Investigating the Influence of Microclimate on Bryophyte Species Richness in a Cornish Atlantic Oak Woodland

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I dedicate this work to my Bampy who sadly passed away during the last few weeks of writing this dissertation. My Bampy always checked in on me and loved hearing about how I was getting on with my university work. He was such an inspiration to me, and I hope I make him proud.

Cover photo: Assemblage of epiphytic bryophytes at the study site (author's photography).

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GLOSSARY OF TERMS

VPD Vapour pressure deficit

AOW Atlantic oak woodland

BSR Bryophyte species richness

SR Species richness

ABSTRACT

The Earth is currently in a state of biodiversity crisis and the UK is no exception to this trend. Despite being the most biodiversity-poor European country, the UK has roughly 1,100 known species of bryophytes. The UK therefore has an international responsibility to protect such a rich bryophyte flora to aid UK biodiversity goals and support ecosystem functioning. Understanding the factors that influence bryophyte distribution within an ecosystem is critical for effective management practices that optimise bryophyte richness. This study collected microclimatic data and conducted a bryophyte survey in a Cornish Atlantic oak woodland. Significant linear relationships were found between mean lux and minimum temperature. However, no other microclimatic variables had any relationships with bryophyte species richness. The absence of any casual relationship between vapour pressure deficit and species richness may be explained by a riparian buffer zone creating overall moist conditions along the sampling transects. Woodland age was found to have no influence over bryophyte richness, and instead varied substrate cover of dead wood and boulders was important. The results of this study indicate that management should focus on and exploit riparian buffer zones in Atlantic woodlands and ensure varied substrate cover for the proliferation and protection of bryophytes.

Key words: Bryophyte, microclimate, moss, liverwort, Atlantic oak woodland, species richness, bryoflora

1. INTRODUCTION

1.1 The global biodiversity crisis and the role of the UK in bryophyte conservation

The Earth is currently in a state of biodiversity crisis. Biodiversity across the globe is diminishing at alarming rates. Indeed, up to 13% of all known species globally have gone extinct since the year 1500 AD (Cowie *et al.*, 2022). Several studies have confirmed that the current rate of extinction is up to 100 times the baseline average and is likely to continue to increase under predicted trends (Barnosky *et al.*, 2011; Ceballos *et al.*, 2015). This is highly problematic as biodiversity is essential for the functioning of ecosystems (Hong *et al.*, 2022; Tilman *et al.*, 2014), the provisioning of ecosystem services to humans (Balvanera *et al.*, 2016; Zhang *et al.*, 2019), and climate regulation (Daba and Dejene, 2018; Shin *et al.*, 2022). Yet, the influence of anthropogenic activity on the biosphere through land-use and land-cover changes, causing habitat fragmentation and loss, are major drivers in the reduction of global biodiversity (Hautier *et al.*, 2015; Jaureguiberry *et al.*, 2022; Prakash and Verma, 2022). Moreover, anthropogenic climate change caused by the combustion of fossil fuels is contributing to warming that threatens to alter the habitat conditions of many taxonomic groups, resulting in phenological changes (Bertin, 2008; Ibáñez *et al.*, 2010), range shifts (Freeman *et al.*, 2018), and extinction (Malcolm *et al.*, 2006).

The UK is no exception to this global trend. Indeed, the UK stands as one of the most biodiversity-poor countries in Europe (Hayhow *et al.,* 2019). Poor woodland and agricultural management alongside rapid urbanisation have driven reductions in up to 41% of UK species since the 1970s (Hayhow *et al*., 2019). In addition, a mere 13.2% of UK land is covered in woodlands, making the UK one of the least forested countries in Europe (Woodland Trust, 2021). Consequently, the UK government has pledged to reverse biodiversity loss by the year 2030 which will require broad scale conservation efforts, proper woodland management, and a reform of current agricultural practices (Smith *et al.*, 2023). Furthermore, the government have set ambitious targets to increase woodland cover to 17% which will undoubtedly facilitate biodiversity and other ecosystem services associated with woodland landscapes (Defra, 2021).

Despite having significantly lower biodiversity in comparison to other European nations, the UK has the richest bryophyte flora (hereafter 'bryoflora') in Europe, and one of the richest bryofloras in the world. The UK has around 1,100 known species of mosses, liverworts, and hornworts; roughly 65% of the total European bryoflora or an astonishing 5% of all known species globally, which totals approximately 25,000 (Rothero, 2005). There are 883, 782, 906 and 587 known species in England, Wales, Scotland, and Northern Ireland, respectively (Hill *et al.*, 2007). The UK even hosts near-endemic bryophyte species and some species that, despite being rare in Europe, are common in the UK such as the liverworts *Saccogyna viticulosa and Plagiochila spinulosa* (Plant life, 2016).

Thus, the UK has an international responsibility to protect bryophytes due to their significance in national and international biodiversity and overall ecosystem health and functioning (Hallingbäck *et al.*, 2000). However, doing so requires well informed management that considers the multifaceted influences upon bryophyte distribution within an ecosystem. Hence, this study explores the influence of habitat conditions on the distribution of bryophytes within an Atlantic woodland ecosystem in attempt to better inform management practices in a time of biodiversity crisis and climate change.

1.2 Bryophyte physiology and their ecological significance

Bryophytes are small, lower order plants that differ from vascular plants in their size and physiology. Survival and reproduction of bryophytes is greatly dependent on their environments due to their unique physiology and morphology (He *et al.,* 2016; Marschall, 2017). Bryophytes lack a vascular system and instead have a poikilohydric strategy to uptake water and nutrients from the environment across the surface of the gametophore, where leafy shoots of the plant rapidly equilibrate with the water potential of the environment (Proctor, 1990). The moisture is then retained by a network of capillaries and rhizoids (Marschall, 2017). Bryophytes have varying desiccation-tolerance, meaning they are able to lose virtually all intracellular water through warm and dry environmental conditions but can recover full function upon rehydration (Proctor, 1990; Proctor *et al*., 2007). Though, recovery time depends upon the degree to which desiccation occurs and for how long this state persists as well as environmental conditions such as temperature and humidity (Proctor *et al*., 2007). Moreover, the degree of desiccation-tolerance varies by species due to habitat niche requirements, and liverworts tend to be less tolerant than mosses in general (Proctor *et al*., 2007).

In general, bryophytes prefer cooler temperatures due to having a low optimum temperature for photosynthesis (Marschall, 2017). Additionally, whilst bryophyte species across biomes encounter varying light conditions, it can be generalised that they are shade-adapted plants (Marschall and Proctor, 2004). Indeed, most photosynthesis occurs in 20% full light conditions and only when the plant is fully moist as under bright and dry weather conditions bryophytes are metabolically inactive due to desiccation (Marschall and Proctor, 2004). Bryophytes also have low thermal-acclimation potential, raising the necessity for consistent temperatures in their habitats for productivity (He *et al.*, 2016). As external water is vital for photosynthesis and the growth of bryophytes, this factor accordingly guides their distribution within ecosystems. Though, bryophytes occur in virtually all terrestrial habitats globally, from the arctic to tropical regions (Hallingbäck *et al.*, 2000). In these ecosystems, bryophytes are often found blanketing forest floors, colonising rocks, boulders, deadwood (epixylic species) and as epiphytic vegetation on tree trunks and branches.

Bryophytes play an essential role in the dynamics of ecosystem functioning. For instance, in temperate forest ecosystems bryophytes form vast mixed communities that contribute to the overall forest structure and function (Hallingbäck *et al.*, 2000). Due to their structure, bryophytes have a high water-retention capacity. This means they can rapidly absorb water and slowly release it back into the environment which helps mediate humid forest microclimates as well as restrict the impact of flash flooding and erosion within a drainage basin (Coelho *et al.*, 2023; Hallingbäck *et al.*, 2000; Oishi, 2018). Additionally, bryophytes have crucial nutrient recycling and carbon and nitrogen fixation properties which are comparable across ecosystem types (Turetsky, 2003). Hence, the loss of bryophytes from an ecosystem would have cascading effects for the overall ecosystem health and functioning (Marschall, 2017), prompting the necessity of protection and conservation.

1.3 Microclimates, climatic buffering effects, and woodland composition

Although bryophytes are ubiquitous in terrestrial ecosystems, their occurrence and distribution within an ecosystem are controlled by a range of factors. At the coarse spatial scale, these include, but are not limited to, climatic factors, light-shade conditions (Tinya *et al.*, 2009), substrate availability and type, aspect (Hylander, 2005), and topography (Bennie *et al.*, 2008). Specifically, microclimates within a habitat are largely generated by temperature, the moisture regime (which affects relative humidity) and canopy cover (which affects light conditions) (De Frenne *et al.*, 2021). Many studies have highlighted the influence of microclimate on bryophytes within an ecosystem (Chen and Franklin, 1997; Ellis, 2020; Ellis and Eaton, 2021; Man *et al.*, 2022; Oishi, 2019; Sonnleitner *et al.*, 2009; Sporn *et al.*, 2009; Stewart and Mallik, 2006; Táborská *et al.*, 2020) due to their environmentally dependent water and nutrient uptake strategy.

It is well documented that woodland or forest microclimates differ greatly to the climate outside (De Frenne *et al.*, 2019, 2021). This is important for bryophytes, which require niche climatic optima and are more sensitive to macro-scale climate change (Frego, 2007). A woodland is a spatially complex and varied system with differing light, moisture, and temperature gradients created by the stand structural characteristics, watercourses, site location, and canopy cover. This variation of parameters creates below-canopy microclimates which are important for a rich and varied dispersal of bryophytes (Chen and Franklin, 1997; Ellis, 2020; Ellis and Eaton, 2021; McCune *et al.*, 2000). Indeed, even a small change in microclimatic conditions within an ecosystem may have a notable effect on bryophyte richness (Zhang *et al.*, 2023). Thus, woodlands may create and facilitate microrefugia for bryophytes by buffering the effects of habitat fragmentation and macroclimatic change (Ellis, 2020; Ellis and Eaton, 2021; Suggitt *et al.*, 2018). This alone highlights the importance of understanding the spatial patterns of microclimate and bryophyte richness within a woodland ecosystem.

Moreover, tree species composition and woodland (stand) age can influence the distribution of bryophytes. Several studies have identified that various measures of bryophyte diversity are directly influenced by stand age (Fenton and Bergeron, 2008; Fritz *et al.*, 2009; Király *et al.*, 2013; Rola *et al.*, 2021). Generally, older stands are often associated with higher bryophyte richness when compared to younger or secondary woodlands (Fritz *et al.*, 2009; McGee and Kimmerer, 2002; Müller *et al.*, 2019). Older trees, especially oaks, may have more gnarled features which in themselves provide specific microhabitats for bryophytes (Plant life, 2016). In fact, over-matured trees have been shown to have increased epiphyte diversity, with some species being exclusively limited to ancient trees (McGee and Kimmerer, 2002). Additionally, older trees are responsible for the input of deadwood into the environment which provides an essential substrate for bryophytes to colonise (Müller *et al.*, 2019; Táborská *et al.*, 2020). Though, in some woodland types, the influence of stand age is minor compared to tree-specific factors such as tree species and bark chemistry (Mežaka *et al.*, 2012).

1.4 The oceanic climate of the UK and Atlantic woodlands

Climatic conditions are a major reason for the markedly rich bryoflora in the UK. A zone of oceanicity covers the west coast of the UK, including Scotland, Wales, Northern Ireland, Cumbria, Cornwall, and Devon (**Figure 1**). Woodlands that lie within these climatic zones are often Atlantic woodlands. Atlantic woodlands are characterised by high annual rainfall, little incidence of frost, and relatively small differences in the mean summer and winter temperatures (DellaSala *et al.*, 2011). Notably, roughly 25% of the total annual rainfall occurs over the warmest months, creating an absence of long dry periods that would otherwise create unsuitable conditions for bryophytes to proliferate (DellaSala *et al.*, 2011). As well as climatic conditions, the recently glaciated landscape of the western UK provides suitable rocky substrates and steep valleys that may have experienced reduced grazing pressure (Rothero, 2005). Furthermore, the distance from urban hubs of the UK over recent history has buffered against the influence of pollution on bryophyte abundance (Rothero, 2005).

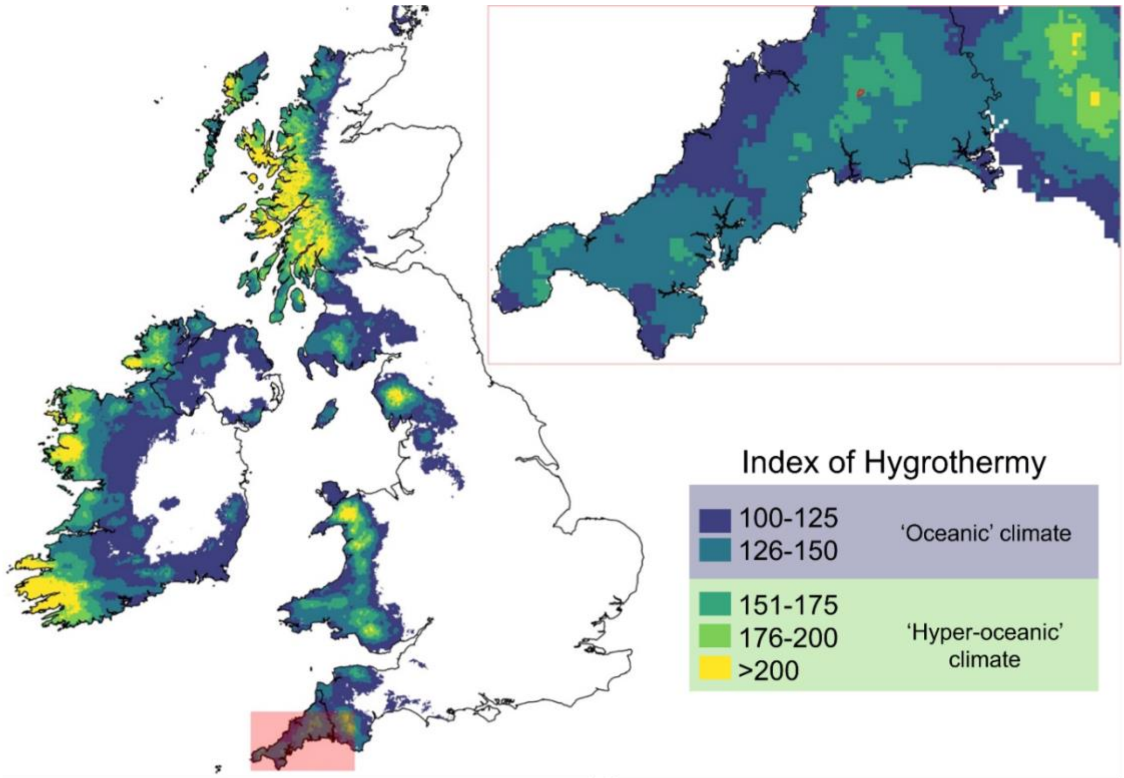


Figure 1: Distribution of oceanic and hyper-oceanic climatic zones in the UK. Pockets of hyper-oceanicity are present in the Southwest of England. Red polygon represents study site. The index of hygrothermy considers mean annual precipitation and temperatures and the mean temperatures of the warmest can coolest months. Methodology from: (Ellis, 2016). 5 km grid-scale data from: (Met Office, 2024).

Atlantic woodlands are some of the most biodiverse habitats in the UK and correspondingly play an important role in the conservation of bryophytes. In fact, these woodlands, especially those with boulder covered streams or ravines (**Figure 2**), are not too dissimilar to other bryophyte rich ecosystems of the world such as tropical montane cloud forests (Gotsch *et al*., 2017; Rothero, 2005). Hence, various organisations in the UK are highlighting the need to protect these woodland ecosystems (Plant life, 2016). Arguably, to do this optimally, an understanding of the spatial distribution of bryophytes with microclimate is needed.

