Swansea University
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The Effect of Spatial Scale on Aquatic Insect Communities in Peatlands

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Summary

Despite their ecological importance, 50% of Europe's peatlands have been degraded. Restoration efforts include rewetting, however, the effects on aquatic insects are poorly understood. This study investigated aquatic insect diversity, community similarity and spatial synchrony across newly-created peatland pools at the Castell Nos Habitat Restoration Area, South Wales. The questions addressed were: Does pool diversity change with distance from a source? Does distance between pools affect community similarity? Does spatial synchrony between neighbouring pools change with distance from a source?

One hundred pools at varying distances from an established source pond (64-377 m) were sampled as 25 clusters of four. Aquatic insects were collected by standardised dip-netting, preserved in ethanol, and identified to species or family level. Pool temperature, pH, TDS and depth were measured. Abundance and richness were recorded per pool, with associated coefficients of variation calculated per cluster. Generalised linear models investigated variation with distance from source. Simpson's similarity index was calculated between pairwise pools, and a Mantel test analysed correlation with pairwise distance.

Twenty-eight species were identified representing 13 families, with Chironomidae being most abundance and Dytiscidae most widespread. Neither abundance nor richness varied with distance, suggesting strong dispersal by key taxa. Community similarity between pools decreased weakly with increasing distance, but this was only significant at very short ranges. Coefficient of variation in abundance and richness increased significantly with increasing distance from source, indicating a homogenising effect of the pond on nearby communities.

Findings suggest that, whilst strong dispersal ability may enable widespread colonisation, local patterns of community similarity and synchrony can be shaped by fine-scale spatial structure. For effective peatland conservation, restoration efforts should consider creating well-connected landscapes with environmental heterogeneity to promote asynchrony and enhance community resilience and diversity. Future research should examine patterns on larger spatial and temporal scales to inform long-term management.

University Declarations and Statements

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

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The University's ethical procedures have been followed and, where appropriate, that ethical approval has been granted.

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Statement of Expenditure

Student name: Imogen Cockwell

Student number: 980978

Project title: The effect of spatial scale on aquatic insect communities in peatlands

Category	Item	Description	Cost*
Travel	Car fuel	Travel to field site	£355.32
Conference	Conference fee	Ento24: RES Student Member	£95.00
Consumables	Falcon tubes	Centrifuge tube 50ml conical bottom	£10.00
Reference material	Identification Guide	Key to the Larvae of British Corixidae	£16.99
Reference material	Identification Guide	RES Handbook, Volume 4, Part 5a: Keys to Adults of the Water Beetles of Britain and Ireland	£27.99
Reference material	Identification Guide	RES Handbook, Volume 4, Part 5b: Keys to Adults of the Water Beetles of Britain and Ireland	£24.99
Reference material	Identification Guide	RES Handbook, Volume 4, Part 1a: British Coleoptera Larvae. A Guide to the Families and Major Subfamilies	£51.99
Reference material	Identification Guide	Guide to British Freshwater Macroinvertebrates for Biotic Assessment	£28.99
Total:			**£611.27**

*including VAT and delivery where applicable

I hereby certify that the above information is true and correct to the best of my knowledge.

[redacted]
Signature (Supervisor)

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Statement of Contributions

Contributor Role	**P**ersons Involved
Conceptualisation	IC, WH, JB
Data curation	IC
Formal analysis	IC, JB
Investigation	IC
Methodology	IC, WH, JB
Project admin	IC
Resources	IC, WH
Supervision	WH, JB
Validation	WH, JB
Visualisation	IC, WH, JB
Writing – original draft preparation	IC
Writing – review and editing	IC, WH, JB

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1. Introduction

1.1 Peatland Significance, Degradation and Restoration

Peatlands are amongst the most important ecosystems on Earth, providing essential ecosystem services such as climate regulation, flood mitigation and biodiversity support. Despite covering only 3% of global land surface, peatlands store nearly 30% of all soil carbon, making them the largest carbon pools of all terrestrial ecosystems (Joosten et al., 2016; Humpenöder et al., 2020; United Nations Environment Programme, 2022). The ability of peat to retain water also reduces the risk of downstream flooding and maintains surface water quality by preventing leaching of organic pollutants (Allott et al., 2019; Martin-Ortega et al., 2014). Peatlands are able to support a range of specialist species (Littlewood et al., 2010) including *Sphagnum* mosses that are essential for peat formation (Rydin et al., 2006). They also have important conservation value, providing habitat for declining species such as the azure hawker (*Aeshna caerulea*) (Batty, 2019) and water vole (*Arvicola amphibius*) (Harris & Yalden, 2008; Glossop & Morse, 2024).

Despite their ecological importance, around 50% of the peatlands in Europe are classified as degraded, with drainage for agriculture or forestry being the primary threat (UNEP, 2022). Lowering of the water table results in accelerated decomposition, releasing stored carbon and significantly contributing to greenhouse gas emissions (Word et al., 2022). Peatland degradation also results in biodiversity loss, with studies showing reduced abundance and species richness of Carabidae, Lepidoptera and Odonata on degraded sites (Elo et al., 2015; Sushko & Novikova, 2024). The decrease in moisture and increased nutrient availability allows plant species more typical of surrounding grassland, such as tussock-forming *Molinia*, to outcompete those that are dependent on wet, acidic conditions (Glaves, 2016). This change in vegetation consequently threatens rare species such as the large heath butterfly (*Coenonympha tullia*) that feeds primarily on the peatland specialist *Eriophorum vaginatum* (Dennis & Eales, 1997).

In response to growing environmental concerns, large-scale peatland restoration efforts have been implemented across Europe (Nordbeck & Hogl, 2024). Rewetting techniques, including blocking drainage ditches and reintroducing specialist vegetation, aim to raise and stabilise the water table and improve habitat condition (Karimi et al., 2024; Renou-Wilson et al., 2019). Whilst there has been considerable research on the hydrological and carbon responses to peatland restoration, the recovery of biodiversity, especially for insects, remains poorly understood.

1.2 Aquatic Insect Communities in Peatlands

Aquatic insects are crucial for ecosystem functioning, contributing to processes such as nutrient cycling and decomposition (Verma et al., 2021). They support food web dynamics as grazers or predators of other invertebrates, and are also a major food source for amphibians and important breeding birds such as the golden plover (*Pluvialis apricaria*) (Murkin & Wrubleski, 1988; Pearce-Higgin & Yalden, 2004). Since many have life cycles with both aquatic and terrestrial stages, their influence extends beyond aquatic habitats to the wider environment (Starr & Wallace, 2021), and their sensitivity to change makes them valuable indicators of habitat quality (Chowdhury et al., 2023). Investigating the community structure of aquatic insects in peatlands can aid understanding of how these species respond to restoration efforts and provide insight into broader ecosystem resilience.

Peatland landscapes are usually characterised by networks of small open-water pools enclosed by peat (Belyea & Lancaster, 2002). However, drainage and vegetation change in degraded peatlands may reduce the number and quality of these pools, limiting opportunities for colonisation by aquatic insects. Restoration efforts often involve creating new pools, either intentionally or as a result of ditch blocking (Jolin et al., 2024), which can increase habitat availability and quality for a range of species that are able to persist in acidic, nutrient-poor conditions. The community composition within restored pools will firstly depend on species' ability to reach new pools for colonisation, and this may be determined by dispersal mechanism (Beadle et al., 2023; Padial et al., 2014). Some taxa, such as Odonata and Coleoptera, generally exhibit strong flight capabilities which enable active dispersal (Bilton, 2023; Curry & Baird, 2015). However, some Diptera such as Chironomidae are weak fliers but are very effective at dispersing passively by wind (Bitušík et al., 2017; Armitage et al., 2012). Establishment in a new pool will then depend on factors such as abiotic environmental conditions, food availability, and competition (Beadle et al., 2023).

1.3 Theoretical Framework

Conceptual ecology can aid understanding of aquatic insect distribution in peatland habitats. In particular, theories that explore the interaction between local dynamics and dispersal processes can give insight into patterns of biodiversity in patchy populations such as that found in a pool system. Source-sink dynamics describe how individuals disperse from a high-quality 'source' habitat to poorer quality 'sink' habitats, where populations are not self-sustaining and only persist through continuous recolonisations (Pulliam, 1988). In the context of peatland pools, a well-established pond may act as a source, supplying species to surrounding pools in a connected landscape (Figure 1.1). However, the degree of isolation between the 'source' and 'sink' will influence dispersal success, potentially creating a gradient of species richness where more distant pools experience lower colonisation rates (Fahrig, 2003).

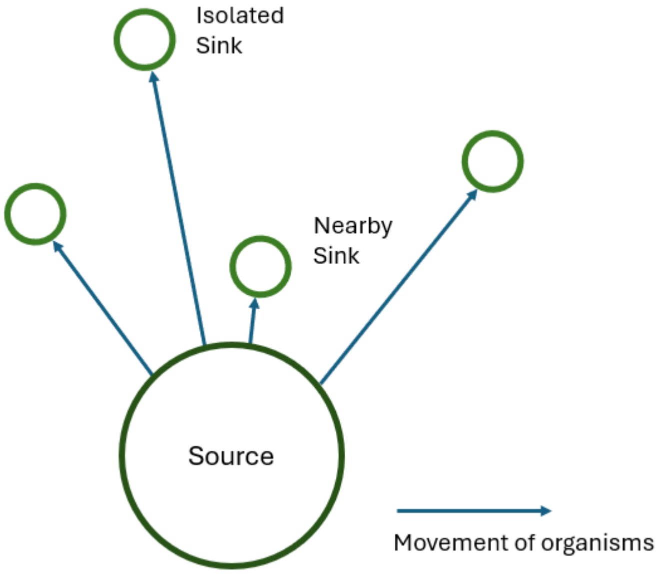

Figure 1.1. Source-sink dynamics between a well-established pond and pools.

Alternatively, metacommunity dynamics considers each pool as part of an interconnected network, with the assumption that they are identical and capable of supporting populations (Leibold et al., 2004). In this instance, community composition is determined by continuous colonisation and extinction events (Figure 1.2). It is expected that pools in close proximity are more likely to be colonised by the same species as they experience frequent recolonisation from each other, leading to spatial clustering of similar communities (Van de Meutter et al., 2007).

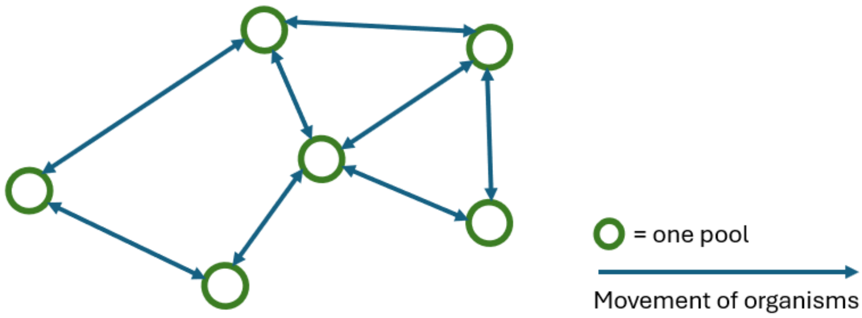

Figure 1.2. Metacommunity dynamics between well-connected pools.

In addition to these theories, investigating how species synchrony between neighbouring pools is influenced by distance from a source could provide understanding into the strength and scale of connectivity across peatland pools and give insight into metacommunity persistence. Species richness and abundance may fluctuate synchronously across the environment, driving spatial processes (Loreau & de Mazancourt, 2008; Walter et al., 2021). Since dispersal from a source pond may be driving community structure, clusters of pools in close proximity to the source are expected to experience synchronous colonisation events, resulting in greater spatial similarity of species composition (Figure 1.3). As distance from the source pond increases, colonisation become less frequent and more stochastic, and the homogenising influence of the source is reduced. As a result, spatial synchrony between neighbouring pools is expected to decrease with increasing distance from the source.

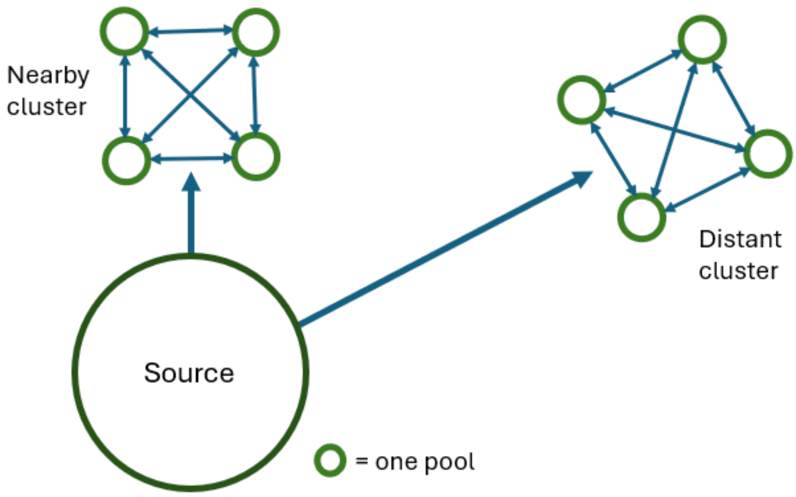

Figure 1.3. Synchrony within clusters of four pools varies with distance from source.

1.4 Castell Nos Restoration Area

Predictions about source-sink and metacommunity dynamics can be explored *in situ* by using a recently restored peatland as a model landscape. The Castell Nos Habitat Restoration Area (HRA) is a key site within the Lost Peatlands Project, South Wales. Historically, this area has undergone heavy modification with extensive conifer plantations being established on peat soils, leading to altered hydrology and biodiversity loss. Restoration efforts have focused on rewetting, with the installation of peat dams in 2021 creating a network of shallow pools across the landscape (Pickard & Shewring, 2020). Whilst some hydrological connectivity between pools may occur along drainage channels, this study relies on the assumption of closed populations. Each pool is considered to be a distinct ecological unit which, with the presence of a large, well-established pond on site, provide the ideal landscape to study patterns in aquatic insect colonisation. Since restoration, there have been hydrological and carbon monitoring efforts to determine success, as well as ecological surveys on birds and mammals, but insect surveys have been limited to terrestrial sampling conducted prior to the restoration efforts.

