Dalhousie University – Environmental Science

Bryophyte dynamics across wetland and lakeshore edges in southwest Nova Scotia

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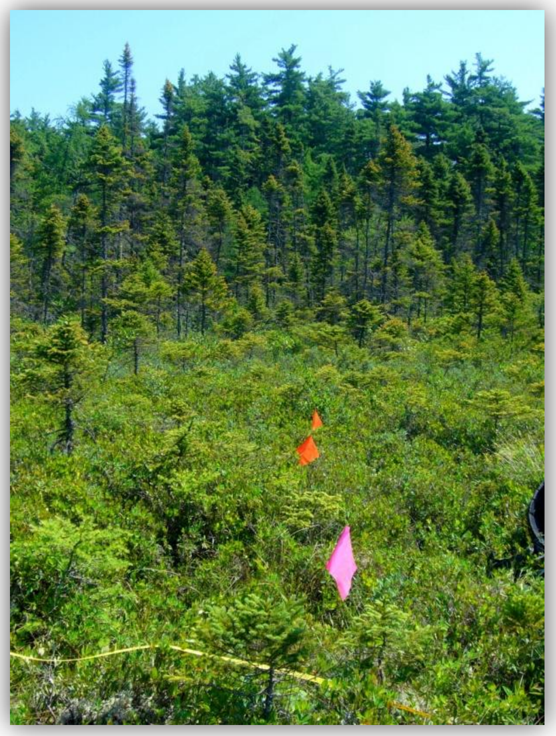

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Inspiring Minds

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Abstract

Wetlands are effective carbon sinks, supply clean water, enhance soil nutrition, and are regarded as valuable ecosystems. Bryophytes play a key role in wetland functioning. Previous studies have looked at wetlands as whole systems; however, little is known about the dynamics at their edges. To better understand the transitions between wetlands and the surrounding forest, I had three objectives for both bog and lakeshore edges: (1) to determine if substrate moisture and pH are associated with different bryophytes, (2) to estimate the distance of edge influence (the distances from the edge where a variable is significantly different from the interior bog or forest) for bryophyte abundance, and (3) to determine the pattern of bryophyte species richness. Transects 360m long were set up across 4 bog and 4 lakeshore edges in southwest Nova Scotia extending from the wetlands into the forest. Cover was estimated for all identifiable bryophyte species in 1m x 1m contiguous quadrats. Bryophytes and soils were collected at given sampling points and analyzed in the lab. The results found that soil moisture was more associated with edge structure than was pH and canopy cover, and differed greatly between wetland and lakeshore edges. Distance of edge influence was found to be quite variable depending on the species and extended as far as 40m from the edge for some bryophyte species. While the levels of bryophyte species richness were found to be higher at the edge, bryophyte abundance was found to be relatively low. The higher bryophyte species richness and different characteristics of the edge zone indicate that it is a unique habitat on the landscape and could therefore be important for conservation. A distance of edge influence extending as far as 40m from the edge also suggests that any riparian zone or forested buffer around wetland habitats should be at least this wide to effectively conserve these unique edge habitats.

Introduction

Wetlands are generally regarded as valuable and important ecosystems. Not only are they effective and efficient carbon sinks, but they also act as a filter by supplying clean water to rivers and are known for effectively enhancing soil nutrition. Many wetlands are also very diverse and act as habitat for a variety of plants and animals. For these reasons, wetlands are ecosystems of interest to many biological and environmental researchers. Most studies, however, look at wetlands as whole systems; little is known about the variability within wetlands including the dynamics at their edges. It is important to understand how wetlands transition to their surrounding ecosystems. The edge between a wetland and a forest can help us understand the differences in processes between these two ecosystems. Edges not only act as a boundary line, but they can also create a buffer zone between ecosystems, and provide a refuge for certain species of plants and animals.

The edge of a wetland is often defined by a change in bryophyte composition. Bryophytes form a substantial component of the biomass and diversity in wetlands, and can affect soil acidity, local nutrients and general habitat structure (Munch 2006). However, little research has been done looking specifically at bryophytes at any kind of forest edge with the exception of a few studies (Hylander 2005, Hylander et al. 2005, and Stewart & Mallik 2006) none of which focus on edges at wetlands. Wetland bryophytes are important to consider at edges because they can influence other communities around them. For example, studies have already shown that *Sphagnum*, one of the major bryophytes found in wetland bogs, influences the growth and development of vascular plants more significantly than it itself is influenced by vascular plants (Malmer et al, 1994).

Different types of bryophytes are found in different types of wetlands, and as in many areas around the world, wetlands in Nova Scotia are very diverse. Due to the geography and climate, the southern part of Nova Scotia is home to some very ecologically important and unique wetlands (Province of Nova Scotia, 2009). Different wetlands have been classified in southern Nova Scotia, more specifically in and around Kejimikujik National Park, (Hurlburt et al. 2007). This classification of the wetlands in this area provided an opportunity for this research.

Sites were chosen based on their classification, thus keeping wetland sites as similar as possible.

Purpose:

By determining the effective edge depth for different types of bryophytes at bog and lake edges, this study can compare the two edge types and establish any major differences that may be important when considering riparian zones at different types of forest edges. The results of this research can be used to determine whether or not sufficient riparian zones are currently being implemented and whether they should be different depending on edge type. Also, bryophyte diversity across edges is worth exploring as it may help determine patterns of bryophyte diversity in our environment and therefore could eventually lead to identifying key areas for conservation.

My study focuses on the question: How does the bryophyte distribution and abundance change across the transition from bog to forest, and how does it compare to lakeshore edges? To attempt to answer this question, I have established three main objectives: (1) to determine if trends of substrate moisture and acidity are associated with trends found for different types of bryophytes across bog and lakeshore edges; (2) to determine the distance of edge influence for the frequency and abundance of bryophytes at these two different edges types (bog and lake); and, (3) to compare bryophyte biodiversity at bog edges and at lakeshore edges. For this study, distance of edge influence (DEI) is defined as a set of distances from the edge where a variable is significantly different from the reference plots in the interior bog or forest (Harper & Macdonald, 2001).

Literature Review

This literature review provides a context for studying bryophytes at wetland edges. As the study of ecosystem edges is a relatively new field, the source search for this section was limited to studies done after 1990. While research for this study focused on bog wetlands specifically, the literature review was expanded to include different types of wetlands to get a broader sense of what has been studied. Although studies have been conducted on edges, wetlands and bryophytes separately, little is known about the collaboration of these three components together.

Edges:

Ecosystem edges are very important components of the landscape, and include boundaries in which one ecosystem type transforms into another. These transitions into surrounding environments are some of the most dynamic and complex systems on earth (Naiman et al., 1993). How an ecosystem transitions into another, which variables change, and what happens to the structure, can reveal a lot about how ecosystems work and connect with their bordering ecosystems. Not only do edges house important ecotonal (or transitional habitat) features, but their structure and composition are particularly important to biodiversity (Wuyts et al., 2009).

The structure of an edge can have an effect on the adjacent ecosystems near the edge. Determining the edge width of different types of variables can help establish how the structural components at the edge are influenced by environmental variables such as moisture, pH levels and/or canopy cover. The edge width is often referred to as “distance of edge influence” and can be very different depending on the species or variable (Moen & Jonsson, 2003). In a study of natural lakeshore edges, edge structure was examined by looking at the individual species composition, and the distance of edge influence varied depending on the species (Harper & Macdonald, 2001). The structure at edges can affect edge permeability (Cadenasso & Pickett, 2001). This permeability will help determine both what flows through the edge and what is deterred. These fluctuations in flows from one ecosystem to the other can lead to high levels of biodiversity at ecosystem edges (Naiman & Decamps 1997).

Ecosystem edges can be unique for their high levels of biodiversity (Naiman et al., 1993). Studies on birds for example, have shown that riparian zone edges play an important role in maintaining bird diversity as the native edge vegetation provides vital habitat for a broad variety of bird species (Berges et al., 2010). In addition, studies looking at diversity at edges in terms of grasses, herbaceous plants, and vegetation in general have found there can be higher levels of biodiversity across an edge than compared to within the ecosystems themselves (Luczaj & Sadowska, 1997). In the case of invertebrates, edges have been found to act as a broad ecotone for certain invertebrates causing significantly different gradients of change across an edge depending on the species (Dangerfield et al., 2003). It should be noted that studies focusing on mammalian species have actually shown higher rates of diversity away from edges (Stevens & Husband, 1998 and Asqulth & Mejia-Chang, 2005). However, it is generally understood that overall biodiversity is higher at ecosystem edges. This increase in biodiversity is due to many different factors. While interactions of variables such as nutrient composition, light, acidity, and temperature do affect the overall structure and composition of edges, hydrology has the greatest influence for riparian ecotones (Naiman, & Decamps 1997). Changes in biodiversity may be more prominent across edges of water-sensitive ecosystems such as wetlands.