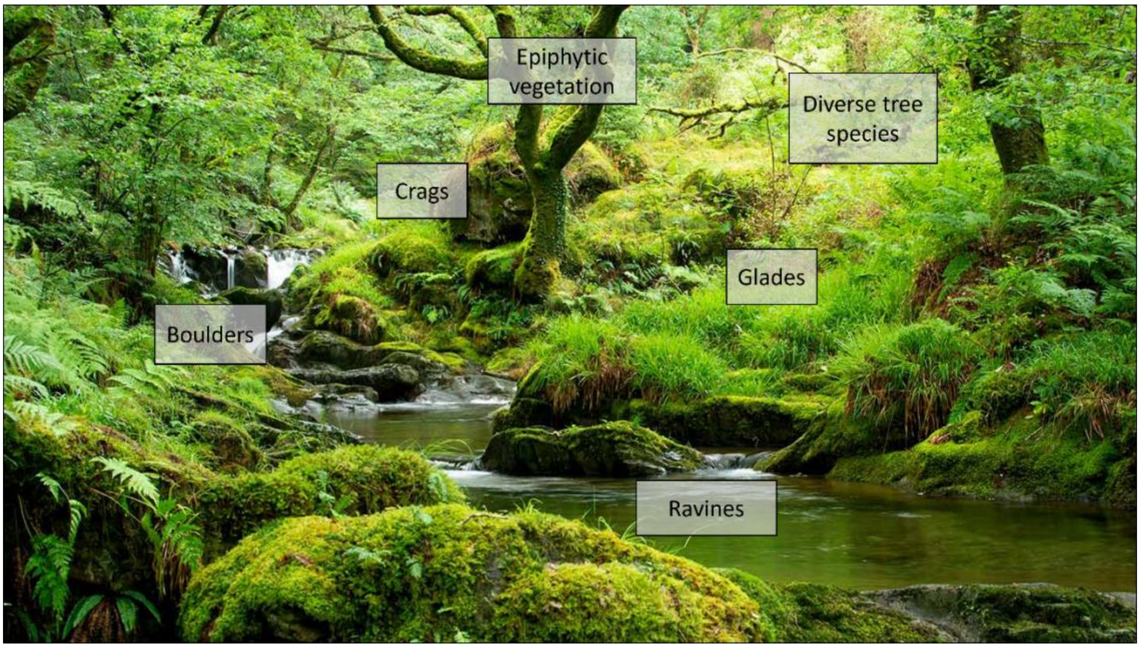


Figure 2: Example of typical Atlantic Woodland. Habitat heterogeneity is created through various features. Tree species composition depends on latitude but often include oak, hazel, birch, and ash. Luxuriant epiphytic vegetation is characteristic of this ecosystem. Image adapted from: (Woodland Trust, 2024).

1.5 Atlantic oak woodlands in Cornwall and the importance of management

Existing studies in ecosystems such as tropical forests (Gotsch *et al*., 2017; Karger *et al.*, 2012), Japanese urban gardens (Oishi, 2019), and temperate forests (Király *et al.*, 2013; Táborská *et al.*, 2020) have explored the relationship between microclimatic factors (air temperature, relative humidity, Vapour Pressure Deficit (VPD; see section 2.3.1), and light), substrate, tree characteristics and varying metrics of bryophyte diversity, richness, or cover. Yet, limited studies exist in Atlantic woodlands in the UK, of which are concentrated in Scotland and often focus on lichens or epiphytic groups only due to their importance as indicator species (Ellis, 2016, 2020; Ellis and Eaton, 2021). Nonetheless, Southwest England too has a role to play in bryoflora conservation and diversity in the UK but there exists no comprehensive study on the influence of microclimate and substrate on bryophyte richness in this ecosystem. This study therefore aims to fill this research gap.

Atlantic Oak Woodland (AOW) in the Southwest tends to be less wet and experiences more sun than its hyper-oceanic counterparts in Scotland. This makes Cornish AOWs important for a range of southern oceanic species that may have limited distribution in other parts of the UK. Considering the current biodiversity crisis, conservation and optimal management of these habits is therefore essential to protect the UK's bryoflora and biodiversity over coming decades. To achieve this, study at a fine spatial scale provides an opportunity to collect data across different oceanic gradients with the aim of generating a consensus that can be used to guide and implicate effective management based on microclimatic factors in AOWs.

1.6 Research objectives

This study primarily aims to investigate how microclimatic factors (air temperature, relative humidity, VPD and light) influence Bryophyte Species Richness (BSR) in a Cornish AOW. Furthermore, it will explore whether stand age and structural composition influences BSR. These study aims therefore give rise to the following research questions:

1) *How does temperature, humidity, light, and VPD microclimatic variables affect BSR in a Cornish AOW?*

2) *Does woodland age and composition influence BSR in a Cornish AOW?*

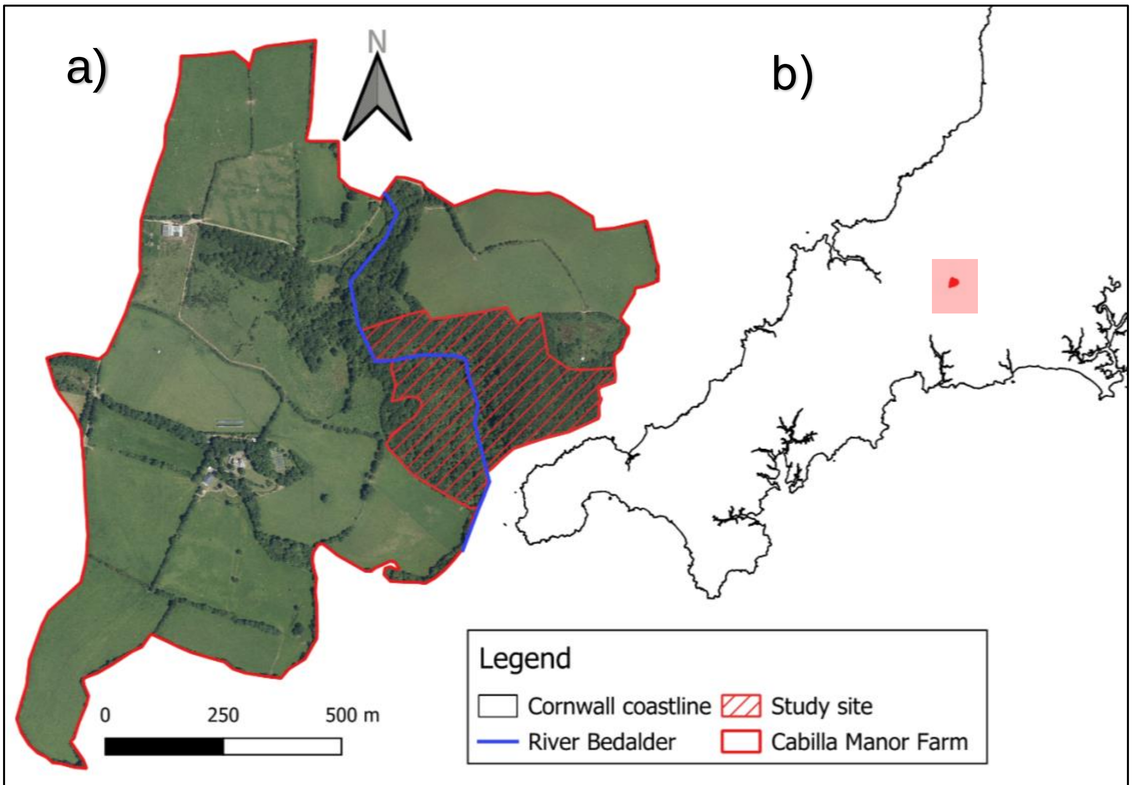
3) *How can the findings of this study be used to assist woodland landowners and managers in optimising BSR?*

2. METHODOLOGY

2.1 Study site

Cabilla Manor Farm is a 297 acre traditional upland hill farm situated on the edge of Bodmin moor, Cornwall, Southwest England (**Figure 3**). The site is roughly 200 m above mean sea level. The local climate is characteristically mild-temperate with an oceanic influence. The annual mean temperature is 13.5°C, ranging from 8.1°C to 19.2°C (Met Office, 2020). Additionally, the total annual rainfall is 1431.7 mm yr^{-1}, with 20% of this occurring over the summer months (Met Office, 2020).

Cabilla Manor Farm has ~70 acres of native broadleaf woodland. The woodland is an SSSI designated partly for the abundance of bryophytes including forty-six species of moss with the locally rare *Atrichum undulatum* and the first record of *Pohlia muyldermansii* in Cornwall at the time of designation (Natural England, 1989). The study site is situated within a wooded valley to the east of the farm with the river Bedalder meandering through from north to south (**Figure 3, Figure 4**). The river itself provides habitat for both flora and fauna being structurally diverse with pools, overhanging banks, and scattered granitic boulders. The woodland bordering the river is of differing ages. The patch to the west of the river is an ancient woodland (AW) whereas the patch to the east of the river is a secondary woodland (SW) of around 200 years old (Merlin-Hanbury Tenison, *Pers. Comm.)* (**Figure 5**). The woodland on site has evidence of historical coppice management for charcoal, as characteristic of AOWs (Thompson *et al.*, 2001), and quarry activity in the valley to the far east of the site.



High Resolution (25 cm) Vertical Aerial Imagery [Tiff], Scale: 1:500, Updated 2019, Ordnance Survey, GB. Using: EDINA Digimap Aerial, Downloaded: July 2023.

Figure 3: Location map showing **(a)** the study site within Cabilla Manor Farm, **(b)** Cabilla Manor Farm's location within Cornwall (OS grid reference: SX 14649 69718, 50.502N, 4.667W).

Figure 4: Example of the woodland structure at the study site (author's photography).

2.2 Sampling design

QGIS version 3.26.2 (QGIS Development Team, 2024) was used to do a preliminary exploration of the site. National LiDAR programme data at 1 m resolution were downloaded from Defra's environmental data platform (Defra, 2019) and loaded into QGIS to analyse the topographical features of the site using the slope and aspect tools. This allowed for generally suitable transect locations to be identified that were at a reasonable (for site access) and similar slope gradient. In addition, canopy cover was analysed using 3cm resolution drone photogrammetry data (Merlin Hanbury-Tenison, *Pers. Comm*.). Both transect locations had 100% canopy cover of vegetation >3 m. Resultantly, canopy cover was removed as an explanatory variable for the analysis. A subsequent site visit allowed for in-situ confirmation of the study locations, ensuring they had similar substrate cover, were not overly dominated by bracken that had been growing throughout the summer, and were representative of the overall woodland structure and composition.

A systematic sampling approach was taken using an interrupted transect. A transect of 20 m was placed either side of the banks of the river Bedalder (**Figure 5**). Sample points were placed at 1 m, 4 m, 8 m, 13 m, 19 m points along the transect to encapsulate any possible sharp changes in relative humidity or air temperature with increasing distance from the river (**Figure 6**).

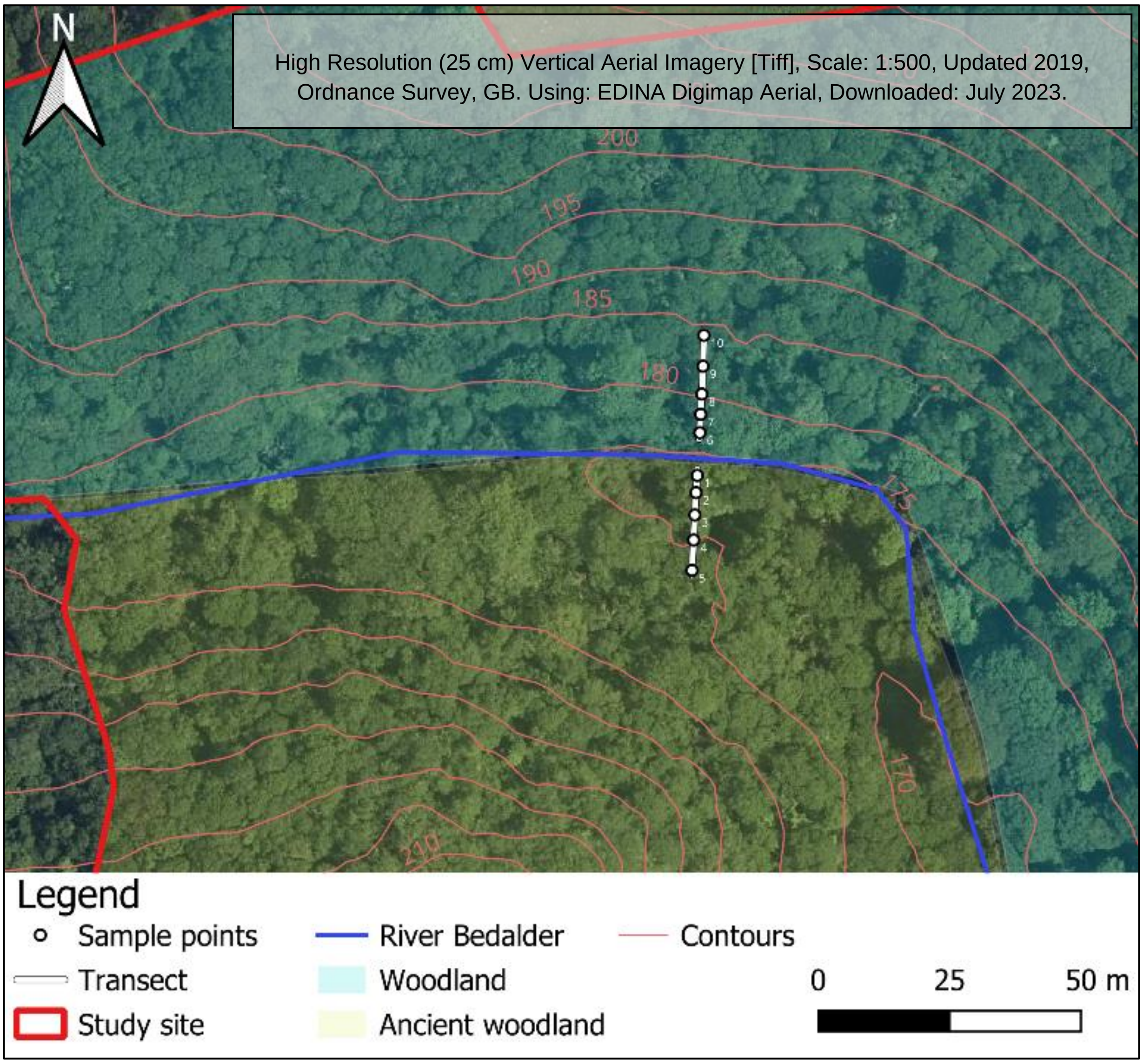


Figure 5: Study site map showing the two different woodland patches within the valley and the location of both transects. Transect 1 is located inside the AW whereas transect 2 is located opposite in the 200-year-old SW.

Figure 6: Transect 1 (sensors 1-5) SX15008 69828 at 191 m elevation to SX14999 69813 at 192 m elevation. Transect 2 (sensors 6-10) SX14996 69836 at 195 m elevation to SX14997 69856 at 201 m elevation.

2.3 Data collection

2.3.1 Microclimatic data

Light (Onset HOBO UA-002-64) and temperature/relative humidity (Onset HOBO U23-002 Pro v2) data loggers were attached to a bamboo cane at 1.3 m above ground level (Király *et al.*, 2013) (**Figure 7**). Temperature/humidity sensors were sealed with a rainproof shield (closed around the top and sides, but open at the bottom) and electrical tape to ensure water droplets did not interfere with the humidity reading. Measurements were programmed to be continuously taken every 15 minutes on both types of data loggers. Equipment was placed at all 10 transect sample locations where data collection occurred from 00:00 19th August – 00:00 22nd September 2023.