1.5 Study Aims

The main objective of this study was to investigate the how landscape structure influences aquatic insect community composition in restored peatland pools. Three specific questions were addressed with associated predictions.

1. **Does aquatic insect diversity in the pools change with increasing distance from the source pond?**
    - Under source-sink dynamics, abundance and species richness are predicted to decrease with increasing distance from the source pond
2. **Does distance between pools affect how similar their communities are?**
    - Metacommunity theory predicts that similarity in community composition will decrease as distance between pools increases
3. **Does spatial synchrony between neighbouring pools change with increasing distance from the source pond?**
    - Variation in abundance and species richness between neighbouring pools is predicted to increase with increasing distance from the source pond

2. Methods and Materials

2.1 Study Area

The Castell Nos HRA covers approximately 80.5 hectares within the upland plateau landscape above Maerdy, South Wales (Figure 2.1). The site of interest is an area covering approximately 8 ha within the Castell Nos HRA that consists of wet modified bog and *Molinia* grassland, bordered by planted coniferous woodland and extensive areas of felled woodland (Appendix 1). The HRA lies on the watershed plateau at approximately 400 m above sea level and is exposed. The climate is characterised by high rainfall, with an average of 2544 mm per year, and cool upland temperatures. The recorded peat depth across the HRA varies from 0 to 3.8 m, with 64% of measurements recording depths greater than 0.5 m.

Historically, the study area was used for agriculture before being afforested with Sitka spruce, altering the hydrology of the site through extensive drainage. Large areas of the plantation have since been felled and restoration has focussed on rewetting techniques such as ground smoothing, cross-tracking, timber dams and *Sphagnum* inoculation. Cross-tracking was completed in 2021, which involved the blocking of forestry plough furrows and drainage ditches by peat dams. This resulted in the creation of hundreds of small pools that are similar in area (~1 m^2) and depth (~30 cm).

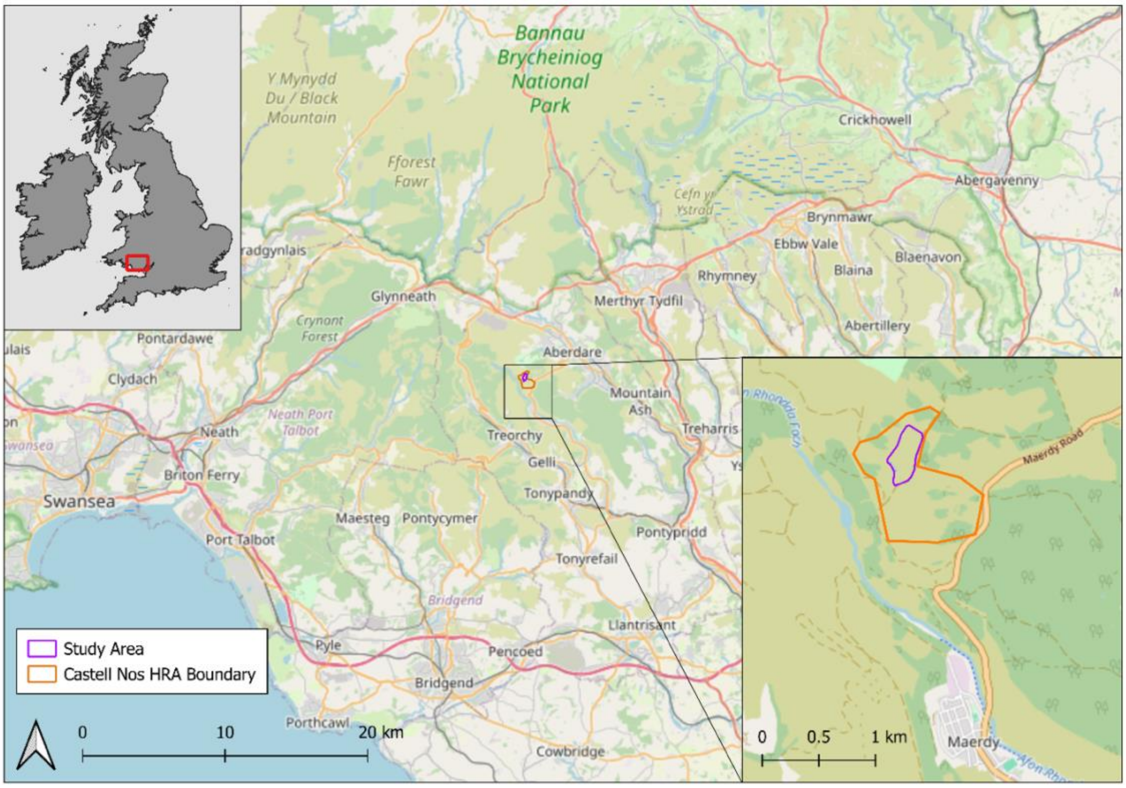

Figure 2.1. The Castell Nos HRA boundary (orange) and study site area (purple) located near Maerdy, South Wales.

2.2 Experimental Design

Using QGIS version 3.42.1 (QGIS Development Team, 2025), 100 pools were identified for sampling. All sampled pools were situated to the northeast of a large pond at distances ranging from 64.3 to 377.3 metres from the pond (Appendix 2). Pools to the southeast of the pond were not easily accessible or did not retain water so were not considered. Pools were selected as clusters of four to allow invertebrate assemblages to be compared within and between clusters (Figure 2.2).

The QField mobile app (OPENGIS.ch, 2024) was used on site to navigate the environment and locate the sampling pools. Eleven days of sampling were carried out between 20th June and 12th August, 2024, and two to three clusters were randomly selected to be sampled each visit. To avoid depleting natural populations, no pool was sampled more than once and never more than 30% of the pool's area was sampled (Smith & Pearson, 1987). The source pond was sampled once each visit, at multiple locations throughout the sampling period, although access was limited to the northeast side.

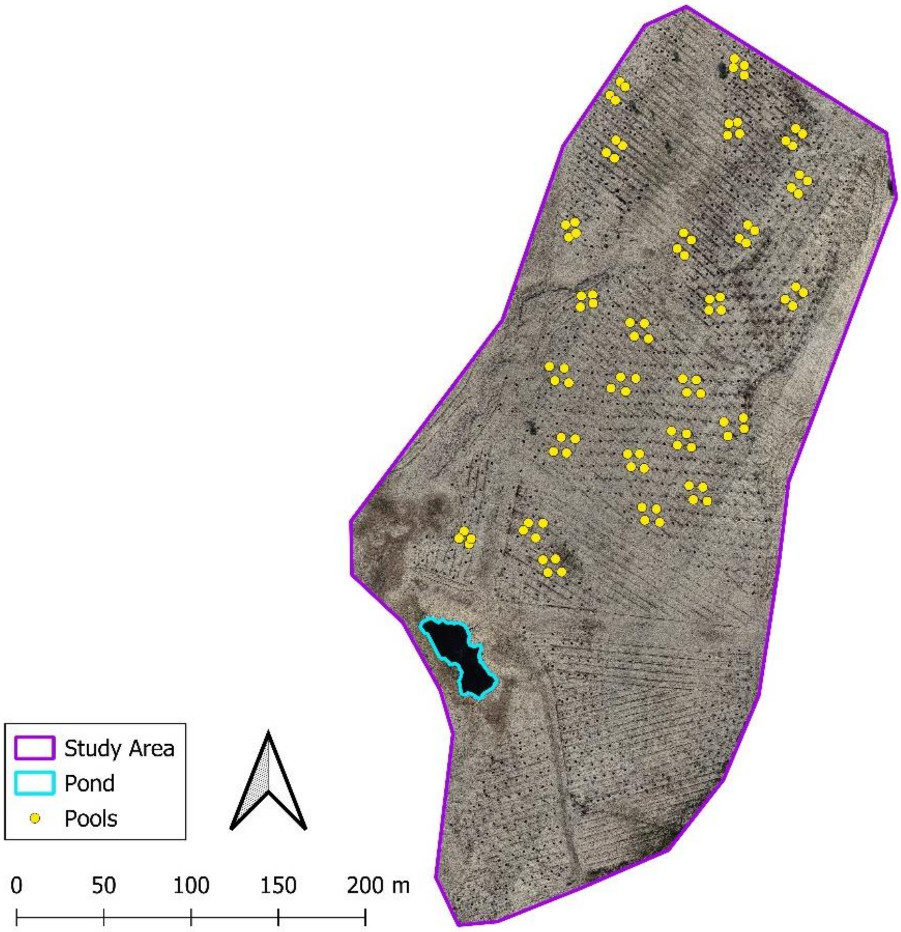

Figure 2.2. The study site within the Castell Nos HRA. One hundred pools arranged in clusters of four were sampled across the area (yellow dots). Pools are located to the northeast of a well-established source pond (blue).

2.3 Sampling Methods

2.3.1 Sampling Insects

Aquatic insects were collected using a long-handled dip net with a 25 x 25 cm head and 1.5 mm polyester mesh. To standardise sampling for each pool, the net was placed straight down into the centre, then swept towards the edge of the pool and upwards. This was repeated in the source pond at points around the northeast perimeter that were accessible by foot. The contents of the net were emptied into a tray and aquatic insects were collected for counting and identification. A two-step euthanasia method was used which meets all welfare and scientific requirements for aquatic invertebrates (Gilbertson & Wyatt, 2016). Individuals were immersed in 5% ethanol in the field, before immersion in euthanising solution of 70% ethanol on return to the laboratory. The abundance of chironomids was estimated in the field by visually counting individuals in one quarter of the tray, then multiplying by four to provide a total estimate. Abundance values are therefore approximate, reflecting a visual estimation rather than a precise count.

2.3.2 Environmental Conditions

At each pool, temperature, pH and total dissolved solids (TDS) values were recorded using a Hanna HI-98129 tester. Presence of emergent vegetation within the pool was noted, and depth was estimated visually using the known length of the dip net (25 cm).

2.4 Insect Identification

Where possible, insects were identified to species level using a dissecting microscope and taxonomic keys (Appendix 3). Individuals that could not be identified past family level included Chironomidae and Chaoboridae larvae (Diptera), and Dytiscidae and Scirtidae larvae (Coleoptera), as specialised equipment and reference material was not available, and the technical challenge of identification was beyond the scope of the project timeframe.

2.5 Data Analysis

2.5.1 Insect diversity, synchrony and similarity

Abundance and richness values were determined for each individual pool. The coefficient of variation, $CV = \sigma / \mu$, where σ = standard deviation and μ = mean, was calculated for abundance and richness within each cluster to be used as a metric for spatial synchrony within clusters of pools. The centre point of each cluster was used to measure distance from the source pond.

To investigate community similarity between pools, Simpson's similarity index was calculated between each pair of pools. The index is calculated by the formula $D = a / (a + min(b,c))$, where a = the number of shared species, b = the number of species only in pool 1, and c = the number of species only in pool 2. It measures the proportion of the smaller community that is shared with the larger one, giving the probability that randomly selected individuals from each pool will belong to the same species. This makes Simpson's index the most suitable for comparing communities of unequal size, as it reduces bias from differences in species richness. A distance matrix was created using QGIS to calculate the distance between the centre of each pair of pools. The pairwise distance and Simpson values were considered for every unique combination of pools.

Due to difficulty in identification, Chironomidae spp., Chaoboridae spp. and Scirtidae spp. were each treated as a single species for analyses. Chironomidae, in particular, often dominate aquatic insect communities in species richness (Armitage et al., 2012; Ferrington Jr, 2008), so there may be an under representation of species within this family. Similarly, due to difficulty in identifying Dytiscidae larvae, these were excluded from these calculations, potentially resulting in an under representation of Dytiscidae species that were present as larvae but not adults.

2.5.2 Statistical analyses

All statistical analyses were carried out using R version 4.3.3 (R Core Team, 2024) (Appendix 4). Pairwise correlations for environmental variables (distance, temperature, TDS, pH and depth) were assessed using correlation matrices generated with the GGally package (Schloerke et al., 2025). The explanatory variable for all analyses was distance (m), and the response variables were abundance, richness, abundance CV, and richness CV. Negative binomial generalised linear models were used to test diversity-related hypotheses, as this model accounts for overdispersion in the count data. Hypotheses on synchrony were tested using generalised linear models with gamma distribution errors and log link functions, as coefficient of variation is a continuous variable with a lower bound of zero. Environmental variables that varied significantly with distance were included in the models as additive effects. Graphs were generated using the ggplot2 package (Wickham, 2016).

To investigate the relationship between community similarity and distance between pools, species occurrence data was first organised into a presence-absence matrix. Simpsons similarity index was calculated for all pairwise combinations of pools using the proxy package (Meyer & Buchta, 20227). A matrix of pairwise distances between pools was calculated in QGIS and imported separately. A Mantel test with Spearman's rank correlation was performed using the ecodist package (Goslee & Urban, 2007) to assess the overall relationship between pairwise Simpson's similarity and distance. To further explore the relationship, as correlogram was created which grouped distances into 14 bins, allowing correlation coefficients to be calculated for each bin separately. Distance was transformed on a square root scale to highlight changes over short distances, and the significance of correlation values in each bin was adjusted using the Bonferroni correction.

3. Results

The environmental conditions of all pools sampled were characteristic of nutrient-poor, acidic peatlands. Pool temperatures averaged 18.9˚C, ranging from 13.4 to 25.7˚C throughout the summer sampling period. The pH was consistently acidic, ranging from 4.1 to 4.99 (mean 4.41), while total dissolved solids remained low, ranging from 6 to 34 mg/L (mean 14.6 mg/L). Pools were shallow with a mean depth of 30.6 cm, ranging between 5 and 55 cm, and emergent vegetation was present in 37% of pools. With increasing distance from the source pond, temperature increased and TDS decreased significantly in pools (Appendix 5).

From one hundred pools, 925 individuals were counted, with 780 being identified to species level. Twenty-eight species were identified representing 13 families and five insect orders (Appendix 6). Three families, Scirtidae, Chironomidae, and Chaoboridae could not be identified past family level. Chironomidae were most abundant, with approximately 1000 individuals being estimated across 57 pools (Figure 3.1), followed by Corixidae (329), Dytiscidae (308) and Libellulidae (146). Dytiscidae were most widespread, occurring in 72 ponds, despite being absent from the source pond. Six insect families were present in the pond. Of these, only Notonectidae (represented by *Notonecta obliqua*) was absent from pools. A total of 106 individuals were counted from the pond from the 11 samples taken throughout the study period.

