A Study of the Effects of Aspect on the Plant Communities in the Bog Ecosystems of Calvert Island

by

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Abstract

The relationship between plant species composition and aspect was studied in a bog ecosystem on Calvert Island, British Columbia. Calvert Island is located on the central coast of British Columbia and is part of the Coastal Western Hemlock Central Very Wet Hypermaritime biogeoclimatic subzone (CWHvh2) of the provincial Biogeoclimatic Ecosystem Classification (BEC) system This subzone is characterized by extensive bog ecosystems in areas where the terrain is relatively subdued. Although bog ecosystems within this subzone have been the source of intensive study, considerations of how northern and southern slope-aspects might affect plant communities has not been thoroughly examined. A survey of northern and southern aspects at three separate sites on Calvert Island was conducted in order to examine whether plant communities changed in relation to aspect. Our findings suggest that aspect does play a role in determining plant community composition. We therefore recommend that future research on the bog ecosystems species of the CWHvh2 subzone consider aspect as an important driver of species composition.

Key words: aspect, bog, Calvert Island, CWHvh2

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Introduction

Calvert Island lies in shared Heiltsuk and Wuikinuxv First Nations territory, roughly midway in latitude between the northern tip of Vancouver Island and the southern tip of Haida Gwaii on the central Pacific coast of British Columbia. Under the provincial biogeoclimatic ecosystem classification system Calvert Island is part of the Coastal Western Hemlock Central Very Wet Hypermaritime subzone (CWHvh2) (Klinka et al.1991). This hypermaritime climate is characterized by moderate annual temperatures, high precipitation and high ambient humidity. The coast of British Columbia receives the greatest amount of precipitation in North America (Asada et al. 2003). On Calvert Island this climate is combined with a mineral-poor bedrock that promotes widespread bog formation on subdued terrains (Klinka et al. 1991; Asada et al. 2003).

Bog ecosystems make up a large portion of Calvert Island's landscape. These ecosystems can be classified as per the BEC system into bog forests, bog woodlands, and blanket bogs (Banner et al. 2005). Bogs are nutrient-poor, *Sphagnum*-dominated peatland ecosystems with a rooting zone that is isolated from the mineral enriched ground water. The soils of bogs are acidic and few minerotrophic plants species occur. Bogs also have a poor nutrient regime despite mineral enriched groundwater. (Banner et al. 2005; MacKenzie & Moran 2004).

These bog ecosystems have a globally unusual vegetation species composition due to the hypermaritime climate of the outer coast (MacKenzie & Moran 2004). They are characterized by abundant *Sphagnum* mosses, conifers and ericaceous shrubs that are well adapted to nutrient-poor conditions (MacKenzie & Moran 2004). Sphagnum mosses drive these ecosystems as they acidify the organic soil and slow decomposition through moisture retention. This in turn promotes peat accumulation. Stunted conifer trees, such as shore pine (*Pinus contorta*), yellow cedar (*Chamaecyparis nootkatensis*), western redcedar (*Thuja plicata*), sparse shrub and herb layers are common in this ecosystem. Dwarf shrubs dominate in areas where the watertable is at the surface as trees are incapable of survival (MacKenzie & Moran 2004).

Bogs of the CWHvh2 subzone have been studied extensively (see: Banner et al. 2005). Asada et al. (2003) studied the environmental factors responsible for shaping bog ecosystem vegetation communities in the CWHvh2, and found that vegetation gradients in this subzone are primarily explained by slope and minimum ground water table. However in Asada et al.'s (2003) research the effect of aspect was not considered as one of the environmental factors influencing bog vegetation communities. The effect of aspect on plant communities has been widely studied (see: Bennie et al. 2008; Holland & Steyn 1975; Påhlsson 1974). Slope and aspect affect the amount of solar radiation a vegetated surface is exposed to, and this exposure has been shown to influence surface ambient temperature and water movements. Additionally, aspect determines the amount of exposure to photosynthetic wavelengths that vegetation receives (Bennie et al. 2008; Holland & Steyn 1975).

Equatorial slopes (south-facing in the northern hemisphere) receive far more solar radiation than polar slopes (north-facing in the northern hemisphere) and this results in differences in irradiation, temperature, and moisture availability between north-facing and south-facing slopes. In the northern hemisphere south-facing slopes having relatively warmer and drier microclimates (Warren II 2010). Variation in slope and aspect is therefore a key determinant of vegetation patterns, species distribution and ecosystem processes in many environments (Bennie et al. 2008), and should provide a basis for predicting the likelihood of local variations in vegetative species richness and abundance.

In consideration of the body of research showing aspect as a key determinant of plant community composition and structure, and aspect's absence in Asada et al.'s research this study seeks to address the question: do changes in north and south aspect affect plant community structure in bog ecosystems on Calvert Island?

We hypothesize (H_a) that aspect will change vegetation composition at three different treatment sites. The null hypothesis (H_0) is that aspect will not change vegetation composition at three different treatment sites.

Methodology

Study Site Selection

Sites were chosen based on terrain requirements of slope, aspect, and vegetation. Considerations of proximity to the Hakai Beach Institute (HBI) and to areas where other research was being conducted were also determinants.

In order to determine the effect of aspect on plant communities sites with sufficient slope were required – too gentle of a slope and changes in solar radiation exposure would be difficult to detect (Holland & Steyn, 1975). Only north-facing and south-facing slopes were sampled as Holland and Steyn (1975) indicate that the effect of aspect is greatest on a slope of 45 degrees. In the field a compass was used to locate north and south facing slopes. A clinometer was used to measure slope angle. Preliminary field observations indicated that sites with slopes near 45 degrees and greater were either bare rock or heavily forested. These heavily forested sites were determined to be too impractical to sample within and therefore the average slope of our sites was constrained to between 10 and 25 degrees.

Three sites were selected, hereafter referred to as Lagoon (on the eastern slopes above the lagoon northeast of HBI; UTM coordinate: 0560345-5723397), Keith's Anchorage (on the ridge southwest of Keith's Anchorage; UTM coordinate: 0560599-5721902), and Telus Tower (on slopes south of Telus Tower; UTM coordinate: 0562562 - 5721031).

Figure 1. Map of site locations; (Blue) Lagoon site, (Red) Keith's Anchorage site, and (Yellow) Telus Tower site.