VPD is an indicator of the evaporation potential of the air that considers relative humidity and temperature, leading it to be an important metric to consider in assessments of bryophyte diversity due to desiccation-tolerance (Gotsch *et al*., 2017). Relative humidity only gives a measure of the proportion of air that is currently saturated whereas VPD indicates how much more water the air can hold at a given temperature (Monteith and Unsworth, 2013). Therefore, temperature and relative humidity data were used to calculate the VPD using the following equation:

$$VPD = \left(1 - \left(\frac{RH}{100}\right)\right) * SVP$$

Where SVP is the saturated vapour pressure, calculated using the following equation (Monteith and Unsworth, 2013):

$$SVP = 0.61078e^{\wedge}\left(\frac{17.27T}{T + 237.3}\right)$$

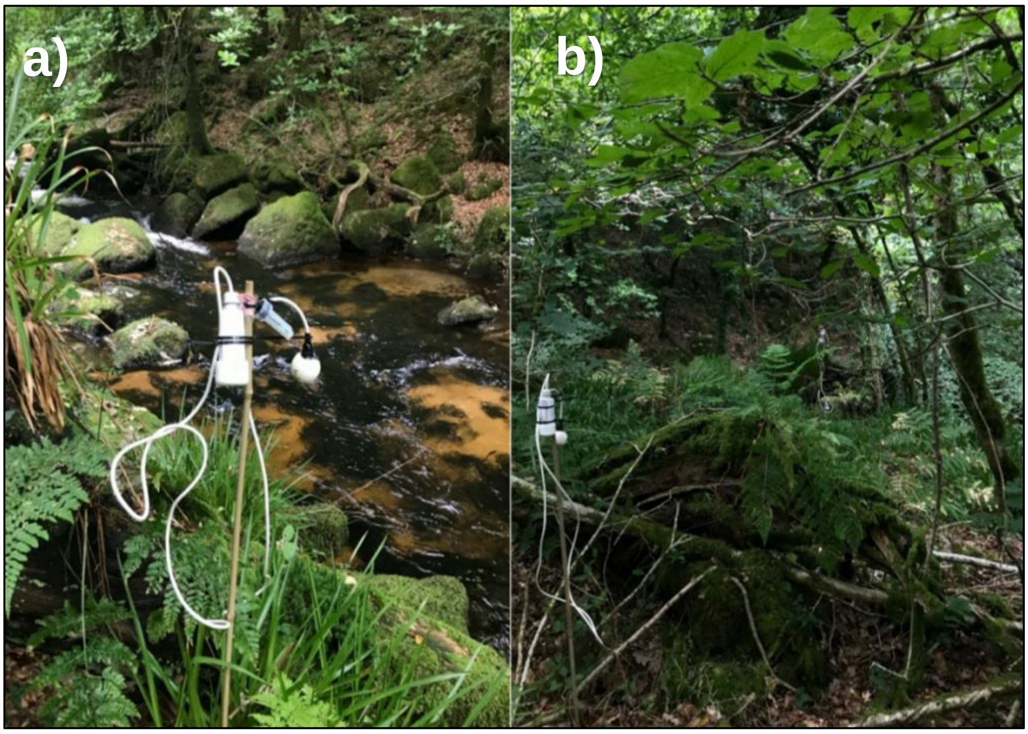


Figure 7: (a) Equipment used to collect microclimatic data (plot 1); **(b)** transect 1 (author's photography).

2.3.2 Woodland composition

Woodland composition was calculated using a point-centred-quarter sampling method (Wainscott, 2015). Two 20 m sample transects were carried out along the existing transects in both woodland patches to account for the tree density, species composition, basal area, and relative dominance. Resultantly, importance values for each tree species component could be calculated.

2.3.3 Bryophyte species richness

A bryophyte survey was conducted on 1st September 2023 using a hand lens (x10 and x20). All bryophyte occurrences (presence/absence) at each sample location within a 1 m radius plot surrounding the bamboo cane were recorded. Nomenclature followed that of the British Bryological Society (British Bryological Society, 2010). Species substrate was recorded as either ground, rock/boulder, tree, or logs/deadwood. Epiphytic bryophytes were considered on trees with DBH of at least 10 cm and at a height of 1 m (Király *et al.*, 2013). Unidentified species were collected and later identified using a microscope (Matt Stribley, *Pers. Comm.)*. The number of different species recorded within each sample plot was regarded as the Species Richness (SR). SR was chosen as a metric due to its simplicity to measure and ease of communicating to land managers who may not understand various ecological measures of diversity. It also easily identifies areas that are ecologically important due to high SR and overall contribution to biodiversity (Scott *et al.*, 1987), so focusing management is more straightforward.

2.4 Data analyses

2.4.1 Data processing

Initially microclimatic data were processed and downloaded using HOBOware pro version 3.7.26 (Onset Computer Corporation, 2023). Data were then processed from raw measurements into the mean, max, min, and range statistics for light, temperature, relative humidity, and VPD across all 10 sample plots. Minimum light and range data were excluded from analysis due to null values during dark hours having little influence on BSR. New datasets of all microclimate variables at each of the 10 sample plots were created.

All data analysis was conducted using RStudio (version 2023.09.1) (RStudio Team, 2020) and interpreted using a 95% confidence interval ($p \leq 0.05$). Plots were made using base and ggplot2 packages. Each variable was tested for parametricity using visual inspection of histograms and QQ plots, skewness, kurtosis, mean and median values, and a Shapiro-Wilkes test. All microclimatic explanatory variables except mean lux and max lux were non-parametric whereas the response variable, SR, was parametric.

2.4.2 Influence of woodland age on SR

To determine whether BSR differed between the AW and the SW, the SR dataset was split into half in accordance with the transect design. As these variables were parametric, an F-test was performed. Resultantly, as the variance was equal, an independent t-test was performed to test for a significant difference between the woodland patches.

2.4.3 Relationship between microclimate and species richness

To test for significant relationships between microclimate and BSR, each microclimatic variable was plotted against SR, as well as one another to test for collinearity. A subsequent Spearman's (Pearson's) corelation test between non-parametric pairs of (parametric pairs of) variables was performed and where a significant relationship was found, regression analysis was performed to determine the strength of an explanatory relationship between variables and SR. Multivariate regression was performed where multiple variables were significantly correlated with SR to determine whether the combination of variables had a stronger influence upon SR than in isolation.

2.4.4 Ellenburg indicator values and the BRYOATT tool

Ellenburg indicator values (Ellenberg *et al.*, 1991) are utilised in vegetation science due to their excellent ability to assess environmental conditions without the need to take in-situ measurements. The values are derived from long-term vegetation surveys and give insight into the optimal habitat conditions (for instance light, temperature, and continentality) for peak species occurrence. These data have been complied into a database format for bryophytes (Hill *et al.*, 2007). The BRYOATT tool provides a detailed database of attribute data for UK bryophyte species that allow the many factors that make up a species autecology to be recognized. Used in conjunction with in-situ data, a detailed description of site-specific microhabitats and bryophyte distributions can be established.

The BRYOATT tool was used to calculate the Ellenburg light and moisture values and the mean biogeographic element (BGE) score for each sample plot. This was done using the list of species present at each plot. A mean and mode value for each variable was subsequently calculated for each plot. These new variables were finally tested for relationships with the collected microclimatic data and SR in the same way as stated in section 2.4.3.

3. RESULTS

3.1 Bryophyte species richness

A total of 42 bryophyte species were identified across all 10 plots, 10 of which were liverworts and 32 were mosses (**Figure 8**; see appendix 1.1 for a full species list). No hornworts were identified at any of the sample plots. The most dominant species found were *Isothecium myosuroides, Kindbergia parelonga* and *Thuidium tamariscinum,* which were present at 7 out of the 10 sample plots. Other species such as *Amblystegium serpens* and *Fontinalis squamosa* were only present at 1 sample plot across both transects. In addition, *Lepidozia reptans, Nowelia curvifolia*, and *Fissidens polyphyllus* were only identified along transect 1 whereas *Loeskeobryum brevirostre* and *Plagiomnium undulatum* were only identified along transect 2.

Figure 8: Bryophyte assemblages at sample plots **(a)** 1, **(b)** 3, **(c)** 7, and **(d)** 10 (author's photography).

All species found are of least conservation concern in accordance with the IUCN Red list (Callaghan, 2022). All identified species are commonly found in the UK, with many having a broad range across different oceanic gradients, especially species such as *Isothecium myosuroides, Kindbergia parelonga, Thuidium tamariscinum and Brachythecium rutabulum* (British Bryological Society, 2010). Species found such as *Loeskeobryum brevirostre*, *Plagiochila punctata, Isothecium holtii* and *Neckera pulmila,* although not rare, follow a more oceanic distribution in the UK and are common in Cornwall (British Bryological Society, 2010; Paton, 1969).

Overall, plot 1 had the highest SR at 16 (**Figure 9**). In addition, plot 1 had the highest number of liverworts and mosses as separate groups. By contrast, plot 2 had the lowest SR at 5. Across all sampling plots, the average SR was 10 ± 3.4 (mean ± SD) and the range was 11. Logs and deadwood were the most common substrate class across all sampling plots, closely followed by rocks and boulders (**Table 1**).

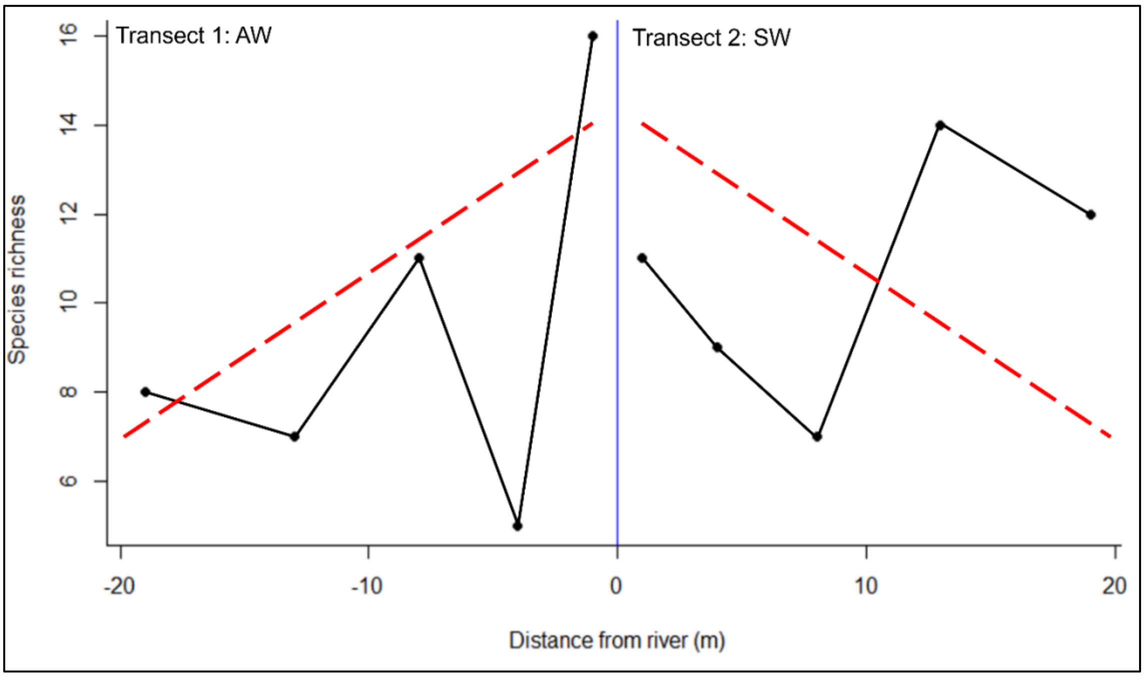


Figure 9: Schematic visualising BSR across both transects. Red dashed lines represent the general expected trend based on the findings of other studies (Gotsch *et al*., 2017; Oishi, 2019). Vertical blue line represents the river Bedalder.

Table 1: Number of bryophyte occurrences in different substrate classes.

	Logs/deadwood	Trees	Ground	Rocks and boulders
Occurrences	28	9	4	22

3.2 Influence of woodland age on species richness

The t-test revealed no significant difference in SR between the two woodland types (t = -0.53033, p= 0.61). Yet, the SW had marginally higher SR on average compared to the AW. The mean SR of transect 1 was 9.4 ± 4.3, whereas the mean for transect 2 was 10.6 ± 2.7 (**Figure 10**).

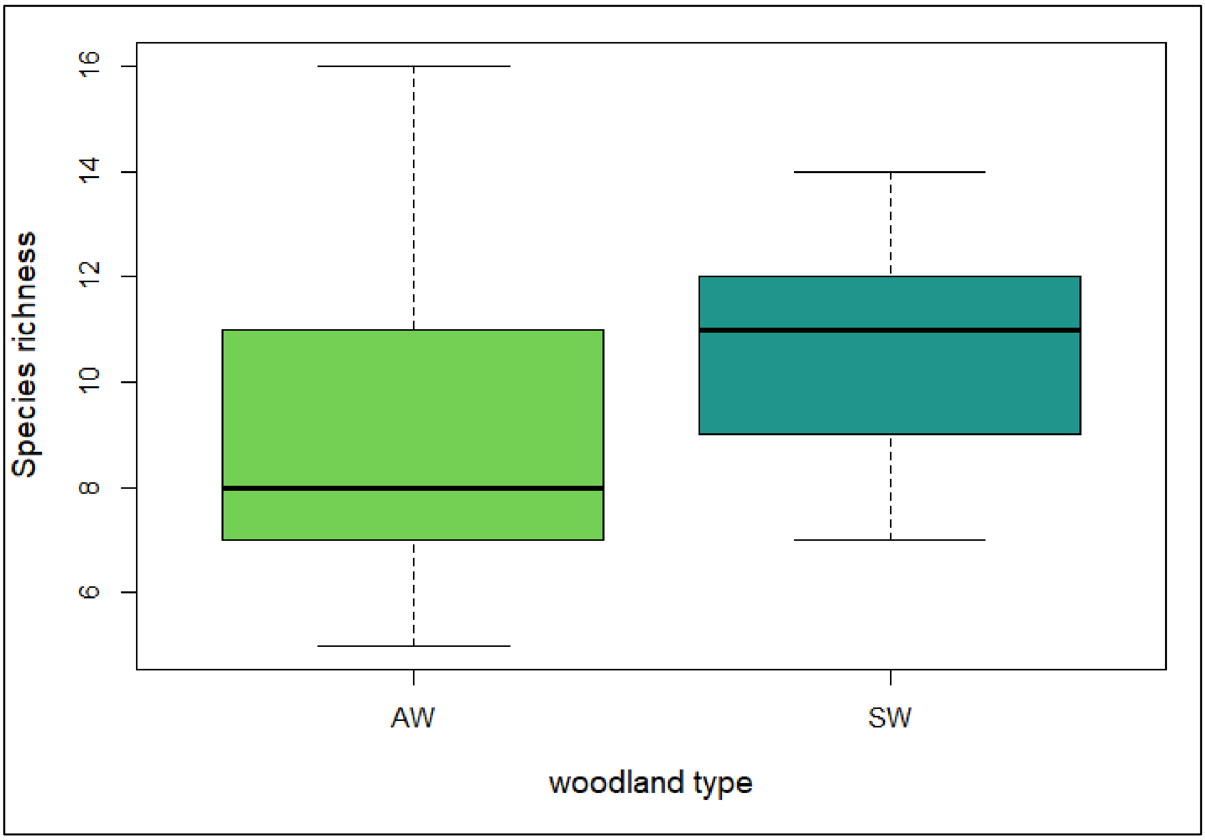


Figure 10: Distribution of SR values in both the AW and SW patches. AW richness = 9.4 ± 4.3 and SW = 10.6 ± 2.7 (mean ± SD). Black line on plot represents the median value.

3.3 Relationship between microclimate and bryophyte species richness

Of all tested microclimatic variables, only mean light and minimum temperature showed moderate significant relationships with SR (rho= -0.6, p= 0.04 and rho=0.63, p= 0.05, respectively). Though, mean temperature and max relative humidity were closer to significance than other variables (rho= 0.42, p= 0.23 and rho= 0.48, p= 0.16, respectively) (**Figure 11**). However, regressional analysis could not be justified due to insignificant test statistics, despite normally distributed residuals in both the mean light (W = 0.94244, p = 0.58) and minimum temperature (W = 0.90172, p = 0.23) models. Resultantly, no further regression analysis could be performed between microclimatic explanatory variables and SR. Moreover, multivariate regression did not show any stronger relationships when microclimatic variables were tested in conjunction with one another.