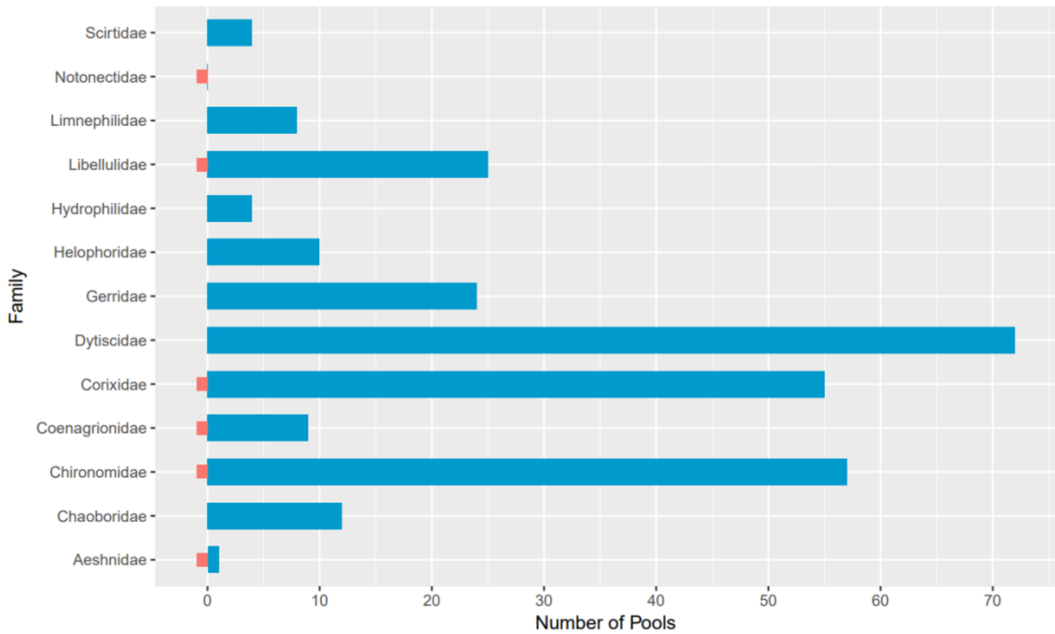

Figure 3.1. Aquatic insect families that were recorded from 100 pools and the number of pools that they occurred in (blue). Pink indicates presence in the source pond.

3.1 How does diversity in the pools change with increasing distance from the source pond?

The abundance and species richness of aquatic insects was recorded at each pool to investigate how distance from the source pond influences their distribution. The abundance within individual pools ranged from zero to 159, with the mean across all pools being 19.46. Only two pools were found to contain zero individuals. The greatest species richness was found to be 10 in a single pool, which occurred at nearly the furthest distance from the source pond (371 m). The mean richness across all pools was 3.26.

The abundance of aquatic insects remained constant with increasing distance from the source pond (Slope = 9.637×10^{-4}, SE = 1.206×10^{-3}, $z = 0.799$, $p = 0.424$) (Figure 3.2a). Species richness of pools also remained constant (Slope = 3.769×10^{-5}, SE = 7.052×10^{-4}, $z = 0.053$, $p = 0.9574$) (Figure 3.2b). Distance from the source pond had no significant effect on the abundance or species richness within pools (Appendix 7).

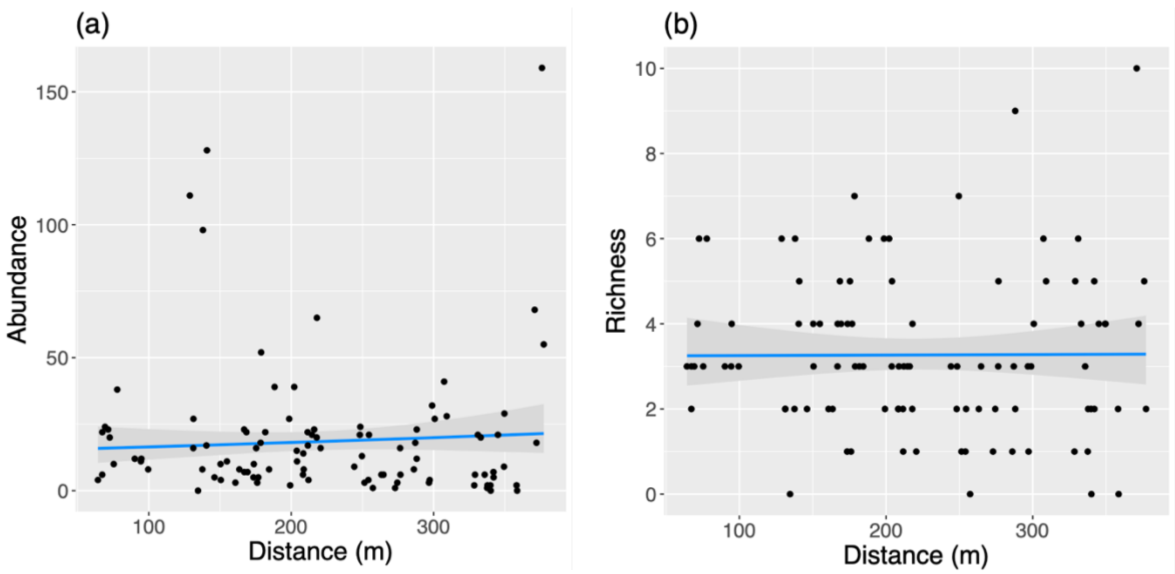

Figure 3.2. The change in a) abundance and b) species richness of aquatic insects in individual pools with increasing distance. Grey ribbon shows 95% confidence intervals for the fitted line. • = one pool.

3.2 Does distance between pools affect how similar their communities are?

Simpson similarity values were calculated for each pair of pools to determine the similarity of aquatic insect communities. The results show that similarity decreases significantly with increasing distance between pools, and the relationship is weak (Mantel r = -0.075, p = 0.018) (Appendix 8). This indicates that pools closer together have aquatic insect communities that are more similar to each other, but the effect of distance on similarity is small.

A Mantel correlogram allowed this correlation to be studied at different points along the distance axis. This revealed that the correlation is only significant at very short distances (<10 m) (Figure 3.3), suggesting a strong influence of distance on community similarity at this scale. At larger distances, the correlation declined and was non-significant.

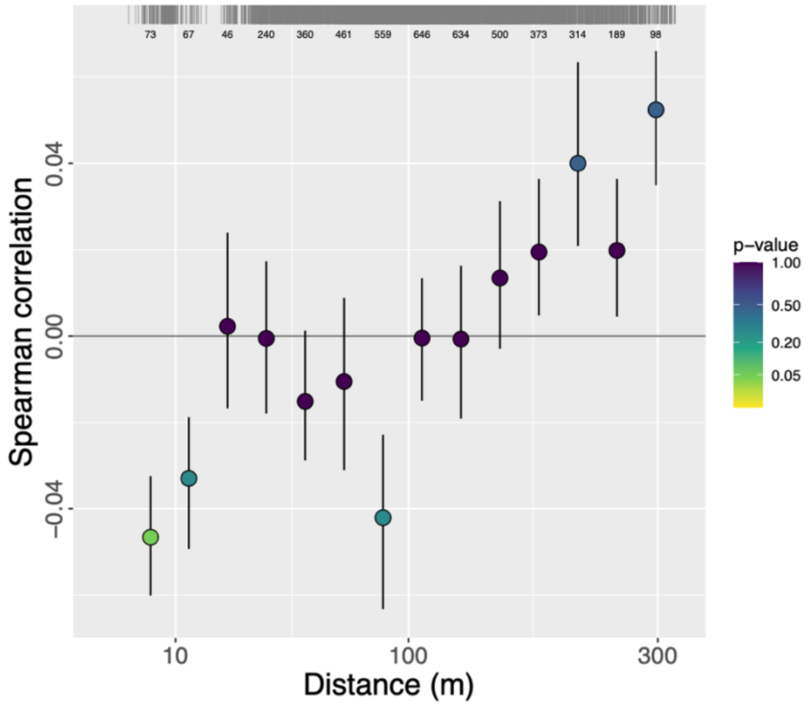

Figure 3.3. Correlogram to assess the correlation between Simpson's similarity and distance at different sections along the distance gradient. Each circle represents the Spearman correlation coefficient for 14 distance bins, and they are colour-coded by significance. Rug lines along the top axis represent each individual pairwise comparison (n = 9,900) at their relative distances. Numeric labels above circle indicate the number of pairwise comparisons included in each distance bin. Distance is square root transformed to better observe patterns at smaller spatial scales.

3.3 How does synchrony between neighbouring pools change with increasing distance from the source pond?

To investigate the influence of distance from a source pond on species synchrony, the coefficient of variation was calculated for both abundance and richness within clusters of pools.

The coefficient of variation for abundance within clusters increased with increasing distance from the source pond (Slope = 1.950×10^{-3}, SE = 9.104×10^{-4}) (Figure 3.4a), and this relationship was significant ($t = 2.142$, $p = 0.044$, gamma glm). The coefficient of variation for species richness within clusters also increased significantly with increasing distance (Slope = 2.653×10^{-3}, SE = 1.007×10^{-3}, $t = 2.635$, $p = 0.0155$, gamma glm) (Figure 3.4b). This suggests a significant decrease in synchrony between the species present in clusters as distance from the source pond increases (Appendix 7).

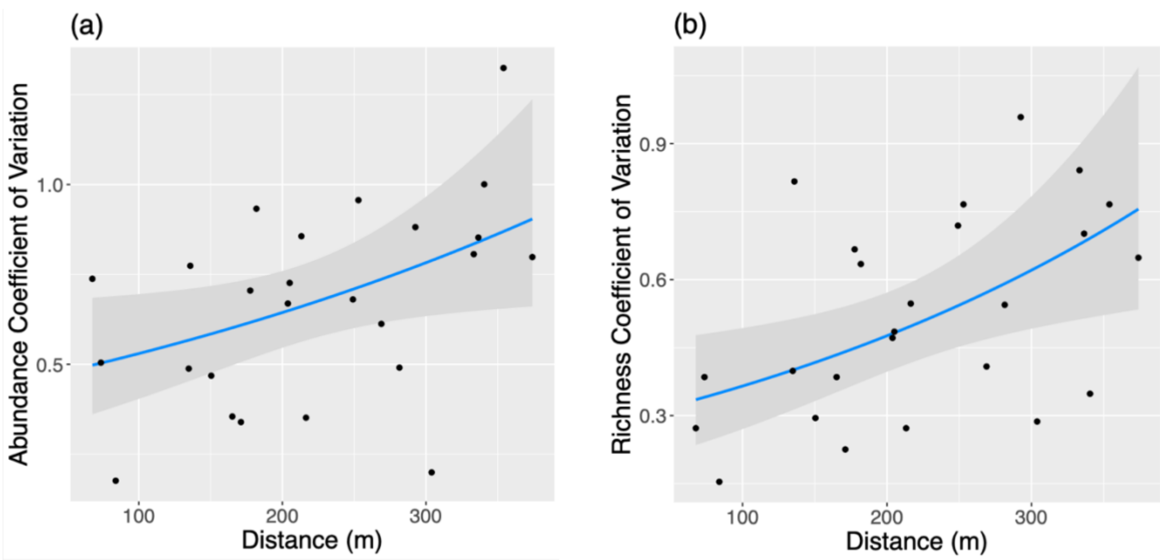

Figure 3.4. The change in a) abundance coefficient of variation within clusters and b) species richness coefficient of variation within clusters with increasing distance. Grey ribbon shows 95% confidence intervals for the fitted line. • = one cluster of four pools.

4. Discussion

This study demonstrates that restored peatland pools can support diverse aquatic insect communities, with strong dispersal enabling colonisation across the landscape, whilst local spatial processes influence patterns of community structure. Abundance and species richness in pools did not vary with increasing distance from the source pond, and differences in community similarity between pairwise pools was only significant at very short distances. Patterns in spatial synchrony revealed that variation in abundance and species richness within clusters of pools increased significantly with increasing distance from the source.

4.1 How does diversity in the pools change with increasing distance from the source pond?

It was expected that abundance and species richness of aquatic insects would decrease with increasing distance from the source pond, as pools at greater distances may experience reduced colonisation rates (Fahrig, 2003). However, this was not reflected in the results which showed that neither abundance nor richness were significantly affected by distance (Figure 3.2). The highest species richness (10) was recorded in a pool at almost the furthest distance away (371 m), suggesting that even the most distant pools were successfully colonised by a variety of species, and there was no loss of diversity across the range of the study site.

The relatively consistent species richness values across all distances may suggest that aquatic insects dispersed effectively from the source pond throughout the full extent of the peatland pools, preventing local extinctions and maintaining diversity across the landscape. Many Dytiscidae and Corixidae species have strong flight abilities as adults which could have allowed them to disperse to new habitats (Bilton, 2023), which is consistent with their occurrence in 72% and 55% of the sampled pools respectively. This is supported by findings from Mazerolle et al. (2006) that found Coleoptera and Hemiptera readily colonised man-made peatland pools. It is also possible that some colonisation has occurred from other pools within the network, meaning that some of the distance effect from the pond has been lost, particularly as the pools were created three years prior to sampling and the current successional stage is unknown. Odonata are also known for their excellent flight abilities (Salami et al., 2019) and have shown positive responses to rewetting (Minot et al., 2021; Strobl et al., 2020), colonising new pools within a year of creation. *Sympetrum danae* was the most common Odonate species sampled, occurring in 25% of the pools at a variety of distances from the source. However, Odonata can remain in their larval stage for several years, so the establishment of some species in newly created peatland pools may be delayed due to low population sizes (Brown et al., 2016). Chironomidae are effective at dispersing passively by wind and were found in 57% of the pools at varying distances from the source. They often occurred in great numbers (more than 100 individuals sampled from some pools), which is consistent with findings from other peatland pool studies (Brown et al., 2016; Beadle et al., 2015). Since prevailing winds across the study site are mainly south-westerly, the spatial arrangement of the pools downwind of the source pond may have further facilitated dispersal, potentially strengthening colonisation success at greater distances. The presence of Chironomidae in more distant pools may also contribute to high abundance values at further distances.