Data Collection

In order to determine the effects of aspect change on plant communities species richness and species abundance were measured on north-facing and south-facing slopes at each of the three sites. Species richness and abundance were assessed by visual estimation of the percent cover of each species within a $1m^2$ quadrat. Visual estimation was chosen over a point-intercept method for logistical reasons, and because random point intercept methods can have increased chances of missing rare species (Dethier et al. 1993)

Sampling was restricted to the shrub layer (0.5m and below) as incorporation of the tree stratum would require additional, larger, quadrats (Nagy et al 2002). A quadrat size of $1m^2$ was determined to be most ideal for the sampling of the shrub layer (Asada et al. 2003, Krebs 1999, *Brian Starzomski, personal communication*). To facilitate estimating percent coverage each quadrat was divided into 100 squares, each representing 1% of total cover. On the north and south aspect at each site 10 quadrats were sampled for a total of 30 quadrats per aspect (N=60).

Once a suitable north or south slope was chosen a 'start' location was established at its apex, and UTM coordinates recorded. Quadrat placement was randomized by using a random number generator to determine a compass azimuth bearing. Distance in meters from apex was then determined in the same manner and the quadrat placed. For example, to establish random quadrat locations on a south facing slope, a compass bearing between 135 and 225 (corresponding to bearings between southwest, south, and southeast) was randomly chosen. The distance away from the start location was then generated randomly from a number between 1 and 20 meters and the quadrat placed. Each individual quadrat location and elevation was recorded by GPS.

Quadrat measurements were divided into 3 vertical layers: ground (surface level), middle (above ground surface – 15cm high), and high (15cm – 50cm high). In each layer all visible plant species were identified and recorded, and their percent coverage was estimated with the aid of the gridded quadrat. Percent cover of the ground layer always totaled 100%, whereas the mid and high layers did not.

After species identification and percent coverage were recorded, soil pits were dug for each quadrat in order to measure soil depth and rooting depth. Soil moisture has been shown to be an important driver of species composition in the CWHvh2 bioregion (Asada et al. 2003), however, precise and site-specific information on soil moisture regime would require numerous measurements gathered over a period of three to five years (Klinka et al. 1989). The digging of a soil pit to assess rooting depth was seen as the best available alternative. Rooting depth should indicate average water table height as the roots of many plants are hydrophobic (*Bill Floyd, Ministry Hydrologist - personal communication*). Quadrat-specific elevation and angle of slope were recorded. Average site slope was also recorded. This was done to assess other confounding drivers of plant community diversity.

Statistical Analysis Methods

Species richness and abundance data was analyzed by non-metric Multi-Dimensional Scaling ordination (MDS) using the Bray-Curtis similarity measure in PRIMER version 6.1.13 (Clarke 1993; Clarke and Gorley 2006). The species abundance data was square root transformed (Clarke 1993). All treatment areas, Telus Tower, the Lagoon and Keith's Anchorage, were tested for differences in vegetation composition in the high, middle and low layers. All vegetation data was compiled from all sites to test the differences in the north and south aspect. A two-way crossed Analysis of Similarities (ANOSIM) was used to see if the sites species composition was significantly different from one another (Clarke 1993). The north and south aspects were included in the two way ANOSIM as an amalgamation of all sites to see how vegetation composition varied in aspect with all sites. A two-way analysis Similarity Percentages-species contribution (SIMPER) was then run to see how the vegetation composition was different between sites and between aspects (Clarke 1993). All of these tests were run for the high, middle and low quadrat layers.

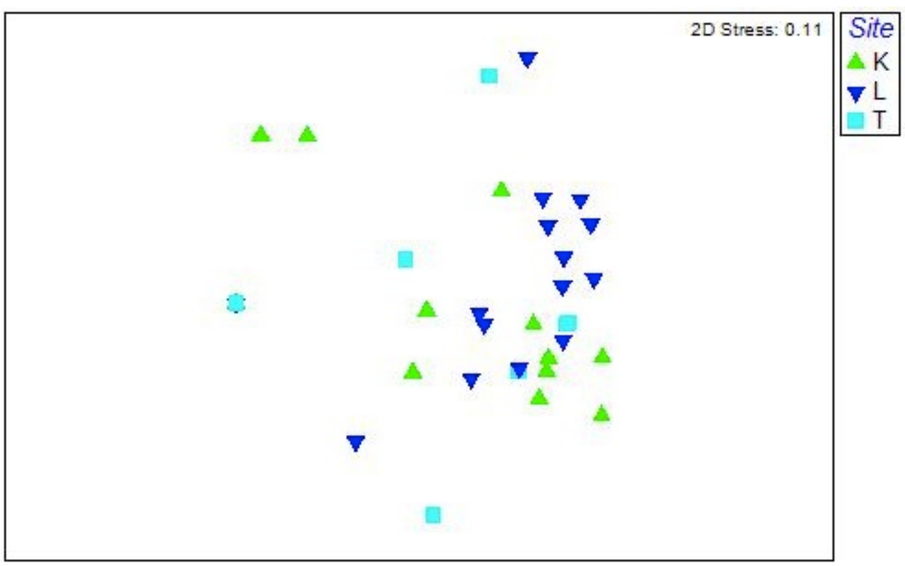
The middle layer data was further analysed to look for within site vegetation composition differences between north and south aspect. All study areas were treated as independent site treatments. nMDS, ANOSIM and SIMPER tests were run for each of the three sites at the middle layer to find within-site differences in vegetation composition in regards to north and south aspects.

Results

Between (Aggregated) Site Analysis of Aspects

High

Between sites in the high layer, vegetation composition was not significantly different (R= 0.101 p=1.4%) (Figure 2a.)Although the p-value indicates a significant value, this significance is driven by zero inflated data. Therefore, based on the low R value our results are not significantly significant. Vegetation composition between north and south aspects in the high layer is not significantly different (R= 0.128, p=1%) (Figure 2b.) Again, zero inflated data is increasing -the statistical significance, as indicated by the low R value.



