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University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

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School of
Biological, Earth and
Environmental Sciences

Urban Trees & Biodiversity in Cork City

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Declaration

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism and intellectual property.

1 Abstract

Biodiversity is poorly quantified in urban landscapes and is not effectively incorporated into urban planning and policymaking. Land-use change (e.g., urbanisation) is one of the key drivers of biodiversity loss. Furthermore, urbanisation is expected to increase from 50 to 70% by 2050. The CSO reported a 0.6% decrease of residents living in highly rural areas of Ireland (2011-2016), including a 5.5% increase in residents living in independent urban towns. Urban trees have a broad range of ecosystem services; it is likely that many of these services will become increasingly important due to climate change pressures (e.g., changing climatic conditions, extreme natural occurrences). This thesis examines the role of urban trees/green spaces in supporting the biodiversity of other taxa (lichens, invertebrates, birds, and ground vegetation) in Cork city. There was a total of 102 individual trees studied across 6 Cork city sites, including the UCC arboretum (n=26); Cork city Marina (n=12); the Atlantic Pond (n=17); Kennedy Park (n=11); The Lee Fields (n=18); Fitzgerald's Park (n=18). A full survey of all 4 taxa was conducted per tree, including the use of sticky traps for invertebrates; quadrat sampling for both vegetation and lichens; and observational point-counts for birds. There were no significant differences/associations between the species richness of the various taxa and the species of tree. This could be due to a limited number of replicate trees, which can be expected with an observational-based approach. However, community-level analyses have shown significant variations in the taxa communities among the 6 sites ($p<0.001$ for all taxa). These data suggest that the type of urban site is significantly associated with biotic community composition. Additionally, the research investigates the relationship that microclimate (light intensity and temperature) and canopy openness have with urban tree species. Microclimate data loggers were deployed at the base of all trees for each experiment and hemispherical canopy images were taken to determine canopy openness in Fitzgerald's Park. In general, there were no, or little associations found between microclimate data, canopy openness and biodiversity. Thus, the assessment of the hypothesis that microclimate conditions impact taxa communities was inconclusive. Overall, the study supported the hypothesis that urban trees and green spaces support a large variety of individuals from other taxa and provides a baseline for biodiversity in Cork city, specifically regarding future studies and urban planning.

2 Introduction

2.1 Urbanisation & Biodiversity Loss

Land-use changes have corresponded to increased biodiversity loss in the Anthropocene (Moreno *et al.,* 2017). Urban expansion has replaced or fragmented many natural landscapes and has been identified as one of the lead causes of land-use changes globally (IPBES Report, 2019). This assessment by the IPBES estimated 1 million species out of approximately 10 million globally that have threatened ecosystems (Baw *et al.,* 2020). Where natural vegetation is lost to urbanisation, the entire ecosystem function and structure is altered. Ecosystem resilience is decreased because of habitat fragmentation; this can be due to decreased shelter and depletion of resources for various taxa, for example (European Environment Agency, 2023). Fragmentation ultimately acts by decreasing carbon sequestration, productivity, and climate regulation by plants (Xiao *et al.,* 2020). The IPBES' 2019 report outlines several solutions to be implemented to improve urban areas and ecosystems, including increasing the number of green spaces, increasing ecological connectivity, and sustainable production/consumption.

The Central Statistics Office have reported a 2.6% decrease of grassland in Ireland between 1990 and 2018. Forest cover increased by 4.1% between these years in Ireland; however, Ireland was reported to have the second lowest forest cover among the EU member states in 2016 (Central Statistics Office, 2019). While many studies focus on the preservation of pre-existing natural ecosystems, researchers have begun to study urban green spaces to assess the types of ecosystems that urban settings can support, and the strategies which can be implemented to increase biodiversity (Moreno *et al.,* 2017). IPBES' 2019 also reports that 85% of Irish habitats are in inadequate condition, and 46% of habitats are in continuous decline. This is exemplified by the co-occurring biodiversity loss evident in Ireland; for example, the All-Ireland Pollinator Plan estimates that one third of bee species are currently under threat of extinction in Ireland (National Biodiversity Data Centre, 2017).

The Convention on Biological Diversity insists that maintaining biodiversity should be prioritised on a global scale (Zhang and Jim, 2014). Biodiversity loss will impact ecosystem functioning/performance due to the strong positive correlation between them (Taylor *et al.,* 2014). Some prominent concerns have arisen in social policy

relating to the effects of biodiversity loss on the continued functioning of ecosystem services, for human benefit (Duffy, 2009). The effects of biodiversity on ecosystem services are well-established, with ecosystem services including pollination, climate regulation, and the control of agricultural disease (Naeem *et al.,* 2016). Ecosystem services are defined as 'a complex of living organisms and the abiotic environment with which they interact in a specified location' by the Convention of Biological Diversity (1992) (UNECE, 2023). Humans can benefit from ecosystem services via noise reduction, water purification, medicines, food production, and the mitigation of the 'urban heat island' effect. Ultimately, they provide security for the effects of climate change (Díaz *et al*., 2006).

Cities currently occupy approximately 2% of the earth's surface and there is an increased number of rural residents migrating to these urban settings each year (Gago *et al.,* 2013). More than 50% of the world's population currently live in urban settings (Moreno *et al.,* 2017), with this figure being expected to increase to 70% by the year 2050 (Fontana *et al.,* 2011). The Central Statistics Office reported a 0.6% decrease of residents living in highly rural areas of Ireland (between 2011 and 2016). This includes a 5.5% increase in residents living in independent urban towns (Central Statistics Office, 2019).

Recent studies have begun to focus on the enhancement of biodiversity in urban environments for the benefit of both humans and biodiversity. Urban green spaces have been shown to harbour high biodiversity levels for certain species, particularly in parks heavily populated by trees (Zhang and Jim, 2014). They provide a habitat for many species, influence microclimate and aid in the regulation of hydrology (Taylor *et al.,* 2014). The broad definition of urban green space is an open space with vegetation in an urban area (Lee *et al.,* 2015). This can broadly include parks, churchyards, university campuses, cemeteries, hedgerows, and more. It is even common for many moderately urbanised areas to harbour a higher level of species richness than rural settings (Fontana *et al*., 2011). Presently, however, urban sustainability strategies are largely concerned with man-made aspects of the urban setting; there is less emphasis on biodiversity and urban green spaces (Sandifer *et al.,* 2015). However, the heterogeneity and abundance of urban habitats, green infrastructure, and correct ecosystem governance can contribute to biodiversity increase efforts (Baw *et al.,* 2020; Prather *et al.,* 2018). Additionally, there are

recreational, economic, and human health benefits linked to urban green spaces. Urban green spaces provide an opportunity for public engagement with nature, which can aid in the development of scientifically informed members of the public. This can ultimately lead to an increased number of citizens capable of making informed decisions regarding biodiversity and climate policies.

Cork City is the second largest city in Ireland and policies have been drawn up for the 'Cork city Heritage and Biodiversity Plan 2021-2026'. This aims to increase awareness, knowledge, and appreciation of the biodiversity and heritage of Cork city. The previous Cork City Development Plan (2015-2021) and the Cork City Heritage Plan (2015-2020) had outlined the insufficient habitat and species data which was necessary for ongoing monitoring in Cork city. This research study aims to address some of these issues by surveying bird, lichen, vegetation, and invertebrate diversity in Cork City across a range of different urban green spaces. These include urban parks, streets, and the University College Cork campus in the city. This study will generate current data for biodiversity across different urban habitats. This data could further influence the policies set in place for the 'Cork City Heritage and Biodiversity Plan' and aid the protection of biodiversity in Cork city. This data could also inform policies set out by 'Ireland's 4th Biodiversity Action Plan 2023'; for example, aiding the achievement of their objective to 'enhance the evidence base for Action on Biodiversity'. This study will enhance the evidence base by demonstrating the biodiversity present in Ireland's second largest city.

2.2 Biodiversity & Human Well-Being

With increased necessity to develop a more sustainable society, there is a greater need to investigate the link between biodiversity and well-being (Naeem *et al.,* 2016). However, there is a lack of information relating to the direct link between human health and biodiversity (Sandifer *et al.,* 2015). Recent studies have shown that human health and well-being is strongly correlated to exposure to nature (Naeem *et al.,* 2016). The main features that should be focused on in urban design which have been shown to impact human well-being include walkable space, community space, and green spaces (Taylor *et al.,* 2014). Natural components and biodiversity in urban areas are particularly overlooked by urban planners and government bodies when considering human wellbeing, treating them in isolation of each other (Taylor *et al.,* 2014).

A study by Barboza *et al.,* 2021 investigated the number of natural deaths that could potentially be avoided by increasing the access and presence of green spaces in European urban settings (going by the World Health Organisation's recommendations of green space access). They deduced that by meeting the WHO standard for green spaces, 42,968 deaths could be circumvented globally per annum (Barboza *et al.,* 2021). A review by Sandifer *et al.* (2015) concluded that the link between biodiversity and ecosystem services is significant enough to consider human health as reliant on biodiversity as well as ecosystem services. This is consistent with the results of Dean *et al*. (2011) which concluded that contact with biodiversity directly improves the human quality of life.

Research conducted by Barton and Rogerson (2017) has shown that sensory, perceptual, and immunological responses are linked to the positive relationship between human well-being and green spaces. Additionally, they stated that this is aided by increased air quality, physical activity, and social factors.

