Factors influencing epiphytic moss and lichen distribution within Killarney National Park

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The niches of epiphytes are widely studied and have been shown to be complex involving interspecific competition, succession and predation. This study is unique in that it applies the niche concept to moss and lichen distributions within Killarney National Park, Kerry, Ireland. We studied 75 trees between three pristine ancient woodlands and measured a range of physical and biological factors to ascertain influences on epiphyte cover. The species of tree was found as the principal determinant in community structure as it bioengineers conditions such as light, temperature and humidity that the epiphytes are reliant upon. Furthermore, the bark character and trunk circumference were important. Zonation of the epiphytes was apparent with both aspect and height on the trunk. Typically, moss dominated over lichen within a niche that was relatively sheltered. Lichen tolerated drier and lighter niches often being further up the trunk on sun facing aspects. Ultimately, there was succession up the tree mediated through competition. This study highlights the complexity and interrelatedness between biotic and abiotic factors in a relatively unstudied geographical and biological area. Understanding agents behind a population’s distribution enables manipulation for conservation or sustainable exploitation.

Key words: competition, niche, epiphyte, resource availability, succession, Killarney national park

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Introduction

Mosses and lichens are abundant and ubiquitous across a diverse array of biomes and latitudes (Mezaka, Brumelis, Piterans, 2012). They fill a particularly important and often overlooked niche (Bergamini et al., 2004) while displaying a complex distributional pattern determined not only by differential response to environmental conditions but also interspecific competition (Harris, 1971b). Biochemically they influence nutrient and water balances (Pyper, Unsworth, Bond, 2006; Odor et al., 2013), decomposition (Liu et al., 2000; Hagemann and Moroni, 2015) and soil environments (Van der Wal and Brooker, 2004). Ecologically they house and sustain rich biodiversity as habitats (Helle and Aspi, 1983; Lindo and Gonzalez, 2010). Both groups are photosynthetic autotrophs gaining water and minerals from the atmosphere (Begon, Townsend, Harper, 2006). Since neither group require soil, ground reservoirs or mychorrizal associations to survive (Nash, 1996; Bergamini et al., 2004) many species are commensally epiphytic (Pojar and MacKinnon, 1994; Sterry, 2007). However, this increases their susceptibility to atmospheric pollution (Beltman et al., 1980; Larsen et al., 2007) that has led to their utilisation as ecological indicators of air quality, pollution, fragmentation and disturbance (Conti and Cecchetti, 2001; Mölder et al., 2015).

Trees stabilise understory insolation and temperature regimes and provide microhabitats for attachment, thus engineering ideal conditions for epiphytic mosses and lichens (Mandahl-Barth, 1966; Sterry, 2007; Eaton and Ellis, 2012;...
Boreal and temperate forests are particularly cool and moist resulting in high epiphyte abundance and diversity that has attracted numerous studies (Mezaka, Brumelis, Piterans, 2012; Odor et al., 2013). These include the effect of bark pH (Larsen et al., 2007; Mezaka, Brumelis, Piterans, 2012), aspect (Song et al., 2015), temperature (Hauck, 2011), inclination (Johansson et al., 2009), humidity (Eaton and Ellis, 2012), age (Hofmeister et al., 2015) and light intensity (Gauslaa et al., 2008) on epiphyte distribution.

Inter-tree variation in biotic and abiotic factors has been demonstrated to be more important when compared with stand level variation. However, few have incorporated intra-tree aspects (Juriado, Liira, Paal, 2009). Even though boreal forests create favourable conditions for rich diversity and abundance of epiphytes (Hauck, 2011; Eaton and Ellis, 2012), a lot of them have been understudied. One such example is Killarney National Park in south-west Ireland, which is famed for its epiphytic flora (Cross, 1973; Cross, 1981; Kelly, 1981; Power, Igoe, Neylon, 2007), as well as being Ireland’s most extensive native forest (Ratcliffe, 1968; Mitchell et al., 2005).