(a)

(b)

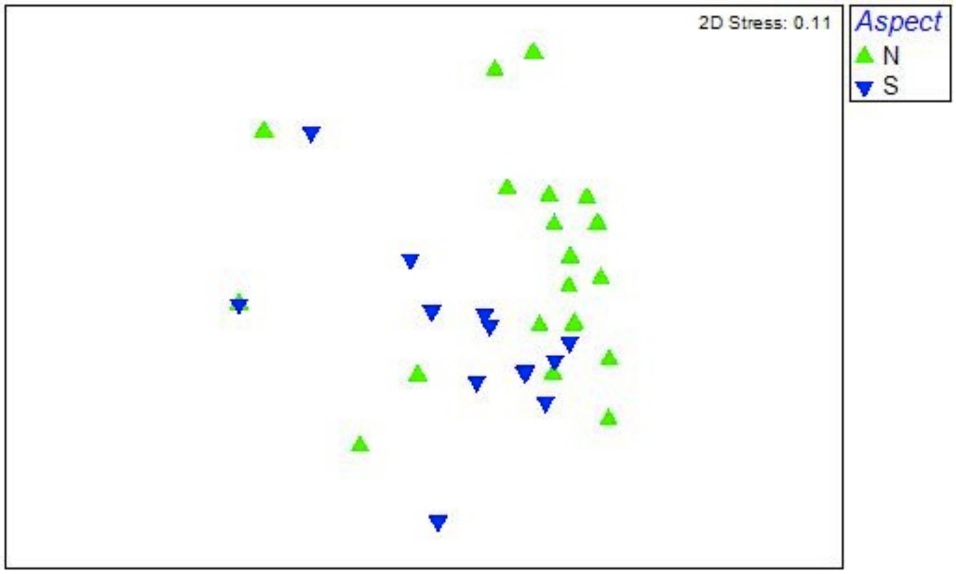
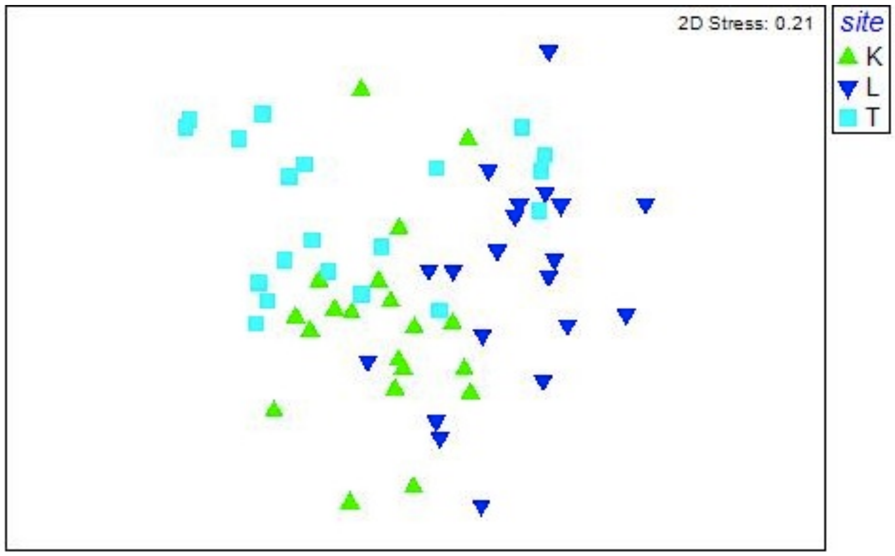


Figure 2. High layer difference in species composition between sites at (a) Keith's Anchorage (K), Lagoon (L), Telus Tower (T) and (b) between aspects: north (N) and south (S).

Low

Vegetation composition between sites were significantly different (R=.303, p=0.1%) (Figure 3a.). The north and south aspects were not significantly different (R=.039, p=19%) (Figure 3b.).

(a)



(b)

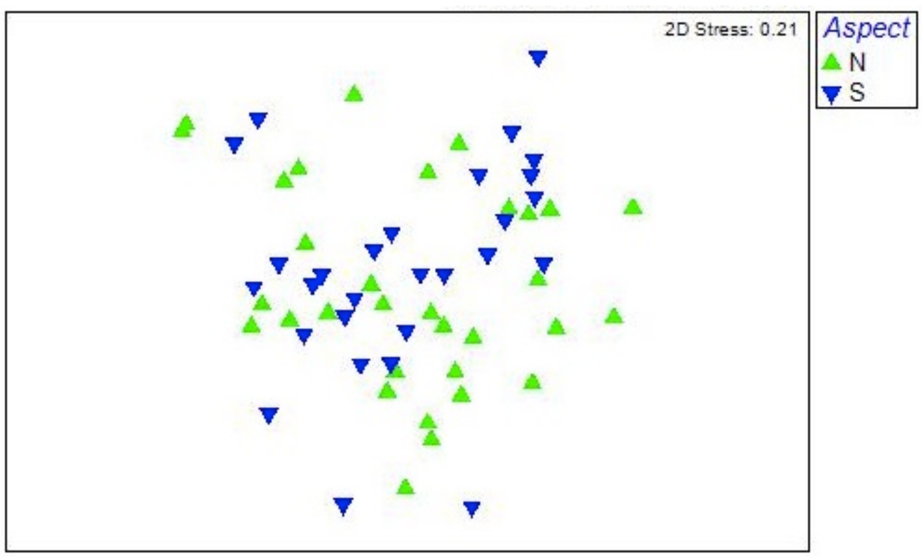
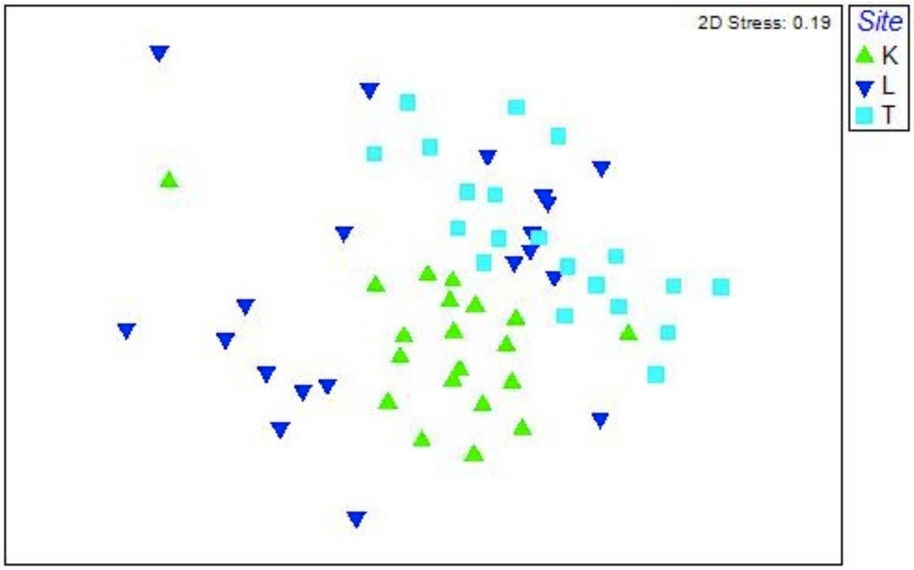


Figure 3. Low layer difference in species composition between sites at (a) Keiths Anchorage (K), Lagoon (L), Telus Tower (T) and (b) between aspects: north (N) and south (S).