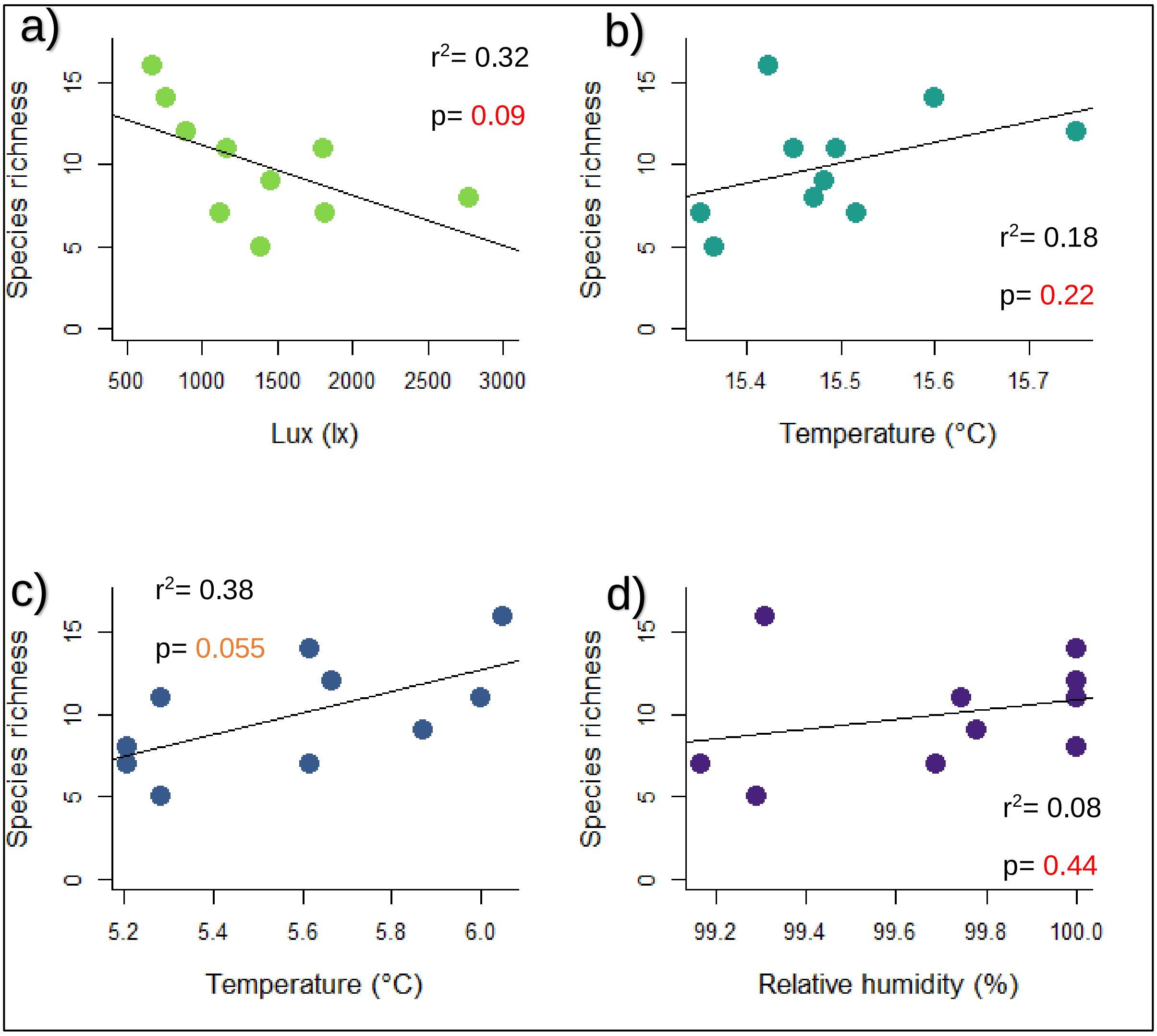


Figure 11: Relationships between **(a)** mean lux, **(b)** mean temp, **(c)** min temp and, **(d)** max rh and SR. Line represents the linear regression model. None of the regression models were significant. Despite this, minimum temperature (c) was approaching significance.

3.4 BRYOATT habitat indicator scores

Across all plots, 'temperate European' BGE scores were most common. In addition, some plots had mode BGE scores relating to 'boreo-temperate sub-oceanic' distributions. Within this, plots 1, 3, 4, 5, 9, and 10 had at least one species of temperate 'hyper-oceanic' biogeographic distribution.

When Ellenburg light and moisture indicator values were used as explanatory variables for SR, no significant relationships were found. Thus, no further regressional analysis could be carried out. Additionally, when microclimatic data were used as explanatory variables for BGE scores, no significant relationships were found despite mean temperature and max temperature approaching significance (rho= 0.60, p= 0.06 and, rho= 0.57, p= 0.08, respectively) (**Figure 12**). No combination of explanatory and response variables in multivariate analysis produced any stronger relationships.

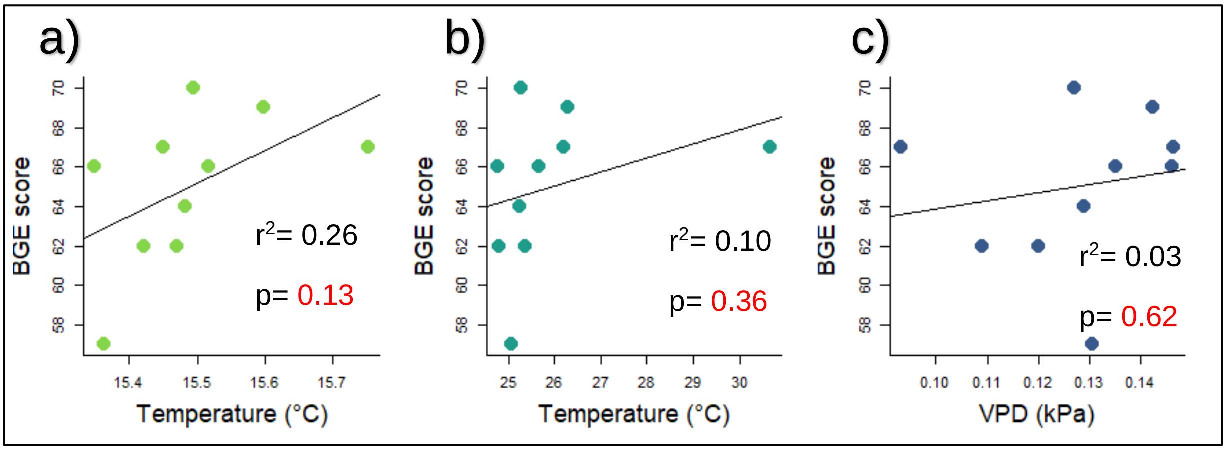


Figure 12: Relationships between microclimatic explanatory variables **(a)** mean temperature, **(b)** max temperature, and **(c)** mean VPD and BGE scores. Line represents linear model.

3.5 Woodland composition

Overall, the AW has a density of 845 trees/ha whereas the SW has slightly higher density at 892 trees/ha. 50% of the AW is dominated by hazel, with a further 44% being oak. This was different in the SW where the dominant species is sycamore (~32%). In contrast to the AW, other tree species such as beech, hawthorn and ash are present (**Figure 13a**). However, oak is the most important species in both the AW and SW with a calculated importance value of 121 and 102, respectively (**Figure 13b**). The average DBH in the AW was 27 cm whereas in the SW it was 23 cm, and the range was 66 and 60, respectively.

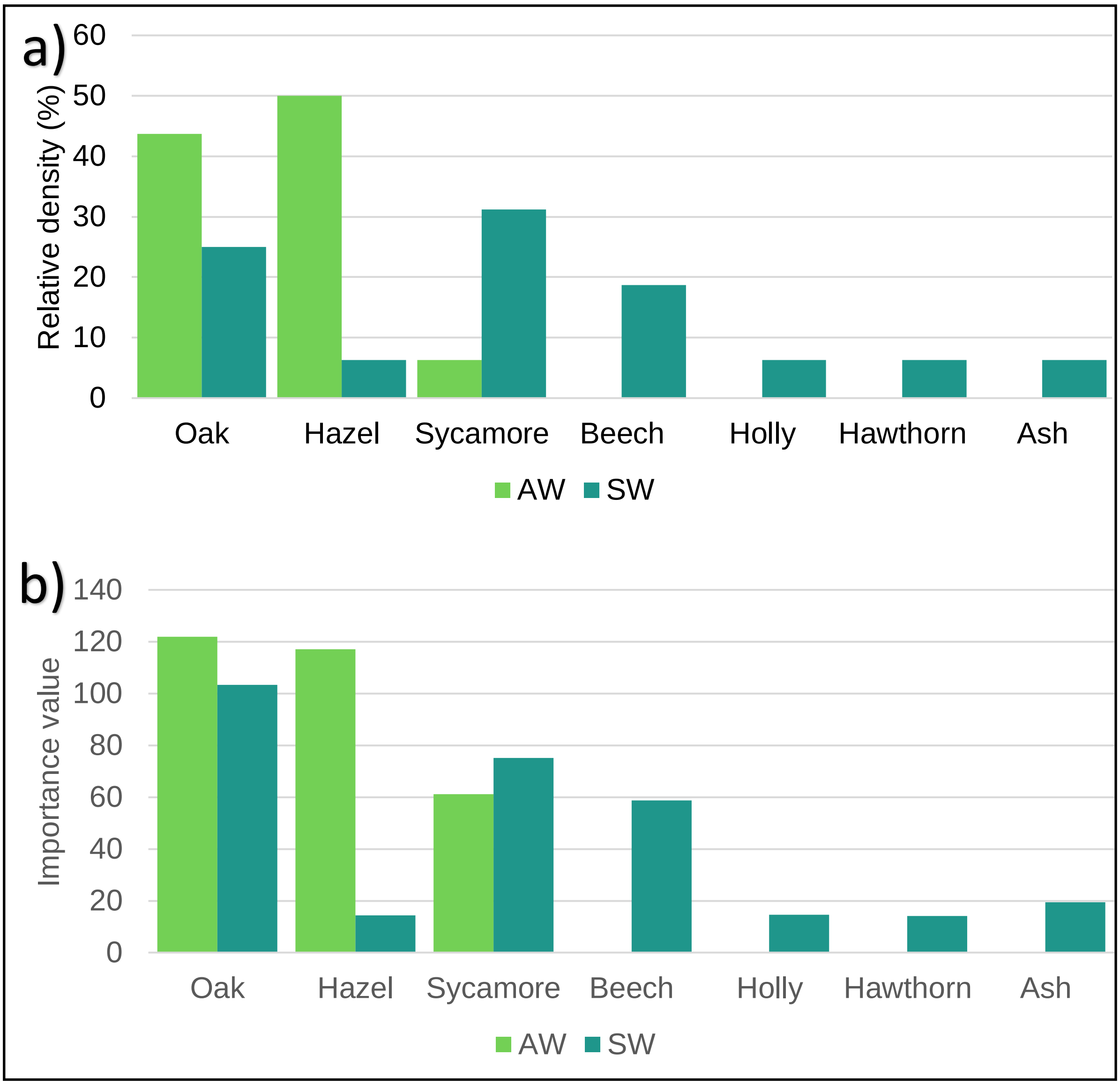


Figure 13: (a) Relative density of tree species in both woodland patches, and **(b)** the importance value of each tree species in both woodland patches. Importance values take into consideration the relative density, frequency, and dominance of the tree species within the woodland.

4. DISCUSSION

Effective management for the protection and proliferation of bryophytes in an ecosystem requires an understanding of the influence of microclimate on bryophyte distribution. This is the first known study that explores the influence of microclimate on bryophyte richness in a Cornish AOW. This study has demonstrated the complexity in bryophyte richness in AOWs and thus highlighted why these ecosystems are renowned for having such a rich bryoflora. Although no IUCN red list or rare species were identified, *Plagiochila punctata*, *Isothecium holtii* and *Fissidens polyphyllus* are 'very good' indicator species for oceanic woodlands (Averis, 2023). The abundance of these indicator species identified during the survey alongside the hyper-oceanic climate of the site (**Figure 1**) indicates that the study woodland is indeed very suitable for the proliferation of oceanic bryophyte species, despite the absence of rare or notable species in this instance.

4.1 The influence of microclimate on bryophyte richness and distribution

4.1.1 VPD and bryophyte species richness

The results of this study show no significant relationships with any measure of VPD and bryophyte richness. These findings do not align with the general trend presented in numerous other studies in varying bryophyte rich ecosystems (Gotsch *et al.,* 2017; Karger *et al*., 2012; Király *et al.,* 2013; Oishi, 2019). For instance, VPD was found to be the strongest microclimatic predictor of epiphyte abundance in a tropical montane forest (Gotsch *et al*., 2017). Although, when compared to other influential microclimatic variables in a different habitat type, the relationship between VPD and bryophyte diversity was not as strong as that of temperature and humidity metrics when analysed individually (Oishi, 2019). The lack of a relationship between VPD and BSR in this study indicates that other local-scale factors may be influencing the richness and distribution of bryophytes in the woodland.

The design of the present study may begin to explain these results. The presence of a waterway within the woodland valley will indeed have a large impact on the localised climate and thus microclimates sampled along the transects. Several other studies have presented the significance of riparian zones in woodlands for cooling the air temperature and regulating the relative humidity of the local climate, and thus the VPD (Ellis, 2020; Ellis and Eaton, 2021; Higgins and Yasué, 2014; Stewart and Mallik, 2006). A riparian buffer zone of up to 500 m has been shown to enhance the cover of and protect bryophytes and lichens, both characteristic groups of AOWs, from unsuitable macroclimatic conditions (Ellis, 2020). Specifically, a study in a coastal temperate rainforest in Canada identified that a riparian buffer zone of up to 35 m either side of a watercourse protected liverworts from microclimatic change due to unfavourable woodland management conditions (Higgins and Yasué, 2014).

This implies that a riparian buffer zone wider than the span of the transects may have been present in the study area, resulting in an insufficient change between VPD of the sampling plots to have any causal relationship with BSR i.e. the riparian buffering effect has created suitable microclimatic conditions for a rich bryoflora across both transects so distance from the river has a limited effect on BSR. Across all the transect sampling plots, the VPD was relatively low (mean at each plot=<0.16), suggesting that the bryophytes sampled are under little drought stress and thus can proliferate in the environment, explaining the high BSR across most of the sampling plots. This finding supports the overall importance of riparian zones in mediating suitable climatic conditions in AOWs for the conservation of bryophytes (and particularly liverworts) that are adapted to wetter conditions. With this in mind, future study may build on these findings by utilising longer transects, allowing for greater data acquisition across a wider moisture gradient and possibly identifying differing relationships to those found here.

4.1.2 Temperature and bryophyte species richness

Notwithstanding the non-significant liner model between temperature variables and SR (**Figure 11**), minimum temperature was found to have a significant positive relationship with SR (rho=0.63, p= 0.05). This may be explained by the fact that high temperatures reduce the rates of net photosynthesis in bryophytes, which can lead to inhibited growth and reproduction and ultimately decrease the richness of species present (Frahm, 1990). Temperatures that are too low can also inhibit photosynthesis; the optimum temperature tends to be close to the mean daily temperature during the growing season (Rothero, 2005). Additionally, high temperatures can lead to desiccation which inhibits metabolic function (Marschall, 2017; Proctor *et al*., 2007). Indeed, minimum, and average temperature variables have been found in other studies to be the primary environmental drivers for forest bryophyte diversity and distribution (Oishi, 2019; Zhang *et al.*, 2023). Zhang *et al*. (2023) found that a minor increase in temperature from a cool optimum lead to a decrease in overall bryophyte diversity. Therefore, the significant relationship identified with minimum temperature and BSR here aligns with findings of other studies in the literature.

As this study only measured BSR, it remains unknown what effect the varying microclimatic conditions had on the cover or community composition of bryophytes across the transects. For instance, bryophyte community composition (Sporn *et al.*, 2009) and cover (Király *et al.*, 2013; Oishi, 2019) have both been shown to change with microclimatic variables, whilst species richness has remained constant (Sporn *et al.*, 2009). Further study may build on the methods and results presented here by including measures of cover and diversity across some e.g. only epiphytic, or all, substrate types to better understand the distribution of bryophytes with microclimate in an AOW.

4.1.3 Light conditions and bryophyte species richness

It was found that mean lux had a moderate negative relationship with SR (rho= -0.6, p= 0.04) i.e. plots with higher mean light intensities had lower BSR. Although, a causal relationship could not be determined with these data due to a non-significant linear model (**Figure 11**). Despite the lack of regressional analysis, this relationship aligns with what was expected. Bryophytes are generally shade adapted plants, with optimal photosynthesis occurring under 20% of the max light conditions within an environment (Marschall and Proctor, 2004). High light intensities are also associated with desiccation, which through reduced metabolic rate, hinders the proliferation of bryophytes within an environment (Proctor *et al.,* 2007). However, species living closer to watercourses i.e. under less desiccation-stress, may be able to withstand higher light intensities due to being fully, or sufficiently hydrated for metabolic processes to continue (Proctor *et al.,* 2007).