Understanding the drivers of epiphyte distribution can inform forestry management to maximise diversity and protect these unique habitats within a changing world (Schei et al., 2013). We studied factors controlling the richness, diversity and abundance of bryophytes and lichens. Here we investigate (i) whether lichen and moss richness and diversity varies between oak, holly and yew; (ii) whether moss and lichen display differential surface area cover between oak, holly and yew; and (iii) whether moss and lichen cover varied in relation to canopy cover, trunk circumference and aspect.

Materials and methods

Study site and habitat sampling strategy
The study was carried out in Killarney National Park (52°0′N, –9°5′E; Fig. 1), which is characterized by ancient woodland pre-dating the 1600s (Craig, 2001; O’Sullivan and Kelly, 2006; Sterry, 2007). The region has experienced relatively little deforestation and land use change enabling more accurate observation of natural interactions (Ratcliffe, 1968; Peterken, 2001; Power, Igoe, Neylon, 2007). Killarney has Annex I status in the EU habitats directive because of its epiphyte richness and the rarity of the unique Rendianna forest dominated by English yew (Taxus baccata) (Smal and Fairley, 1980; Mitchell, 1990; Philip, Kelly, Mitchell, 2006). The wood is complemented by two others: Derrycunihy sessile oak wood (Quercus petraea) (Turner and Watt, 1939; Mitchell, 1988) and Carr wood rich in European holly (Ilex aquifolium) (Kelly, 1981; Mitchell and Bradshaw, 1984) centred within 10 km of each other on Lough Leane (Fig. 1). The sites were chosen to include three dominant tree species (Table 1) and for their accessibility. The distance between each sample site was relatively small reducing larger variation in precipitation, altitude and temperature that are known to effect epiphyte distributions (Ratcliffe, 1968; Kelly, 2002; Mitchell et al., 2005).

Tree sampling strategy
Sampling occurred between 14th and 16th September 2011 using a transect bisecting each woodlands longest diameter. From an accessible point on the woodlands edge, a random number of steps were generated to a suitable trunk. Trunks unsuitable for surveying including those which had fallen, had obstructing branches and vines or a circumstance at breast height (CBH) measuring less than 50 cm were excluded. The transect continued until 25 trees had been sampled, if the woodland edge was reached the transect reflected back towards the interior.

Moss, lichen and abiotic factor survey
Each tree’s GPS grid reference (Garmin etrex H) was recorded. CBH was measured with a tape at breast height; 1.4 m from the ground. Trunks were divided into four faces corresponding to compass aspect. At each aspect, 1.4 m up the trunk and 10 cm away, air temperature (°C) and relative humidity (RH) were measured with a digital meter (Skywatch handheld) in addition to light intensity with a lux meter (Hanna portable). Canopy cover was estimated 50 cm away from the trunk using a convex spherical densitometer (Lemmon, 1956).

To assess the epiphyte cover at each of the four aspects a linear string transect consisting of seven 20 × 20 cm² quadrats was hung against the trunk 1.4 m high. This technique provided flexibility and minimised damage (Mitchell et al., 2005; Fig. 2). Each tree was considered a data point composed as a sum of its four aspects; the total area of bark analysed per tree was 1.12 × 10⁶ cm². Species richness and diversity were calculated for moss and lichen systematically at each quadrant. Richness was the number of moss and lichen species present that could be identified in the field using Watson (1981) and Whelan (2008). The Simpson’s index of diversity (D−1) (see Equation 1) provided a measure of relative species abundance, or evenness, derived from richness and surface area. It is defined as the probability that two individuals randomly selected from a sample will belong to different species. This index was not affected by the large variation in site richness nor the presence of rare epiphytes and did not assume the species list was comprehensive for the habitat.