Wetlands:

Wetlands have been a source of interest for conservation ecologists primarily because they are considered to be unique and sensitive ecosystems. Many studies have documented the sensitivity and unique structure of these ecosystems, and even very small wetlands have been found to be of great importance when considering biodiversity (Gibbs, 1993). Wetlands are important for providing habitat for a large variety of plant and animal species and provide all species with vital ecosystem services. Wetlands assist in nutrient retention from agricultural run-off (Vellidis et al., 2003), filter and purify water, provide protection against flooding (Woodward & Wui, 2001), and play a major role in mercury cycling (St. Louis et al., 1994). While some of these services provided by wetlands are well understood, there is still much to learn about individual wetland classification and wetland gradients

There are many different ways of classifying wetlands. The differences and similarities between bogs, fens and swamps tend to overlap between wetland types, making classification very challenging. For example, bogs and fens are similar in composition but can be distinguished chemically, while the chemical comparison between fens and swamps overlap a great deal (Locky et al., 2005). Under the Nova Scotia Wetlands and Coastal Habitats Inventory, Nova Scotia's Department of Natural Resources has classified different types of wetlands in Nova Scotia based on peat depth and hydrology, and then sub-classified these types further based on vegetation type (Hurlburt et al., 2007). However, this kind of interpretation scheme does not take into consideration the differences in peat depth and/or nutrient status within forested wetlands, which then results in incorrectly classifying certain types of fens and shrub swamps (Hurlbert et al., 2007). Hubley (2007) took on the challenge of classifying wetlands more fully in and around Kejimikujik National Park and the Tobiatic area by assigning wetlands a true bog value. To differentiate between a poor fen and a true bog, Hubley (2007) took into account the differences in vegetative grasses, open water close to the surface, landscape profiles including the presence of dry hummocks, and the proportions of three specific tree species: larch (*Larix laricina*), red maple (*Acer rubrum*), and black spruce (*Picea mariana*) (Hubley, 2007). This study extensively classified entire wetlands in southwest Nova Scotia, and helped define and clarify true bogs. This classification greatly assists other studies on wetlands in Nova Scotia located in the southwest, and provided a foundation for this study on wetland edges.

Bryophytes:

Most studies on wetland edges have focused on the dynamics of vascular plants (Stewart & Mallik, 2006), as well as lichens and liverworts (Moen et al., 2003). Few studies have looked specifically at how bryophyte composition changes over a wetland edge. The study of bryophytes can reveal a great deal of information about the functions of a wetland ecosystem, as they contribute to system biodiversity and biomass, influence microclimate, soil moisture, vertebrate and invertebrate populations, and assist with nutrient cycling (Stewart & Mallik, 2006). One of the very few studies to have looked at bryophytes at a wetland edge found that many species of bryophytes responded to ecotonal changes by varying their abundance (Bauer et al., 2007). A study by Hylander (2005) looked at bryophytes across a clear cut edge, and also found differences in bryophyte abundance depending on the species. However, the pattern of this variation and the distance of edge influence of bryophytes at wetland edges in particular are yet to be understood.

Past studies have expressed a need for more in-depth research in the area of bryophyte dynamics across these edge systems (Stewart & Mallik, 2006; Bauer et al. 2007). The literature thus far has indicated that wetland ecosystems are sensitive, that the edge systems play a key role in local diversity and in defining the flows in and out of the system, and that bryophytes have the potential to reveal information about the functions of these systems. By tying these three major components (wetlands, edges and bryophytes) together, this thesis will add to the growing field of ecosystem edge research, and will attempt to demonstrate the role bryophytes play in these systems and what they can reveal about these systems' functions.

Methods

Study Area

The study area is located in southwest Nova Scotia, with the sites located in Kejimkujik National Park and close surrounding areas (Figure 1). This part of Nova Scotia has a modified continental climate with an average annual rainfall (for Kejimkujik) of 1155.4 mm, and temperatures averaging -6.1 ° C in January and 18.4° C in July (Environment Canada, 2010). In the southwest, Nova Scotia is generally found to be slightly warmer with higher levels of precipitation than eastern Nova Scotia due to the gradual slope upwards from the Atlantic coast (Nova Scotia Museum of Natural History, 1996). The proximity to the coast also causes humidity levels to be relatively high throughout the year. This humid and moist climate is what drives a soil-forming process known as podzolization, causing soils, particularly in the southern part of the province, to be fairly acidic (Nova Scotia Museum of Natural History, 1996). This climate is ideal for wetlands and peat land bogs that are particularly abundant in southwest Nova Scotia.

Data collection

Data were collected across four bog edges and four lakeshore edges in Kejimkujik National Park and surrounding areas in southern Nova Scotia (Figure 1) from June to August 2010. All four of the bog sites were classified as true bogs (values of 0.98-1.0 out of 1.0) by Hubley (2007), who considered differences in vegetative grasses, surface water, landscape profiles (presence of dry hummocks), and proportions of specific tree species to classify the wetlands. Only bog and lakeshore edges next to *Picea* (spruce) dominated stands were selected.

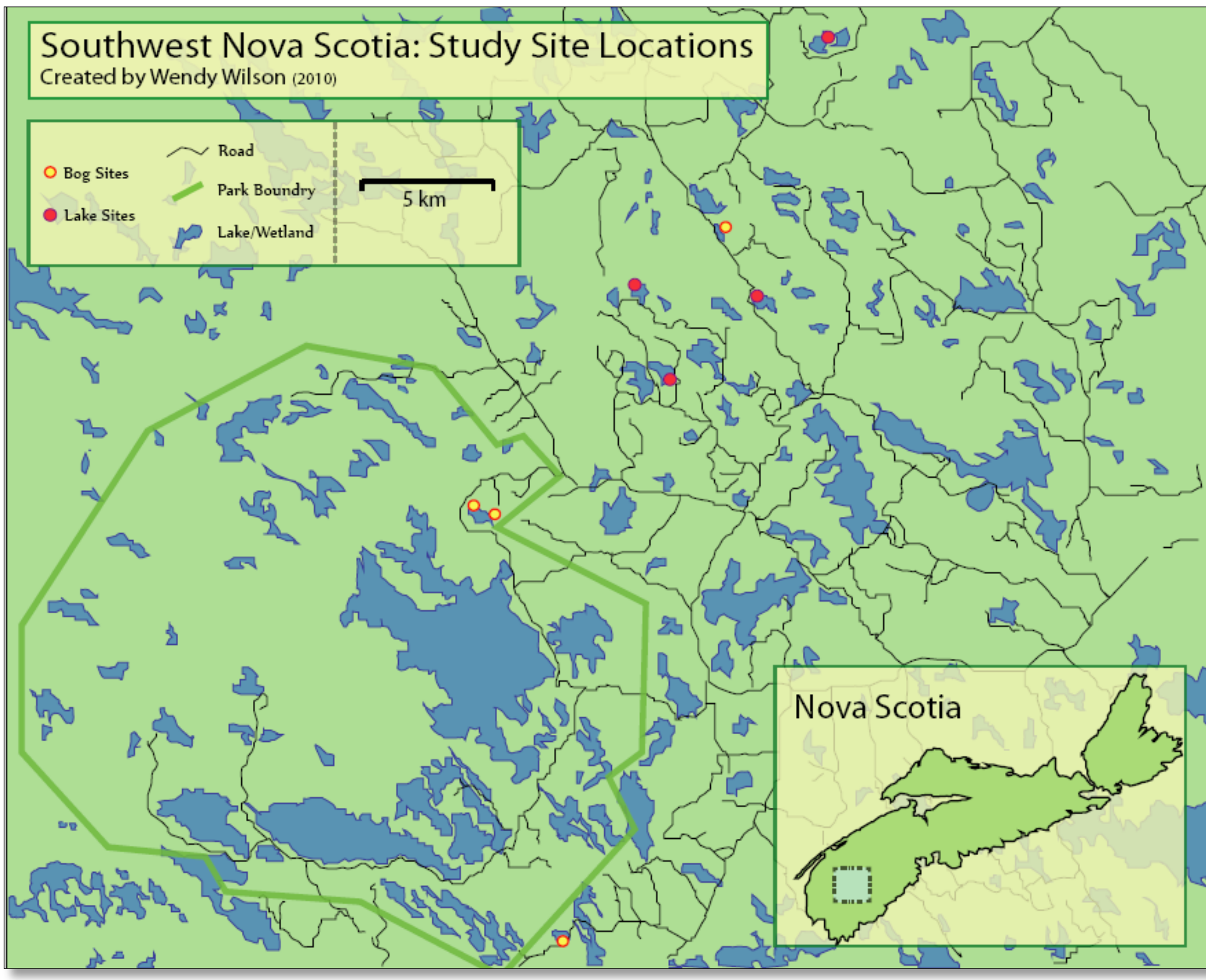

Figure 1. Map of site locations.

Transects 360m in length were set up perpendicular to 4 lakeshore edges and 4 bog edges extending +180m from the lake/bog into the inner forest and -180m into the lake/bog. At both the lakeshore and bog edge sites, the limit of continuous forest canopy was used to determine the 0m marker. Along each transect, sampling points were set up at ±5, ±15, ±25, ±40, ±60, ±100, ±140, and ±180m from either side of the edge (Data in the lake was not actually measured; values for bryophyte and vegetation cover were assumed to be 0% where there was open water). Sampling points at ±100m, ±140m, and ±180m provided reference sample points to ensure that the transect edge had fully transitioned into true forest or bog. At each sampling point, several small handfuls of bryophytes were collected across 5m spans along the transect (e.g., +97.5m to +102.5m for the +100m sampling point). The bryophytes were then taken back to the lab and identified. Soil samples were also taken at each sampling points as three small handfuls in 1m increments perpendicular to the transect. The soil was weighed shortly after collection then air-dried and weighed again to determine moisture content. The differences between the wet and dry weights were each divided by the wet weights to normalize the values. Using a pH meter on the dried soil samples, I also measured the pH of the soil along the transect. Tree cover was also estimated at each sampling point using a convex densitometer. Two people provided an estimate facing either end of the transect. This provided 4 different estimates that were averaged at each sampling point to achieve more accurate canopy cover estimates.

