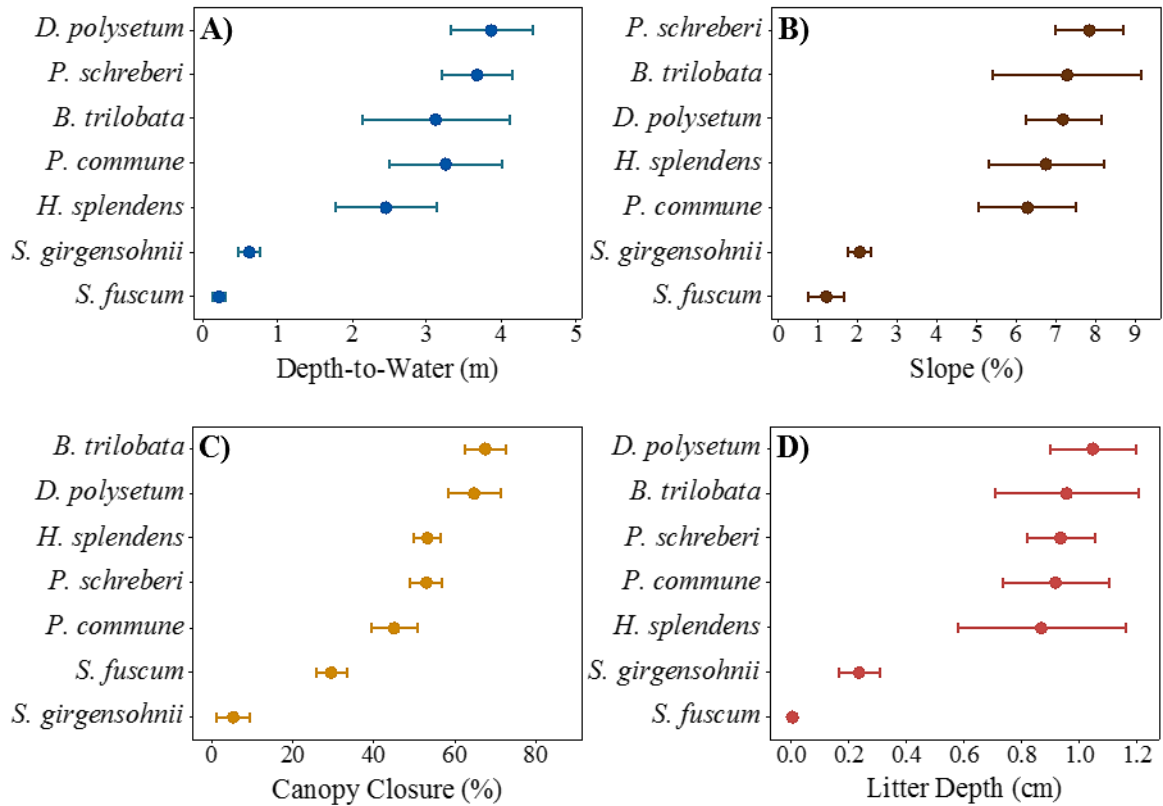
classes (drier areas), whereas *S. fuscum* and *S. girgensohnii* show the inverse relationship.

No clear trends are visible for *B. trilobata*, *H. splendens*, or *P. commune*.



**Figure 7. Frequency (count) of species observations categorized by DTW class**

Means were calculated using modelled DTW values extracted for each plot where a species was present. When the mean values are graphed, the species appear ordered, each occupying a slightly different position along the DTW gradient (Figure 8A).



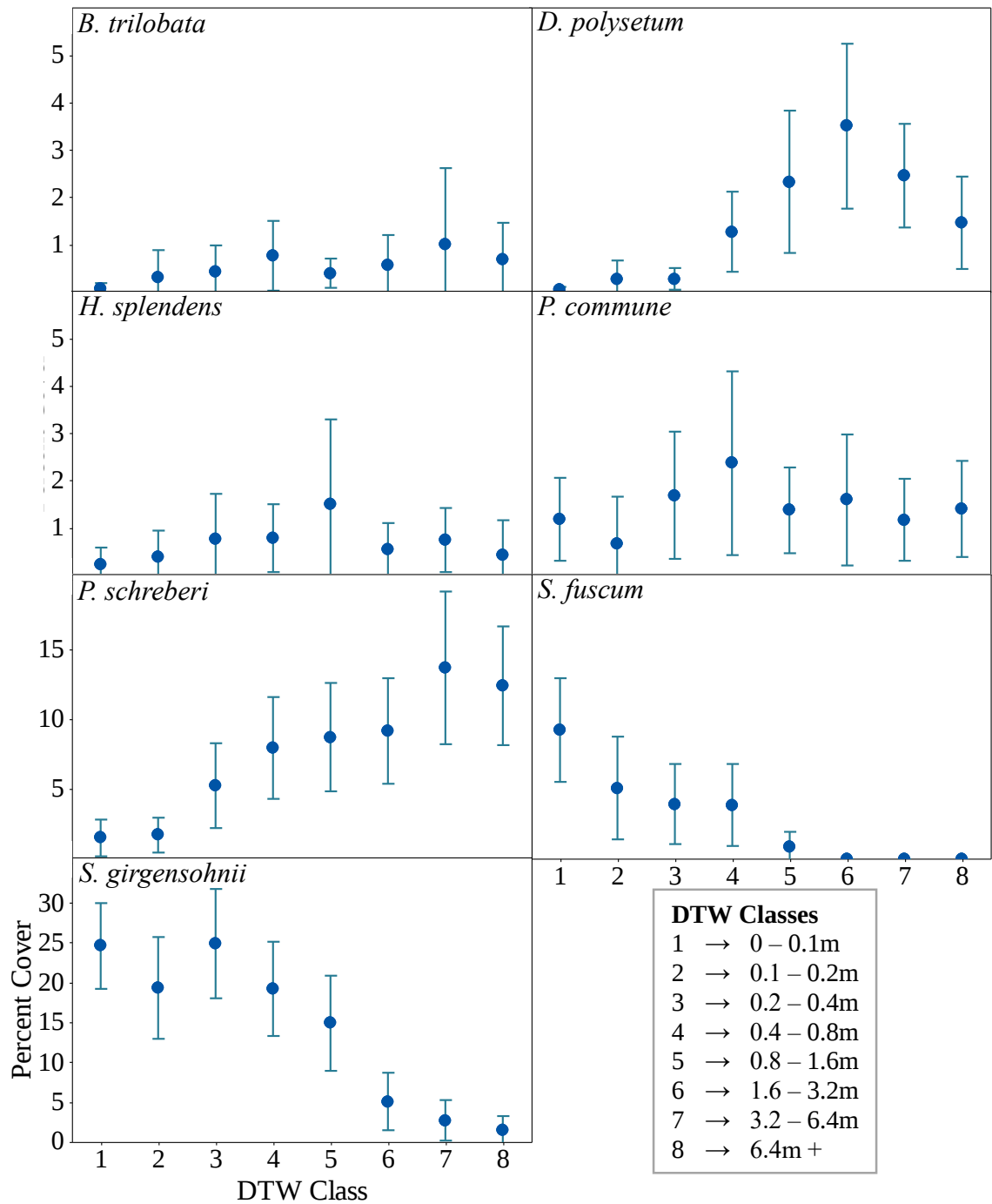
**Figure 8. Mean values of A) depth-to-water, B) percent slope, C) percent canopy closure, and D) leaf litter depth, with 95% confidence intervals calculated for 7 bryophyte species, representing the raw optima of each species, in ascending order.**

Mean values were similarly calculated for slope, canopy closure, and leaf litter depth (Figure 8 B-D). *B. trilobata*, *D. polysetum*, *H. splendens*, *P. commune*, and *P. schreberi* have similar raw mean values for slope, canopy closure, and leaf litter depth. *S. fuscum* and *S. girgensohnii* stand apart from the others, with much lower mean slope, canopy closure, and leaf litter depth values. Further analyses of relationships follow in the next section.

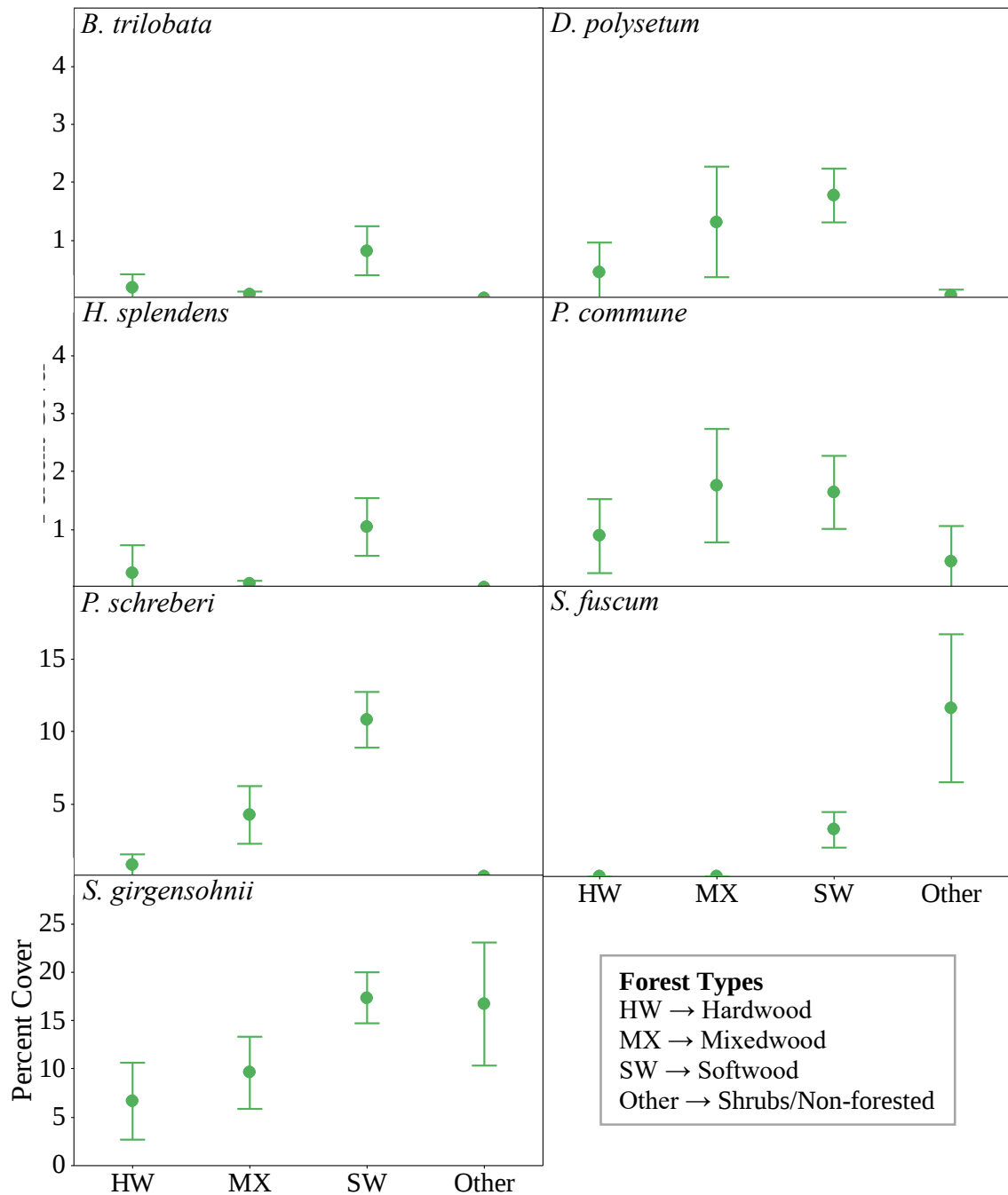
### **Abundance/Percent Cover**

In addition to recording species presence, percent cover was also estimated as a measure of relative abundance. Some bryophyte species show trends when percent cover was averaged by DTW class (Figure 9) or by forest cover type (Figure 10). The observable trends for mean percent cover by DTW class are similar to those for the presence/absence frequency graphs in Figure 7; *D. polysetum* and *P. schreberi* again show increased percent cover in higher (drier) DTW classes, and *S. fuscum* and *S. girgensohnii* show the reverse relationship. Once again, no obvious trends are visible for *B. trilobata*, *H. splendens*, or *P. commune*.

For forest cover type, most species have their lowest mean percent cover (when present) in the HW forest type, and the greatest mean percent cover in SW forests. The *Sphagnum* mosses have high mean percent cover in the ‘other’ category, which applies to non-forested areas such as open bogs or shrub wetlands composed primarily of shrubs, herbaceous plants, and bryophytes.

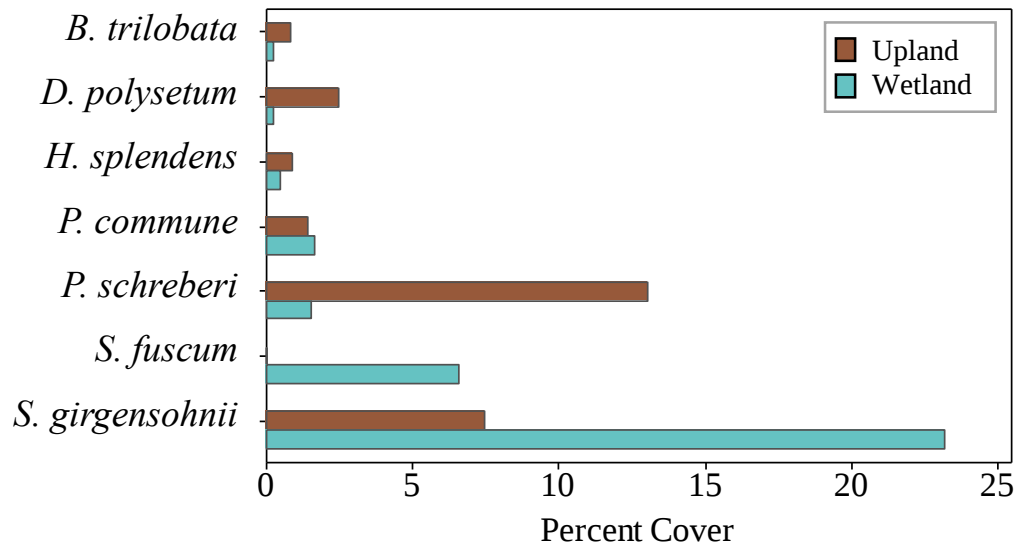


**Figure 9.** Abundance (measured as percent cover) averaged by DTW class for *Bazzania trilobata*, *Dicranum polysetum*, *Hylocomium splendens*, *Polytrichum commune*, *Pleurozium schreberi*, *Sphagnum fuscum*, and *Sphagnum girgensohnii*, with 95% confidence intervals.



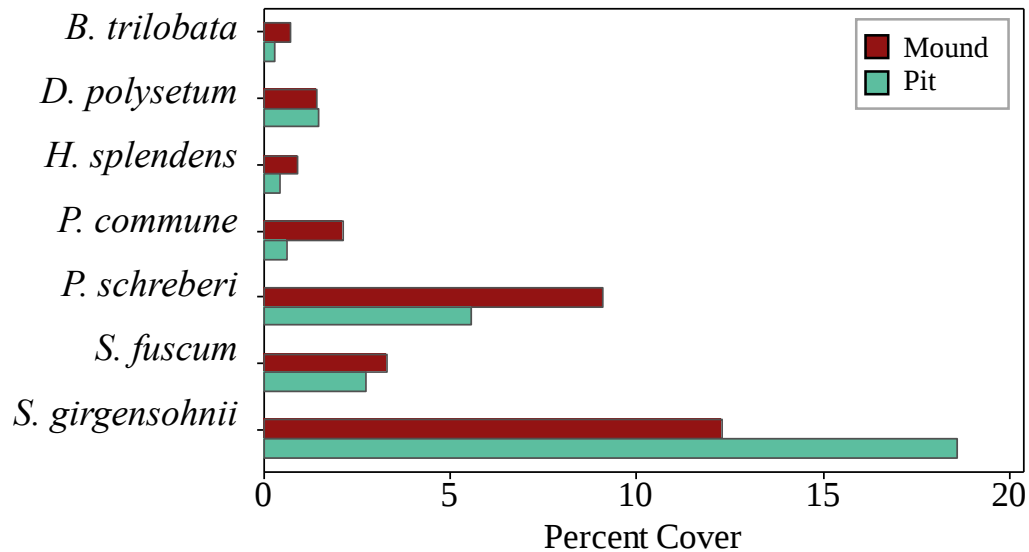
**Figure 10. Abundance (measured as percent cover) averaged by forest type for *Bazzania trilobata*, *Dicranum polysetum*, *Hylocomium splendens*, *Polytrichum commune*, *Pleurozium schreberi*, *Sphagnum fuscum*, and *Sphagnum girgensohnii*, with 95% confidence intervals.**

Mean percent cover is higher in uplands for *B. trilobata*, *D. polysetum*, *H. splendens*, *P. commune*, and *P. schreberi*, whereas *S. fuscum* and *S. girgensohnii* had greater mean abundance in wetlands (Figure 11).



**Figure 11.** Comparison of mean percent cover for *Bazzania trilobata*, *Dicranum polysetum*, *Hylocomium splendens*, *Polytrichum commune*, *Pleurozium schreberi*, *Sphagnum fuscum*, and *Sphagnum girgensohnii*, in uplands versus wetlands.

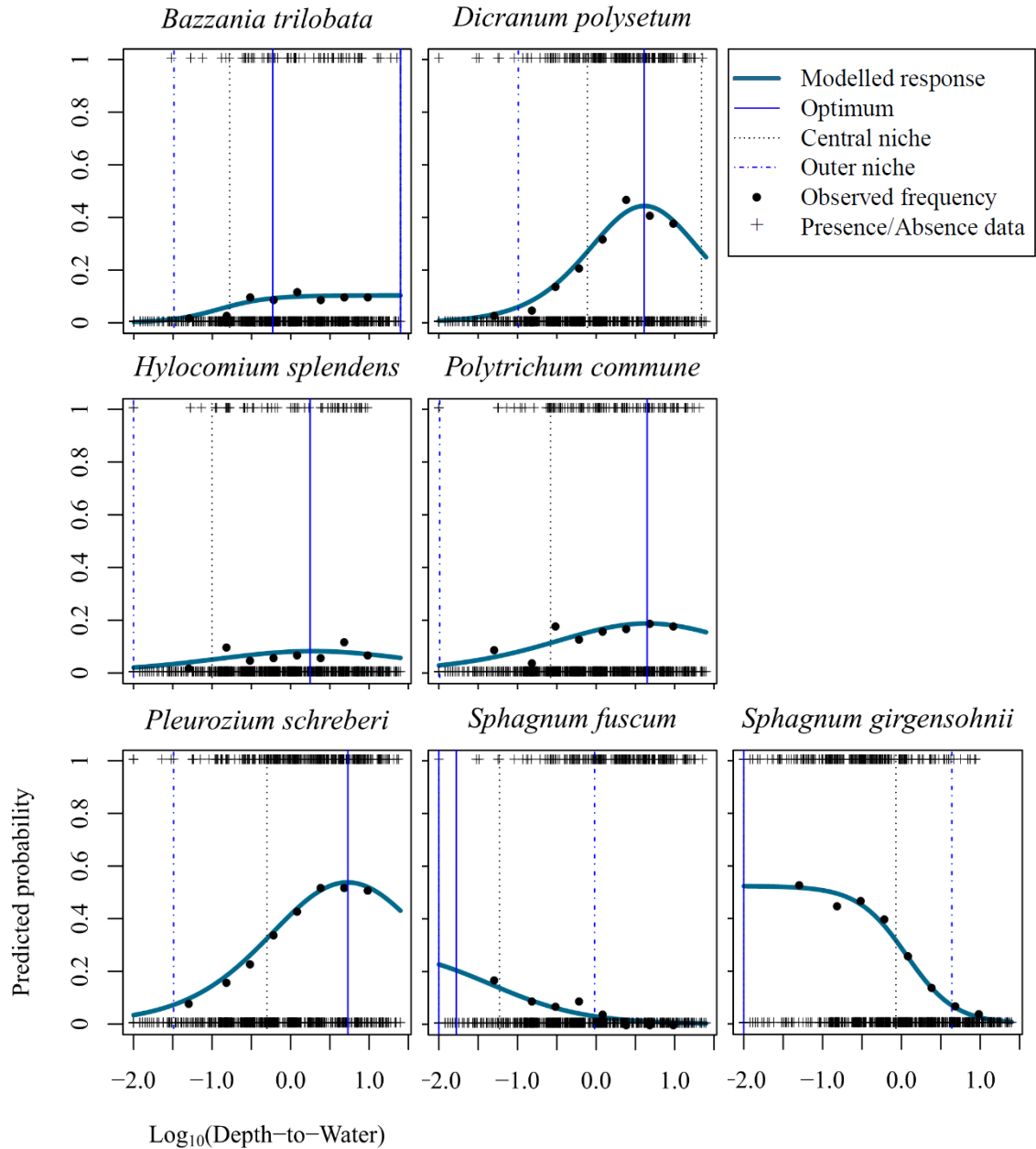
Most species (5 of 7) have higher mean percent cover on mounds than in pits (Figure 12).



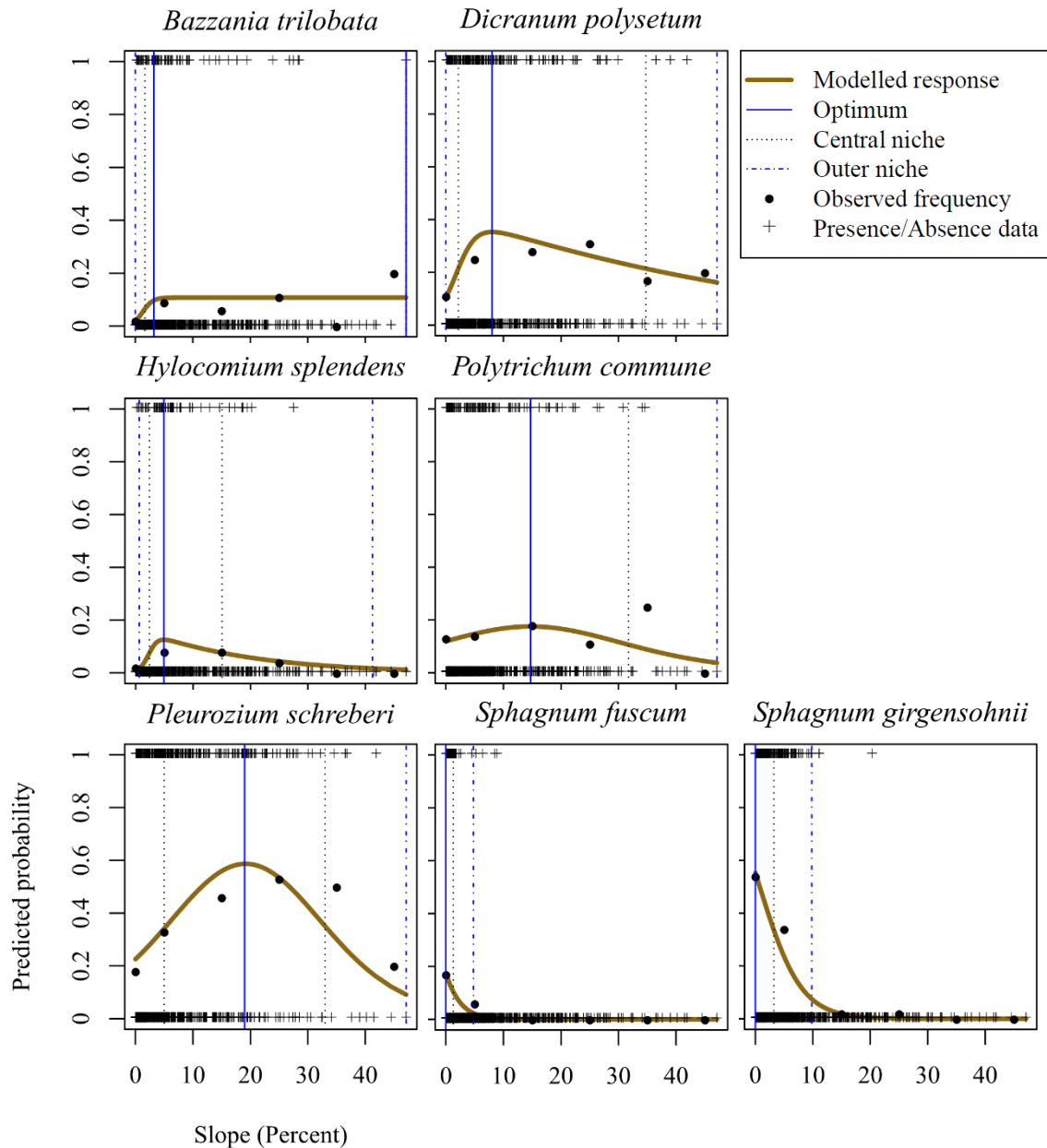
**Figure 12.** Comparison of mean percent cover for *Bazzania trilobata*, *Dicranum polysetum*, *Hylocomium splendens*, *Polytrichum commune*, *Pleurozium schreberi*, *Sphagnum fuscum*, and *Sphagnum girgensohnii*, in mounds versus pits (depressions).

### HOF Modelled Response Curves

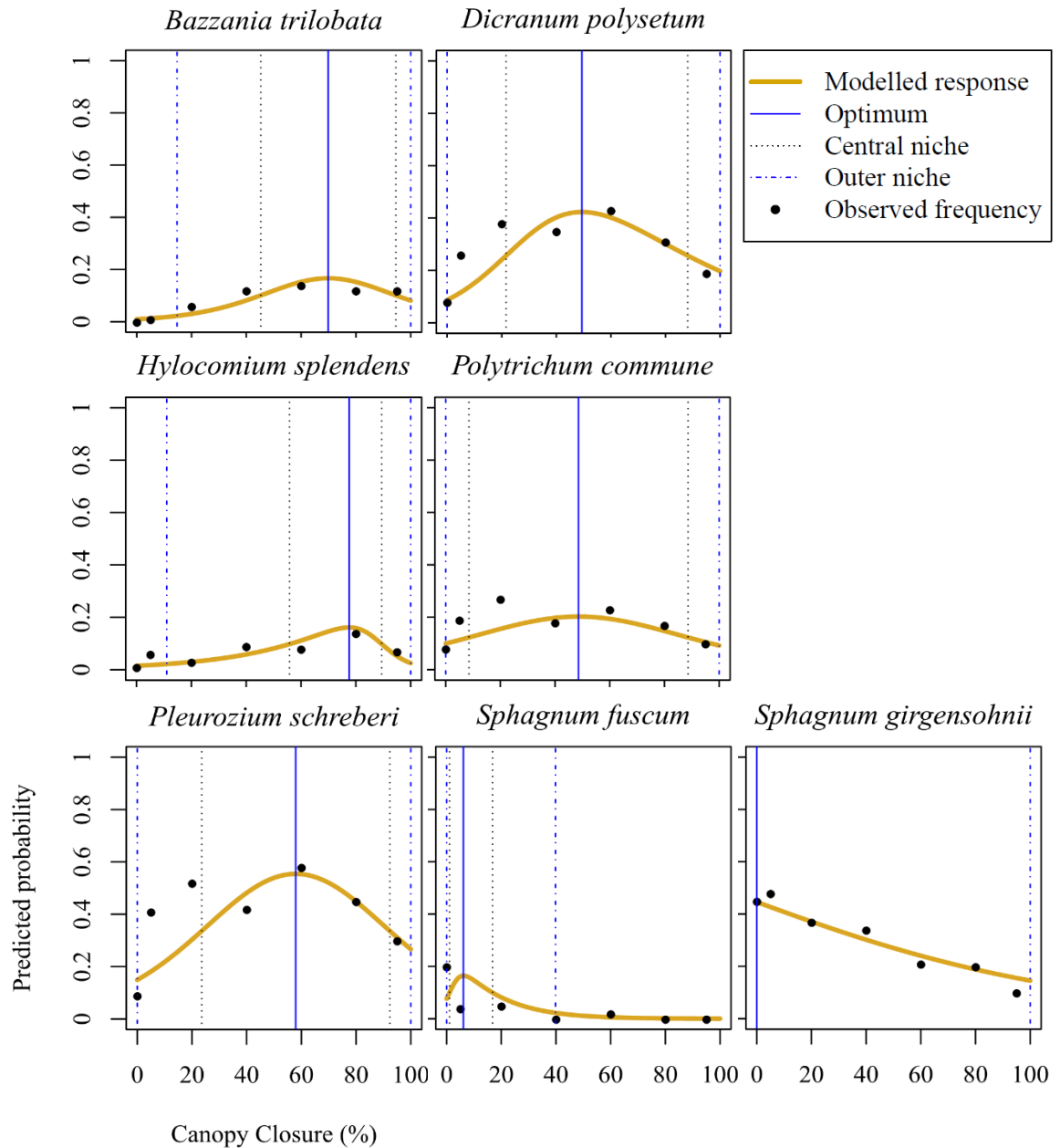
Huisman-Olff-Fresco (HOF; Jansen and Oksanen, 2013) models were employed to visualize species responses to each variable and to predict probability of occurrence. The modelled response curves differed slightly for each species and environmental variable (Figures 13-16). For each individual species, habitat optima (gradient value where species response is highest) and realized niche width (distance from the optimum in both directions, calculated using fractions of response curve maxima) were estimated by the models and are shown on the graphs.



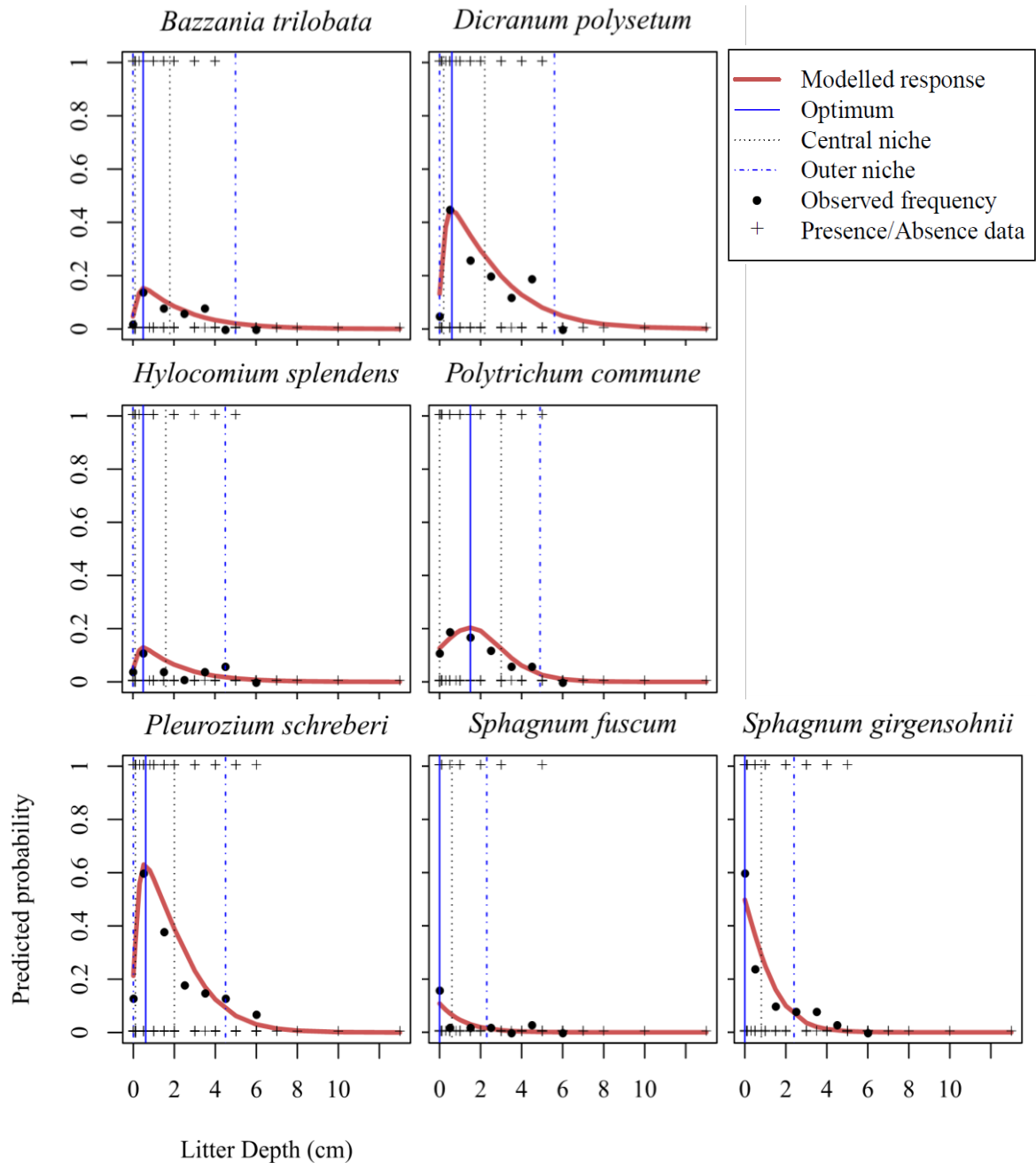
**Figure 13.** Species response curves, fitted by Huisman-Olff-Fresco (HOF; Jansen and Oksanen, 2013) modelling for 7 bryophyte species, displaying each species' probability of occurrence with respect to the  $\text{log}_{10}$  transformed depth-to-water gradient. The maximum estimated probability of occurrence ranged from 0.54 (*Pleurozium schreberi*) to 0.10 (*Bazzania trilobata*). For each species, vertical lines highlight the estimated optimum (solid blue lines), central niche (dotted black lines), and outer niche (dashed blue lines). The observed frequencies are superimposed as points on the graphs. The binary (presence/absence) data are represented by '+' symbols.



**Figure 14.** Species response curves, fitted by Huisman-Olff-Fresco (HOF; Jansen and Oksanen, 2013) modelling for 7 bryophyte species, displaying each species' probability of occurrence with respect to the slope (percent) gradient. The maximum predicted probability of occurrence ranged from 0.59 (*Pleurozium schreberi*) to 0.11 (*Bazzania trilobata*). For each species, vertical lines highlight the estimated optimum (solid blue lines), central niche (dotted black lines), and outer niche (dashed blue lines). The observed frequencies are superimposed as points on the graphs. The binary (presence/absence) data are represented by '+' symbols.



**Figure 15.** Species response curves, fitted by Huisman-Olff-Fresco (HOF; Jansen and Oksanen, 2013) modelling for 7 bryophyte species, displaying each species' probability of occurrence with respect to the percent canopy closure gradient. Maximum predicted probability of occurrence for all models ranged from 0.55 (*Pleurozium schreberi*) to 0.16 (*Hylocomium splendens*). For each species, vertical lines highlight the estimated optimum (solid blue lines), central niche (dotted black lines), and outer niche (dashed blue lines). The observed frequencies are superimposed as points on the graphs. The binary (presence/absence) data are represented by '+' symbols.



**Figure 16.** Species response curves, fitted by Huisman-Olff-Fresco (HOF; Jansen and Oksanen, 2013) modelling for 7 bryophyte species, displaying each species' probability of occurrence with respect to leaf litter depth. Maximum predicted probability of occurrence ranged from 0.63 (*Pleurozium schreberi*) to 0.11 (*Sphagnum fuscum*). For each species, vertical lines highlight the estimated optimum (solid blue lines), central niche (dotted black lines), and outer niche (dashed blue lines). The observed frequencies are superimposed as points on the graphs. The binary (presence/absence) data are represented by '+' symbols.

The modelled species response curves illustrate non-linear trends. Almost all possible HOF model response shapes were used, with the exception of model type I (no response). The majority of the HOF models (68%) had unimodal (bell-shaped) response curves. These models (types IV and V) were most associated with *D. polysetum*, *H. splendens*, *P. commune*, and *P. schreberi*. Linear increasing or decreasing models (models II and III) were less common, representing 32% of all response models, and tended to be the prevalent response types for *B. trilobata*, *S. girgensohnii* and *S. fuscum*. Model parameters, optima and niche values are provided in APPENDIX E.