2.3 Urban Heat Island Effect & Microclimates

Cities are characterized by a greater relative surface air temperature than rural areas due to the 'urban heat island' effect (UHI) (Merckx and van Dyck, 2019). The UHI effect is a result of several factors including solar radiation, limited vegetation, heat-absorbance or trapping due to urban geometry, and human activities (Gago *et al.*, 2013). This leads to increased temperatures, particularly during the night (Diamond *et al*., 2015). For example, the temperature in Amsterdam during a heatwave in 2006 was 7-9-degree Celsius higher than the maximum temperature in rural areas (Chapman *et al.,* 2017). Dealing with the issue of the UHI effect is critical due to the expected effect it will have on many cities in a short period of time. This is exemplified by the prediction that CO2 emissions will quintuple in London by 2050 due to the formation of UHIs (Gago *et al*., 2013). However, the UHI effect is often localised and dependent on wind, cloud coverage and proximity to the sea (IPCC, 2022).

Cities which lack water bodies and vegetation have a higher prevalence of the UHI effect, as these factors both strongly contribute to local cooling (IPCC, 2022). Urbanization drives changes in microclimate conditions with several studies showing that trees aid microclimate regulation and thermal comfort (Wang *et al.,* 2015).

Wang *et al.* (2015) suggested that urban temperature on a local scale is affected by three main factors: green spaces, buildings, and pavements. The cooling effect of urban parks has been noted globally and they are often known as park cool islands (PCI) (Konarska *et al.,* 2016). Urban parks can have a cooling effect of up to 7 degrees Celsius in the evening, in hot or dry climates (Konarska *et al.,* 2016). Taha (1997) determined that the increased presence of vegetation in urban areas leads to an increase in evapotranspiration, creating areas which are 2-8 degrees Celsius cooler than the surrounding areas in the urban setting. A reduced level of green spaces leads to a decrease in evapotranspiration and latent heat flux (Chapman *et al*., 2017).

Previous studies have highlighted that there is a higher day time cooling effect in parks which have more tree cover in comparison to those which have mainly vegetative cover (Konarska *et al.,* 2016). It is known that canopy gap sizes impact ecosystem dynamics in natural forests and are also known to influence microclimates and act as plant growth hot spots (Bagaram *et al*., 2018). There are not currently many studies relating to the impact of gap size in urban settings. However, Konarska *et al*. (2016) showed that single trees are more limited in their cooling ability but still aid thermal comfort. The inclusion of a significant level of vegetation in the urban make-up can counterbalance the UHI effects (IPCC, 2022).

Various studies have disagreed on the predicted effects that climate change will have on the UHI effect itself. However, increasing urbanisation will expand the UHI areas, which will increase future warming in many locations. Additionally, longer and more severe heatwaves caused by climate change will impact cities' inhabitants and biodiversity strongly (IPCC, 2022). Ultimately, the additional temperature increases from the UHI effect will exacerbate the impacts of climate change.

2.4 Lichens & Epiphytes

Epiphytes are plants which grow on host plants (predominantly trees) for structural support, as opposed to deriving their nutrients and water from them (Bhatt *et al*., 2015). They do not operate the same stomatal system for obtaining water as other plants; they acquire water directly from the atmosphere and from rain (hence, they have high atmospheric and microclimate sensitivity) (Koch *et al*., 2019).

Epiphytes provide many species with food such as nectar, water, a habitat, and materials used for nesting (Prather *et al.,* 2018). This correlates to the results of a study by Diaz *et al*. (2012), which showed increased overall species richness on trees with epiphytes in comparison to trees which had none. Hence, they act as a good indicator of biodiversity and can aid the early detection of ecosystem degradation; they are a crucial consideration in the conservation of biodiversity in urban settings (Prather *et al.,* 2018).

Lichens are considered a symbiosis between fungi and alga (specifically Cyanobacterieae or Chlorophyceae) and are commonly epiphytic. Epiphytic lichens are good indicators of air quality, climate change and the UHI effect (Koch *et al.,* 2019). Thus, lichen populations and community structure vary in different levels of urbanization (Prather *et al.,* 2018). Lichens are notably sensitive to pollution, with sulphur and nitrogen oxides causing the most damage (Lättman *et al*. 2014). These pollutants are most likely to alter lichen communities and can subsequently, impact the ecological services of epiphytic lichens (Bhatt *et al.,* 2015). For example, nitrogen pollution is a major issue for human and ecosystem health. In many environments, nitrogen has a limiting effect on plant productivity and vegetation structure (due to various plant responses to nitrogen) (Delves *et al.,* 2023). Previously, lichens were commonly used as bioindicators of sulphur dioxide; however, in recent years the most prominent pollutants in Europe have shifted towards Nitrogen Oxides and Ammonia (Munzi *et al*., 2014).

Bioindicators are a group of organisms or a living entity which signal the qualitative status of the environment (Asif *et al.,* 2018). Lichens are the most studied bioindicator, with studies dating as far back as 1866 (Conti and Cecchetti, 2001). This is due to their specific morphology, physiology, and anatomy (Asif *et al*, 2018). Firstly, they can be used as bioindicators by mapping all the species present in a specific study area. Secondly, they can be individually sampled to measure pollutants, or by measuring morphological changes when exposed to different environments (Conti and Cecchetti, 2001). The individual species as well as the lichen growth type can vary in terms of their tolerance to pollutants. For example, crustose lichens are more tolerant of nitrogen pollution than fruticose or foliose growth types. A more specific example is the high tolerance of the genus Usnea

(fructicose lichens) towards sulphur dioxide i.e., Usnea lichens are indicative of high sulphur dioxide pollution (Askham, 2020).

Among the roles of the lichen community are nitrogen fixation, nutrient cycling, and providing food, camouflage, or shelter (Will-Wolf *et al.,* 2002). The associations between invertebrates and lichen are varied, however, the most frequent mimics of lichens are the Lepidoptera, with greater than 30 European moth species mimicking or eating lichens (Lenka Mulligan, 2009). However, despite this strong association between lichens and biodiversity, it has been demonstrated that the lichen biota of trees will deplete over time if exposed to high levels of urbanisation (Lättman *et al*. 2014).

Various studies have addressed the abundance, diversity, and distribution of lichens in Irish woodlands (Coppins and Coppins, 2002). There is potential, however, for the development of more insights in relation to lichen communities in urban Irish settings.

2.5 Birds & Urbanisation

Birds are also sensitive to environmental changes and act as a good indicators of habitat alterations (Xu e*t al.,* 2018). They are often considered the optimal model group to study the ecological effects of urbanisation (Fontana *et al.,* 2011). Small arboreal insectivore populations are usually the most affected by the increase of urbanization (Helden *et al.,* 2012). Birds are largely threatened due to habitat loss or fragmentation because of urbanization (Myczko *et al.,* 2014). This can impact non-native species' breeding success, reduced levels of dispersal and a reduction in their ability to acquire food and resources (Xu e*t al.,* 2018).

A study conducted by Fontana *et al*. (2011) in three Swiss cities demonstrated that there's a negative impact on bird biodiversity and species richness when there is a higher number of buildings and areas which are closed in. There was an increased level of biodiversity and richness in areas with more vegetation in all three cities (Fontana *et al.,* 2011). From this study, it was predicted that 6 species could be added to the species richness of the study sites with the addition of coniferous trees to the woody deciduous population; showing a 43% increase in species richness (Fontana *et al.,* 2011).

With an estimated 12% of bird species being under the threat of extinction, there is an increasing level of concern for the conservation of bird biodiversity (Xu e*t al.,* 2018). Generally, increased urbanization leads to a decrease of species richness and alterations to the structure of the bird community, when compared to natural environments (Xu e*t al.,* 2018). The conservation statuses of 211 bird species in Ireland were assessed by BirdWatch Ireland and all species' conservation statuses were determined for the years 2020-2026. According to this survey, 26% of bird species are of high conservation concern (Red-List) and 37% are of medium conservation concern (Amber-List) (Birdwatch Ireland, 2020).

It could also be argued that in some cases, human influence in urban habitats can be beneficial to the maintenance of biodiversity. For example, bird-feeding in cities is common and has an impact on urban bird populations (Jones and Reynolds, 2008). Additionally, preferences of aesthetically pleasing tree species in urban green spaces can benefit pollinating insects and can act as food sources for birds during the winter months.

A recent study conducted in Cork city, Ireland by Lambert (2019) suggests that green spaces were the main drivers of increasing bird species richness and abundance in the city, having significantly more impact than blue spaces. Forty percent of the birds listed in this study were listed as species of conservation concern, five of which were Red List species. This study demonstrated that urban spaces in Cork city can harbour many species which are vulnerable, suggesting a need for the implementation of novel conservation strategies for urban biodiversity in Cork city.

2.6 Invertebrates & Urbanisation

Urbanization is strongly linked to and represents a large proportion of the cause of insect population decline, with studies highlighting that species richness and abundance varies with different levels of urbanization (Baldock *et al.,* 2016). The direct impacts of urbanization include pollution and physical extermination. The indirect impacts involve unstable food resources, as well as the fragmentation and decreased quality of habitats (Eremeeva and Sushchev, 2005). According to the National Biodiversity Data Centre, only 1051 (out of a total 11,500 species in Ireland) have had their conservation status assessed. It was determined that 26% of

species are regionally extinct, with 194 species in decline (and a further 13% of these are threatened). Providing resources for invertebrates (e.g., native host plants and nectar plants) and urban green planning can aid the mitigation of invertebrate biodiversity loss (Merckx and van Dyck, 2019).