Moreover, transect 2 (SW) had on average 21% lower light intensity, despite the canopy cover being 100% in both the AW and SW. This may be part of the explanation as to why BSR was marginally higher in the SW in contrast to the AW. In this instance, bryophytes in the SW may be under less desiccation-stress and at a more optimum light intensity for photosynthesis to occur, allowing for greater abundance across the sample locations. Although the non-significant difference in SR implies that this effect is not influential enough for a statistically distinguishable effect to be recorded.

4.2 The influence of woodland age and composition on bryophyte richness

Contrary to what was expected (Fenton and Bergeron, 2008; Fritz *et al.*, 2009), no significant difference was found between the BSR of the AW and the SW (**Figure 10**). Although, the SW had marginally higher mean SR than the AW. Tree species composition may be a reason as to why this is the case. There were marked differences in species composition between the AW and the SW (**Figure 13a**). In comparison to the AW, the SW had higher tree species diversity that may have contributed greater variance in epiphytic substrate for bryophytes (Király *et al.*, 2013; McCune *et al.*, 2000). In addition, the SW was denser than the AW, which may provide larger surface area for epiphytic bryophytes. Despite this, oak trees had the highest importance values (**Figure 13b**) in both woodland patches which indicates that oak may be the dominant species substrate in each regardless of the or structure woodland age (Wainscott, 2015).

Considering this, only 9 species occurrences were recorded as epiphytic. Thus, the influence of species composition and density may not be the only driving factor in the woodland. By contrast, woody substrates made up the most abundantly colonised group, which is similarly the case in other studies (McCune *et al.*, 2000; Riffo-Donoso *et al.*, 2021). The structural diversity, continuity, and presence of varying decay stages are all important factors in creating a continuum of microhabitats within the substrate group which is crucial for overall epixylic bryophyte richness and health (Ódor and Van Hees, 2004; Táborská *et al.*, 2020).

Additionally, it was expected that aspect may have an influence on the SR between the woodland patches. There is a marked difference between North facing and South facing slopes which has been documented in the literature for a range of plant species (Badano *et al*., 2005; Bennie *et al.,* 2008; Sternberg and Shoshany, 2001; Zhang *et al.,* 2022). The aspect differentiates the intensity of incoming solar radiation, and this affects rates of evaporation and soil moisture content (Sternberg and Shoshany, 2001). Indeed, North facing slopes tend to support a greater abundance, cover, and diversity of bryophytes due lower average temperatures and higher moisture (Luis *et al.*, 2010). However, the findings of this study are inconsistent with this general trend as on average transect 1 in the AW with the North facing slope had less bryophyte richness than transect 2 in the SW with a South facing slope. Thus, aspect can be ruled out as a confounding factor. To account for any differences that may be caused by slope aspect, which ultimately influences light conditions and bryophyte physiology, future study could ideally select sample locations of the same aspect to test for differences between these variables.

4.3 The importance of substrate cover and implications for management in Atlantic oak woodlands

Ultimately, protection of bryophytes through the formation of microclimates in a woodland not only enhances biodiversity but also maintains ecosystem resilience through the ecosystem services that they provide (Glime, 2024). For this reason, understanding the major drivers in bryophyte richness in a woodland is crucial for both ecologists and woodland managers alike. This study has started to explore these relationships and has alluded to several major ways in which management practices in Cornish AOWs can be enhanced.

Firstly, this study has emphasised the importance of varied substrate cover for the proliferation of bryophytes. Boulders, rocks, and deadwood proved to be important for bryophyte richness, whereas epiphytic bryophytes were less rich overall (**Table 1**). Many studies support this finding (Humphrey *et al.*, 2002; Oishi, 2019; Spitale, 2017; Táborská *et al.*, 2020), especially under riparian influence (Higgins and Yasué, 2014). The abundance of woody substrates in the bryophyte survey coveys the importance of allowing native tree species to stand and age naturally, eventually producing deadwood which should be left on the woodland floor to provide substrate for bryophytes (Radu, 2006). Indeed, deadwood has often been found to be the limiting substrate for bryophytes in managed woodlands (Spitale, 2017). In addition, this study has identified that rocks and boulders provide a large proportion of the overall substrate for bryophytes in this woodland. Rocky substrates provide important habitats for bryophytes due to their varying chemistry, surface textures and the presence of cavities and fissures which allows for the growth of varying species (Hespanhol *et al.*, 2011; Táborská *et al.*, 2020). Thus, a woodland with higher coverage of rocky substrates provides greater potential for colonisation and a rich bryoflora and these substrates should be encouraged rather than cleared from a woodland under management.

Moreover, topographic gradients, including distance to streams and rivers, should be exploited to create microclimatic heterogeneity within the ecosystem (Ellis and Eaton, 2021). This study has highlighted the importance of riparian zones in mediating suitable climatic conditions over a large buffer area (Ellis, 2020; Higgins and Yasué, 2014; Stewart and Mallik, 2006). This in conjunction with the suitable oceanic macro-climate facilitates bryophyte ‘hotspots’ within AOWs that offer prime areas to focus conservation efforts. Indeed, afforestation or reforestation within the suitable climatic pockets (**Figure 1**) and in riparian zones would exploit this buffering effect and maximise the biodiversity net gain of newly planted woodlands due to the potential for oceanic bryophyte proliferation under high atmospheric moisture conditions.

Overall, AOWs themselves act as strongholds for the protection of bryophytes (Averis, 2023; Plant life, 2016). However, the addition of microclimatic buffer zones created by waterways may provide suitable buffering of temperature extremes and the maintenance of a low VPD. This in the face of climate change may buffer the effects of macro-climatic change and protect bryophytes from warmer temperatures and drought-stress (IPCC, 2021). With this in mind, studies using this methodology at different AOW sites in

Cornwall and wider oceanic areas in the UK would build on the results presented here and help form a consensus on the influence of microclimate on bryophyte richness in AOWs and ultimately optimise understanding and management on a wider scale. This study consequently presents useful indications of the influence of microclimate on BSR in AOWs and opens many avenues for future research in this field.

5. CONCLUSION

This study sought to investigate the influence of microclimate on BSR in a Cornish AOW. Primarily, the findings of this study have shown that BSR is highly variable within the woodland and has many influential factors. Significant relationships between mean lux and minimum temperature and BSR were identified. These findings corroborate general trends identified in the literature; bryophyte distribution within an ecosystem is controlled by temperature and light preferences. Specifically, the data presented here show that bryophytes in this Cornish AOW prefer an optimum of cooler temperatures and lower light intensities. However, no other microclimatic variables, notably VPD, had any significant relationships with BSR. The absence of any relationship between VPD and BSR may be explained by the presence of a riparian buffer zone broader than the sampled transect length. Here, the river Bedalder is likely to be creating a low VPD over at least a 20 m buffer, creating suitable moist conditions for bryophytes to photosynthesise and proliferate across the riverbanks and adjacent woodlands.

Additionally, no significant difference in BSR was found between the AW and SW. This was likely due to the overall importance of oak as a habitat for bryophytes, the influence of the riparian buffer zone, and the even abundance of rocky and deadwood substrate in both woodland patches. This study has highlighted the overall importance of varied substrate cover in contrast to woodland age and structure in this instance. Thus, management should ensure that key substrate classes are abundant in an AOW to provide varied substrate for high bryophyte richness. Particularly, ensuring that there is a high cover of boulders and deadwood within 20-35 m of a watercourse may provide optimal substrate cover and microclimatic conditions (low VPD and cooler temperatures) for a rich bryoflora. Indeed, exploiting riparian areas for expansion and restoration of oak dominated woodlands in Cornwall and the wider Southwest may enhance local biodiversity through the formation of a rich bryoflora over time. Future study should build on the methods and findings of this present study and acquire measurements over a broader temporal and spatial scale. These expansions would test whether the findings of this study hold true across a broader range of conditions to best generalise and optimise management practices in AOWs for bryophytes.

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APPENDICES

1. Supplementary tables and figures

Species	Moss/Liverwort
Amblystegium serpens	M
Atrichum undulatum	M
Brachythecium rutabulum	M
Cephalozia curvifolia	L
Dicranum scoparium	M
Eurhynchinum striatum	M
Fissidens polyphyllus	M
Fissidensbryoides sp. Caespitans	M
Fontinalis squamosa	M
Frullania dilatata	L
Frullania tamarisci	L
Heterocladium flaccidum	M
Heterocladium heteropterum	M
Homalothecium sericeum	M
Hookeria lucens	M
Hyocominium amoricum	M
Hypnum cupressiforme	M
Isothecium alopecuroides	M
Isothecium holtii	M
Isothecium myosuroides	M
Kindbergia parelonga	M
Lejeunea lamacerina	L
Lepidozia reptans	L
Leucobryum albidum	M
Loeskeobryum brevirostre	M
Metzgeria furcata	L
Mnium Hornum	M
Neckera pumila	M
Plagiochila punctata	L
Pellia sp.	L
Plagiomnium undulatum	M
Plagiothecium succulentum	M
Polytrichum formosum	M
Pseudotaxiphyllum elegans	M
Radula complanta	L
Rhizomnium punctatum	M
Rhynchostegium alopecuroides	M
Rhytidiadelphus loreus	M
Scapania undulata	L
Tetraphis pellucida	M
Thamnobryum alopecurum	M
Thuidium tamariscinum	M

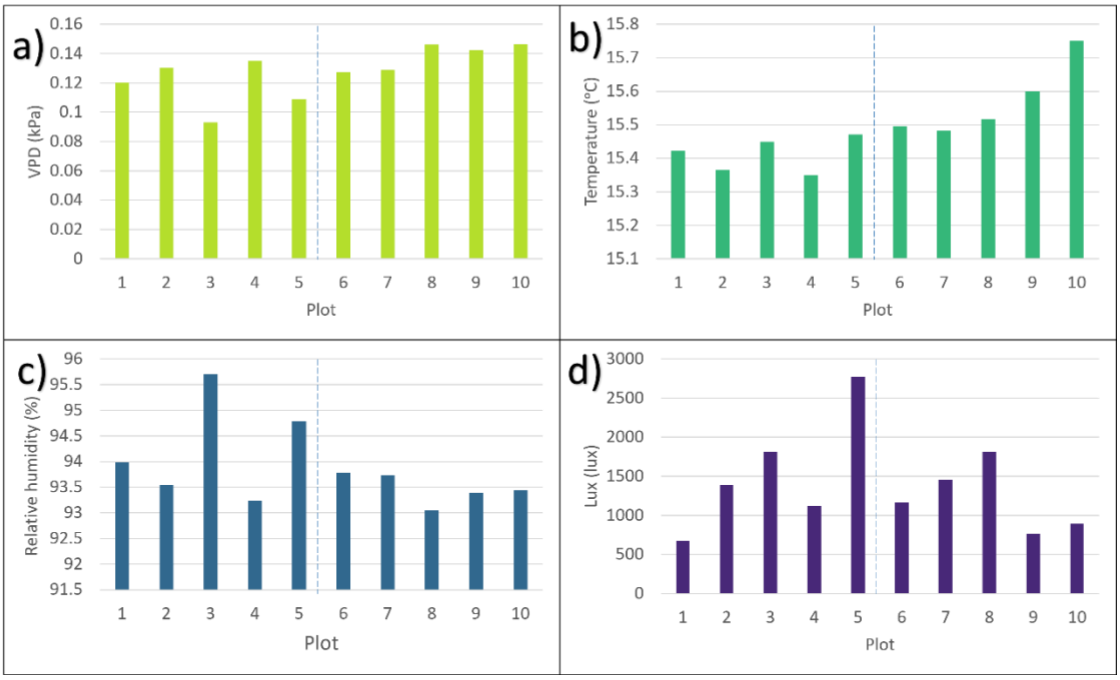
S1: Full species list

Variable	Hist	Qqplot	Shapiro	Skewness	Kurtosis	Normal?
light mean	no	no	0.278	0.98	3.36	yes
light max	no	no	0.016	0.8	2.07	no
light min						
light range						
temp mean	yes	no	0.26	1.02	3.6	yes
temp max	no	no	0.00015	2.25	6.8	no
temp min	no	no	0.17	0.16	1.58	no
temp range	no	no	0.001	2.02	6.16	no
rh mean	no	no	0.04	1.34	3.77	no
rh max	no	no	0.03	-0.55	1.73	no
rh min	no	no	0.02	-1.53	4.51	no
rh range	no	no	0.02	1.5	4.41	no
VPD mean	no	no	0.35	-0.8	2.82	no
VPD max	no	no	0.0023	1.86	5.51	no
VPD min	no	no	0.05	0.32	1.55	no
VPD range	no	no	0.003	1.85	5.48	no
Species richness	yes	yes	0.88	0.3	2.11	yes

S2: Descriptive statistics used to test all variables for parametricity.

Variable	species richness	light mean	light max	light min	light range	temp mean	temp max	temp min	temp range	rh mean	rh max	rh min	rh range
light mean	**-0.6, p= 0.04**												
light max	-0.01, p= 0.97												
light min													
light range													
temp mean	0.42, p= 0.23	-0.05, p= 0.89	-0.43, p= 0.22										
temp max	0.37, p= 0.30	0.11, p= 0.76	-0.07, p= 0.86										
temp min	**0.63, p= 0.05**	-0.49, p= 0.15	-0.32, p= 0.36										
temp range	0.05, p= 0.90	0.21, p= 0.56	0.08, p= 0.84										
rh mean	0.31, p= 0.38	0.21, p= 0.56	**0.73, p= 0.02**			-0.26, p= 0.47	-0.03, r= 0.95	0.09, p= 0.8	0.08, p= 0.84				
rh max	0.48, p= 0.16	0.19, p= 0.60	0.12, p= 0.74			**0.66, p= 0.03**	**0.85, p= 0.002**	-0.003, p= 0.99	**0.69, p= 0.03**				
rh min	0.09, p= 0.81	0.03, p= 0.95	0.53, p= 0.12			**-0.65, p= 0.05**	-0.58, p= 0.09	0.26, p= 0.46	-0.61, p= 0.07				
rh range	-0.02, p= 0.96	0.02, p= 0.97	-0.52, p= 0.13			**0.71, p= 0.03**	0.6, p= 0.07	-0.20, p= 0.59	0.58, p= 0.09				
VPD mean	-0.12, p=0.76	-0.3, p=0.39	**-0.73, p=0.02**			0.5, p=0.14	0.28, 0.43	0.06, 0.87	0.27, p=0.45	**-0.9, p=0.0005**	-0.13, p=0.73	**-0.77, p=0.01**	**0.75, p=0.02**
VPD max	0.14, p=0.70	0.05, p=0.89	-0.59, p=0.08			**0.88, p=0.002**	**0.72, p=0.02**	0.06, p=0.88	0.54, p=0.11	-0.50, p=0.15	0.57, p=0.09	**-0.89, p=0.001**	**0.93, p=<0.001**
VPD min	-0.37, p=0.30	-0.25, p=0.49	-0.13, p=0.7			**-0.64, p=0.04**	**-0.86, p=0.0013**	0.09, p= 0.82	**-0.74, p=0.01**	-0.33, p= 0.35	**-0.99, p= <0.001**	0.41, p=0.24	-0.43, p= 0.21
VPD range	0.19, p=0.6	0.10, p=0.79	-0.53, 0.12			**0.92, p=0.0005**	**0.81, p=0.008**	0.08, p=0.83	0.6, p=0.07	-0.39, p=0.26	**0.66, p= 0.04**	**-084, p=0.004**	**0.88, p=0.002**

S3: Rho and p-values for correlation tests between all variables. Bold values in a green cell are significant at the 95% confidence interval. Those highlighted in orange were identified as approaching significance, so were included in multivariate regression analysis and plotted.



S4: Bar chart to visualise the mean microclimatic measurements at each sampling plot.