For DTW, the modeled optima are higher than the raw (observed) optima, and varied from 0.59 to 25.12 metres for the upland species, and between 0.01 and 0.02 metres DTW for the wetland (*Sphagnum*) species (Figure 13). *D. polysetum* and *P. schreberi* show bell-shaped response curves which are positioned towards the drier end of the DTW gradient (optimum between 4.0 and 5.3m DTW). *P. commune* and *H. splendens* also have unimodal curves, however the predicted frequency is very low (close to 0.1 probability) across the entire DTW gradient. *B. trilobata* exhibits a plateau response at depth-to-water values above 0.6m, while *S. girgensohnii* and *S. fuscum* both show a negative response to increasing DTW.

The modeled optimum slope values were quite different from the raw means, ranging between ~3 and 47% slope for most species, except for the two *Sphagnum* species, both of which had estimated optima of 0% slope (Figure 14). *B. trilobata* showed a plateau response above a threshold of about 5% slope. The response curves for *D. polysetum* and *H. splendens* were skewed towards the flatter end of the slope gradient, peaking at an optimum of about 5% slope then steadily decreasing as slope increases. *P. schreberi* had

a symmetric unimodal curve with an estimated optimum of 19% slope. *S. girgensohnii* and *S. fuscum* show high predicted probability at 0 percent slope, and a sharply decreasing response to increasing slope.

The modeled optimum depth of the litter layer for *Sphagnum* species was estimated to be 0 cm, and ranged from 0.5 to 0.6 cm for *B. trilobata*, *D. polysetum*, *H. splendens*, and *P. schreberi* (Figure 16). The species with the highest estimated optimum litter layer depth (1.5 cm) was *P. commune*. All other species increase in predicted frequency from 0 cm until about 1 cm leaf litter depth then sharply decrease at litter levels above this threshold. *Sphagnum fuscum* and *S. girgensohnii* have a greatly decreased probability of occurrence with increased litter layer depth.

Predicted optimum canopy closure values were generally lower than the raw mean values, ranging from 30-55% for the upland mosses, and 0% for *Sphagnum* species. *B. trilobata* was found under a variety of canopy closure classes, resulting in a wide estimated optimum range of 8-80% canopy closure. *D. polysetum*, *P. commune*, and *P. schreberi* have similar unimodal response curves with optima of 49-58% canopy closure, decreasing slowly as canopy closure either decreases or increases from this level. *H. splendens* shows a response that is skewed towards the higher end of the canopy closure gradient, with an optimum around 78% canopy closure. *S. girgensohnii* and *S. fuscum* both show steadily decreasing responses as canopy closure increases.

R<sup>2</sup> values were calculated as an expression of model goodness of fit between predicted and observed values; many of the models show agreement between observed and fitted values, with R<sup>2</sup> values ranging from 0.16 to 0.99 (Table 5). The agreement between

observed and model fitted values for *H. splendens* was not statistically significant (at  $P < 0.05$ ) for 3 out of 4 models. *B. trilobata* and *P. commune* also had some poor goodness of fit for the slope and canopy closure models.

**Table 5. Model type, fit, and predicted optima for 7 bryophyte species along depth-to-water, slope, canopy closure, and leaf litter depth gradients.**

| Species                      | HOF Model Type | Model fit |       | Optima                     |
|------------------------------|----------------|-----------|-------|----------------------------|
| R <sup>2</sup> P             |                |           |       |                            |
| Depth-to-Water               |                |           |       |                            |
| <i>Bazzania trilobata</i>    | III            | 0.82      | 0.002 | 0.59 to 25m <sup>*</sup>   |
| <i>Dicranum polysetum</i>    | IV             | 0.98      | 0.000 | 4.11m                      |
| <i>Hylocomium splendens</i>  | IV             | 0.20      | 0.266 | 1.91m                      |
| <i>Polytrichum commune</i>   | IV             | 0.61      | 0.023 | 4.47m                      |
| <i>Pleurozium schreberi</i>  | IV             | 0.99      | 0.000 | 5.31m                      |
| <i>Sphagnum fuscum</i>       | III            | 0.90      | 0.000 | 0.01 to 0.02m <sup>*</sup> |
| <i>Sphagnum girgensohnii</i> | III            | 0.99      | 0.000 | 0.01m                      |
| Slope                        |                |           |       |                            |
| <i>Bazzania trilobata</i>    | III            | 0.16      | 0.433 | 3.22 to 47% <sup>*</sup>   |
| <i>Dicranum polysetum</i>    | V              | 0.69      | 0.041 | 8.02%                      |
| <i>Hylocomium splendens</i>  | V              | 0.77      | 0.021 | 4.92%                      |
| <i>Polytrichum commune</i>   | IV             | 0.19      | 0.393 | 14.74%                     |
| <i>Pleurozium schreberi</i>  | IV             | 0.63      | 0.060 | 19.17%                     |
| <i>Sphagnum fuscum</i>       | II             | 0.94      | 0.001 | 0.00%                      |
| <i>Sphagnum girgensohnii</i> | II             | 0.97      | 0.000 | 0.00%                      |
| Canopy Closure               |                |           |       |                            |
| <i>Bazzania trilobata</i>    | IV             | 0.85      | 0.003 | 70%                        |
| <i>Dicranum polysetum</i>    | V              | 0.64      | 0.031 | 49%                        |
| <i>Hylocomium splendens</i>  | V              | 0.74      | 0.013 | 78%                        |
| <i>Polytrichum commune</i>   | IV             | 0.41      | 0.112 | 49%                        |
| <i>Pleurozium schreberi</i>  | IV             | 0.49      | 0.079 | 58%                        |
| <i>Sphagnum fuscum</i>       | V              | 0.15      | 0.385 | 6%                         |
| <i>Sphagnum girgensohnii</i> | II             | 0.95      | 0.000 | 0%                         |
| Litter Depth                 |                |           |       |                            |
| <i>Bazzania trilobata</i>    | V              | 0.84      | 0.004 | 0.5cm                      |
| <i>Dicranum polysetum</i>    | V              | 0.84      | 0.004 | 0.6cm                      |
| <i>Hylocomium splendens</i>  | V              | 0.53      | 0.064 | 0.5cm                      |
| <i>Polytrichum commune</i>   | IV             | 0.86      | 0.003 | 1.5cm                      |
| <i>Pleurozium schreberi</i>  | V              | 0.92      | 0.001 | 0.6cm                      |
| <i>Sphagnum fuscum</i>       | II             | 0.66      | 0.026 | 0.0cm                      |
| <i>Sphagnum girgensohnii</i> | II             | 0.87      | 0.002 | 0.0cm                      |

\*Model optima are expressed as intervals for model type III, and refer to a data-driven optima value since these models only allow for an open-ended response (Huisman et al. 1993).

## Multiple Logistic Regression Models

Multivariate binary logistic regression models were created to incorporate more than one variable at a time. While multiple regression models were created for all seven species, not all of the models can be mapped, because some had insufficient relationships with the ‘mappable’ predictor variables. Three of the seven bryophyte species (*D. polysetum*, *P. schreberi*, *S. girgensohnii*) use solely predictor variables that are available in ArcGIS and will now be the focus. The additional (unmapped) statistical models for *B. trilobata*, *H. splendens*, *P. commune*, and *S. fuscum* are provided in APPENDIX F.

Since modest spatial autocorrelations were detected in the residuals of the logistic regression models, both logistic regression (LR) and autologistic regression (ALR) models were used. The final models for *D. polysetum*, *P. schreberi*, and *S. girgensohnii* contained 2 - 4 variables (Table 6). The number of predictor variables used in each model was kept to a minimum to retain model parsimony.

Although leaf litter depth was a significant predictor, it could not be incorporated because there is no reliable way to map this variable across the landscape. The categorical variables for softwood forest stands (SW) and mixedwood (MX) were significant predictors. Slope was not used in the final models due to multicollinearity with the DTW variable.

**Table 6. Binary logistic regression model specifications for *Dicranum polysetum*, *Pleurozium schreberi*, and *Sphagnum girgensohnii* (SE: standard error, LR: logistic regression, ALR: autologistic regression, logDTW: log<sub>10</sub> depth-to-water, SW: softwood, MX: mixedwood).**

| Response Variable      | n   | Model | Predictor Variable | $\beta$ | SE $\beta$ | Wald's $X^2$ | P     | Odds Ratio |
|------------------------|-----|-------|--------------------|---------|------------|--------------|-------|------------|
| <i>D. polysetum</i>    | 233 | LR    | logDTW             | 0.032   | 0.01       | 15.54        | 0.000 | 1.03       |
|                        |     |       | Wetland            | -2.218  | 0.27       | 65.34        | 0.000 | 0.11       |
|                        |     |       | SW                 | 1.878   | 0.31       | 36.34        | 0.000 | 6.54       |
|                        |     |       | MX                 | 0.791   | 0.35       | 5.06         | 0.024 | 2.21       |
|                        |     |       | Constant           | -2.773  | 0.42       | 44.55        | 0.000 | 0.06       |
|                        |     | ALR   | logDTW             | 0.026   | 0.01       | 9.54         | 0.002 | 1.03       |
|                        |     |       | Wetland            | -1.986  | 0.29       | 48.54        | 0.000 | 0.14       |
|                        |     |       | SW                 | 1.651   | 0.32       | 26.56        | 0.000 | 5.21       |
|                        |     |       | MX                 | 0.685   | 0.35       | 3.74         | 0.053 | 1.98       |
|                        |     |       | Autocov            | 0.001   | 0.00       | 8.73         | 0.003 | 1.00       |
|                        |     |       | Constant           | -2.936  | 0.42       | 48.36        | 0.000 | 0.05       |
| <i>P. schreberi</i>    | 328 | LR    | logDTW             | 0.031   | 0.01       | 22.03        | 0.000 | 1.03       |
|                        |     |       | Wetland            | -1.440  | 0.21       | 47.82        | 0.000 | 0.24       |
|                        |     |       | SW                 | 2.340   | 0.29       | 64.72        | 0.000 | 10.38      |
|                        |     |       | MX                 | 1.431   | 0.32       | 19.96        | 0.000 | 4.18       |
|                        |     |       | Constant           | -3.055  | 0.42       | 53.98        | 0.000 | 0.05       |
|                        |     | ALR   | logDTW             | 0.022   | 0.01       | 9.89         | 0.002 | 1.02       |
|                        |     |       | Wetland            | -1.174  | 0.22       | 29.28        | 0.000 | 0.31       |
|                        |     |       | SW                 | 2.029   | 0.30       | 46.26        | 0.000 | 7.61       |
|                        |     |       | MX                 | 1.279   | 0.33       | 15.47        | 0.000 | 3.59       |
|                        |     |       | Autocov            | 0.002   | 0.00       | 23.59        | 0.000 | 1.00       |
|                        |     |       | Constant           | -3.129  | 0.42       | 55.43        | 0.000 | 0.04       |
| <i>S. girgensohnii</i> | 301 | LR    | logDTW             | 0.060   | 0.01       | 135.45       | 0.000 | 1.06       |
|                        |     |       | SW                 | 0.849   | 0.16       | 27.02        | 0.000 | 2.34       |
|                        |     |       | Constant           | -3.444  | 0.25       | 190.89       | 0.000 | 0.03       |
|                        |     | ALR   | logDTW             | 0.051   | 0.01       | 78.08        | 0.000 | 1.05       |
|                        |     |       | SW                 | 0.676   | 0.17       | 16.21        | 0.000 | 1.97       |
|                        |     |       | Autocov            | 0.002   | 0.00       | 20.41        | 0.000 | 1.00       |
|                        |     |       | Constant           | -3.900  | 0.29       | 181.09       | 0.000 | 0.02       |

The autocovariate was a statistically significant addition to the models for all three species, albeit with a small coefficient. After fitting the autologistic models, the coefficients of most other variables were reduced slightly and the associated  $p$  values of some increased, however there was no loss of significance. The overall model evaluation and goodness of fit measures are summarized in Table 7. The results of the likelihood ratio tests were all statistically significant ( $p < 0.001$ ). The pseudo  $R^2$  values were slightly higher for ALR models.

**Table 7. Comparison of overall model evaluation and goodness of fit tests for logistic and autologistic regression models for *Dicranum polysetum*, *Pleurozium schreberi*, and *Sphagnum girgensohnii* (Cox and Snell, 1989; Nagelkerke, 1991).**

| Response Variable      | Model | Likelihood Ratio Test |    |       | R <sup>2</sup> -type Indices |                           |
|------------------------|-------|-----------------------|----|-------|------------------------------|---------------------------|
|                        |       | X <sup>2</sup>        | df | $p$   | Cox and Snell R <sup>2</sup> | Nagelkerke R <sup>2</sup> |
| <i>D. polysetum</i>    | LR    | 289.25                | 4  | 0.000 | 0.26                         | 0.38                      |
|                        | ALR   | 297.96                | 5  | 0.000 | 0.26                         | 0.39                      |
| <i>P. schreberi</i>    | LR    | 299.75                | 4  | 0.000 | 0.26                         | 0.37                      |
|                        | ALR   | 323.51                | 5  | 0.000 | 0.28                         | 0.39                      |
| <i>S. girgensohnii</i> | LR    | 210.77                | 2  | 0.000 | 0.19                         | 0.27                      |
|                        | ALR   | 231.46                | 3  | 0.000 | 0.21                         | 0.30                      |

The autologistic models had slightly higher areas under the ROC curve than their non-spatial counterparts (Table 8). All models predicted species' occurrences better than null models (all  $p < 0.000$ ) and all had AUC > 0.78, indicating good discriminatory ability.

**Table 8. Comparison of areas under the receiver operating characteristic (ROC) curves for logistic and autologistic regression models for *Dicranum polysetum*, *Pleurozium schreberi*, and *Sphagnum girgensohnii*.**

| Species                | Model | AUC  | Std. Error | Sig.    | 95% Confidence Intervals |             |
|------------------------|-------|------|------------|---------|--------------------------|-------------|
|                        |       |      |            |         | Lower Bound              | Upper Bound |
| <i>D. polysetum</i>    | LR    | 0.84 | 0.013      | <0.0001 | 0.82                     | 0.87        |
|                        | ALR   | 0.85 | 0.013      | <0.0001 | 0.82                     | 0.87        |
| <i>P. schreberi</i>    | LR    | 0.82 | 0.014      | <0.0001 | 0.79                     | 0.84        |
|                        | ALR   | 0.83 | 0.013      | <0.0001 | 0.80                     | 0.86        |
| <i>S. girgensohnii</i> | LR    | 0.78 | 0.015      | <0.0001 | 0.75                     | 0.80        |
|                        | ALR   | 0.79 | 0.015      | <0.0001 | 0.76                     | 0.82        |

### ***Residual Spatial Autocorrelation***

There was no significant spatial autocorrelation among sites detected in the response variable, nor in the standardized residuals of the logistic regressions. When each site was tested separately, modest correlations (all Mantel  $r < 0.22$ ) between geographic distances and species occurrence were detected in the residuals of the logistic regression models of some species at some sites (Table 9). Semi-variograms revealed that there was positive spatial autocorrelation at proximate distances (<15m), but in most cases the autocorrelation decreased with increasing threshold distance.

**Table 9. Tests for within-site spatial autocorrelation in the logistic model standardized residuals of *Dicranum polysetum*, *Pleurozium schreberi*, and *Sphagnum girgensohnii*. Bolded numbers represent statistically significant correlations between species occurrence and distance separating plots.**

| Site        | <i>D. polysetum</i> |              | <i>P. schreberi</i> |              | <i>S. girgensohnii</i> |              |
|-------------|---------------------|--------------|---------------------|--------------|------------------------|--------------|
|             | Mantel Correlation  | <i>P</i>     | Mantel Correlation  | <i>P</i>     | Mantel Correlation     | <i>P</i>     |
| Bathurst    | 0.037               | 0.223        | 0.031               | 0.234        | 0.079                  | 0.051        |
| Blackbrook  | <b>0.113</b>        | <b>0.003</b> | 0.003               | 0.443        | -0.087                 | 0.999        |
| Deersdale   | <b>0.069</b>        | <b>0.026</b> | 0.015               | 0.308        | -0.026                 | 0.821        |
| Dorn Ridge  | -0.024              | 0.707        | 0.018               | 0.321        | -0.010                 | 0.593        |
| Grand Bay   | 0.049               | 0.198        | <b>0.221</b>        | <b>0.000</b> | -0.025                 | 0.737        |
| Grand Lake  | 0.035               | 0.170        | 0.001               | 0.448        | <b>0.157</b>           | <b>0.001</b> |
| Miramichi   | 0.052               | 0.056        | <b>0.063</b>        | <b>0.017</b> | <b>0.075</b>           | <b>0.009</b> |
| Noonan      | <b>0.127</b>        | <b>0.000</b> | <b>0.059</b>        | <b>0.027</b> | 0.042                  | 0.062        |
| St. Stephen | 0.010               | 0.404        | -0.031              | 0.835        | -0.070                 | 0.948        |
| Sackville   | 0.031               | 0.257        | 0.018               | 0.322        | <b>0.160</b>           | <b>0.000</b> |
| Tracadie    | 0.033               | 0.209        | -0.001              | 0.486        | <b>0.091</b>           | <b>0.004</b> |

Despite accounting for some of the residual autocorrelation with the autocovariate, statistically significant spatial autocorrelation remained in the residuals of the autologistic regression models at some sites, but was considerably decreased (Table 10).

**Table 10. Tests for within-site spatial autocorrelation in the autologistic model standardized residuals of *Dicranum polysetum*, *Pleurozium schreberi*, and *Sphagnum girgensohnii*. Bolded numbers represent statistically significant correlations between species occurrence and distance separating plots. Autocorrelation is no longer present for Blackbrook, Deersdale, or Sackville sites.**

| Site        | <i>D. polysetum</i> |              | <i>P. schreberi</i> |              | <i>S. girgensohnii</i> |              |
|-------------|---------------------|--------------|---------------------|--------------|------------------------|--------------|
|             | Mantel Correlation  | <i>P</i>     | Mantel Correlation  | <i>P</i>     | Mantel Correlation     | <i>P</i>     |
| Bathurst    | 0.046               | 0.176        | 0.028               | 0.265        | 0.078                  | 0.053        |
| Blackbrook  | 0.075               | 0.053        | -0.001              | 0.495        | -0.084                 | 0.996        |
| Deersdale   | 0.012               | 0.368        | 0.013               | 0.332        | -0.029                 | 0.853        |
| Dorn Ridge  | -0.011              | 0.587        | 0.033               | 0.195        | -0.018                 | 0.672        |
| Grand Bay   | 0.044               | 0.222        | <b>0.218</b>        | <b>0.000</b> | -0.028                 | 0.763        |
| Grand Lake  | 0.049               | 0.085        | 0.209               | 0.215        | <b>0.143</b>           | <b>0.000</b> |
| Miramichi   | 0.052               | 0.056        | <b>0.061</b>        | <b>0.021</b> | <b>0.072</b>           | <b>0.005</b> |
| Noonan      | <b>0.123</b>        | <b>0.001</b> | 0.024               | 0.193        | 0.041                  | 0.071        |
| St. Stephen | 0.011               | 0.383        | -0.035              | 0.864        | -0.065                 | 0.927        |
| Sackville   | 0.043               | 0.185        | 0.052               | 0.117        | 0.071                  | 0.054        |
| Tracadie    | 0.029               | 0.238        | -0.002              | 0.490        | <b>0.071</b>           | <b>0.011</b> |

### ***Classification Accuracy***

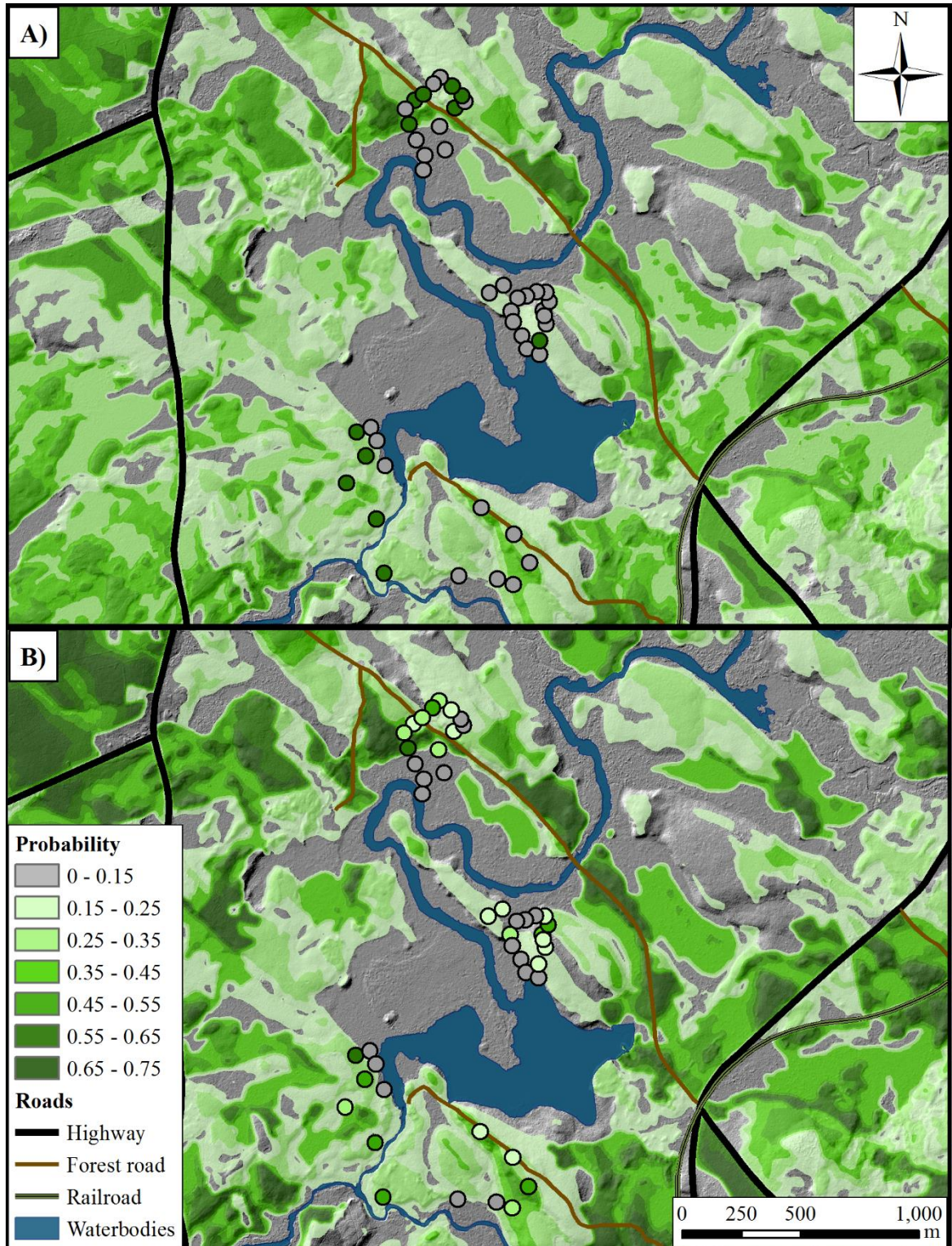
Classification accuracy rates for observed and predicted frequencies ranged from 73% to 81%, and all models met the proportional by chance classification criterion (better than 25% increase above chance) (Table 11).

**Table 11. Observed and predicted frequencies for bryophyte presence by logistic regression (LR) and autologistic regression (ALR) (with 0.50 threshold).**

| Response Variable      | Model | Observed | Predicted |     | % Correct | Overall Percentage Correct | Prop. by Chance Accuracy Rate | Prop. Chance Criteria (25%) | % False Positives | % False Negatives |
|------------------------|-------|----------|-----------|-----|-----------|----------------------------|-------------------------------|-----------------------------|-------------------|-------------------|
|                        |       |          | 0         | 1   |           |                            |                               |                             |                   |                   |
| <i>D. polysetum</i>    | LR    | 0        | 657       | 90  | 0.88      | 0.80                       | 0.64                          | 0.80                        | 0.43              | 0.14              |
|                        |       | 1        | 106       | 127 | 0.55      |                            |                               |                             |                   |                   |
|                        | ALR   | 0        | 674       | 73  | 0.90      | 0.81                       |                               |                             | 0.38              | 0.14              |
|                        |       | 1        | 112       | 121 | 0.52      |                            |                               |                             |                   |                   |
| <i>P. schreberi</i>    | LR    | 0        | 539       | 113 | 0.83      | 0.76                       | 0.55                          | 0.69                        | 0.36              | 0.19              |
|                        |       | 1        | 123       | 205 | 0.63      |                            |                               |                             |                   |                   |
|                        | ALR   | 0        | 550       | 102 | 0.84      | 0.77                       |                               |                             | 0.33              | 0.18              |
|                        |       | 1        | 124       | 204 | 0.62      |                            |                               |                             |                   |                   |
| <i>S. girgensohnii</i> | LR    | 0        | 582       | 97  | 0.86      | 0.73                       | 0.57                          | 0.72                        | 0.39              | 0.17              |
|                        |       | 1        | 165       | 136 | 0.45      |                            |                               |                             |                   |                   |
|                        | ALR   | 0        | 578       | 101 | 0.85      | 0.75                       |                               |                             | 0.40              | 0.20              |
|                        |       | 1        | 147       | 154 | 0.51      |                            |                               |                             |                   |                   |

## Maps

Species distribution maps were created for *D. polysetum*, *P. schreberi*, and *S. girgensohnii* for each study site using the final regression models. Given the large number of maps generated, two sites (St. Stephen and Dorn Ridge) were arbitrarily chosen as examples (Figures 17-22). Each figure consists of a comparison between maps created with logistic regression and autologistic regression for one species. The two model types show spatial similarities, however the autologistic models tend to predict higher probabilities of occurrence and have slightly higher classification accuracy.



**Figure 17. Maps depicting probability of occurrence of *Dicranum polysetum* at the St. Stephen site, created using A) logistic and B) autologistic regression. Points in A) denote actual presence (green) and absence (grey) observations, while those in B) represent model fitted probabilities (same colour scheme as shown in legend).**

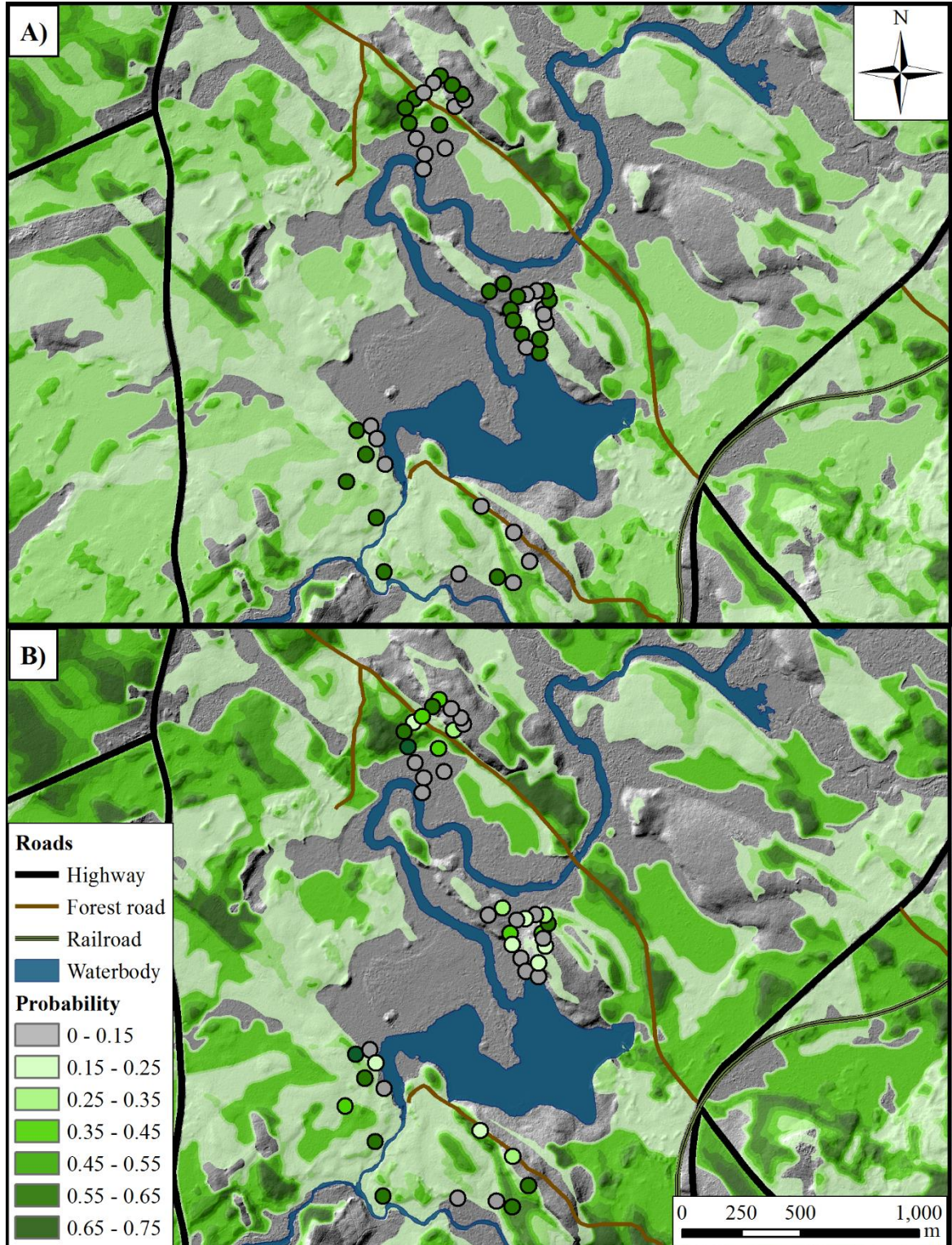
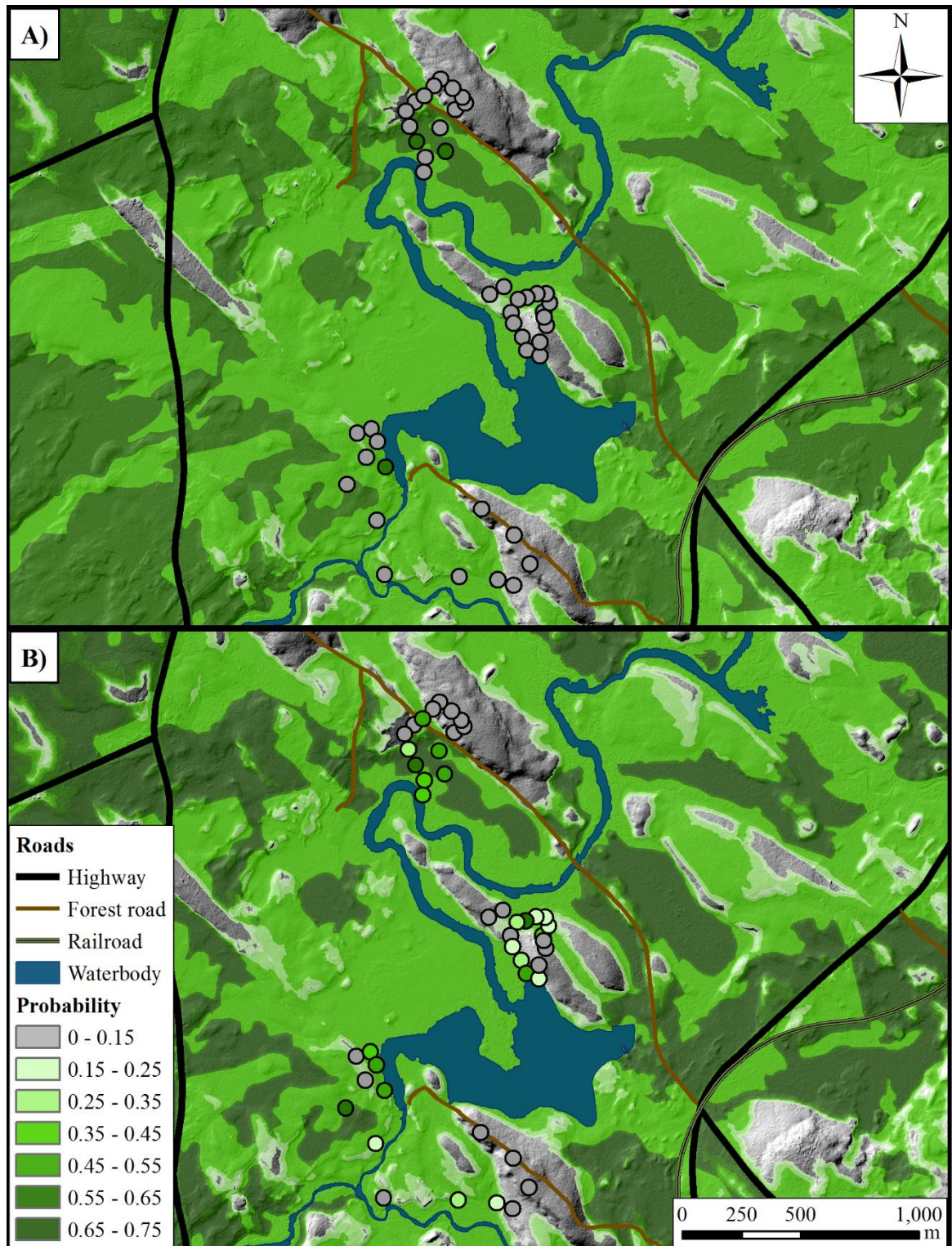
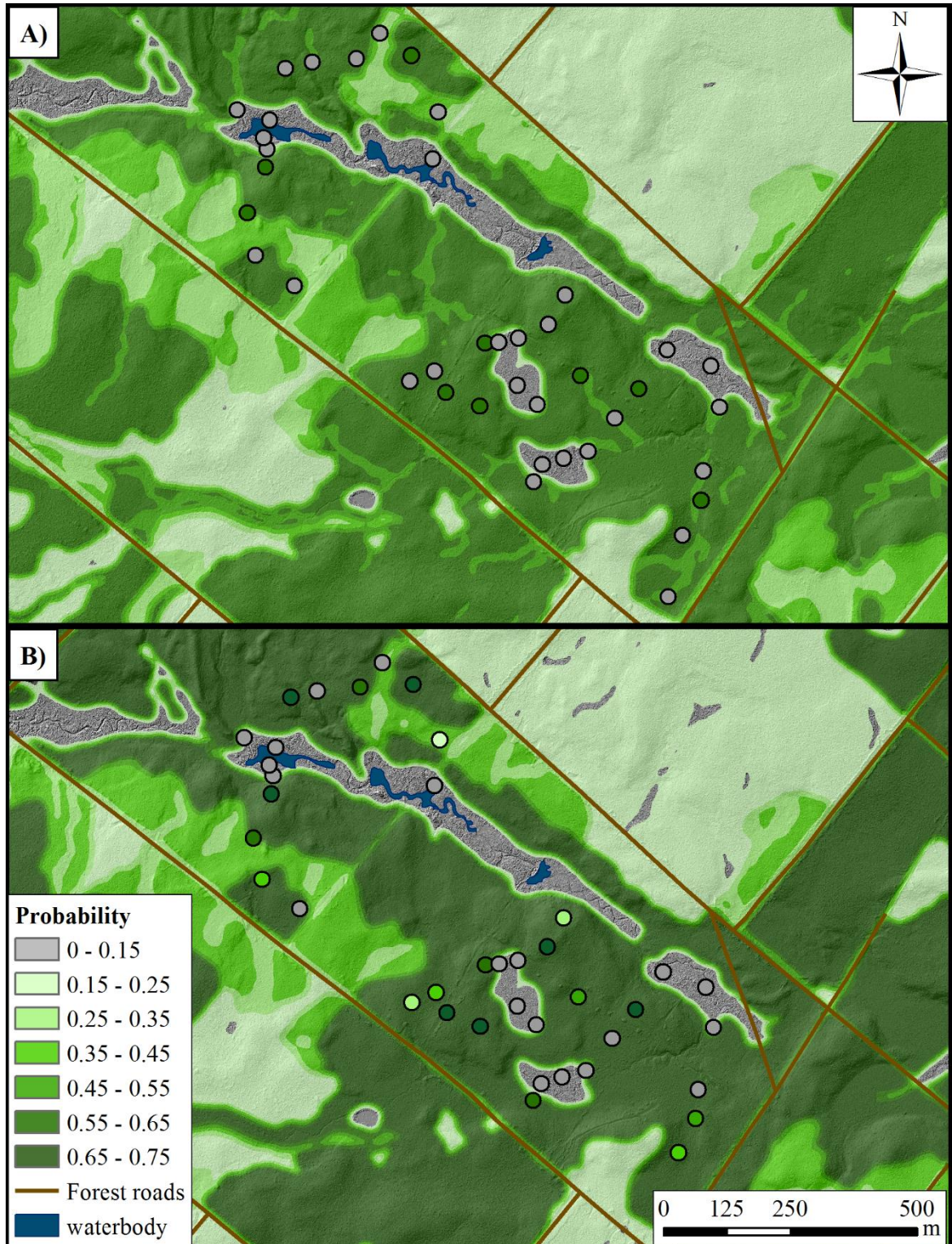


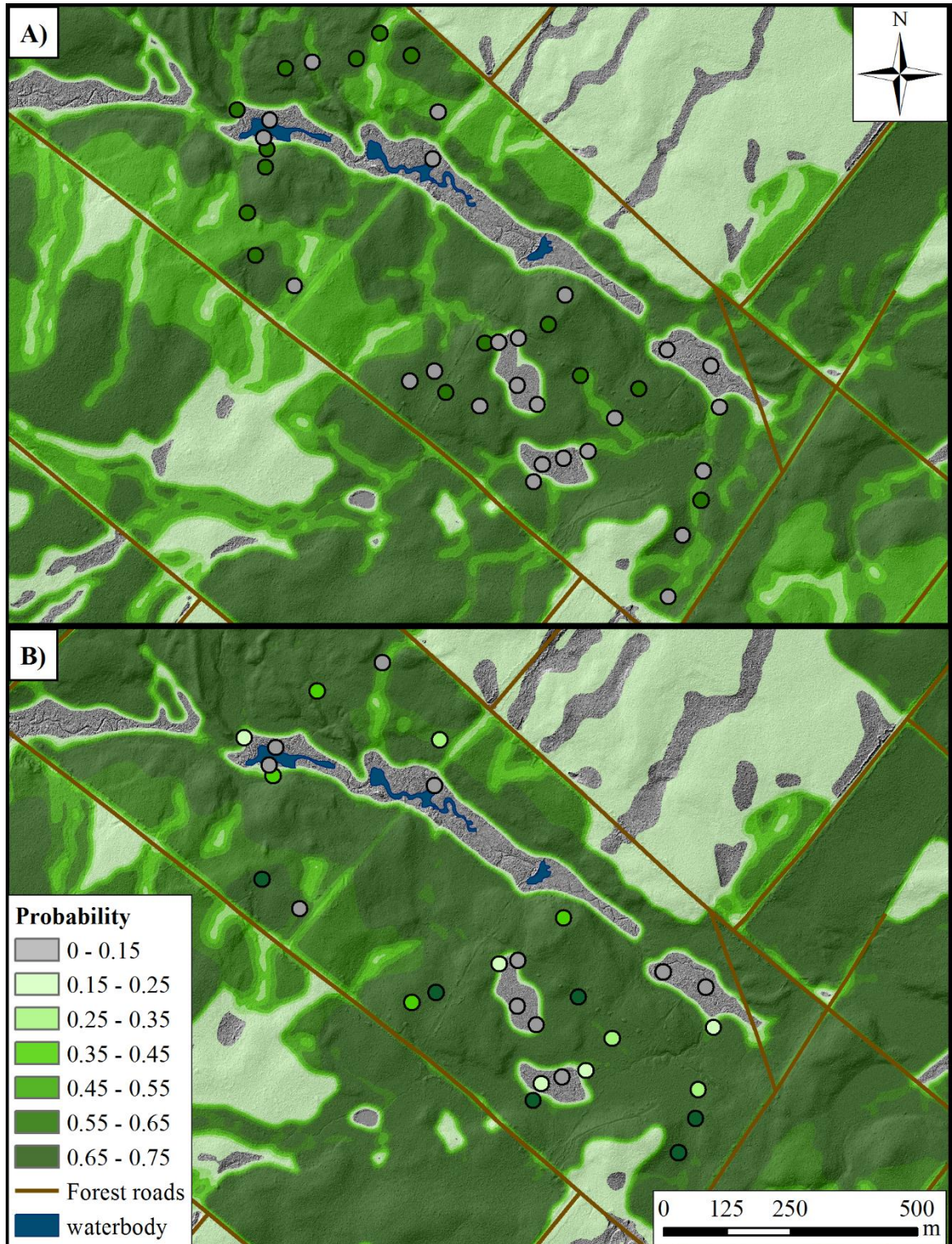
Figure 18. Maps depicting probability of occurrence of *Pleurozium schreberi* at the St. Stephen site, created using A) logistic and B) autologistic regression. Points in A) denote actual presence (green) and absence (grey) observations, while those in B) represent model fitted probabilities (same colour scheme as shown in legend).