Mid

The mid-layer displayed significant differences in vegetation composition between sites and north and south aspect. Vegetation composition at each site was significantly different from one another (R=0.515, p=0.1%) (Figure 4a.). The mid layer's north and south aspect vegetation communities were significantly different from one another (R=0.464, p=0.1%) (Figure 4b.).

(a)



(b)

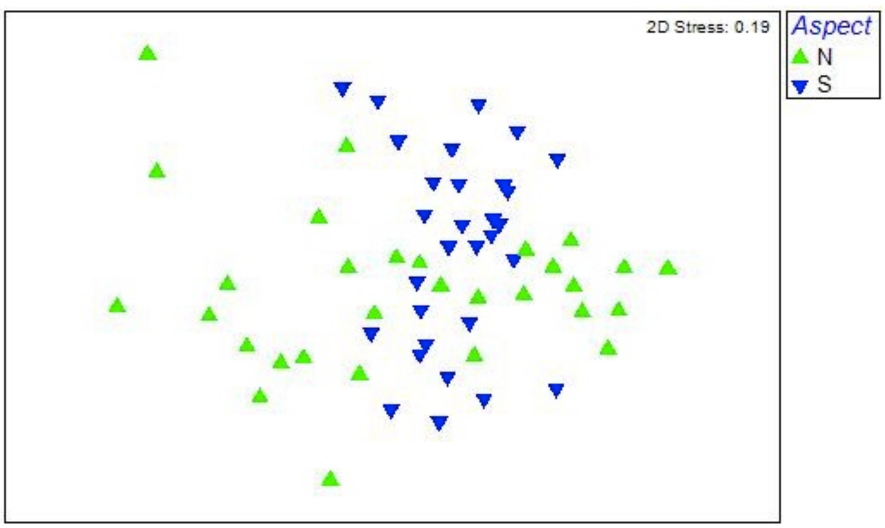
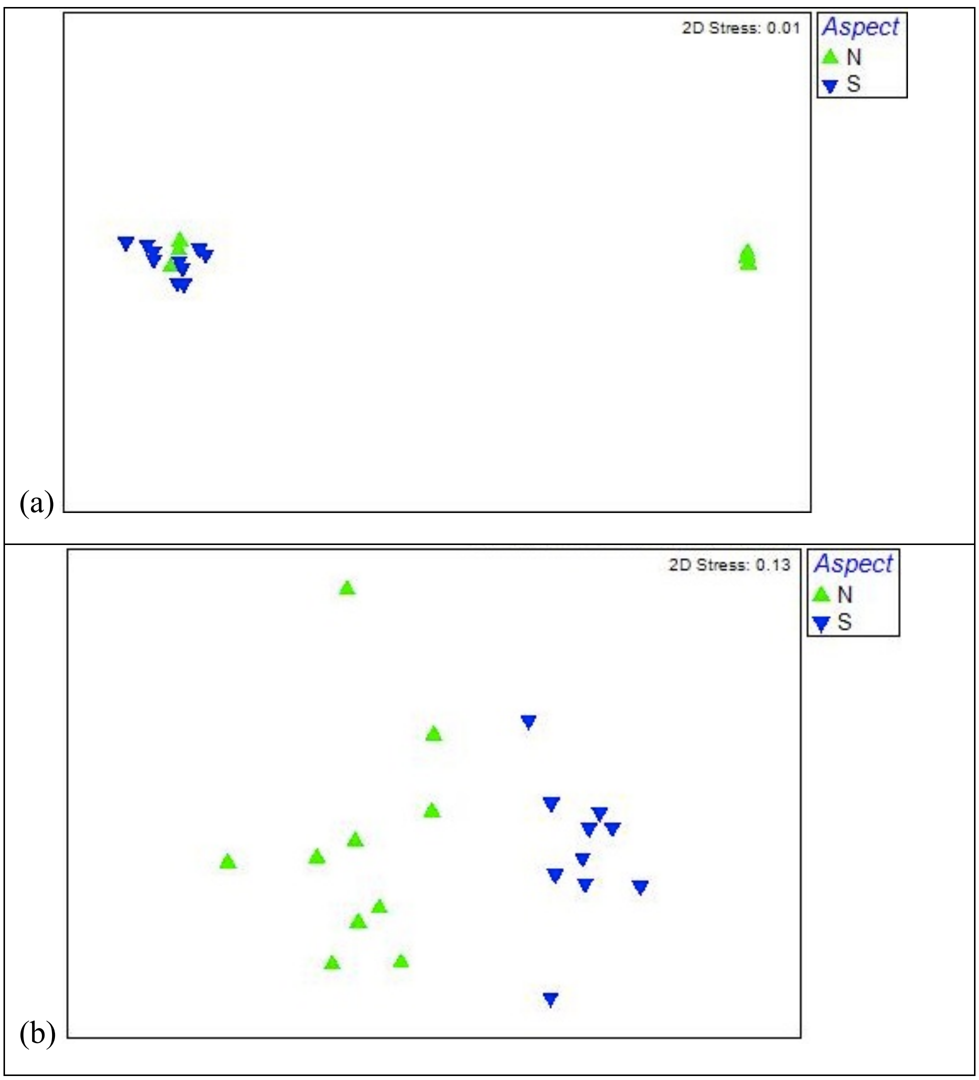
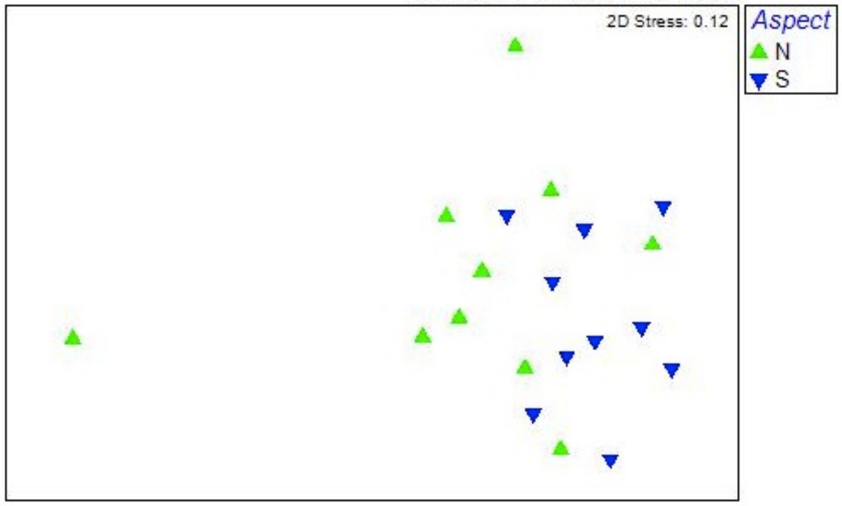