Fragmentation of habitats induces biodiversity loss and biotic homogenization; whereby regional biotas develop more similarities over time (Merckx and van Dyck, 2019). Changes in the quality of a habitat relate to the quality of the host plant, soil quality, microclimate, or predator attack (Connor *et al.,* 2002). Generalist invertebrate species are more likely to be favoured by homogenization due to a decrease in resources within urban environments (Merckx and van Dyck, 2019). It is also predicted that thermophilic species will be favoured by the UHI effect, which has already been exhibited by beetle species (Merckx and van Dyck, 2019). Merckx and van Dyck (2019) has also demonstrated that Lepidoptera species richness depletes with increased urbanization, which was amplified by the decline of specialist and non-thermophilic species.

Urbanization can diminish breeding sites and resources needed by pollinating insects, such as nectar and pollen (Somme *et al.,* 2016). Gardens and urban green spaces provide alternate levels of floral resources than that of a natural environment (Somme *et al.,* 2016). Short blooming periods in urban settings could lead to an inadequate nutritional intake for pollinating species, due to a decrease in floral resource availability or quality (Somme *et al.,* 2016). It is generally acknowledged that native tree species are higher in biodiversity value in comparison to non-native tree species (Helden *et al.,* 2012). Particularly in urban parks, it is well-documented that the introduction of non-native species can hinder the invertebrate biodiversity capacity of the green space (Mata *et al.,* 2021). However, while some exotic plant species provide no floral resources, others garner a larger abundance of floral resources than native species, increasing nutritional intake of pollinating insects (Somme *et al.,* 2016). Although urban trees and urban green spaces are crucial for insect biodiversity, areas with only canopy and green space will not harbour as much insect biodiversity as those which are multi-layered (Mata *et al.,* 2021).

It has also been reported that there is a relatively high measure of insect biodiversity in some cities such as London and Rome (Zanette *et al.,* 2005). Stress is common in urban trees (i.e., water stress, pesticides, soil compaction, temperature imbalance and

air pollution) and these stresses can instigate and increase plant susceptibility to insect attack (Connor *et al*., 2002). Connor *et al.* (2022) suggests that it is for this reason that there is an increased number of some herbivorous insects in urban settings in comparison to more rural settings, in addition to a decreased level of predation. Additionally, urban environments also have the potential to harbour an abundance of insect pollinators which can be accredited to the efficient foraging environments that they provide for generalist species (Somme *et al.,* 2016). Thermal tolerance is one of the most pronounced traits shared and adopted by insects when their habitats are subjected to urbanization, which could also be a cause of high insect abundance in some urban areas (Diamond *et al*., 2015).

2.7 Hypotheses

- Urban trees in Cork city support a diverse and abundant variety of species from multiple different taxa.
- Taxa communities differ among urban sites in Cork city (urban parks, university campus, street trees).
- Taxa communities differ among various tree species in Cork city.
- Microclimate conditions (temperature and light intensity) of the trees in Cork city impacts the taxa communities supported by those urban trees.

3 Methods

3.1 Study Area & Overview of Experiments



Figure 1. The blue pin represented the location of the research study: Cork City, Ireland (GoogleMyMaps)

This study was based in Cork city, Ireland. A total of 102 trees (n=102) were surveyed in the city to assess the levels of biodiversity present. This included 29 different tree species in total. An initial visit to each of the chosen sites was conducted. This visit ensured that there were enough trees which were both accessible for deployment of equipment, as well as to assess whether they would be vulnerable to public interference. It was highly important to choose trees which would not be interfered with, once the equipment was in place (e.g., data loggers and sticky traps).

The first experiment for each site involves surveys of 4 taxa and deployment of data loggers for trees which have greater than one individual per species. This aimed to examine the recorded data across multiple replicates of the same tree species. There was an additional experiment conducted per site which involved surveys and data logger deployment for each tree, with only one individual per tree species. Although

it is more beneficial to assess the data cross replicates, this experiment was initially conducted with the intention of examining the microclimate data cross multiple species on the same day. Thus, due to the limited number of data loggers, the experiments were conducted with one sample per species. However, the survey data collected for the 4 taxa (invertebrates, lichens, birds, and vegetation) is beneficial as biotic community data.

The first site was the University College Cork (UCC) arboretum. All surveyed trees were located between the Main Campus, Mardyke Walk and Distillery Fields campus (figure 5). There was a total of 27 trees surveyed in UCC (n=27), with 15 tree species in total.

Table 1. The experimental design of the UCC arboretum experiment.

UCC Arboretum Experiments	**Number of Tree Species**	**Number of Individuals per Species**	**Samples (n)**
A	4	3	12
B	4	2	8
C	7	1	7

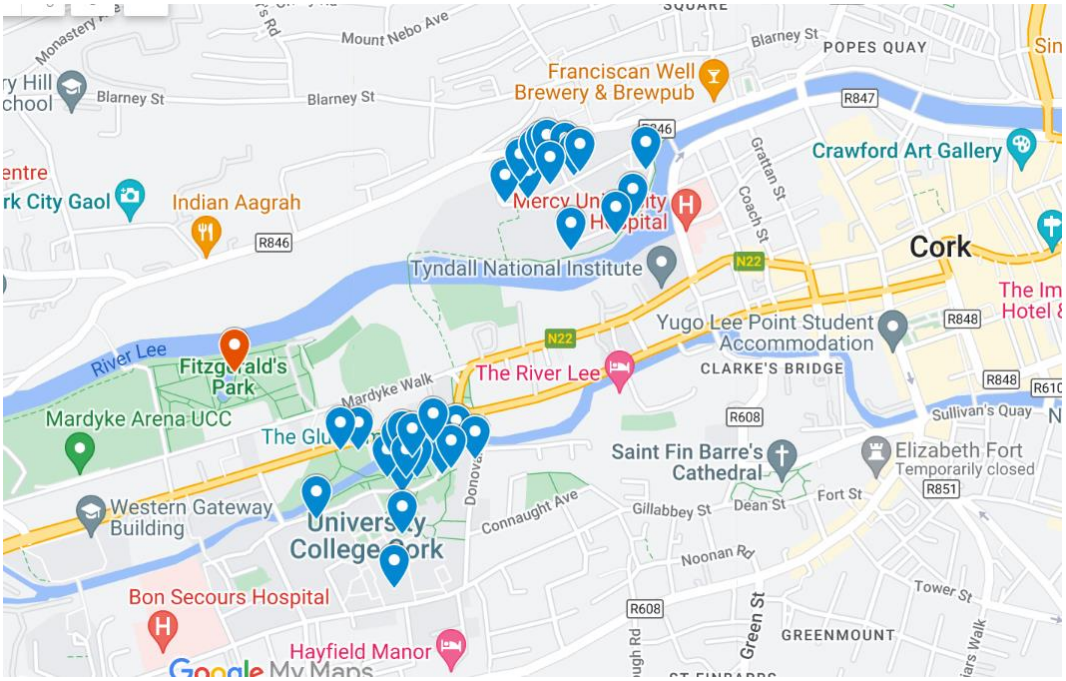


Figure 2. The blue pins represent each individual tree surveyed on the UCC campus (GoogleMyMaps)

The second experiment assessed street trees in a particularly urbanized area of the city. The locations of each tree are all within the Marina area of Cork city (figure 6). This area is characterised by areas of industrial and commercial activity, as well as new parkland and recreational areas. It is anticipated that the area will be redeveloped for residential use in the next two decades. Sites were chosen which were urbanized, yet it was important to choose sites that would not be too exposed to the public (to avoid the potential of experimental equipment being tampered with). There was a total of 12 trees surveyed in this area (n=12), with 8 tree species in total.

Table 2. Experimental design of the Marina area street tree experiments.

Marina Street Tree Experiments	**Number of Tree Species**	**Number of Individuals per Species**	**Samples (n)**
A	4	2	8
B	4	1	4

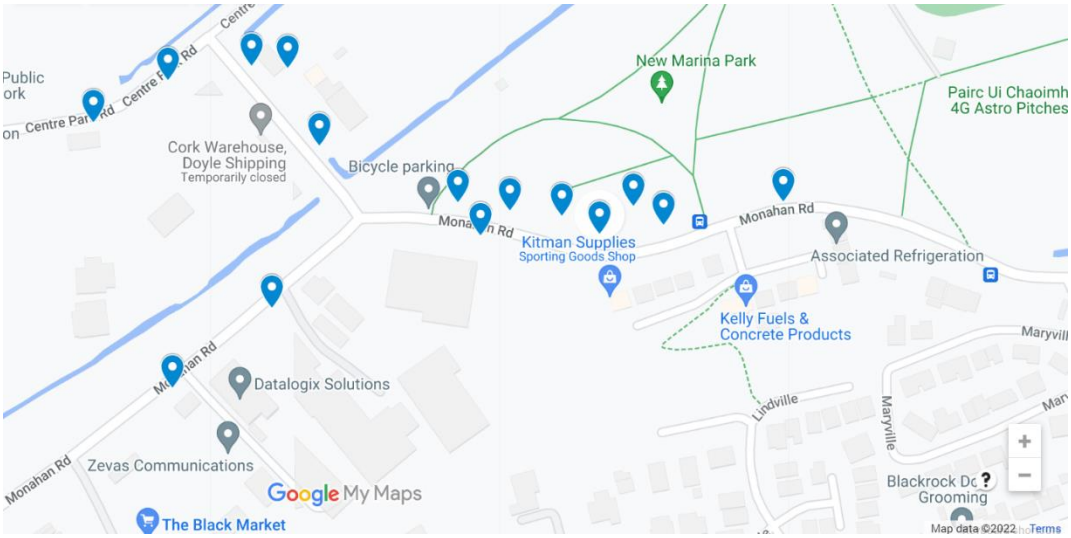


Figure 3. The blue pins represent the locations of all 'street trees' surveyed in the Marina area of Cork city (GoogleMyMaps).