Continuous 1m x 1m quadrats were set up from -60 to +60m across the bog edges, from 0 to +60 m across the lakeshore edges, and across 5m spans at the reference sampling points (±100m, ±140m, ±180m, e.g., +97.5m to +102.5m for +100m). Within each quadrat, cover was estimated for individual bryophyte species as well as the total the bryophyte cover. Cover values were estimated visually to the nearest 10%, except to the nearest 1% for cover less than 5%.

Data Analysis:

The frequency and abundance of bryophytes were compared between bog and lake edges. Variables that were analyzed include: bryophyte species richness, soil acidy, soil moisture, canopy cover total bryophyte cover and the cover of common bryophyte species.

Species richness was calculated as the mean number of species. For the cover of individual species as well as total bryophyte cover, cover values were averaged over 5 contiguous quadrats at each sampling point (e.g., from +2.5 to +7.5 for +5m). The distance of edge influence (DEI) was estimated for variables at each type of edge using an Excel Add-In called RTEI that runs randomization tests (Harper & Macdonald, unpublished). The DEI is defined as a set of distances from the edge where a variable is significantly different from the reference plots in the interior bog or forest (Harper & Macdonald, 2001). RTEI analysis takes the mean difference between reference values and values at a given distance from the edge and compares it to a distribution of differences created by randomizing the set of data from the reference distances and the given distance from the edge (Mascarúa López et al., 1996). For determining significance, p-values used were 5 and 10%, respectively for significant and moderately significant, using a two-tailed test.

Results

Overall there were 20 different bryophyte species identified along the bog transects and 16 bryophytes species along the lakeshore transects (Appendix 4). Species richness ranged from a minimum of 1 species to a maximum richness of 8 species per sampling point, both located in the bog transects. The lakeshore bryophytes included: *Pleurozium schreberi, Dicranum spp, Hylocomium splendens, Bazzania trilobata, Hypnum imponens, and Leucobryum glaucum*. The bog bryophytes were the same with the addition of *Sphagnum* spp.. There were a total of 24 different bryophyte species that were identified in the lab (Appendix 4).The most common species found at both the lakeshore sites and the bog sites was *Pleurozium sherberi*. Total moss cover varied along the transects, but was lower near both types of edge (Figure 2.).

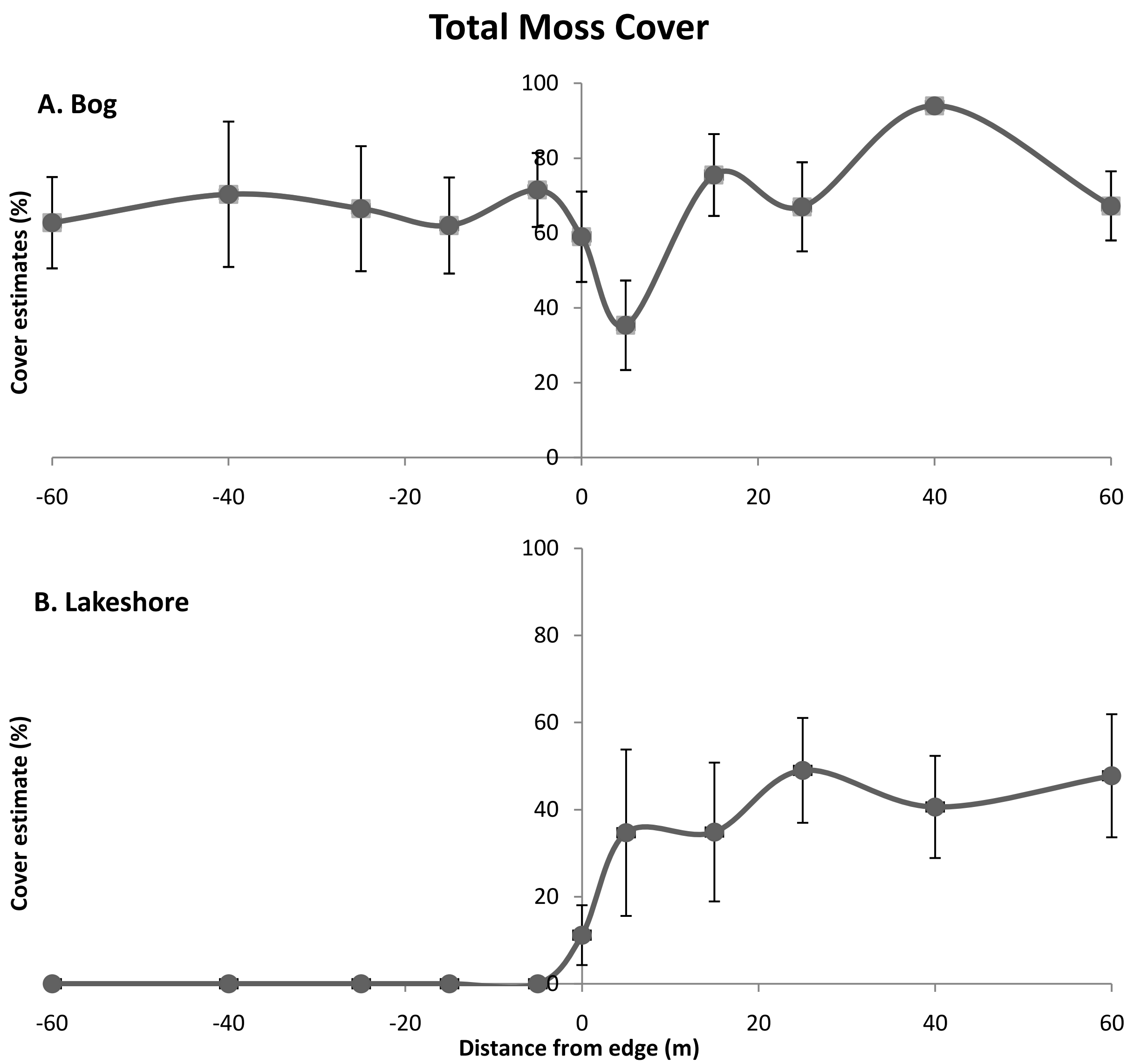

Figure 2. Mean cover ± standard error for total bryophyte across A) bog and B) lake edges.

Species richness across the bog edge peaked at all four bogs within the edge sampling points from -60m to +60m (Appendix 3). At lakeshore edges, species richness started high, increased and then decreased from the lake to the forest (Figure. 3b). Along the bog transect, species richness at -40m, -25m, -15m, -5m, +5m and +40m was significantly greater than in the bog reference. Along the lakeshore transect, +40m had significantly higher species richness than in the forest.