Equation 1. Calculation of Simpson’s diversity index (D)

\[ D = 1 - \left( \frac{\sum (n/N)^2}{N} \right) \]

(Simpson, 1949)
Figure 1. Map of the woodland study sites within Killarney National Park, County Kerry, Ireland. Wooded areas around Lough Leane are highlighted in grey while dark grey areas are sampling sites. (A) Derrychunihy sessile oak wood; (B) Carr wood; and (C) Rendianna yew wood.
Species richness and the Simpson’s index of diversity were not normally distributed and could not be transformed so non-parametric Kurskall–Wallis tests on median ranks were used. Significant differences between woods were differentiated by pairwise permutations of Mann Whitney U tests with Bonferroni corrections applied. Similarly, the bark surface area covered by moss and lichen, the CBH and canopy cover could not be normalised via transformation consequently Spearman’s rank correlations explored the relations between them across all trees. Moss and lichen surface area grouped by aspect and tree species were normally distributed were analysed using a two-way ANOVA. Statistical analyses were performed in SPSS Statistics 22 (IBM Corp, 2013). For clarity all graphical outputs were based on untransformed data.

**Results**

Of $8.4 \times 10^5$ cm$^2$ of bark sampled across 75 trees, 16 epiphyte species were identified with seven being moss (Table 2). The mean epiphyte species richness for each tree independent of species was: moss, $3.45 \pm 0.12$; lichen, $2.99 \pm 0.21$ and both $6.43 \pm 0.24$. Since epiphytes were identified within the field, the number of species may be under-representative of the true community composition. However, due to a consistent sampling strategy this does not impact the overall results of the study.

**The tree species effected lichen and moss richness and diversity**

There was no significant variation in moss richness between the three tree species ($H_{24} = 0.63, p = 0.73$), the mean values were $3.52 \pm 0.14$SE, $3.40 \pm 0.18$SE and $3.44 \pm 0.27$SE for yew, oak and holly respectively (Fig. 3). Conversely there was significant variation in both lichen richness ($H_{24} = 59.58, p < 0.01$) and total richness ($H_{24} = 37.93, p < 0.01$) between the tree species. Holly had the most lichen species $5.16 \pm 0.18$SE which was over double that of oak, $2.20 \pm 0.14$SE ($U_{24} = 43.31, p < 0.01$), and yew $1.60 \pm 0.29$SE ($U_{24} = 33.33, p < 0.01$). Holly also had the greatest total richness of $8.60 \pm 0.35$SE which was significantly larger than oak’s $5.60 \pm 0.25$SE ($U_{24} = 32.5, p < 0.01$) and yew’s $5.12 \pm 0.23$SE ($U_{24} = 27.84, p < 0.01$) (Fig. 3).

The epiphyte community on holly was more even and diverse than that on oak and yew ($H_{24} = 19.6, p < 0.001$) (Fig. 4). Particularly holly’s diversity was $0.71 \pm 0.02$SE being significantly higher than yew’s $0.58 \pm 0.02$SE ($U_{24} = 13.6, p < 0.01$) and oak’s $0.45 \pm 0.04$ ($U_{24} = 16.5, p < 0.01$). Oak and yew did not differ ($U_{24} = 1.6, p = 0.63$) (Fig. 4).

Epiphyte community composition varied with 57% of mosses and 11% of lichens being ubiquitous between tree species. The most unique species was found on holly within this study; four lichens and one moss, whereas oak only had one and yew none. Lichens seemed more specialised to the tree species for example *Parmeliella parvula* was dominant on yew but was the rarest on oak and only *Loxospora elatina* was universal to all three.

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**Table 1. Summary of abiotic conditions at each wood sampled Killarney National Park on the 14th–16th September 2011**