The third experiment assessed urban parks, with four study areas including: Fitzgerald's Park, the Atlantic Pond, The Lee Fields, and Kennedy Park. These parks were in areas of varying urbanization around Cork city. There was a total of 64 (n=64) individual trees surveyed among the 4 parks, with 37 tree species.

Table 3. Experimental design of the four urban park experiments.

Urban Park Experiments	Number of Tree Species	Number of Individuals per Species	Samples (n)
The Atlantic Pond A	4	3	12
The Atlantic Pond B	5	1	5
Kennedy Park A	3	2	6
Kennedy Park B	5	1	5
The Lee Fields A	4	3	12
The Lee Fields B	6	1	6
Fitzgerald's Park A	4	3	12
Fitzgerald's Park B	6	1	6

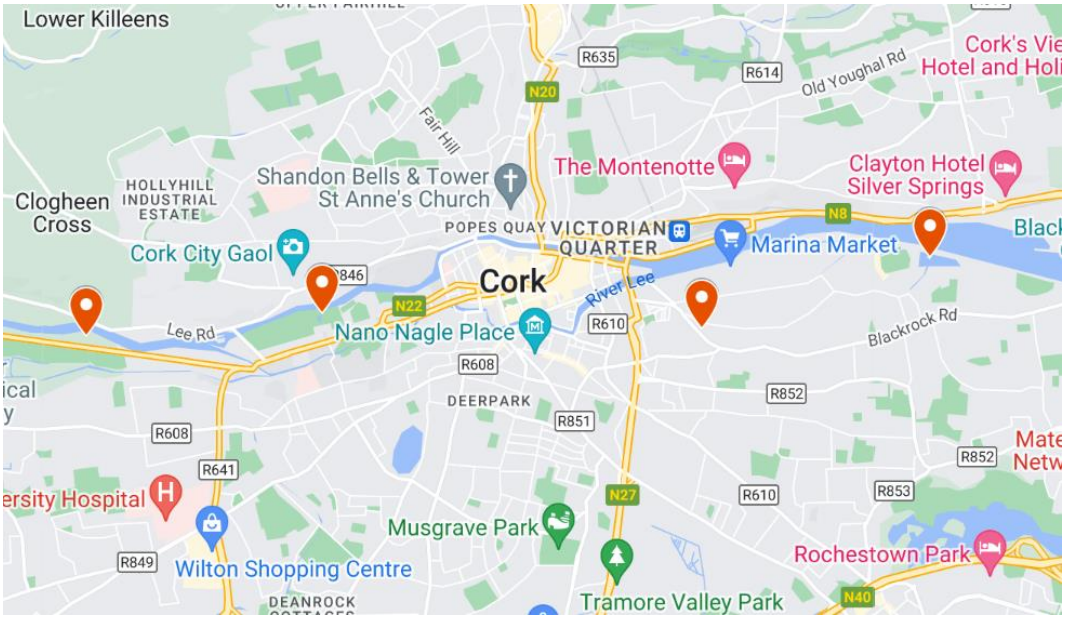


Figure 4. The red pins represent all 4 urban parks/green spaces surveyed in Cork city (GoogleMyMaps).

Table 4. An overview of the sample size and number of tree species surveyed per location.

Site Number	Location	Samples (n)	Number of tree species
1	UCC Arboretum	27	15
2	Marina Area Street Trees	12	8
3	The Atlantic Pond	17	9
4	Kennedy Park	11	8
5	The Lee Fields	18	10
6	Fitzgerald's Park	18	10

3.2 Taxa Surveys

There were 102 trees (n=102) surveyed during the research period. A survey of invertebrates, birds, lichens, and ground vegetation were undertaken for each of the 102 trees at all sites. The following methods were used for every single sample and experiment.

3.2.1 *Invertebrates*

Sticky traps (22x10cm) were deployed at each site to estimate the total number of invertebrates, which were identified by their order. The sticky traps were pinned to each tree (on the North side) using a piece of string, through a hole at the top of each sheet. All sticky traps were left at each site for 4 consecutive days during periods of standardised meteorological conditions, as best as possible. On day 4, all invertebrates were identified by their Order, and the total number of individuals counted. Photographs were taken of any unknown invertebrates for identification purposes. All invertebrates were identified to the level of their Orders using the 'Insects of Ireland: A Field Guide' (McCormack *et al.,* 2012).

Pit-fall traps were initially used as an additional method of assessing invertebrate abundance. These pit-fall traps were deployed at each site using a small trowel to dig a hole into the ground near the base of the tree. A small pot was then placed into the hole securely with some ethanol in the base to trap the invertebrates. However, these pit-fall traps were discarded following the initial experiment. This was largely due to the urban environment, with many trees being planted near to concrete, for example. Additionally, the weather and public interference acted as a major constraint for this part of the experiment. Thus, all invertebrate abundance data was gathered using the sticky traps alone in this research paper.



Figure 5. A sticky trap deployed on a Common Beech tree (*Fagus sylvatica*) in the UCC arboretum. This sticky trap yielded only invertebrates of the order Diptera. Photo: Caoimhe Marron, 2022.

3.2.2 *Birds*

Bird surveys were conducted at each site using point-counts, which involved a 5-minute observation period at each tree. This involves a tally of all bird species detected by sight over the specified time-period. These point-counts were conducted in a single visit per tree. These observation periods were undertaken 2 to 4-hours after sunrise. All birds within a 50 m radius from the tree were recorded and identified visually. Birds were identified using the 3rd edition of 'Collins Bird Guide – The Most Complete Guide to the Birds of Britain and Europe' (Svensson *et al.*, 2009).

3.2.3 *Lichens*

Lichens were surveyed following the 'European Guideline for Mapping Lichen diversity as an Indicator of Environmental Stress' (Asta *et al.*, 2002). A standard quadrat frame of 10x50 cm was used, which was divided into five 10x10 cm squares. This quadrat was attached to the trunk at the four cardinal points. The 10 cm side of the quadrat was placed 1 m above the base of the tree. Lichen frequency was assessed by counting the number of 10x10 cm squares on the quadrat (1-20) in which each identified species was present. Any unknown species was photographed for identification. Lichen species were identified using 'Lichens – An Illustrated Guide to the British and Irish Species' (Dobson, 2011).

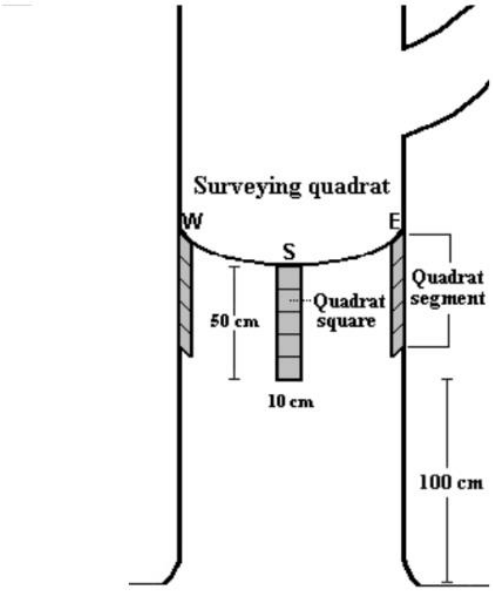


Figure 6. Showing the layout of quadrats at the four cardinal points for lichen surveying on a sample tree (Asta *et al.*, 2002).

3.2.4 *Ground Vegetation*

Ground vegetation cover was visually estimated at each of the four cardinal points around the base of each tree. Following the 'National Forest Inventory' guidelines, a quadrat was placed randomly within a 7m radius around the base of the tree (Department of Agriculture, Food and Marine, 2017). The frequency of each species was determined at each cardinal point by visually estimating how many 10x10cm squares were occupied by the species on the quadrat. Any unknown species were photographed for identification.

3.3 Microclimate Data Loggers

The microclimate conditions of all 102 trees were assessed using HOBOware data loggers (HOBO Pendant Temp/Light 64K Logger; Onset), which were deployed at the base of each tree using pins to attach them to the bark. The first experiment of each site had more than one individual per tree species. The second experiment for each site was conducted with just one individual sample per species. There was a limited number of data loggers available for use, thus, the second experiment was planned for the purpose of investigating a broader range of tree species' microclimate at once.

For a single experiment, all loggers had to be deployed on each tree on the same day, pre-set to begin logging at the same time. Loggers were activated using the associated HOBOware software. All loggers were numbered using a sharpie, as well as being numbered on the software. Each logger was set to begin logging at 9pm on that day, for a 24-hour period. The logger was set to log the temperature (degrees Celsius) and light intensity (Lux/lx) in 15-minute intervals for this 24-hour period. Once the 24-hours was completed, all loggers were collected for analysis. The loggers were stopped using the software and the data was saved to the assigned files for each date.