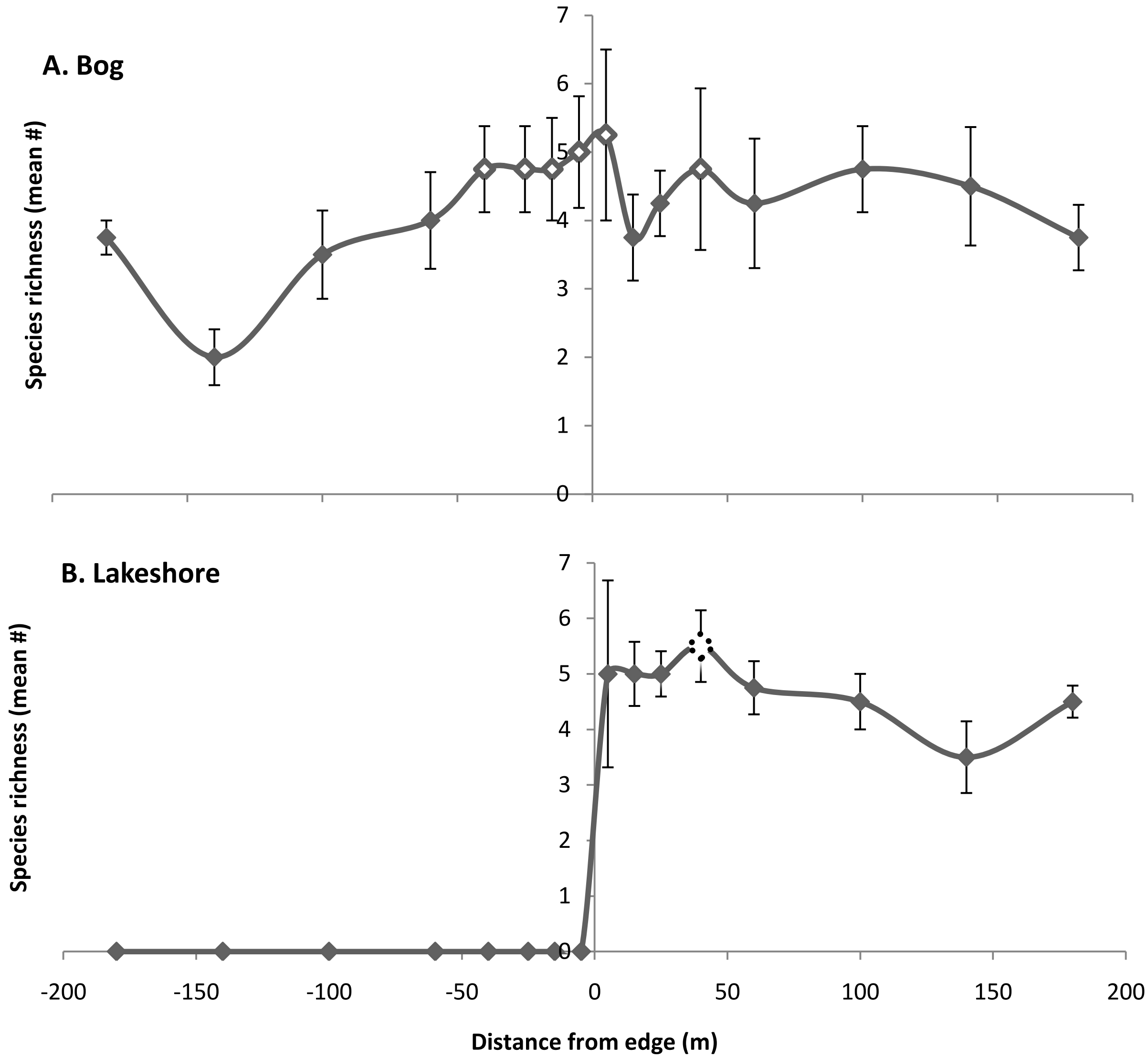

Figure 3. Mean species richness ± standard error along A) bog and B) lake edge transects. Values that are significantly different from the bog references are represented by open points, and values significantly different from the forest references are represented by dashed open points.

Only seven bryophyte species across the bog transects and six across the lakeshore transect could be identified in the field and therefore had their abundance estimated. Edge influence was significant for four bryophyte species that could be identified in the field: *Pleurozium schreberi*, *Dicranum* spp., *Hylocomium splendens*, and *Sphagnum* spp. Within the bog transects*, Pleurozium schreberi*, *Dicranum* spp., and *Sphagnum* spp. were all found to be significantly different than the bog from +15m to +60m (Table 1). *Hylocomium splendens* had a narrower distance of edge influence from +40m to +60m. When bog edge transects were compared with the forest, *Pleurozium schreberi* was found to be significantly more abundant from +25m to +40m, and *Sphagnum* sp. more abundant from -60m to +5m. *Dicranum* spp. was found to be significantly less abundant than forest from -5m to +5m. For the lakeshore edge, only *Pleurozium schreberi* was significantly less abundant than the forest from 0 to +5m and at +40m.

Table 1. Significant distance of edge influence (DEI) for different bryophyte species across bog and lakeshore edges. Significant differences are defined as DEIs calculated with p-values outside 5% confidence interval using a two-tailed test. Bold values indicate significantly more abundant, while normal font represents significantly less than the reference.

	Significant DEI (m)		
Species	Bog edge vs. bog reference	Bog edge vs. forest reference	Lake edge vs. forest reference
Bazzania trilobata	ns[1]	ns	ns
Dicranum spp.	**+15 to +60**	-5 to +5	ns
Hylocomium splendens	**+40 to +60**	ns	ns
Hypnum imponens	ns	ns	ns
Leucobryum glaucum	ns	ns	ns
Pleurozium schreberi	**+15 to +60**	**+25 to +40**	0 to +5, +40
Sphagnum spp.	**-60 to -40**, +15 to +60	**-60 to +5**	np[2]

[1]ns= non-significant
[2]np= not present

Cover estimates across the edge from -60m to +60m for different bryophytes revealed some overall trends. *Dicranum* spp. abundance across the bog edge was lower from -5m to +15m, and also across the lakeshore edge from 0m to +15m (Figure 4). There was a noticeable increase in *Pleurozium schreberi* abundance from the edge into forest (Figure 5) as it became a dominant species between +15m and +25m, covering more than 40% of the sample plots. This trend for was not visible at the lakeshore edges.

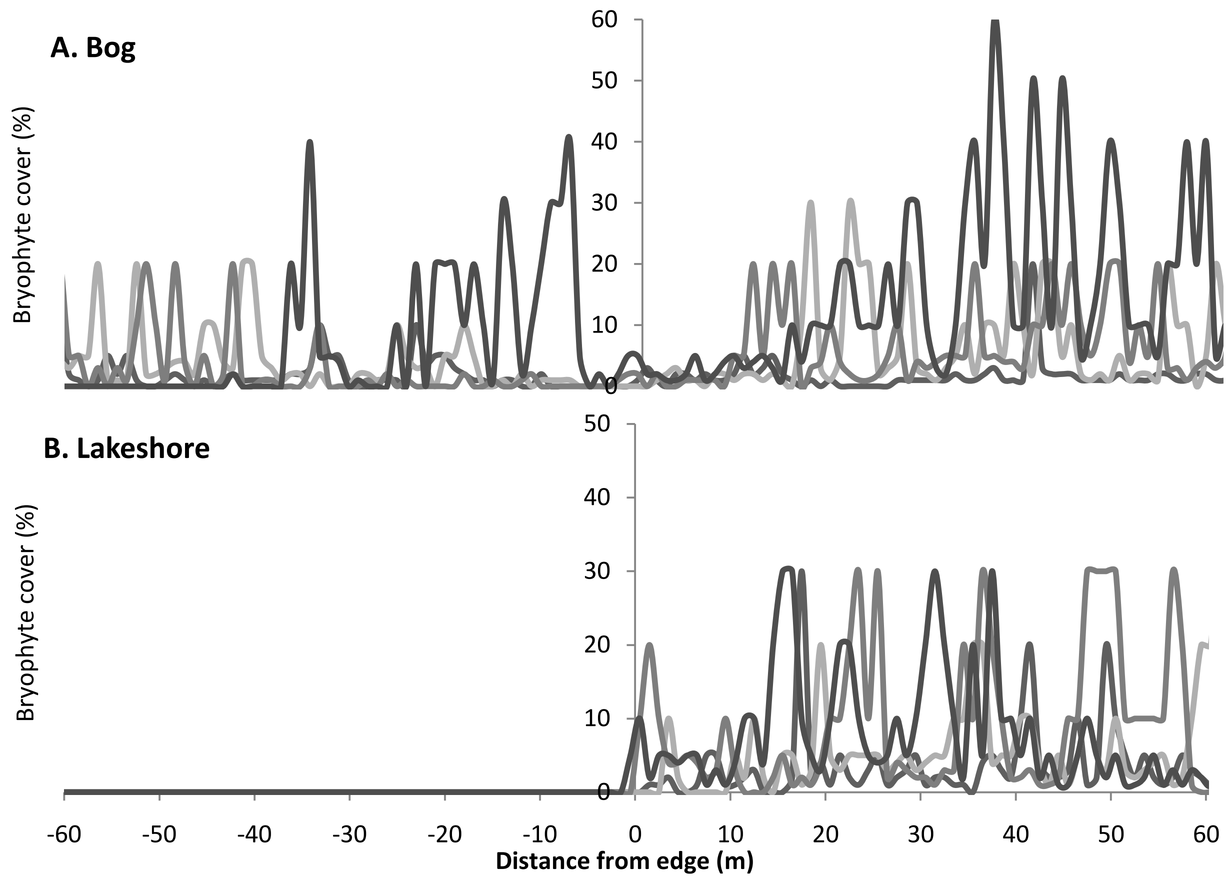

Figure 4 Cover of *Dicranum* sp. as measured in the contiguous quadrats across individual transects at A) bog and B) lakeshore edges. Four transects are represented by different lines in each graph.

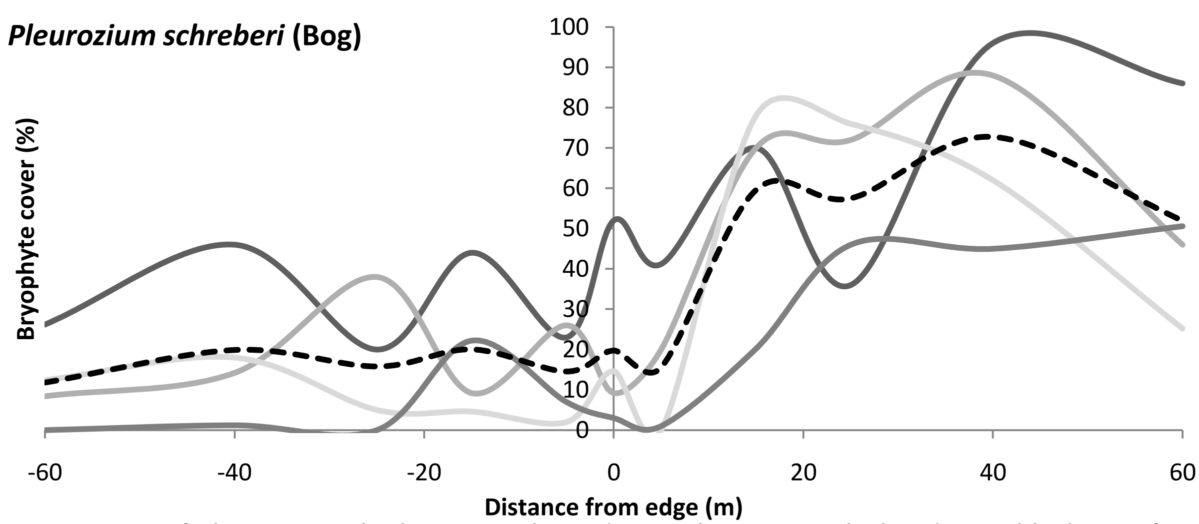

Figure 5. Cover of *Pleurozium schreberi* across bog edges. Values were calculated using blockings of 5m at the designated sampling points (0m, ±5m, ±15m, ±25m, ±40m, and ±60m). Four transects are represented by different lines in each graph, with the mean of all four transects represented by the dashed line.