2. R code

```
VPD_max<-read.csv("VPD_max.csv", header=TRUE)

VPD_mean<-read.csv("VPD_mean.csv", header=TRUE)

VPD_min<- read.csv("VPD_min.csv", header=TRUE)

VPD_range<- read.csv("VPD_range.csv", header=TRUE)

temp_range<-read.csv("Temp_range.csv", header=TRUE)

temp_max<-read.csv("temp_max.csv", header=TRUE)

temp_min<- read.csv("temp_min.csv", header=TRUE)

temp_mean<- read.csv("temp_mean.csv", header=TRUE)

lux_max<-read.csv("lux_max.csv", header=TRUE)

lux_mean<-read.csv("lux_mean.csv", header=TRUE)

rh_mean<-read.csv("rh_mean.csv", header=TRUE)

rh_max<- read.csv("rh_max.csv", header=TRUE)

rh_min<- read.csv("rh_min.csv", header=TRUE)

rh_range<-read.csv("rh_range.csv", header=TRUE)

richness<- read.csv('species_richness.csv', header=TRUE)


library(moments)


#####variable normality testing#####

#####lux_mean#####

hist(lux_mean$mean)

shapiro.test(lux_mean$mean)

qqnorm(lux_mean$mean)

qqline(lux_mean$mean)

skewness(lux_mean$mean)

kurtosis(lux_mean$mean)


#####lux_max#####
```

```
hist(lux_max$max)
shapiro.test(lux_max$max)
qqnorm(lux_max$max)
qqline(lux_max$max)
skewness(lux_max$max)
kurtosis(lux_max$max)

#####temp_mean#####
hist(temp_mean$mean)
shapiro.test(temp_mean$mean)
qqnorm(temp_mean$mean)
qqline(temp_mean$mean)
skewness(temp_mean$mean)
kurtosis(temp_mean$mean)

#####temp_max#####
hist(temp_max$max)
shapiro.test(temp_max$max)
qqnorm(temp_max$max)
qqline(temp_max$max)
skewness(temp_max$max)
kurtosis(temp_max$max)

#####temp_min#####
hist(temp_min$min)
shapiro.test(temp_min$min)
qqnorm(temp_min$min)
qqline(temp_min$min)
skewness(temp_min$min)
kurtosis(temp_min$min)
```

```
#####temp_range#####
hist(temp_range$range)
shapiro.test(temp_range$range)
qqnorm(temp_range$range)
qqline(temp_range$range)
skewness(temp_range$range)
kurtosis(temp_range$range)

#####rh_mean#####
hist(rh_mean$mean)
shapiro.test(rh_mean$mean)
qqnorm(rh_mean$mean)
qqline(rh_mean$mean)
skewness(rh_mean$mean)
kurtosis(rh_mean$mean)

#####rh_max#####
hist(rh_max$max)
shapiro.test(rh_max$max)
qqnorm(rh_max$max)
qqline(rh_max$max)
skewness(rh_max$max)
kurtosis(rh_max$max)

#####rh_min#####
hist(rh_min$min)
shapiro.test(rh_min$min)
qqnorm(rh_min$min)
qqline(rh_min$min)
```

```
skewness(rh_min$min)
kurtosis(rh_min$min)

#####rh_range#####
hist(rh_range$range)
shapiro.test(rh_range$range)
qqnorm(rh_range$range)
qqline(rh_range$range)
skewness(rh_range$range)
kurtosis(rh_range$range)

#####VPD_mean#####
hist(VPD_mean$mean)
qqnorm(VPD_mean$mean)
qqline(VPD_mean$mean)
skewness(VPD_mean$mean)
kurtosis(VPD_mean$mean)
shapiro.test(VPD_mean$mean)

#####VPD_max#####
hist(VPD_max$max)
qqnorm(VPD_max$max)
qqline(VPD_max$max)
shapiro.test(VPD_max$max)
skewness(VPD_max$max)
kurtosis(VPD_max$max)

#####VPD_min#####
hist(VPD_min$min)
qqnorm(VPD_min$min)
```

```
qqline(VPD_min$min)

shapiro.test(VPD_min$min)

skewness(VPD_min$min)

kurtosis(VPD_min$min)


#####VPD_range#####

hist(VPD_range$range)

qqnorm(VPD_range$range)

qqline(VPD_range$range)

shapiro.test(VPD_range$range)

skewness(VPD_range$range)

kurtosis(VPD_range$range)


#species richness#####

hist(richness$species_richness)

shapiro.test(richness$species_richness)

qqnorm(richness$species_richness)

qqline(richness$species_richness)

mean(richness$species_richness)

median(richness$species_richness)

skewness(richness$species_richness)

kurtosis(richness$species_richness)


#################################################################################

#####Relationships#####

plot(VPD_max$max, richness$species_richness)

cor.test(VPD_max$max, richness$species_richness, method = "spearman")


plot(VPD_mean$mean, richness$species_richness)

cor.test(VPD_mean$mean, richness$species_richness, method='spearman')
```

```
plot(temp_range$range, richness$species_richness)

cor.test(temp_range$range, richness$species_richness, method="spearman")


plot(lux_mean$mean, richness$species_richness, ylab= 'Species richness', xlab='Mean light')

cor.test(log(lux_mean$mean), richness$species_richness, method= "spearman")


plot(temp_max$max, richness$species_richness)

cor.test(temp_max$max, richness$species_richness, method= "spearman")


plot(temp_min$min, richness$species_richness)

cor.test(temp_min$min, richness$species_richness, method="spearman")


plot(temp_mean$mean, richness$species_richness)

cor.test(temp_mean$mean, richness$species_richness, method="spearman")


plot(VPD_min$min, richness$species_richness)

cor.test(VPD_min$min, richness$species_richness, method="spearman")


plot(VPD_range$range, richness$species_richness)

cor.test(VPD_range$range, richness$species_richness, method="spearman")


plot(lux_max$max, richness$species_richness)

cor.test(lux_max$max, richness$species_richness, method="spearman")


plot(rh_mean$mean, richness$species_richness)

cor.test(rh_mean$mean, richness$species_richness, method="spearman")


plot(rh_max$plot, richness$species_richness)

cor.test(rh_max$max, richness$species_richness, method="spearman")
```

```
plot(rh_min$min, richness$species_richness)

cor.test(rh_min$min, richness$species_richness, method= "spearman")


plot(rh_range$range, richness$species_richness)

cor.test(rh_range$range, richness$species_richness, method="spearman")


#####additional correlation tests#####

cor.test(temp_mean$mean, lux_max$max, method="spearman")

cor.test(temp_mean$mean, lux_mean$mean, method ="spearman")

cor.test(temp_max$max, lux_mean$mean, method= "spearman")

cor.test(temp_min$min, lux_mean$mean, method= "spearman")

cor.test(temp_range$range, lux_mean$mean, method= "spearman")

cor.test(rh_mean$mean, lux_mean$mean, method= "spearman")

cor.test(rh_max$max, lux_mean$mean, method= "spearman")

cor.test(rh_min$min, lux_mean$mean, method= "spearman")

cor.test(rh_range$range, lux_mean$mean, method= "spearman")

cor.test(VPD_mean$mean, lux_mean$mean, method= "spearman")

cor.test(VPD_max$max, lux_mean$mean, method= "spearman")

cor.test(VPD_min$min, lux_mean$mean, method= "spearman")

cor.test(VPD_range$range, lux_mean$mean, method= "spearman")

cor.test(temp_max$max, lux_max$max, method= "spearman")

cor.test(temp_min$min, lux_max$max, method= "spearman")

cor.test(temp_range$range, lux_max$max, method= "spearman")

cor.test(rh_mean$mean, lux_max$max, method= "spearman")

cor.test(rh_max$max, lux_max$max, method= "spearman")

cor.test(rh_min$min, lux_max$max, method= "spearman")

cor.test(rh_range$range, lux_max$max, method= "spearman")

cor.test(VPD_mean$mean, lux_max$max, method= "spearman")

cor.test(VPD_max$max, lux_max$max, method= "spearman")
```

```
cor.test(VPD_min$min, lux_max$max, method= "spearman")
cor.test(VPD_range$range, lux_max$max, method= "spearman")
cor.test(rh_mean$mean, temp_mean$mean, method= "spearman")
cor.test(rh_max$max, temp_mean$mean, method= "spearman")
cor.test(rh_min$min, temp_mean$mean, method= "spearman")
cor.test(rh_range$range, temp_mean$mean, method= "spearman")
cor.test(VPD_mean$mean, temp_mean$mean, method= "spearman")
cor.test(VPD_max$max, temp_mean$mean, method= "spearman")
cor.test(VPD_min$min, temp_mean$mean, method= "spearman")
cor.test(VPD_range$range, temp_mean$mean, method= "spearman")
cor.test(rh_mean$mean, temp_max$max, method="spearman")
cor.test(rh_min$min, temp_max$max, method ="spearman")
cor.test(rh_max$max, temp_max$max, method= "spearman")
cor.test(rh_range$range, temp_max$max, method= "spearman")
cor.test(VPD_mean$mean, temp_max$max, method= "spearman")
cor.test(VPD_max$max, temp_max$max, method= "spearman")
cor.test(VPD_min$min, temp_max$max, method= "spearman")
cor.test(VPD_range$range, temp_max$max, method= "spearman")
cor.test(rh_mean$mean, temp_min$min, method= "spearman")
cor.test(rh_max$max, temp_min$min, method= "spearman")
cor.test(rh_min$min, temp_min$min, method= "spearman")
cor.test(rh_range$range, temp_min$min, method= "spearman")
cor.test(VPD_mean$mean, temp_min$min, method= "spearman")
cor.test(VPD_max$max, temp_min$min, method= "spearman")
cor.test(VPD_min$min, temp_min$min, method= "spearman")
cor.test(VPD_range$range, temp_min$min, method= "spearman")
cor.test(rh_mean$mean, temp_range$range, method="spearman")
cor.test(rh_max$max, temp_range$range, method="spearman")
cor.test(rh_min$min, temp_range$range, method="spearman")
cor.test(rh_range$range, temp_range$range, method="spearman")
```

```
cor.test(VPD_mean$mean, temp_range$range, method="spearman")
cor.test(VPD_max$max, temp_range$range, method="spearman")
cor.test(VPD_min$min, temp_range$range, method="spearman")
cor.test(VPD_range$range, temp_range$range, method="spearman")
cor.test(VPD_mean$mean, rh_mean$mean, method ="spearman")
cor.test(VPD_max$max, rh_mean$mean, method ="spearman")
cor.test(VPD_min$min, rh_mean$mean, method ="spearman")
cor.test(VPD_range$range, rh_mean$mean, method ="spearman")
cor.test(VPD_mean$mean, rh_max$max, method ="spearman")
cor.test(VPD_max$max, rh_max$max, method ="spearman")
cor.test(VPD_min$min, rh_max$max, method ="spearman")
cor.test(VPD_range$range, rh_max$max, method ="spearman")
cor.test(VPD_mean$mean, rh_min$min, method ="spearman")
cor.test(VPD_max$max, rh_min$min, method ="spearman")
cor.test(VPD_min$min, rh_min$min, method ="spearman")
cor.test(VPD_range$range, rh_min$min, method ="spearman")
cor.test(VPD_mean$mean, rh_range$range, method ="spearman")
cor.test(VPD_max$max, rh_range$range, method ="spearman")
cor.test(VPD_min$min, rh_range$range, method ="spearman")
cor.test(VPD_range$range, rh_range$range, method ="spearman")


#####Linear regression#####
#####lux_mean#####
plot(lux_mean$mean, richness$species_richness, xlab='Mean light (lx)', ylab='Species richness')
lux_mean_lm<-lm(richness$species_richness ~ lux_mean$mean)
lux_mean_lm<-lm(richness$species_richness ~ +I(lux_mean$mean^1)+I(lux_mean$mean^2))
abline(lux_mean_lm, col ="red")
summary(lux_mean_lm)
resid_lux_mean_lm<-resid(lux_mean_lm)
plot(resid_lux_mean_lm)
```

```
abline(0,0, col="red")

shapiro.test(resid_lux_mean_lm)

plot(richness$species_richness, resid_lux_mean_lm)


install.packages("ggplot2")

library(ggplot2)


ggplot(data=lux_mean, aes(x=mean, y=richness))+

 geom_point()+

 geom_smooth(method=lm, level = 0.95, color = "red") + # Change the line color to red

 theme_bw() + # Use a white background theme

 theme(panel.grid = element_blank())+

 labs(x = 'Mean lux (lx)', y= 'Species richness')+

 coord_cartesian(xlim = c(750,2700), ylim = c(0,16))+

 theme(panel.border = element_blank())+

    axis.line.x = element_line(size = 0.5, linetype = "solid", colour = "black")# Add the x axis line

    axis.line.y = element_line(size = 0.5, linetype = "solid", colour = "black")# Add the y axis line


plot(temp_min$min, richness$species_richness, ylim=c(0,20), ylab='Species richness', xlab='Minimum
temperature (°C)')

temp_min_lm<-lm(richness$species_richness ~ temp_min$min)

abline(temp_min_lm, col ="red")

summary(temp_min_lm)

resid_temp_min_lm<-resid(temp_min_lm)

plot(resid_temp_min_lm)

abline(0,0, col = "red")

shapiro.test(resid_temp_min_lm)


 ggplot(data=temp_min, aes(x=min, y=richness))+

  geom_point()+

  geom_smooth(method=lm, level = 0.95, color = "red") +
```

```
  theme_bw() +
  theme(panel.grid = element_blank())+
  labs(x = 'Minimum temperature (°C)', y= 'Species richness')+
  coord_cartesian(xlim = c(5.2,6.02), ylim = c(0,20))+
  theme(panel.border = element_blank(),
        axis.line.x = element_line(size = 0.5, linetype = "solid", colour = "black"),
        axis.line.y = element_line(size = 0.5, linetype = "solid", colour = "black"))

 #####multivariate_regression#####
multi_regression<-lm(richness$species_richness ~ lux_mean$mean + temp_min$min)
summary(multi_regression)

#####T-test#####
n<-2
richness_split<-split(richness, factor(sort(rank(row.names(richness))%%n)))
print(richness_split$'0')
print(richness_split$'1')
mean_1<-mean(richness_split$'0'$species_richness)
mean_2<-mean(richness_split$'1'$species_richness)
mean_2-mean_1
sd_1<-sd(richness_split$'0'$species_richness)
sd_2<-sd(richness_split$'1'$species_richnes)
var.test(richness_split$'0'$species_richness,richness_split$'1'$species_richnes)
t.test(richness_split$'0'$species_richness, richness_split$'1'$species_richness)

#####ANOVA#####
one.way.VPD.mean<- aov(richness$species_richness ~ VPD_mean$mean)
summary(one.way)

one.way.VPD.max<- aov(richness$species_richness ~ VPD_max$max)
```

```
summary(one.way.VPD.max)


two.way<- aov(richness$species_richness ~ temp_max$max * lux_mean$mean)

summary(two.way)


one.way.temp.min<-aov(richness$species_richness ~ temp_min$min)

summary(one.way.temp.min)


two.way.significant<-aov(richness$species_richness ~ temp_min$min + lux_mean$mean)

summary(two.way.significant)


#####plot#####

plot(lux_mean$mean, richness$species_richness, ylab= 'Species richness', xlab='Lux (lx)', ylim=c(0,17), xlim=c(500,3000), col="#85d54aff", pch= 19, cex.lab=1.3, cex=2, bty='l')

lm1<-lm(richness$species_richness ~ lux_mean$mean)

abline(lm1)


plot(temp_mean$mean, richness$species_richness, xlab='Temperature (°C)', ylab='Species richness', ylim=c(0,17), pch = 19, col = "#1e9b8aff", cex.lab=1.3, cex=2, bty='l')

lm2<- lm(richness$species_richness ~ temp_mean$mean)

abline(lm2)

summary(lm2)


plot(temp_min$min, richness$species_richness, xlab='Temperature (°C)', ylab='Species richness', ylim=c(0,17), pch = 19, col = "#38598cff", cex.lab=1.3, cex=2, bty='l')

lm3<-lm(richness$species_richness ~ temp_min$min)

abline(lm3)

summary(lm3)


plot(rh_max$max, richness$species_richness, xlab='Relative humidity (%)', ylim=c(0,17), ylab= 'Species richness', pch = 19, col = "#48217cff", cex.lab=1.3, cex=2, bty='l')

lm4<- lm(richness$species_richness ~ rh_max$max)
```

```
abline(lm4)


#####make figures#####

figure<-read.csv("figure_1_data.csv", header=TRUE)

plot(figure$Distance, figure$species_richness, ylab= 'Species richness', xlab= 'Distance from river (m)', pch=16, col='black', bty='n')

abline(v=0, col='blue')


plot(figure$Distance, figure$mean_VPD, ylab= "VPD Mean (kPa)", xlab= "Distance from river (m)", pch =16)

abline(v=0, col= "blue")


master<-read.csv("master_data.csv", header= TRUE)


master$plot <- factor(master$plot)

levels(master$plot) <-c("1", "2", "3", "4", "5", "6", "7", "8", "9", "10")

boxplot(master$VPD ~ master$plot, ylab= "VPD", xlab = "Plot", col="#85d54aff", range= 0)

boxplot(master$temp ~ master$plot, ylab= "Temperature", xlab = "Plot", col = "#1e9b8aff", range= 0)

boxplot(master$rh ~ master$plot, ylab= "Relative humidity (%)", xlab = "Plot", col = "#38598cff", range= 0)

boxplot(master$lux ~ master$plot, ylab= "Lux(lx)", xlab = "Plot", col = "#48217cff", range= 0)


par(mfrow=c(2,2))
```