<table>
<thead>
<tr>
<th></th>
<th>Yew (Taxus baccata)</th>
<th>Holly (Ilex aquifolium)</th>
<th>Oak (Quercus petraea)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grid reference</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of trees sampled</td>
<td>Grid reference of trees sampled</td>
<td>Grid reference of trees sampled</td>
<td>Grid reference of trees sampled</td>
</tr>
<tr>
<td><strong>Circumference</strong></td>
<td>123 ± 53</td>
<td>85 ± 33</td>
<td>256 ± 68</td>
</tr>
<tr>
<td>at breast height (cm)</td>
<td>99.2 ± 0.7</td>
<td>97 ± 1.5</td>
<td>95.5 ± 2.7</td>
</tr>
<tr>
<td><strong>Canopy cover</strong></td>
<td>16.6 ± 0.3</td>
<td>15.9 ± 0.3</td>
<td>15.8 ± 0.0</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td>60.0 ± 0.2</td>
<td>57.5 ± 5</td>
<td>65.2 ± 0.3</td>
</tr>
<tr>
<td><strong>Humidity</strong></td>
<td>13.3 ± 2.1</td>
<td>27.0 ± 3.7</td>
<td>20.1 ± 2.7</td>
</tr>
<tr>
<td><strong>Light intensity</strong></td>
<td></td>
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</tbody>
</table>
Table 2. A record of the epiphytic bryophyte and lichen flora present on three tree species within in Killarney, County Kerry on 2011 (N = 25)

<table>
<thead>
<tr>
<th></th>
<th>Yew (Taxus baccata)</th>
<th>%</th>
<th>Holly (Ilex aquifolium)</th>
<th>%</th>
<th>Oak (Quercus petraea)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moss</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neckera crispa</td>
<td>32.8</td>
<td></td>
<td>Eurhynchium striatum</td>
<td>13.0</td>
<td>Homalothecium sericeum (**)</td>
<td>1.0</td>
</tr>
<tr>
<td>Thamnobryum alopecurum</td>
<td>12.7</td>
<td></td>
<td>Neckera crispa</td>
<td>3.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thuidium tamariscinum</td>
<td>4.8</td>
<td></td>
<td>Homalothecium sericeum (*)</td>
<td>2.5</td>
<td>Neckera crispa</td>
<td>0.7</td>
</tr>
<tr>
<td>Thamnobryum alopecurum</td>
<td>1.7</td>
<td></td>
<td>Thamnobryum alopecurum</td>
<td>12.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thuidium tamariscinum</td>
<td>3.3</td>
<td></td>
<td>Thuidium tamariscinum</td>
<td>6.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total moss</strong></td>
<td>70.1</td>
<td></td>
<td>18.7</td>
<td></td>
<td>60.5</td>
<td></td>
</tr>
<tr>
<td><strong>Lichen</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arthonia vinosa (*)</td>
<td>0.1</td>
<td></td>
<td>Arthonia cinnabarina (**)</td>
<td>3.7</td>
<td>Arthonia vinosa (*)</td>
<td>0.8</td>
</tr>
<tr>
<td>Arthonia vinosa (*)</td>
<td>1.7</td>
<td></td>
<td>Chrysorthrix candelaris (**)</td>
<td>3.8</td>
<td>Flavoparmelia caperata</td>
<td>3.8</td>
</tr>
<tr>
<td>Loxospora elatina</td>
<td>0.6</td>
<td></td>
<td>Flavoparmelia caperata (*)</td>
<td>0.4</td>
<td>Loxospora elatina</td>
<td>3.8</td>
</tr>
<tr>
<td>Micarea denigrata (**)</td>
<td>0.7</td>
<td></td>
<td>Parmeliella parvula (*)</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrenula dermatodes (**)</td>
<td>6.7</td>
<td></td>
<td>Thelotrema lepadinum (*)</td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theotrema lepadinum (*)</td>
<td>15.3</td>
<td></td>
<td>Thelotrema lepadinum (*)</td>
<td>15.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loxospora elatina</td>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total lichen</strong></td>
<td>1.6</td>
<td></td>
<td>28.4</td>
<td>5.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total epiphyte</strong></td>
<td>75.7</td>
<td></td>
<td>49.3</td>
<td>74.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(*) and (**) indicate species present on two and one tree species respectively. Numbers indicate the mean bark percentage cover of each (cm²).