Figure 4. Mid layer difference in species composition between sites at (a) Keith's Anchorage (K), Lagoon (L), Telus Tower (T) and (b) between aspects: north (N) and south (S).

Within sites aspect analysis

A within site analysis of north and south aspect was conducted based on the fact that sites were determined to be significantly different from one another. This analysis was only conducted on with the mid-layer data due to the statistical weakness of the high and low layers. Significant differences in vegetation composition between the north and south aspects was found at the Telus Tower (R=0.535, p=0.5%) (Figure 5a.) and Lagoon (R=0. 734, p=0.1%) (Figure 5b.) sites. At the Keith's Anchorage site no significant difference was found between the north and south vegetation composition (R=0.129, p=3.1%) (Figure 5c.).





(c)

Figure 5. Within site comparison between north (N) and south (S) aspect at (a) Telus Tower, (b) Lagoon and (c) Keith's anchorage.

Alpha, Gamma and Beta diversity

The gamma diversity of vascular plants in sites sampled on Calvert Island numbered 36 (see Appendix A). Alpha species diversity between sites did not differ greatly. Telus Tower had 32 species, the Lagoon site had 31 species and Keith's Anchorage had 32 species. Looking within sites the north and south aspects within sites difference between vegetation composition became more apparent. Telus Tower had much lower species diversity with 24 species at the northern aspect site and 27 species at the southern aspect site. The northern aspect of the Lagoon site had 29 species while the southern aspect had 22 species. The northern aspect of Keith's Anchorage had 30 species and the southern aspect had 25 species.

In each site the beta diversity was small with many similar plants between the three sites with a few unique species in each site (Table 1). Based on our SIMPER results the top seven contributors to percent cover in all sites combined at the mid layer were (in descending order): tufted club-rush (*Trichophorum cespitosum*), common juniper (*Juniperus communis),* sweet gale (*Myrica gale),* great burnet (*Sanguisorba officinalis),* alpine azalea (*Loiseleuria procumbens),* crowberry (*Empetrum nigrum),* and *Poaceae spp.* The top seven contributors to vegetation diversity per site in descending order can be viewed in Table 1.

Table 1.vegetation diversity per site in descending order (parenthesis on more common aspect) North (N), South (S).

Telus Tower	**Lagoon Site**	**Keith's Anchorage**
Tufted Club Rush (S)	Tufted Clubrush (S)	Deer Cabbage (S)
Sweet Gale (S)	Juniper (S)	Tufted Clubrush (S)
Juniper (S)	Crowberry (N)	Sweet Gale (N)
Alpine Azalea (S)	Great Burnet (S)	Juniper (N)
Great Burnet (S)	Shooting star (S)	Crowberry (N)
Shooting Star (S)	Alpine azalea (N)	Alpine-Azalea (N)
Rosemary (S)	Bog blueberry (S)	Shore Pine (S)

Discussion

At all three sites there was very little vegetation found in the high layer and this offers a good explanation for why a significant difference was not found in vegetation composition between sites and between aspects. This is because our site selection criteria did not include sampling in areas with shrub layers above 0.5m in height. This also explains the low p-value (1.4%) with a corresponding low R value (R=0.101). The contrast between these two values is best explained by zero inflated data - we had a high sample size that contained many zeros (indicating absence) in the high layer. This zero inflated data is the justification for disregarding the p-value.

Statistical analysis of the ground layer showed significant difference between sites, but no significant difference between north and south aspects. Ground layer data collection was separated into functional groups (moss, sphagnum, lichen, and liverwort) instead of individual species as identification of individual bryophyte and lichen species can require specialized lab analysis (Vitt et al. 1988). Our results may be due to the coarseness of our ground layer data. By separating our survey of the ground layer plant community into functional groups we may have missed changes in the community structure. An alternative (though not mutually exclusive) explanation is that we may not have a large enough sample size to identify differences in the ground layer. Field observations support the first explanation as we observed diversity in ground layer species composition that was not represented by our data. Composition appeared to change more in regards to micro-site ground moisture levels than to aspect.

Analysis of the mid-layer across all the sites data showed significant differences in vegetative composition for both the aspect and between sites. This result allowed us to narrow the analysis and investigate only the mid-layer vegetation composition differences between the north and south aspects. Each site was analyzed as an individual treatment, rather than as a replicate, as a consequence of the statistical differences in vegetation composition. The results show a significant difference in the vegetation composition between the north and south aspects at Telus Tower and the Lagoon site but no significant difference at Keith's Anchorage.