The lack of distance effects on diversity aligns with findings from other studies that show isolation has little or no influence on species richness over distances that are short relative to the scale of dispersal of the organisms being studied. Brooks and Colburn (2012) found that benthic macroinvertebrate richness was not related to isolation in seasonal forest pools. This pattern has also been observed in carabid beetles (Brose, 2003) and wetland plants (Brose, 2001), where water chemistry and pond size were found to be drivers of richness, but isolation showed only weak, non-significant results over distances of less than one kilometre. This suggests that where dispersal is not a limiting factor, environmental factors may play a greater role in structuring community composition than spatial processes (Padial et al., 2014). Insects with high dispersal abilities are less likely to be influenced by spatial structure than those with low dispersal ability, since they may reach suitable habitat more easily (De Bie et al., 2012).

Although there were no observed effects of distance on aquatic insect abundance or richness, the spatial extent of this study, which covered around 400 metres, may be too limited to detect spatial patterns. If dispersal is important in determining community composition, then the effect of distance is unlikely to be detected if the pools are sampled within species' dispersal range (Spencer, 2002). Conducting the study over a greater distance with more isolated pools will improve the chance of patterns in source-sink dynamics emerging for highly dispersing aquatic insects.

4.2 Does distance between pools affect how similar their communities are?

Similarity in aquatic insect community composition between pairs of pools was expected to be lower for those separated by greater distances. A Mantel test revealed that Simpson's similarity index did decrease significantly with increasing distance, but this relationship was very weak ($r = -0.075$, $p = 0.016$). A correlogram further revealed that the only significant decrease in similarity occurred at the shortest distance range of less than 10 metres (Figure 3.3), representing pools that were sampled within clusters. This indicates that pools share more similar communities with other pools in the same cluster than they do with pools outside of the cluster. At distances greater a few metres, the relationship between distance and community similarity was non-significant. It must be acknowledged, however, that pools within clusters were always sampled on the same day, whereas different clusters were usually sampled on different days, therefore the observed effects of distance may be confounded with time.

The result of increased similarity between neighbouring pools suggests that spatial proximity only has an influence at very close distances. Pools within clusters likely experience frequent inter-pool dispersal, with aquatic insects having to disperse only a few metres between adjacent pools, resulting in more similar communities. In contrast, outside the of the cluster, the strong dispersal abilities of many of the sampled species may allow them to colonise pools across the range of the landscape. Higher similarity within clusters may be due to the influence of species with lower dispersal abilities that are able to move short distances but cannot colonise pools outside of this range. This is reflected by species that were sampled more than once but only from pools within the same cluster. These included *Agabus affinis* that only has the capacity for short distance flight shortly after emergence (Jackson, 1956), and *Scirtidae* sp. that has low flight capacity and may use jumping as its primary method of locomotion (Nadein et al., 2022; Verbeck & Esselink, 2005).

The distance-decay of community similarity is a widely studied ecological phenomenon that has been documented for many taxa across different ecosystems (Soininen et al., 2007). However, the strength and scale of these patterns can vary considerably. In aquatic habitats, studies have found that distance has a weak or inconsistent effect on community similarity on small scales. Spencer et al. (2002) found no significant relationship between distance and invertebrate community dissimilarity for rock pools within an area of 800 m^2, suggesting that dispersal was sufficient to homogenise species composition. Where significant effects of distance on similarity are found, they often occur on larger spatial scales or in less connected networks. For example, Briers and Briggs (2005) found that there was a significant effect of distance on similarity in pond community compositions over distances of up to 13 kilometres. Similarly, a study on Dytiscidae communities in urban ponds found that dissimilarity increases as connectivity decreases over distances up to 15 kilometres (Liao et al., 2022). Over a short range, the effects of distance on community similarity are more likely to emerge for weaker dispersing species. This was demonstrated by Astorga et al. (2012) who found that in stream networks, invertebrate groups with low dispersal ability had community similarity that decreased with distance, but the same pattern was not observed for strong dispersers that were more strongly sorted by environmental conditions.

These comparative studies support the results of this investigation, suggesting that the strength of the effect of distance on community similarity depends on the range of the study area, with aquatic insect communities tending to show weak spatial structuring on small scales when dispersal ability is high. However, it must be acknowledged that the pools in this study were sampled during a single season, capturing the community composition only at that point in time. Aquatic insect populations and metacommunity processes are known to undergo seasonal and annual fluctuations due to environmental variability and life-cycle phenology (Cayrou et al., 2005; Ivkovic et al., 2013), so it is possible that patterns in spatial structuring may be different over longer timescales, particularly as community interactions develop. Short-term data may not consider priority effects, where the identity of early colonists can influence community composition through competition or predation (Eglesfield et al., 2023). Similarly, pulses in seasonal dispersal, such as mass emergences, may lead to colonisation events that influence conclusions about dispersal ability (Corbet, 1964). Additionally, species that emerge outside of this sampling period may be under-represented. Long-term monitoring over multiple seasons and years would provide a more comprehensive view of patterns in aquatic insect community composition.

4.3 How does synchrony between neighbouring pools change with increasing distance from the source pond?

Two principal mechanisms have been suggested as drivers of synchrony in ecological communities: dispersal and environmental variation (Haynes & Walter, 2022; Kendall et al.,

2000; Lande et al., 1999; Peltonen et al., 2002). Dispersal can directly synchronise populations through simultaneous immigration events that causes pools to align in population growth. Alternatively, environmental synchrony, often termed the 'Moran effect', occurs when separate populations experience similar fluctuations in response to shared environmental conditions (Engen & Sæther, 2005; Loreau et al., 2008). However, on a local scale, it is difficult to disentangle the relative effects of these two mechanisms as they may occur simultaneously and likely interact (Haynes & Walter, 2022; Kendall et al., 2000).
A possible explanation for the observed result is that both frequent dispersal near the source and gradually decreasing environmental similarity with distance are driving a decrease in synchrony. The source pond may have a homogenising effect on nearby pools, where they experience similar colonisation events and shared environmental conditions. In contrast, pools at greater distances experience more stochastic colonisation and greater environmental heterogeneity, leading to greater variability in abundance and richness between neighbouring pools. However, since the abundance and species richness of aquatic insects across the Castell Nos landscape have been found to be relatively uniform, it is unlikely that limited dispersal is the primary process driving a decrease in synchrony at this scale. Even though all pools are considered to be similar in their environmental conditions, it is possible that environmental variation could be influencing synchrony at greater distances. Pools in close proximity to the source may experience more similar habitat conditions, such as water chemistry and microclimate, resulting in synchronised colonisation and extinction events, whereas at greater distances from the source, there may be slight differences in local conditions that cause populations to fluctuate more variably.

These findings are consistent with broader research that shows population synchrony generally decreases with increasing distance between habitats (Lande et al., 1999; Walter et al., 2021). However, these studies are usually conducted over a range of a few to hundreds of kilometres, in contrast to the small scale of this study. For example, studies of insect outbreaks in forest ecosystems have shown that local dispersal can synchronise nearby populations, but over regional scales, correlated climate fluctuations become the dominant driver of synchrony (Peltonen et al., 2002).

The degree of synchrony across the Castell Nos landscape has important implications for the stability of the metacommunity (Wilcox et al., 2017). When there is high synchrony between pools and populations fluctuate in unison, a disturbance or extreme event could impact them all simultaneously, contributing to species extinction (Pandit et al., 2013). In contrast, asynchrony allows for rescue effects (Brown & Kodric-Brown, 1977), where one pool experiencing a decline or local extinction can be recolonised by neighbouring pools. These asynchronous dynamics spatially spread risk, enhancing regional persistence, and recent studies have emphasised that the degree of synchrony within local communities can be as critical for ecosystem stability as biodiversity (Valencia et al., 2020). Regarding the pools at Castell Nos, the increase in coefficient of variation for both abundance and species richness reflects a decrease in synchrony, suggesting that at greater distances, pools fluctuate variably in composition across space, mitigating the risk of a single stressor causing widespread population collapse.

For peatland management, this presents a trade-off between connectivity and resilience in a restored landscape. Strong connectivity can promote colonisations and maintain local diversity through continuous immigration of species (Morel-Journel et al., 2016). However, high connectivity can lead to tightly linked dynamics, making neighbouring pools vulnerable to synchronous population declines if disturbed.

4.4 Implications for peatland restoration and future research

Understanding the processes that influence aquatic insect community structure in peatland pools can be useful for informing restoration strategies. This study demonstrates that the high dispersal abilities of aquatic insects such as Dytiscidae, Corixidae and Chironomidae, enable successful colonisation of pools across the full extent of the area, maintaining similar levels of diversity across the Castell Nos landscape. Creating new pools even hundreds of metres away from an existing source can allow aquatic insects to readily colonise new habitats, enhancing the biodiversity outcomes of restoration projects. The high connectivity of pools allows low dispersing species to colonise new habitats more easily, however, this can also lead to synchronous population dynamics where stressors affect multiple pools simultaneously and result in local extinctions. Therefore, a key consideration in restoration planning should be to create environmental heterogeneity across the landscape, promoting variability in conditions that result in population asynchrony and increased resilience. Since aquatic insects have important roles in ecosystem processes (Verma et al., 2021), ensuring their persistence in peatlands also supports wider conservation objectives and strengthens the ecological functioning of restored habitats.

Monitoring aquatic insects in restored peatlands could provide a valuable indication of restoration success and help to guide adaptive management. Continued surveying will be important to understand how assemblages change over time, as succession is likely to influence community structure and population stability. Further research should also investigate aquatic insect community structure over a larger spatial scales, as patterns of dispersal are likely to extend beyond the boundaries of this site.

5. Conclusion

Since restoration through rewetting, the Castell Nos HRA has the potential to support diverse aquatic insect communities. Diversity did not vary with increasing distance from the source pond with abundance and richness remaining consistent throughout the landscape. This may be due to the strong dispersal abilities of some taxa that enabled successful colonisation even at the furthest distances sampled. Community similarity decreased with increasing distance between pools, but this was only significant at distances of less than 10 metres, indicating that pools within clusters were more similar in composition than those in different clusters. Synchrony in the abundance and species richness within clusters of neighbouring pools decreased with increasing distance from the source, suggesting that the source has a homogenising effect on nearby pools where they experience similar colonisation events. This study highlights the importance of creating well-connected peatland landscapes with environmental heterogeneity to promote asynchrony and decrease the risk of stressors that may cause synchronous population declines. Future studies should investigate how spatial scale influences community structure across greater distances, whilst also considering the effects of dispersal ability, environmental conditions and local interactions.

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Word, C.S., McLaughlin, D.L., Strahm, B.D., Stewart, R.D., Varner, J.M., Wurster, F.C., Amestoy, T.J. and Link, N.T., 2022. Peatland drainage alters soil structure and water retention properties: Implications for ecosystem function and management. *Hydrological Processes*, *36*(3), p.e14533.

7. Appendices

Appendix 1: Castell Nos Satellite Map

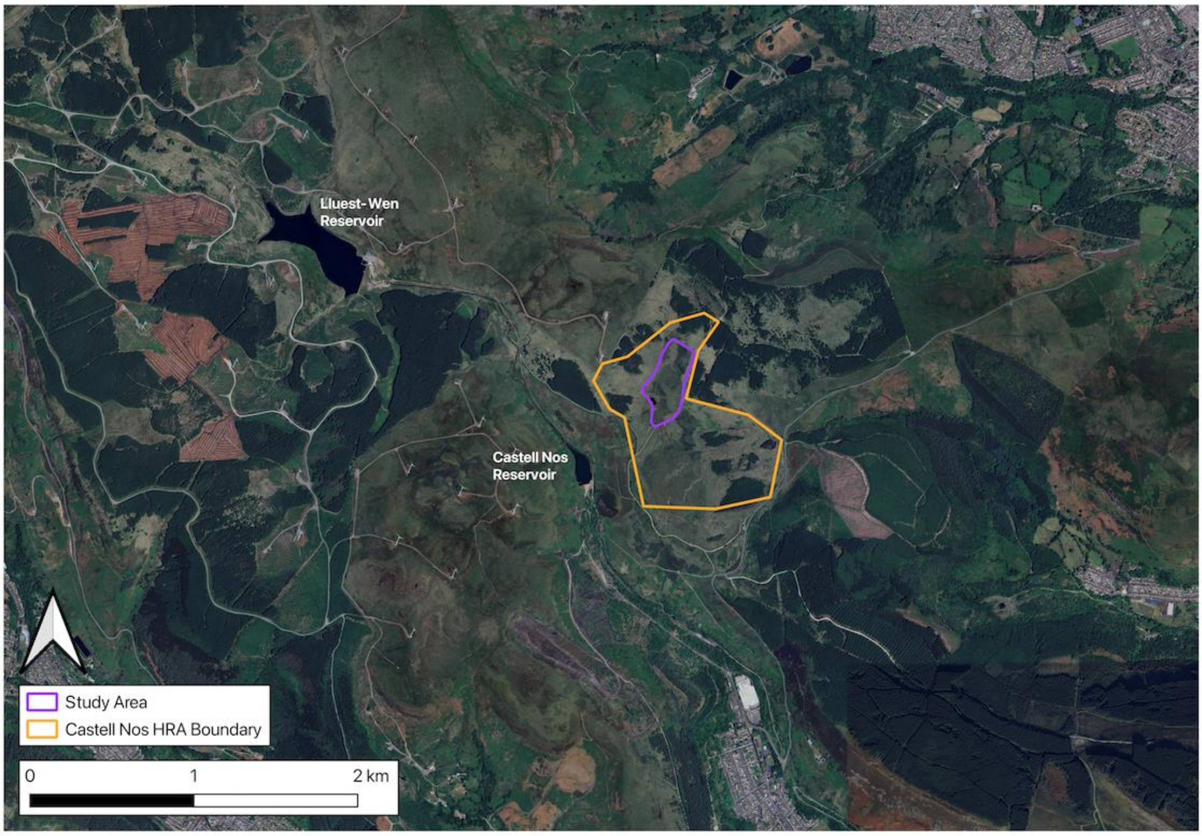

Figure 7.1. Satellite image of landscape surrounding Castell Nos HRA (orange) and study site (purple). Nearby water bodies are labelled. (Google satellite, 2023).