All the collected microclimate temperatures for each date/time were compared to MET Éireann air temperature data from the Cork Airport weather station (nearest to Cork city) on the same date/time. MET Éireann historical weather data is available on their website: www.met.ie.

3.4 Hemispherical Photography

The tripod (equipped with a levelling device) was set up at a height of 1m above the ground and in the centre of the study site i.e., the plot area around the tree was 7 m, thus the tripod was set at 3.5 m from the base of each tree trunk. The top of the camera is aligned with the geographical North in each photo and the camera was set up in the South cardinal of each tree. An 8mm fisheye lens (Samyang lens; Barker Photographic, Cork) was used on the digital camera (Canon D5600; Barker Photographic, Cork) to create a hemispherical photograph of the tree canopy.

The image was then run through the Gap Light Analyser software to generate a black and white image. The software then calculates a percentage of canopy openness (i.e., the percentage of sky visible through the canopy). This image will only represent the Southern portion of the tree's canopy, yet it gives insight into the estimated canopy openness of the tree, including both its own canopy and the surrounding canopies in its periphery.

In figure 7 below, the image on the left is the original hemispherical canopy image (black corresponds to canopy; white corresponds to sky). The image on the right is the resulting image once the cardinals and thresholds have been identified and it has been processed through the Gap Light Analyser software.



Figure 7. Sample images of a Silver Birch (*Betula pendula*) in Fitzgerald's Park using the Gap Light Analyser software. Photos: Caoimhe Marron, 2022.

3.5 Data Analysis

All analysis was carried out in the statistical software SPSS (version 29). To assess any differences in species richness among tree species of the 4 taxa being surveyed, a Kruskal-Wallis H test was conducted for each experiment which had 2 or more replicates. Any experiments which did not have replicates of a tree species were analysed using the Chi-squared statistical test. P-values were generated from these tests to determine the significance of the results ($p<0.05$). Shannon diversity indices were calculated per site and plotted in a bar chart; these data were also analysed using the Chi-squared method.

For community-level analysis among the 6 urban sites, irrespective of tree species, non-metric multidimensional scaling (NMDS) was used. Mean abundance data was initially transformed into a dissimilarity matrix (Euclidean distance; nearest-neighbour) per taxon. NMDS was then performed on this matrix, using 2-dimensions for all plots, and the stress and R-squared value were recorded per plot. MANOVA analysis was conducted to determine the significance of each NMDS plot. A post-hoc analysis (Tukey) was conducted to determine the variance between sites.

Microclimate data (mean daytime light intensity; temperature; canopy openness) were analysed using linear regression analysis to investigate any significant relationships the data had with taxa species richness. Significant data were visualised in a scatter plot, including a regression line showing the positive/negative correlations.

4 Results

4.1 UCC Arboretum

The UCC campus is 42 acres in size and is host to 2,500 trees, with 120 different species. The UCC arboretum was chosen as the first site due to the abundance and large range of species present which were not common in other areas of the city. The UCC arboretum was divided into 3 experiments (n=26). This decision was influenced by the number of individuals per tree species that were accessible for surveys and not vulnerable to public interference. Thus, experiments were conducted in relation to the number of samples surveyed per tree species.

4.1.1 Species Richness

4.1.1.1 UCC Experiment A

This experiment surveyed the biodiversity supported by 4 tree species, with 3 individual samples surveyed per tree species (n=12):

1. *Acer pseudoplatanus* (Sycamore)
2. *Tilia x europea* (Common Lime)
3. *Betula pendula* (Silver Birch)
4. *Fagus sylvatica* (Common Beech)



Figure 8. An example of one site used on the UCC main campus in this experiment. This walkway is in the UCC Arboretum and it is where one Sycamore was located. Photos: Caoimhe Marron, 2022.

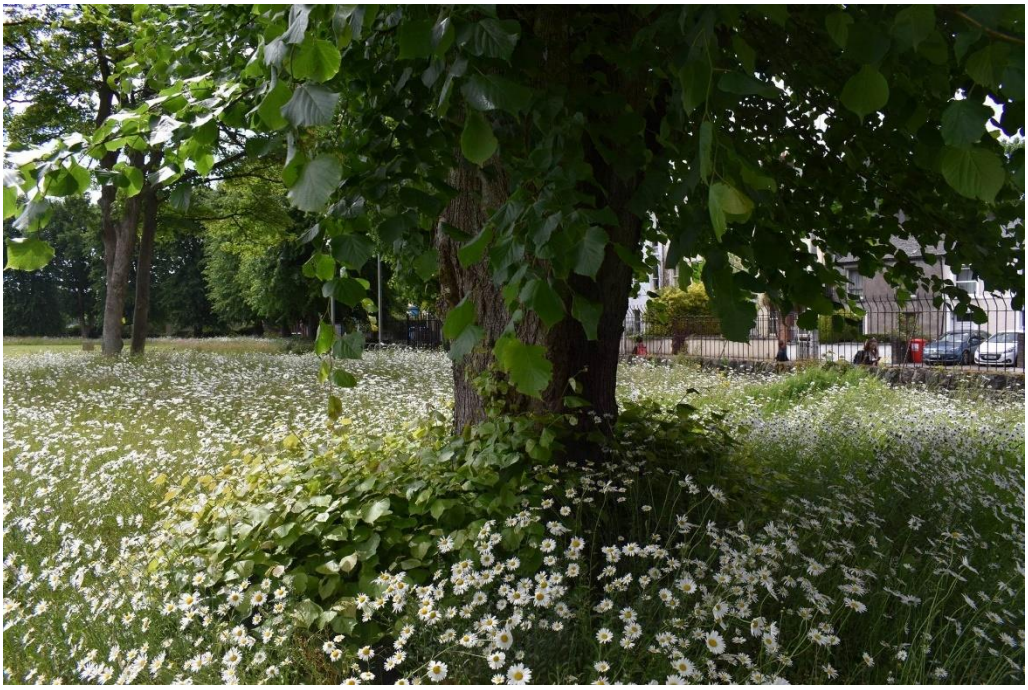


Figure 9. A Common Lime tree surveyed in the wildflower meadow of the UCC arboretum. Photo: Caoimhe Marron, 2022.



Figure 10. Two examples of trees surveyed in the UCC arboretum: Silver Birch (left) and Sycamore (right). Photos: Caoimhe Marron, 2022.

The Kruskal-Wallis H test showed that there was no signficant differences in the species richness of lichens (p=0.316), vegetation (p=0.674), or birds (p=0.151) between the medians of the 4 different tree species.

Table 5. The median species richness of lichens, vegetation, and birds for all 4 tree species surveyed in experiment A of the UCC Arboretum (n=12).

Tree Species	Lichens*	Vegetation**	Birds***
Sycamore	2	5	2
Common Lime	1	5	4
Silver Birch	1	3	2
Common Beech	1	5	1

* H = 3.537, df = 3, p > 0.05; ** H = 1.536, df = 3, p > 0.05: *** H = 5.301, df = 3, p > 0.05.

4.1.1.2 UCC Experiment B

This experiment surveyed the biodiversity supported by 4 tree species, with 2 individual samples surveyed per tree species (n=8):

1. *Fraxinus excelsior* (Ash)
2. *Prunus cerasifera* (Cherry Plum)
3. *Taxus baccata* 'Fastigiata' (Irish Yew)
4. *Aesculus hippocastanum* (Horsechestnut).



Figure 11. Examples of one Irish Yew tree (left) and a Horse Chestnut tree (right) used in this second UCC arboretum experiment. These photos were taken in October (2022), although the trees were surveyed during the summer. Photo: Caoimhe Marron, 2022.

The Kruskal-Wallis H test showed that there was no signficant differences in the species richness of lichens ($p = 0.203$), vegetation ($p = 0.374$), or birds ($p = 0.288$) between the 4 different tree species.

Table 6. Showing the median species richness of lichens, vegetation, and birds for all 4 tree species surveyed in experiment B of the UCC arboretum (n=8).

Tree Species	Lichens*	Vegetation**	Birds***
Ash	0.5	5	1.5
Cherry Plum	2.5	8.5	1
Irish Yew	1.5	5	1.5
Horse Chestnut	1.5	3.5	2

* $H = 4.605$, $df = 3$, $p > 0.05$: ** $H = 3.116$, $df = 3$, $p > 0.05$; *** $H = 3.766$, $df = 3$, $p > 0.05$.

4.1.1.3 UCC Experiment C

This experiment surveyed the biodiversity supported by 7 different tree species, with only 1 individual surveyed per tree species (n=7):

1. *Carpinus betulus* (Hornbeam)
2. *Pinus contorta* (Lodgepole Pine)
3. *Quercus robur* (English Oak)
4. *Salix babylonica* (Willow)
5. *Liriodendreon tulipifera* (Tulip)
6. *Fagus sylvatica* f. *purpurea* (Copper Beech)
7. *Quercus petraea* (Sessile Oak)

This experiment had only one indivudal tree surveyed per tree species, thus the microclimate data of a larger quantity of different species could be measured at consecutive times (this is due to limited numbers of data loggers that were available). The most promiment data arising from this experiment was the abundance of other taxa present in the UCC arboretum.





Figure 12. Photos of a green space in the UCC arboretum where a number of trees were surveyed for this experiment inlcuding, for example, the Tulip tree, Common Beech, Copper Beech, English Oak, and Douglas Fir.

A chi-squared test has shown that there is no significant association between taxa species richness and tree species. Bird, lichen, and vegetation species richness have all got no association with the type of tree species they are present at ($p>0.05$ for all taxa).