Although our results suggest that there is a difference between the north and south aspects at two of three sites, they do not necessarily indicate whether aspect is the only driving factor. Other confounding factors that play a role in shaping the vegetation composition may be present at each of our three sites. Different species have different needs, and plants are no exception. Each plant species is adapted to a range of environmental conditions and is restricted to sites that fall within this range (Klinka et al. 1989). By examining the species composition of each of our sites it may be possible to further tease out site conditions and determine whether these site conditions confound or agree with our statistical analysis. For instance, if we have a species like running clubmoss - which is an indicator of a moderately dry and fresh soil moisture regime (Klinka et al. 1989) - at one site and deer cabbage - an indicator of surface-level groundwater (Klinka et al. 1989) - at another site then we may be able to infer that the latter site is wetter than the former. If we repeat this process for each species at each site then we may see a pattern emerge that might help to explain what is occurring at each site.

Table 2. Nitrogen Poor Indicator Species	
Fern-leaved goldthread *Coptis aspleniifolia*	Labrador Tea *Ledum groenlandicum*
Three-leaved goldthread *Coptis trifolia*	Alpine Azalea *Loiseleuria procumbens*
Bunchberry *Cornus Canadensis*	Running clubmoss *Lycopodium clavatum*
Round leaved sundew *Drosera rotundifolia*	White beaked sedge *Rhynchospora alba*
Crowberry *Empetrum nigrum*	Waterworm *Siphula ceratites*
Deer Cabbage *Nephrophyllidium crista-galli*	Tufted Clubrush *Trichophorum cespitosum*
Salal *Gaultheria shallon*	Northern Starflower *Trientalis arctica*
Swamp gentian *Gentiana douglasiana*	Dwarf Blueberry *Vaccinium caespitosum*
Western Bog laurel *Kalmia microphylla ssp. occidentalis*	Bog blueberry *Vaccinium uliginosum*

In our surveys there was an abundance of species that indicate our sites were nitrogen poor (see Table 2.) (Klinka et at. 1989). The majority of our species also indicate the presence of surface ground-water (Klinka et al. 1989); this matches with expectations from the literature (see: Banner et al. 2005). However, under Klinka et al. (1989) species are lumped together into indicator groups, which may overlook species-specific biological processes that can occur at the micro-site level. These species-specific biological process could also shape the plant community.

To account for this we investigated the literature for information on the biology of our indicator plants.

The species composition at Keith's Anchorage was not found to be significantly different based on aspect. We expect soils to be drier and surface temperatures to be higher on southern slopes (Påhlsson 1974; Rorison et al. 1986). However, when we look at indicator plant species we find that the southern aspect may have been more wet. If this is the case, then it is possible that this increased soil moisture may be creating an equilibrium effect between the aspects.

This interpretation is of a wetter southern aspect is based on the higher average abundance of deer cabbage (*Nephrophyllidium crista-galli*) (8.58% higher; see Appendix B). Deer cabbage is an indicator of surface-level groundwater (Klinka et al 1989). On the southern aspect it was the highest contributor to dissimilarity between the two sites, and was the second most abundant species (*Trichophorum cespitosum* was most abundant). In contrast, the northern aspect at Keith's Anchorage had nearly twice the abudance crowberry (*Empetrum nigrum*) as the southern aspect. Crowberry occurs in a wide variety of habitats but is intolerant of prolonged water logging (Bell and Tallis 1973). Alpine azalea (*Loiseleuria procumbens*) and three-leaved goldthread (*Coptis trifolia*) are also associated with marginally drier soils and had very slightly higher abundances on the northern aspect. In contrast, the abundance of round-leaved sundew (*Drosera rotundifolia*) was slightly higher on the south aspect. This species is also associated with ground-water surface levels (Klinka et al. 1989). Differences between abundances of the other species present at Keith's Anchorage are not explained if they: fall outside a 60% threshold for contribution to dissimilarity; have very similar relative abundances; are considered generalists based on interpretation of the literature and data; or relevant biological information could not be sourced.

The Lagoon site had pronounced differences in the average abundances of common juniper (*Juniperus communis)* and tufted clubrush (*Trichophorum cespitosum)* between north and south aspects. The southern aspect had significantly higher abundance of these two species (8.55% and 10.53% higher respectively; see Appendix B), matching with expectations from the literature that suggest southern aspects receive more solar insolation (Bennie et al. 2008). Both of these species are shade intolerant (Dioette and Bergeron 1989; Klinka et al. 1989). Average abundances of great burnet (*Sanguisorba officinalis ssp. microcephala*), shooting star (*Dodecatheon pulchellum*) and bog blueberry (*Vaccinium uliginosum*) were all higher on the southern slope. Although contributing less to dissimilarity, western bog-laurel (*Kalmia microphylla ssp. occidentalis*), labrador tea (*Ledum groenlandicum*), and deer cabbage, were much higher on the north slope. These three species are indicative of surface ground-water (Klinka et al. 1989). These species distributions suggests that the southern slope is drier than the north. Furthermore, Shooting star was found only on the southern aspect of the Lagoon site, and western bog-laurel was found only on the northern aspect. Shooting star is associated with moderately dry soils whereas western bog-laurel is associated with surface ground-water (Klinka et al. 1989). Other species at the Lagoon site either fell below a 60% contribution to dissimilarity threshold, had similar average abundances, or biological information could not be sourced.

One interpretation of this presence-absence is that higher solar insolation on the southern slope is helping to dry the soil. This together with the increased available light may help to explain the higher average species abundances on the southern slope. However, the average abundance of crowberry was higher on the northern slope and this contradicts this interpretation of the southern slope being drier. One possible explanation is that crowberry is a species that aggregates on drier microsites (Bell and Tallis 1973) and it may therefore be over-represented in our data for the northern aspect due to a small sample size. This interpretation of a drier southern slope at the Lagoon site contradicts the above interpretation of Keith's Anchorage. However, different hydrologic regimes is a strong possibility, as evidenced by dissimilarity between all three of our survey sites.

Species abundance at Telus Tower was significantly higher on the southern slope, than on the northern slope. This matches with expectations from the literature, however an important caveat is offered. There is a chance that the driver of this difference is not aspect alone. Although each of our sites were significantly different in their species assemblages the average abundances on all slopes at the Lagoon and Keith's Anchorage sites were higher than those found at the northern Telus Tower site. For example, tufted clubrush (*Trichophorum cespitosum*), which was the dominant species in the mid layer at all sites and all aspects, had an average disimiliarty measure of 17.22 at Telus Tower, as compared to 6.06 and 3.17 at the Lagoon and Keith's anchorage, respectively (See: Appendix B). Based on Asada et al. (2003) and our observational data there may be productivity differences in the southern and northern slopes.