Appendix 2: Castell Nos sampled pools

Table 7.1. Spatial and environmental data for 100 individual pools sampled.

ID	Date	Latitude	Longitude	Distance from pond (m)	Temp (℃)	pH	TDS (mg/L)	Depth (cm)	Emergent vegetation
01a	25/07/24	51.69692	-3.49521	71.47	16.5	4.49	14	30	No
01b	25/07/24	51.69688	-3.49515	67.34	17.7	4.36	15	25	Yes
01c	25/07/24	51.69685	-3.49516	64.26	17.2	4.35	15	40	No
01d	25/07/24	51.69688	-3.49525	67.27	17.4	4.37	11	40	No
03a	12/08/24	51.69696	-3.49467	99.54	18.4	4.58	20	35	Yes
03b	12/08/24	51.69696	-3.49455	94.42	18.4	4.5	18	25	Yes
03c	12/08/24	51.69688	-3.49461	90.15	18	4.33	18	25	Yes
03d	12/08/24	51.69692	-3.49472	94.78	18.7	4.32	19	40	No
04a	18/07/24	51.69678	-3.49445	77.81	16.9	4.34	15	50	Yes
04b	18/07/24	51.69671	-3.4944	75.35	17.8	4.31	34	40	Yes
04c	18/07/24	51.69671	-3.49451	69.26	19	4.37	8	30	No
04d	18/07/24	51.69677	-3.49455	72.55	20.9	4.36	8	35	No
05a	20/06/24	51.6974	-3.49441	138.00	18.1	4.11	19	40	No
05b	20/06/24	51.6974	-3.49429	140.83	17.5	4.28	25	15	No
05c	20/06/24	51.69732	-3.49436	131.34	16.7	4.93	20	30	No
05d	20/06/24	51.69733	-3.49447	128.80	17	4.35	24	30	No
06a	21/08/24	51.69704	-3.49373	134.55	13.9	4.75	18	5	Yes
06b	21/08/24	51.69704	-3.49361	140.46	14.2	4.38	19	30	Yes
06c	21/08/24	51.69697	-3.49359	137.59	14.3	4.36	18	30	Yes
06d	21/08/24	51.69698	-3.49371	131.23	13.7	4.63	18	30	Yes
07a	05/08/24	51.69777	-3.49451	173.77	16.6	4.54	18	30	Yes
07b	05/08/24	51.69776	-3.49439	175.40	16.4	4.36	17	40	No
07c	05/08/24	51.69769	-3.49435	168.52	16.6	4.39	15	30	Yes
07d	05/08/24	51.6977	-3.49446	166.92	16.9	4.48	17	30	Yes
08a	22/07/24	51.69732	-3.49386	150.36	18.6	4.64	16	35	Yes
08b	22/07/24	51.69732	-3.49376	154.86	19.2	4.61	12	40	No
08c	22/07/24	51.69725	-3.49372	150.57	18.8	4.45	15	35	Yes
08d	22/07/24	51.69725	-3.49383	146.12	19.6	4.41	13	35	No
09a	29/07/24	51.69716	-3.49334	163.57	18.7	4.35	19	40	No
09b	29/07/24	51.69715	-3.49323	169.34	17.3	4.25	16	30	No
09c	29/07/24	51.69708	-3.49319	167.04	19	4.26	14	35	Yes
09d	29/07/24	51.69709	-3.49331	160.80	19.7	4.27	12	35	No
10a	20/06/24	51.69772	-3.49392	184.44	19	4.35	14	30	No
10b	20/06/24	51.69771	-3.49379	188.30	18.4	4.28	16	40	No
10c	20/06/24	51.69764	-3.49387	178.89	19.3	4.24	13	30	No
10d	20/06/24	51.69766	-3.494	176.12	18.8	4.1	16	35	No
11a	11/07/24	51.69744	-3.49349	176.89	14.8	4.45	25	40	No
11b	11/07/24	51.69743	-3.49337	181.78	15.7	4.24	15	35	No
11c	11/07/24	51.69736	-3.49333	178.50	15.2	4.17	17	20	Yes
11d	11/07/24	51.69737	-3.49344	173.48	15.7	4.27	14	40	No

12a	24/06/24	51.69813	-3.49425	217.89	24	4.21	23	20	No
12b	24/06/24	51.69814	-3.49415	220.62	22.8	4.3	16	40	No
12c	24/06/24	51.6981	-3.49415	216.11	24	4.45	14	40	No
12d	24/06/24	51.69808	-3.49426	211.69	24	4.27	16	25	No
13a	01/08/24	51.698	-3.49384	214.59	20.7	4.4	15	30	Yes
13b	01/08/24	51.69799	-3.49372	218.03	20.9	4.34	13	25	No
13c	01/08/24	51.69792	-3.49369	211.52	21.3	4.34	16	20	Yes
13d	01/08/24	51.69793	-3.49381	208.78	21.8	4.42	14	35	Yes
14a	11/07/24	51.69771	-3.4934	203.88	16.5	4.3	14	35	No
14b	11/07/24	51.6977	-3.49329	208.27	16.5	4.27	14	35	No
14c	11/07/24	51.69763	-3.49325	204.08	15.9	4.22	14	30	No
14d	11/07/24	51.69764	-3.49337	199.26	16.7	4.17	15	30	No
15a	12/08/24	51.69751	-3.4929	212.11	19.5	4.42	16	10	Yes
15b	12/08/24	51.69745	-3.49289	208.49	20.8	4.38	15	25	Yes
15c	12/08/24	51.69742	-3.49303	198.58	21.3	4.32	17	30	Yes
15d	12/08/24	51.69749	-3.49306	202.11	20.4	4.4	17	10	Yes
16a	25/07/24	51.69851	-3.49431	257.32	18.1	4.27	16	25	No
16b	25/07/24	51.69846	-3.4943	251.45	18.3	4.24	14	35	No
16c	25/07/24	51.69844	-3.49436	248.16	18.3	4.27	15	20	No
16d	25/07/24	51.6985	-3.49438	254.60	18.3	4.24	17	25	No
17a	22/07/24	51.69846	-3.4934	274.48	18.6	4.47	13	55	Yes
17b	22/07/24	51.69843	-3.49334	272.96	17.8	4.54	12	35	Yes
17c	22/07/24	51.69835	-3.4934	263.28	19	4.5	11	35	No
17d	22/07/24	51.69838	-3.49346	264.80	19	4.58	10	40	Yes
18a	01/08/24	51.69813	-3.4931	254.16	21.8	4.44	14	30	No
18b	01/08/24	51.69807	-3.49309	248.51	22.3	4.47	11	50	No
18c	01/08/24	51.69806	-3.49319	244.25	22.7	4.61	6	50	No
18d	01/08/24	51.69812	-3.49318	249.65	23.1	4.41	14	30	No
20a	24/06/24	51.69894	-3.49397	309.15	21.5	4.45	22	25	No
20b	24/06/24	51.69891	-3.49391	307.35	21.8	4.51	28	30	No
20c	24/06/24	51.69885	-3.49398	298.94	21.5	4.45	13	35	No
20d	24/06/24	51.69887	-3.49405	300.74	22.1	4.4	16	30	No
22a	18/07/24	51.69851	-3.49287	297.21	23.2	4.5	9	30	No
22b	18/07/24	51.69848	-3.49281	296.73	23.54	4.46	10	35	No
22c	18/07/24	51.69841	-3.49288	288.12	22.6	4.54	10	30	No
22d	18/07/24	51.69844	-3.49294	288.10	22.2	4.55	6	30	No
23a	29/07/24	51.69819	-3.49247	287.11	22.7	4.85	6	15	Yes
23b	29/07/24	51.69816	-3.49241	286.12	25.7	4.72	11	5	No
23c	29/07/24	51.69809	-3.49249	276.68	23.9	4.79	7	10	No
23d	29/07/24	51.69812	-3.49256	276.48	19.6	4.99	6	5	No
24a	18/07/24	51.69924	-3.49394	341.99	22.4	4.2	16	30	No
24b	18/07/24	51.69922	-3.4939	340.05	19.8	4.12	15	50	No
24c	18/07/24	51.69914	-3.49398	331.03	21	4.18	15	35	No
24d	18/07/24	51.69917	-3.49402	333.07	20.4	4.32	13	30	No

25a	11/07/24	51.69904	-3.49296	345.10	19.1	4.41	10	35	Yes
25b	11/07/24	51.69898	-3.49294	339.84	19.7	4.44	9	45	Yes
25c	11/07/24	51.69897	-3.49304	335.81	19.6	4.38	8	35	No
25d	11/07/24	51.69903	-3.49303	342.08	19.6	4.38	8	35	No
26a	25/07/24	51.69901	-3.49248	358.62	18.2	4.67	6	35	No
26b	25/07/24	51.69898	-3.49242	358.22	17.1	4.62	7	30	Yes
26c	25/07/24	51.69892	-3.4925	349.38	18.3	4.5	8	30	Yes
26d	25/07/24	51.69894	-3.49256	349.66	17.6	4.65	7	25	Yes
27a	21/08/24	51.69877	-3.49245	337.79	13.4	4.48	16	30	Yes
27b	22/08/24	51.69874	-3.49238	337.56	14.6	4.57	14	10	No
27c	23/08/24	51.69867	-3.49245	328.50	14.1	4.46	16	10	Yes
27d	24/08/24	51.6987	-3.49251	329.03	13.8	4.46	16	10	Yes
30a	20/06/24	51.69937	-3.49299	377.30	19	4.28	16	30	Yes
30b	20/06/24	51.69933	-3.49291	376.04	18.8	4.23	17	35	No
30c	20/06/24	51.69928	-3.49291	370.92	14	4.15	15	35	No
30d	20/06/24	51.69932	-3.493	372.19	18.8	4.18	14	25	No

Appendix 3: Taxonomic keys and field guides

Cham, S., 2012. *Field guide to the larvae and exuviae of British dragonflies.* British Dragonfly Society.

Finfand, H., 1986. Identification of the waterstrider (Gerridae) nymphs of Northern Europe. *Annales Zoologici Fennici*, 52*,* pp.63-77.

Foster, G.N. and Friday, L.E., 2014. *Keys to the adults of water beetles of Britain and Ireland. Part 1.* Royal Entomological Society.

Foster, G.N., Bilton, D.T. and Friday, L.E., 2014. *Keys to adults of the water beetles of Britain and Ireland. Part 2*. Royal Entomological Society.

Savage, A.A., 1989. *Adults of the British aquatic Hemiptera Heteroptera: a key with ecological notes.* Freshwater Biological Association.

Savage, A.A., 1999. *Key to the larvae of British Corixidae*. Freshwater Biological Association.

Wallace, I.D., Wallace, B. and Philipson, G.N., 2003. *Keys to the case-bearing caddis larvae of Britain and Ireland*. Freshwater Biological Association.