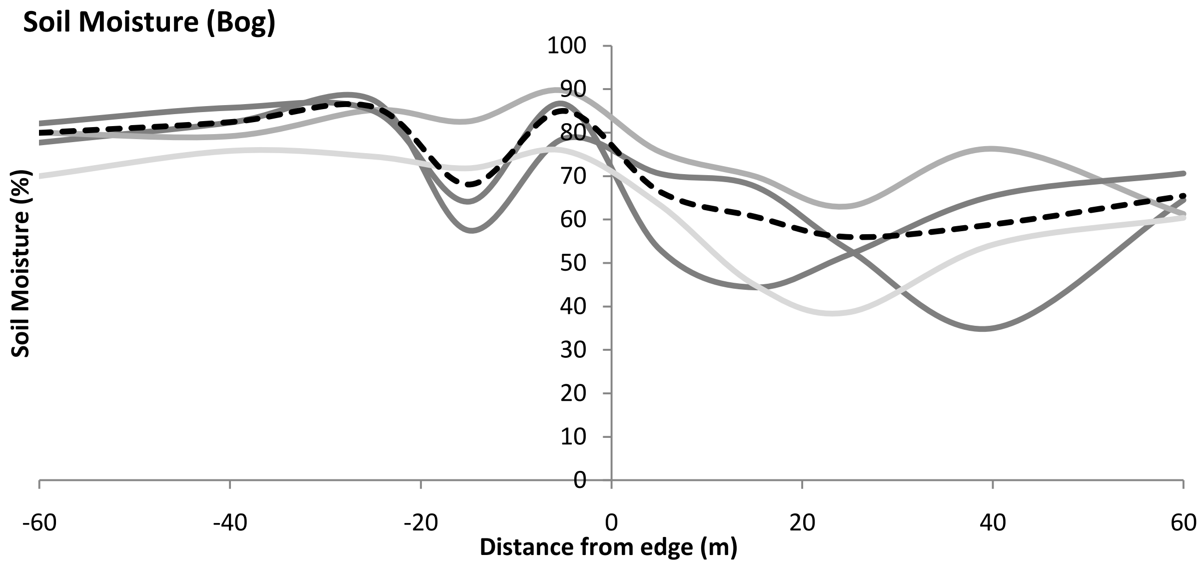

Figure 6. Soil moisture across the bog edge. Proportions were calculated (wet weight- dry weight)/ wet weight). All four bog transects are shown in different shades, with the mean of all four transects represented by the dashed line.

The environmental variables measured (pH, soil moisture, canopy cover) showed no noticeable trend at the lakeshore transects (Appendix 1). At the bog edge, soil moisture decreased from the bog to the forest (Figure 6), pH stayed generally the same across the edge, and canopy cover increased from bog to forest (Appendix 1).

Discussion

Of the soil attributes (moisture and pH), only soil moisture showed an interesting trend of an overall decrease from bog to forest. *Pleurozium schreberi* did the opposite and increased in abundance from bog to forest. These opposing trends support my first objective that soil moisutre is connected to the structure of bryophytes across an edge and compliments a study by Bauer et al (2007) which found that *Pleurozium shreberi* growth was limited to the drier areas of the moisture regime across wetland edges. This also supports the idea by Naiman & Decamps (1997) that hydrology plays one of the major roles in influencing the structure of riparian ecotones. At the lakeshore edge, no trend was found for either soil moisture or pH, and similarly there was no trend found for different types of bryophytes.

Regarding the second objective, distance of edge influence (DEI) was different for different bryophytes and for the different edge types. This corresponds with what has been found for other species such as liverworts and lichens (Moen & Jonsson, 2003). While each variable differed in terms of where its DEI started, there were some common distances to where the DEI would extend to. When compared to the forest reference, both *Dicranum* spp. and *Sphagnum* spp. had significant DEI's up to +5m from the edge. *Pleurozium scherberi* had a significant DEI as far as +40m from the edge. This supports the idea that a bryophyte edge differs according to species type. In terms of edge type, more species had significant DEI's across the bog edges, where as only 1 of the 8 common species (*Pleurozium schreberi*) had a significant DEI at the lakeshore edge. When comparing values to the forest reference, the farthest DEI was found at both edge types at +40m for *Pleurozium scherberi*, however the bog edge also had *Sphagnum* spp. and *Dicranum* spp. DEI's at +5m, suggesting that the edge influence on bryophyte abundance at lakeshore edges may not be as prominent compared to bog edges.

In regards to my third objective, the results supported what has been found by many other vegetation edge studies: ecosystem edges tend to have unique high levels of biodiversity (Naiman et al., 1993, Luczaj & Sadowska, 1997). Significant differences were found from -40m to +40m in the bog, indicating significantly greater species richness between those distances than compared to the bog references. While significant differences were not found when compared to the forest references, it should be noted that the mean species richness does peak within the edge (Figure 3.). This peak may be an indicator of a trend that is not statistically found in this study due to the small sample size. The lakeshore edge only showed one distance from the edge (+40m), that was significant in terms of species richness.

The results indicate that there are unique features of bog edges that are not found in either bog or forest. At the bog transect, there is lower total bryophyte cover only at the edges. While the reason for this abrupt decline in bryophyte abundance is not clear and was not found to be directly associated with the environmental factors measured (pH, soils moisture, canopy cover), greater tree density was another unique feature found at bog edges (Harper, unpublished data). These features are unique to the edge and may have an influence on other components in the edge ecosystem such as other vegetation, insects and/or other invertebrates.

The lack of correlations and significant differences found at the lakeshore edge suggests that bryophytes may not be as sensitive to edge transitions at lakeshore edges as compared to bog edges. This relates to the findings of Naiman & Decamps (1997) that hydrology is a major influencing variable across an edge. The bog transects had much more variation in terms of soil moisture than the lakeshore edges (Appendix 1). While this does indicate a difference between the two edge types, the trend in *Dicranum* spp. abundance was shared between both edge types. The decrease in *Dicranum* spp. abundance at both edge types between 0m and +15m corresponds with the general trend for total bryophyte abundance (Figure 2). Species richness had the opposite trend of lower values farther from the edge. This suggests that while an edge generally has less bryophyte abundance than the surrounding ecosystem, the species richness is actually higher.

This study was limited in terms of sample size. Future studies should be done with a greater sample size to take into account bog variability. A closer look at how bryophyte richness across edges varies compared to bryophyte abundance is needed to establish a definite correlation.

The results from this study suggest that a look at current development regulations in terms of riparian zones is needed to determine whether or not sufficient distances are being implemented in terms of bryophyte edge widths. Edges can have unique structures that may be ideal for certain plants, insects, and/or other species that are not found within the surrounding ecosystems. The different characteristics found in this study that are exclusive to the edge, indicate that it is a unique habitat on the landscape and could therefore be important for conservation.