Table 7. The species richness of lichens, birds, and ground vegetation recorded for all indivudals in experiment C of the UCC Abroretum (n=7)

Tree Species	Lichens*	Birds**	Vegetation***
Hornbeam	2	0	0
Lodgepole Pine	1	0	2
English Oak	2	1	4
Willow	2	2	0
Tulip	4	3	5
Copper Beech	4	0	9
Sessile Oak	1	1	4

*$X^2(12) =14$, $p>0.05$; ** $X^2(18) =21$, $p>0.05$; *** $X^2(24) =28$, $p>0.05$.

4.1.2 Abundance of Taxa

The tables below show the recorded abundance of 4 different taxa in the UCC arboretum. These inlclude the identification of lichens, birds, and ground vegetation to the species level and inverterbrates by Order. There were two species of bird identified in the UCC arboretum which have been amber-listed by BirdWatch Ireland: the Herring Gull and the House Sparrow. A full list of taxa recorded per tree species can be viewed in section 8.4.1 of the appendix.

Table 8. The abundance of inveretebrate Orders recorded in the UCC arboretum.

Invertebrate Orders	**Abundance**
Diptera	883
Coleoptera	12
Lepidoptera	12
Hymenoptera	5
Dermaptera	2
Isopoda	123
Araneae	9

Table 9. The abundance of lichen species recorded in the UCC arboretum.

Lichen Species	**Abundance**
A. calcarea	160
P. perlatum	55
C. candelaris	17
F. carpeta	31
R. farinacea	66
O. parella	32
C. aurantia	7

Table 10. The abundance of bird species recorded in the UCC arboretum.

Bird Species	**Abundance**
Jackdaw *(Coloeus)*	6
Wood Pigeon *(Columba palumbus)*	20
Crow *(Corvus)*	1
Magpie *(pica pica)*	8
Robin *(Erithacus rubecula)*	6
Great Tit *(Parus major)*	2
Dunnock *(Prunella modularis)*	4

Rook *(Corvus frugilegus)*	8
House Sparrow (*Passer domesticus*)	5
Coal Tit *(Periparus ater)*	2
Herring Gull *(Larus argentatus)*	9

Table 11. The abundance of ground vegetation species recorded in the UCC arboretum.

Vegetation Species	Abundance
Nettles *(Urtica dioica)*	4
Oxeye daisy *(Leucanthemum vulgare)*	5
Buttercup *(Ranunculus repens)*	50
Sticky chickweed *(Cerastium glomeratum)*	9
Bracken *(Pteridium aquilinum)*	1
Perennial Ryegrass *(Lolium perenne)*	418
Germander Speedwell *(Veronica chamaedrys)*	32
Broadleaf Dock *(Rumex obtusifolius)*	1
Spear Thistle *(Cirsium vulgare)*	5
Curled Dock *(Rumex crispus)*	5
Dandelion *(Taraxacum officinale)*	29
Harebell *(Campanula rotundifolia)*	4
Daisies *(Bellis perennis)*	10
White Clover *(Trifolium repens)*	20
Greater plantain *(Plantago major)*	10
Wood aven *(Geum urbanum)*	1
Irish Ivy *(Hedera hibernica)*	38
Cow Parsnip *(Heracleum maximum)*	10
Pink Sorrel *(Oxalis articulata)*	1
Common Nipplewort *(Laspana communis)*	1
Ground Elder *(Aegopodium podagraria)*	1
Tansy Ragwort *(Jacboaea vulgaris)*	5
Clustered Dock *(Rumex conglomeratus)*	6
Greater Birdsfoot Trefoil *(Lotus pedunculatus)*	5
Common Selfheal *(Prunella vulgaris)*	4
Old Man's Beard *(Clematis vitalba)*	6
Fox-and-Cubs *(Pilosella aurantiaca)*	1
Herb Robert *(Gernaium robertianum)*	3
Baby's Tears *(Soleirolia soleirolii)*	1
Yellow Pimpernel *(Lysimachia nemorum)*	6
Short-fruited Willowherb *(Epilobium obsurum)*	2
Wall-lettuce *(Lactuca muralis)*	7

4.2 Marina Street Trees

This experiment aimed to survey the communites of 4 taxa (invertebrates, lichens, birds, ground vegetation) supported by individual 'street trees' in the Marina area of Cork city (n=12). The trees surveyed are characterised as 'street trees' for the purpose of this experiment. This area was chosen for the purpose of investigating trees in areas of high commercial activity and urbanisation. These trees are indivudal trees outside of the defined urban green spaces (e.g., roadside with concrete).

4.2.1 Species Richness

4.2.1.1 Marina Experiment A

This experiment aimed to survey the biodiversity supported by 4 different tree species, with 2 replicates per tree species (n=8):

1. *Platanus x hispanica* (London Plane)
2. *Fagus sylvatica* (Common Beech)
3. *Tilia x europea* (Common Lime)
4. *Acer pseudoplatanus* (Sycamore)



Figure 13. Google Street View screenshot showing the location of a Sycamore Maple in the Marina area of Cork city. *Source*: Google (2022) Monahan Road. Available at: http://maps.google.co.uk (Accessed: 3rd January 2022).



Figure 14. Google Street View screenshot showing the location of a Common Lime street tree in this experiment in the new Marina area of Cork city. *Source:* Google (2022). Available at: http://maps.google.co.uk (Accessed: 3rd January 2022).

The Kruskal-Wallis H test showed that there was no signficant differences in the median species richness of lichens (p = 0.2), vegetation (p = 0.194), or birds (p = 0.164) between the 4 tree species.

Table 12. Showing the median species richness of lichens, vegetation, and birds for all 4 tree species surveyed in experiment A of the street tree experiments (n=8).

Tree Species	Lichens*	Vegetation**	Birds***
London Plane	1	2	1
Common Beech	1	4	1
Common Lime	2	3	0
Sycamore	1	5.5	0

*H = 4.642, df = 2, p > 0.05; **H = 4.714, df = 3, p > 0.05; *** H=5.111, df=3, p>0.05.

4.2.1.2 Marina Experiement B

This experiment surveyed the biodiversity supported by 4 tree species in the Marina area of Cork city, with just one inidividual per tree species (n=4):

1. *Betula pendula* (Silver Birch)
2. *Sorbus x intermedia* (Swedish Whitebeam)
3. *Fraxinus excelsior* (Ash)
4. *Acer platanoides* (Norway Maple)

Experiment B surveyed 1 indivudal per tree species. This was due to limitations in the number of accessible trees per species.



Figure 15. Two examples of individual street trees surveyed in the new Marina area of Cork city for this experiment: Silver Birch (left) and Swedish Whitebeam with berries (right). Both are located directly next to busy paths and roads. Photos: Caoimhe Marron, 2022.

There were no significant associations observed in the data, following a Chi-squared statistical test. All associations between lichens or vegetation and tree species were insignficant ($p>0.05$). The median species richness or birds for all tree species was 0; however, the small number of bird species recorded can be viewed in section 8.4.2 of the appendix.

Table 13. The species richness of lichens and vegetation for all 4 tree species surveyed in experiment B of the Marina trees (n=4).

Tree Species	Lichens*	Vegetation**
Silver Birch	1	8
Swedish Whitebeam	4	4
Ash	1	4
Norway Maple	2	4

*$X^2(6) = 8$, $p > 0.05$; ** $X^2(3) = 4$, $p > 0.05$; **

4.2.2 Abundance of Taxa

The tables below represent the abundance of various taxa recorded in the Marina area of Cork city across both experiments A and B. Total abudance data for indivdual trees can be viewed in section 8.4.2 of the appendix.

Table 14. The abundance of lichen species recorded in the Marina area of Cork city.

Lichen Species	Abundance
A. calcarea	153
P. perlatum	18
C. candelaris	23
F. carpeta	2
T. flexuosa	4

Table 15. The abundance of invertebrate Orders recorded at all street trees in the new Marina area of Cork city.

Invertebrate Orders	Abundance
Diptera	244
Coleoptera	1
Hymenoptera	17
Dermaptera	13
Isopoda	18
Araneae	1

Table 16. The abundance of bird species recorded in the new Marina area of cork city.

Bird Species	Abundance
Wood Pigeon *(Columba palumbus)*	3
Crow *(Corvus)*	4

Table 17. The abundance of ground vegetation species recorded in the new Marina area of Cork city.

Vegetation Species	Abundance
Dandelion *(Taraxacum officinale)*	36
Perennial Ryegrass *(Lolium perenne)*	119
Irish Ivy *(Hedera hibernica)*	51
Herb Robert *(Gernaium robertianum)*	10
Nettles *(Urtica dioica)*	22
Old Man's Beard *(Clematis vitalba)*	17
Holly *(Ilex aquifolium)*	30
Greater plantain *(Plantago major)*	18
Hairy Bolesia *(Bowlesia incana)*	5
Baby's Tears *(Soleirolia soleirolii)*	2
Wall-lettuce *(Lactuca muralis)*	1
White Clover *(Trifolium repens)*	22
Daisy *(Bellis perennis)*	24
Red Clover *(Trifolium pratense)*	2
Buttercup *(Ranunculus repens)*	1

4.3 The Atlantic Pond

The Atlantic Pond is an urban green and blue space in the Marina area of Cork city. This green space is 6 acres in size, originally presented to the public as an ornametal pond. A total of 17 indivudal trees were surveyed in this green space.