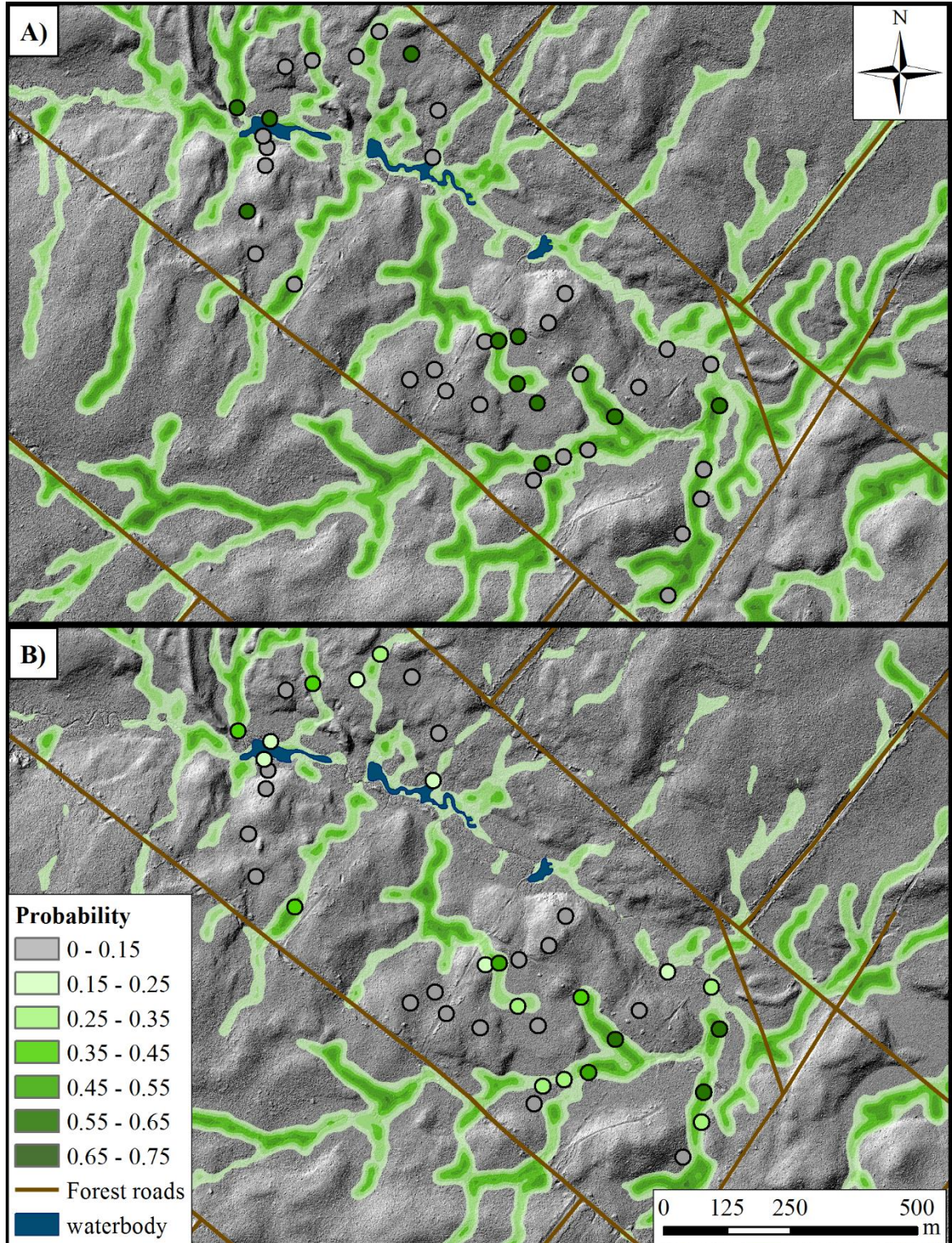
**Figure 19.** Maps depicting probability of occurrence of *Sphagnum girgensohnii* at the St. Stephen site, created using A) logistic and B) autologistic regression. Points in A) denote actual presence (green) and absence (grey) observations, while those in B) represent model fitted probabilities (same colour scheme as shown in legend).



**Figure 20.** Maps depicting probability of occurrence of *Dicranum polysetum* at the Dorn Ridge site, created using A) logistic and B) autologistic regression. Points in A) denote actual presence (green) and absence (grey) observations, while those in B) represent model fitted probabilities (same colour scheme as shown in legend).



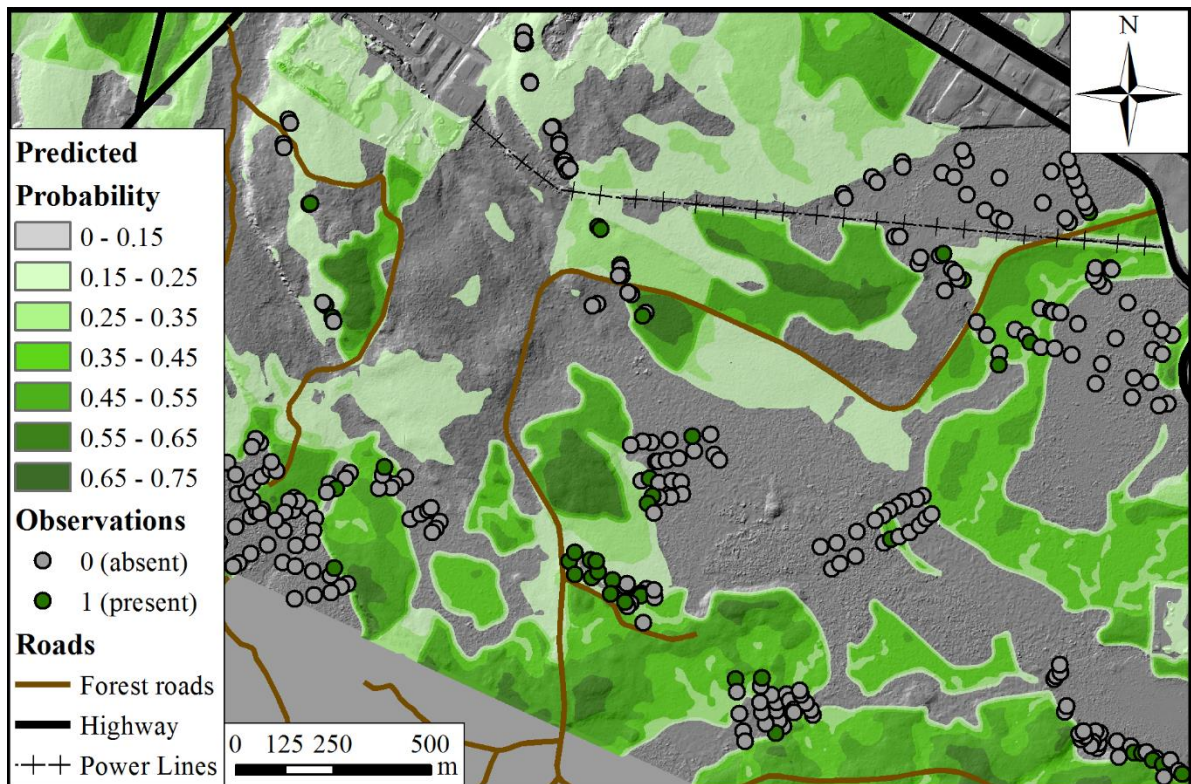
**Figure 21. Maps depicting probability of occurrence of *Pleurozium schreberi* at the Dorn Ridge site, created using A) logistic and B) autologistic regression. Points in A) denote actual presence (green) and absence (grey) observations, while those in B) represent model fitted probabilities (same colour scheme as shown in legend).**



**Figure 22. Maps depicting probability of occurrence of *Sphagnum girgensohnii* at the Dorn Ridge site, created using A) logistic and B) autologistic regression. Points in A) denote actual presence (green) and absence (grey) observations, while those in B) represent model fitted probabilities (same colour scheme as shown in legend).**

## Validation

The logistic regression models were tested on an independent data set, as described in Chapter 3. The maps provide a visual comparison between model-predicted probabilities of occurrence and actual occurrences observed in the field for *D. polysetum* (Figure 23), *P. schreberi* (Figure 24), and *Sphagnum* species (Figure 25).



**Figure 23.** Map depicting modelled probability of occurrence of *Dicranum polysetum* at the UNB woodlot in Fredericton, NB. Points represent observations of presence (green) and absence (grey).

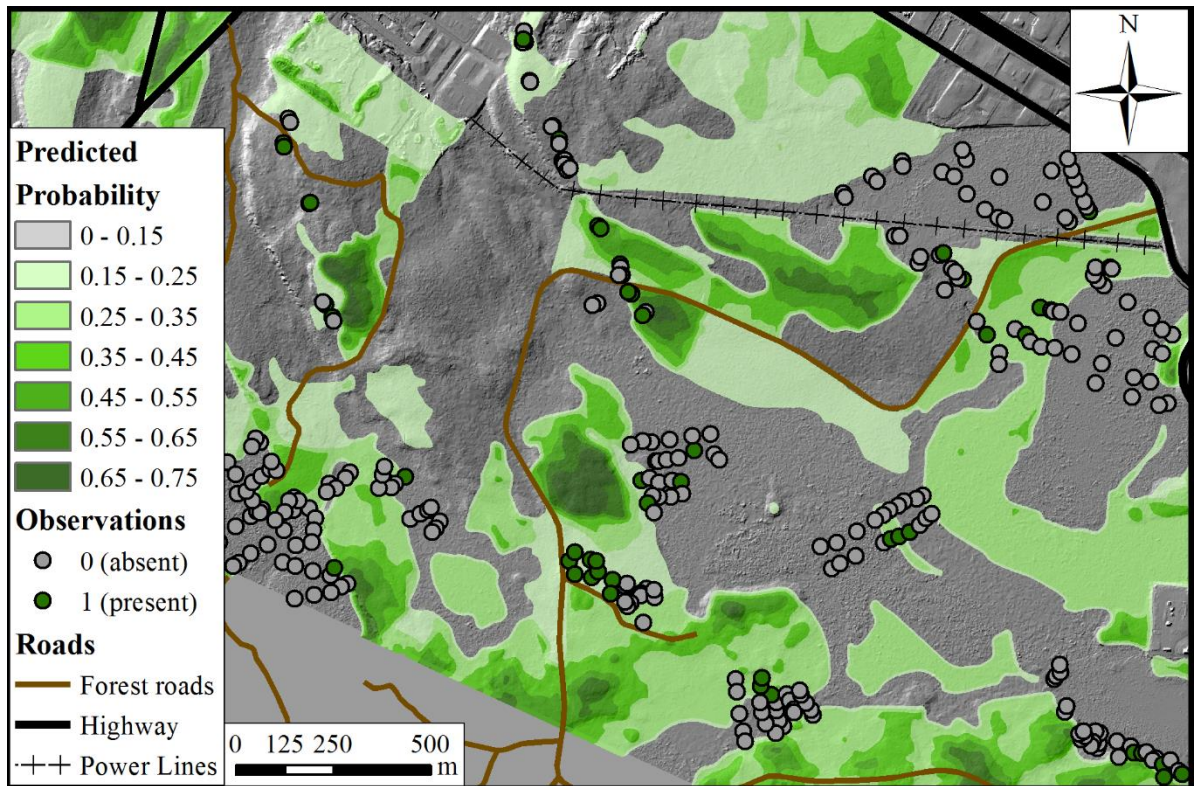


Figure 24. Modelled probability of occurrence of *P. schreberi* at the UNB woodlot.

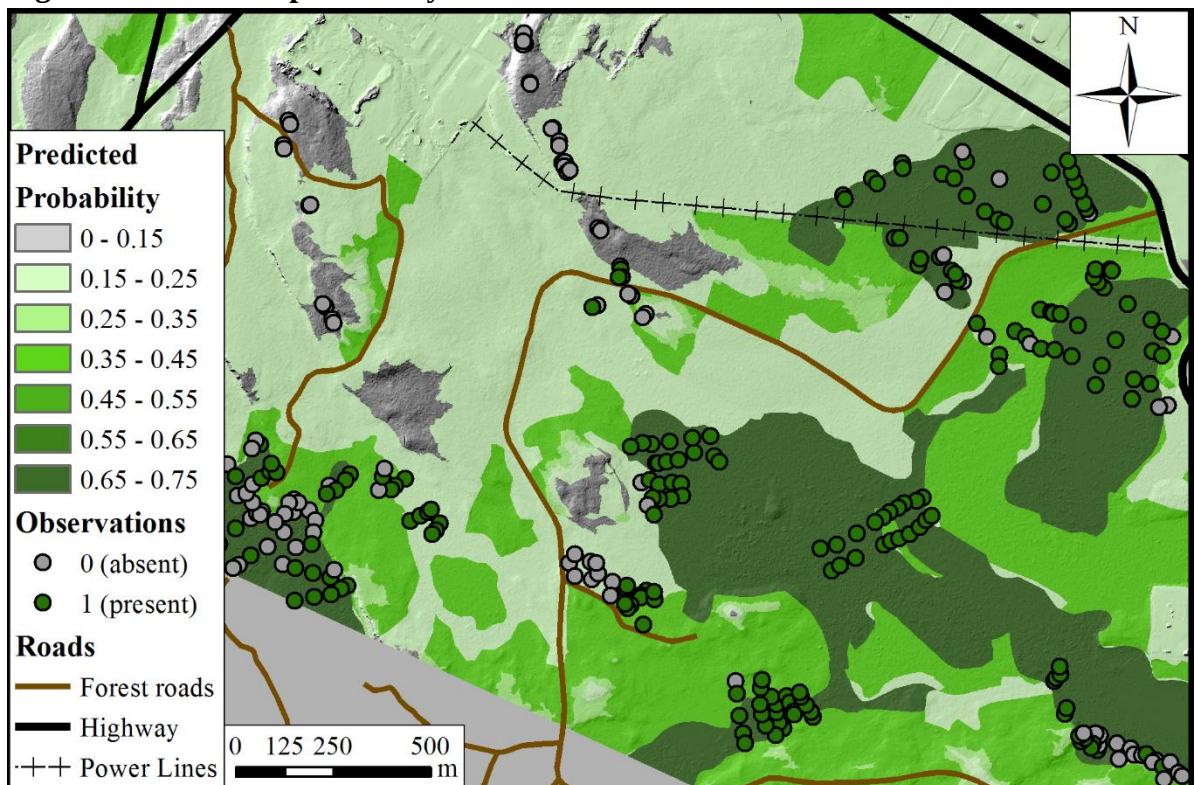


Figure 25. Map depicting modelled probability of occurrence of *Sphagnum* moss at the UNB woodlot in Fredericton, N.B. Points represent observations of presence/absence.

The three models predicted species' occurrences better than null models (all  $p < 0.0001$ ) and all had  $AUC > 0.75$ , indicating good discriminatory ability (Table 12).

**Table 12. Area under the receiver operating characteristic curves (AUC) for logistic regression models for *Dicranum polysetum*, *Pleurozium schreberi*, and *Sphagnum* species using the independent validation data set.**

| Species              | AUC  | Std. Error | Sig.    | 95% Confidence Interval |             |
|----------------------|------|------------|---------|-------------------------|-------------|
|                      |      |            |         | Lower Bound             | Upper Bound |
| <i>D. polysetum</i>  | 0.81 | 0.027      | <0.0001 | 0.75                    | 0.86        |
| <i>P. schreberi</i>  | 0.82 | 0.026      | <0.0001 | 0.77                    | 0.87        |
| <i>Sphagnum</i> spp. | 0.75 | 0.029      | <0.0001 | 0.69                    | 0.81        |

Classification accuracy rates for observed and predicted frequencies ranged from 67% to 83% (Table 13). The models for *P. schreberi* and *Sphagnum* species met the proportional by chance classification criteria (better than 25% increase above chance), however the model for *D. polysetum* did not (it only had a 19% increase above chance), and subsequently had a high percentage of false positive predictions (42%).

**Table 13. Observed and predicted frequencies for bryophyte presence by logistic regression (with 0.50 cut-off).**

| Response Variable    | Observed | Predicted |     | % Correct | Overall Percentage Correct | Proportional by Chance Accuracy Rate | Proportional Chance Criteria (25%) | % False Positives | % False Negatives |
|----------------------|----------|-----------|-----|-----------|----------------------------|--------------------------------------|------------------------------------|-------------------|-------------------|
|                      |          | 0         | 1   |           |                            |                                      |                                    |                   |                   |
| <i>D. polysetum</i>  | 0        | 254       | 11  | 0.96      | <b>0.83</b>                | 0.70                                 | 0.87                               | 0.42              | 0.15              |
|                      | 1        | 45        | 15  | 0.25      |                            |                                      |                                    |                   |                   |
| <i>P. schreberi</i>  | 0        | 250       | 5   | 0.98      | <b>0.82</b>                | 0.65                                 | 0.82                               | 0.24              | 0.18              |
|                      | 1        | 54        | 16  | 0.23      |                            |                                      |                                    |                   |                   |
| <i>Sphagnum</i> spp. | 0        | 88        | 47  | 0.65      | <b>0.67</b>                | 0.51                                 | 0.64                               | 0.26              | 0.40              |
|                      | 1        | 59        | 131 | 0.69      |                            |                                      |                                    |                   |                   |

## CHAPTER 5 – DISCUSSION AND CONCLUSION

The initial prediction was that DTW, determined by LiDAR, would provide good prediction of bryophyte distribution; specifically that hydric species would primarily be found where the modeled water table was near the surface, and that mesic/xeric species would mainly occur in upland areas with greater predicted water table depths. The species observations generally aligned with expectations; the frequency of six mosses and one liverwort show a trend when examined by DTW class (Figure 7). The studied mosses can be classified into two broad groups based on their observed moisture regime preferences: mosses most frequently observed in wetlands (*Sphagnum fuscum*), and mosses found in drier forested upland areas (*Bazzania trilobata*, *Dicranum polysetum*, *Hylocomium splendens*, *Pleurozium schreberi*, and *Polytrichum commune*). Some species were observed growing in a number of diverse habitats; *Sphagnum girgensohnii* was found in the expected wet areas, such as fens, bogs, and forested wetlands, however 26% of *S. girgensohnii* observations were in moderately well-drained upland forests. In these otherwise dry environments, *Sphagnum* mosses are mainly restricted to wet microsites that contain sufficient moisture for at least a part of the year (Tiner, 2005).

### Univariate Models

The question of whether changes in bryophyte distribution could be modelled using a cartographic depth-to-water index was first answered using HOF models, which showed generally good agreement between observed/predicted values for most of the seven species along the DTW gradient. *S. girgensohnii* and *S. fuscum* were less abundant with increasing DTW, while all other species showed the opposite trend. The low end of the depth-to-water axis represents areas with very poorly drained soils, which is a limiting

factor for many plant species (Cronk and Fennessy, 2001; Tiner, 2005). *Sphagnum* mosses typically dominate the higher parts of the water-table gradient as they are adapted to these wet conditions (Gignac, 1992). Gradient extremes often represent fundamentally distinct ecosystems to which separate guilds of terricolous bryophytes have become adapted (Carleton, 1990). The peat mosses (i.e. *Sphagnum* spp.) are tough competitors and generally outcompete all other mosses where the depth of the water table is closest to the surface, except in areas that are subject to prolonged desiccation (Bragazza and Gerdol, 1996). *S. fuscum* and *S. girgensohnii* have similar predicted optima (0-1m DTW) however their forecasted frequency along the DTW gradient is quite different. The maximum predicted probability for *S. fuscum* was 0.2, which is likely due to its more specialized habitat requirements and subsequently lower number of observations (n=63, present in just 6.4% of samples, vs. 30.7% for *S. girgensohnii*). *S. fuscum* is usually only found growing in hummocks in open bogs, while *S. girgensohnii* can be found in a larger variety of ecosystems including boggy woods, swamps, wet depressions in forests, and at margins of rivers and lakes (Ireland and Hanes, 1982).

Bryophytes often grow intermixed with each other in dynamic communities, and thus many of their response curves overlap on the soil moisture gradient. *D. polysetum* and *P. schreberi* were typically found growing together, and each had bell-shaped response curves positioned towards the drier end of the DTW gradient (optimum between 4 and 5 m DTW) (Figure 13). Species that grow together in a community usually have similar requirements for survival (Kent, 2012). The typical habitat of both *P. schreberi* and *D. polysetum* is described as dry woodlands, occasionally in bogs and at the margins of swamps, sometimes occurring on stumps (Ireland and Hanes, 1982). The low ends of the

response curves for both these species' models fall into the wet portion of the DTW gradient. The points that are near the ends of a response curve can be indicative of a major limiting factor, or the conditions beyond which it is too unfavourable for a species to grow (Kent, 2012).

Species responses are best described by bell-shaped symmetric unimodal curves, however linear or threshold response models can also be used (Lawesson and Oksanen, 2002). Unimodal response curves were more frequently used to represent the responses of species adapted to mesic and drier portions of the wetland-to-upland gradient, such as *D. polysetum*, *H. splendens*, *P. commune*, and *P. schreberi*. Carleton (1990) found that the response curves of *D. polysetum* and *P. schreberi* were unimodal along a upland-bottomland gradient, but are asymmetric, i.e. they extended more toward one end of the gradient, which consisted of dry, nutrient rich stands dominated by conifers (the other end of the gradient was a floodplain). Most of the unimodal response curves found in the present study were asymmetric or skewed towards one end of the gradient, and some of the curves were truncated. Skewed, asymmetric, and truncated response curves are common for species with optima near gradient end points (Austin and Gaywood, 1994), and this was the case for some species, such as *S. fuscum* and *S. girgensohnii*. The properties of species response curves have been debated among ecologists for decades; ultimately, each species has a different response curve for every environmental factor (Lawesson and Oksanen, 2002; Rydgren et al., 2003).

Some species showed very little response to changes in DTW; the model for *H. splendens* had low goodness of fit ( $R^2=0.20$ ,  $P=0.266$ ). Feather mosses, such as *H. splendens*, are known to have wide ecological amplitudes, and small populations can survive in

microhabitats where the growing conditions are immensely different from the surrounding area (Longton, 1992). This species can grow on a variety of substrates, but was most often observed growing directly on the forest floor where it would presumably be most affected by DTW and soil drainage regimes, however this does not seem to be the case. *H. splendens* had a low frequency (6.5%) within the data set, which may explain the inability to model its response properly. While the model goodness of fit for *B. trilobata* was acceptable, the predicted probability of occurrence remained low (<0.10 probability) along the entire DTW gradient and the species' predicted optimum DTW range is very wide, from 0.6 to 25m DTW (Figure 13). The lack of clear response curve patterns in relation to predicted DTW levels suggests that the spatial distributions of *H. splendens* and *B. trilobata* are either not largely influenced by landscape-scale soil moisture and drainage patterns (aside from major limitations present at the gradient end points), or that relationships were not detected due to low frequency of occurrence.

## **Multiple Logistic Regressions**

### ***DTW and Forest Cover***

For the multiple logistic regression analyses, the DTW index worked best as a predictor when combined with the forest cover and wetland categorical variables. A plausible explanation as to why DTW is not an effective predictor when used alone, is the number of different ecosystem types which may have similar depth-to-water levels. For example, while bogs and floodplains have similar high water table levels, they differ in nutrient availability, vegetation structure, and plant species composition. When the DTW is combined with forest cover type, an approximation of vegetation type (VT) is made. Low DTW in combination with SW forest type could be a bog, fen, or forested wetland, likely

a nutrient poor area (VT1). In contrast, low DTW in combination with HW forest type, is more likely to be a nutrient rich floodplain area (VT4). Both wetland and forest type have been shown to play a significant role in the variation of bryophyte species occurrence across the landscape (Carleton, 1990; Frego and Carleton, 1995; Vanderpoorten and Engels, 2002). Using DTW in conjunction with the SW variable allows differentiation between wet coniferous forests (where water is at or near the surface for most of the year) and drier coniferous forests which may have streams, wet depressions, and vernal pools, however the soil is not saturated year round.

The softwood stands surveyed generally had abundant bryophyte mats, and so the SW variable was significant in all species models. It is typical to have an extensive moss layer making up the understory of coniferous forests (Neily *et al.*, 2010). *Sphagnum girgensohnii* was associated with wet coniferous forests dominated by black spruce (*Picea mariana*), tamarack (*Larix laricina*), and balsam fir (*Abies balsamea*). *P. schreberi* and *D. polysetum* were most associated with upland coniferous forests dominated by red spruce (*Picea rubens*), eastern hemlock (*Tsuga canadensis*), balsam fir, and white pine (*Pinus strobus*). *P. schreberi* and *D. polysetum* were also correlated with the MX variable, which represents early to late successional mixedwood forests dominated by red maple (*Acer rubrum*), white birch (*Betula papyrifera*), and balsam fir, and later successional stages composed of yellow birch (*Betula alleghaniensis*), along with red spruce or eastern hemlock (*Tsuga canadensis*). Herb and bryophyte diversity is usually high in mixedwood stands (Neily *et al.*, 2010). None of the studied bryophyte species was correlated with hardwood forest types; this is thought to be due to burial by leaf litter and competition from vascular plants. Deciduous forests typically have extensive layers of shrubs and

ferns; bryophytes, if present, are usually confined to coarse woody debris (Neily *et al.*, 2010).

### ***Slope***

It is possible that the slope of the land may affect bryophytes only indirectly, by affecting drainage patterns, and the resultant ecosystems found at different landscape positions. *S. girgensohnii* and *S. fuscum* had higher predicted probability at 0 percent slope that sharply decreased with increasing slope. These *Sphagnum* species were predominantly found in flat wet areas. This is in agreement with results from other studies; for example, a study of mosses in New Zealand found that the probability of occurrence of certain moss species increased with decreasing slope angle, indicating preferences for poorly drained sites (Michel *et al.*, 2010). Likewise, Alpert and Oechel (1982) found *Sphagnum* mosses to be present only on the lowest, most consistently wet portion of the slope.

There was little agreement between observed and predicted values in the HOF models created using slope for *B. trilobata* and *P. commune*; changes in slope did not appear to have a strong effect on the occurrence of these species. It is probable that *B. trilobata* and *P. commune* respond instead to smaller scale variations in slope on the forest floor (*i.e.*, mound and pit microtopography). While none of the studied species showed a preference for steep slopes, each species had a different estimated optimum slope percentage. Slope was not used as a variable in the logistic regression analyses because it was highly correlated with the DTW index (Pearson's  $r=0.59$ ).

### ***Canopy Closure***

Forest canopy closure affects light and precipitation reaching the forest floor, creating a complex microclimatic gradient, with differing levels of light, temperature, and humidity (Fenton and Frego, 2005). Canopy closure (or lack of) helps explain some variation in bryophyte occurrence, particularly for *Sphagnum* mosses, which were typically found in wetlands with little to no tree canopy. In dry environments exposed to full sun, many bryophytes can become desiccated and metabolically inactive, however this is not the case for *Sphagnum* species (Marschall and Proctor, 2004). Most other bryophytes require at least small amounts of shade, which is best provided by trees that do not shed copious amounts of litter that bury the mosses (Glime, 2007b). Intermediate levels of shading may be more desirable for bryophyte growth than heavy shade or high light levels (Olsson and Staaf, 1995; Peterson, 1999; Fenton and Frego, 2005). Økland (1994) found increasing bryophyte favourability along a canopy closure gradient, and hypothesized that it may be due to reduced light under dense canopies. In the present study, canopy closure was not a significant predictor for the studied species and was subsequently left out of the multiple regressions. It is possible that canopy closure is not a good variable for understanding bryophyte distribution at the landscape level, since it is really a stand-level variable. It is theorized that canopy closure and its associated light/shade effects may only act as a limiting factor once all other resource needs are met (Austin, 1980). In a correlational study, Fenton *et al.* (2003) found that although bryophyte community composition was related to canopy closure, other environmental factors such as leaf litter were more influential.

### ***Leaf litter depth***

The effects of leaf litter on bryophytes differ among species and ecosystems. Bryophytes growing on the forest floor have been shown to be negatively affected by deciduous leaf litter (Startsev *et al.*, 2008). In the present study, most species showed a significant response to the depth of the litter layer, and in general, all species had considerably lower predicted frequency with increased accumulation of leaf litter on the forest floor. The occurrence of most species declined rapidly after litter depth surpasses 0.5-1 cm.

Some bryophytes appear to have adapted to growing over abundant litter fall from broadleaf trees and tall shrubs (Carleton, 1990). Of the species included in this study, none were frequently found where the leaf litter was thicker than 6 cm, although some species (*i.e.*, *D. polysetum* and *P. commune*) fared better than others. This could be due, at least in part, to their growth form; studies have found that mosses possessing acrocarpous (upright) forms respond differently to litter burial than mosses with pleurocarpous (prostrate) forms (Schmalholz and Granath, 2013). The larger and more erect moss species tend to have lower mortality from litter burial, regardless of micro habitat (Schmalholz and Granath, 2013). *D. polysetum* and *P. commune* are acrocarpous mosses, a robust growth form which may give individual moss shoots an advantage, allowing for upward growth through the leaf litter layer. Creeping, prostrate species tend to have higher mortality from litter burial, particularly when found in sheltered microhabitats (*i.e.* at the base of trees or close to logs or rocks, as opposed to unsheltered microhabitat directly on the forest floor). Fenton *et al.* (2003) found that bryophyte community composition at the local scale is closely related to microhabitat, especially leaf litter. Macro habitat features including topography, aspect, and canopy were also related, but seemed less influential

with regards to species distribution patterns (Fenton *et al.*, 2003). Mound and pit microtopography also creates differences in leaf litter accumulation on the forest floor, with a tendency for concentration of leaf litter in depressions (Roy and Singh, 1994). Differences between moss occurrence and mounds were observed (Figure 12). This is a common phenomenon in deciduous stands, as the high amount of leaf litter found in depressions acts as a physical barrier to bryophytes, making the mounds more suitable microhabitat (Longton, 1992). While leaf litter thickness as well as the presence of mounds and depressions were both measured during sampling, these variables are not currently capable of being effectively mapped, and were thus not used in the final regression models.

### ***Ecosite***

The ecosite variable was expected to be a more significant predictor in the habitat models than it ultimately proved to be. Two possible explanations for its lack of predictive power could be attributed to (1) the large number of categories of ecosites (eight); each species was found in multiples categories, effectively confounding any discernable patterns; and (2) ecosites do not merely reflect the elevation above the water table. If species differ in their ranges of tolerance and limiting variables, combining multiple variables in an ecosite definition is likely to blur any groupings. Categorical variables used in regression analyses should typically be limited to a small number of evenly distributed categories (Tutz, 2012). Furthermore, when compared to vascular plants, wetland bryophytes are much less likely to occur only in one particular wetland type (Slack, 1994; Locky *et al.*, 2005; Gillrich *et al.*, 2010). A binary wetland/upland variable was used instead of the 8 ecosite categories; this simplified variable was a significant predictor in all of the regression

models, helping to explain variation in species distribution alongside forest type and DTW. This indicates that the impact of DTW is primarily a separation of peat mosses from most other terrestrial bryophytes.