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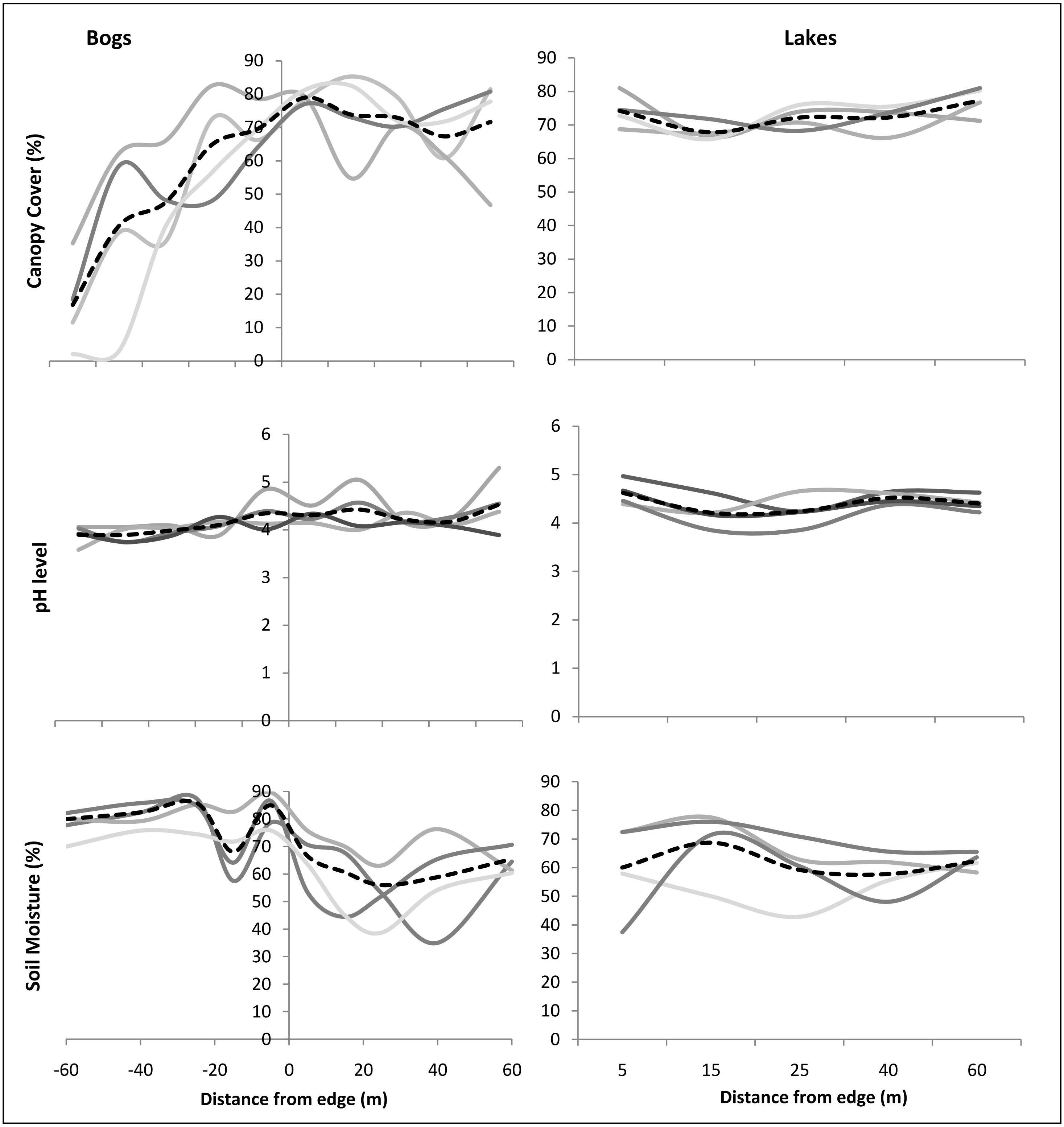
Appendix 1 - Environmental Variables



Appendix 1. Canopy cover(%), pH levels, and soil moisture(%) across bog and lakeshore edges. All four transects are shown for each edge in different shades, with the mean of all four transects represented by the dashed line.

Appendix 2a. – Bryophyte Cover Data (Bog)

Bryophyte Cover	Distance from bog edge (m)								
		-180	-140	-100	-60	-40	-25	-15	-5
Pleurozium sherberi		26 ± 13.9	24 ± 17.7	19.2 ± 11.2	11.8 ± 5.5	19.8 ± 9.4	15.8 ± 8.5	20 ± 8.8	14.5 ± 5.9
Dicranum spp.		3.2 ± 2	0.1 ± 0.1	0.8 ± 0.3	3.7 ± 1.9	4.1± 2.2	3.4 ± 1.2	4.6 ± 3.9	2.4 ± 2.3
Bazzania trilobata		3.7 ± 2.3	0.6 ± 0.5	0.8 ± 0.3	1.6 ± 0.9	1.6 ± 0.8	1.9 ± 1.1	0.9 ± 0.6	0.8 ± 0.5
Leucobryum glaucum		0	0	0	0	0	0	0.3 ± 0.3	0
Hypnum imponens		0	0	0	0	0.1 ± 0.1	0	0	0
Hylocomium splendens		0	0	0	0	0	0	0	0.3 ± 0.3
Sphagnum spp.		19.9 ± 7.8	15.8 ± 3.9	24.0 ± 9.6	48.8 ± 7.6	47.7 ± 12	47.1 ± 16	37.5 ± 15.6	50.3 ± 13.9
	0	**+5**	**+15**	**+25**	**+40**	**+60**	**+100**	**+140**	**+180**
Pleurozium sherberi	19.7 ± 11	15.6 ± 9.7	59.6 ± 13.2	57.5 ± 9.8	72.8 ± 11.8	52 ± 12.6	15.3 ± 5.5	15.5 ± 10	47.8 ± 16.8
Dicranum spp.	1.5 ± 0.6	1.4 ± 0.3	5.2 ± 2	8.2 ± 3.4	12.7 ± 5.3	7.9 ± 2.8	5.8 ± 1.3	7.8 ± 4	7.3 ± 2.7
Bazzania trilobata	5.2 ± 5.1	4.6 ± 4.6	7.1 ± 6.5	5.7 ± 4.4	1.8 ± 1.8	4.2 ± 4.2	3.0 ± 2.9	1.9 ± 0.7	11.3 ± 11.3
Leucobryum glaucum	0.1 ± 0.1	0.6 ± 0.2	0.1 ± 0.1	0	0.2 ± 0.2	0.1 ± 0.1	0.2 ± 0.1	0.8 ± 0.8	0
Hypnum imponens	0.8 ± 0.8	1.3 ± 1	0.8 ± 0.8	0.5 ± 0.5	0.3 ± 0.3	0.3 ± 0.3	0.6 ± 0.4	1.6 ± 1.2	0
Hylocomium splendens	2.7 ± 2	0.6 ± 0.6	9.3 ± 6.2	3.1 ± 3.1	9.6 ± 5.6	6.9 ± 2.6	0.9 ± 0.7	3.2 ± 3.0	8.4 ± 6.6
Sphagnum spp.	30.8 ± 2.4	13.0 ± 5.3	0.2 ± 0.2	0	0	0	0	0	0

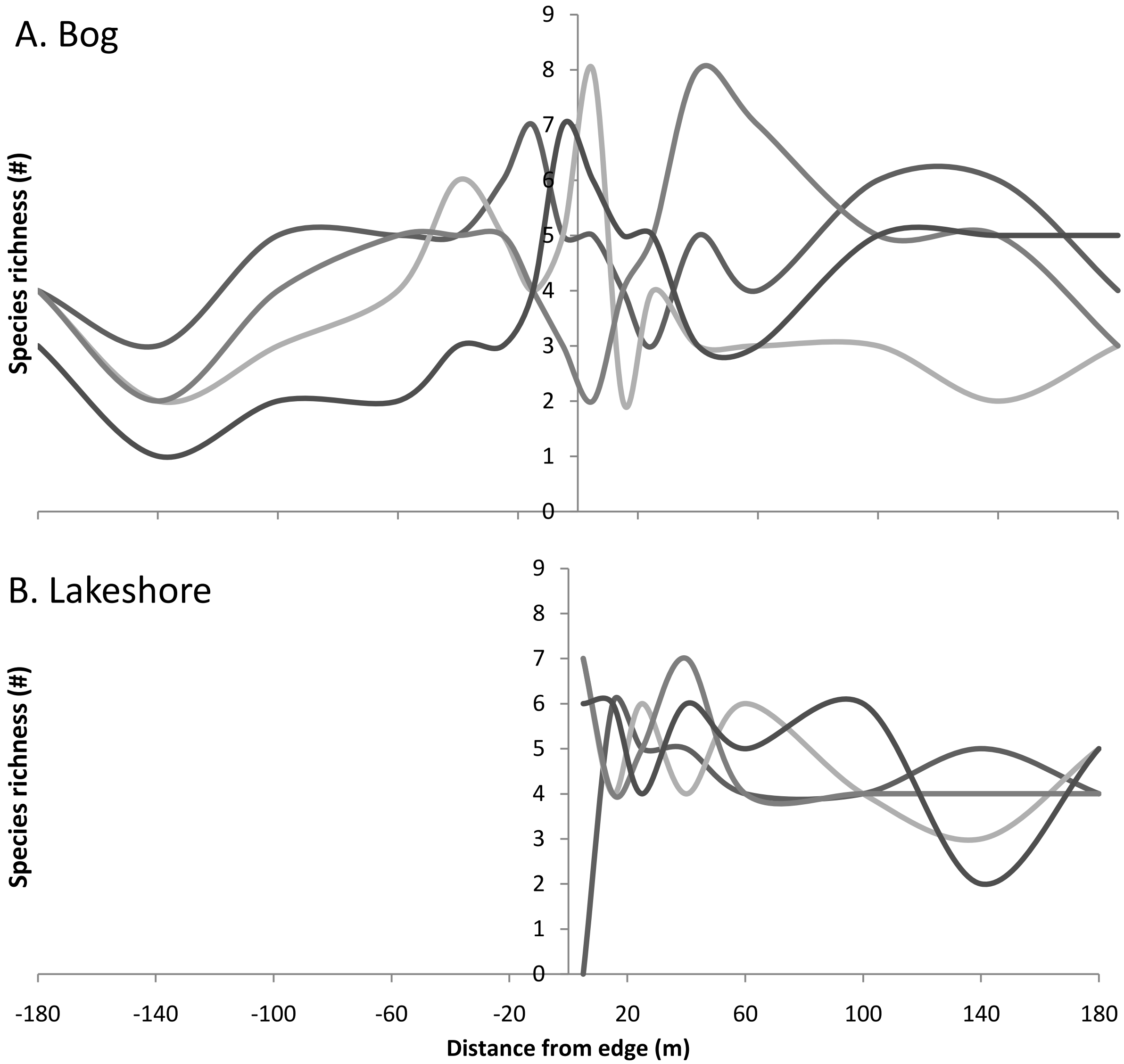
Appendix 2a. Mean percent cover estimates ± standard error for the common bryophytes across all four bog transects.