Appendix 4: R code

```
####################### COMPLETE CODE #######################

# Load packages
library(ggplot2)    # graphics
library(GGally)     # ggpairs function
library(visreg)     # graphics
library(dplyr)      # data wrangling
library(readxl)     # data input
library(MASS)       # binomial GLM
library(patchwork)  # arranging plots
library(ecodist)    # Mantel test and related
library(proxy)      # similarity indices
library(readr)      # data input
library(stringr)    # data wrangling

##############################################################
##################### ENVIRONMENTAL DATA #####################

# Load data for pool analyses
pooldata <- read_excel("PoolData.xlsx")
View(pooldata)

# Select variables of interest
env_vars <- pooldata[, c("Date", "Distance", "Temp", "TDS",
"pH", "Depth")]

# Pairwise correlations between environmental variables
g0 <- ggpairs(env_vars,
              diag = list(continuous = wrap("barDiag")))

g0

##############################################################
################# NUMBER OF POOLS PER FAMILY #################

# Load the data
poolpresence <- read_excel("PoolPresence.xlsx")

# Prepare data
poolpresence <- poolpresence %>%
  mutate(
    PondPresent = ifelse(Pond == "Y", 1, 0),
    Pool = Pools
  ) %>%
  arrange(Family)  # alphabetical order

# Plot
ggplot() +
  # Pool presence bars
```

```
  geom_col(
    data = poolpresence,
    aes(x = Pool, y = Family),
    fill = "#00B2EE",
    width = 0.6,
    show.legend = FALSE
  ) +

  # Pond presence bars
  geom_col(
    data = poolpresence %>% filter(PondPresent == 1),
    aes(x = -1, y = Family, fill = factor("Pond")),
    width = 0.3,
    show.legend = FALSE
  ) +

  # Axis settings
  scale_x_continuous(
    breaks = seq(0, max(poolpresence$Pool) + 5, by = 10)
  ) +
  labs(y = "Family", x = "Number of Pools") +
  theme(
    axis.text.y = element_text(size = 9))

##############################################################
################### ABUNDANCE VS DISTANCE ####################

# Create negative binomial glm with TDS and Temp added
m1 <- glm.nb(TotalAbundance ~ Distance + TDS + Temp, data =
pooldata)

# View output
summary(m1)

# Plot
g1 <- visreg(m1, xvar = "Distance", scale = "response", rug =
F, gg = T) +
  geom_point( inherit.aes = F, data = pooldata, aes(x =
Distance, y = TotalAbundance) ) +
  labs(title = "(a)", x = "Distance (m)", y = "Abundance")

# Axis settings
mytheme = theme(
  plot.title = element_text(size = 20),
  axis.title.x = element_text(size = 18),
  axis.title.y = element_text(size = 18),
  axis.text = element_text(size = 14)
)

# Graph output
g1 + mytheme
```

```
################################################################
#################### RICHNESS VS DISTANCE ####################

# Create negative binomial glm
m2 <- glm.nb( Richness ~ Distance + TDS + Temp, data =
pooldata)

# View output
summary(m2)

# Plot
g2 <- visreg(m2, xvar = "Distance", scale = "response", rug =
F, gg = T) +
  geom_point( inherit.aes = F, data = pooldata, aes(x =
Distance, y = Richness) ) +
  labs(title = "(b)", x = "Distance (m)", y = "Richness")

# Graph output
g2 + mytheme + scale_y_continuous( breaks = seq(0,10,2) )

################################################################
################## ABUNDANCE CV VS DISTANCE ##################

# Load the data
clusterdata <- read_excel("ClusterData.xlsx")
View(clusterdata)

# Make a new variable in 'pooldata' that identifies the pool
cluster
pooldata$cluster <- factor( rep(1:25, each = 4) )

# Create TDS and Temperature means, SDs, and CVs for each
cluster of pools
clusterdata$meanTDS <- tapply(pooldata$TDS, pooldata$cluster,
mean)
clusterdata$sdTDS <- tapply(pooldata$TDS, pooldata$cluster,
sd)
clusterdata$cvTDS <- clusterdata$sdTDS / clusterdata$meanTDS

clusterdata$meanTemp <- tapply(pooldata$Temp,
pooldata$cluster, mean)
clusterdata$sdTemp <- tapply(pooldata$Temp, pooldata$cluster,
sd)
clusterdata$cvTemp <- clusterdata$sdTemp /
clusterdata$meanTemp

# Create gamma glm with variability in TDS and Mean added to
the model
m3 <- glm( AbundanceCV ~ Distance + cvTDS + cvTemp, family =
Gamma("log"), data = clusterdata )
```

```
# View output
summary(m3)

# Plot
g3 <- visreg(m3, xvar = "Distance", scale = "response", rug =
F, gg = T) +
  geom_point( inherit.aes = F, data = clusterdata, aes(x =
Distance, y = AbundanceCV) ) +
  labs(title = "(a)", x = "Distance (m)", y = "Abundance
Coefficient of Variation")

# Graph output
g3 + mytheme

##############################################################
################### RICHNESS CV VS DISTANCE ##################

# Create gamma glm
m4 <- glm( RichnessCV ~ Distance + cvTDS + cvTemp, family =
Gamma("log"), data = clusterdata )

# View output
summary(m4)

# Plot
g4<- visreg(m4, xvar = "Distance", scale = "response", rug =
F, gg = T) +
  geom_point( inherit.aes = F, data = clusterdata, aes(x =
Distance, y = RichnessCV) ) +
  labs(title = "(b)", x = "Distance (m)", y = "Richness
Coefficient of Variation")

# Graph output
g4 + mytheme

##############################################################
#################### SIMPSONS SIMILARITY #####################

# Load raw species occurrence data
spp_df <- read_csv("Similarity.csv")

# Clean and prepare species data
spp_df$ID <- str_trim(tolower(spp_df$ID))  # standardize pool
IDs
species_data <- spp_df %>%
  mutate(across(-ID, as.numeric))          # convert species
cols to numeric

# Load distance data
dist_df <- read_csv("PoolMatrix.csv")
```

```
# Data wrangling
dist_df <- dist_df %>%
  mutate(InputID = str_trim(tolower(InputID)),
         TargetID = str_trim(tolower(TargetID)))

# Function to calculate species richness in the smaller of two
pools being compared,
# for scaling a plot later
smaller_richness <- function(pool1, pool2, data) {
  vec1 <- data[data$ID == pool1, -1]
  vec2 <- data[data$ID == pool2, -1]

  if (nrow(vec1) == 1 & nrow(vec2) == 1) {
    smaller <-   min( c( sum(vec1 == 1, na.rm = T), sum(vec2
== 1, na.rm = T) ) )
    total <- sum(vec1, na.rm = TRUE) + sum(vec2, na.rm = TRUE)
    if (total == 0) return(0)
    return(smaller)
  } else {
    return(NA)
  }
}

# Select unique pairwise distances.
nn <- nrow(dist_df) / 2
uniqueDist <- rep(NA, nn)
for(i in 1:nn){uniqueDist[i] <- which( dist_df$Distance ==
unique(dist_df$Distance)[i] )[1]}
uniqueDist_df <- dist_df[uniqueDist,]

# Apply 'smaller_richness' function to each pairwise pool
comparison.
dist_df$Smaller <- mapply(
  smaller_richness,
  dist_df$InputID,
  dist_df$TargetID,
  MoreArgs = list(data = species_data)
)

# Simpson similarity index
uniqueDist_df$Simpson <- simil( species_data[,-1], method =
"Simpson" )

# Remove NAs
uniqueDist_df <- na.omit(uniqueDist_df)

# Plot the similarity against distance.
g5 <- uniqueDist_df %>%
  ggplot( aes(x = Distance, y = Simpson) ) +
```

```
  geom_smooth(method = "loess", se = F, col = "grey50",
method.args = list(family = "gaussian")) +
  geom_point(pch = 21, fill = "grey50", alpha = 0.2 ) +
  scale_x_continuous( trans = "sqrt", limits = c(1, 320),
breaks = c(10, 100, 300) ) +
  scale_size( range = c(0, 3) ) +
  labs(x = "Distance (m)", y = "Simpson similarity index") +
  theme( aspect.ratio = 1,
         legend.position = "none",
         axis.text.y = element_text(angle = 90, hjust = 0.5) )

g5 + mytheme

# Check overall correlation between Simpson similarity index
and pairwise distance between pools.
mantelSimpson <- with( uniqueDist_df, mantel( c(Simpson) ~
c(Distance), mrank = T ) )
mantelSimpson

# See how correlation with distance changes across distance
'bins'.
# Distance on a square root scale to highlight the changes
over smaller distances
myBreaks <- ( seq( sqrt( min(uniqueDist_df$Distance) ), sqrt(
max(uniqueDist_df$Distance) ), length.out = 15) ) ^ 2
correlogramSimpson <- with( uniqueDist_df, mgram(Simpson,
Distance, mrank = T, breaks = myBreaks) )

# Code the resulting points as 'ns' (non-significant) or 's'
(significant),
# based on a 0.05 threshold that has been adjusted for
multiple comparisons using Bonferoni's approach.
mgramDF <- as_tibble(correlogramSimpson$mgram)
mgramDF$signif <- rep( "ns", nrow(mgramDF) )
mgramDF$signif[mgramDF$pval < 0.05 / nrow(mgramDF)] <- "s"

# Plot the correlogram. It includes printing the number of
points in each distance bin.
g6 <- mgramDF %>%
  ggplot( aes(x = lag, y = mantelr, ymin = llim, ymax = ulim,
fill = p.adjust(pval, method = "BY") ) ) +
  geom_hline(yintercept = 0, col = "grey50") +
  geom_errorbar(width = 0) +
  geom_point(pch = 21, size = 4) +
  geom_rug( inherit.aes = F, data = uniqueDist_df, aes( x =
Distance), sides = "top", linewidth = 0.05, col = "grey50" ) +
  geom_text( aes(y = rep( 0.07, nrow(mgramDF) ), label =
ngroup ), size = 2 ) +
  # geom_ribbon(alpha = 0.3) +
  scale_x_continuous( trans = "sqrt", limits = c(1, 320),
breaks = c(10, 100, 300) ) +
```

```
  # scale_fill_manual( values = c("white", "grey50") ) +
  scale_fill_viridis_c( direction = -1, limits = c(0, 1),
trans = "sqrt", breaks = c(0.05, 0.2, 0.5, 1), name = "p-
value" ) +
  scale_size( range = c(0, 3) ) +
  labs(x = "Distance (m)", y = "Spearman correlation") +
  theme( aspect.ratio = 1,
         axis.text.y = element_text(angle = 90, hjust = 0.5) )
g6 + mytheme

##############################################################
```

Appendix 5: Environmental variables correlation matrix

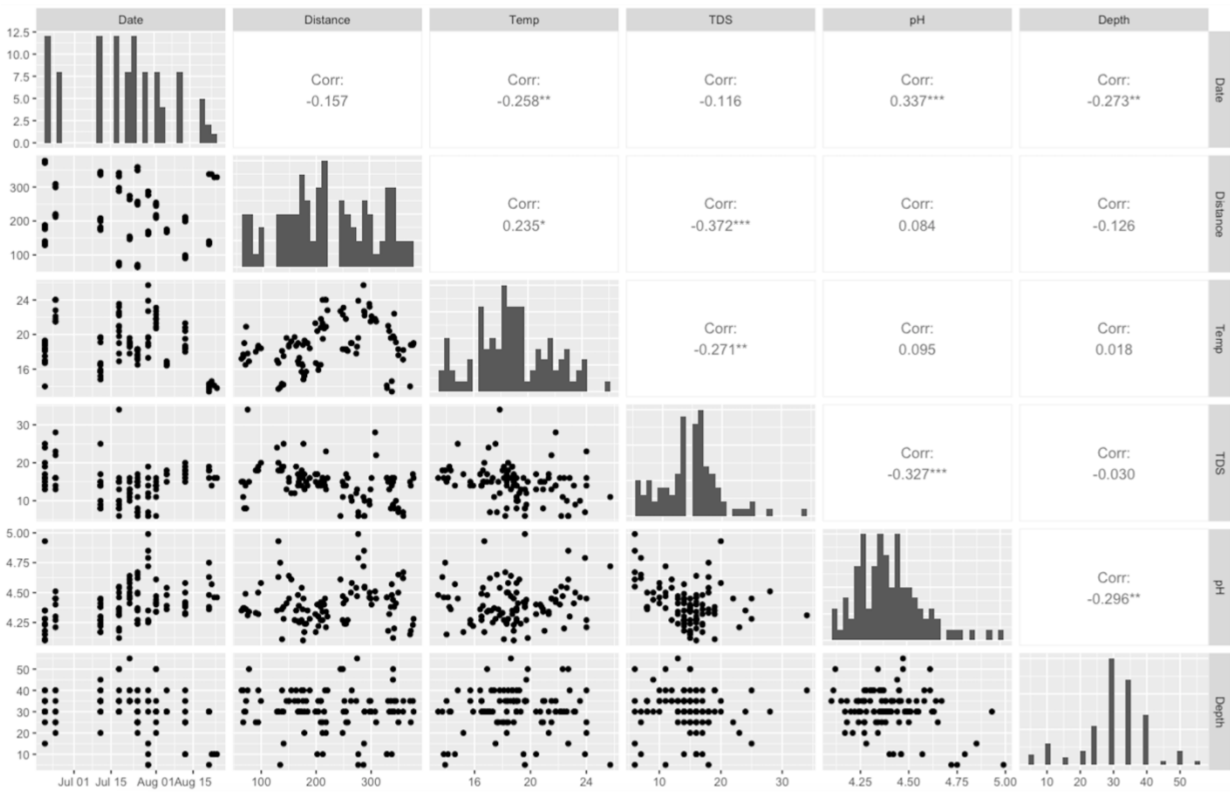

Figure 7.2. Correlation matrix of environmental variables measured from 100 sampled pools at Castell Nos. Histograms display the distribution for each variable, scatterplots show pairwise correlations, and correlation coefficients are presented in upper right panels.

Appendix 6: Species list

Table 7.2. Species list of aquatic insect species sampled at Castell Nos between 20th June and 12th August. Y and N indicate presence and absence of species in the pools and source pond.

Species	Family	Order	Pool	Pond
Agabus bipustulatus	Dytiscidae	Coleoptera	Y	N
Anacaena globulus	Hydrophilidae	Coleoptera	Y	N
Helochares punctatus	Hydrophilidae	Coleoptera	Y	N
Helophorus brevipalpis	Helophoridae	Coleoptera	Y	N
Hydroporus gyllenhalii	Dytiscidae	Coleoptera	Y	N
Hydroporus melanarius	Dytiscidae	Coleoptera	Y	N
Hydroporus memnonius	Dytiscidae	Coleoptera	Y	N
Hydroporus nigrita	Dytiscidae	Coleoptera	Y	N
Hydroporus pubescens	Dytiscidae	Coleoptera	Y	N
Hydroporus striola	Dytiscidae	Coleoptera	Y	N
Suphrodytes figuratus	Dytiscidae	Coleoptera	Y	N
Scirtidae sp.	Scirtidae	Coleoptera	Y	N
Chaoboridae sp.	Chaoboridae	Diptera	Y	N
Chironomidae sp.	Chironomidae	Diptera	Y	Y
Callicorixa praeusta	Corixidae	Hemiptera	Y	N
Corixa punctata	Corixidae	Hemiptera	Y	N
Gerris gibbifer	Gerridae	Hemiptera	Y	N
Gerris lacustris	Gerridae	Hemiptera	Y	N
Hesperocorixa castanae	Corixidae	Hemiptera	Y	Y
Hesperocorixa sahlbergi	Corixidae	Hemiptera	Y	N
Notonecta obliqua	Notonectidae	Hemiptera	N	Y
Sigara fossarus	Corixidae	Hemiptera	Y	N
Sigara nigrolineata	Corixidae	Hemiptera	Y	N
Aeshna juncea	Aeshnidae	Odonata	N	Y
Aeshna mixta	Aeshnidae	Odonata	Y	N
Enallagma cyathigerum	Coenagrionidae	Odonata	N	Y
Pyrrhosoma nymphula	Coenagrionidae	Odonata	Y	Y
Libellula quadrimaculata	Libellulidae	Odonata	Y	Y
Sympetrum danae	Libellulidae	Odonata	Y	Y
Limnephilus coenosus	Limnephilidae	Trichoptera	Y	N

Appendix 7: Model outputs

Table 7.3. Output from negative binomial GLM testing the effect of distance on aquatic insect abundance in 100 pools, with temperature and TDS as added effects. * indicates significant value.

Coefficient	Estimate	Standard Error	t-value	p-value
Intercept	0.666	0.879	0.758	0.499
Distance	9.637×10^{-4}	1.206×10^{-3}	0.799	0.424
TDS	0.089	0.022	3.984	6.79×10^{-5}*
Temperature	0.038	0.037	1.014	0.311

Table 7.4. Output from negative binomial GLM testing the effect of distance on aquatic insect species richness in 100 pools, with temperature and TDS as added effects.