3. Ethics approval

NAME: Eloise Fleur Evans
WORKING TITLE OF DISSERTATION:
Investigating the influence of microclimate on bryophyte species richness in a Cornish Atlantic oak woodland
Summary of your dissertation research project (200 words max).
For my study, I will be looking at how bryophyte distribution and richness varies with microclimate within the Atlantic oak woodland habitat. I will be carrying out my primary data collection at Cabilla Cornwall whilst on work placement over the summer. I will also be using secondary LiDAR data during the analysis stage of my project. To collect my data, I will be putting up microclimate probes at a range of sample locations within the forest. I will be collecting data on the bryophyte distribution at these sites using a quadrat sampling method. From these data, I can explore what species are present under different microclimatic conditions. Using LiDAR data, I can also study how canopy cover, aspect and topography relate to these microclimates and thus species distributions. Through this study I aim to assess whether there is a relationship between microclimate and species richness. Overall, I would like to demonstrate and evaluate the importance of Atlantic oak woodlands for UK biodiversity.
Summary for any participants – what will taking part mean from the perspective of the participants? (200 words max) - *if no participants, leave blank.*
N/A
Summary of ethical issues, and how they will be managed (200 words max).
To carry out my study at Cabilla, I have spoken to the landowner and managers there, ensuring my plans are transparent and that I have full permission. Only since then have I been planning the study and have stayed in touch with them through all developments to ensure there are no discrepancies. My data collection will not involve removing any samples, therefore avoiding environmental harm. I will be working with some members of the British Bryological Society (BBS) so will fully acknowledge their help where necessary. I will of course respect confidentiality if they wish. I will fully acknowledge and respect the use of secondary data sources (LiDAR, BBS records) ensuring I have full permission to use them. My report will be used by the management at Cabilla to better understand the species distribution of their woodland. It may also be shared with the BBS and other interested individuals, especially those who contribute to site surveys during my placement and data collection. I will ensure integrity when evaluating the habitat at Cabilla to avoid any adverse influence on the work of the Charity.
Student: I confirm that I have read and understood the material included in this form and agree to act ethically and in accordance with the requirements set out here.
Student initials: EFE
Date initialled: 20th March 2023

Advisor: I confirm that I have reviewed this 'About your dissertation' page, and any participant information and consent sheets, that I have raised any issues needing correction or clarification, and that any issues have been addressed to my satisfaction.
Advisor's signature:
Date signed:15/03/24

4. Risk assessments

Desk-based risk assessment:

Name:	**Eloise Fleur Evans**
College/Service & Department:	**CGES- Environmental Science**
Line Manager / Supervisor's Name:	**Dr Jon Bennie**
Date of Assessment:	**20th March 2023**

- Answer all the questions below (*all the questions have been allocated a score)*
- A total score is generated at the end of the assessment
- Refer to the chart with your total score to determine if any action is required

DSE Component	Y/N or N/A	Action Required / Comments
Desk		
Is there enough space on your desktop for the flow of work?	**Y**	
Have you got enough leg room beneath the desk?	**Y**	
Is the desk deep enough for you to position the monitor set at a distance, approximatley at arm's length away, from you when you are seated in the correct position?	**Y**	
NB: *Standard desks are usually 800mm deep*		
Is there enough room on the desktop to allow a space between your keyboard and you for your wrists to rest near the edge of the desktop when not typing?	**Y**	
Is your desk surface free from reflection?	**Y**	
NB: *Desktops should have a matt finish*		
Chair (adjustable)		
Is your chair at a height where your elbows are slightly above the height of the desktop when using the keyboard? (approximately 1" / 2cm recommended)	**Y**	Chairs differ depending on whether I am working from home or at uni

Does the back rest support you in the curve of your spine (lumbar region) when seated in an upright posture?	**Y**	Again, it depends where I am working. At home I do not have special desk chairs. Some chairs on campus do.
If the back rest support does not support you in the curve of your spine can the back rest be adjusted e.g. raised/lowered to achieve this?	**Y**	depends where I am working.
Can you sit back into the chair using the seat base fully without incurring any pressure behind the knees?	**Y**	
NB: *Seat base is not too deep/long for you*		
Are your legs (hip to back of knee) fully supported by the seat base i.e. can you fit a clenched fist in the gap between the edge of the chair and the back of the knee?	**Y**	the chairs on campus do this better than the chairs I have at home
NB: *Seat base is not too short for you*		
If fitted, are armrests set up correctly i.e. positioned at the correct height to support your elbows?	**N**	most chairs do not have arm rests on campus. My chairs at home do not have arm rests either.
NB: *Armrests should be positioned so that the shoulders are relaxed when your forearms meet the armrests without the need to hunch your shoulders or reach your arms down to meet the armrests*		
Can you position yourself close to the desk to type with the elbows vertically under the shoulders i.e. elbows in line with your body?	**Y**	
Is the chair comfortable to sit in after adjustments have been made?	**Y**	depends where I am working.
Is the chair stable and all adjustment levers working?	**Y**	depends where I am working.
With seat height adjusted correctly for the elbows (1"/2cms above the desktop) can you place your feet firmly on the floor without compressing the underside of your thighs?	**Y**	Most chairs on campus are adjustable.
NB: *If not, a footest is required*		
If a footrest is required, have you got access to one or know how to purchase one?	**N/A**	
Monitor		
Is the monitor/screen placed at a distance at approximately an arm's length away from your eyes?	**Y**	A lot easier to achieve when working on a computer at campus
Is the monitor directly in front of you?	**N**	Most of the time I work on my laptop so it is not at eye level. I will need to buy a laptop stand to allow the screen to be spositioned properly.
NB: *For multiple screen users, monitors should be positioned directly in front of you if you use both screens equally throughout the day OR the primary monitor positioned directly in front of you with the secondary (reference) monitor positioned to the right or left of the primary screen*		
Is your line of sight (when looking straight ahead) level with the toolbar at the top of the screen?	**N**	I work on my laptop most of the time
Is the screen free from glare/reflections?	**Y**	
NB: *Flat screen monitors have basic anti-glare built in as standard*		

Is the information on the screen well defined and easy to read?	**Y**	
NB: *Text can be enlarged using the + bar on the bottom right hand corner of the screen (not very effective with Outlook)*		
Are the images on the screen flicker free?	**Y**	
Do you clean the screen regularly?	**Y**	
NB: *If not, clean the screen with soft cleaning wipes*		
Is the monitor positioned vertically flat or tilted slightly upwards off the vertical?	**N**	Most of the time I work on my laptop so it is not at eye level. I will need to buy a laptop stand to allow the screen to be spositioned properly.
NB: *Too much upward tilt will increase glare/reflection from artificial lighting and natural daylight*		
Can you adjust the brightness and contrast easily either via the monitor or control panel?	**Y**	
NB: *If not, access settings or type in display settings in the search box at the bottom of the screen or seek advice from your line manager*		
Keyboard		
Is the keyboard at the correct angle to prevent any bending of the wrist (up or down)?	**Y**	Will need to purchese bluetooth keyboard to allow me to use my screen properly
NB: *A flat keyboard reduces the need to bend the wrists when typing*		
Is your keyboard positioned close to you on the desk to ensure your elbows remain directly under your shoulders when typing?	**Y**	
Do you move your keyboard out of the way when you are using only the mouse?	**N**	
Is the keyboard clean?	**Y**	
NB: *If not, clean the keyboard with soft cleaning wipes*		
Are the digits clear and not faded?	**Y**	
NB: *If you need a replacement keyboard contact your line manager*		
Mouse		
Is the mouse positioned close to you on the desktop to avoid the need to extend the arm to operate?	**Y**	
Does the mouse run freely and is responsive when operating it?	**Y**	
NB: *If you need a replacement mouse contact your line manager*		
Do you regularly clean your mouse?	**Y**	
NB: *If not, clean the mouse with soft cleaning wipes*		

Do you reduce the time using your mouse to the lowest period by using keyboard short cuts?	**Y**	
NB: *Refer to the DSE Website for further information on keyboard shortcuts*		
Document Holder		
Can you refer to documents and papers without having to excessively or frequently move your head up and down e.g. papers placed on the desk instead of a document holder?	**N/A**	
Do you have a document holder (if required)?	**N/A**	
If a document holder is required, have you got access to one or know how to purchase or improvise to create one?	**N/A**	
NB: *If not, contact your line manager for advice*		
Other Equipment		
Is all equipment and items around you required? (Can it be moved/removed to provide more desk space?)	**Y**	
Is all other equipment (phone etc.) in a position that enables you to maintain your posture when using them (no overreaching, stretching, twisting etc.)?	**Y**	
NB: *Place the phone on the opposite side to the mouse (e.g.mouse right, phone left and vice versa) and operate the phone with the non-dominant hand*		
Space and Environment		
Can you move in and out of your workstation area easily?	**Y**	
Is there adequate space to manoeuvre your chair?	**Y**	
Is the area free from trailing cables or other objects which may pose a trip hazard?	**Y**	
Is the lighting adequate?	**Y**	
NB: *Not too bright or too dark*		
Do windows have curtains or blinds fitted to prevent glare and reflection?	**Y**	
Do you use curtains or window blinds to prevent glare and reflection?	**Y**	
Do you find the working environment quiet enough?	**Y**	I wear noise canceling headphones most of the time with some abient music
Is the temperature comfortable for most of the time e.g. not too hot or too cold?	**Y**	
About You		
Are you free from any upper body pain?	**Y**	
NB: *This means back, neck and shoulders*		

Are you free from any pain in your upper limbs?	**Y**	
***NB:** This means elbows, wrists, hands and fingers*		
Do you organise your work to ensure you take a regular 'fidget' breaks throughout the working day when using the DSE?	**Y**	
***NB:** Fidget breaks include comfort breaks and generally standing up and moving from being in a static position*		
Is your workstation set up to ensure that you have a flow of work i.e. you don't have to keep standing up, twisting or reaching for things unnecessarily?	**Y**	
Do you feel you understand and can effectively use all of the computer programmes you are required to use as part of your job?	**Y**	
***NB:** If not, speak to your line manager to request further training*		
Do you have an existing medical condition that you feel is being aggravated by your current workstation set-up?	**N**	
Do you suffer from dry or sore eyes when using your DSE?	**N**	
***NB:** Frequently looking away from the screen will encourage increased blinking to lubricate the eyes naturally*		
Do you feel you require extra DSE information or guidance?	**N**	
***NB:** If yes, refer to the DSE website and speak to your line manager to request further assistance if required*		
Have you had an eye test in the last 2 years?	**N**	Eye-care voucher request
***NB** If Yes, please wait until it is two years since your last eye test. If No, please use thie link above to apply for an eyecare voucher*		
TOTAL SCORE	**7**	

0 – 18 Workstation set-up is good, however if you have any concerns raise these with your line manager

19 – 40 Contact your line manager for help and advice. Consider whether there are any actions you can take

that will improve your score (e.g. clean the screen, adjusting your chair, purchasing or improvising by creating a footrest or document holder)?

41+ Contact your line manager in the first instance. Line Manager to contact the Health and Safety (safety@exeter.ac.uk) for further advice and/or to request and arrange a telephone assessment (if required)

Action Plan:

Complete the sections below/overleaf indicating what action is required to address the issues identified in your Self-Assessment.

- Key information must be passed onto your line manager to ensure that action can be taken
- All actions must be agreed with the line manager
- Actions that requires purchasing new equipment must be approved by the line manager and the relevant College/Service key contact
- Action plans must be monitored and completed within a reasonable timeframe

Actions Required	**Responsible Person**	**Date for Completion**
Purchase a laptop stand	Myself	01/09/2023
Purchase a bluetooth keyboard	Myself	01/09/2023
Work on campus as often as possible to ensure I can use adjustable chairs and a larger screen if needed.	Myself	ongoing

Jon Bennie

ASSESSMENT SIGN OFF				
Assessor's Signature				
Approver's Name	Jon Bennie		**Approver's Signature or confirmation that email has been received**	
Date signed/emailed	***15/03/2024***		**Local monitoring to be performed by:**	
Review Period: (please circle as appropriate)				
Risk Assessment Review Dates:			**Copies of Assessment to:** (please identify)	

Field risk assessment:

Part 1: General information about the trip			
Reference / Module Number/Name *(if applicable)*		Module Project: Dissertation Project	
Fieldworkers Name: *(Lead person if a group)*	Eloise Fleur Evans	College(s):	CGES
Assessors Name: *(if different form above)*	Eloise Fleur Evans	Discipline(s):	BSc Environmental Science
Fieldtrip Start Date:	n/a	Fieldtrip End Date:	n/a
Number of staff travelling?	n/a	Number of students travelling?	n/a
Number of Undergraduates?		Number of Postgraduates?	
1		n/a	

Is this a research trip?	Y	N	Is this a teaching trip?	Y	N
Exact destination location(s)?			Cabilla Cornwall Clay Road Cardinham Bodmin PL30 4DW England		
Do you have previous knowledge of this location?				Y	N
Describe the purpose of the trip *(Provide as much detail as possible)*					
I am carrying out my dissertation research whilst I am at Cabilla Cornwall for a summer internship. Alongside my work there on placement, I will be collecting my primary data. For this, I will studying microclimatic effects on bryophyte distributions within the Atlantic Oak woodland they have on site. To do so, I will be placing microclimate probes out at set study locations within the forest and leaving for a set period of time (weather dependent) and collecting data on the species distribution of bryophytes via quadrat sampling. The fieldwork is likely to take place over a few days.					

What activities / tasks being carried out on the trip? (*include both work and recreational activities*)			
Activity / Task		Activity / Task	
Select only the activities that apply			
NB: Where multiple examples are provided in the activity / task list delete as appropriate e.g. if 'Photography' only, delete the word 'Filming'			
Surveying (terrestrial)	Y	Photography / Filming	
Swimming / Snorkelling (freshwater/marine)		Lifting / Carrying equipment	Y
Sailing / Boating (freshwater/marine)		Teaching	
Diving (open water and/or restricted access)		Laboratory work	
Skiing		Water sports e.g. surfing, body boarding	
Caving / Pot holing		Manufacturing / Engineering	

Climbing (hills, cliffs, rocks)		Clerical / Administration / Attending Conferences/Meetings	
Work involving Mammals		Work involving Amphibians	
Work involving Insects		Work involving Fish	
Work involving Reptiles		Work involving Birds	
Mining / Blasting / Quarrying		Tree Felling	
Drilling / Coring		Farming (Agriculture)	
Interviewing people		Driving (roads/off-road)	
Hunting / shooting		Archaeological excavation	
Other: Use these columns/rows to add / insert other activities not listed in the examples provided above			

Training and Experience		
Is there any specific training and/or experience required for this trip?	Y	N
If Yes, what specific training and/or experience are required for this trip? *Provide details below*		
May include some learning about bryophyte identification skills. May take place during my time at Cabilla with the British Bryological Society.		
Are all participants sufficiently trained and/or experienced to partake in this trip?	Y	N
If No, what arrangements are in place to protect the unqualified / inexperienced participants? *e.g. supervision etc.*		
Equipment		
Is there any equipment being taken on the trip?	Y	N
If Yes, list the equipment being taken on the trip? *Provide details below*		
• Quadrat • Field guides/key • Field magnifying lenses		
Is there any equipment / items that could harm users or others being taken on the trip e.g. x-ray, laser, containing radioactive equipment etc? ***NB:*** *Care should be taken depending on the type and destination/route of travel*	Y	N
If Yes, list and describe the equipment / items being taken on the trip? *Provide details below*		
Is there a need for personal protective equipment (PPE)?	Y	N
If Yes, list and describe any PPE equipment being taken on the trip? *Provide details below*		

Part 2: Travel and accommodation arrangements		
	Select all that apply	*Risk Rating*

What modes of transport are you using to travel to your destination and at your destination?	Private Vehicle	Y	**L**
	University Vehicle		**L**
	Hired Vehicle (Driving Self)		**L**
	Hire Vehicle with Driver (Road)		**L**
	Public Transport (Road)		**M**
	Public Transport (Rail)		**M**
	Taxi		**M**
	Motorcycle		**M**
	On Foot	Y	**M**
	Aircraft (from UK airport)		**M**
	Sailing Vessel		**M**
	Other: Insert Here		**M**
Are you being met at your destination country and/or final location destination?	*Select all that apply*		*Risk Rating*
	Traveling alone		**M**
	Meeting an unknown person	Y	**M**
	Meeting a known person	Y	**L**
If multiple answers given, provide a brief explanation?	Will possibly be working with bryologists whom I have been guided to contact by the manager of Cabilla, so even though they are not well known by myself, they are trusted by the staff there.		
What are your return journey arrangements?	Car		
Will you require overnight accommodation?		**Y**	**N**
If No, proceed to Part 3 If Yes, how is your accommodation being arranged?	*Select all that apply*		
	Arranged and booked yourself		
	Arranged and booked by the destination host		
	Arranged and booked by the University from the UK		

PART 3: Preparation arrangements	
Answer all the questions in this section	Y / N
Do you have a contact(s) at the location?	Y
Do you need any licences, permissions or site access permits for this trip?	N
If yes, describe what licences (including driving), permissions or site access permits required including conservation areas and sites of special scientific interest	
***NB:** If you've answered negatively to any of the questions in Part 3 above indicating that further actions are required please transfer these to the action plan below*	

Remedial Action to be Taken	By Whom	By When
Insert the action to be taken and arrangements to be put in place in these rows	*Insert Name*	*Insert Date*
Add More Rows as necessary		

PART 4: About the work and lone working *Answer all the questions in this section*			
When will work be carried out?	Day:	Y	N
	Night:	Y	N
Is there a possibility that someone will be lone working?		Y	N

If Yes to lone working, what are the arrangements for maintaining contact with lone worker(s)?
Refer to the [Lone Worker Standard] and [lone worker risk assessment] for further information and guidance.