### ***Aspect***

Although aspect has the potential to affect microclimates and hence plant species distribution (Glime, 2007c), no relationships were found in this study relating bryophyte distribution patterns with aspect. This is likely due to the small size of the plants being considered, which are more likely affected by microsite conditions, such as mound and pit microtopography at the forest floor, than large scale changes in aspect.

### **Spatial Autocorrelation**

After some degree of spatial autocorrelation was detected in the model residuals at certain sites, an additional step was undertaken to address the effects of neighboring cells via an autocovariate. The autocovariate terms were statistically significant additions to the logistic models, although their parameter estimates remained very low, suggesting little predictive influence. The addition did not render any predictor variables insignificant. Predictor variable effects often decrease after autocorrelation is incorporated into models, because space and habitat are confounded in the absence of explicit incorporation of geographic space (Lichstein *et al.*, 2002). As such, lower parameter estimates are often seen in autologistic models (Augustin *et al.*, 1996; Lichstein *et al.*, 2002; Jewell *et al.*, 2007; Wu *et al.*, 2009). The autologistic models showed slight improvement in performance and prediction success over their non-spatial counterparts.

The use of the autocovariate reduced, but did not completely eliminate, the autocorrelation in the model residuals. It is not uncommon for autocorrelation to still be present in final autologistic models (usually to a lesser extent than found in non-spatial models) (Lichstein *et al.*, 2002; Wintle and Bardos, 2006; Jewell *et al.*, 2007). Although a 15 m neighborhood was used, at some sites the autocorrelation was also present at a larger scale (>40 m). It is thus possible that the 15 m neighborhood only captured the fine-scale autocorrelation, and left the large-scale autocorrelation unaccounted for in the models.

### **Model Performance**

There was good predictive performance (average correct classification ranging from 73 to 81%) in the models developed. When the final models were tested against an independent data set, the overall classification accuracy was still fairly good (ranging from 67 to 83%). The validation models had limitations though; for example, the models for *D. polysetum* and *P. schreberi* were better at predicting species absences than presences (Table 13). The model for *Sphagnum* species had a high percentage of false negatives (40%). It is not wholly unexpected that the models would perform less well on a separate data set. Betts *et al.* (2006) found that only half of their models performed reliably when tested against independent data in a new area, and that high predictive power based on training data did not forecast good performance with the testing data. Despite limitations, the classification rates suggest that trends in distributions of very common bryophytes may be predicted using landscape scale environmental factors such as depth to the water table and forest cover type.

### **Abundance (Percent Cover)**

Percent cover as a measure of abundance proved to be difficult to work with for several reasons. Whenever a species is not present at a sampling point, the percent cover is zero; since the total number of absences for any given species heavily outweighs the total number of presences, the resulting data set is zero-inflated. This causes problems for data analysis, as the frequency distribution is skewed with zeros, which limits what statistical tests and/or models can be used. Although several data transformations were attempted, none was able to remedy this issue. The other option is to omit the zeros, in which case the recorded percentages represent species abundance *when present*. The issue with this method is that it drastically reduces the total number of samples, and also eliminates the ability to examine changes in spatial distribution of a species across the landscape, which necessarily must include both presences and absences. For these reasons, modelling efforts were focused solely on frequency of occurrence rather than abundance, and only descriptive statistics were employed to examine trends with regards to changes of abundance across the landscape.

Although some interesting trends were apparent when percent cover values were averaged by DTW class, this is partly due to the influence of the frequency of occurrence of the species within each DTW class, i.e. frequent absences (zeros) in unsuitable habitats decreases the mean percent cover considerably. When percent cover values were averaged with the zeros removed, there were few notable trends for any of the environmental variables tested. This suggests that once individuals are established, the size of the patch (abundance/percent cover) is primarily determined by smaller scale processes such as

vegetative propagation or the presence of a small wet depression in the forest, as opposed to landscape scale features.

### **Limitations**

The sampling was stratified into an even number of plots among 8 DTW classes. The heterogeneous nature of the Acadian forest (DeWolfe *et al.*, 2005) is such that when sampling across the landscape from uplands to wetlands, a large number of varied ecosystems were traversed. Some of these ecosystems (softwood stands in particular) ultimately ended up being sampled in greater proportion than others. This uneven distribution is fairly consistent with the natural distribution of forests, since the dominant forest types in New Brunswick are spruce-fir coniferous, and to a lesser extent, mixed deciduous-coniferous (Martin, 2003). A similar unevenness is found in the types of wetlands sampled; when wet areas were selected, a focus was placed on bogs and fens. Forested riparian areas are also wet areas, but were sampled with much less frequency than large wetlands, because sampling efforts were focused mainly on bogs and fens. As such, the species that commonly grow in riparian areas (such as *Climacium dendroides* and *Aulacomnium palustre*) were subsequently under sampled and could not be analyzed further. A more equally distributed sample could have been obtained by stratifying by more than one environmental variable, instead of just DTW alone.

Dominant tree species were recorded during sampling and these data (transformed into forest type SW, MX, etc.) were used to calibrate the models, however in order to map occurrence probabilities across the entire site (over unsampled cells), the New Brunswick Department of Natural Resources GIS forest cover type layers were required. These GIS layers are mainly delineated using aerial photography, and are not always accurate,

meaning error present in these data layers is unavoidably propagated into model predictions and maps. Another (rather unavoidable) source of error is that the GPS unit used (Magellan Professional) is accurate to only approximately 3-5 meters, meaning that the exact location of the quadrats could deviate by a few meters. This in turn could affect the DTW value assigned to each plot.

## Conclusion

The question of whether changes in bryophyte distribution could be modelled using a cartographic depth-to-water index was explored using a series of regression models. Univariate HOF models provided a succinct depiction of 7 individual species responses, sampled in a design stratified by DTW, to measured/modelled environmental variables including depth-to-water, slope, forest canopy closure, and depth of the leaf litter layer. Binary logistic regression and autologistic regression models were also employed to calculate the probability of these bryophytes' occurrence as a function of explanatory variables, including depth-to-water, forest cover type, and upland/wetland classification.

Patterns in predicted distributions were variable among species. Along the DTW gradient, five of seven species (*Bazzania trilobata*, *Dicranum polysetum*, *Polytrichum commune*, *Hylocomium splendens*, and *Pleurozium schreberi*) had greater probability of occurrence towards the drier end of the water table gradient (well-drained forested land), whereas *Sphagnum fuscum* and *S. girgensohnii* showed the reverse trend. In fact the response curves of *Sphagnum* mosses differed from the upland-adapted species for all the variables analyzed. Slope worked best as a predictor for these *Sphagnum* mosses, due to their affinity for poorly drained, flat areas. Four of seven species (*Bazzania trilobata*, *Dicranum polysetum*, *Hylocomium splendens*, and *Sphagnum girgensohnii*) had good fit on the canopy closure models and the response curves elucidated some interesting trends, however the effects were not strong enough to be used in the multivariate regression models. Finally, it was noted that deciduous leaf litter inhibits the growth of bryophytes on the forest floor, and all species had considerably lower predicted frequency of occurrence in microsites with increased accumulation of leaf litter.

The predicted species optima agree with written descriptions of bryophyte habitat that are available in the literature. Overall, the results support the prediction that it is possible to model and map wetness related changes in distribution of some species of bryophytes (specifically, *Dicranum polysetum*, *Pleurozium schreberi*, and *Sphagnum girgensohnii*) using the depth-to-water index in combination with forest type and wetlands.

This research adds to existing knowledge regarding bryophyte species' responses to environmental gradients. The relative importance of individual environmental variables in determining the distribution of most plant species is presently unknown, and there are very few species distribution studies dealing exclusively with bryophytes. The results from this study help support existing research and theories regarding bryophyte habitat requirements and response curve shapes. This provides baseline data for current bryophyte distributions, and allows for predictive modelling of species occurrences at unsurveyed areas for forest management and/or conservation purposes in New Brunswick.

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**APPENDIX A: Average values of daily average temperature, precipitation, degree days above 5 °C,  
elevation range, and coordinates for each study site**

| <b>Location</b>     | <b># of Plots</b> | <b>Daily Average Temperature (°C)</b> | <b>Precipitation (mm)</b> | <b>Degree Days Above 5 °C</b> | <b>Elevation Range (MASL)</b> | <b>X Coordinates</b> | <b>Y Coordinates</b> |
|---------------------|-------------------|---------------------------------------|---------------------------|-------------------------------|-------------------------------|----------------------|----------------------|
| Bathurst            | 80                | 4.8                                   | 1110.1                    | 1690.8                        | 20 - 98                       | 65° 30' 28.352" W    | 47° 36' 18.942" N    |
| Blackbrook          | 90                | 3.5                                   | 1104.1                    | 1532.6                        | 212 - 325                     | 67° 47' 56.469" W    | 47° 12' 40.761" N    |
| Deersdale           | 90                | 3.7                                   | 1159.7                    | 1544.3                        | 360 - 492                     | 67° 14' 39.079" W    | 46° 28' 19.719" N    |
| Dorn Ridge          | 80                | 4.3                                   | 1088.9                    | 1608.7                        | 199 - 305                     | 66° 57' 27.465" W    | 46° 9' 46.043" N     |
| Fredericton         | 325               | 5.6                                   | 1077.7                    | 1803.5                        | 1 - 186                       | 66° 40' 42.408" W    | 45° 55' 52.062" N    |
| Grand Bay-Westfield | 160               | 5.2                                   | 1295.5                    | 1542.4                        | 44 - 118                      | 66° 13' 45.396" W    | 45° 17' 24.246" N    |
| Grand Lake          | 80                | 5.2                                   | 1175.8                    | 1738.5                        | -19 - 41                      | 66° 11' 2.744" W     | 45° 58' 4.157" N     |
| Miramichi           | 90                | 4.9                                   | 1072.4                    | 1718.5                        | 0 - 98                        | 65° 26' 0.137" W     | 47° 2' 34.122" N     |
| Noonan              | 80                | 5.2                                   | 1175.8                    | 1738.5                        | 13 - 150                      | 66° 26' 23.165" W    | 46° 0' 18.091" N     |
| Sackville           | 70                | 5.6                                   | 1146.5                    | 1629.9                        | -16 - 43                      | 64° 15' 41.994" W    | 45° 55' 24.145" N    |
| St. Stephen         | 90                | 5.2                                   | 1429.7                    | 1388.4                        | 85 - 162                      | 67° 15' 55.725" W    | 45° 19' 21.677" N    |
| Tracadie            | 70                | 4.8                                   | 1077.2                    | 1658.5                        | 0 - 20                        | 64° 54' 16.418" W    | 47° 25' 59.695" N    |

## APPENDIX B: Data from vegetation surveys

(Abbreviations - BZ: *Bazzania trilobata*, DP: *Dicranum polysetum*, HS: *Hylocomium splendens*, PC: *Polytrichum commune*, PS: *Pleurozium schreberi*, SF: *Sphagnum fuscum*, SG: *Sphagnum girgensohnii* (all seven species are measured as percent cover of 1m<sup>2</sup> quadrat), DTW Class: depth-to-water class (1-8), VT: vegetation type (1-4), WL: wetland, SW: softwood, HW: hardwood, MX: mixedwood, CC: canopy closure class (0-5), L Layer: leaf litter in cm)

| Plot | BZ | DP   | HS | PC  | PS  | SF | SG | DTW Class | VT | Ecosite     | Forest | CC | L Layer |
|------|----|------|----|-----|-----|----|----|-----------|----|-------------|--------|----|---------|
| B01  |    | 18   |    |     | 17  |    |    | 4         | 1  | Forest      | SW     | 0  | 0.1     |
| B02  |    | 0.2  |    |     | 0.2 |    | 5  | 4         | 1  | Forest      | SW     | 0  | 2       |
| B03  |    |      |    |     |     |    | 90 | 1         | 2  | Forested WL | SW     | 0  | 0       |
| B04  |    |      |    |     |     |    | 95 | 1         | 2  | Forested WL | SW     | 1  | 0       |
| B05  |    |      |    |     | 1.5 |    |    | 5         | 2  | Forest      | HW     | 1  | 1       |
| B06  |    | 5    |    |     | 5   |    |    | 5         | 2  | Forest      | HW     | 3  | 0.5     |
| B07  |    | 0.4  |    |     |     |    |    | 7         | 3  | Forest      | HW     | 4  | 4       |
| B08  |    |      |    |     |     |    |    | 7         | 3  | Forest      | HW     | 3  | 6       |
| B09  |    |      |    |     |     |    |    | 8         | 3  | Forest      | SW     | 4  | 1       |
| B10  |    | 4    |    |     | 0.2 |    |    | 8         | 3  | Forest      | SW     | 0  | 2       |
| B11  |    | 0.3  |    |     |     |    |    | 8         | 2  | Forest      | SW     | 3  | 2       |
| B12  |    | 10   |    |     | 0.5 |    |    | 8         | 2  | Forest      | SW     | 0  | 0.1     |
| B13  |    |      |    |     |     |    |    | 8         | 2  | Forest      | MX     | 5  | 4       |
| B14  |    | 0.25 |    |     |     |    |    | 8         | 2  | Forest      | MX     | 4  | 1       |
| B15  |    |      |    |     |     |    |    | 6         | 2  | Forest      | MX     | 5  | 1       |
| B16  |    | 0.2  |    |     | 0.2 |    |    | 6         | 2  | Forest      | MX     | 4  | 2       |
| B17  |    |      |    | 0.4 |     |    | 99 | 3         | 1  | Forest      | SW     | 0  | 0       |
| B18  |    |      |    |     |     |    | 85 | 3         | 1  | Forest      | SW     | 2  | 0.5     |
| B19  |    |      |    |     |     |    | 90 | 1         | 1  | Forested WL | SW     | 0  | 0       |
| B20  |    |      |    |     |     |    | 5  | 1         | 1  | Forested WL | SW     | 0  | 0       |
| B21  | 20 | 16   |    |     | 4   |    |    | 4         | 2  | Riparian    | SW     | 4  | 0.1     |
| B22  |    |      |    |     |     |    | 70 | 1         | 1  | Riparian    | SW     | 3  | 0.1     |
| B23  |    |      |    | 45  |     |    | 55 | 1         | 1  | Forested WL | SW     | 0  | 0       |
| B24  |    |      |    |     |     |    | 50 | 1         | 1  | Forested WL | SW     | 0  | 0       |
| B25  |    |      |    |     |     |    | 90 | 1         | 1  | Forested WL | SW     | 0  | 0       |
| B26  |    |      |    |     |     |    | 75 | 1         | 1  | Forested WL | SW     | 2  | 0       |
| B27  |    |      |    |     |     | 35 | 30 | 3         | 1  | Fen         | SW     | 0  | 0       |
| B28  |    |      |    |     |     |    | 98 | 3         | 1  | Fen         | SW     | 0  | 0       |
| B29  |    | 3    |    |     | 96  |    |    | 5         | 1  | Forest      | SW     | 3  | 0.1     |
| B30  |    |      |    |     | 15  |    |    | 5         | 1  | Forest      | SW     | 0  | 0.1     |
| B31  |    |      |    |     |     |    | 75 | 1         | 1  | Fen         | SW     | 0  | 0       |
| B32  |    |      |    |     |     |    | 25 | 2         | 1  | Fen         | SW     | 0  | 0       |
| B33  |    |      |    |     |     |    | 90 | 2         | 1  | Fen         | SW     | 0  | 0       |
| B34  |    |      |    |     |     |    | 90 | 2         | 1  | Fen         | SW     | 0  | 0       |
| B35  |    |      |    |     |     |    | 12 | 2         | 1  | Riparian    | MX     | 4  | 0.1     |
| B36  |    |      |    |     |     |    | 20 | 2         | 1  | Riparian    | MX     | 2  | 0       |
| B37  |    |      |    |     |     |    |    | 4         | 2  | Forest      | SW     | 2  | 0.5     |
| B38  |    | 0.25 |    |     | 40  |    |    | 4         | 2  | Forest      | SW     | 0  | 5       |

| Plot | DTW |     |    |     |     |    |     |       | L  |             |        |    |       |
|------|-----|-----|----|-----|-----|----|-----|-------|----|-------------|--------|----|-------|
|      | BZ  | DP  | HS | PC  | PS  | SF | SG  | Class | VT | Ecosite     | Forest | CC | Layer |
| B39  |     | 8   |    |     | 80  |    |     | 6     | 2  | Forest      | SW     | 0  | 0.5   |
| B40  |     | 0.5 |    |     | 1   |    |     | 6     | 2  | Forest      | SW     | 0  | 1     |
| B41  | 2   |     |    |     | 6   |    |     | 8     | 2  | Forest      | SW     | 4  | 1     |
| B42  |     | 6   |    |     | 4   |    |     | 8     | 2  | Forest      | SW     | 5  | 1     |
| B43  |     | 2   |    |     | 88  |    |     | 7     | 2  | Forest      | SW     | 0  | 0.1   |
| B44  |     |     |    |     | 98  |    |     | 7     | 2  | Forest      | SW     | 0  | 0.1   |
| B45  |     |     |    |     |     |    |     | 7     | 3  | Forest      | SW     | 5  | 1     |
| B46  |     |     |    |     |     |    |     | 7     | 3  | Forest      | SW     | 5  | 3     |
| B47  |     |     |    |     |     |    |     | 2     | 1  | Riparian    | SW     | 5  | 1     |
| B48  | 30  |     | 25 |     |     |    |     | 4     | 1  | Riparian    | SW     | 4  | 1     |
| B49  |     | 1   |    |     | 8   |    |     | 6     | 1  | Forest      | SW     | 0  | 1     |
| B50  |     |     |    |     | 0.1 |    |     | 6     | 1  | Forest      | SW     | 0  | 1     |
| B51  |     | 1   |    |     | 96  |    |     | 5     | 1  | Forest      | SW     | 0  | 0.1   |
| B52  |     | 2   |    | 18  | 20  |    |     | 5     | 1  | Forest      | SW     | 0  | 1     |
| B53  |     |     |    |     | 2   |    |     | 4     | 1  | Forest      | MX     | 0  | 1     |
| B54  |     | 1   |    |     | 10  |    |     | 4     | 1  | Forest      | MX     | 0  | 1     |
| B55  |     |     |    |     |     |    |     | 8     | 3  | Forest      | HW     | 0  | 3     |
| B56  |     |     |    |     |     |    |     | 8     | 3  | Forest      | HW     | 1  | 3     |
| B57  |     |     |    |     |     |    |     | 7     | 3  | Forest      | SW     | 3  | 2     |
| B58  |     |     |    |     |     |    |     | 7     | 3  | Forest      | SW     | 0  | 4     |
| B59  |     |     |    |     |     |    |     | 5     | 3  | Ecotone     | MX     | 0  | 5     |
| B60  | 0.5 |     |    | 2   |     |    |     | 5     | 3  | Ecotone     | MX     | 3  | 2     |
| B61  |     |     |    |     |     |    |     | 3     | 3  | Marsh       | MX     | 0  | 0     |
| B62  |     |     |    |     |     |    |     | 3     | 1  | Marsh       | Other  | 0  | 0     |
| B63  |     |     |    |     |     |    |     | 2     | 3  | Marsh       | Other  | 0  | 0.1   |
| B64  |     |     |    |     |     |    |     | 2     | 3  | Marsh       | Other  | 0  | 2     |
| B65  |     |     |    |     |     |    |     | 3     | 3  | Shrub WL    | MX     | 5  | 3     |
| B66  |     |     |    |     |     |    |     | 3     | 2  | Shrub WL    | MX     | 4  | 2     |
| B67  |     |     |    |     |     |    | 8   | 4     | 2  | Ecotone     | SW     | 0  | 0     |
| B68  |     |     |    |     | 15  |    |     | 4     | 3  | Ecotone     | SW     | 3  | 2     |
| B69  |     |     |    |     |     |    | 12  | 2     | 1  | Marsh       | SW     | 0  | 1     |
| B70  |     |     |    |     |     |    |     | 2     | 1  | Marsh       | SW     | 0  | 2     |
| B71  |     |     |    |     |     |    | 2   | 5     | 3  | Riparian    | MX     | 4  | 0.5   |
| B72  |     |     |    |     |     |    |     | 5     | 3  | Riparian    | MX     | 5  | 1     |
| B73  |     |     |    |     |     |    |     | 6     | 3  | Forest      | HW     | 4  | 6     |
| B74  |     |     |    |     |     |    |     | 6     | 3  | Forest      | HW     | 4  | 4     |
| B75  |     |     |    |     |     |    |     | 3     | 3  | Riparian    | SW     | 0  | 1     |
| B76  |     |     |    |     |     |    |     | 3     | 3  | Riparian    | SW     | 5  | 3     |
| B77  |     |     |    |     |     |    |     | 6     | 2  | Forest      | MX     | 4  | 1     |
| B78  |     |     |    |     | 85  |    |     | 6     | 2  | Forest      | MX     | 4  | 0.5   |
| B79  |     |     |    |     | 3.5 |    | 48  | 7     | 1  | Forest      | SW     | 0  | 0.5   |
| B80  |     | 1   |    |     |     |    |     | 7     | 1  | Forest      | SW     | 1  | 0.1   |
| BB01 |     |     |    | 4   |     |    | 70  | 4     | 1  | Fen         | SW     | 0  | 0.1   |
| BB02 |     |     |    | 0.3 | 1   |    | 90  | 4     | 1  | Fen         | SW     | 3  | 1     |
| BB03 |     |     |    |     |     |    | 30  | 1     | 1  | Fen         | SW     | 0  | 0     |
| BB04 |     |     |    |     |     |    | 1.5 | 1     | 1  | Fen         | SW     | 0  | 0     |
| BB05 |     |     |    | 40  |     |    | 25  | 1     | 1  | Fen         | MX     | 0  | 0     |
| BB06 |     |     |    |     |     |    | 95  | 1     | 1  | Fen         | MX     | 0  | 0     |
| BB07 |     |     |    |     | 2   |    | 50  | 2     | 1  | Forested WL | SW     | 0  | 0     |
| BB08 |     |     |    |     |     |    | 10  | 2     | 1  | Forested WL | SW     | 0  | 0     |
| BB09 | 0.3 | 1   |    |     | 98  |    |     | 4     | 2  | Forest      | SW     | 3  | 0.1   |

| Plot | DTW  |      |     |      |     |     |      |   |   | Class | VT          | Ecosite | Forest | CC | L<br>Layer |
|------|------|------|-----|------|-----|-----|------|---|---|-------|-------------|---------|--------|----|------------|
|      | BZ   | DP   | HS  | PC   | PS  | SF  | SG   |   |   |       |             |         |        |    |            |
| BB10 | 10   | 1    | 1   |      | 4   |     |      |   | 4 | 2     | Forest      | SW      | 4      |    | 0.5        |
| BB11 | 30   | 15   | 20  |      | 20  |     |      |   | 4 | 3     | Forest      | SW      | 3      |    | 0.1        |
| BB12 | 1    | 0.1  | 4   |      | 0.5 |     |      |   | 4 | 3     | Forest      | SW      | 5      |    | 0.3        |
| BB13 |      | 17   |     |      | 82  |     |      |   | 7 | 2     | Forest      | MX      | 1      |    | 0.1        |
| BB14 |      | 0.3  | 1   |      | 4   |     |      |   | 7 | 2     | Forest      | MX      | 3      |    | 0.5        |
| BB15 |      | 0.45 |     |      | 3   |     |      |   | 8 | 2     | Forest      | MX      | 3      |    | 3          |
| BB16 | 0.25 |      | 0.5 |      | 1   |     |      |   | 8 | 2     | Forest      | MX      | 3      |    | 2          |
| BB17 |      | 1    |     |      | 2   |     |      |   | 8 | 3     | Forest      | MX      | 3      |    | 3          |
| BB18 |      | 0.25 |     |      |     |     |      |   | 8 | 3     | Forest      | MX      | 4      |    | 3          |
| BB19 |      |      |     |      | 3   |     |      |   | 8 | 3     | Forest      | MX      | 4      |    | 0.5        |
| BB20 |      |      |     |      |     |     |      |   | 8 | 3     | Forest      | MX      | 4      |    | 3          |
| BB21 |      |      |     |      |     |     |      |   | 5 | 3     | Riparian    | MX      | 2      |    | 1.5        |
| BB22 |      |      |     |      |     |     |      |   | 5 | 3     | Riparian    | MX      | 2      |    | 0          |
| BB23 |      |      |     |      |     |     |      |   | 4 | 3     | Forest      | SW      | 4      |    | 5          |
| BB24 |      |      |     |      |     |     |      |   | 4 | 3     | Forest      | SW      | 4      |    | 2          |
| BB25 |      | 2.2  |     |      | 6   |     |      |   | 6 | 2     | Forest      | SW      | 3      |    | 0.5        |
| BB26 | 20   | 0.25 | 0.5 | 20   | 10  |     |      |   | 6 | 2     | Forest      | SW      | 4      |    | 0.5        |
| BB27 |      | 3    |     |      | 6   |     | 50   |   | 6 |       | Forest      | SW      | 3      |    | 0.1        |
| BB28 |      | 18   | 15  | 8    | 35  |     |      |   | 6 |       | Forest      | SW      | 0      |    | 0.1        |
| BB29 |      |      |     |      | 5   |     |      |   | 2 |       | Riparian    | SW      | 4      |    | 1          |
| BB30 |      |      |     |      |     |     |      |   | 2 |       | Riparian    | SW      | 0      |    | 5          |
| BB31 |      |      |     |      | 87  |     | 3    | 1 | 1 | 1     | Riparian    | SW      | 3      |    | 0.1        |
| BB32 | 1    | 0.5  |     |      | 1   |     | 0.25 | 3 | 1 | 1     | Riparian    | SW      | 5      |    | 1          |
| BB33 |      |      |     |      |     |     |      | 1 | 3 |       | Marsh       | Other   | 0      |    | 0          |
| BB34 |      |      |     |      |     |     |      | 2 | 3 |       | Marsh       | Other   | 0      |    | 0          |
| BB35 |      | 5    |     |      | 4   |     | 45   | 5 |   |       | Forest      | SW      | 1      |    | 0.1        |
| BB36 |      | 0.5  |     |      | 80  |     | 22   | 5 |   |       | Forest      | SW      | 2      |    | 0.1        |
| BB37 |      |      |     |      |     |     | 70   | 3 |   |       | Forest      | SW      | 0      |    | 0          |
| BB38 |      | 2    |     | 45   | 80  |     |      | 3 |   |       | Forest      | SW      | 2      |    | 0.1        |
| BB39 |      |      |     | 5    |     |     | 88   | 7 |   |       | Forest      | SW      | 0      |    | 0.5        |
| BB40 |      |      | 14  | 0.25 | 60  |     |      | 7 |   |       | Forest      | SW      | 1      |    | 1          |
| BB41 |      |      |     |      | 90  |     |      | 8 |   |       | Forest      | SW      | 2      |    | 0.5        |
| BB42 |      | 2    |     | 50   | 70  |     |      | 8 |   |       | Forest      | SW      | 1      |    | 0.1        |
| BB43 |      | 4    |     |      | 95  |     |      | 8 |   |       | Forest      | SW      | 1      |    | 1          |
| BB44 |      | 1    |     | 3    | 95  |     |      | 8 |   |       | Forest      | SW      | 1      |    | 1          |
| BB45 |      | 2    |     | 2.5  | 40  |     |      | 8 |   |       | Forest      | SW      | 4      |    | 2          |
| BB46 |      | 5    |     | 35   | 45  |     |      | 8 |   |       | Forest      | SW      | 3      |    | 2          |
| BB47 | 6    | 4    |     |      | 89  |     |      | 8 |   |       | Forest      | SW      | 2      |    | 0.1        |
| BB48 |      | 3    |     |      | 60  |     |      | 8 |   |       | Forest      | SW      | 3      |    | 0.1        |
| BB49 |      | 3    |     |      | 79  |     |      | 8 |   |       | Forest      | SW      | 3      |    | 1          |
| BB50 |      | 2    |     | 20   | 40  |     |      | 8 |   |       | Forest      | SW      | 1      |    | 0.5        |
| BB51 |      |      |     |      |     | 4.5 | 50   | 5 | 1 |       | Forested WL | SW      | 0      |    | 0          |
| BB52 |      |      |     | 1    | 5   | 2   | 20   | 5 | 1 |       | Forested WL | SW      | 0      |    | 0          |
| BB53 |      |      |     |      |     |     | 42   | 1 | 1 |       | Forested WL | MX      | 0      |    | 0          |
| BB54 |      |      |     |      |     |     | 99   | 1 | 1 |       | Forested WL | MX      | 4      |    | 0          |
| BB55 |      |      |     |      |     |     |      | 7 | 2 |       | Forest      | MX      | 5      |    | 4          |
| BB56 |      | 1    |     |      |     |     |      | 7 | 2 |       | Forest      | MX      | 0      |    | 3          |
| BB57 |      |      |     |      |     |     |      | 8 | 3 |       | Forest      | HW      | 2      |    | 1          |
| BB58 |      |      |     | 2.5  |     |     |      | 8 | 3 |       | Forest      | HW      | 1      |    | 3          |
| BB59 |      |      |     |      |     |     |      | 3 | 3 |       | Forest      | SW      | 4      |    | 3          |
| BB60 |      |      |     |      |     |     |      | 3 | 3 |       | Forest      | SW      | 4      |    | 3          |

| Plot | BZ  | DP  | HS  | PC  | PS  | SF | SG | DTW   |    | Ecosite     | Forest | CC | L<br>Layer |
|------|-----|-----|-----|-----|-----|----|----|-------|----|-------------|--------|----|------------|
|      |     |     |     |     |     |    |    | Class | VT |             |        |    |            |
| BB61 |     |     |     |     |     |    |    | 2     | 3  | Riparian    | HW     | 2  | 4          |
| BB62 |     |     |     |     |     |    |    | 2     | 3  | Riparian    | HW     | 2  | 0          |
| BB63 |     |     |     |     |     |    |    | 3     | 3  | Marsh       | Other  | 0  | 0          |
| BB64 |     |     |     |     |     |    |    | 3     | 3  | Marsh       | Other  | 0  | 0          |
| BB65 |     |     |     |     | 0.1 |    |    | 3     | 1  | Shrub WL    | SW     | 0  | 0.1        |
| BB66 |     |     |     |     |     |    |    | 3     | 1  | Shrub WL    | SW     | 1  | 3          |
| BB67 |     |     | 0.4 |     | 0.3 |    | 88 | 2     | 1  | Forested WL | SW     | 0  | 0          |
| BB68 |     |     |     |     |     |    |    | 2     | 2  | Forested WL | SW     | 0  | 0          |
| BB69 |     |     |     |     |     |    | 96 | 3     | 1  | Forested WL | SW     | 0  | 0.1        |
| BB70 |     |     | 0.7 |     | 0.1 |    | 50 | 2     | 1  | Forested WL | SW     | 4  | 0          |
| BB71 |     |     |     | 0.4 |     |    | 93 | 6     | 3  | Forested WL | SW     | 0  | 0          |
| BB72 |     |     |     |     | 0.2 |    | 4  | 6     | 3  | Forested WL | SW     | 0  | 0          |
| BB73 |     |     |     |     | 4   |    |    | 4     | 3  | Forest      | SW     | 0  | 1          |
| BB74 |     |     |     |     |     |    |    | 4     | 3  | Forest      | SW     | 0  | 0          |
| BB75 |     |     |     |     |     |    |    | 6     | 3  | Forest      | MX     | 5  | 2          |
| BB76 |     |     |     |     |     |    |    | 6     | 3  | Forest      | MX     | 3  | 3          |
| BB77 |     |     |     |     | 5   |    |    | 7     | 4  | Forest      | HW     | 3  | 6          |
| BB78 |     |     |     |     |     |    |    | 7     | 4  | Forest      | HW     | 3  | 5          |
| BB79 |     |     |     |     |     |    |    | 5     | 3  | Forest      | SW     | 4  | 6          |
| BB80 |     | 6   |     |     |     |    |    | 5     | 3  | Forest      | SW     | 4  | 3          |
| BB81 |     |     |     |     |     |    | 13 | 1     | 3  | Forested WL | SW     | 0  | 0          |
| BB82 |     |     |     |     |     |    | 7  | 1     | 3  | Forested WL | SW     | 0  | 0          |
| BB83 |     | 1.4 | 4   | 15  | 3   |    |    | 5     |    | Forest      | SW     | 3  | 1          |
| BB84 |     | 6   |     |     | 16  |    | 10 | 5     |    | Forest      | SW     | 4  | 0.5        |
| BB85 |     |     |     |     | 1   |    |    | 6     |    | Forest      | HW     | 4  | 2          |
| BB86 |     |     |     |     |     |    |    | 6     |    | Forest      | HW     | 0  | 1.5        |
| BB87 |     | 4   |     |     | 4.3 |    |    | 7     |    | Forest      | SW     | 5  | 0.5        |
| BB88 |     | 5   |     |     | 65  |    |    | 7     |    | Forest      | SW     | 4  | 0.5        |
| BB89 |     | 45  |     | 18  | 22  |    |    | 8     |    | Forest      | SW     | 1  | 0.1        |
| BB90 |     |     |     |     | 30  |    | 35 | 8     |    | Forest      | SW     | 2  | 3          |
| DD01 |     |     |     |     |     |    |    | 4     | 4  | Forest      | MX     | 4  | 2          |
| DD02 |     |     |     |     |     |    | 15 | 4     | 4  | Forest      | MX     | 5  | 0.1        |
| DD03 |     |     |     |     |     |    | 8  | 1     | 3  | Shrub WL    | SW     | 4  | 3          |
| DD04 |     |     |     |     |     |    | 80 | 2     | 3  | Shrub WL    | SW     | 4  | 0          |
| DD05 | 4   | 0.3 |     |     | 3.8 |    | 18 | 4     | 2  | Forest      | SW     | 1  | 0.1        |
| DD06 |     |     |     |     |     |    | 80 | 4     | 2  | Forest      | SW     | 0  | 0          |
| DD07 |     |     |     |     |     |    | 5  | 2     | 3  | Shrub WL    | MX     | 0  | 0          |
| DD08 |     |     |     |     |     |    |    | 2     | 3  | Shrub WL    | MX     | 0  | 0          |
| DD09 |     |     |     |     |     |    |    | 2     | 3  | Shrub WL    | Other  | 0  | 0          |
| DD10 |     |     |     |     |     |    |    | 1     | 3  | Shrub WL    | Other  | 0  | 0          |
| DD11 |     |     |     |     |     |    | 10 | 1     | 3  | Shrub WL    | SW     | 0  | 0          |
| DD12 |     |     |     |     |     |    | 85 | 3     | 3  | Shrub WL    | SW     | 2  | 0          |
| DD13 | 0.9 |     |     |     | 12  |    | 60 | 3     | 3  | Forest      | SW     | 3  | 0          |
| DD14 |     |     |     |     |     |    | 97 | 3     | 3  | Forest      | SW     | 0  | 0          |
| DD15 |     |     |     |     | 5.5 |    |    | 5     | 4  | Forest      | MX     | 5  | 1          |
| DD16 |     |     |     |     |     |    |    | 5     | 4  | Forest      | MX     | 5  | 1          |
| DD17 |     |     |     |     |     |    |    | 7     | 4  | Forest      | HW     | 5  | 2          |
| DD18 |     |     |     |     |     |    |    | 7     | 4  | Forest      | HW     | 5  | 5          |
| DD19 |     |     |     |     |     |    |    | 7     | 4  | Forest      | MX     | 4  | 5          |
| DD20 |     |     |     |     |     |    |    | 7     | 4  | Forest      | MX     | 5  | 5          |
| DD21 |     |     |     |     |     |    |    | 6     | 4  | Forest      | HW     | 4  | 3          |