Asada et al. (2003) looked at open-bog ecosystems elsewhere in the CWHvh2 subzone and grouped the species assemblages he found there into nine functional communities using a TWINSPAN analysis (Hill 1979). Of these nine communities five were open bog variants. What is remarkable is that only one of these communities contains the lichen *Siphula ceratites. Siphula ceratites* is distinct from many other lichens in that it is highly water tolerant; it withstands soaking for months at a time (Pojar and MacKinnon 1994). Asada et al. (2003) also found that the community that contained *Siphula ceratites* (described as "*Rhynchospora alba – Sphagnum tenellum* lawns") had the lowest productivity of the five communities. This should be qualified by the fact that Asada et al.'s (2003) analysis for establishing community groups excludes species that are not strong contributors; waterworm may therefore have been present within the other communities, but at background levels.

Based on our observational data for Telus Tower, *Siphula ceratites* was present only at the northern site. In contrast, the southern slope of Telus Tower had only reindeer lichen (*Cladina sp.*) present. Reindeer lichen are often associated with very dry soils (Klinka et al 1989). Although this data is limited, it is possible that the differences in species abundances between the northern and southern slopes of Telus Tower is being driven by factors other than aspect, such as soil moisture or site productivity. This interpretation is based the presence absence of the above two lichen species and on the high abundance of open exposed ground on the northern aspect site. These two observations suggest the possibility that we may not have been comparing like-with-like in terms of the hydrologic regime.

The absence and presence of *Siphula ceratites* at Telus Tower is a good illustration of the need to incorporate a finer-grained survey of the ground layer within our plots. The decision to clump groundcover species into functional groups resulted in data that was too coarse to tease out any statistical relationships between sites and north-south aspects. Likewise, analysis of the "high" and "mid" layer may benefit by being reworked to differentiate based on species type, such as shrubs and herbaceous plants as per Asada et al. (2003), rather than on species height. Asada et al. (2003) demonstrate through their five open-bog communities - differentiated predominantly by moss species composition - that future research should better distinguish between moss species. Bryophytes are amongst the best indicators for bog ecosystems along climatic, chemical and physical gradients (Gignac et al. 1991). Gignac et al. (1991) note that bryophyte responses to these gradients can be used to characterize the habitat preference of indicator species. However, it appears that climate may override the effects of these chemical and physical gradients. Since aspect can alter ground surface temperatures, local air temperature and moisture regimes (Påhlsson 1974; Rorison et al. 1986) pinpointing important climate-related bryophyte indicator species in future research may assist in determining the effects of aspect on community composition.

Our rationale for examining the effect of aspect on open bog plant communities was, in part, based on the absence of aspect-related considerations by Asada et al. (2003). Asada et al. (2003) found, however, that slope and minimum groundwater level were the two dominant environmental factors driving differences in the vegetation gradient. Although efforts were made to account for these variables preliminary data analysis suggested that our measurements of soil depth, rooting depth and slope did not show any statistically significant effect. Similarly, soil composition was not systematically assessed although distinct variations in soil types was observed (clay, sand and organic layers all varied). Thus, despite our best efforts, these factors may be confounding our results.

The use of visual estimations of percent cover has documented weaknesses. These include the possibility of differences between-observers and within-observers data, and overestimation of small or rare species. (Legg & Nagy 2006; Nagy et al. 2002; Dethier et al. 1993; Kennedy and Addison 1987). Although efforts were made to increase the power of visual estimations by dividing quadrats into a grid, between observer differences could still be a source of error (Legg & Nagy 2006; Kercher et al. 2003). Sykes et al. (1987) suggest that correction of observation bias by calibrating individual observations against a standard may be beneficial to precision.

Additionally, our ability to detect small changes in a species' abundance is weak. Nagy et. al (2002) suggest that for a quadrat 50 cm by 40 cm that detecting a 10% relative change to a species with 30% cover would require 47 quadrats (10 % Type II error rate and 5 % Type I error rate); A quadrat $1m^2$ in size requires more sampling. Future research should devote significant effort on producing replicates rather than treatments in order to achieve more statistically powerful results.

Conclusion

Our data show a statistical difference between vegetation communities on the northern and southern aspects at 2 of our 3 sites. Although only two of these sites match with other research on the effects of aspect on community structure (Warren II 2010; Bennie et al. 2008; Rorison et al. 1986; Pahlsson 1974), differences in hydrologic regime at the third, Keith's Anchorage, site is proffered as the possible confounding factor. This is based on interpretation of the plant communities that are present on the northern and southern aspects of Keith's Anchorage that indicate the southern slope is possibly more wet. If this is the case then the effects of aspect may be overridden and producing an equilibrium effect. This equilibrium in turns results in a statistically insignificant difference between the two aspects.

In consideration of future research efforts we offer a number of recommendations. First, in detail examination of bryophyte communities within the bog ecosystem should be considered crucial to assessing how changes in aspect might be influencing community composition. Bryophytes are amongst the best indicators for changes in climatic, chemical and physical gradients in bog ecosystems (Gignac et al. 1991). Further, there is the possibility of examining the specific biology of bryophyte species in order to determine whether there are good indicator species à la Klinka et al. (1989). Second, increasing sample size and focusing on producing replicates rather than treatments would help to increase statistical power (Nagy et al. 2002; Krebs

1999). Third, controlling more adequately for the effects of minimum groundwater level and slope would help to improve robustness of results.