Figure 16. Photo showing an example of one Willow tree surveyed in the Atlantic Pond (left) and a second photo showing a view of the Atlantic Pond with the walkway on the periphery (right). Photos: Caoimhe Marron, 2022.

4.3.1. Species Richness

4.3.1.1 Atlantic Pond Experiment A

This experiment surveyed the biodiversity supported by four tree species in the Atlantic Pond park in Cork city, with three indiivduals surveyed per tree species (n=12):

1. *Fraxinus excelsior* (Ash)
2. *Salix babylonica* (Willow)
3. *Alnus glutinosa* (Alder)
4. *Betula pubsecens* (Downy Birch)

The Kruskal-Wallis H test showed that there was no signficance associated with the species richness of lichens (p=0.777), vegetation (p=0.14), or birds (p=0.491) between the 4 different tree species. Thus, there is no association between tree species and taxa species richness in this experiment.

Table 18. The median species richness of lichens, vegetation, and birds for all 4 tree species surveyed in this experiment.

Tree Species	Lichens*	Vegetation**	Birds***
Ash	0	6	0
Willow	3	4	1
Alder	2	5	1
Downy Birch	3	2	1

* H=1.101, df=3, p>0.05; ** H=5.480, df=3, p>0.05; *** H=2.417, df=3, p>0.05.

4.3.1.2 Atlantic Pond Experiment B

This experiment investigated the biodiversity supported by 5 tree species in the Atlantic Pond, with 1 individual per tree species (n=5):

1. *Acer campestre* (Field Maple)
2. *Platanus x hispanica* (London Plane)
3. *Acer pseudoplatanus* (Sycamore)
4. *Acer saccharum* (Sugar Maple)
5. *Sorbus intermedia* (Swedish Whitebeam)

The results of a Chi-squared test have shown that there is no significant association between the species of tree and species richness of the following taxa: lichens, birds, and vegetation ($p>0.05$ for all taxa).

Table 19. The species richness of lichens, birds, and vegetation per tree species in the second experiment of the Atlantic Pond (n=5).

Tree Species	Lichens*	Vegetation**	Birds***
Field Maple	1	3	0
London Plane	2	5	1
Sycamore	0	3	1
Sugar Maple	3	3	0
Swedish Whitebeam	6	3	1

* $X^2(16) =20$, $p>0.05$; ** $X^2(4) =5$, $p>0.05$; *** $X^2(4) =5$, $p>0.05$.

4.3.2 Abundance of Taxa

The tables below represent the abundance of various taxa recorded in the Atlantic Pond across both experiments A and B. Total abudance data for indivdual trees can be viewed in section 8.4.3 of the appendix. Two amber-listed bird species were recorded in the Atlantic Pond: the House Sparrow and the Lesser Black-backed Gull.

Table 20. The abundance of invertebrate Orders recorded in the Atlantic Pond.

Invertebrate Orders	Abundance
Diptera	558
Coleoptera	1
Lepidoptera	2
Hymenoptera	20
Dermaptera	1
Isopoda	5
Araneae	17

Table 21. The abundance of lichen species recorded in the Atlantic Pond.

Lichen Species	Abundance
A. calcarea	62
P. perlatum	25
C. candelaris	86
F. carpeta	47
R. farinacea	9
O. parella	10
X. parietina	4

Table 22. The abundance of bird species recorded in the Atlantic Pond.

Bird Species	Abundance
Wood Pigeon *(Columba palumbus)*	17
Lesser Black-backed Gull *(Larus fuscus)*	1
Magpie *(Pica pica)*	1
House Sparrow *(Passer domesticus)*	4

Table 23. The abundance of ground vegetation species recorded in the Atlantic Pond.

Vegetation Species	Abundance
Greater Plantain *(Plantago major)*	79
White Clover *(Trifolium repens)*	4
Dandelion *(Taraxacum officinale)*	20
Perennial Ryegrass *(Lolium perenne)*	350
Bracken *(Pteridium aquilinum)*	6
Clustered Dock *(Rumex conglomeratus)*	2
Irish Ivy *(Hedera hibernica)*	45
Nettles *(Urtica dioica)*	10
Germander Speedwell *(Veronica chamaedrys)*	18
Lambsquarters *(Chenopodium album)*	1
Daisy *(Bellis perennis)*	9
Thyme-leaved Speedwell *(Veronica serpyllifolia)*	4
Baby's Tears *(Soleirolia soleirolii)*	1
Buttercup *(Ranunculus repens)*	13
Tansy Ragwort *(Jacboaea vulgaris)*	2

4.4 Kennedy Park

Kennedy Park is a 7.5-acre urban park on the outskirts of the city centre. This site had a very small number of trees in comparison to the other sites. Thus, experiment A surveys just 2 individuals and experiment B surveys 1 individual per species. There were a limited number of tree species which had more than one individual present in the park, however a total of 11 individuals were surveyed (n=11).

4.4.1 Species Richness

4.4.1.1 Kennedy Park Experiment A

This experiment surveyed the biodiversity supported by 3 tree species, with 2 individuals per species (n=6). Due to the size of this small urban green space, these three trees were the only species which had more than one individual each:

1. *Acer pseudoplatanus* (Sycamore)
2. *Fraxinus excelsior* (Ash)
3. *Fagus sylvatica* (Common Beech)



Figure 17. Google Street View screenshot showing Kennedy Park, with a Sycamore on the right-hand side that was surveyed in this experiment. Google Maps (2022) 15 Victoria Road. Available at: http://maps.google.co.uk (Accessed: 3rd January 2022).

The Kruskal-Wallis H test showed that there was no signficant differences in the species richness of lichens ($p = 0.058$), vegetation ($p = 0.167$), or birds ($p = 0.202$) between the 4 different tree species.

Table 24. Showing the median species richness of lichens, vegetation, and birds for all 3 tree species surveyed in experiment A of Kennedy Park (n=6).

Tree Species	Lichens*	Vegetation**	Birds***
Sycamore Maple	1	2	1
Ash	1	4	1
Common Beech	2	3	0

* $H = 5.708$, $df = 3$, $p > 0.05$; ** $H = 3.582$, $df = 3$, $p > 0.05$; *** $H = 3.2$, $df = 2$, $p > 0.05$.

4.4.1.2 Kennedy Park Experiment B

This experiment surveyed the biodiversity of 5 different tree species, with just 1 individual surveyed per species:

1. *Acer saccharinum* (Silver Maple)
2. *Acer saccharum* (Sugar Maple)
3. *Aesculus hippocastanum* (Horse chestnut)
4. *Tilia europaea* (Common Lime)
5. *Platanus x hispanica* (London Plane)

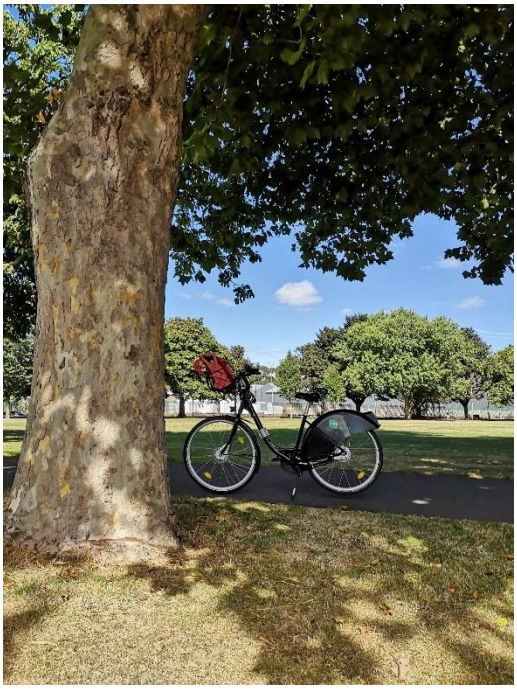


Figure 18. Photo showing a London Plane tree which was surveyed in Kennedy Park. Photo: Caoimhe Marron, 2022.

The results of a Chi-squared test have shown no significant associations between the taxa species richness and tree species. This includes lichen, bird, and vegetation species richness, all of which had $p>0.05$.

Table 25. The species richness of lichens, vegetation, and birds for all 5 tree species surveyed in experiment B of Kennedy Park (n=5).

Tree Species	Lichens*	Vegetation**	Birds***
Silver Maple	4	4	1
Sugar Maple	3	3	1
Horse Chestnut	4	4	1
Common Lime	5	3	0
London Plane	1	4	1

* $X^2(12) =15$, $p>0.05$; ** $X^2(4) =5$, $p>0.05$; *** $X^2(4) =5$, $p>0.05$.

4.4.2 Abundance of Taxa

The abundance of 4 taxa (invertebrates, lichens, birds, ground vegetation) was recorded at every individual sample in Kennedy Park (n=11). This data represents the total abundance across experiment A and B. There was 1 amber-listed bird species recorded in Kennedy Park: The House Sparrow. A full list of taxa abundance per individual tree can be seen in section 8.4.3 of the appendix.

Table 26. The abundance of invertebrate Orders recorded in Kennedy Park.

Invertebrate Orders	**Abundance**
Diptera	315
Coleoptera	3
Lepidoptera	6
Hymenoptera	21
Dermaptera	2
Araneae	1

Table 27. The abundance of lichen species recorded in Kennedy Park.

Lichen Species	**Abundance**
A. calcarea	104
P. perlatum	57
C. candelaris	68
F. carpeta	1
R. farinacea	7
O. parella	61
X. parietina	15
T. flexuosa	42

Table 28. The abundance of bird species recorded in Kennedy Park.