| Plot | DTW |     |    |    |     |    |     |       | L  |          |          |    |       |     |
|------|-----|-----|----|----|-----|----|-----|-------|----|----------|----------|----|-------|-----|
|      | BZ  | DP  | HS | PC | PS  | SF | SG  | Class | VT | Ecosite  | Forest   | CC | Layer |     |
| DD22 |     |     |    |    |     |    |     | 6     | 4  | Forest   | HW       | 5  | 2     |     |
| DD23 |     |     |    |    |     |    |     | 8     | 4  | Forest   | HW       | 1  | 2     |     |
| DD24 |     |     |    |    |     |    |     | 8     | 4  | Forest   | HW       | 5  | 4     |     |
| DD25 |     |     |    |    |     |    |     | 8     | 4  | Forest   | HW       | 5  | 3     |     |
| DD26 |     |     |    |    |     |    |     | 8     | 4  | Forest   | HW       | 5  | 3     |     |
| DD27 |     |     |    |    |     |    |     | 8     | 4  | Forest   | HW       | 5  | 2     |     |
| DD28 |     |     |    |    |     |    |     | 8     | 4  | Forest   | HW       | 5  | 10    |     |
| DD29 |     |     |    |    |     |    |     | 8     | 4  | Forest   | HW       | 5  | 2     |     |
| DD30 |     |     |    |    |     |    |     | 8     | 4  | Forest   | HW       | 5  | 7     |     |
| DD31 |     |     |    |    |     |    |     | 8     | 4  | Forest   | HW       | 5  | 3     |     |
| DD32 |     |     |    |    |     |    |     | 8     | 4  | Forest   | HW       | 5  | 4     |     |
| DD33 |     |     |    |    |     |    |     | 7     | 4  | Forest   | HW       | 5  | 3     |     |
| DD34 |     |     |    |    |     |    |     | 7     | 4  | Forest   | HW       | 5  | 4     |     |
| DD35 |     |     |    |    |     |    |     | 90    | 1  | 1        | Forest   | MX | 0     | 0   |
| DD36 |     |     |    |    |     |    |     | 97    | 1  | 1        | Forest   | MX | 1     | 0   |
| DD37 |     |     |    |    |     |    |     | 35    | 4  | 2        | Forest   | MX | 0     | 0   |
| DD38 |     |     |    |    |     |    |     | 95    | 4  | 2        | Forest   | MX | 0     | 0   |
| DD39 |     |     |    |    |     |    |     | 45    | 1  | 1        | Shrub WL | SW | 4     | 0   |
| DD40 |     |     |    |    | 6   |    |     | 40    | 2  | 1        | Shrub WL | SW | 4     | 0   |
| DD41 |     |     |    |    |     |    |     | 40    | 3  | 2        | Forest   | MX | 2     | 0   |
| DD42 |     |     | 2  |    | 40  |    |     | 4     | 2  | Forest   | MX       | 4  | 0     |     |
| DD43 |     |     |    |    |     |    |     | 94    | 5  | 1        | Forest   | SW | 4     | 0.1 |
| DD44 | 0.5 |     |    |    | 4   |    |     | 5     | 1  | Forest   | SW       | 2  | 0     |     |
| DD45 |     |     |    |    |     |    |     | 2     | 1  | Shrub WL | Other    | 0  | 0     |     |
| DD46 |     |     |    |    |     |    |     | 3     | 1  | Shrub WL | Other    | 0  | 0     |     |
| DD47 |     |     |    |    |     |    |     | 4     | 1  | 1        | Shrub WL | SW | 0     | 0   |
| DD48 |     |     |    |    |     |    |     | 95    | 2  | 1        | Shrub WL | SW | 0     | 0   |
| DD49 |     |     |    |    | 4   |    |     | 10    | 3  | 1        | Shrub WL | SW | 1     | 0   |
| DD50 |     |     | 6  |    |     |    |     | 90    | 2  | 1        | Shrub WL | SW | 0     | 0   |
| DD51 | 1   |     | 4  |    | 0.2 |    |     | 2     | 4  | 3        | Shrub WL | SW | 4     | 0.1 |
| DD52 | 10  |     | 2  |    |     |    |     | 3     | 3  | Forest   | SW       | 4  | 0.1   |     |
| DD53 |     |     |    |    | 2   |    |     | 7     | 3  | Forest   | MX       | 5  | 1     |     |
| DD54 |     |     |    |    |     |    |     | 7     | 3  | Forest   | MX       | 5  | 0.5   |     |
| DD55 |     | 3   |    |    | 4   |    | 45  | 6     | 3  | Forest   | SW       | 3  | 0.1   |     |
| DD56 |     |     |    |    | 1.5 |    |     | 6     | 3  | Forest   | SW       | 4  | 0.5   |     |
| DD57 |     |     |    |    | 4   |    |     | 8     | 4  | Forest   | SW       | 2  | 0.1   |     |
| DD58 |     |     |    |    | 5   |    |     | 8     | 4  | Forest   | SW       | 0  | 1     |     |
| DD59 |     | 0.6 |    |    |     |    |     | 8     | 3  | Forest   | SW       | 1  | 1     |     |
| DD60 |     |     |    |    |     |    |     | 8     | 3  | Forest   | SW       | 4  | 1     |     |
| DD61 |     | 2.4 |    |    |     |    |     | 6     | 4  | Forest   | SW       | 2  | 0.1   |     |
| DD62 |     |     |    | 3  | 7   |    |     | 6     | 4  | Forest   | SW       | 2  | 1     |     |
| DD63 |     |     |    |    | 6   |    |     | 7     | 4  | Forest   | SW       | 2  | 1     |     |
| DD64 |     | 1.5 |    | 1  | 75  |    |     | 7     | 4  | Forest   | SW       | 3  | 0.5   |     |
| DD65 |     |     |    |    |     |    | 2.3 | 4     | 2  | Forest   | SW       | 0  | 2     |     |
| DD66 |     |     |    |    |     |    | 96  | 4     | 2  | Forest   | SW       | 0  | 0     |     |
| DD67 |     |     |    |    |     |    |     | 6     | 4  | Forest   | HW       | 5  | 3     |     |
| DD68 |     |     |    |    |     |    |     | 6     | 4  | Forest   | HW       | 5  | 6     |     |
| DD69 |     |     |    |    |     |    |     | 5     | 4  | Forest   | HW       | 5  | 3     |     |
| DD70 |     |     |    |    |     |    |     | 5     | 4  | Forest   | HW       | 4  | 3     |     |
| DD71 |     |     |    |    |     |    |     | 3     | 4  | Riparian | MX       | 4  | 2     |     |
| DD72 |     |     |    |    |     |    |     | 3     | 4  | Riparian | MX       | 5  | 0     |     |

| Plot | DTW |      |     |     |      |    |     |   | Class | VT       | Ecosite | Forest | CC  | L<br>Layer |
|------|-----|------|-----|-----|------|----|-----|---|-------|----------|---------|--------|-----|------------|
|      | BZ  | DP   | HS  | PC  | PS   | SF | SG  |   |       |          |         |        |     |            |
| DD73 |     |      |     | 1   |      |    |     | 3 | 4     | Riparian | HW      | 2      | 3   |            |
| DD74 |     |      |     |     |      |    |     | 1 | 4     | Riparian | HW      | 1      | 0   |            |
| DD75 |     |      |     |     |      |    |     | 2 | 3     | Riparian | MX      | 5      | 4   |            |
| DD76 |     |      |     |     |      |    |     | 1 | 3     | Riparian | MX      | 1      | 0   |            |
| DD77 |     |      |     |     |      |    |     | 2 | 3     | Riparian | MX      | 4      | 1   |            |
| DD78 |     |      |     |     |      |    |     | 1 | 3     | Riparian | MX      | 2      | 0   |            |
| DD79 |     |      |     |     |      |    |     | 6 | 4     | Forest   | MX      | 3      | 2   |            |
| DD80 | 1   |      |     |     |      |    |     | 6 | 4     | Forest   | MX      | 4      | 2   |            |
| DD81 |     |      | 3   |     |      |    |     | 5 | 3     | Forest   | MX      | 4      | 1   |            |
| DD82 |     |      |     |     |      |    |     | 5 | 3     | Forest   | MX      | 2      | 2   |            |
| DD83 | 2   | 1    |     |     | 4    |    |     | 5 | 4     | Forest   | SW      | 0      | 0.5 |            |
| DD84 | 6   | 0.1  |     |     | 0.75 |    |     | 5 | 4     | Forest   | SW      | 4      | 0.1 |            |
| DD85 |     |      |     |     |      |    |     | 8 | 4     | Forest   | MX      | 5      | 4   |            |
| DD86 |     |      |     |     |      |    |     | 8 | 4     | Forest   | MX      | 5      | 4   |            |
| DD87 |     |      |     |     |      |    |     | 8 | 4     | Forest   | HW      | 3      | 5   |            |
| DD88 |     |      |     |     |      |    |     | 8 | 4     | Forest   | HW      | 5      | 5   |            |
| DD89 |     |      |     |     |      |    |     | 8 | 4     | Forest   | MX      | 5      | 6   |            |
| DD90 |     |      |     |     |      |    |     | 8 | 4     | Forest   | MX      | 5      | 5   |            |
| DR01 |     |      |     |     |      |    |     | 8 | 4     | Forest   | HW      | 3      | 4   |            |
| DR02 |     |      |     |     | 0.25 |    |     | 8 | 4     | Forest   | HW      | 3      | 3   |            |
| DR03 |     |      |     |     |      |    |     | 7 | 4     | Forest   | MX      | 3      | 5   |            |
| DR04 |     |      |     | 1   | 0.1  |    |     | 7 | 4     | Forest   | MX      | 3      | 4   |            |
| DR05 |     | 0.9  | 0.3 |     | 2.5  |    |     | 5 | 2     | Forest   | SW      | 4      | 1   |            |
| DR06 |     | 0.1  |     | 1   | 75   |    |     | 6 | 2     | Forest   | SW      | 5      | 0.5 |            |
| DR07 |     |      |     | 25  |      |    | 73  | 3 | 3     | Ecotone  | SW      | 0      | 0   |            |
| DR08 |     |      | 1   | 10  | 10   |    | 40  | 2 | 3     | Ecotone  | SW      | 0      | 0   |            |
| DR09 |     |      |     | 0.3 |      |    | 99  | 5 | 1     | Bog      | Other   | 0      | 0   |            |
| DR10 |     |      |     | 3   |      |    | 99  | 5 | 1     | Bog      | Other   | 0      | 0   |            |
| DR11 |     |      |     |     | 2    |    |     | 7 | 2     | Forest   | SW      | 5      | 2   |            |
| DR12 |     |      |     |     | 25   |    |     | 8 | 2     | Forest   | SW      | 4      | 0.5 |            |
| DR13 |     |      |     |     |      |    |     | 8 | 3     | Forest   | HW      | 5      | 3   |            |
| DR14 | 0.1 | 0.25 | 0.1 |     | 30   |    |     | 8 | 3     | Forest   | HW      | 2      | 0.1 |            |
| DR15 | 1.3 | 6    |     |     | 15   |    |     | 3 | 2     | Forest   | SW      | 3      | 0.5 |            |
| DR16 |     | 9    |     |     | 60   |    |     | 4 | 2     | Forest   | SW      | 3      | 0.5 |            |
| DR17 |     |      |     |     |      |    | 95  | 5 | 1     | Ecotone  | MX      | 0      | 0   |            |
| DR18 |     |      |     | 8   |      |    | 90  | 5 | 1     | Ecotone  | MX      | 0      | 0   |            |
| DR19 |     |      |     |     |      |    | 80  | 1 | 1     | Bog      | Other   | 0      | 0   |            |
| DR20 |     |      |     | 30  |      |    | 25  | 3 | 1     | Bog      | Other   | 0      | 0   |            |
| DR21 |     | 1.1  |     |     |      |    |     | 7 | 2     | Forest   | SW      | 4      | 2   |            |
| DR22 |     |      |     | 1   |      |    |     | 7 | 2     | Forest   | SW      | 2      | 1   |            |
| DR23 | 0.5 | 43   |     |     | 42   |    |     | 8 | 3     | Forest   | SW      | 4      | 1   |            |
| DR24 |     |      |     |     | 15   |    |     | 8 | 3     | Forest   | SW      | 0      | 1   |            |
| DR25 |     |      |     |     |      |    |     | 1 | 3     | Riparian | MX      | 5      | 0.5 |            |
| DR26 |     |      |     |     |      |    |     | 2 | 3     | Riparian | MX      | 4      | 0.5 |            |
| DR27 |     |      |     | 13  | 0.2  |    |     | 7 | 4     | Forest   | MX      | 5      | 3   |            |
| DR28 |     |      |     |     | 1    |    |     | 7 | 4     | Forest   | MX      | 3      | 2   |            |
| DR29 | 2.5 | 4    |     |     | 2    |    | 0.2 | 6 | 3     | Forest   | SW      | 4      | 2   |            |
| DR30 | 25  | 1.25 |     |     | 0.1  |    |     | 6 | 3     | Forest   | SW      | 4      | 2   |            |
| DR31 |     | 0.4  | 4   |     | 24   |    |     | 8 | 2     | Forest   | SW      | 2      | 2   |            |
| DR32 |     | 0.5  | 0.1 |     | 35   |    |     | 8 | 2     | Forest   | SW      | 2      | 2   |            |
| DR33 | 1.3 |      | 40  |     | 10   |    |     | 5 | 3     | Ecotone  | SW      | 2      |     |            |

| Plot | DTW |      |     |     |      |     |     |    | Class | VT          | Ecosite  | Forest | CC  | L<br>Layer |
|------|-----|------|-----|-----|------|-----|-----|----|-------|-------------|----------|--------|-----|------------|
|      | BZ  | DP   | HS  | PC  | PS   | SF  | SG  |    |       |             |          |        |     |            |
| DR34 |     | 20   | 15  |     | 10   |     |     | 6  | 3     | Ecotone     | SW       | 0      | 0.5 |            |
| DR35 |     |      |     |     |      |     |     | 4  | 1     | Shrub WL    | MX       | 0      | 0   |            |
| DR36 |     |      |     |     |      |     |     | 3  | 1     | Shrub WL    | Other    | 0      | 0   |            |
| DR37 |     |      | 0.1 |     | 0.2  |     | 97  | 3  | 1     | Shrub WL    | SW       | 0      | 0   |            |
| DR38 |     |      |     |     |      |     |     | 1  | 3     | Shrub WL    | SW       | 0      | 0   |            |
| DR39 |     |      |     |     |      |     |     | 5  | 4     | 1           | Shrub WL | Other  | 0   | 0          |
| DR40 |     |      |     |     |      |     |     | 3  | 1     | Shrub WL    | Other    | 0      | 0   |            |
| DR41 |     |      |     |     | 14   |     |     | 7  | 3     | Forest      | SW       | 1      | 1   |            |
| DR42 |     | 0.5  |     |     | 6    |     |     | 7  | 3     | Forest      | SW       | 2      | 3   |            |
| DR43 |     |      |     | 0.3 |      |     |     | 3  | 3     | Riparian    | SW       | 3      | 2   |            |
| DR44 |     |      |     |     |      |     |     | 1  | 3     | Riparian    | SW       | 2      | 0.1 |            |
| DR45 | 0.2 |      |     |     | 8    |     |     | 5  | 3     | Forest      | SW       | 5      | 3   |            |
| DR46 |     |      |     |     | 0.75 |     | 45  | 5  | 3     | Forest      | SW       | 4      | 1   |            |
| DR47 |     |      |     |     | 2    |     |     | 2  | 3     | Riparian    | MX       | 4      | 4   |            |
| DR48 |     |      | 2   |     |      |     |     | 2  | 3     | Riparian    | MX       | 4      | 4   |            |
| DR49 | 2.5 | 8.5  |     |     | 21   |     | 12  | 6  | 1     | Forest      | SW       | 3      | 0.5 |            |
| DR50 |     |      |     |     |      |     |     | 75 | 6     | 1           | Forest   | SW     | 5   | 0          |
| DR51 |     |      |     |     |      |     |     | 6  | 4     | Forest      | HW       | 5      | 4   |            |
| DR52 |     |      |     |     |      |     |     | 7  | 4     | Forest      | HW       | 4      | 6   |            |
| DR53 |     |      |     |     |      |     |     | 4  | 1     | Shrub WL    | Other    | 0      | 0   |            |
| DR54 |     |      |     |     |      |     |     | 4  | 1     | Shrub WL    | Other    | 0      | 0   |            |
| DR55 |     |      | 0.4 |     |      |     |     | 5  | 3     | Forest      | SW       | 4      | 0   |            |
| DR56 | 1.5 |      | 90  |     | 0.5  |     | 1.5 | 5  | 3     | Forest      | SW       | 3      | 0.5 |            |
| DR57 |     |      |     |     |      | 0.5 | 98  | 4  | 1     | Shrub WL    | SW       | 1      | 0   |            |
| DR58 |     |      |     |     |      |     | 96  | 4  | 1     | Shrub WL    | SW       | 0      | 0   |            |
| DR59 |     |      |     |     |      |     | 44  | 1  | 1     | Shrub WL    | Other    | 3      | 0   |            |
| DR60 |     |      |     |     |      |     |     | 1  | 3     | 1           | Shrub WL | Other  | 1   | 0          |
| DR61 |     |      |     |     |      |     |     | 2  | 3     | Forested WL | SW       | 5      | 0   |            |
| DR62 | 0.5 |      | 30  |     |      |     |     | 4  | 3     | Forested WL | SW       | 4      | 0   |            |
| DR63 |     |      |     |     |      |     | 1.2 | 1  | 1     | Riparian    | SW       | 1      | 0   |            |
| DR64 |     |      |     |     | 40   |     | 55  | 2  | 1     | Riparian    | SW       | 4      | 0   |            |
| DR65 |     | 10   |     |     | 44   |     |     | 6  | 3     | Forest      | SW       | 3      | 1   |            |
| DR66 |     | 0.25 | 5   |     | 2    |     |     | 6  | 3     | Forest      | SW       | 3      | 2   |            |
| DR67 |     |      |     |     |      |     |     | 3  | 3     | Shrub WL    | Other    | 0      | 0   |            |
| DR68 |     |      |     |     |      |     |     | 2  | 3     | Shrub WL    | Other    | 0      | 3   |            |
| DR69 |     |      |     |     |      |     |     | 2  | 2     | Shrub WL    | Other    | 0      | 3   |            |
| DR70 |     |      |     |     |      |     |     | 2  | 1     | Shrub WL    | Other    | 0      | 3   |            |
| DR71 |     |      | 28  |     |      |     | 7   | 2  | 3     | Riparian    | SW       | 3      | 0.1 |            |
| DR72 |     |      |     |     |      |     |     | 3  | 3     | Riparian    | SW       | 4      | 1.5 |            |
| DR73 |     |      | 3   |     |      |     |     | 1  | 3     | Riparian    | SW       | 4      | 0.5 |            |
| DR74 |     |      |     |     |      |     |     | 1  | 3     | Riparian    | SW       | 0      | 0   |            |
| DR75 |     | 10   | 16  |     | 8    |     |     | 4  | 3     | Forest      | SW       | 4      | 1   |            |
| DR76 |     |      |     | 0.5 | 95   |     |     | 4  | 3     | Forest      | SW       | 3      | 0.5 |            |
| DR77 |     |      |     |     |      |     |     | 6  | 4     | Forest      | MX       | 3      | 1   |            |
| DR78 |     |      |     |     | 5    |     |     | 8  | 4     | Forest      | MX       | 0      | 2   |            |
| DR79 |     |      | 6   |     |      |     |     | 1  | 3     | Forest      | SW       | 5      | 1   |            |
| DR80 |     |      | 30  |     |      |     |     | 1  | 3     | Forest      | SW       | 4      | 0   |            |
| G001 |     |      |     |     |      |     |     | 8  | 3     | Forest      | SW       | 2      | 2   |            |
| G002 |     |      |     |     |      |     |     | 8  | 3     | Forest      | SW       | 3      | 1   |            |
| G003 |     |      |     |     | 0.2  |     |     | 8  | 3     | Forest      | SW       | 5      | 2   |            |
| G004 |     |      |     |     | 0.1  |     |     | 8  | 3     | Forest      | SW       | 3      |     |            |

| Plot | DTW |      |    |     |     |    |     |   | Class | VT          | Ecosite | Forest | CC  | L<br>Layer |
|------|-----|------|----|-----|-----|----|-----|---|-------|-------------|---------|--------|-----|------------|
|      | BZ  | DP   | HS | PC  | PS  | SF | SG  |   |       |             |         |        |     |            |
| G005 |     |      |    |     |     |    |     | 7 | 3     | Forest      | MX      | 5      | 3   |            |
| G006 |     |      |    |     |     |    |     | 7 | 3     | Forest      | MX      | 4      | 3   |            |
| G007 |     |      |    |     |     |    |     | 6 | 3     | Forest      | MX      | 5      | 4   |            |
| G008 |     |      |    |     |     |    |     | 6 | 3     | Forest      | MX      | 5      | 5   |            |
| G009 |     |      |    |     |     |    | 45  | 4 | 3     | Forest      | MX      | 4      | 0.5 |            |
| G010 |     |      |    |     |     |    | 2   | 4 | 3     | Forest      | MX      | 3      | 1   |            |
| G011 |     |      |    |     |     |    | 2   | 1 | 3     | Riparian    | SW      | 5      | 3   |            |
| G012 | 3   |      |    |     |     |    | 2   | 1 | 3     | Riparian    | SW      | 4      | 0.5 |            |
| G013 |     |      |    |     |     |    |     | 8 | 3     | Forest      | MX      | 4      | 5   |            |
| G014 |     |      |    |     |     |    |     | 8 | 3     | Forest      | MX      | 4      | 2   |            |
| G015 |     |      |    |     |     |    |     | 7 | 3     | Forest      | SW      | 4      | 4   |            |
| G016 |     |      |    | 15  | 18  |    |     | 7 | 3     | Forest      | SW      | 4      | 0.5 |            |
| G017 |     | 2.5  |    |     | 3   |    |     | 8 | 2     | Forest      | MX      | 3      | 0.5 |            |
| G018 |     | 0.5  |    |     | 2   |    |     | 8 | 2     | Forest      | MX      | 3      | 3   |            |
| G019 |     |      |    | 0.5 | 2   |    |     | 8 | 2     | Forest      | SW      | 4      | 3   |            |
| G020 | 0.1 | 0.25 |    |     | 20  |    |     | 8 | 2     | Forest      | SW      | 4      | 0.5 |            |
| G021 |     |      |    |     |     |    |     | 8 | 3     | Forest      | SW      | 5      | 3   |            |
| G022 |     |      |    |     | 2   |    |     | 8 | 3     | Forest      | SW      | 4      | 4   |            |
| G023 |     |      |    |     |     |    |     | 6 | 2     | Forest      | MX      | 3      | 3   |            |
| G024 |     |      |    |     |     |    |     | 7 | 2     | Forest      | MX      | 3      | 1   |            |
| G025 |     |      |    |     |     |    |     | 5 | 2     | Forest      | SW      | 3      | 2   |            |
| G026 | 10  |      |    |     |     |    |     | 5 | 2     | Forest      | SW      | 4      | 0.5 |            |
| G027 |     |      |    |     |     |    | 0.1 | 3 | 1     | Forested WL | SW      | 4      | 0   |            |
| G028 | 0.5 |      |    |     | 55  |    | 3   | 3 | 1     | Forested WL | SW      | 5      | 0   |            |
| G029 |     |      |    |     |     |    | 50  | 1 | 1     | Forested WL | SW      | 3      | 0   |            |
| G030 | 10  |      | 2  |     |     |    | 80  | 1 | 1     | Forested WL | SW      | 2      | 0   |            |
| G031 |     |      |    |     |     | 93 |     | 4 | 1     | Fen         | SW      | 0      | 0   |            |
| G032 |     |      |    |     |     | 65 |     | 4 | 1     | Fen         | SW      | 0      | 0   |            |
| G033 |     |      |    |     |     | 93 | 3   | 2 | 1     | Fen         | SW      | 0      | 0   |            |
| G034 |     |      |    |     |     | 85 |     | 3 | 1     | Fen         | SW      | 0      | 0   |            |
| G035 |     | 1    |    |     | 0.3 |    |     | 8 | 3     | Forest      | SW      | 5      | 1   |            |
| G036 |     |      |    |     |     |    |     | 8 | 3     | Forest      | SW      | 4      | 2   |            |
| G037 |     |      |    |     |     |    | 1.5 | 3 | 1     | Fen         | Other   | 4      | 0   |            |
| G038 |     |      |    |     |     |    | 95  | 3 | 1     | Fen         | Other   | 0      | 0   |            |
| G039 |     |      |    |     |     |    |     | 1 | 1     | Fen         | Other   | 0      | 0   |            |
| G040 |     |      |    |     |     | 15 | 6   | 1 | 1     | Fen         | Other   | 0      | 0   |            |
| G041 |     |      |    |     |     |    | 45  | 1 | 1     | Fen         | Other   | 0      | 0   |            |
| G042 |     |      |    |     |     |    | 85  | 1 | 1     | Fen         | Other   | 0      | 0   |            |
| G043 |     |      |    |     | 0.5 |    | 97  | 4 | 1     | Ecotone     | SW      | 0      | 0   |            |
| G044 |     |      |    | 10  |     |    | 85  | 4 | 1     | Ecotone     | SW      | 0      | 0   |            |
| G045 |     | 4.5  |    |     |     |    |     | 6 | 1     | Forest      | SW      | 4      | 2   |            |
| G046 |     |      |    |     |     |    |     | 6 | 1     | Forest      | SW      | 4      | 3   |            |
| G047 |     | 0.5  |    |     |     |    | 4.5 | 5 | 2     | Fen         | Other   | 0      | 0   |            |
| G048 |     |      |    |     |     | 20 | 50  | 4 | 2     | Fen         | Other   | 0      | 0   |            |
| G049 |     |      |    |     |     |    |     | 2 | 2     | Fen         | Other   | 0      | 0   |            |
| G050 |     |      |    |     |     |    |     | 2 | 2     | Fen         | Other   | 0      | 0   |            |
| G051 |     |      |    |     |     |    | 6   | 2 | 1     | Fen         | Other   | 0      | 0   |            |
| G052 |     |      |    |     |     |    | 85  | 2 | 1     | Fen         | Other   | 0      | 0   |            |
| G053 |     |      |    |     |     |    | 90  | 2 | 1     | Fen         | Other   | 0      | 0   |            |
| G054 |     |      |    |     |     |    | 95  | 2 | 1     | Fen         | Other   | 0      | 0   |            |
| G055 | 0.3 |      |    |     | 89  |    |     | 7 | 1     | Forest      | SW      | 3      | 0.  |            |

| Plot | DTW  |     |     |      |     |    |     |       |    |          | L      |    |       |
|------|------|-----|-----|------|-----|----|-----|-------|----|----------|--------|----|-------|
|      | BZ   | DP  | HS  | PC   | PS  | SF | SG  | Class | VT | Ecosite  | Forest | CC | Layer |
| G056 | 3.5  |     | 1   |      | 3   |    |     | 7     | 1  | Forest   | SW     | 4  | 1     |
| G057 |      |     | 1.5 |      |     |    |     | 5     | 2  | Riparian | MX     | 4  | 4     |
| G058 |      |     |     |      |     |    | 100 | 5     | 2  | Riparian | MX     | 2  | 0     |
| G059 | 11   |     |     |      |     |    |     | 5     | 4  | Forest   | HW     | 3  | 4     |
| G060 |      |     |     |      |     |    | 95  | 5     | 4  | Forest   | HW     | 3  | 4     |
| G061 |      |     |     | 20   | 6   |    | 1   | 4     | 1  | Ecotone  | SW     | 3  | 1     |
| G062 |      |     |     |      |     |    | 60  | 4     | 1  | Ecotone  | SW     | 2  | 0     |
| G063 |      |     |     |      |     |    |     | 8     | 3  | Forest   | HW     | 4  | 5     |
| G064 |      |     |     |      |     |    |     | 8     | 3  | Forest   | HW     | 4  | 6     |
| G065 |      | 10  |     |      | 0.4 |    |     | 6     | 1  | Forest   | SW     | 5  | 0.1   |
| G066 |      | 5   |     | 0.25 | 65  |    |     | 6     | 1  | Forest   | SW     | 5  | 0.5   |
| G067 |      |     |     |      |     |    |     | 4     | 2  | Forest   | MX     | 5  | 3     |
| G068 | 0.1  | 3   |     |      | 25  |    |     | 5     | 2  | Forest   | MX     | 2  | 0.1   |
| G069 | 0.4  |     |     |      |     |    | 87  | 5     | 2  | Forest   | MX     | 3  | 0.5   |
| G070 |      |     |     |      |     |    | 85  | 5     | 2  | Forest   | MX     | 4  | 0.1   |
| G071 |      |     |     |      | 1.8 |    |     | 6     | 3  | Forest   | MX     | 1  | 2     |
| G072 | 1    |     |     | 1    | 1   |    |     | 6     | 3  | Forest   | MX     | 2  | 4     |
| G073 | 1.7  | 0.3 |     |      | 6   |    |     | 7     | 2  | Forest   | SW     | 5  | 0.5   |
| G074 | 6    |     | 1.5 |      | 20  |    |     | 6     | 2  | Forest   | SW     | 5  | 0.5   |
| G075 |      |     |     |      |     |    | 30  | 3     | 1  | Fen      | SW     | 0  | 0     |
| G076 |      |     |     |      |     |    | 70  | 3     | 1  | Fen      | SW     | 0  | 0     |
| G077 |      |     |     |      |     |    | 98  | 3     | 1  | Fen      | Other  | 0  | 0     |
| G078 |      |     |     |      |     |    | 80  | 3     | 1  | Fen      | Other  | 0  | 0     |
| G079 |      |     |     |      |     |    | 5   | 3     | 1  | Ecotone  | SW     | 0  | 0     |
| G080 |      |     |     |      |     |    | 1   | 2     | 1  | Ecotone  | SW     | 0  | 0     |
| G081 |      | 1   |     | 10   | 88  |    | 1   | 8     | 1  | Forest   | SW     | 3  | 0.5   |
| G082 | 0.75 | 1.5 | 0.5 | 3    | 4   |    |     | 8     | 1  | Forest   | SW     | 4  | 1     |
| G083 |      |     |     | 0.2  |     |    |     | 8     | 1  | Forest   | SW     | 5  | 1     |
| G084 | 15   |     |     |      |     |    |     | 8     | 1  | Forest   | SW     | 5  | 1     |
| G085 |      |     | 0.1 |      | 0.2 |    |     | 2     | 3  | Riparian | MX     | 3  | 5     |
| G086 |      |     |     |      |     |    | 25  | 2     | 3  | Riparian | MX     | 4  | 0.1   |
| G087 |      |     |     |      |     |    |     | 1     | 3  | Riparian | MX     | 4  | 0     |
| G088 |      |     |     |      |     |    |     | 1     | 3  | Riparian | MX     | 4  | 0     |
| G089 |      | 18  |     |      | 15  |    |     | 7     | 1  | Forest   | SW     | 3  | 0.5   |
| G090 | 5    | 6   |     |      | 8   |    |     | 7     | 1  | Forest   | SW     | 3  | 0.5   |
| G091 |      |     |     |      |     |    |     | 1     | 1  | Fen      | SW     | 0  | 2     |
| G092 |      |     |     |      |     |    |     | 3     | 1  | Fen      | SW     | 0  | 1     |
| G093 |      |     |     |      |     |    |     | 1     | 3  | Fen      | SW     | 0  | 3     |
| G094 |      |     |     |      |     |    | 50  | 3     | 1  | Fen      | SW     | 0  | 1     |
| G095 |      |     |     |      |     | 60 |     | 2     | 1  | Fen      | SW     | 0  | 1     |
| G096 |      |     |     |      |     |    |     | 3     | 3  | Fen      | MX     | 0  | 2     |
| G097 |      |     |     |      |     |    |     | 3     | 2  | Fen      | SW     | 0  | 7     |
| G098 |      |     |     |      |     |    | 20  | 1     | 3  | Fen      | SW     | 0  | 4     |
| G099 |      |     |     |      |     |    |     | 1     | 3  | Fen      | HW     | 0  | 6     |
| G100 |      |     |     |      |     |    | 15  | 4     | 2  | Fen      | MX     | 0  | 2     |
| G101 |      |     |     |      |     |    |     | 1     | 2  | Fen      | Other  | 0  | 3     |
| G102 |      |     |     |      |     |    |     | 3     | 1  | Fen      | Other  | 0  | 2     |
| G103 |      |     |     |      |     |    |     | 3     | 2  | Fen      | SW     | 0  | 3     |
| G104 |      |     |     |      |     |    |     | 4     | 2  | Fen      | Other  | 0  | 4     |
| G105 |      |     |     |      |     |    |     | 4     | 3  | Fen      | MX     | 0  | 3     |
| G106 |      |     |     |      |     |    |     | 5     | 1  | Fen      | SW     | 0  | 5     |

| Plot | DTW |    |    |    |    |    |     |       |    |         | L      |    |       |
|------|-----|----|----|----|----|----|-----|-------|----|---------|--------|----|-------|
|      | BZ  | DP | HS | PC | PS | SF | SG  | Class | VT | Ecosite | Forest | CC | Layer |
| G107 |     |    |    |    |    |    |     | 2     | 1  | Fen     | Other  | 0  | 3     |
| G108 |     |    |    |    |    |    | 90  | 2     | 1  | Fen     | Other  | 0  | 5     |
| G109 |     |    |    |    |    |    |     | 3     | 1  | Fen     | Other  | 0  | 0.5   |
| G110 |     |    |    |    |    |    | 70  | 4     | 1  | Fen     | SW     | 0  | 0.5   |
| G111 |     |    |    |    |    |    | 90  | 5     | 1  | Fen     | MX     | 0  | 0.5   |
| G112 |     |    |    |    |    |    | 15  | 4     | 1  | Fen     | Other  | 0  | 1     |
| G113 |     |    |    |    |    |    |     | 4     | 1  | Fen     | Other  | 0  | 3     |
| G114 |     |    |    |    |    |    |     | 1     | 1  | Fen     | Other  | 0  | 0.5   |
| G115 |     |    |    | 10 | 5  |    |     | 4     | 1  | Fen     | SW     | 0  | 2     |
| G116 |     |    |    |    |    |    |     | 5     | 1  | Fen     | SW     | 0  | 0.5   |
| G117 |     |    |    |    |    |    |     | 5     | 1  | Fen     | SW     | 0  | 0.5   |
| G118 |     |    |    |    |    |    |     | 5     | 1  | Fen     | SW     | 0  | 0.5   |
| G119 |     |    |    |    |    | 60 |     | 5     | 1  | Fen     | SW     | 0  | 1     |
| G120 |     |    |    |    |    | 90 |     | 4     | 1  | Fen     | SW     | 0  | 1     |
| G121 |     |    |    |    |    | 50 |     | 3     | 1  | Fen     | SW     | 0  | 0.5   |
| G122 |     |    |    |    |    |    |     | 4     | 2  | Fen     | SW     | 0  | 8     |
| G123 |     |    |    |    |    |    |     | 3     | 1  | Fen     | SW     | 0  | 1     |
| G124 |     |    |    |    |    |    |     | 3     | 1  | Fen     | SW     | 0  | 3     |
| G125 |     |    |    |    |    |    |     | 2     | 1  | Fen     | SW     | 0  | 1     |
| G126 |     |    |    |    |    |    |     | 1     | 1  | Fen     | SW     | 0  | 1     |
| G127 |     |    |    |    |    |    | 60  | 1     | 1  | Fen     | SW     | 0  | 0.1   |
| G128 |     |    |    |    |    |    |     | 1     | 1  | Fen     | MX     | 0  | 1     |
| G129 |     |    |    |    |    |    |     | 2     | 1  | Fen     | MX     | 0  | 1     |
| G130 |     |    |    |    |    |    | 40  | 3     | 1  | Fen     | MX     | 0  | 0.1   |
| G131 |     |    |    |    |    |    |     | 3     | 1  | Fen     | SW     | 0  | 0.1   |
| G132 |     |    |    |    |    |    |     | 4     | 1  | Fen     | SW     | 0  | 0.1   |
| G133 |     |    |    |    |    | 15 |     | 5     | 1  | Fen     | SW     | 0  | 0.1   |
| G134 |     |    |    |    |    | 5  |     | 4     | 1  | Fen     | SW     | 0  | 0.1   |
| G135 |     |    |    |    |    |    | 40  | 3     | 1  | Fen     | MX     | 0  | 0.1   |
| G136 |     |    |    |    |    |    | 90  | 4     | 1  | Ecotone | SW     | 0  | 0.1   |
| G137 |     |    |    |    |    |    | 25  | 4     | 1  | Fen     | HW     | 0  | 0.1   |
| G138 |     |    |    |    |    |    |     | 4     | 1  | Fen     | Other  | 0  | 2     |
| G139 |     |    |    |    |    |    |     | 5     | 1  | Fen     | Other  | 0  | 2     |
| G140 |     |    |    |    |    |    |     | 5     | 1  | Fen     | Other  | 0  | 5     |
| G141 |     |    |    | 15 |    |    |     | 4     | 1  | Fen     | Other  | 0  | 5     |
| G142 |     |    |    |    |    |    |     | 5     | 1  | Fen     | SW     | 0  | 5     |
| G143 |     |    |    |    |    |    |     | 5     | 1  | Fen     | SW     | 0  | 5     |
| G144 |     |    |    |    |    |    |     | 4     | 1  | Ecotone | HW     | 0  | 3     |
| G145 |     |    |    |    |    |    |     | 4     | 2  | Ecotone | MX     | 0  | 3     |
| G146 |     |    |    | 10 |    |    |     | 4     | 1  | Fen     | SW     | 0  | 2     |
| G147 |     |    |    |    |    |    | 50  | 2     | 1  | Fen     | SW     | 0  | 4     |
| G148 |     |    |    |    |    |    | 35  | 1     | 1  | Fen     | SW     | 0  | 4     |
| G149 |     |    |    |    |    |    |     | 2     | 1  | Fen     | SW     | 0  | 4     |
| G150 |     |    |    |    |    |    |     | 3     | 1  | Fen     | SW     | 0  | 3     |
| G151 |     |    |    |    |    | 65 |     | 4     | 1  | Fen     | SW     | 0  | 2     |
| G152 |     |    |    |    |    |    | 35  | 4     | 1  | Fen     | SW     | 0  | 3     |
| G153 |     |    |    |    |    | 15 |     | 5     | 1  | Fen     | SW     | 0  | 3     |
| G154 |     | 5  |    |    |    | 65 |     | 3     | 1  | Fen     | Other  | 0  | 5     |
| G155 |     |    |    | 5  |    | 45 |     | 3     | 1  | Fen     | SW     | 0  | 3     |
| G156 |     |    |    |    |    |    |     | 2     | 1  | Fen     | Other  | 0  | 3     |
| G157 |     |    |    |    |    |    | 100 | 1     | 3  | Fen     | SW     | 0  | 2     |