Coefficient	Estimate	Standard Error	t-value	p-value
Intercept	8.368×10^{-1}	5.053×10^{-1}	1.656	0.098
Distance	3.769×10^{-5}	7.052×10^{-4}	0.053	0.957
TDS	1.541×10^{-2}	1.261×10^{-2}	1.222	0.222
Temperature	5.756×10^{-3}	2.163×10^{-2}	0.266	0.790

Table 7.5. Output from gamma GLM testing the effect of distance on coefficient of variation in abundance of aquatic insects in 25 clusters of four pools, with temperature CV and TDS CV as added effects. * indicates significant value.

Coefficient	Estimate	Standard Error	t-value	p-value
Intercept	-0.768	0.238	-3.230	4.01×10^{-3}*
Distance	1.950×10^{-3}	9.104×10^{-4}	2.142	0.044*
TDS CV	-0.363	0.559	-0.649	0.523
Temperature CV	-0.824	2.707	-0.304	0.764

Table 7.6. Output from gamma GLM testing the effect of distance on coefficient of variation in species richness of aquatic insects in 25 clusters of four pools, with temperature CV and TDS CV as added effects. * indicates significant value.

Coefficient	Estimate	Standard Error	t-value	p-value
Intercept	-1.279	0.263	-4.867	8.22×10^{-5}*
Distance	2.653×10^{-3}	1.01×10^{-3}	2.635	0.0115*
TDS CV	0.218	0.618	0.353	0.728
Temperature CV	-0.688	2.994	-0.230	0.821

Appendix 8: Simpson's similarity index vs distance

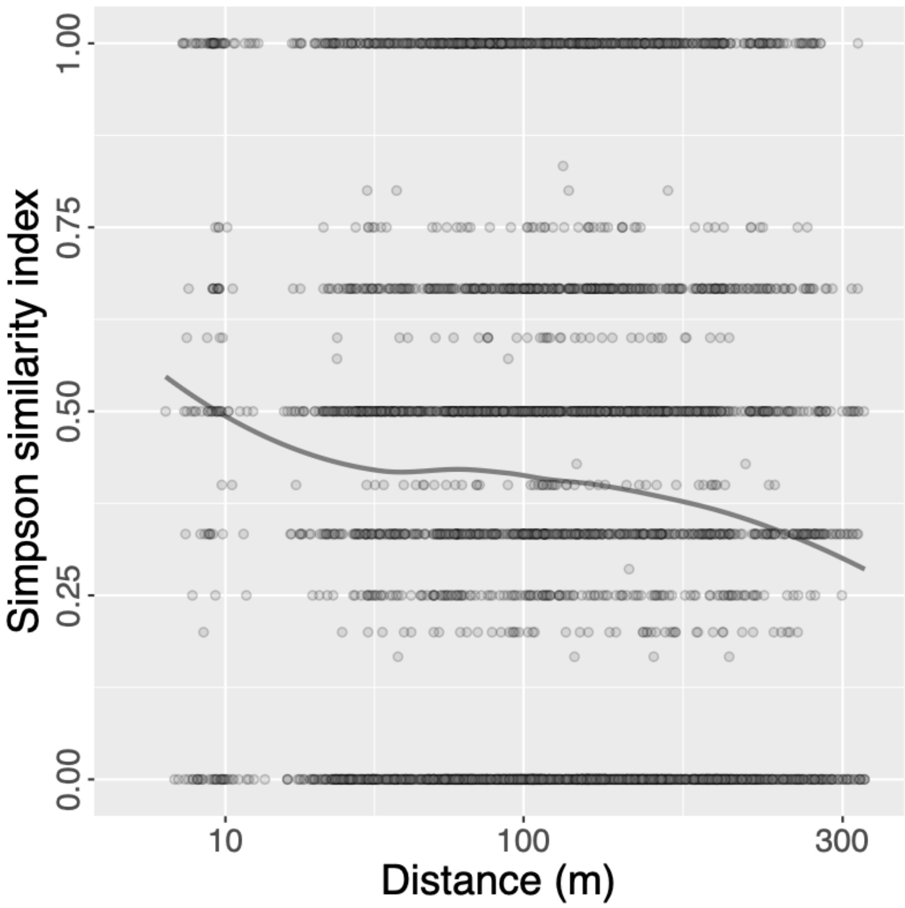

Figure 7.3. The change in Simpson's similarity index between pairwise pools with increasing distance between pools. Smooth curve plotted using LOESS method. • = one pair of pools (n = 9,900).

Appendix 9: Ethics approval and permissions

Swansea University
Prifysgol Abertawe

Approval Date: 17/04/2024

Research Ethics Approval Number: 2 2024 9425 8568

Thank you for completing a research ethics application for ethical approval and submitting the required documentation via the online platform.

Project Title	The role of spatial scale in structuring peat bog invertebrate communities
Applicant name	MISS IMOGEN KATE COCKWELL
Submitted by	MISS IMOGEN KATE COCKWELL /
Full application form link	https://swansea.forms.ethicalreviewmanager.com/Project/Index/11452

The Science and Engineering ethics committee has approved the ethics application, subject to the conditions outlined below:

Approval conditions

1. The approval is based on the information given within the application and the work will be conducted in line with this. It is the responsibility of the applicant to ensure all relevant external and internal regulations, policies, and legislations are met.
2. This project may be subject to periodic review by the committee. The approval may be suspended or revoked at any time if there has been a breach of conditions.
3. Any substantial amendments to the approved proposal will be submitted to the ethics committee prior to implementing any such changes.

Specific conditions in respect of this application:

The application has been classified as Low Risk to the University.

No additional conditions.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees. It complies with the guidelines of UKRI and the concordat to support Research Integrity.

Science and Engineering Research and Ethics Chair

Swansea University.

If you have any queries regarding this notification, then please contact your research ethics administrator for the faculty.

- For Science and Engineering contact FSE-Ethics@swansea.ac.uk
- For Medicine, Health and Life Science contact FMHLS-Ethics@swansea.ac.uk
- For Humanities and Social Sciences contact FHSS-Ethics@swansea.ac.uk

The Lost Peatlands Project
Neath Port Talbot County Council
The Quays
Brunel Way
Neath
SA11 2GG

To whom it may concern,

On behalf of the Lost Peatlands of South Wales Project, I would like to offer my support for Imogen Cockwell's MRes project looking at invertebrate communities on Castell Nos HRA being undertaken from March-September 2024. Lost Peatlands has a history of successful collaboration with Swansea University and is very pleased to have the opportunity to expand on this. The research project delivers important evidence for biodiversity recovery following peatland restoration, a key output for the Lost Peatlands Project and a significant evidence gap for the peatland restoration community both here in Wales and further afield.

As part of this agreement, Lost Peatlands is happy to provide Imogen with access to data previously collected from the site by the Lost Peatlands Project for her use, covering water table dynamics as a time series of pressure transducer readings; peat depth from peat probing measurements; vegetation percentage coverage from permanent quadrats; terrestrial invertebrates as species presence; and aerial imagery in the form of drone orthomosaics. Lost Peatlands is also happy to provide as reference material maps and GIS files for the site related to the above, as well as internal reports and management plans covering activities which have been completed on Castell Nos HRA. This agreement extends to her supervisory team and others involved in the research project, namely Dr Wendy Harris, Dr Jim Bull, Dr Jon Walker, and Joey Pickard. I can confirm that no data provided contains any information regarding individuals and should satisfy all aspects of Swansea University's ethics and governance policy.

I am also happy to confirm that the research project may be undertaken under the standard access arrangement between Lost Peatlands and NRW as the land manager, including for RAMS, with support from Lost Peatlands for logistics as required.

I look forward to seeing the outcomes of this project and am very happy to support Imogen in this work.

Yours Sincerely

Richard Pulman

r.pulman@npt.gov.uk
Lost Peatlands Project Manager
Neath Port Talbot County Council

For and on behalf of the Lost Peatlands Project

Appendix 10: Risk assessments

Site Risk Assessment			
College/ PSU	FSE	Assessment Date	30/04/2024
Location	Castell Nos	Assessor	Jonathan Walker
Activity	Peatland Research	Review Date (if applicable)	
Associated documents	● Activity Risk Assessment ● Dynamic Risk Assessment ● Emergency plan, including a site map		

This assessment covers **Castell Nos.**

Access to Site

Identifier	Type of barrier	Access	Location
Forestry Gate to access site from	NRW Estates Key	SU Keyholders: Joey Pickard; Jonathan Walker	Grid Reference: SN 97284 00023 X, Y: 297284 , 200023 Lat:, Long: 51.689537, -3.4873465 51°41′22″N , 003°29′14″W W3W: tangent.spaceship.breaches

Site Summary

Castell Nos	
Description	Previously forested site, now restored peatland.
Working Location	Grid Reference: SN 96925 00743 X: 296925, Y: 200743 Lat: 51.695943" Long: -3.4927619 Postcode: n/a W3W: results.defends.producing Location along track in middle of site
Parking Location	Grid Reference: SN 97291 00024 X: 297291 , Y: 200024 51°41′22″N , 003°29′14″W Postcode: n/a W3W: scary.deduced.powering
Nearest Turbine	n/a
Distance from main exit point	1.7 km A4233 Maerdy Road
Nearest Hospital	Ysbty Cwm Rhondda Hospital CF40 2LX
Access constraints / control	Access along NRW forestry track from the A4233 Maerdy Road; this requires passing through a gate controlled by a padlock that requires a NRW estate key.
Special considerations	Track that leads along middle of site requires 4x4 access. Other tracks accessible by normal vehicle

Site Risk Assessment

What are the hazards?	Who might be harmed?	How could they be harmed?	What are you already doing?	L	S	Risk (SxL)	Do you need to do anything else to manage this risk?	S	L	Risk (SxL)	Additional Action Required
Weather											
Weather – Cold, wet	All field workers	Exposure	Wear appropriate clothing and footwear – waterproof / windproof. Carry extra clothing to site. Stop work if any worker is affected by the cold / wet – seek temporary shelter in a vehicle, terminate fieldwork.	4	2	8	Continual review of the condition of all fieldworkers during fieldwork	4	1	4	No
Weather – Hot, dry	All field workers	Tiredness, heat stroke, dehydration, sun burn	Wear appropriate clothing - light clothing & hat. Avoid sunburn risk by not exposing skin and using suitable high factor sun block – do not provide sun block to others unless they can confirm that they have used the product before without adverse reactions. Ensure workers have plenty of drinking water. Taking breaks to ensure workers are not getting too hot and tired.	3	2	6	Continual review of the condition of all fieldworkers during fieldwork	3	2	6	No
Adverse Weather	All field workers	Exposure (risks from rain, cold conditions, sunstroke)	Checking weather forecast(s) before fieldwork to be informed about weather conditions. Do not undertake fieldwork if adverse weather forecast. Stop fieldwork promptly if 'adverse' weather sets in. Take shelter (in a vehicle) and exit site if / when safe to do so, following Emergency Exit Plan protocols.	3	3	9	Continual review of the condition of all fieldworkers during fieldwork	3	2	6	No
Changing weather conditions	All field workers	Exposure (risks from rain, cold conditions, sunstroke)	Check weather forecast(s) before fieldwork to be informed about weather conditions. Carrying essential clothing and equipment to be prepared for changeable weather conditions.	3	3		Continual review of weather conditions				

What are the hazards?	Who might be harmed?	How could they be harmed?	What are you already doing?	L	S	Risk (SxL)	Do you need to do anything else to manage this risk?	S	L	Risk (SxL)	Additional Action Required
Poor visibility (fog / low cloud)	All field workers	Getting lost, resulting in stress, exhaustion / exposure	Fieldworkers should stay together and make a plan of action on whether and how to safely proceed with the fieldwork. Have maps of the site available to consult to navigate to know and safe location (possibly a vehicle) Ensure phones are fully charged before fieldwork so can be used as navigation aids during poor visibility. Be aware of daylight availability (take a torch in winter) and plan accordingly so as not to be on site when it is dark.	3	3	9	When visibility starts to decline review fieldwork; promptly stop fieldwork if the situation is considered hazardous.	3	2	6	No
Driving to, from, and during fieldwork											
Driving to and from site	All field workers	Accident. Minor and major injuries; death	Check weather conditions at destination before setting off – whilst conditions might be fine at the journey start point, they might be very different at the site. Do not drive in adverse weather conditions. Do not drive if you do not feel comfortable / able to drive safely to site for any reason (weather, health, mechanical etc). Park safely and in well-lit places if possible. Reverse into a parking space if possible, so as to enable a quick exit if needed (unless this adds risks to unloading a vehicle, but consider turning car around after it has been unloaded). Do not leave valuables on view in your vehicle when you are driving or stationary, for example mobile phone or cash. Don't pick up hitch hikers on route to fieldwork Ensure mobile phone is fully charged, so it can be used in case of an emergency.	3	3	12	Consider being a member of a rescue service in case your vehicle breaks down or in case of a minor accident	3	3	9	No

What are the hazards?	Who might be harmed?	How could they be harmed?	What are you already doing?	L	S	Risk (SxL)	Do you need to do anything else to manage this risk?	S	L	Risk (SxL)	Additional Action Required
			In case of a breakdown, stay with your vehicle with your doors locked and await emergency rescue services (unless on a motorway or busy roundabout – if possible, stand by barrier away from vehicle). If followed, drive to a busy area or to the nearest police station and report details to them. If possible, establish a procedure for a 'next of kin' to carry out in case of no return and that they have the contact details of the line manager.								
Driving around site	All field Workers; other workers on site; public	Minor and major injuries; death	Drive with hazard warning light on and at a maximum speed of 15 mph. Pull over to let lorries pass safely. Park safely off the main, or active, roads – in laybys, or along 'side' roads / crane pads, if possible. Check for vehicles, bikes and pedestrians when getting out of vehicles to avoid incidents and injuries.	2	3	6					
Site infrastructure and operations											
Danger of traffic when crossing or working near site roads	All field workers	Minor and major injuries; death	Be mindful of traffic at all times. Check for vehicles, bikes and pedestrians when crossing roads to avoid incidents and injuries.	3	3	9					
Forestry and peatland restoration operations	All field workers	Minor and major injuries; death	Do not enter areas where operations are in progress without written prior approval from Natural Resources Wales. Wear highly visible clothing and a hard hat on 'live' sites	2	4	4	Before fieldwork check with Natural Resources Wales whether operations are	2	3	6	No