Figure 3. A comparison of epiphyte species richness between the three woodlands in Killarney National Park, County Kerry, on 14th–16th September 2011. N = 25. Each tree species is subdivided into lichen, moss and total richness to allow further comparison. Richness was purely the sum of different species present in the quadrats. Error bars are 95% confidence intervals.

Figure 4. The mean Simpson’s index of diversity of epiphytes between the three woodlands in Killarney National Park, County Kerry, on 14th–16th September 2011. N = 25. The index was calculated from species richness and the relative surface area of bark covered by each species. Error bars are 95% confidence intervals.
Tree species had the strongest influence on moss ($F_2 = 211.5, p < 0.001$), and lichen cover ($F_2 = 177, p < 0.001$) (Fig. 5). Overall coverage varied between species. Generally, yew had the greatest surface area covered by epiphytes and holly the least; relatively yew had the greatest moss cover yew holly lichen cover.

**Moss and lichen displayed differential growth on each tree species**

Moss and lichen were negatively correlated ($r_s = -0.82, p < 0.01$) across all tree species (oak: $r_s = -0.40, p < 0.05$; holly: $r_s = -0.36, p = 0.08$; yew: $r_s = -0.47, p < 0.05$) (Fig. 6). Notable exceptions in the context of this study were the lichens *Loxospora elatina* and *Flavoparmelia caperata* that were often epiphytic on moss. Small scale distributions were observed such as *Thelotrema lepadinum*, *Arthonia cinnabarina*, *Pyrenula dermatodes* forming a mosaic across the smooth areas on oak while *Chrysothrix candelaris* dominated the indents in the bark. Clear vertical distributions were also observed, particularly on yew where at CBH *Neckera crispa* monopolised, midway down *Eurhynchium striatum* was prominent, then *Thamnobryum alopecurum* and finally *Thuidium tamariscinum* adjacent to the ground. On holly generally *Dicranum scoparium* dominated near ground instead of *Thuidium tamariscinum*.

**Moss and lichen distribution showed differential responses to CBH, canopy cover, aspect**

**CBH**

CBH showed a moderate positive correlation with the surface area of bark covered by moss ($r_s = 0.36, p < 0.01$) conversely, there was a weak negative correlation between lichen and CBH ($r_s = -0.24, p < 0.05$) (Fig. 7).

**Aspect**

Aspect did not have any effect on cover in isolation ($F_2 = 0.23, p > 0.05$). However, when taken into account with the tree species it was significantly different ($F_6 = 3.1, p < 0.001$) (Fig. 5). The mean moss cover on holly across the aspects was $-500 \text{cm}^2$, being one third of oak and yew cover ($p < 0.05$) and displayed no difference ($p > 0.05$). Holly shows the greatest cover of moss in the north while oak in the west. The variability between aspects of lichen was the inverse of the moss cover for example, yew had the greatest moss cover in the east but the lowest lichen there too.

**Canopy cover**

Canopy cover had a moderate positive correlation with moss ($r_s = 0.32, p < 0.01$) and moderate negative correlation with lichen ($r_s = 0.32, p < 0.05$).

**Discussion**

The tree species affected lichen and moss richness and diversity

The relation between tree species and the diversity, richness and distribution of moss and lichen species is a known phenomenon (Juriado, Liira, Paal, 2009; Nascimbene et al., 2009a, 2009b, Kiraly et al., 2013). On a stand level heterogeneity in age and size of trees as well as abundance of dead wood has been repeatedly emphasised (Fritz, 2009; Odor et al., 2013; Hofmeister et al., 2015). However, when comparisons are made between specific tree species a more complex distribution of moss and

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**Figure 5.** The difference in area of bark covered by epiphytes in relation aspect with reference to the four point compass where (A) total moss coverage and (B) total lichen coverage. Trees were sampled within the three woodland types in Killarney National Park, County Kerry, on 14th –16th September 2011.
lignum is revealed. Of the epiphytes identified, holly was found to have the highest epiphytic total richness and diversity while oak and yew displayed similar, lower diversity levels. Furthermore, holly was characterised by the highest number and coverage of lichen species compared to oak and yew which were dominated by mosses. This is in contrast with Kiraly et al. (2013) who found an increase in lichen species richness with increased proportion of oaks within mixed forests.