| Plot | DTW  |      |     |     |      |    |     |       |    | L           |        |    |       |   |
|------|------|------|-----|-----|------|----|-----|-------|----|-------------|--------|----|-------|---|
|      | BZ   | DP   | HS  | PC  | PS   | SF | SG  | Class | VT | Ecosite     | Forest | CC | Layer |   |
| G158 |      |      |     |     |      |    |     | 1     | 3  | Fen         | Other  | 0  | 4     |   |
| G159 |      |      |     |     |      |    |     | 1     | 2  | Fen         | HW     | 0  | 3     |   |
| G160 |      |      |     |     |      |    | 5   | 2     | 1  | Fen         | Other  | 0  | 2     |   |
| GL01 |      | 0.5  |     |     |      |    |     | 5     | 2  | Forest      | MX     | 3  | 2     |   |
| GL02 |      | 50   |     |     | 0.2  |    |     | 5     | 2  | Forest      | MX     | 4  | 0.1   |   |
| GL03 |      | 4    |     |     | 1    |    |     | 6     | 1  | Forest      | SW     | 4  | 0.5   |   |
| GL04 |      | 1    |     |     | 0.1  |    |     | 6     | 1  | Forest      | SW     | 4  | 1.5   |   |
| GL05 |      |      |     |     |      |    |     | 3     | 2  | Riparian    | MX     | 4  | 0     |   |
| GL06 | 0.25 |      |     |     |      |    |     | 3     | 2  | Riparian    | MX     | 3  | 1.5   |   |
| GL07 |      |      |     |     | 2    |    |     | 8     | 1  | Forest      | SW     | 4  | 0.5   |   |
| GL08 |      | 0.25 | 0.7 |     | 25   |    |     | 8     | 2  | Forest      | SW     | 4  | 0.5   |   |
| GL09 |      |      | 50  |     |      |    |     | 8     | 1  | Forest      | SW     | 4  | 0.5   |   |
| GL10 | 12   | 1.5  | 2   |     |      |    |     | 8     | 3  | Forest      | SW     | 3  | 1     |   |
| GL11 |      | 0.1  |     |     | 0.5  |    | 95  | 8     | 3  | Forested WL | SW     | 4  | 0.5   |   |
| GL12 |      |      |     |     | 20   |    | 70  | 8     | 3  | Forested WL | SW     | 3  | 0.1   |   |
| GL13 |      |      |     |     |      |    |     | 8     | 3  | Forest      | MX     | 4  | 1     |   |
| GL14 |      | 1.2  |     |     |      |    |     | 8     | 3  | Forest      | MX     | 4  | 5     |   |
| GL15 |      |      | 1.5 |     |      |    | 8   | 8     | 2  | Forest      | SW     | 4  | 0.5   |   |
| GL16 | 50   | 1    |     |     | 8    |    |     | 8     | 3  | Forest      | SW     | 3  | 0.5   |   |
| GL17 |      |      |     |     |      |    |     | 7     | 2  | Forest      | MX     | 5  | 3     |   |
| GL18 | 2.5  |      |     |     |      |    |     | 7     | 2  | Forest      | MX     | 4  | 1.5   |   |
| GL19 |      |      | 0.5 |     |      |    | 8   | 7     | 1  | Forest      | SW     | 4  | 1     |   |
| GL20 | 2.5  | 1    |     |     | 8    |    |     | 7     | 2  | Forest      | SW     | 3  | 2     |   |
| GL21 | 3    | 2.3  |     |     | 0.35 |    | 47  | 7     | 1  | Forest      | SW     | 4  | 0.1   |   |
| GL22 |      |      | 10  | 0.2 | 5    |    |     | 7     | 2  | Forest      | SW     | 4  | 0.5   |   |
| GL23 | 2    | 25   |     |     | 27   |    | 22  | 7     | 3  | Forest      | SW     | 5  | 0.1   |   |
| GL24 | 85   | 1.75 | 1.2 |     | 2.5  |    |     | 7     | 3  | Forest      | SW     | 4  | 0.1   |   |
| GL25 |      | 0.4  | 0.3 |     |      |    | 0.2 | 7     | 3  | Forest      | HW     | 4  | 0.1   |   |
| GL26 |      | 25   | 25  |     | 2.5  |    |     | 7     | 3  | Forest      | HW     | 4  | 1     |   |
| GL27 |      | 49   |     |     | 50   |    |     | 6     | 2  | Forest      | SW     | 5  | 0.1   |   |
| GL28 |      |      |     | 1.2 | 1.5  |    | 0.5 | 6     | 1  | Forest      | SW     | 3  | 0.1   |   |
| GL29 | 3.3  | 40   |     |     | 55   |    |     | 5     | 2  | Forest      | SW     | 2  | 0.1   |   |
| GL30 |      | 0.3  |     | 0.5 | 2    |    | 80  | 5     | 1  | Forest      | SW     | 4  | 0.1   |   |
| GL31 |      | 0.1  |     |     | 20   |    |     | 4     | 1  | Forested WL | SW     | 2  | 0     |   |
| GL32 |      |      |     |     |      |    | 85  | 4     | 1  | Forested WL | SW     | 2  | 0     |   |
| GL33 |      | 0.2  |     |     | 15   |    |     | 5     | 1  | Forested WL | SW     | 0  | 0     |   |
| GL34 |      |      |     |     | 0.75 |    | 90  | 5     | 1  | Forested WL | SW     | 1  | 0     |   |
| GL35 |      | 35   |     |     | 65   |    |     | 6     | 2  | Forest      | SW     | 2  | 0.1   |   |
| GL36 |      |      |     |     |      |    |     | 6     | 2  | Forest      | SW     | 4  | 2     |   |
| GL37 | 30   |      | 40  |     | 10   |    | 15  | 3     | 1  | Forested WL | SW     | 1  | 0.1   |   |
| GL38 |      |      |     |     | 6    |    | 99  | 3     | 1  | Forested WL | SW     | 3  | 0     |   |
| GL39 |      |      |     |     |      |    | 30  | 30    | 2  | 1           | Bog    | SW | 1     | 0 |
| GL40 |      |      |     | 0.1 |      |    |     | 98    | 2  | 1           | Bog    | SW | 0     | 0 |
| GL41 |      |      |     |     |      |    |     | 1     | 1  | Bog         | Other  | 0  | 0     |   |
| GL42 |      |      |     |     |      |    |     | 1     | 1  | Bog         | Other  | 0  | 0     |   |
| GL43 |      |      |     |     |      |    |     | 2     | 1  | Bog         | Other  | 0  | 0     |   |
| GL44 |      |      |     |     |      |    |     | 2     | 1  | Bog         | Other  | 0  | 0     |   |
| GL45 |      |      |     |     |      |    |     | 1     | 1  | Bog         | SW     | 0  | 0     |   |
| GL46 |      |      |     |     |      |    | 95  | 1     | 1  | Bog         | SW     | 0  | 0     |   |
| GL47 |      | 5    |     |     | 5    |    | 5   | 2     | 1  | Forested WL | SW     | 4  | 0     |   |
| GL48 |      |      |     |     |      |    | 92  | 2     | 1  | Forested WL | SW     | 3  | 0     |   |

| Plot | DTW |      |    |     |      |    |     |       |    |         | L      |    |       |
|------|-----|------|----|-----|------|----|-----|-------|----|---------|--------|----|-------|
|      | BZ  | DP   | HS | PC  | PS   | SF | SG  | Class | VT | Ecosite | Forest | CC | Layer |
| GL49 |     |      |    |     |      |    |     | 6     | 2  | Forest  | SW     | 5  | 3     |
| GL50 | 0.1 | 0.5  |    |     |      |    |     | 6     | 2  | Forest  | SW     | 5  | 3     |
| GL51 |     | 1    |    |     | 88   |    | 4   | 4     | 1  | Forest  | SW     | 2  | 0.1   |
| GL52 |     |      |    |     | 0.2  |    | 90  | 4     | 1  | Forest  | SW     | 0  | 0     |
| GL53 | 8   | 1    |    |     | 89   |    | 3   | 5     | 1  | Forest  | SW     | 3  | 0.1   |
| GL54 |     |      |    | 0.1 |      |    | 100 | 5     | 1  | Forest  | SW     | 4  | 0.1   |
| GL55 |     |      |    |     |      |    | 100 | 2     | 1  | Forest  | SW     | 3  | 0     |
| GL56 |     |      |    | 0.5 | 45   |    | 35  | 1     | 1  | Forest  | SW     | 3  | 0.1   |
| GL57 |     |      |    |     |      |    | 95  | 1     | 1  | Forest  | SW     | 0  | 0.1   |
| GL58 |     |      |    |     | 55   |    | 2   | 1     | 1  | Forest  | SW     | 3  | 0.1   |
| GL59 |     |      |    |     |      |    | 90  | 4     | 1  | Forest  | SW     | 3  | 0     |
| GL60 |     | 0.75 |    |     | 50   |    | 0.5 | 4     | 1  | Forest  | SW     | 1  | 0.1   |
| GL61 |     |      |    |     |      |    | 97  | 4     | 1  | Forest  | SW     | 1  | 0.1   |
| GL62 | 0.5 | 0.5  |    |     | 35   |    | 1   | 4     | 1  | Forest  | SW     | 1  | 0     |
| GL63 |     |      |    |     |      |    |     | 1     | 1  | Bog     | SW     | 0  | 0     |
| GL64 |     |      |    |     |      |    | 60  | 2     | 1  | Bog     | SW     | 0  | 0     |
| GL65 |     |      |    |     |      |    |     | 1     | 1  | Bog     | Other  | 0  | 0     |
| GL66 |     |      |    |     |      |    |     | 1     | 1  | Bog     | Other  | 0  | 0     |
| GL67 |     |      |    |     |      |    | 2   | 2     | 1  | Bog     | SW     | 0  | 0     |
| GL68 |     |      |    |     |      |    |     | 2     | 1  | Bog     | SW     | 0  | 0     |
| GL69 |     | 44   |    |     | 56   |    |     | 4     | 1  | Forest  | SW     | 3  | 0.1   |
| GL70 |     | 4    |    |     | 90   |    |     | 4     | 1  | Forest  | SW     | 0  | 0.1   |
| GL71 |     | 0.3  |    | 0.1 |      |    | 95  | 3     | 1  | Forest  | SW     | 0  | 0.1   |
| GL72 |     | 0.5  |    |     | 85   |    | 1   | 3     | 1  | Forest  | SW     | 0  | 0.1   |
| GL73 |     |      |    |     |      |    | 100 | 3     | 1  | Forest  | SW     | 2  | 0.1   |
| GL74 |     |      |    | 0.1 | 85   |    | 2   | 3     | 1  | Forest  | SW     | 3  | 0     |
| GL75 |     | 1    |    |     | 5    |    | 89  | 3     | 1  | Forest  | SW     | 3  | 0.5   |
| GL76 |     | 1    |    |     | 8    |    |     | 3     | 1  | Forest  | SW     | 4  | 0.5   |
| GL77 |     | 50   |    |     | 30   |    |     | 6     | 2  | Forest  | MX     | 2  | 0.5   |
| GL78 |     | 1.5  |    |     |      |    |     | 6     | 2  | Forest  | MX     | 1  | 1     |
| GL79 |     |      |    |     |      |    |     | 5     | 1  | Forest  | SW     | 0  | 1     |
| GL80 |     | 0.5  |    |     | 0.75 |    |     | 5     | 1  | Forest  | SW     | 0  | 1     |
| M01  |     |      |    | 10  |      |    | 55  | 2     | 1  | Bog     | SW     | 3  | 0.1   |
| M02  |     |      |    |     |      |    | 2   | 2     | 1  | Bog     | SW     | 0  | 0     |
| M03  |     |      |    |     |      |    | 93  | 3     | 1  | Bog     | SW     | 0  | 0     |
| M04  |     |      |    |     |      |    | 60  | 3     | 1  | Bog     | SW     | 0  | 0     |
| M05  |     |      |    |     |      |    | 20  | 2     | 1  | Bog     | SW     | 0  | 0     |
| M06  |     |      |    |     |      |    | 80  | 2     | 1  | Bog     | SW     | 0  | 0     |
| M07  |     |      |    |     |      |    | 4   | 1     | 1  | Bog     | SW     | 0  | 1     |
| M08  |     |      |    |     |      |    |     | 1     | 1  | Bog     | SW     | 0  | 4     |
| M09  |     | 3    |    |     | 1    |    | 14  | 3     | 1  | Bog     | SW     | 0  | 2     |
| M10  |     | 0.1  |    | 0.2 | 2    |    | 80  | 3     | 1  | Bog     | SW     | 1  | 0     |
| M11  |     | 9    |    |     |      |    |     | 4     | 1  | Bog     | SW     | 0  | 0     |
| M12  |     | 4    |    |     | 35   |    |     | 4     | 1  | Bog     | SW     | 0  | 1     |
| M13  |     |      |    |     |      |    | 95  | 2     | 1  | Bog     | SW     | 0  | 0     |
| M14  |     |      |    |     |      |    |     | 2     | 1  | Bog     | SW     | 0  | 0     |
| M15  |     |      |    |     |      |    | 25  | 1     | 1  | Bog     | SW     | 3  | 0     |
| M16  |     |      |    |     |      |    | 85  | 1     | 1  | Bog     | SW     | 2  | 0     |
| M17  |     |      |    |     |      | 40 |     | 2     | 1  | Bog     | SW     | 0  | 0     |
| M18  |     |      |    |     |      |    |     | 2     | 1  | Bog     | SW     | 0  | 0     |
| M19  |     |      |    |     |      | 35 |     | 1     | 1  | Bog     | SW     | 0  | 0     |

| Plot | DTW |     |     |      |      |    |    |       |    |          | L      |    |       |   |
|------|-----|-----|-----|------|------|----|----|-------|----|----------|--------|----|-------|---|
|      | BZ  | DP  | HS  | PC   | PS   | SF | SG | Class | VT | Ecosite  | Forest | CC | Layer |   |
| M20  |     |     |     |      |      |    |    | 1     | 1  | Bog      | SW     | 0  | 3     |   |
| M21  |     |     |     |      |      |    |    | 3     | 3  | 1        | Bog    | SW | 0     | 2 |
| M22  |     |     |     |      |      |    |    | 1     | 3  | 1        | Bog    | SW | 0     | 2 |
| M23  |     |     |     |      |      |    |    | 99    | 1  | 1        | Bog    | MX | 0     | 0 |
| M24  |     |     |     |      |      |    |    | 0.75  | 1  | 1        | Bog    | MX | 0     | 2 |
| M25  |     | 4   |     |      |      |    |    | 4     | 2  | Forest   | HW     | 0  | 2     |   |
| M26  |     |     |     |      |      |    |    | 4     | 2  | Forest   | HW     | 2  | 4     |   |
| M27  |     | 4   |     |      |      |    |    | 6     | 1  | Forest   | SW     | 3  | 2     |   |
| M28  |     | 6   |     |      |      |    |    | 6     | 1  | Forest   | SW     | 0  | 0.5   |   |
| M29  |     | 4   |     |      |      |    |    | 6     | 2  | Forest   | MX     | 3  | 5     |   |
| M30  |     | 6   |     | 0.5  | 8    |    |    | 6     | 2  | Forest   | MX     | 3  | 1     |   |
| M31  |     | 0.5 |     | 8    |      |    |    | 5     | 2  | Forest   | MX     | 4  | 3     |   |
| M32  |     |     |     | 7    | 0.2  |    |    | 5     | 2  | Forest   | MX     | 1  | 2     |   |
| M33  |     | 40  |     |      | 44   |    |    | 5     | 1  | Forest   | MX     | 1  | 0.1   |   |
| M34  |     | 5   |     |      | 80   |    |    | 5     | 1  | Forest   | MX     | 0  | 0     |   |
| M35  |     |     |     |      |      |    |    | 7     | 1  | Forest   | SW     | 5  | 1.5   |   |
| M36  |     | 3.5 |     |      | 0.25 |    |    | 7     | 1  | Forest   | SW     | 5  | 1.5   |   |
| M37  |     | 5   |     | 0.3  | 1    |    |    | 7     | 1  | Forest   | SW     | 3  | 1     |   |
| M38  |     |     |     | 3    |      |    |    | 7     | 1  | Forest   | SW     | 3  | 0.5   |   |
| M39  |     | 0.3 | 0.4 | 1.1  | 98   |    |    | 7     | 1  | Forest   | SW     | 4  | 0     |   |
| M40  |     |     |     | 0.5  | 50   |    |    | 7     | 1  | Forest   | SW     | 3  | 1     |   |
| M41  |     | 2   |     | 14   | 8    |    |    | 8     | 1  | Forest   | SW     | 3  | 1     |   |
| M42  |     |     |     | 0.25 |      |    |    | 8     | 1  | Forest   | SW     | 3  | 2     |   |
| M43  |     | 0.2 |     | 4    | 96   |    |    | 8     | 2  | Forest   | SW     | 3  | 0.5   |   |
| M44  |     |     |     |      | 10   |    |    | 8     | 2  | Forest   | SW     | 4  | 2     |   |
| M45  |     | 2   |     |      | 38   |    |    | 8     | 2  | Forest   | SW     | 5  | 0.5   |   |
| M46  |     |     |     | 1    |      |    |    | 8     | 2  | Forest   | SW     | 4  | 2     |   |
| M47  |     |     |     |      |      |    |    | 8     | 2  | Forest   | SW     | 5  | 1.5   |   |
| M48  |     |     |     | 0.2  | 2.5  |    |    | 8     | 2  | Forest   | SW     | 3  | 1.5   |   |
| M49  |     |     |     |      | 98   |    |    | 8     | 1  | Forest   | SW     | 3  | 0.1   |   |
| M50  |     | 0.3 |     |      | 25   |    |    | 8     | 1  | Forest   | SW     | 4  | 0.5   |   |
| M51  |     | 1   |     |      | 30   |    |    | 8     | 2  | Forest   | SW     | 4  | 0.1   |   |
| M52  |     |     |     |      | 0.25 |    |    | 8     | 2  | Forest   | SW     | 3  | 1     |   |
| M53  |     |     |     |      | 1    |    |    | 6     | 2  | Forest   | SW     | 4  | 0.5   |   |
| M54  | 1   |     |     |      | 0.25 |    |    | 7     | 2  | Forest   | SW     | 3  | 0.5   |   |
| M55  |     |     |     |      |      |    |    | 5     | 3  | Riparian | SW     | 3  | 0     |   |
| M56  |     |     |     |      |      |    |    | 5     | 3  | Riparian | SW     | 4  | 0.1   |   |
| M57  |     |     |     |      | 5    |    |    | 7     | 4  | Riparian | SW     | 4  | 0.1   |   |
| M58  |     |     |     |      |      |    |    | 6     | 4  | Riparian | SW     | 1  | 0     |   |
| M59  |     | 1.5 |     |      | 0.5  |    |    | 8     | 3  | Forest   | MX     | 4  | 1     |   |
| M60  | 1   |     |     |      |      |    |    | 8     | 3  | Forest   | MX     | 5  | 1.5   |   |
| M61  |     |     |     |      | 0.8  |    |    | 8     | 2  | Forest   | SW     | 4  | 2     |   |
| M62  |     |     |     |      |      |    |    | 8     | 2  | Forest   | SW     | 4  | 2     |   |
| M63  |     |     |     |      |      |    |    | 8     | 2  | Forest   | MX     | 5  | 2     |   |
| M64  |     |     |     |      | 7    |    |    | 8     | 2  | Forest   | MX     | 4  | 2     |   |
| M65  |     | 10  |     |      | 7    |    |    | 7     | 2  | Forest   | SW     | 3  | 2     |   |
| M66  |     | 4   |     |      | 3    |    |    | 7     | 2  | Forest   | SW     | 2  | 1     |   |
| M67  |     |     |     | 5    | 7    |    |    | 8     | 2  | Forest   | MX     | 4  | 1.5   |   |
| M68  |     |     |     |      | 8    |    |    | 8     | 2  | Forest   | MX     | 3  | 2     |   |
| M69  |     |     |     |      |      |    |    | 5     | 1  | Forest   | SW     | 4  | 4     |   |
| M70  |     |     |     |      |      |    |    | 5     | 1  | Forest   | SW     | 3  | 4     |   |

| Plot | DTW |      |     |      |      |      |     |       |    |             | L        |    |       |     |
|------|-----|------|-----|------|------|------|-----|-------|----|-------------|----------|----|-------|-----|
|      | BZ  | DP   | HS  | PC   | PS   | SF   | SG  | Class | VT | Ecosite     | Forest   | CC | Layer |     |
| M71  |     | 3    |     |      | 1    |      |     | 2     | 1  | Forest      | SW       | 0  | 2     |     |
| M72  |     | 1    |     |      | 25   |      |     | 2     | 1  | Forest      | SW       | 3  | 0.5   |     |
| M73  |     |      |     | 11   | 8    |      |     | 3     | 1  | Forest      | SW       | 1  | 2     |     |
| M74  |     | 1    |     | 50   | 25   |      |     | 3     | 1  | Forest      | SW       | 0  | 0     |     |
| M75  |     |      |     |      |      |      | 83  | 1     | 1  | Fen         | HW       | 4  | 0     |     |
| M76  |     |      |     | 10   | 0.5  |      | 20  | 1     | 1  | Fen         | HW       | 0  | 0     |     |
| M77  |     |      |     |      |      |      | 66  | 3     | 1  | Fen         | SW       | 5  | 0     |     |
| M78  |     |      |     | 3    |      |      | 60  | 3     | 1  | Fen         | SW       | 0  | 0     |     |
| M79  |     |      |     |      |      |      | 80  | 4     | 1  | Fen         | SW       | 0  | 0     |     |
| M80  |     | 1    |     |      | 0.2  |      | 85  | 4     | 1  | Fen         | SW       | 0  | 0     |     |
| M81  |     |      |     |      |      |      | 90  | 4     | 1  | Fen         | SW       | 0  | 0     |     |
| M82  |     |      |     | 2    |      |      | 40  | 4     | 1  | Fen         | SW       | 0  | 0     |     |
| M83  |     |      |     |      |      |      | 100 | 4     | 1  | Riparian    | MX       | 0  | 0     |     |
| M84  |     |      |     |      |      |      | 5   | 4     | 1  | Riparian    | MX       | 0  | 0     |     |
| M85  |     |      |     |      |      |      |     | 5     | 1  | Forest      | SW       | 1  | 2     |     |
| M86  |     | 8    |     |      | 4    |      |     | 5     | 1  | Forest      | SW       | 0  | 3     |     |
| M87  |     |      |     |      |      |      | 55  | 6     | 1  | Forested WL | SW       | 0  | 0.5   |     |
| M88  |     |      |     |      |      |      | 5   | 6     | 1  | Forested WL | SW       | 2  | 0     |     |
| M89  |     |      |     |      |      |      | 4   | 6     | 1  | Forested WL | SW       | 2  | 3     |     |
| M90  |     |      |     |      |      |      |     | 6     | 1  | Forested WL | SW       | 0  | 4     |     |
| N01  |     | 2.5  |     | 0.25 | 99   |      |     | 7     | 2  | Forest      | SW       | 0  | 0.1   |     |
| N02  |     | 10   |     |      | 78   |      |     | 7     | 2  | Forest      | SW       | 4  | 0.1   |     |
| N03  |     | 4    |     |      | 18.5 |      |     | 7     | 3  | Forest      | SW       | 3  | 0.5   |     |
| N04  |     | 0.3  |     | 0.2  |      |      |     | 6     | 3  | Forest      | SW       | 3  | 1     |     |
| N05  |     | 0.5  |     | 38   | 0.25 |      |     | 5     | 2  | Forest      | MX       | 4  | 1     |     |
| N06  |     | 0.25 |     | 2    | 0.1  |      |     | 4     | 2  | Forest      | MX       | 5  | 3     |     |
| N07  |     |      |     | 7.5  | 7.5  |      |     | 4     | 2  | Forest      | SW       | 0  | 2     |     |
| N08  |     |      |     | 50   | 1    |      |     | 2     | 2  | Riparian    | MX       | 0  | 1     |     |
| N09  |     |      |     | 17   | 11   |      | 0.8 | 1     | 1  | Riparian    | SW       | 0  | 1     |     |
| N10  |     | 2.5  |     |      | 20   |      | 20  | 1     | 1  | Riparian    | SW       | 1  | 0.5   |     |
| N11  |     | 20   |     |      | 14   |      |     | 2     | 2  | Riparian    | SW       | 4  | 0.5   |     |
| N12  |     | 3    | 10  |      | 5    | 60   |     | 3     | 2  | Forest      | SW       | 2  | 0.5   |     |
| N13  |     | 0.5  | 0.5 |      | 7    |      |     | 3     | 2  | Forest      | SW       | 5  | 0.5   |     |
| N14  |     |      |     | 96   |      |      |     | 3     | 4  | 2           | Riparian | SW | 1     | 0.1 |
| N15  |     |      |     | 70   |      | 0.25 |     | 4     | 2  | Riparian    | SW       | 0  | 0     |     |
| N16  |     | 0.5  |     |      | 2    |      |     | 1     | 2  | Forest      | SW       | 0  | 0.5   |     |
| N17  |     | 5    |     |      | 25   |      |     | 1     | 2  | Forest      | SW       | 3  | 1     |     |
| N18  |     | 2    |     |      | 0.75 |      |     | 5     | 2  | Forest      | SW       | 4  | 3     |     |
| N19  |     | 1    |     |      | 7    |      |     | 5     | 2  | Forest      | SW       | 5  | 2     |     |
| N20  |     |      |     | 0.25 |      |      |     | 8     | 2  | Forest      | MX       | 2  | 3     |     |
| N21  |     | 3.5  |     | 10   | 3    |      |     | 7     | 2  | Forest      | MX       | 4  | 0     |     |
| N22  |     |      |     | 5    | 1    |      | 80  | 4     | 1  | Forested WL | SW       | 4  | 0     |     |
| N23  |     | 5    |     |      | 30   |      |     | 5     | 1  | Forested WL | SW       | 4  | 0.1   |     |
| N24  |     |      |     |      |      |      | 90  | 1     | 1  | Forested WL | SW       | 0  | 0     |     |
| N25  |     | 1    |     | 6    |      | 35   |     | 1     | 1  | Forested WL | SW       | 3  | 0     |     |
| N26  |     |      |     |      |      |      | 99  | 3     | 1  | Forested WL | SW       | 3  | 0     |     |
| N27  |     |      |     | 0.3  | 15   | 20   |     | 3     | 1  | Forested WL | SW       | 3  | 0     |     |
| N28  |     |      |     |      | 1.2  | 94   |     | 1     | 1  | Fen         | SW       | 0  | 0     |     |
| N29  |     |      |     |      |      | 55   |     | 1     | 1  | Fen         | SW       | 0  | 0     |     |
| N30  |     |      |     |      |      | 60   | 35  | 1     | 1  | Fen         | SW       | 0  | 0     |     |
| N31  |     |      |     |      |      | 85   | 3   | 1     | 1  | Fen         | SW       | 0  | 0     |     |

| Plot | DTW |      |    |     |     |    |     |       |    |             | L      |    |       |
|------|-----|------|----|-----|-----|----|-----|-------|----|-------------|--------|----|-------|
|      | BZ  | DP   | HS | PC  | PS  | SF | SG  | Class | VT | Ecosite     | Forest | CC | Layer |
| N32  |     | 9    |    |     | 3   |    |     | 6     | 1  | Forest      | SW     | 3  | 1.5   |
| N33  |     | 30   | 20 | 1.5 | 6   |    |     | 7     | 1  | Forest      | SW     | 4  | 0.5   |
| N34  |     |      |    |     | 2   | 78 | 3   | 1     | 1  | Fen         | SW     | 0  | 0     |
| N35  |     |      |    |     |     | 90 |     | 1     | 1  | Fen         | SW     | 0  | 0     |
| N36  |     |      |    | 0.3 |     |    | 98  | 1     | 1  | Fen         | Other  | 0  | 0     |
| N37  |     |      |    |     |     |    | 70  | 1     | 1  | Fen         | Other  | 0  | 0     |
| N38  |     | 0.75 |    |     | 0.6 |    |     | 6     | 1  | Forest      | MX     | 4  | 4     |
| N39  |     | 35   |    |     | 20  |    |     | 6     | 1  | Forest      | MX     | 0  | 0.5   |
| N40  |     |      |    | 0.3 | 0.5 |    |     | 6     | 2  | Forest      | MX     | 4  | 0.5   |
| N41  |     | 0.3  |    |     | 5   |    |     | 6     | 2  | Forest      | MX     | 3  | 2     |
| N42  |     | 11   |    |     | 9.5 |    |     | 6     | 3  | Forest      | SW     | 4  | 0.1   |
| N43  |     |      |    |     | 1   |    |     | 6     | 3  | Forest      | SW     | 3  | 0.5   |
| N44  |     | 3    |    |     | 4   |    |     | 7     | 2  | Forest      | SW     | 2  | 0.5   |
| N45  |     | 0.5  |    |     | 60  |    |     | 8     | 2  | Forest      | SW     | 2  | 1     |
| N46  |     | 4    |    |     | 2.5 |    |     | 8     | 2  | Forest      | SW     | 1  | 0.1   |
| N47  |     | 2    |    | 3   | 7   |    |     | 8     | 2  | Forest      | SW     | 0  | 1     |
| N48  |     | 2    |    | 12  | 0.2 |    |     | 7     | 2  | Forest      | SW     | 4  | 3     |
| N49  |     | 9    |    |     |     |    |     | 7     | 2  | Forest      | SW     | 4  | 1     |
| N50  |     | 6    |    |     |     |    |     | 7     | 2  | Forest      | SW     | 4  | 1     |
| N51  |     | 6.5  |    |     | 0.5 |    |     | 7     | 2  | Forest      | SW     | 3  | 2     |
| N52  |     | 1.2  |    |     |     |    |     | 7     | 1  | Forest      | SW     | 0  | 3     |
| N53  |     | 7    |    |     | 11  |    |     | 7     | 1  | Forest      | SW     | 0  | 1     |
| N54  |     |      |    | 12  |     |    | 21  | 1     | 1  | Fen         | SW     | 0  | 0     |
| N55  |     |      |    |     |     |    | 100 | 1     | 1  | Fen         | SW     | 0  | 0     |
| N56  |     |      |    | 3   |     |    | 87  | 5     | 1  | Fen         | SW     | 0  | 0     |
| N57  |     |      |    |     | 3   |    | 80  | 6     | 1  | Fen         | SW     | 4  | 0     |
| N58  |     |      |    | 3   |     |    | 90  | 1     | 1  | Fen         | SW     | 0  | 0     |
| N59  |     |      |    | 4   |     |    | 95  | 1     | 1  | Fen         | SW     | 0  | 0     |
| N60  |     |      |    |     |     |    | 93  | 1     | 1  | Fen         | SW     | 0  | 0     |
| N61  |     |      |    |     | 5   |    | 95  | 1     | 1  | Fen         | SW     | 0  | 0     |
| N62  |     |      |    | 38  |     |    | 25  | 1     | 1  | Fen         | SW     | 1  | 0     |
| N63  |     |      |    | 2   |     |    | 80  | 1     | 1  | Fen         | SW     | 2  | 0     |
| N64  |     | 15   |    |     | 3   |    |     | 7     | 3  | Forest      | SW     | 4  | 0.5   |
| N65  |     |      |    |     | 0.3 |    | 19  | 3     | 3  | Forested WL | SW     | 4  | 0.5   |
| N66  |     |      |    |     |     |    |     | 3     | 3  | Forested WL | SW     | 3  | 0     |
| N67  |     |      |    |     |     |    | 78  | 3     | 1  | Forested WL | SW     | 0  | 0     |
| N68  |     |      |    |     | 60  |    | 99  | 3     | 1  | Forested WL | SW     | 1  | 0     |
| N69  |     | 7    |    |     | 93  |    |     | 4     | 2  | Forest      | SW     | 3  | 0.5   |
| N70  |     | 7    |    |     |     |    |     | 4     | 2  | Forest      | SW     | 3  | 1     |
| N71  |     | 20   |    |     | 50  |    | 6   | 6     | 2  | Forest      | SW     | 0  | 0.5   |
| N72  |     | 2    | 20 |     | 70  |    |     | 6     | 2  | Forest      | SW     | 2  | 0.5   |
| N73  |     | 10   |    |     | 90  |    |     | 8     | 1  | Forest      | SW     | 3  | 0.1   |
| N74  |     | 20   |    | 0.1 | 18  |    |     | 8     | 1  | Forest      | SW     | 3  | 1     |
| N75  |     | 17   |    |     | 88  |    |     | 7     | 1  | Forest      | SW     | 1  | 0.1   |
| N76  |     | 0.2  |    |     | 98  |    |     | 7     | 1  | Forest      | SW     | 3  | 0.5   |
| N77  |     | 4    |    |     | 7   |    |     | 5     | 2  | Forest      | SW     | 3  | 1     |
| N78  |     | 0.3  |    |     |     |    |     | 6     | 2  | Forest      | SW     | 5  | 3     |
| N79  |     |      |    |     |     |    | 70  | 1     | 1  | Riparian    | MX     | 0  | 0     |
| N80  |     |      |    |     |     |    | 5   | 2     | 1  | Riparian    | MX     | 0  | 0     |
| S01  |     | 1    |    | 9   | 8   |    |     | 6     | 3  | Forest      | HW     | 1  | 2     |
| S02  |     | 4    |    |     | 1   |    |     | 6     | 3  | Forest      | HW     | 5  | 4     |