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Appendix A

Species List

Latin Name	**Common Name**
High Layer	
Chamaecyparis nootkatensis	Yellow Cedar
Pinus contorta	Shore Pine
Juniperus communis	Common Juniper
Trichophorum cespitosum	Tufted Club Rush
Fauria crista-galli	Deer-cabbage
Rhododendron groenlandicum	Labrador Tea
Sanguisorba officinalis	Great Burnet
Myrica gale	Sweet Gale
Mid Layer	
Chamaecyparis nootkatensis	Yellow Cedar
Pinus contorta	Shore Pine
Myrica gale	Sweet Gale
Juniperus communis	Common Juniper
Trichophorum cespitosum	Tufted Club Rush
Rhododendron groenlandicum	Labrador Tea
Sanguisorba officinalis	Great Burnet
Vaccinium uliginosum	Bog Blueberry
Vaccinium caespitosum	Dwarf blue B
Loiseleuria procumbens	Alpine-Azalea
Andromeda polifolia	Bog Rosemary
Kalmia microphylla	Bog Laurel
Rhynchospora alba	White Beak-Rush

Nephrophyllidium crista-galli	Deer-cabbage
Lycopodium clavatum	Run Club Moss
Cornus canadensis	Bunch Berry
Trientalis europaea	Northern Starflower
Drosera rotundifolia	Round-Leaved Sundew
Dodecatheon pulchellum	Few-flowered Shootingstar
Empetrum nigrum	Crow Berry
Poaceae spp.	Grass species
Triantha glutinosa	Sticky-false Asphodel
Geum calthifolium	Caltha-leaved Aven
Blechnum spicant	Deer Fern
Coptis trifolia	Three-leaved Goldthread
Lycopodium spp.	Unknow Clubmoss Species
Pinguicula vulgaris	Common Butterwort
Gentiana douglasiana	Swamp Gentian
Gentiana sceptrum	King Gentian
Lycopodium dendroideum	Ground-Pine
Microseris borealis	Apargidium
Elliottia pyroliflora	Copper Bush
Coptis aspleniifolia	Fern-leaved Goldthread
Gaultheria shallon	Salal
Cypraceae spp.	Sedge spp.

Appendix B

SIMPER Results:
Lagoon Site N & S
Data Type: Abundance
Groups N & S
Average dissimilarity = 59.65

Species	Group N Av.Abund	Group S Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
T. Club R	10.57	21.10	6.06	1.72	10.16	10.16
Juniper	7.49	16.04	5.72	1.50	9.58	19.75
Crow B	10.03	5.36	3.67	1.24	6.15	25.90
G burnett	2.12	8.96	3.51	1.86	5.88	31.78
shooting st	0.00	5.79	2.90	1.59	4.86	36.64
Alp. Azaila	6.85	6.29	2.89	1.34	4.84	41.48
Bog Blue B	2.99	7.47	2.77	1.58	4.64	46.12
Bog Laurel	5.31	0.00	2.65	2.29	4.45	50.57
L. Tea	5.49	0.35	2.61	2.23	4.37	54.94
Deer Cab	4.17	1.65	2.49	1.14	4.18	59.12
M. Gale	5.88	5.68	2.49	1.39	4.17	63.29
Rosemary	0.96	5.93	2.48	2.50	4.16	67.45
Bunch B	4.85	0.68	2.17	1.77	3.64	71.09
Vaccinum spp.	4.24	0.40	2.02	1.54	3.39	74.48
Poaceae spp.	5.60	5.79	1.82	1.39	3.05	77.53
C. trufoliia	3.59	0.00	1.80	1.46	3.01	80.54
S. Asphodel	4.98	2.41	1.65	1.35	2.76	83.30
Yellow Cedar	2.43	0.00	1.22	0.61	2.04	85.34
Salal	0.53	2.03	1.18	0.60	1.97	87.31
Dwarf blue B	2.23	0.23	1.14	0.58	1.90	89.22
Sun Dew	1.91	0.70	1.12	0.80	1.87	91.09

Telus Tower N & S
Data Type: Abundance
Groups N & S
Average dissimilarity = 81.22

Species	Group N Av.Abund	Group S Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
T. Club R	0.96	3.47	17.22	1.28	21.20	21.20
M. Gale	0.50	1.67	8.41	1.46	10.36	31.56
Juniper	0.46	1.58	6.76	1.23	8.32	39.88
Alp. Azaila	0.30	1.45	6.42	1.57	7.90	47.78
G burnett	0.33	1.37	6.15	1.67	7.57	55.36
shooting st	0.16	0.87	5.06	1.07	6.23	61.59

Rosemary	0.29	0.98	4.64	1.37	5.71	67.31
Bog Blue B	0.22	0.93	3.83	1.04	4.72	72.03
Poaceae spp.	0.12	0.76	3.59	1.14	4.42	76.45
Crow B	0.09	0.77	3.10	0.68	3.81	80.26
S. Asphodel	0.25	0.51	2.86	0.95	3.52	83.78
C. lved Aven	0.19	0.35	2.32	0.74	2.86	86.65
Sun Dew	0.14	0.37	2.21	0.80	2.72	89.36
N. star	0.14	0.44	2.09	0.98	2.58	91.94

Keith's Anchorage N & S
Data Type: Abundance
Groups N & S
Average dissimilarity = 38.20

	Group N	Group S				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Deer Cab	3.02	11.60	4.66	1.74	12.20	12.20
T. Club R	12.84	13.42	3.17	1.32	8.29	20.49
M. Gale	7.70	7.17	2.49	1.36	6.51	27.00
Juniper	11.95	11.29	2.35	1.36	6.14	33.14
Crow B	4.33	2.13	1.90	1.33	4.97	38.11
Alp. Azaila	5.97	3.08	1.87	1.41	4.89	42.99
S. Pine	1.54	3.01	1.68	1.01	4.39	47.39
C. trufoliia	2.89	2.19	1.60	1.18	4.20	51.58
Sun Dew	4.59	5.09	1.58	1.36	4.13	55.71
Poaceae spp.	4.90	5.08	1.56	1.49	4.09	59.80
G burnett	7.43	6.69	1.50	1.30	3.93	63.73
Shooting st	3.36	4.79	1.42	1.35	3.73	67.46
S. Asphodel	3.75	2.30	1.06	1.36	2.77	70.23
Run Club M	1.22	1.36	1.05	0.75	2.75	72.98
L. Tea	2.82	3.15	1.03	1.44	2.69	75.67
Bog Blue B	1.20	1.61	0.99	1.05	2.59	78.26
Wht Beak R	1.19	1.28	0.89	0.99	2.34	80.60
Rosemary	3.79	3.90	0.83	1.12	2.16	82.76
Dwarf blue B	1.17	0.70	0.82	0.57	2.15	84.92
Bog Laurel	4.30	4.09	0.82	1.07	2.15	87.06
Vaccinum spp.	1.52	0.40	0.76	1.00	1.99	89.05
C.lved Aven	1.37	0.00	0.69	0.43	1.79	90.85