Many of the epiphytes identified were unique to a single tree species which is consistent with other studies in boreal woodlands (Nascimbene et al., 2009a, 2009b; Hauck, 2011; Odor et al., 2013). This could be related to species specific characteristics including bark pH and texture (Armstrong and Welch, 2007; Nascimbene et al., 2013). Highly textured bark provide shelter, increased humidity, protection from predation and attachment security (Armstrong and Welch, 2007; Ranius et al., 2008). However, the textured yew bark was dominated by shade loving Chrysothrix candelaris, perhaps due to the lower light intensity (Whelan, 2008; Seawright, 2011).

Epiphytes have a narrow pH tolerance controlling colonisation of bark surfaces (Watson, 1981; Pojar and MacKinnon, 1994; Hocking et al., 2008). Oak and holly prefer acidic sandstone and so their bark is expected to have a lower pH (Peterken, 2001) in comparison to yew that prefers basic limestone thus higher pH. Dicranum scoparium and Bartramia pomiformis favour low pH and therefore were absent from yew (Watson, 1981; BBS, 2005). Flavoparmelia caperata was more abundant on oak and holly being adapted to acidic environments (Larsen et al., 2007). Despite this four calcilicole mosses including Neckera crispa and Thamnobryum alopecurum, were found in ‘acidic woods’ studies suggesting other factors are significant. Compensation can occur when the majority of resources are ideal, Thuidium tamariscinum and Thamnobryum alopecurum have been found in less basic woods if they are extremely humid (Ratcliffe, 1968; Watson, 1981) whereas Eurhynchium strictum in ion rich environments (Watson, 1981; BBS, 2005).

Variation of the epiphytic communities between tree species may also be due to overall lifespan, for instance holly has one tenth the lifespan of oak and yew trees (Hocking et al., 2008). The general lichen complexity on holly could be at an intermediate point in succession, the four native species being adapted to quick growth in the relatively ephemeral habitat (Richards, 1938; Harris, 1971b; Hocking et al., 2008). Studies have shown that community is also dependant on age. Homalothecium sericeum is found on wood around 250 years old whereas Micaeia denigrata on 100 years (Ireland, 1975; Fritz, Niklasson, Churski, 2008). Older trees are generally more textured and have greater surface areas providing more suitable epiphytic habitat (Matthews, 1994; Fritz, Niklasson, Churski, 2008; Ranius et al., 2008). They may also reach an epiphytic climax community that many not be as diverse but often is characterised by specialist species (Molder et al., 2015).

**Moss and lichen displayed differential growth on each tree species**

A clear vertical gradient was observed from the tree base to breast height. Tree bases are more sheltered with higher humidity and lower light intensity (Richards, 1938; Harris, 1971b; Hocking et al., 2008). Here, climax communities of Thamnobryum alopecurum and Thuidium tamariscinum or...
**Moss and lichen distribution showed differential responses to canopy cover, CBH and aspect**

**Canopy cover**
Canopy cover had a moderate positive correlation with moss and moderate negative correlation with lichen. The positive association between canopy cover and moss could be explained in terms of local humidity where shaded conditions protect moss from wind and desiccation (Kiraly et al., 2013). At a broader scale is the canopy type; denser canopies are correlated with greater humidity and thermal stability at the expense of light intensity and maximum temperature. Holly-dominated woods have sparse canopies, often being found in clearings (Peterken, 2001). Oak wood is intermediary being taller and having denser leavs whereas yew wood casts intense shade due to rot resistant lateral growth (Smal and Fairley, 1980). It should be noted that holly and yew are more stable environments for moss and lichen as they are evergreen.