| Plot | DTW  |      |     |      |      |    |     |       |    |            | L      |    |       |
|------|------|------|-----|------|------|----|-----|-------|----|------------|--------|----|-------|
|      | BZ   | DP   | HS  | PC   | PS   | SF | SG  | Class | VT | Ecosite    | Forest | CC | Layer |
| S03  |      |      |     |      | 8    |    |     | 7     | 3  | Forest     | MX     | 5  | 1     |
| S04  |      | 5    |     | 4    | 70   |    |     | 7     | 3  | Forest     | MX     | 2  | 0.5   |
| S05  |      | 40   |     |      | 50   |    |     | 5     | 2  | Forest     | SW     | 4  | 0.5   |
| S06  |      |      |     |      |      |    |     | 5     | 2  | Forest     | SW     | 4  | 3     |
| S07  |      |      |     |      |      |    | 0.4 | 1     | 1  | Shrub WL   | HW     | 2  | 0.1   |
| S08  |      |      |     |      |      |    |     | 1     | 1  | Shrub WL   | HW     | 3  | 6     |
| S09  |      |      |     |      |      |    |     | 1     | 1  | Shrub WL   | Other  | 0  | 0     |
| S10  |      |      |     |      |      |    |     | 1     | 1  | Shrub WL   | Other  | 0  | 0     |
| S11  |      |      |     |      |      |    |     | 1     | 1  | Marsh      | Other  | 0  | 0     |
| S12  |      |      |     |      |      |    |     | 1     | 1  | Marsh      | Other  | 0  | 0     |
| S13  |      |      |     |      |      |    |     | 5     | 2  | 1 Shrub WL | HW     | 2  | 0     |
| S14  |      |      |     |      |      |    |     | 2     | 1  | Shrub WL   | HW     | 1  | 0     |
| S15  | 3    |      | 0.8 |      | 6    |    |     | 2     | 1  | Forest     | SW     | 5  | 3     |
| S16  | 1    |      | 1   |      |      |    |     | 2     | 1  | Forest     | SW     | 5  | 0.5   |
| S17  |      | 0.5  |     |      |      |    |     | 8     | 3  | Forest     | MX     | 4  | 3     |
| S18  |      | 0.1  |     |      |      |    |     | 8     | 3  | Forest     | MX     | 5  | 4     |
| S19  |      |      |     |      |      |    |     | 8     | 3  | Forest     | HW     | 4  | 3     |
| S20  |      |      |     |      |      |    |     | 8     | 3  | Forest     | HW     | 5  | 13    |
| S21  | 4    | 5    |     |      | 4    |    |     | 8     | 4  | Forest     | HW     | 3  | 3     |
| S22  |      |      |     |      |      |    |     | 8     | 4  | Forest     | HW     | 5  | 4     |
| S23  | 2    | 0.7  |     |      | 0.6  |    |     | 8     | 3  | Forest     | HW     | 3  | 4     |
| S24  |      |      |     |      |      |    |     | 8     | 3  | Forest     | HW     | 4  | 4     |
| S25  |      |      |     | 17   | 18   |    |     | 8     | 3  | Forest     | MX     | 4  | 5     |
| S26  |      |      |     | 0.5  |      |    |     | 8     | 3  | Forest     | MX     | 5  | 4     |
| S27  |      |      |     |      |      |    |     | 8     | 4  | Forest     | SW     | 5  | 3     |
| S28  | 0.75 |      |     |      |      |    |     | 7     | 4  | Forest     | SW     | 5  | 4     |
| S29  |      | 0.6  | 4   | 2    |      |    |     | 3     | 3  | Forest     | SW     | 3  | 2     |
| S30  | 0.5  |      |     | 7    |      |    | 20  | 3     | 2  | Forest     | SW     | 5  | 1     |
| S31  | 30   | 0.2  |     |      | 27   |    |     | 2     | 1  | Forest     | SW     | 4  | 1     |
| S32  |      |      |     | 0.75 | 0.75 |    |     | 3     | 1  | Forest     | SW     | 4  | 1     |
| S33  |      | 6    |     |      | 44   |    |     | 6     | 3  | Forest     | SW     | 3  | 2     |
| S34  |      | 3    |     | 15   | 10   |    |     | 6     | 3  | Forest     | SW     | 4  | 0.5   |
| S35  |      | 0.4  | 2   |      | 24   |    |     | 7     | 3  | Forest     | SW     | 5  | 5     |
| S36  |      | 0.25 | 1.5 |      | 60   |    |     | 7     | 3  | Forest     | SW     | 3  | 1     |
| S37  |      |      |     |      |      |    |     | 1     | 1  | Bog        | Other  | 0  | 0     |
| S38  |      |      |     |      |      |    |     | 1     | 1  | Bog        | Other  | 0  | 0     |
| S39  |      |      | 2   |      |      |    |     | 2     | 1  | Ecotone    | SW     | 3  | 0     |
| S40  |      |      |     |      | 35   |    | 10  | 2     | 1  | Ecotone    | SW     | 0  | 0     |
| S41  |      |      |     |      |      |    | 0.5 | 2     | 2  | Ecotone    | SW     | 5  | 0.5   |
| S42  |      |      | 2   |      | 35   |    |     | 3     | 3  | Ecotone    | SW     | 5  | 0.5   |
| S43  |      | 22   |     |      | 30   |    |     | 5     | 3  | Forest     | SW     | 2  | 0.75  |
| S44  |      | 1    | 35  |      | 55   |    |     | 5     | 3  | Forest     | SW     | 2  | 0.5   |
| S45  |      |      |     |      |      |    |     | 8     | 4  | Forest     | HW     | 4  | 4     |
| S46  |      |      |     |      |      |    |     | 8     | 4  | Forest     | HW     | 4  | 4     |
| S47  |      |      |     |      |      |    |     | 8     | 4  | Forest     | MX     | 4  | 1     |
| S48  |      | 0.2  |     |      | 0.4  |    |     | 8     | 4  | Forest     | MX     | 3  | 4     |
| S49  |      |      |     |      |      |    |     | 8     | 4  | Forest     | SW     | 3  | 2     |
| S50  |      |      |     | 0.5  | 0.75 |    |     | 8     | 4  | Forest     | SW     | 3  | 1     |
| S51  |      |      |     |      |      |    |     | 8     | 4  | Forest     | MX     | 3  | 2     |
| S52  |      |      | 2   |      |      |    |     | 7     | 4  | Forest     | MX     | 5  | 1     |
| S53  |      |      |     |      | 5    |    |     | 5     | 3  | Riparian   | MX     | 1  | 1     |

| Plot | DTW |      |    |     |      |    |     |   | Class | VT       | Ecosite | Forest | CC  | L<br>Layer |
|------|-----|------|----|-----|------|----|-----|---|-------|----------|---------|--------|-----|------------|
|      | BZ  | DP   | HS | PC  | PS   | SF | SG  |   |       |          |         |        |     |            |
| S54  |     |      |    |     |      |    |     | 4 | 3     | Riparian | MX      | 5      | 3   |            |
| S55  |     |      |    |     |      |    |     | 3 | 3     | Riparian | MX      | 3      | 0   |            |
| S56  |     |      |    |     |      |    |     | 3 | 3     | Riparian | MX      | 3      | 0.1 |            |
| S57  |     | 2    |    |     | 6    |    |     | 6 | 3     | Forest   | SW      | 2      | 2   |            |
| S58  |     | 0.5  |    | 1   | 30   |    |     | 6 | 3     | Forest   | SW      | 1      | 1   |            |
| S59  |     |      |    |     |      |    |     | 4 | 3     | Forest   | SW      | 3      | 0.5 |            |
| S60  |     |      |    |     |      |    |     | 4 | 3     | Forest   | SW      | 5      | 1   |            |
| S61  |     |      |    |     | 0.3  |    |     | 5 | 3     | Forest   | SW      | 4      | 2   |            |
| S62  |     | 0.5  |    |     | 0.5  |    |     | 5 | 3     | Forest   | SW      | 4      | 1   |            |
| S63  |     |      |    | 7.5 | 60   |    |     | 5 | 3     | Forest   | MX      | 5      | 0.5 |            |
| S64  |     |      |    |     |      |    |     | 4 | 3     | Forest   | MX      | 3      | 2   |            |
| S65  |     |      |    | 35  |      |    |     | 4 | 3     | Ecotone  | MX      | 4      | 0.5 |            |
| S66  |     |      |    | 1   | 0.1  |    | 0.5 | 4 | 2     | Ecotone  | MX      | 4      | 3   |            |
| S67  |     |      |    |     |      | 90 |     | 1 | 1     | Marsh    | SW      | 0      | 0   |            |
| S68  |     |      |    |     |      |    |     | 1 | 1     | Marsh    | SW      | 1      | 0   |            |
| S69  | 3   |      |    |     | 3    |    |     | 3 | 2     | Ecotone  | MX      | 4      | 1   |            |
| S70  |     | 0.25 |    |     | 2    |    |     | 3 | 1     | Ecotone  | MX      | 5      | 0.5 |            |
| S71  |     |      |    | 10  | 7    |    |     | 5 | 3     | Forest   | MX      | 5      | 2   |            |
| S72  |     | 0.25 |    |     | 0.25 |    |     | 5 | 3     | Forest   | MX      | 4      | 1   |            |
| S73  |     |      |    | 18  | 3    |    |     | 7 | 3     | Forest   | HW      | 4      | 2   |            |
| S74  |     |      |    |     |      |    | 75  | 7 | 2     | Forest   | HW      | 4      | 0   |            |
| S75  |     |      |    | 25  | 25   |    |     | 6 | 2     | Forest   | MX      | 5      | 1.5 |            |
| S76  |     |      |    |     |      |    |     | 6 | 2     | Forest   | MX      | 4      | 2   |            |
| S77  | 0.5 |      |    |     | 1    |    |     | 4 | 2     | Ecotone  | MX      | 3      | 0.5 |            |
| S78  |     |      |    |     |      |    |     | 4 | 2     | Ecotone  | MX      | 3      | 1   |            |
| S79  |     |      |    | 18  | 2    |    |     | 4 | 3     | Ecotone  | MX      | 3      | 1   |            |
| S80  |     |      |    |     |      |    |     | 3 | 3     | Ecotone  | MX      | 5      | 0.5 |            |
| S81  |     |      |    |     |      |    |     | 2 | 1     | Marsh    | SW      | 0      | 0   |            |
| S82  |     |      |    |     |      |    |     | 2 | 1     | Marsh    | SW      | 0      | 0   |            |
| S83  |     |      |    |     | 10   |    |     | 4 | 3     | Ecotone  | MX      | 3      | 0.5 |            |
| S84  |     |      |    |     | 12   |    |     | 4 | 3     | Ecotone  | MX      | 5      | 0.5 |            |
| S85  |     | 1.2  |    |     | 20   |    |     | 8 | 3     | Forest   | HW      | 2      | 0.1 |            |
| S86  |     |      |    |     |      |    |     | 8 | 3     | Forest   | HW      | 5      | 3   |            |
| S87  |     |      |    | 2   |      |    |     | 7 | 4     | Forest   | HW      | 4      | 0.5 |            |
| S88  |     |      |    |     |      |    |     | 7 | 4     | Forest   | HW      | 4      | 4   |            |
| S89  | 2   |      |    |     |      |    |     | 6 | 4     | Forest   | HW      | 3      | 3   |            |
| S90  |     | 0.1  |    |     | 0.5  |    |     | 6 | 4     | Forest   | HW      | 3      | 3   |            |
| SV01 |     | 5    |    | 20  | 40   |    |     | 5 | 2     | Forest   | MX      | 2      | 0.1 |            |
| SV02 | 1.5 | 5    |    |     | 18   |    |     | 5 | 2     | Forest   | MX      | 2      | 1.5 |            |
| SV03 | 2   |      |    |     | 40   |    | 30  | 4 | 1     | Forest   | SW      | 1      | 0.1 |            |
| SV04 |     | 0.75 |    |     |      |    | 90  | 4 | 1     | Forest   | SW      | 4      | 0.1 |            |
| SV05 |     |      | 40 |     | 20   |    | 40  | 3 | 1     | Forest   | SW      | 4      | 0   |            |
| SV06 |     |      |    | 0.1 |      |    | 85  | 3 | 1     | Forest   | SW      | 4      | 0   |            |
| SV07 |     | 1    |    |     |      |    |     | 3 | 2     | Shrub WL | SW      | 0      | 5   |            |
| SV08 |     |      |    |     |      |    |     | 3 | 2     | Shrub WL | SW      | 0      | 5   |            |
| SV09 |     |      |    |     |      |    |     | 4 | 2     | Shrub WL | Other   | 0      | 2   |            |
| SV10 |     |      |    |     |      |    |     | 4 | 2     | Shrub WL | Other   | 0      | 1.5 |            |
| SV11 |     |      |    |     |      |    | 20  | 5 | 1     | Shrub WL | MX      | 5      | 3   |            |
| SV12 |     |      |    |     |      |    | 5   | 5 | 1     | Shrub WL | MX      | 2      | 1   |            |
| SV13 |     |      |    |     |      |    | 100 | 3 | 1     | Shrub WL | Other   | 0      | 0.1 |            |
| SV14 |     |      |    |     |      |    | 25  | 3 | 1     | Shrub WL | Other   | 0      | 0.1 |            |

| Plot | DTW |    |    |    |     |     |    |       |    |             | L      |    |       |
|------|-----|----|----|----|-----|-----|----|-------|----|-------------|--------|----|-------|
|      | BZ  | DP | HS | PC | PS  | SF  | SG | Class | VT | Ecosite     | Forest | CC | Layer |
| SV15 |     |    |    |    |     |     |    | 1     | 1  | Shrub WL    | Other  | 0  | 0     |
| SV16 |     |    |    |    |     |     | 85 | 1     | 1  | Shrub WL    | Other  | 0  | 0     |
| SV17 |     |    |    |    |     |     |    | 2     | 1  | Shrub WL    | Other  | 0  | 0     |
| SV18 |     |    |    |    |     |     | 2  | 2     | 1  | Shrub WL    | SW     | 0  | 0     |
| SV19 |     |    |    | 8  |     |     |    | 3     | 3  | Shrub WL    | HW     | 4  | 1     |
| SV20 |     |    |    |    |     |     |    | 3     | 2  | Shrub WL    | HW     | 5  | 0.1   |
| SV21 |     |    |    | 6  |     |     |    | 5     | 2  | Forest      | HW     | 4  | 1     |
| SV22 |     |    |    | 12 |     |     | 2  | 5     | 1  | Forest      | HW     | 4  | 0.1   |
| SV23 |     |    |    |    |     |     |    | 5     | 2  | Meadow      | Other  | 0  | 4     |
| SV24 |     |    |    |    |     |     |    | 5     | 2  | Meadow      | Other  | 0  | 3     |
| SV25 |     |    |    |    |     |     |    | 6     | 2  | Meadow      | SW     | 0  | 2     |
| SV26 |     |    |    |    |     |     |    | 6     | 2  | Meadow      | SW     | 0  | 3.5   |
| SV27 |     |    |    |    |     |     | 94 | 6     | 1  | Forest      | MX     | 5  | 0.1   |
| SV28 |     |    |    | 15 |     |     |    | 6     | 1  | Forest      | MX     | 5  | 0.5   |
| SV29 |     |    |    |    |     |     |    | 6     | 2  | Shrub WL    | HW     | 3  | 1     |
| SV30 |     |    |    |    |     |     |    | 6     | 2  | Shrub WL    | HW     | 4  | 0.5   |
| SV31 |     |    |    |    |     |     | 4  | 2     | 1  | Bog         | SW     | 0  | 0     |
| SV32 |     |    |    |    |     |     |    | 2     | 1  | Bog         | SW     | 0  | 0     |
| SV33 |     |    |    |    |     | 6   |    | 1     | 1  | Bog         | Other  | 0  | 0     |
| SV34 |     |    |    |    |     | 100 |    | 1     | 1  | Bog         | Other  | 0  | 0     |
| SV35 |     |    |    |    |     |     |    | 7     | 2  | Meadow      | SW     | 0  | 0.5   |
| SV36 |     |    |    |    |     |     |    | 7     | 2  | Meadow      | SW     | 0  | 0.1   |
| SV37 |     |    |    |    |     |     |    | 7     | 1  | Meadow      | HW     | 0  | 5     |
| SV38 |     |    |    |    |     |     |    | 7     | 1  | Meadow      | HW     | 0  | 5     |
| SV39 |     |    |    |    |     |     |    | 7     | 1  | Meadow      | SW     | 0  | 4     |
| SV40 |     |    |    |    |     |     |    | 7     | 1  | Meadow      | SW     | 0  | 5     |
| SV41 |     |    |    |    |     |     |    | 7     | 3  | Forest      | SW     | 5  | 0.5   |
| SV42 |     |    |    |    |     |     |    | 7     | 3  | Forest      | SW     | 3  | 1     |
| SV43 |     |    |    |    |     |     |    | 7     | 1  | Forest      | SW     | 1  | 1     |
| SV44 |     |    |    | 35 |     |     |    | 7     | 1  | Forest      | SW     | 2  | 0.5   |
| SV45 |     |    |    |    |     |     |    | 6     | 2  | Meadow      | Other  | 0  | 1     |
| SV46 |     |    |    |    |     |     |    | 6     | 2  | Meadow      | Other  | 0  | 4     |
| SV47 |     | 3  |    | 19 |     |     |    | 6     | 1  | Meadow      | SW     | 2  | 1     |
| SV48 |     |    |    | 60 |     |     |    | 6     | 1  | Meadow      | SW     | 2  | 0.5   |
| SV49 |     |    |    |    |     |     |    | 2     | 1  | Forested WL | SW     | 0  | 0     |
| SV50 |     |    |    |    |     |     | 3  | 2     | 1  | Forested WL | SW     | 0  | 0     |
| SV51 |     |    |    |    |     |     |    | 4     | 1  | Forested WL | SW     | 4  | 0     |
| SV52 |     |    |    |    |     |     | 85 | 4     | 1  | Forested WL | SW     | 2  | 0     |
| SV53 |     |    |    |    |     |     |    | 5     | 1  | Forested WL | SW     | 2  | 0.1   |
| SV54 |     |    |    |    |     |     | 95 | 5     | 1  | Forested WL | SW     | 2  | 0.1   |
| SV55 |     |    |    |    |     | 55  |    | 4     | 1  | Bog         | SW     | 0  | 0     |
| SV56 |     |    |    |    |     | 90  |    | 4     | 1  | Bog         | SW     | 0  | 0     |
| SV57 |     |    |    |    |     | 7   | 6  | 4     | 1  | Bog         | SW     | 1  | 0     |
| SV58 |     |    |    |    | 0.5 |     | 5  | 4     | 1  | Bog         | SW     | 4  | 0     |
| SV59 |     |    |    |    |     | 90  |    | 3     | 1  | Bog         | Other  | 0  | 0     |
| SV60 |     |    |    |    |     | 55  |    | 3     | 1  | Bog         | Other  | 0  | 0     |
| SV61 |     |    |    |    |     | 76  |    | 2     | 1  | Bog         | Other  | 0  | 0     |
| SV62 |     |    |    |    |     | 75  |    | 2     | 1  | Bog         | Other  | 0  | 0     |
| SV63 |     |    |    |    |     | 95  |    | 2     | 1  | Bog         | Other  | 0  | 0     |
| SV64 |     |    |    |    |     | 50  |    | 2     | 1  | Bog         | Other  | 0  | 0     |
| SV65 |     |    |    |    |     | 99  |    | 1     | 1  | Bog         | Other  | 0  | 0     |

| Plot | DTW  |      |    |    |     |    |    |       |    |             | L      |    |       |
|------|------|------|----|----|-----|----|----|-------|----|-------------|--------|----|-------|
|      | BZ   | DP   | HS | PC | PS  | SF | SG | Class | VT | Ecosite     | Forest | CC | Layer |
| SV66 |      |      |    |    |     | 75 |    | 1     | 1  | Bog         | Other  | 0  | 0     |
| SV67 |      |      |    |    |     |    | 19 | 1     | 1  | Forested WL | SW     | 0  | 0     |
| SV68 |      |      |    |    |     |    | 40 | 1     | 1  | Forested WL | SW     | 0  | 0     |
| SV69 |      |      |    |    |     | 50 |    | 1     | 1  | Forested WL | SW     | 0  | 0     |
| SV70 |      |      |    |    |     |    |    | 1     | 1  | Forested WL | SW     | 0  | 0     |
| T01  |      |      |    |    |     |    | 63 | 4     | 1  | Forest      | SW     | 4  | 0     |
| T02  |      |      |    |    |     |    |    | 4     | 2  | Forest      | SW     | 4  | 2     |
| T03  |      |      |    |    |     |    | 99 | 1     | 1  | Forested WL | HW     | 4  | 0     |
| T04  |      |      |    |    |     |    | 75 | 1     | 1  | Forested WL | HW     | 2  | 0.1   |
| T05  |      |      |    |    |     |    | 10 | 1     | 1  | Forested WL | SW     | 0  | 0     |
| T06  |      |      |    |    |     |    | 1  | 1     | 1  | Forested WL | SW     | 0  | 0.5   |
| T07  |      |      |    |    |     | 60 |    | 1     | 1  | Bog         | SW     | 0  | 0.1   |
| T08  |      |      |    |    |     | 95 |    | 1     | 1  | Bog         | SW     | 0  | 0     |
| T09  |      |      |    |    |     | 7  |    | 1     | 1  | Bog         | SW     | 0  | 0     |
| T10  |      |      |    |    |     |    | 6  | 1     | 1  | Bog         | SW     | 1  | 0     |
| T11  |      |      |    |    |     | 30 |    | 1     | 1  | Bog         | Other  | 0  | 0     |
| T12  |      |      |    |    |     | 80 |    | 1     | 1  | Bog         | Other  | 0  | 0     |
| T13  |      |      |    |    |     |    | 6  | 1     | 1  | Forested WL | SW     | 0  | 0     |
| T14  |      |      |    |    | 15  |    |    | 1     | 1  | Forested WL | SW     | 0  | 0     |
| T15  |      |      |    |    |     |    | 90 | 1     | 1  | Fen         | Other  | 0  | 0     |
| T16  |      |      |    |    |     |    | 60 | 1     | 1  | Fen         | Other  | 0  | 0     |
| T17  |      |      |    |    | 3   | 1  |    | 9     | 1  | Forest      | HW     | 0  | 0     |
| T18  |      |      |    |    | 20  |    |    | 60    | 1  | Forest      | HW     | 1  | 0     |
| T19  |      |      |    |    | 0.7 |    |    | 6     | 2  | Forest      | HW     | 0  | 2     |
| T20  |      |      |    |    |     |    |    | 5     | 2  | Forest      | HW     | 0  | 2     |
| T21  |      |      |    |    |     |    |    | 4     | 1  | Forest      | SW     | 2  | 2     |
| T22  |      |      |    |    | 1   |    |    | 4     | 1  | Forest      | SW     | 0  | 2     |
| T23  |      |      |    |    |     |    |    | 1     | 1  | Forested WL | SW     | 1  | 3     |
| T24  | 0.25 | 0.25 |    |    | 0.5 |    | 60 | 1     | 1  | Forested WL | SW     | 3  | 0     |
| T25  |      |      |    |    | 0.3 |    |    | 5     | 1  | Forest      | SW     | 3  | 1     |
| T26  |      |      |    |    |     |    | 85 | 5     | 1  | Forest      | SW     | 2  | 2     |
| T27  |      |      |    |    |     |    | 18 | 1     | 1  | Bog         | SW     | 0  | 0     |
| T28  |      |      |    |    |     |    | 90 | 1     | 1  | Bog         | Other  | 0  | 0     |
| T29  |      |      |    |    |     | 10 | 3  | 1     | 1  | Bog         | Other  | 0  | 0     |
| T30  |      |      |    |    |     | 30 | 15 | 1     | 1  | Bog         | Other  | 0  | 0     |
| T31  |      |      |    |    |     |    | 5  | 1     | 1  | Ecotone     | Other  | 0  | 0     |
| T32  |      |      |    |    |     |    | 2  | 1     | 1  | Ecotone     | SW     | 0  | 0     |
| T33  |      |      |    |    |     |    |    | 1     | 1  | Forest      | SW     | 4  | 0     |
| T34  |      | 0.5  |    |    |     |    |    | 1     | 1  | Forest      | SW     | 3  | 1     |
| T35  |      |      |    |    |     |    |    | 5     | 1  | Forest      | SW     | 5  | 4     |
| T36  |      |      |    |    |     |    | 20 | 5     | 1  | Forest      | SW     | 5  | 0     |
| T37  |      |      |    |    |     |    |    | 4     | 1  | Forest      | MX     | 4  | 3     |
| T38  |      |      |    |    |     |    |    | 4     | 1  | Forest      | MX     | 5  | 3     |
| T39  |      |      |    |    |     |    |    | 4     | 1  | Riparian    | HW     | 4  | 3     |
| T40  |      |      |    |    |     |    |    | 4     | 1  | Riparian    | HW     | 4  | 3     |
| T41  |      | 10   |    |    | 50  |    |    | 4     | 1  | Forest      | SW     | 3  | 0     |
| T42  |      |      |    |    |     |    | 4  | 4     | 1  | Forest      | SW     | 2  | 0     |
| T43  |      |      |    |    |     |    | 6  | 1     | 1  | Forest      | SW     | 2  | 2     |
| T44  |      |      |    |    |     |    | 30 | 3     | 1  | Forest      | SW     | 2  | 0     |
| T45  |      |      |    |    |     |    | 12 | 1     | 1  | Ecotone     | SW     | 3  | 0     |
| T46  |      |      |    |    |     |    | 70 | 1     | 1  | Ecotone     | SW     | 2  | 0     |

| Plot | BZ | DP | HS | PC | PS | SF  | SG | DTW   |    | Ecosite  | Forest | CC | L     |   |
|------|----|----|----|----|----|-----|----|-------|----|----------|--------|----|-------|---|
|      |    |    |    |    |    |     |    | Class | VT |          |        |    | Layer |   |
| T47  |    |    |    |    |    |     |    | 5     | 1  | Bog      | SW     | 0  |       | 0 |
| T48  |    |    |    |    |    |     |    | 5     | 1  | Bog      | SW     | 0  |       | 0 |
| T49  |    |    |    |    |    |     |    | 2     | 1  | Riparian | HW     | 3  |       | 2 |
| T50  |    |    |    |    |    |     | 40 | 2     | 1  | Riparian | HW     | 4  |       | 0 |
| T51  |    |    |    |    |    |     | 12 | 3     | 1  | Shrub WL | HW     | 2  |       | 2 |
| T52  |    |    |    |    |    |     | 45 | 4     | 1  | Shrub WL | HW     | 4  |       | 0 |
| T53  |    |    |    |    |    |     |    | 1     | 1  | Bog      | SW     | 0  |       | 0 |
| T54  |    |    |    |    |    |     |    | 1     | 1  | Bog      | SW     | 0  |       | 0 |
| T55  |    |    |    |    |    |     |    | 1     | 1  | Bog      | SW     | 0  |       | 0 |
| T56  |    |    |    |    |    |     |    | 1     | 1  | Bog      | SW     | 0  |       | 0 |
| T57  |    |    |    |    |    |     |    | 1     | 1  | Forest   | HW     | 1  |       | 2 |
| T58  |    |    |    |    |    |     | 50 | 1     | 1  | Forest   | HW     | 3  |       | 0 |
| T59  |    |    |    |    |    | 4   |    | 1     | 1  | Bog      | SW     | 0  |       | 0 |
| T60  |    |    |    |    |    |     |    | 1     | 1  | Bog      | SW     | 0  |       | 0 |
| T61  |    |    |    |    |    |     |    | 1     | 1  | Forest   | SW     | 1  |       | 0 |
| T62  |    |    |    |    |    |     |    | 1     | 1  | Forest   | SW     | 2  |       | 0 |
| T63  |    |    |    |    |    | 5   |    | 1     | 1  | Bog      | Other  | 0  |       | 0 |
| T64  |    |    |    |    |    |     | 5  | 1     | 1  | Bog      | Other  | 0  |       | 0 |
| T65  |    |    |    |    |    | 6.6 |    | 1     | 1  | Bog      | SW     | 0  |       | 0 |
| T66  |    |    |    |    |    |     |    | 1     | 1  | Bog      | SW     | 1  |       | 0 |
| T67  |    |    |    |    |    | 15  |    | 1     | 1  | Bog      | Other  | 0  |       | 0 |
| T68  |    |    |    |    |    | 85  |    | 1     | 1  | Bog      | Other  | 0  |       | 0 |
| T69  |    |    |    |    |    | 50  |    | 1     | 1  | Bog      | Other  | 0  |       | 0 |
| T70  |    |    |    |    |    | 80  |    | 1     | 1  | Bog      | Other  | 0  |       | 0 |

## APPENDIX C: UNB Woodlot (Fredericton) data

(Abbreviations - BZ: *Bazzania trilobata*, DP: *Dicranum polysetum*, HS: *Hylocomium splendens*, PC: *Polytrichum commune*, PS: *Pleurozium schreberi*, Sphag: *Sphagnum* spp. (1 indicates presence), DTW Class: depth-to-water class (1-8), SW: softwood, MX: mixedwood)

| Plot ID | BZ | DP | HS | PC | PS | Sphag | DTW Class | Ecosite | Forest |
|---------|----|----|----|----|----|-------|-----------|---------|--------|
| 1001    |    |    |    |    |    | 1     | 4         | Fen     | SW     |
| 1002    |    |    |    |    |    | 1     | 4         | Fen     | SW     |
| 1003    |    |    |    |    |    | 1     | 4         | Fen     | Other  |
| 1004    |    |    |    |    |    |       | 4         | Fen     | Other  |
| 1005    |    |    |    |    |    | 1     | 1         | Fen     | Other  |
| 1006    |    |    |    |    |    |       | 2         | Fen     | Other  |
| 1007    |    |    |    |    |    | 1     | 2         | Fen     | Other  |
| 1008    |    |    |    |    |    | 1     | 4         | Fen     | Other  |
| 1009    |    |    |    |    |    | 1     | 4         | Fen     | Other  |
| 1010    |    |    |    |    |    | 1     | 2         | Fen     | Other  |
| 1011    |    |    |    |    |    | 1     | 1         | Fen     | Other  |
| 1012    |    |    |    |    |    | 1     | 2         | Fen     | SW     |
| 1013    |    |    |    |    |    |       | 3         | Fen     | Other  |
| 1014    |    |    |    |    |    | 1     | 3         | Fen     | SW     |
| 1015    |    |    |    |    |    | 1     | 1         | Fen     | Other  |
| 1016    |    |    |    |    |    | 1     | 2         | Fen     | Other  |
| 1017    |    |    |    |    |    | 1     | 1         | Fen     | Other  |
| 1018    |    |    |    |    |    | 1     | 3         | Forest  | MX     |
| 1019    |    |    |    |    |    | 1     | 3         | Fen     | Other  |
| 1020    |    |    |    |    |    | 1     | 3         | Fen     | MX     |
| 1021    |    |    |    |    |    | 1     | 1         | Fen     | Other  |
| 1022    |    |    |    | 1  |    | 1     | 3         | Forest  | MX     |
| 1023    |    |    |    |    |    | 1     | 1         | Fen     | Other  |
| 1024    |    |    |    |    |    | 1     | 1         | Forest  | Other  |
| 1025    |    |    |    |    |    | 1     | 2         | Forest  | Other  |
| 1026    |    |    |    |    |    | 1     | 3         | Forest  | Other  |
| 1027    |    |    |    |    |    | 1     | 1         | Forest  | Other  |
| 1028    |    |    |    |    |    | 1     | 1         | Forest  | Other  |
| 1029    |    |    |    |    |    | 1     | 2         | Forest  | Other  |
| 1030    |    |    | 1  |    |    | 1     | 1         | Forest  | Other  |
| 1031    |    |    |    |    | 1  | 1     | 2         | Forest  | Other  |
| 1032    |    |    |    |    |    | 1     | 1         | Forest  | Other  |
| 1033    |    |    |    |    |    | 1     | 2         | Forest  | SW     |
| 1034    |    |    |    |    |    |       | 4         | Forest  | SW     |
| 1035    |    |    |    |    |    | 1     | 2         | Forest  | Other  |
| 1036    |    | 1  |    |    |    |       | 4         | Forest  | SW     |
| 1037    |    |    |    |    |    |       | 5         | Marsh   | Other  |
| 1038    |    |    |    |    |    |       | 5         | Marsh   | Other  |
| 1039    |    |    |    |    |    |       | 5         | Marsh   | Other  |
| 1040    |    |    |    |    |    |       | 2         | Marsh   | Other  |
| 1041    |    |    |    |    |    |       | 3         | Marsh   | Other  |

| Plot ID | BZ | DP | HS | PC | PS | Sphag | DTW Class | Ecosite | Forest |
|---------|----|----|----|----|----|-------|-----------|---------|--------|
| 1042    |    |    |    |    |    | 1     | 5         | Marsh   | Other  |
| 1043    |    |    |    |    |    |       | 4         | Marsh   | Other  |
| 1044    |    |    |    |    |    |       | 5         | Forest  | SW     |
| 1045    |    |    |    |    |    | 1     | 5         | Marsh   | Other  |
| 1046    |    |    |    |    |    | 1     | 5         | Marsh   | Other  |
| 1047    |    |    |    |    |    | 1     | 5         | Marsh   | Other  |
| 1048    |    |    |    |    |    |       | 3         | Marsh   | Other  |
| 1049    |    |    |    |    |    |       | 2         | Marsh   | Other  |
| 1050    |    |    |    |    |    |       | 4         | Marsh   | Other  |
| 1051    |    |    |    |    |    |       | 2         | Marsh   | Other  |
| 1052    |    |    |    |    |    | 1     | 1         | Marsh   | Other  |
| 1053    |    |    |    |    |    |       | 2         | Marsh   | Other  |
| 1054    |    |    |    |    |    | 1     | 2         | Fen     | Other  |
| 1055    |    |    |    |    |    | 1     | 1         | Fen     | Other  |
| 1056    |    |    |    |    |    | 1     | 3         | Fen     | Other  |
| 1057    |    |    |    |    |    | 1     | 3         | Fen     | Other  |
| 1058    |    |    |    |    | 1  | 1     | 4         | Fen     | Other  |
| 1059    |    |    |    |    |    | 1     | 5         | Fen     | Other  |
| 1060    |    |    |    |    |    | 1     | 5         | Fen     | SW     |
| 1061    |    |    |    |    |    | 1     | 4         | Fen     | Other  |
| 1062    |    | 1  |    |    |    | 1     | 4         | Fen     | Other  |
| 1063    |    |    |    |    |    | 1     | 1         | Fen     | Other  |
| 1064    |    |    |    |    |    | 1     | 2         | Fen     | Other  |
| 1065    |    |    |    |    |    | 1     | 2         | Fen     | Other  |
| 1066    |    |    |    |    |    | 1     | 2         | Fen     | Other  |
| 1067    |    |    |    |    | 1  | 1     | 2         | Forest  | SW     |
| 1068    |    |    |    |    |    | 1     | 2         | Forest  | SW     |
| 1069    |    |    |    |    |    | 1     | 3         | Forest  | SW     |
| 1070    |    |    |    |    |    | 1     | 3         | Bog     | SW     |
| 1071    |    |    |    |    |    | 1     | 1         | Bog     | Other  |
| 1072    |    |    |    |    |    | 1     | 4         | Bog     | Other  |
| 1073    |    |    |    |    |    | 1     | 3         | Bog     | SW     |
| 1074    |    |    |    |    |    | 1     | 3         | Forest  | SW     |
| 1075    |    |    |    |    |    |       | 1         | Forest  | SW     |
| 1076    |    |    |    |    |    | 1     | 3         | Bog     | SW     |
| 1077    |    |    |    |    |    | 1     | 4         | Bog     | Other  |
| 1078    |    |    |    |    |    | 1     | 5         | Bog     | Other  |
| 1079    |    |    |    |    |    | 1     | 4         | Bog     | Other  |
| 1080    |    |    |    |    |    | 1     | 3         | Forest  | SW     |
| 1081    |    |    |    |    |    | 1     | 1         | Forest  | SW     |
| 1082    |    |    |    |    |    | 1     | 2         | Forest  | SW     |
| 1083    |    |    |    |    |    | 1     | 1         | Forest  | SW     |
| 1084    |    |    |    |    |    | 1     | 1         | Forest  | SW     |
| 1085    |    |    |    |    |    | 1     | 4         | Fen     | SW     |
| 1086    |    |    |    |    |    |       | 4         | Fen     | Other  |
| 1087    |    |    |    |    |    |       | 4         | Fen     | Other  |
| 1088    |    |    |    |    |    |       | 3         | Fen     | Other  |
| 1089    |    |    |    |    |    | 1     | 4         | Fen     | Other  |
| 1090    |    |    |    | 1  |    | 1     | 3         | Fen     | SW     |
| 1091    |    |    |    |    |    | 1     | 1         | Fen     | SW     |
| 1092    |    |    |    | 1  |    | 1     | 1         | Fen     | Other  |