Appendix 2b. - Bryophyte Cover Data (Lakeshore)

Bryophyte Cover	**Distance from lakeshore edge (m)**								
	0	**+5**	**+15**	**+25**	**+40**	**+60**	**+100**	**+140**	**+180**
Pleurozium sherberi	9.2 ± 5.8	29.3 ± 14.4	28.3 ± 10.5	40.8 ± 13.0	19.7 ± 8.2	27.6 ± 11.5	46.6 ± 11.4	69.6 ± 10.6	58.9 ± 5.3
Dicranum spp.	2.4 ± 1.4	3.4 ± 1.1	6.5 ± 4.2	8.6 ± 3.5	8.8 ± 1.4	7.2 ± 3.8	7.2 ± 2.6	6.7 ± 2.3	6.6 ± 2.3
Bazzania trilobata	2.3 ± 1.9	11.9 ± 4.3	3.4 ± 1.5	2.7 ± 1.0	9.1 ± 8.3	9.3 ± 4.5	7.5 ± 3	15.3 ± 13.1	6.5 ± 3
Leucobryum glaucum	0.4 ± 0.3	1.0 ± 0.7	0	1.6 ± 1.6	0.8 ± 0.4	0.7 ± 0.6	0.3 ± 0.3	0.1 ± 0.1	0.3 ± 0.3
Hypnum imponens	3.0 ± 1.9	3.5 ± 1.2	0.8 ± 0.8	2.2 ± 1.7	1.9 ± 1.4	0.4 ± 0.2	1.7 ± 1.1	0.8 ± 0.8	2.2 ± 1.9
Hylocomium splendens	0	0	1.8 ± 1.4	0.4 ± 0.3	1.1 ± 1.1	0.5 ± 0.5	0.7 ± 0.5	0.1 ± 0.1	5.3 ± 3.5

Appendix 2b. Mean percent cover estimates ± standard error for the common bryophytes across all four lakeshore transects.

Appendix 3 – Species Richness



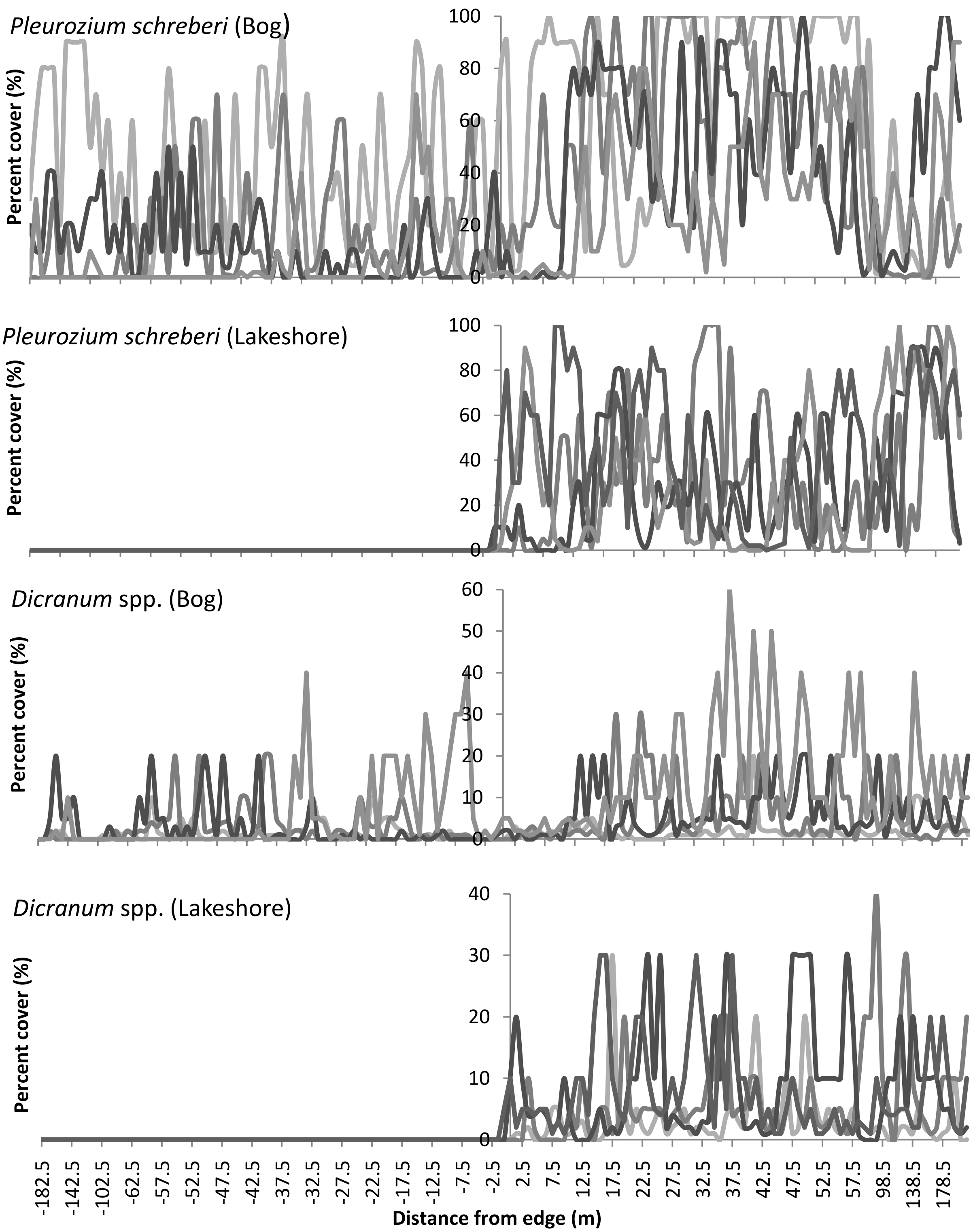
Appendix 3. Species richness along A) bog and B) lake edge transects. All four transect for each edge type are represented by different shades.

Appendix 4- Complete list of bryophyte species identified

Appendix 4. List of total bryophyte species found and identified for each edge type.

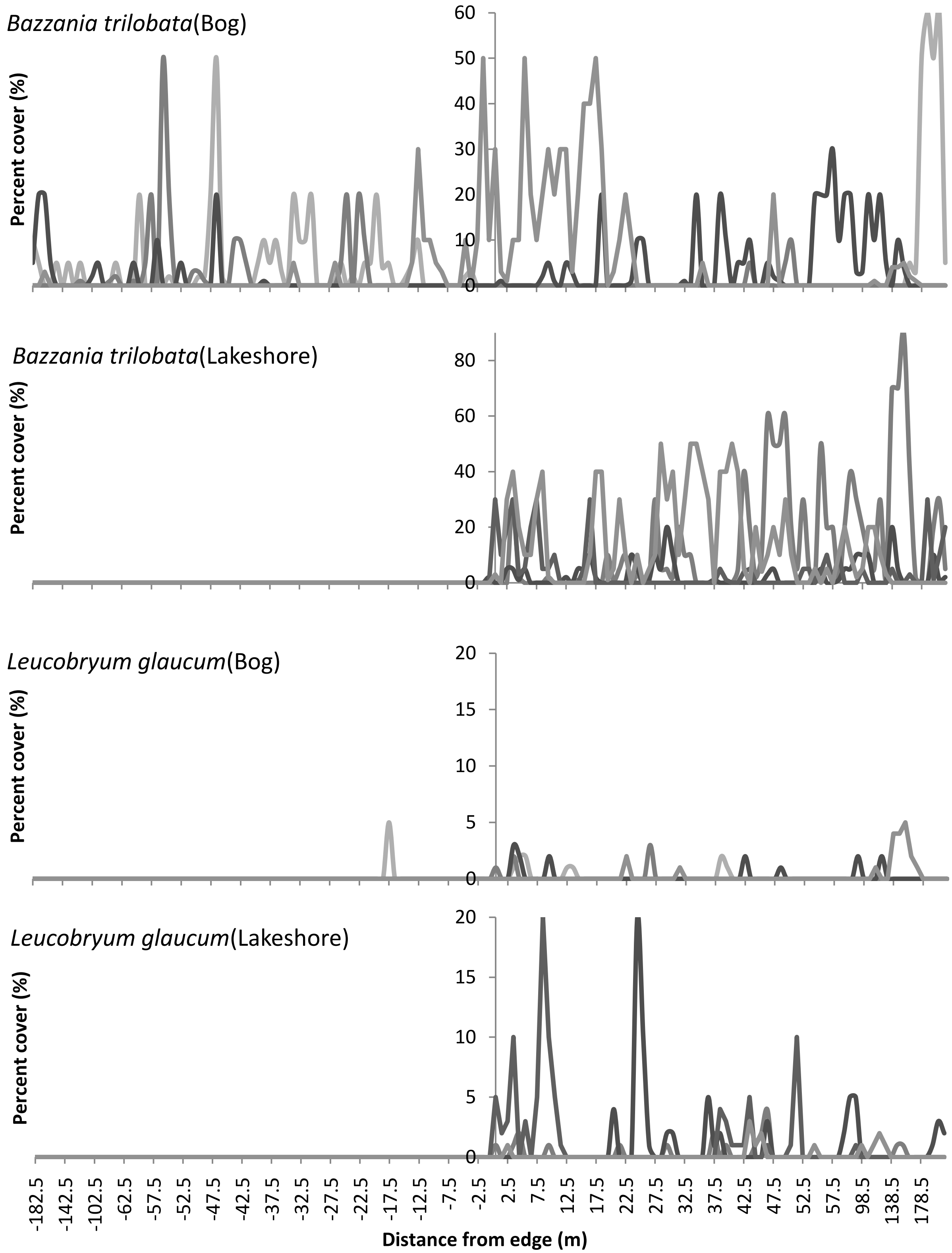
Bog	Lakeshore
Bazzania trilobata	*Aulacomnium palustre*
Brachythecium rutabulum	*Bazzania trilobata*
Dicranum condensatum	*Brachythecium rutabulum*
Dicranum fuscescens	*Dicranella rufescens*
Dicranum polysetum	*Dicranum condensatum*
Dicranum scoparium	*Dicranum fuscescens*
Dicranum spurium	*Dicranum polysetum*
Dicranum undulatum	*Dicranum scoparium*
Hygroamblystegium tenax	*Fissidens strumifer*
Hylocomium splendens	*Hypnum imponens*
Hypnum imponens	*Hypnum pallescens*
Leucobryum glaucum	*Hylocomium splendens*
Ortho dicranum montanum	*Leucobryum glaucum*
Pleurozium schreberi	*Ortho dicranum montanum*
Ptilidium pulcherrimum	*Pleurozium schreberi*
Sphagnum angustifolium	*Ptilidium pulcherrimum*
Sphagnum capillifolium	
Sphagnum cuspidatum	
Sphagnum magellanicum	
Sphagnum rubellum	