What are the hazards?	Who might be harmed?	How could they be harmed?	What are you already doing?	L	S	Risk (SxL)	Do you need to do anything else to manage this risk?	S	L	Risk (SxL)	Additional Action Required
							in progress at, or on way to, the field site(s).				
Moving onto and around sites											
Slips, trips and falls		Minor and major injuries	Wear appropriate footwear to the site; waterproof boots or, if the site is wetter, wellington boots. Take care when walking through areas where there is poor footing visibility. Take care walking through tussocky vegetation, where there are branches, tree stumps and 'brash' on the floor Look for signs nearby of structures that could present a trip hazard eg, partially collapsed fences. Takes care on wet and slippery surfaces (bare soil / rocks) – test before committing / starting to walk on it. Take care when carrying / moving equipment that a fall would not cause an avoidable injury – if you do start to fall, the priority is you not the equipment. Take several trips rather than fewer overloaded, but higher risk journeys.	5	3	12	Determine how to carry equipment safely before crossing 'uneven terrain';	4	2	8	No
Animals and plants											
Animal bites and stings	All field workers	Bite and sting wounds; Reaction to bites and stings	Keep a continual look out biting/stinging animals, avoid if possible. If you have a known allergy to stings take appropriate medication on site. Seek immediate expert help if bitten by venomous animal.	3	2	6					

What are the hazards?	Who might be harmed?	How could they be harmed?	What are you already doing?	L	S	Risk (SxL)	Do you need to do anything else to manage this risk?	S	L	Risk (SxL)	Additional Action Required
			If feeling unwell after a site visit seek medical attention.								
Ticks	All field workers	Lyme disease - Severe illness	Keep a continual look out for ticks. Wear long sleeved shirts and long trousers of a tightly woven material. Trousers should be tucked in. Check regularly for ticks and take care removing them. Carefully inspect clothes and skin for ticks after leaving the site. Be aware of causes and symptoms of Lyme's Disease. Monitor for symptoms of Lyme Disease if exposed to ticks.	2	3	6					
Plants – scratches, cuts and impact	All field workers	Scratches, rashes, cuts	Be vigil for plants with thorns etc. Avoid contact with poisonous plants. If known allergy to stings take appropriate medication on site. Wear long trousers and long-sleeved tops to limit scratches and irritation. If feeling unwell after a site visit seek medical attention Treat wounds to stop them becoming infected	3	2	6					
Contact with plant sap / chemicals	All field workers	Chemical 'burns'; sickness	Identify any hazardous plants on site before carrying out activity. Avoid hazardous plants if possible. Wear long sleeved tops and trousers when working close to hazardous plants. In case of an allergic reaction following accidental contact with plant sap, identify the plant and monitor casualty for shock. If condition of the casualty deteriorates, initial incident response plan and ensure that a sample	3	2	6					

What are the hazards?	Who might be harmed?	How could they be harmed?	What are you already doing?	L	S	Risk (SxL)	Do you need to do anything else to manage this risk?	S	L	Risk (SxL)	Additional Action Required
			of the plant accompanies the casualty to hospital to ensure correct diagnosis and treatment.								
			Working on peatlands								
Floating vegetation (possibly over water)	All field workers	Falling through / submersion, possibly resulting in getting stuck, exposure	Know which areas of the site are hazardous. Do not try to cross areas when in any doubt that they may support your weight. Wear appropriate clothing. Learn procedure on how to escape if stuck in peatland (don't struggle, lie flat). Take warm, dry clothes in case of accidental immersion as required.	3	3	9					
Deep mud, liquefied peat, etc.	All field workers	Strains, panic, getting stuck exposure	Know which areas of the site are hazardous and work cautiously as conditions can change over time and after storm events. Do not try to cross areas when in any doubt that they may support your weight. Wear appropriate clothing. Learn procedure on how to escape if stuck in peatland (don't struggle, lie flat). Take warm, dry clothes in case of accidental immersion as required.	3	3	9					
Plough lines-ridge and furrow	All field workers	Trip / fall hazard / personal injury	There are variable land forms, ditches and trip hazards that may be obscured from view by emerging vegetation. Wear sturdy footwear and take time and extra care walking through.	4	2	8					
Restored ditches on sites that might be obscured from view	All field workers	Falling in, exhaustion, exposure, drowning	Be aware of the location of the restored ditches on the site. These might become obscured by vegetation or become hidden by floating vegetation; they might contain standing water and liquified peat. Do not enter the ditch, cross the ditch only when essential and with care; using a stout / sturdy pole if necessary.	3	2	6					

What are the hazards?	Who might be harmed?	How could they be harmed?	What are you already doing?	L	S	Risk (SxL)	Do you need to do anything else to manage this risk?	S	L	Risk (SxL)	Additional Action Required
Tussocky Vegetation	All field workers	Trip / fall hazard / personal injury	Wear sturdy footwear and take time and extra care walking through this vegetation	4	2	8					
Contact with soil borne micro organisms	All field workers	Sickness	Water / wipes will be available on site to clean hands before eating, drinking etc. Any broken skin must be covered. Any cuts received during surveying must be treated promptly and covered to avoid infection.	2	2	4					
Fire											
Wildfire	All field workers	Burns, smoke inhalation	Maintain an awareness of the possibility of fire. In the event of fire, leave the site by the shortest route that avoids the fire. Check wind and fire direction. Liaise with on-site operators / contacts to get information and advice on the incident. Report any uncontrolled fire to the Fire and Rescue Services	3	3	9					
Personal hygiene											
Food borne illness	All field workers	Sickness; diarrhea and vomiting	Water / wipes will be available on site to clean hands before eating, drinking etc. Ensure any cuts are protected from contact with food	3	3	9					
Refreshments/ scalding from hot drinks	All field workers		Take extra when eating hot food and drinks in the field - cups etc. will be greater risk of them tipping over / spilling if placed down outside. There will also be a greater spill risk if you (your hands) are cold and you are tired. Don't overfill cups with hot drinks. Take extra care if consuming refreshments in a vehicle as restricted space will increase risk of spillage and potential to spill on passenger(s). Don't drink while in a moving vehicle.	2	3	6					

What are the hazards?	Who might be harmed?	How could they be harmed?	What are you already doing?	L	S	Risk (SxL)	Do you need to do anything else to manage this risk?	S	L	Risk (SxL)	Additional Action Required
Members of the public											
Anti-social behaviour / personal attack / other crime			Use your instincts to ensure your safety. Your priority is your own health and wellbeing. Do not worry about any equipment if you feel threatened / concerned, or in event of robbery. Do not engage with people exhibiting anti-social behavior on site. As soon as anti-social behaviour is identified fieldworker should re-group, assess the situation, and call-in the incident if at all concerned. If you don't feel safe stay / get back to a vehicle and exit the site if safe to do so.	2	3	6					
Dogs			Be wary of dogs off leads, unless the dog is known to you. Disinfect any bites and seek medical attention.	2	2	4					

Document / Review Control

Reviewer	Affiliation	Date
Jonathan Walker	Swansea University	30/04/2024

Activity Risk Assessment			
This is a generic assessment of hazards – their likelihood and severity from undertaking field research at the Lost Peatlands Castell Nos Site. Individual researchers are required to undertake a personalized assessment.			
College/ PSU	FSE	Assessment Date	30/04/2024
Location	Castell Nos	Assessor	Imogen Cockwell (IC)
Activity	Aquatic invertebrate sampling	Review Date (if applicable)	
Associated documents	1. Site Risk Assessment 2. Dynamic Risk Assessment 3. Emergency plan, including a site map		

Part 1: Risk Assessment

What are the hazards?	Who might be harmed?	How could they be harmed?	What are you already doing?	L	S	Risk (SxL)	Do you need to do anything else to manage this risk?	L	S	Risk (SxL)	Additional Action Required
General manual handling – carrying survey equipment and samples	IC	Personal injury	Plan in advance any lifting of heavy or awkward items. Designate someone to load and unload tools, heavy items to be carried by two people the number of items one person carries will be limited, special care to be taken when lifting / moving long items that might / could hit surrounding people.	3	3	9					
Sample / survey markers and canes	IC and assistant	Personal injury when bending down;	Make yourself aware of location of canes and plot markers / flags within research plots; before bending down, scan immediate vicinity as from above canes might not be very visible from directly above.	3	3	9					

What are the hazards?	Who might be harmed?	How could they be harmed?	What are you already doing?	L	S	Risk (SxL)	Do you need to do anything else to manage this risk?	L	S	Risk (SxL)	Additional Action Required
Equipment	IC and assistant	Personal injury, cuts	Check equipment before going to site to ensure no broken or sharp plastic. Broken equipment to be removed.	3	2	6					
Dip netting in small pools created by peatland restoration actions	IC	Personal injury, fall due to loss of balance	Avoid leaning too far with nets. Be aware of length of pole. Do not get too close to edge of pools. Wear appropriate sturdy footwear. Take a change of clothes in case of accidental immersion.	2	3	6					
Sampling a larger water body	IC	Falling in, personal injury, drowning	Never lone working so always having a person to help in case of falling in water. Avoid leaning too far over water. Do not get too close to the edge. Wear sturdy footwear. Carry a throwline in event of a fall-in. Take a change of clothes in case of accidental immersion.	2	2	4					
Sweep netting	IC	Personal injury, trip hazard	Wear study footwear. Take time and care when walking along transects. Ditches and trip hazards may be obscured from view by vegetation.	2	3	6					
Ethanol	IC and assistant	Health risk, contamination of environment	5% solution to be prepared into plastics containers prior to sampling. Take care when handling. Avoid ingestion or inhalation	3	1	3					
Animals and plants	Wildlife	Disturbance of protected species	Design methods to minimize disturbance. Reduce noise levels. Be aware of the presence of protected species	1	2	2					

		Consequences				
		1 Insignificant No injuries/ minimal financial loss	**2 Minor** First aid treatment/ medium financial loss	**3 Moderate** Medical treatment/high financial loss	**4 Major** Hospitalised/ large financial loss	**5 Catastrophic** Death/ Massive Finanical Loss
Likelihood	**5 Almost Certain** Often occurs/ once a week	5 Moderate	10 High	15 High	20 Catastrophic	25 Catastrophic
	4 Likely Could easily happen/ once a week	4 Moderate	8 Moderate	12 High	16 Catastrophic	20 Catastrophic
	3 Possible Could happen/ happen once a year	3 Low	6 Moderate	9 Moderate	12 High	15 High
	2 Unlikely Hasn't' yet happened but could happen	2 Low	4 Moderate	6 Moderate	8 High	10 High
	1 Rare Concievable but 1/100 year event	1 Low	2 Low	3 Low	4 Moderate	5 Moderate

Risk Assessment for Teaching, Administration and Research Activities
Swansea University; College of Science

Name Imogen Cockwell..........................**Signature**...[redacted]... **date** 23/04/2024

Supervisor* Dr Wendy Harris.............................**Signature** [redacted] .... **date** 23/04/2024

Activity title The role of spatial scale in structuring peat bog invertebrate communities................
Base location (room no.): Margam lab 105
(* the supervisor for all HEFCW funded academic and non-academic staff is the HOC)

University Activity Serial # (enter Employee No. or STUREC No. [redacted] ....
Start date of activity (cannot predate signature dates) 01/05/2024..
End date of activity (or 'on going') 30/09/2024..

Level of worker (delete as applicable)..

PG

Approval obtained for Gene Manipulation Safety Assessment by SU ? not applicable
Licence(s) obtained under "Animals (Scientific Procedures) Act (1986)" ? not applicable
Approval obtained for use of radioisotopes by COS ? not applicable

Record of specialist training undertaken

Course	date

Summary of protocols used; protocol sheets to be appended plus COSHH details for chemicals of category A or B with high or medium exposure

Protocol Details						Protocol Details					
#	Assessment					#	Assessment				
	1st date	Frequency of re-assessment	Hazard category	Secondary containment level	Exposure potential		1st date	Frequency of re- assessment	Hazard category	Secondary containment level	Exposure potential
1	01/05/2024	N/A	C	OB	3	11					
2						12					
3						13					
4						14					
5						15					
6						16					
7						17					
8						18					
9						19					
10						20					

See notes in handbook for help in filling in form **(Continue on another sheet if necessary)**

Bioscience and Geography Protocol Risk Assessment Form

(Expand or contract fields, or append additional sheets as required; insert NA if not applicable)

Protocol # 1	**Title: Preserving invertebrates**
Associated Protocols #..........................	**Description: Invertebrates collected from the field will be stored in 70% ethanol solution then identified in the lab.**

Location:

circle which Bioscience and Geography Local Rules apply –

Laboratory

Identify here risks and control measures for work in this environment, additional to Local Rules

N/A

Chemicals	Quantity	Hazards	Category (A,B,C,D)*	Exp Scor
70% ethanol	1 L	Flammable liquid Serious eye damage/eye irritation	C	3

Hazard Category (known or potential)
- **A** (e.g. carcinogen/teratogen/mutagen)
- **B** (e.g. v.toxic/toxic/explosive/pyrophoric)
- **C** (e.g. harmful/irritant/corrosive/high flammable/oxidising)
- **D** (e.g. non classified)

Exposure Potential Circle the **highest Exposure Score** above. Use this to calculate the exposure potential for the entire protocol (see handbook). Indicate this value below.

Low

Primary containment (of product):- glass jar

Storage conditions and maximum duration :- room temp. up to 5 months

Secondary containment (of protocol) open bench

Disposal SU chemical disposal

Identify other control measures – protective gloves and goggles

Justification and controls for any work outside normal hours N/A

Emergency procedures Exposure to skin/eyes: wash with soap and water, go to eye wash station. Spill: clean using chemical spill kit and dispose of contaminated material

Supervision/training for worker (circle)

None required

Declaration I declare that I have assessed the hazards and risks associated with my work and will take appropriate measures to decrease these risks, as far as possible eliminating them, and will monitor the effectiveness of these risk control measures.

Name & signature of worker Imogen Cockwell [redacted]

Name & counter-signature of supervisor. Dr Wendy Harris... [redacted] *Date*.....23/04/2024........

Date of first reassessment   Frequency of reassessments