**CBH**
Trees with a larger CBH were colonised by more moss than lichen. Larger trees have been shown to have higher lichen biomass (Arseneau, Sirois, Ouellet, 1997), however, this is a complex relationship as CBH is often representative of age that is interrelated to surface area, bark texture, microclimate and time of colonisation. Within the current study, yew had the greatest CBH but was dominated by moss suggesting that CBH is not always the dominating factor.

**Aspect**
The thick canopies of oak and yews may have diminished differences between aspects in moss and lichen cover. Because, holly showed the greatest variation between the aspects the canopy is less dense, allowing more radiation on the southern
and western bark as the sun passes over the horizon. This favours species more resistant to desiccation and larger abiotic fluctuations (Ratchiffe, 1968). It is a common misconception that the north and east sides are always the most shaded and humid areas in the northern hemisphere because topography is also important (Matthews, 1994). This is demonstrated by the fact that there is a large mountain range to the west blocking the sun.

At the more exposed sites lichen cover dominated while moss was retarded. Many lichen species are adapted to drier environments compared to moss which has a reduced competitive ability in these areas. The capacity to withstand aridity might be a mixture of morphology being low lying to surface where there is greater moisture and less exposed surface area for loss (Hocking et al., 2008). Likewise, in shaded sides moss grows relatively faster and can reach greater heights that can hinder lichen through reducing area and light intensity (Thomas and Polwart, 1958). However, at an individual level the pattern was not necessarily consistent, sometimes the side farthest from the sun leant toward the ground. Moss and lichen found attachment here difficult.

**Conclusion**

Bryophytes and lichens are incredibly important not just phylogenetically but environmentally (Mitchell et al., 2005), as indicators of pollution, nutrient recycler and fixers, producers in food webs and invertebrate habitat providers (Peterken, 2001; Oksanen, 2006; Monthey and Dudzik, 2010). Economically they can be beneficial through medicine, dyes and as a food source (Knowles, 1929; Oksanen, 2006; Monthey and Dudzik, 2010). Therefore, improvement of moss and lichen diversity by forest management increasing tree species diversity is likely to benefit forest function (Nascimbene et al., 2013). The niches of moss and lichens are highly complex and interlinked, however, the tree species is paramount as it defines the abiotic conditions of the substrate and atmosphere as well as other populations interacting with the epiphytes. pH is fundamental to the community but there are homologous variables across the woods. Sub-patterns that act on the humidity, light and temperature across individual trees include aspect, age, bark texture and height from ground. Niches are wettest and darkest in the crevasses at the tree base on the side receiving the least insolation, frequently the north. As one travels up the tree more light penetrates through but wind currents and evaporation lower the humidity. Ultimately, a continuous change in niche gradient occurs. Moss tend to have a niche that require greater humidity and light requirements than lichen (Lisci, Monte, Pacini, 2003). Succession is apparent since moss tends to outcompete lichen due to its mass and growth limiting space available (Thomas and Polwart, 1958; Harris, 1971a). Consequently, lichens are generally found in less hospitable upper reaches. Within similar niches there is intense competition, particularly between the defensive crustoses and offensive foliodes, through allelopathy and mechanical destruction. This increases with richness which is constantly moderated by predation and competition.

Further study could consider whether these findings persist across a wider sample of forest type and could benefit with a more extensive identification method. Controlled experimental design could determine the successional hierarchy of moss and lichen under differing conditions.

**Author biography**

Following his MNatSci, Kris Sales has remained at UEA as a PhD student to study how the fertility of male Coleoptera and Lepidoptera is affected by climate change. He designed the epiphyte study during the assessment period of a second year Field Ecology module. Moreover, he assisted with all aspects of the project, particularly planning, analysis, figure creation and writing the transcripts.

Jessie Gardner also studied Natural Sciences and has just embarked on a PhD with the British Antarctic Survey focusing on the effect of ocean acidification and warming on pteropods. She assisted through all aspects of the project, particularly epiphyte identification, reviewing literature, writing transcripts and editing them.

Laurie Kerr completed her ecology degree at UEA and currently is in France teaching English. She assisted with the data collection, some analysis and reviewed the first transcript.

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