Appendix 5a – Contiguous Quadrat Data.



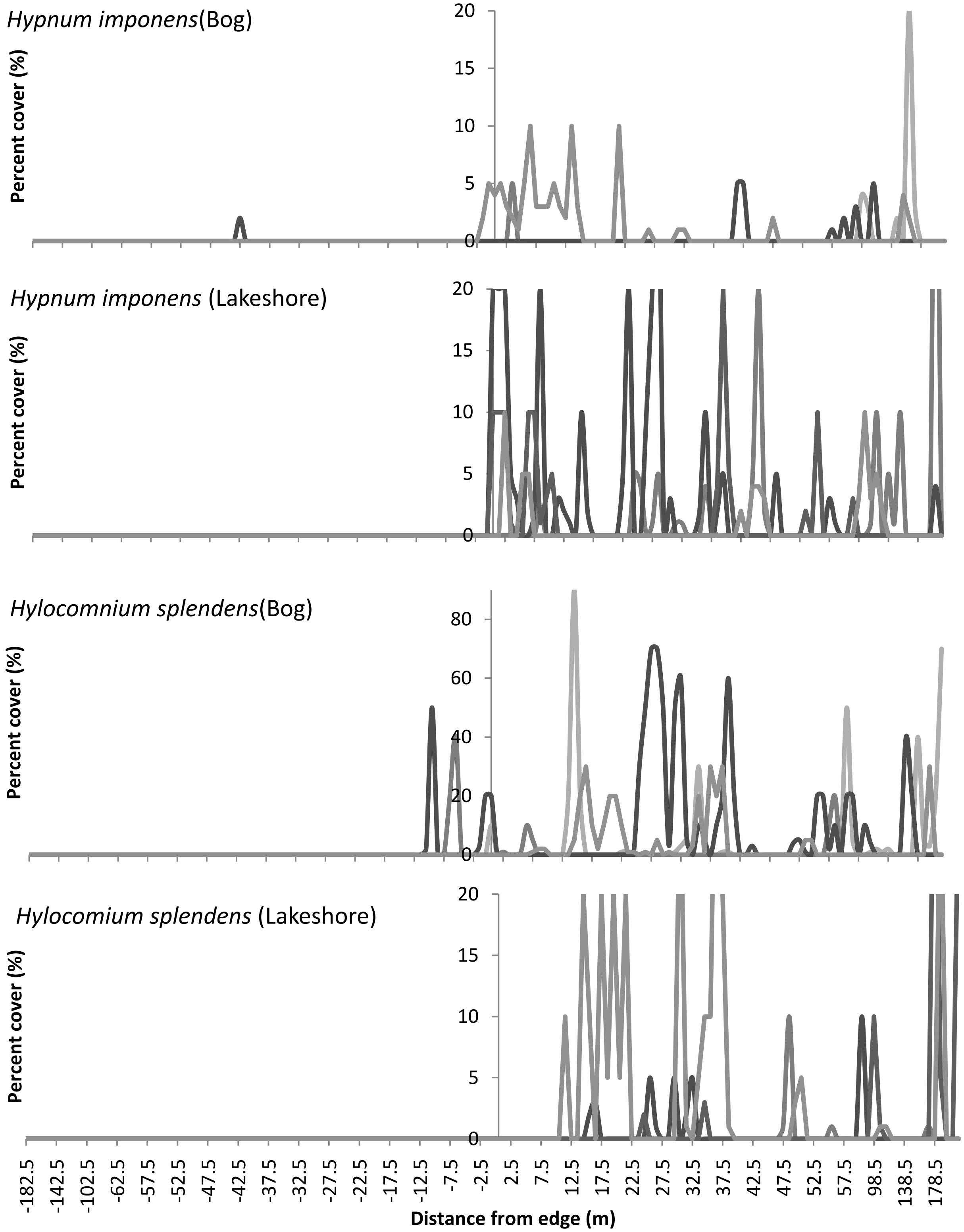
Appendix 5a. Percent cover estimates of contiguous quadrates for *Pleurozium schreberi* and *Dicranum* spp. across bog and lakeshore edges. All four transects are represented by a different shade.

Appendix 5b – Contiguous Quadrat Data.



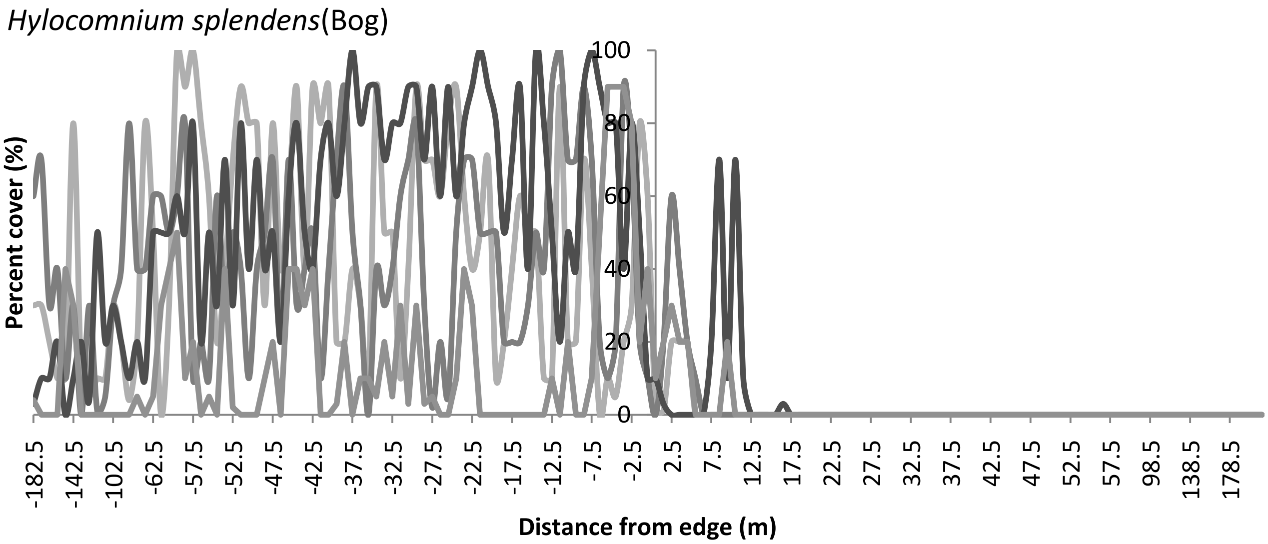
Appendix 5b. Percent cover estimates of contiguous quadrates for *Bazzania trilobata* and *Leucobryum glaucum* across bog and lakeshore edges. All four transects are represented by a different shade.

Appendix 5c – Contiguous Quadrat Data.



Appendix 5c. Percent cover estimates of contiguous quadrates for *Hypnum imponens* and *Hylocomium splendens* across bog and lakeshore edges. All four transects are represented by a different shade.

Appendix 5d – Contiguous Quadrat Data.



Appendix 5d. Percent cover estimates of contiguous quadrates for *Sphagnum* spp. across bog edges. (No *Sphagnum* spp. Was All four transects are represented by a different shade.