| Plot ID | BZ | DP | HS | PC | PS | Sphag | DTW Class | Ecosite | Forest |
|---------|----|----|----|----|----|-------|-----------|---------|--------|
| 1093    |    |    |    |    |    | 1     | 1         | Fen     | SW     |
| 1094    |    |    |    |    |    |       | 1         | Fen     | Other  |
| 1095    |    |    |    | 1  |    | 1     | 3         | Fen     | SW     |
| 1096    |    |    |    |    |    | 1     | 2         | Fen     | Other  |
| 1097    |    |    |    | 1  |    | 1     | 1         | Fen     | Other  |
| 1098    |    |    |    |    |    | 1     | 2         | Fen     | Other  |
| 1099    |    |    |    |    |    | 1     | 3         | Fen     | Other  |
| 1100    |    |    |    |    |    | 1     | 4         | Fen     | Other  |
| 1101    |    |    |    | 1  |    | 1     | 3         | Fen     | SW     |
| 1102    |    |    |    |    |    | 1     | 1         | Fen     | SW     |
| 1103    |    |    |    |    |    | 1     | 2         | Fen     | SW     |
| 1104    |    |    |    |    |    | 1     | 2         | Fen     | SW     |
| 1105    |    |    |    |    | 1  | 1     | 3         | Forest  | SW     |
| 1106    |    |    |    |    |    | 1     | 1         | Forest  | SW     |
| 1107    |    |    |    |    |    | 1     | 1         | Forest  | SW     |
| 1108    |    |    |    |    |    | 1     | 1         | Fen     | SW     |
| 1109    |    |    |    | 1  |    | 1     | 1         | Fen     | SW     |
| 1110    |    |    |    |    |    | 1     | 2         | Forest  | SW     |
| 1111    |    |    |    | 1  |    | 1     | 1         | Fen     | SW     |
| 1112    |    |    |    |    |    | 1     | 2         | Fen     | SW     |
| 1113    |    |    |    |    |    | 1     | 4         | Forest  | SW     |
| 1114    |    |    |    |    |    | 1     | 2         | Forest  | SW     |
| 1115    |    |    |    |    |    | 1     | 1         | Forest  | MX     |
| 1116    |    |    |    |    |    | 1     | 1         | Forest  | MX     |
| 1117    |    |    |    |    |    | 1     | 2         | Forest  | MX     |
| 1118    |    |    |    |    |    | 1     | 2         | Forest  | MX     |
| 1119    |    |    |    |    | 1  | 1     | 1         | Forest  | MX     |
| 1120    |    | 1  |    |    |    | 1     | 1         | Forest  | MX     |
| 1121    |    |    |    |    |    | 1     | 1         | Forest  | SW     |
| 1122    |    |    |    |    |    | 1     | 2         | Forest  | SW     |
| 1123    |    |    |    |    |    | 1     | 1         | Forest  | SW     |
| 1124    |    |    |    |    |    | 1     | 1         | Forest  | MX     |
| 1125    |    |    |    |    |    | 1     | 1         | Forest  | MX     |
| 1126    |    |    |    |    |    | 1     | 2         | Fen     | SW     |
| 1127    |    |    |    |    |    | 1     | 1         | Fen     | Other  |
| 1128    |    |    |    |    |    | 1     | 3         | Fen     | Other  |
| 1129    |    |    |    |    |    | 1     | 3         | Fen     | Other  |
| 1130    |    |    |    |    |    | 1     | 4         | Fen     | SW     |
| 1131    |    |    |    |    |    | 1     | 4         | Forest  | SW     |
| 1132    |    |    |    |    |    | 1     | 5         | Fen     | SW     |
| 1133    |    |    |    |    |    | 1     | 5         | Fen     | Other  |
| 1134    |    |    |    |    |    | 1     | 4         | Fen     | Other  |
| 1135    |    |    |    |    |    | 1     | 3         | Fen     | Other  |
| 1136    |    |    |    |    |    | 1     | 1         | Fen     | SW     |
| 1137    |    |    |    |    |    | 1     | 3         | Fen     | Other  |
| 1138    |    |    |    |    |    | 1     | 5         | Fen     | Other  |
| 1139    |    |    |    |    |    | 1     | 5         | Fen     | Other  |
| 1140    | 1  | 1  |    | 1  | 1  | 1     | 4         | Forest  | SW     |
| 1141    | 1  |    |    | 1  | 1  | 1     | 4         | Forest  | SW     |
| 1142    |    |    |    |    | 1  | 1     | 3         | Fen     | SW     |
| 1143    |    |    |    | 1  |    | 1     | 1         | Fen     | Other  |

| Plot ID | BZ | DP | HS | PC | PS | Sphag | DTW Class | Ecosite | Forest |
|---------|----|----|----|----|----|-------|-----------|---------|--------|
| 1144    |    |    |    |    |    | 1     | 2         | Fen     | Other  |
| 1145    |    |    |    |    |    | 1     | 3         | Forest  | SW     |
| 1146    |    |    |    |    |    |       | 3         | Marsh   | Other  |
| 1147    |    |    |    |    |    |       | 5         | Marsh   | Other  |
| 1148    |    |    |    |    |    |       | 5         | Forest  | Other  |
| 1149    |    |    |    |    |    |       | 5         | Marsh   | Other  |
| 1150    |    |    |    |    |    |       | 4         | Marsh   | Other  |
| 1152    |    |    |    |    |    |       | 4         | Marsh   | Other  |
| 1153    |    |    |    |    |    |       | 4         | Marsh   | Other  |
| 1154    |    |    |    |    |    |       | 3         | Marsh   | Other  |
| 1155    |    |    |    |    |    |       | 4         | Marsh   | Other  |
| 1156    |    |    |    |    |    | 1     | 4         | Marsh   | Other  |
| 1157    |    |    |    |    |    | 1     | 4         | Marsh   | Other  |
| 1158    |    |    |    |    |    | 1     | 4         | Marsh   | SW     |
| 1159    |    |    |    |    |    | 1     | 4         | Marsh   | Other  |
| 1161    |    |    |    |    |    | 1     | 1         | Marsh   | Other  |
| 1162    |    |    |    |    |    |       | 3         | Marsh   | SW     |
| 1163    |    |    |    |    |    |       | 2         | Marsh   | Other  |
| 2001    |    | 1  |    |    | 1  |       | 4         | Fen     | SW     |
| 2002    |    |    |    |    |    | 1     | 4         | Fen     | Other  |
| 2003    |    |    |    | 1  |    | 1     | 4         | Fen     | Other  |
| 2004    |    |    |    | 1  |    | 1     | 5         | Fen     | Other  |
| 2005    |    |    |    | 1  |    | 1     | 5         | Fen     | Other  |
| 2006    |    |    |    | 1  |    | 1     | 5         | Fen     | Other  |
| 2007    |    |    |    | 1  |    | 1     | 4         | Fen     | Other  |
| 2008    |    |    |    | 1  |    | 1     | 5         | Fen     | Other  |
| 2009    |    | 1  |    |    | 1  |       | 4         | Forest  | MX     |
| 2010    |    |    |    | 1  |    | 1     | 2         | Fen     | Other  |
| 2011    |    |    |    |    |    | 1     | 2         | Fen     | MX     |
| 2012    |    |    |    | 1  |    | 1     | 2         | Fen     | Other  |
| 2013    | 1  | 1  |    |    | 1  |       | 4         | Fen     | MX     |
| 2014    |    |    |    | 1  |    | 1     | 2         | Fen     | MX     |
| 2015    |    |    |    |    |    | 1     | 1         | Forest  | Other  |
| 2016    |    |    |    |    | 1  |       | 1         | Forest  | Other  |
| 2017    |    |    |    |    |    | 1     | 3         | Forest  | SW     |
| 2018    | 1  | 1  |    |    |    | 1     | 1         | Forest  | Other  |
| 2019    |    |    |    |    |    | 1     | 2         | Marsh   | SW     |
| 2020    |    |    |    |    |    | 1     | 4         | Marsh   | SW     |
| 2021    |    |    |    |    |    |       | 1         | Marsh   | SW     |
| 2022    |    | 1  |    |    |    | 1     | 4         | Marsh   | SW     |
| 2023    |    |    |    |    |    | 1     | 3         | Marsh   | SW     |
| 2024    |    |    |    |    |    |       | 4         | Marsh   | Other  |
| 2025    |    |    |    |    |    |       | 3         | Marsh   | Other  |
| 2026    |    |    |    |    |    | 1     | 4         | Marsh   | Other  |
| 2027    |    |    |    |    |    |       | 1         | Marsh   | Other  |
| 2028    |    |    |    |    |    |       | 3         | Marsh   | Other  |
| 2029    |    |    |    |    |    | 1     | 4         | Marsh   | Other  |
| 2030    |    |    |    |    |    | 1     | 4         | Marsh   | Other  |
| 2031    |    |    |    |    |    | 1     | 4         | Marsh   | Other  |
| 2032    |    | 1  | 1  |    | 1  |       | 5         | Marsh   | Other  |
| 2033    |    |    |    |    |    | 1     | 5         | Forest  | SW     |

| Plot ID | BZ | DP | HS | PC | PS | Sphag | DTW Class | Ecosite | Forest |
|---------|----|----|----|----|----|-------|-----------|---------|--------|
| 2034    |    |    |    |    |    | 1     | 5         | Marsh   | Other  |
| 2035    |    |    |    |    |    | 1     | 5         | Marsh   | Other  |
| 2036    |    |    |    |    |    | 1     | 5         | Marsh   | Other  |
| 2037    |    |    |    |    |    | 1     | 6         | Marsh   | Other  |
| 2043    |    |    |    | 1  | 1  |       | 4         | Forest  | MX     |
| 2044    |    | 1  |    |    |    | 1     | 3         | Forest  | MX     |
| 2045    |    |    |    |    |    | 1     | 1         | Fen     | Other  |
| 2046    |    |    |    |    |    | 1     | 3         | Fen     | Other  |
| 2047    |    |    | 1  |    | 1  | 1     | 3         | Fen     | Other  |
| 2048    |    |    |    |    |    | 1     | 2         | Fen     | Other  |
| 2049    |    |    |    |    |    | 1     | 3         | Fen     | Other  |
| 2050    |    |    |    |    |    | 1     | 1         | Fen     | Other  |
| 2051    |    | 1  |    |    |    | 1     | 1         | Forest  | Other  |
| 2052    |    | 1  |    |    | 1  |       | 4         | Forest  | MX     |
| 2053    |    |    |    |    |    | 1     | 3         | Fen     | MX     |
| 2054    |    |    |    |    |    | 1     | 1         | Forest  | SW     |
| 2055    |    |    | 1  |    | 1  | 1     | 1         | Forest  | SW     |
| 2056    |    | 1  |    | 1  |    |       | 1         | Forest  | SW     |
| 2057    |    |    |    |    |    | 1     | 4         | Forest  | SW     |
| 2058    |    |    |    |    |    | 1     | 3         | Bog     | Other  |
| 2059    |    |    |    |    |    | 1     | 1         | Bog     | Other  |
| 2060    |    |    |    |    |    | 1     | 3         | Bog     | Other  |
| 2061    |    |    |    |    |    | 1     | 2         | Bog     | Other  |
| 2062    |    |    |    |    |    | 1     | 5         | Bog     | Other  |
| 2063    |    |    |    |    |    |       | 6         | Forest  | Other  |
| 2064    |    |    |    |    |    |       | 2         | Forest  | Other  |
| 2065    |    |    |    |    |    |       | 4         | Bog     | Other  |
| 2066    |    |    |    |    |    | 1     | 3         | Bog     | Other  |
| 2067    |    |    |    |    |    | 1     | 2         | Bog     | Other  |
| 2068    |    |    |    | 1  |    |       | 6         | Fen     | SW     |
| 2069    |    |    |    |    |    |       | 4         | Fen     | Other  |
| 2070    |    |    |    |    |    |       | 4         | Fen     | Other  |
| 2071    |    | 1  |    |    | 1  |       | 5         | Fen     | SW     |
| 2072    | 1  | 1  |    |    | 1  |       | 5         | Fen     | SW     |
| 2073    |    |    |    |    |    | 1     | 5         | Fen     | Other  |
| 2074    |    |    |    |    |    |       | 5         | Fen     | Other  |
| 2075    |    | 1  |    | 1  |    |       | 5         | Fen     | SW     |
| 2076    |    | 1  |    | 1  | 1  | 1     | 5         | Fen     | SW     |
| 2077    |    |    |    | 1  | 1  |       | 5         | Forest  | SW     |
| 2078    |    |    |    |    |    |       | 4         | Fen     | Other  |
| 2079    |    |    |    | 1  |    |       | 5         | Fen     | Other  |
| 2080    |    | 1  |    |    | 1  |       | 5         | Fen     | SW     |
| 2081    | 1  | 1  |    |    |    | 1     | 4         | Fen     | SW     |
| 2082    |    |    |    | 1  |    | 1     | 1         | Fen     | SW     |
| 2083    |    |    |    |    |    | 1     | 1         | Fen     | SW     |
| 2084    |    |    |    |    |    | 1     | 3         | Fen     | SW     |
| 2085    |    |    |    |    | 1  | 1     | 3         | Forest  | SW     |
| 2086    |    | 1  |    |    | 1  | 1     | 1         | Forest  | SW     |
| 2087    |    | 1  |    |    |    |       | 5         | Forest  | SW     |
| 2088    |    |    |    |    |    | 1     | 1         | Forest  | SW     |
| 2089    |    |    |    |    |    | 1     | 3         | Fen     | SW     |

| Plot ID | BZ | DP | HS | PC | PS | Sphag | DTW Class | Ecosite | Forest |
|---------|----|----|----|----|----|-------|-----------|---------|--------|
| 2090    |    |    |    |    |    | 1     | 2         | Fen     | SW     |
| 2091    |    |    |    |    |    | 1     | 2         | Fen     | SW     |
| 2092    |    | 1  |    |    | 1  |       | 4         | Forest  | MX     |
| 2093    |    | 1  |    | 1  | 1  |       | 2         | Forest  | MX     |
| 2094    |    | 1  |    |    | 1  |       | 4         | Forest  | MX     |
| 2095    |    | 1  |    |    | 1  |       | 4         | Forest  | MX     |
| 2096    |    | 1  |    | 1  | 1  |       | 2         | Forest  | MX     |
| 2097    |    | 1  |    |    | 1  |       | 1         | Forest  | MX     |
| 2098    |    | 1  |    | 1  | 1  |       | 4         | Forest  | MX     |
| 2099    |    | 1  |    |    | 1  |       | 3         | Forest  | MX     |
| 2100    |    | 1  | 1  |    | 1  |       | 3         | Forest  | MX     |
| 2101    |    | 1  |    |    |    | 1     | 3         | Forest  | SW     |
| R01     |    |    |    |    |    |       | 7         | Forest  | Other  |
| R02     |    |    |    |    |    |       | 8         | Forest  | Other  |
| R03     |    |    |    |    |    |       | 8         | Forest  | Other  |
| R04     |    |    |    |    | 1  |       | 8         | Forest  | Other  |
| R05     |    |    |    | 1  | 1  |       | 7         | Forest  | Other  |
| R06     |    |    |    |    |    |       | 7         | Forest  | Other  |
| R07     |    | 1  |    | 1  | 1  |       | 6         | Forest  | Other  |
| R08     |    |    |    |    |    |       | 6         | Forest  | Other  |
| R09     |    |    |    |    | 1  |       | 5         | Forest  | Other  |
| R10     |    |    |    |    |    |       | 5         | Forest  | Other  |
| R11     |    |    |    |    |    |       | 2         | Forest  | Other  |
| R12     |    |    |    |    |    |       | 3         | Forest  | Other  |
| R13     |    |    |    | 1  |    |       | 4         | Forest  | Other  |
| R14     |    |    |    |    |    |       | 4         | Forest  | Other  |
| R15     |    |    |    |    |    |       | 5         | Forest  | Other  |
| R16     |    |    |    |    |    |       | 5         | Forest  | Other  |
| R17     |    | 1  |    |    | 1  |       | 7         | Forest  | MX     |
| R18     |    | 1  |    |    | 1  |       | 7         | Forest  | MX     |
| R19     |    | 1  |    | 1  | 1  |       | 7         | Forest  | MX     |
| R20     |    |    | 1  | 1  |    | 1     | 6         | Forest  | MX     |
| R21     |    | 1  |    | 1  | 1  |       | 6         | Forest  | MX     |
| R22     |    |    |    |    |    | 1     | 5         | Forest  | MX     |
| R23     |    |    |    |    | 1  |       | 6         | Forest  | SW     |
| R24     |    |    |    |    | 1  |       | 5         | Forest  | SW     |
| R25     |    |    |    | 1  |    |       | 7         | Forest  | SW     |
| R26     |    | 1  |    |    | 1  |       | 6         | Forest  | SW     |
| R27     |    |    |    |    |    |       | 5         | Forest  | Other  |
| R28     |    |    |    |    |    | 1     | 5         | Forest  | Other  |
| R29     |    |    |    | 1  |    |       | 7         | Forest  | Other  |
| R30     |    |    |    |    |    |       | 7         | Forest  | Other  |
| R31     |    |    |    | 1  | 1  |       | 6         | Forest  | Other  |
| R32     |    |    |    | 1  | 1  |       | 6         | Forest  | Other  |
| R33     |    |    |    |    |    |       | 6         | Forest  | Other  |
| R34     |    | 1  |    | 1  | 1  |       | 6         | Forest  | Other  |
| R35     |    | 1  |    | 1  | 1  |       | 7         | Forest  | Other  |
| R36     |    |    |    | 1  |    |       | 7         | Forest  | Other  |
| R37     |    | 1  | 1  |    | 1  |       | 7         | Forest  | Other  |
| R38     |    |    |    | 1  |    |       | 7         | Forest  | Other  |
| R39     |    | 1  | 1  | 1  | 1  |       | 7         | Forest  | SW     |

| Plot ID | BZ | DP | HS | PC | PS | Sphag | DTW Class | Ecosite | Forest |
|---------|----|----|----|----|----|-------|-----------|---------|--------|
| R40     |    | 1  |    |    | 1  |       | 7         | Forest  | SW     |
| R41     |    | 1  |    | 1  |    |       | 8         | Forest  | SW     |
| R42     |    | 1  |    |    |    |       | 8         | Forest  | SW     |
| R43     |    |    |    |    |    |       | 8         | Forest  | SW     |
| R44     |    |    |    |    | 1  |       | 8         | Forest  | SW     |
| R45     |    |    |    | 1  |    |       | 8         | Forest  | MX     |
| R46     |    |    |    |    |    |       | 8         | Forest  | MX     |
| R47     |    |    |    | 1  |    |       | 8         | Forest  | MX     |
| R48     |    | 1  |    |    | 1  |       | 8         | Forest  | MX     |
| R49     | 1  | 1  |    |    | 1  |       | 8         | Forest  | Other  |
| R50     |    |    |    |    |    |       | 8         | Forest  | Other  |
| R51     |    |    |    | 1  | 1  |       | 8         | Forest  | SW     |
| R52     |    | 1  | 1  |    | 1  |       | 8         | Forest  | SW     |
| R53     |    | 1  |    |    | 1  |       | 8         | Forest  | SW     |
| R54     |    |    |    |    | 1  |       | 8         | Forest  | SW     |
| R55     | 1  |    |    |    | 1  |       | 6         | Forest  | SW     |
| R56     | 1  |    |    |    | 1  |       | 6         | Forest  | SW     |
| R57     | 1  | 1  |    |    | 1  |       | 7         | Forest  | SW     |
| R58     | 1  | 1  |    |    | 1  |       | 7         | Forest  | SW     |
| R59     | 1  | 1  |    |    | 1  |       | 6         | Forest  | SW     |
| R60     |    | 1  |    |    | 1  |       | 6         | Forest  | SW     |
| R61     |    | 1  |    | 1  | 1  |       | 7         | Forest  | SW     |
| R62     |    | 1  | 1  |    | 1  |       | 7         | Forest  | SW     |
| R63     |    | 1  |    | 1  | 1  |       | 8         | Forest  | SW     |
| R64     |    | 1  |    |    | 1  |       | 8         | Forest  | SW     |
| R65     |    | 1  |    | 1  |    |       | 7         | Forest  | MX     |
| R66     |    |    |    | 1  |    |       | 7         | Forest  | MX     |
| R67     |    | 1  |    | 1  | 1  |       | 6         | Forest  | MX     |
| R68     |    | 1  |    |    | 1  |       | 6         | Forest  | MX     |

**APPENDIX D: Mean and standard deviation (SD) of environmental variables used in regression models by species (Abbreviations – DTW: depth-to-water, SW: softwood, HW: hardwood, MX: mixedwood)**

|                              |                      |                        | DTW         |            | Canopy Closure |             | Litter Depth |            | Forest Type             |                         |                         | Land Classification                   |                              |                             |
|------------------------------|----------------------|------------------------|-------------|------------|----------------|-------------|--------------|------------|-------------------------|-------------------------|-------------------------|---------------------------------------|------------------------------|-----------------------------|
| Species                      | Presence/<br>Absence | Total<br>Sample<br>(N) | Mean<br>(m) | SD<br>(m)  | Mean<br>(%)    | SD<br>(%)   | Mean<br>(cm) | SD<br>(cm) | SW<br>(n <sub>1</sub> ) | HW<br>(n <sub>2</sub> ) | MX<br>(n <sub>3</sub> ) | Non-<br>Forested<br>(n <sub>4</sub> ) | Wetland<br>(n <sub>1</sub> ) | Upland<br>(n <sub>2</sub> ) |
| <i>Bazzania trilobata</i>    | 1                    | 76                     | 3.1         | 4.3        | 66.8           | 23.0        | 1.0          | 1.1        | 59                      | 5                       | 12                      | 0                                     | 15                           | 61                          |
|                              | 0                    | 904                    | 2.5         | 4.1        | 40.3           | 35.6        | 1.2          | 1.6        | 523                     | 99                      | 174                     | 108                                   | 468                          | 436                         |
| <i>Dicranum polysetum</i>    | 1                    | 233                    | 3.9         | 4.2        | 52.5           | 30.4        | 1.1          | 1.2        | 182                     | 12                      | 37                      | 2                                     | 22                           | 211                         |
|                              | 0                    | 747                    | 2.1         | 4.0        | 39.2           | 36.4        | 1.2          | 1.7        | 400                     | 92                      | 149                     | 106                                   | 461                          | 286                         |
| <i>Hylocomium splendens</i>  | 1                    | 64                     | 2.5         | 2.7        | 64.0           | 27.1        | 0.9          | 1.1        | 53                      | 3                       | 8                       | 0                                     | 19                           | 45                          |
|                              | 0                    | 916                    | 2.6         | 4.2        | 40.9           | 35.5        | 1.2          | 1.6        | 529                     | 101                     | 178                     | 108                                   | 464                          | 452                         |
| <i>Polytrichum commune</i>   | 1                    | 137                    | 3.2         | 4.3        | 44.6           | 32.7        | 1.0          | 1.1        | 93                      | 12                      | 27                      | 5                                     | 49                           | 88                          |
|                              | 0                    | 843                    | 2.4         | 4.1        | 42.0           | 35.9        | 1.2          | 1.6        | 489                     | 92                      | 159                     | 103                                   | 434                          | 409                         |
| <i>Pleurozium schreberi</i>  | 1                    | 328                    | 3.7         | 4.3        | 53.2           | 31.1        | 0.9          | 1.1        | 252                     | 16                      | 60                      | 0                                     | 64                           | 264                         |
|                              | 0                    | 652                    | 2.0         | 3.9        | 37.0           | 36.4        | 1.3          | 1.8        | 330                     | 88                      | 126                     | 108                                   | 419                          | 233                         |
| <i>Sphagnum fuscum</i>       | 1                    | 63                     | 0.2         | 0.3        | 8.5            | 13.4        | 0.3          | 0.9        | 39                      | 0                       | 0                       | 24                                    | 63                           | 0                           |
|                              | 0                    | 917                    | 2.7         | 4.2        | 44.7           | 35.3        | 1.3          | 1.6        | 543                     | 104                     | 186                     | 84                                    | 420                          | 497                         |
| <i>Sphagnum girgensohnii</i> | 1                    | 301                    | 0.6         | 1.2        | 29.8           | 31.3        | 0.3          | 0.8        | 215                     | 17                      | 36                      | 33                                    | 223                          | 78                          |
|                              | 0                    | 679                    | 3.4         | 4.6        | 48.0           | 35.8        | 1.6          | 1.7        | 367                     | 87                      | 150                     | 75                                    | 260                          | 419                         |
| <b>Summary</b>               |                      | <b>980</b>             | <b>2.5</b>  | <b>4.1</b> | <b>42.4</b>    | <b>35.5</b> | <b>1.2</b>   | <b>1.6</b> | <b>582</b>              | <b>104</b>              | <b>186</b>              | <b>108</b>                            | <b>483</b>                   | <b>497</b>                  |

### APPENDIX E: Huisman-Olff-Fresco (HOF) model parameters and model fit values

| Environmental Variable                 | Species                      | Model Type | HOF Model Parameters |        |       |       | Model Fit      |       |               | Central Border |       | Outer Border |       |
|----------------------------------------|------------------------------|------------|----------------------|--------|-------|-------|----------------|-------|---------------|----------------|-------|--------------|-------|
|                                        |                              |            | a                    | b      | c     | d     | R <sup>2</sup> | P     | Optimum       | Min            | Max   | Min          | Max   |
| Depth-to-Water<br>(log <sub>10</sub> ) | <i>Bazzania trilobata</i>    | III        | 3.47                 | -10.85 | 2.15  |       | 0.82           | 0.002 | 0.59 to 25.00 | 0.17           | 25.00 | 0.03         | 25.00 |
|                                        | <i>Dicranum polysetum</i>    | IV         | -6.26                | 7.24   | 4.87  |       | 0.98           | 0.000 | 4.11          | 0.77           | 21.92 | 0.10         | 25.00 |
|                                        | <i>Hylocomium splendens</i>  | IV         | -1.96                | 4.26   | 3.76  |       | 0.20           | 0.266 | 1.91          | 0.10           | 25.00 | 0.01         | 25.00 |
|                                        | <i>Polytrichum commune</i>   | II         | 2.49                 | -1.22  |       |       | 0.54           | 0.039 | 4.47          | 0.26           | 25.00 | 0.01         | 25.00 |
|                                        | <i>Pleurozium schreberi</i>  | IV         | -5.37                | 5.44   | 3.35  |       | 0.99           | 0.000 | 5.31          | 0.51           | 25.00 | 0.03         | 25.00 |
|                                        | <i>Sphagnum fuscum</i>       | III        | -1.10                | 5.65   | 0.83  |       | 0.90           | 0.000 | 0.01 to 0.02  | 0.01           | 0.06  | 0.01         | 0.95  |
|                                        | <i>Sphagnum girgensohnii</i> | III        | -6.67                | 11.00  | -0.10 |       | 0.99           | 0.000 | 0.01          | 0.01           | 0.85  | 0.01         | 4.32  |
| Slope<br>(percent)                     | <i>Bazzania trilobata</i>    | III        | 1.46                 | -53.40 | 2.11  |       | 0.16           | 0.433 | 3.22 to 47.10 | 1.67           | 47.10 | 0.00         | 47.10 |
|                                        | <i>Dicranum polysetum</i>    | V          | 0.33                 | 1.31   | 1.09  | 26.55 | 0.69           | 0.041 | 8.02          | 2.15           | 34.76 | 0.00         | 47.10 |
|                                        | <i>Hylocomium splendens</i>  | V          | 1.60                 | 2.81   | 2.92  | 57.89 | 0.77           | 0.021 | 4.92          | 2.41           | 15.05 | 0.63         | 41.25 |
|                                        | <i>Polytrichum commune</i>   | IV         | -0.97                | 4.13   | 1.62  |       | 0.19           | 0.393 | 14.74         | -2.25          | 31.72 | 0.00         | 47.10 |
|                                        | <i>Pleurozium schreberi</i>  | IV         | -3.57                | 5.86   | 1.20  |       | 0.63           | 0.060 | 19.17         | 5.56           | 32.78 | 0.00         | 47.10 |
|                                        | <i>Sphagnum fuscum</i>       | II         | 1.57                 | 21.31  |       |       | 0.94           | 0.001 | 0.00          | 0.00           | 1.27  | 0.00         | 4.79  |
|                                        | <i>Sphagnum girgensohnii</i> | II         | -0.21                | 13.07  |       |       | 0.97           | 0.000 | 0.00          | 0.00           | 3.23  | 0.00         | 9.82  |

| Environmental Variable      | Species                      | Model Type | HOF Model Parameters |       |      |        | Model Fit      |       |         | Central Border |     | Outer Border |     |
|-----------------------------|------------------------------|------------|----------------------|-------|------|--------|----------------|-------|---------|----------------|-----|--------------|-----|
|                             |                              |            | a                    | b     | c    | d      | R <sup>2</sup> | P     | Optimum | Min            | Max | Min          | Max |
| Canopy Closure<br>(percent) | <i>Bazzania trilobata</i>    | IV         | -3.87                | 6.06  | 4.61 |        | 0.85           | 0.003 | 70      | 45             | 95  | 15           | 100 |
|                             | <i>Dicranum polysetum</i>    | V          | -1.56                | 2.96  | 2.14 | 7.21   | 0.64           | 0.031 | 49      | 22             | 88  | 0            | 100 |
|                             | <i>Hylocomium splendens</i>  | V          | -16.39               | 18.91 | 4.19 | 3.54   | 0.74           | 0.013 | 78      | 56             | 89  | 11           | 100 |
|                             | <i>Polytrichum commune</i>   | IV         | -1.59                | 3.69  | 2.00 |        | 0.41           | 0.112 | 49      | 8              | 89  | 0            | 100 |
|                             | <i>Pleurozium schreberi</i>  | IV         | -3.85                | 4.81  | 1.72 |        | 0.49           | 0.079 | 58      | 24             | 92  | 0            | 100 |
|                             | <i>Sphagnum fuscum</i>       | V          | 1.05                 | 6.86  | 0.87 | 46.66  | 0.15           | 0.385 | 6       | 1              | 17  | 0            | 40  |
|                             | <i>Sphagnum girgensohnii</i> | II         | 0.22                 | 1.55  |      |        | 0.95           | 0.000 | 0       | 0              | 50  | 0            | 100 |
| Litter Depth<br>(cm)        | <i>Bazzania trilobata</i>    | V          | 1.38                 | 6.44  | 1.17 | 100.00 | 0.84           | 0.004 | 0.5     | 0.1            | 1.8 | 0.0          | 5.0 |
|                             | <i>Dicranum polysetum</i>    | V          | -0.17                | 6.78  | 1.14 | 100.00 | 0.84           | 0.004 | 0.6     | 0.2            | 2.2 | 0.0          | 5.6 |
|                             | <i>Hylocomium splendens</i>  | V          | 1.56                 | 7.19  | 1.06 | 100.00 | 0.53           | 0.064 | 0.5     | 0.1            | 1.6 | 0.0          | 4.5 |
|                             | <i>Polytrichum commune</i>   | IV         | -1.25                | 12.57 | 1.64 |        | 0.86           | 0.003 | 1.5     | 0.0            | 3.0 | -1.9         | 4.9 |
|                             | <i>Pleurozium schreberi</i>  | V          | -1.06                | 9.79  | 0.91 | 100.00 | 0.92           | 0.001 | 0.6     | 0.1            | 2.0 | 0.0          | 4.5 |
|                             | <i>Sphagnum fuscum</i>       | II         | 2.11                 | 11.85 |      |        | 0.66           | 0.026 | 0.0     | 0.0            | 0.6 | 0.0          | 2.3 |
|                             | <i>Sphagnum girgensohnii</i> | II         | 0.01                 | 14.26 |      |        | 0.87           | 0.002 | 0.0     | 0.0            | 0.8 | 0.0          | 2.4 |

**APPENDIX F: Additional multivariate regression models using unmapped variables (Abbreviations – CC: canopy closure, SW: softwood, logDTW: log<sub>10</sub> depth-to-water, VT: vegetation type, SE: standard error)**

| Response Variable           | n   | Predictor Variable | $\beta$ | SE $\beta$ | Wald's $X^2$ | P     | Odds Ratio | Likelihood Ratio Test |    |       | R <sup>2</sup> -type Indices |                           |
|-----------------------------|-----|--------------------|---------|------------|--------------|-------|------------|-----------------------|----|-------|------------------------------|---------------------------|
|                             |     |                    |         |            |              |       |            | $X^2$                 | df | p     | Cox and Snell R <sup>2</sup> | Nagelkerke R <sup>2</sup> |
| <i>Bazzania trilobata</i>   | 76  | Mound              | 0.828   | 0.26       | 10.23        | 0.001 | 2.29       | 65.5                  | 3  | 0.000 | 0.07                         | 0.16                      |
|                             |     | CC                 | 0.121   | 0.03       | 22.50        | 0.000 | 1.13       |                       |    |       |                              |                           |
|                             |     | Leaf Litter        | 0.950   | 0.03       | 10.89        | 0.001 | 1.10       |                       |    |       |                              |                           |
|                             |     | Constant           | -4.939  | 0.42       | 138.70       | 0.000 | 0.01       |                       |    |       |                              |                           |
| <i>Hylocomium splendens</i> | 64  | CC                 | 0.131   | 0.03       | 24.23        | 0.000 | 1.14       | 76.1                  | 3  | 0.000 | 0.08                         | 0.20                      |
|                             |     | Slope              | 0.148   | 0.04       | 16.13        | 0.000 | 1.16       |                       |    |       |                              |                           |
|                             |     | SW                 | 1.370   | 0.35       | 15.67        | 0.000 | 3.94       |                       |    |       |                              |                           |
|                             |     | Constant           | -5.905  | 0.51       | 132.92       | 0.000 | 0.00       |                       |    |       |                              |                           |
| <i>Polytrichum commune</i>  | 137 | Leaf Litter        | 0.078   | 0.02       | 10.47        | 0.001 | 1.08       | 37.7                  | 3  | 0.000 | 0.04                         | 0.07                      |
|                             |     | CC                 | 0.059   | 0.03       | 5.00         | 0.025 | 1.06       |                       |    |       |                              |                           |
|                             |     | logDTW             | 0.077   | 0.02       | 12.16        | 0.000 | 1.08       |                       |    |       |                              |                           |
|                             |     | Constant           | -4.890  | 0.57       | 73.77        | 0.000 | 0.01       |                       |    |       |                              |                           |
| <i>Sphagnum fuscum</i>      | 63  | logDTW             | 0.064   | 0.02       | 12.62        | 0.000 | 1.07       | 129.8                 | 3  | 0.000 | 0.13                         | 0.33                      |
|                             |     | CC                 | 0.152   | 0.03       | 21.56        | 0.000 | 1.17       |                       |    |       |                              |                           |
|                             |     | VT                 | -1.934  | 0.65       | 8.88         | 0.003 | 0.15       |                       |    |       |                              |                           |
|                             |     | Constant           | -2.496  | 0.89       | 7.82         | 0.005 | 0.08       |                       |    |       |                              |                           |

## **CURRICULUM VITAE**

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