We strongly advise that all fieldwork is undertaken as pairs or groups.
Lone working will not be allowed where fieldwork is assessed as being higher risk – for example close to or on water, in areas which are prone to cliff falls / land slips / tidal cut offs, in remote locations with limited mobile signal or at night.
Lone working may be permitted for low risk fieldwork such as interviewing / surveying in public places, on campus or in other low risk environments.
In all cases a detailed itinerary must be left with the supervisor and a robust buddy system in place in case of emergency.

A Buddy system should include informing your "buddy" of the exact locations you will be working on that day and updating them throughout the day if these locations change. You should arrange a time each day to contact your Buddy when you are safe at home. Arrangements should be put in place as to what to do if you do not contact your buddy. This may include sending someone to visit the site or calling emergency services.

I will likely be on site with others and will only be lone for short periods of time, if at all. However, there are always staff at Cabilla. I will be on site with my friend who is also doing fieldwork/placement there, so they will know where I will be and for how long at all times. I will have a map on me at all times and will ensure sites are easily located.

PART 5: Communication methods / arrangements

Detail the arrangements in place for communicating with the University and at local level whilst on the trip e.g. lone working procedures in place - buddy systems, GPS, radios, mobile devices, email, social media etc.

You should check mobile phone coverage for the areas you are visiting and if this is not available consider alternatives such as radios Sat phones.
I will likely be on site with others and will only be lone for short periods of time. However, there are always staff at Cabilla. I will be on site with my friend who is also doing fieldwork/placement there, so they will know where I will be and for how long at all times. A GPS unit will also be very useful to navigate. I will stick to paths where possible.

PART 6: Emergency arrangements for this trip e.g. first aid, location of nearest medical centres etc.

Answer all the questions in this section	Y / N
Do you have appropriately trained first aid participants on the fieldtrip?	Y
Do you have access to professional medical assistance?	Y

Do you have contact numbers for local medical centres?	Y
Detail the emergency arrangements in place for this trip	

Emergency health/safety situations to be dealt with by calling 999
Non-emergency NHS advice available by calling 111
Should fieldworker be incapacitated on site, but not seriously enough to require emergency treatment, and not able to drive home, arrangements will be made for them to be picked up by their buddy, if possible.

Royal Cornwall Hospital
Tel: 01872 250000 (ask for Emergency Department)
Treliske
Truro
Cornwall
TR1 3LQ
Open 24 hours a day, 7 days per week

Bodmin
Bodmin Hospital – Minor injuries unit
01208 251300
Boundary Road , Bodmin, Cornwall, PL31 2QT
Opening hours 8am – 10 pm, 7 days per week

Falmouth
Falmouth Minor Injuries Unit
Tel: 01326 430000
Trescobeas Road
Falmouth
Cornwall
TR11 2JA
Open 8 am – 8pm 7 days per week

Launceston
Launceston Hospital – Minor Injuries unit
Tel: 01566 761000
Link Road, Launceston, Cornwall, PL15 9JD
Open 8am-8pm , 7 days per week

Liskeard
Liskeard Community Hospital
01579 373500
Clemo Road
PL14 3XD
8am-10pm, 7 days per week

Newquay
Newquay Hospital Minor injuries Unit
01637 834800
St Thomas Rd
TR7 1RQ
8am-10pm, 7 days per week

Penryn Falmouth Minor Injuries Unit Tel: 01326 430000 Trescobeas Road Falmouth Cornwall TR11 2JA Open 8 am – 8pm 7 days per week St Austell St Austell Community Hospital Minor Injuries Unit Tel: 01726 873000 Porthpean Road, St. Austell, Cornwall, PL26 6AD Open 8 am – 8pm, 7 days per week
NB: *If you've answered negatively to any of the questions in Parts 6 above indicating that further actions are required transfer these to the action plan below*

Remedial Action to be Taken	By Whom	By When
Insert the action to be taken and arrangements to be put in place in these rows	*Insert Name*	*Insert Date*
Add More Rows as necessary		

PART 7: Are there any cultural issues to be considered? *i.e. the location / people / site where the work is taking place*			
Select only the cultural issues that apply			
Religious Customs / Spiritual Considerations	N	Limitations in Photography / Film / Media	N
If yes to any of the above, provide details of the arrangements in place to address these matters			
N/A			

PART 8: Are there any security issues?					
Select only the security issues that apply					
Crime / Assault	N	Theft	N	Arrest	N
If yes to any of the above, provide details of the arrangements in place to address these issues					
N/A					

PART 9: Are there likely to be any welfare and wellbeing issues?					
Select only the welfare and wellbeing issues that apply					
Lone Working / Isolation *(refer to part 4 for lone worker arrangements)*	N	Stress	N	Relationships *(Working & Recreational)*	N

Workload	N	Medical Needs	N	Fitness / Exhaustion	N
Homesickness	N	Language Barriers	N	Food Intolerance	N
If yes to any of the above, provide details of the arrangements in place to address these issues					

PART 10: Activity and recreation arrangements		
Have all staff and students been made aware of the rules and arrangements for the trip including both work and recreation activities? e.*g. code of conduct, appropriate clothing, equipment, travel, accommodation, alcohol etc.*	Y	N

***NB:** If you've answered negatively to any of the questions in Parts 10 above indicating that further actions are required transfer these to the action plan below*

Remedial Action to be Taken	By Whom	By When
Insert the action to be taken and arrangements to be put in place in these rows	*Insert Name*	*Insert Date*
Add More Rows as necessary		

PART11: Supporting information		
Can you confirm that all the information / documentation required in the 'Supporting Information' checklist have been obtained?	Y	N

	Hazards			**Control measures**	**Score A**	**Score B**	**Risk Rating**	**Additional Actions Needed**
Hazards Inherent with the site/location		Example Hazards	Description of the hazard	Insert the arrangements in place to mitigate the hazard becoming realised	Likelihood score	Severity rating	Score A x Rating B	Additional arrangements required to mitigate the risk
physical Hazards	Extreme weather	Storms / Rain / Sleet / Snow / Winds / Gales / Mists / Fog	May encounter winds and rain due to unpredictable weather	Weather forecast will be checked before heading out. Suitable clothing will always be worn (boots) and waterproofs will be packed in case of rain and wet weather.	3	2	6	
	High temperatures	UV exposure / Heat Exhaustion / Sunburn / Heat Stroke	As fieldwork is being carried out in the summer, sun and hot weather may occur.	Weather forecast will be checked before heading out. Sun cream, a hat and sunglasses will be packed in case of hot and sunny weather. Will ensure I drink enough water and stay in the shade as often as possible (woodland is generally shady and cooler)	3	3	9	
	Low temperatures	Hypothermia / Frostbite						
	Mountains / Cliffs	Ice falls / Crevices / Loose/falling rocks / Oxygen deficiency						

Hazards			Control measures	Score A	Score B	Risk Rating	Additional Actions Needed
Hazards Inherent with the site/location	Example Hazards	Description of the hazard	Insert the arrangements in place to mitigate the hazard becoming realised	Likelihood score	Severity rating	Score A x Rating B	Additional arrangements required to mitigate the risk
	/ Mudslides						
Marshes / Quicksand	Soft ground / Floods						
Excavation / Mines / Quarries / Caves	Roof fall/collapse / Oxygen deficiency / Confined spaces / Hidden shafts / Props/Supports failure / Floods / Radon / Poisonous atmosphere / Explosives / Dead ends / Explosive atmosphere						
Marine / Coastal / Rivers / Lakes	Currents / Abnormal Waves / Lagoons / Quicksand / Obstacles (Underwater) / Riptides / **Inland Waters** / Flotsam & Jetsam / Loose Rocks / Sludge Pits / Unstable substrate	There is a river flowing through the woodland that may be of interest. There may also be loose rocks around the river.	I will ensure that I do not enter the water and stay away from the waters edge.	2	2	4	Wear good grippy boots that are waterproof.
Forests	Fires / Undergrowth / Falling trees	Falling trees may be possible, especially in high winds	Check the weather forecast and do not proceed if weather is due to be bad/windy.	2	3	6	
Roads / Roadsides	Vehicles / Off-road terrain / Railways &						

Hazards				Control measures	Score A	Score B	Risk Rating	Additional Actions Needed
	Hazards Inherent with the site/location	Example Hazards	Description of the hazard	Insert the arrangements in place to mitigate the hazard becoming realised	Likelihood score	Severity rating	Score A x Rating B	Additional arrangements required to mitigate the risk
		Trains / Navigation						
Biological Hazards	Flora	Plants Stings Fungi (consider poisonous /irritants)	The woodland environment may contain poisonous/irritant plants and fungi.	I will research plants/fungi that I should be cautious of, staying well away from these when in the field. I will wear clothing that covers me to protect my skin.	2	4	8	
	Fauna	Animals (Mammals) / Fish / Arthropods / Bites / Stings / Amphibians / Reptiles / Insects / Poisonous Bites / Poisonous / Irritant Stings	The woodland environment may contain insects or mammals that bite/sting.	I will research animals/insects that I should be cautious of, remaining cautious and aware. I will wear clothing that covers me to protect my skin.	2	2	4	Take insect spray for midges or other flying insects that may bite. Take antihistamine cream in case of bites.
	Microbiological	Weil's Disease Malaria / Typhoid / E.coli / Food-borne / Infections Tetanus / Cholera / Lyme disease / Campylobacter / Water borne	May encounter ticks if bracken is present around the site.	I will ensure that I wear clothing that effectively covers me to ensure insects are kept away from my skin.	2	4	8	Check myself thoroughly after being in the field for ticks.
Chemical Hazards	Agrochemicals	Pesticides / Herbicides / Nematicide / Insecticides / Fungicides / Fertiliser						
	Water Pollution	Dumps / Toxic Gases / Waste Material / Sewers / Flammable Gases						

Hazards				Control measures	Score A	Score B	Risk Rating	Additional Actions Needed
Hazards Inherent with the site/location		Example Hazards	Description of the hazard	Insert the arrangements in place to mitigate the hazard becoming realised	Likelihood score	Severity rating	Score A x Rating B	Additional arrangements required to mitigate the risk
Man-made Hazards	Machinery / Plant / Tools / Equipment	Ejected Parts / Sharp Edges / Moving Parts / Poor Maintenance						
	Electricity	Generators / Main Supply (different voltages) / Poor Maintenance / Differing safety standards / Old equipment / Portable Appliances / Damaged Cables / Fire / Exposed circuits / Power lines						
	Vehicles	Poor Maintenance / Differing controls Fuel fires / Collision (RTA) / Loose loads / Hazardous terrain						
	Buildings	Insecure/Damaged / Remote location / Poorly maintained / Utility supplies						
	Slurry and Silage Pits	Uneven ground / Gases						

Hazards				Control measures	Score A	Score B	Risk Rating	Additional Actions Needed
	Hazards Inherent with the site/location	Example Hazards	Description of the hazard	Insert the arrangements in place to mitigate the hazard becoming realised	Likelihood score	Severity rating	Score A x Rating B	Additional arrangements required to mitigate the risk
Environmental	Waste Disposal	Pollution / Disturbance of eco-systems						
General	Slips / Trips / Falls	Loose terrain / Uneven surfaces / Water / Working at height / Slopes / Hills	The forest terrain may be uneven and slippery when wet, especially off footpaths.	I will ensure that I am extra cautious when navigating off the footpaths. I will carry hiking poles with me just in case of loose and uneasy terrain.	2	2	4	
	Lifting / Carrying / Moving Objects / Equipment / Animals	Load (e.g. shape/size /weight etc.) / Environment						
Human Hazards	Knowledge / Experience / Training / Skills	Novices / Unfamiliar surroundings / Inexperience / Unskilled / Lack of Awareness / Lack of Knowledge / Insufficient Supervision / Untrained						
	Health / Fitness / Capabilities	Pre-existing health condition(s) / Disabilities / Lack of fitness / Physical / Sensory / Mental						
Activity	Swimming / Snorkelling	Water / Location / Equipment / Currents / Waves						

Hazards			Control measures	Score A	Score B	Risk Rating	Additional Actions Needed
Hazards Inherent with the site/location	Example Hazards	Description of the hazard	Insert the arrangements in place to mitigate the hazard becoming realised	Likelihood score	Severity rating	Score A x Rating B	Additional arrangements required to mitigate the risk
Diving	Currents / Abnormal Waves / Lagoons / Obstacles (Underwater) / Riptides / Inland Waters / Equipment						
Skiing	Snow / Avalanche / Environment / Equipment /						
Fire Arms and Explosives	Armoury / Equipment / Ammunition / Explosives /						
Climbing / Abseiling	Falls from height / failure of equipment /						
Boating / Sailing	Vessel / Water / Equipment						
Manufacturing / Engineering	Poor Maintenance / Generators / Main Supply (different voltages) / Differing safety standards / Old equipment / Portable Appliances / Damaged Cables / Fire / Exposed circuits / Power lines						
Drilling / Coring	Environment /						

Hazards			**Control measures**	**Score A**	**Score B**	**Risk Rating**	**Additional Actions Needed**
Hazards Inherent with the site/location	Example Hazards	Description of the hazard	Insert the arrangements in place to mitigate the hazard becoming realised	Likelihood score	Severity rating	Score A x Rating B	Additional arrangements required to mitigate the risk
	Equipment / Machinery						
Excavation / Mining / Quarrying / Caving	Environment / Equipment / Machinery / Water / Unstable ground / Collapse of structures /						
Farming & Agriculture	Machinery / Equipment / Environment / Animals / Terrain / Differing safety standards / Old equipment						
Forestry / Felling	Machinery / Equipment / Environment / Terrain / Falling objects / generators / failure of equipment						
Water sports e.g. surfing / wake boarding	Water / Equipment / Waves /						

Approval Process	
Assessors Signature:	**E F Evans**
Confirmation received that all actions have been completed and the required control measures are in place	**Yes**
Approvers Name:	**Jon Bennie**
Approver's Title: *e.g. Supervisor, Line Manager, Tutor, Principle Investigator etc.*	***SUPERVISOR***
Approval Date:	**15/03/24**
Confirmation that copies of this risk assessment and all associated documentation is stored locally with an appropriate person: *e.g. easily accessible if required in the event of an emergency*	**Yes / No** Your supervisor must upload these to the H&S share point
Approver's Signature:	Jon Bennie