Bird Species	**Abundance**
House Sparrow (*Passer domesticus*)	3
Rook *(Corvus frugilegus)*	4
Wood Pigeon *(Columba palumbus)*	13
Jackdaw *(Corvus monedula)*	3

Table 29. The abundance of ground vegetation species recorded in Kennedy Park.

Vegetation Species	Abundance
Greater Plantain *(Plantago major)*	67
Perennial Ryegrass *(Lolium perenne)*	264
Dandelion *(Taraxacum officinale)*	43
White Clover *(Trifolium repens)*	49
Germander Speedwell *(Veronica chamaedrys)*	1
Creeping Cinquefoil *(Potentilla reptans)*	4

4.5 The Lee Fields

The Lee Fields is a waterfront public park, situated along the River Lee in Cork city. This green-space is host to a walking trail that is 1.25-miles in length. A total of 18 trees were surveyed in the Lee Fields, as part of this research (n=18).

4.5.1 Species Richness

4.5.1.1 Lee Fields Experiment A

This experiment surveyed the biodiversity supported by 4 tree species, with 3 individuals per species (n=12):

1. *Betula pubescens* (Downy Birch)
2. *Acer saccharinum* (Silver Maple)
3. *Salix babylonica* (Willow)
4. *Metasequoia glyptostroboides* (Dawn Redwood)



Figure 19. Photo of a Willow tree surveyed in the Lee Fields. Photo: Caoimhe Marron, 2022.

The Kruskal-Wallis H test showed that there was no signficant differences in the species richness of lichens ($p = 0.45$), vegetation ($p = 0.261$), or birds ($p = 0.196$) between the 4 different tree species.

Table 30. The median species richness of lichens, vegetation, and birds for all 4 tree species surveyed in experiment A of the Lee Fields (n=12).

Tree Species	Lichens*	Vegetation**	Birds***
Downy Birch	1	2	1
Silver Maple	1	4	1
Dawn Redwood	2	3	0
Willow	1	5.5	0

* $H = 2.662$, $df = 3$, $p > 0.05$; ** $H = 4.009$, $df = 3$, $p > 0.05$; *** $H = 4.689$, $df = 3$, $p > 0.05$.

4.5.1.2 The Lee Fields Experiment B

This experiment surveyed the biodiversity supported by 6 different tree species, with just 1 individual per species (n=6):

1. *Betula pendula* (Silver Birch)
2. *Quercus robur* (Pedunculate Oak)
3. *Acer saccharum* (Sugar Maple)
4. *Sorbus intermedia* (Swedish Whitebeam)
5. *Quercus palustris* (Swamp Spanish Oak)
6. *Tilia x europeae* (Common Lime)

The results of a Chi-squared test have shown that there is no significant association between either lichen or vegetation species richness and the species of tree in the Lee Fields (both taxa $p>0.05$). There were no median values of bird species richness recorded for this experiment.

Table 31. The species richness of lichens and vegetation for 6 tree species surveyed in experiment B of the Lee Fields (n=6). There were no birds recorded during this experiment in the Lee Fields.

Tree Species	Lichens*	Vegetation**
Silver Birch	3	4
Pedunculate Oak	4	5
Sugar Maple	1	3
Swedish Whitebeam	6	5
Swamp Spanish Oak	4	3
Common Lime	4	5

*$X^2(15) = 18$, $p>0.05$; ** $X^2(10) = 12$, $p>0.05$.

4.5.2 Abundance of Taxa

The abundance of 4 taxa (invertebrates, lichens, birds, ground vegetation) was recorded at every individual tree in the Lee Fields. The abundance of taxa recorded is displayed in the tables below; this data represents the total abundance across experiment A and B. There was 1 amber-listed bird species recorded in the Lee Fields: The Herring Gull. A full list of taxa abundance per individual tree can be viewed in section 8.4.3 of the appendix.

Table 32. The abundance of invertebrate Orders recorded in the Lee Fields.

Invertebrate Orders	**Abundance**
Diptera	435
Coleoptera	6
Hymenoptera	49
Dermaptera	28
Araneae	6
Isopoda	43

Table 33. The abundance of lichen species recorded in the Lee Fields.

Lichen Species	**Abundance**
A. calcarea	145
P. perlatum	121
C. candelaris	31
F. carpeta	25
R. farinacea	17
O. parella	7
C. aurantia	2
X. parietina	5

Table 34. The abundance of bird species recorded in the Lee Fields.

Bird Species	**Abundance**
Rook *(Corvus frugilegus)*	4
Herring Gull *(Larus argentatus)*	1

Table 35. The abundance of ground vegetation species recorded in the Lee Fields.

Vegetation Species	Abundance
Perennial Ryegrass *(Lolium perenne)*	376
Buttercup *(Ranunculus repens)*	55
Greater plantain *(Plantago major)*	33
Dandelion *(Taraxacum officinale)*	65
Daisies *(Bellis perennis)*	13
White Clover *(Trifolium repens)*	47
Bracken *(Pteridium aquilinum)*	10
Nettles *(Urtica dioica)*	5
Clustered Dock *(Rumex conglomeratus)*	4
Broadleaf Dock *(Rumex obtusifolius)*	13
Irish Ivy *(Hedera hibernica)*	2

4.6 Fitzgerald's Park

Fitzgerald's Park is an 18-acre urban public park, located on the banks of the River Lee. Experiment A focuses on surveying some common urban tree species, which had multiple individuals to survey for comparison across an individual species. Due to the number of tree species present in this park, experiment B focused on surveying the biodiversity of a broad range of tree species which only had one individual available for surveying. A total of 18 trees were surveyed in this park (n=18).

4.6.1 Species Richness

4.6.1.1 Fitzgerald's Park Experiment A

This experiment surveyed the biodiversity supported by 4 tree species, with 3 individuals per species (n=12):

1. *Betula pendula* (Silver Birch)
2. *Tilia x europaea* (Common Lime)
3. *Acer pseudoplatanus* (Sycamore)
4. *Metasequoia glyptostroboides* (Dawn Redwood)



Figure 20. Photos taken of two Dawn Redwood trees surveyed in the Fitzgerald's Park experiments. Photos: Caoimhe Marron, 2022.

The Kruskal-Wallis H test showed that there was no signficant differences in the species richness of lichens ($p = 0.06$), vegetation ($p = 0.18$), or birds ($p = 0.76$) between the 4 different tree species.

Table36. The median species richness of lichens, vegetation, and birds for all 4 tree species surveyed in experiment A of Fitzgerald's Park (n=12).

Tree Species	Lichens*	Vegetation**	Birds***
Silver Birch	1	2	1
Common Lime	1	4	1
Dawn Redwood	2	3	0
Sycamore	1	5.5	0

* $H = 7.3$, $df = 3$, $p < 0.05$; ** $H = 4.88$, $df = 3$, $p < 0.05$; *** $H = 1.19$, $df = 3$, $p < 0.05$.

4.6.1.2 Fitzgerald's Park Experiment B

This experiment surveyed the biodiversity supported by 6 tree species, with 1 individual per species (n=6):

1. *Cedar atlantica* (Atlas Cedar)
2. *Platanus x hispanica* (London Plane)
3. *Larix decidua* (Larch)
4. *Fagus sylvatica* (Common Beech)
5. *Quercus rubra* (Northern Red Oak)
6. *Platanus orientalis* (Oriental Plane)

There was no significant association observed between tree species and taxa species richness in Fitzgerald's Park. The results of a Chi-squared test have shown that lichens, birds, and vegetation species richness are not associated with the species of tree ($p>0.05$ for all taxa).

Table 37. The species richness of lichens, vegetation, and birds for all 6 tree species surveyed in experiment B of Fitzgerald's Park.

Tree Species	Lichens*	Vegetation**	Birds***
Atlas Cedar	3	4	0
London Plane	1	2	2
Larch	1	2	2
Common Beech	2	6	4
Northern Red Oak	2	4	3
Oriental Plane	1	8	0

*$X^2(10) =12$, $p>0.05$; ** $X^2(15) =18$, $p>0.05$; *** $X^2(15) =18$, $p>0.05$.

4.6.2 Abundance of Taxa

The abundance of 4 taxa (invertebrates, lichens, birds, ground vegetation) was recorded at every individual tree in the Lee Fields. The abundance of taxa recorded is displayed in the tables below; this data represents the total abundance across experiment A and B. There were 3 amber-listed bird species recorded in the Lee Fields: The Herring Gull, the Lesser Black-backed Gull and the Mallard. The full abundance tables for all individual trees in Fitzgerald's Park can be viewd in section 8.4.3 of the appendix.

Table 38. The abundance of invertebrate Orders recorded in Fitzgerald's' Park.

Invertebrate Orders	**Abundance**
Diptera	365
Coleoptera	2
Isopoda	32
Hymenoptera	34
Dermaptera	5
Araneae	6

Table 39. The abundance of lichen species recorded in Fitzgerald's Park

Lichen Species	**Abundance**
A. calcarea	105
P. perlatum	37
C. candelaris	56
F. carpeta	67
R. farinacea	16
L. muralis	1

Table 40. The abundance of bird species recorded in Fitzgerald's Park.

Bird Species	Abundance
Rook *(Corvus frugilegus)*	23
Wood Pigeon *(Columba palumbus)*	18
Robin *(Erithacus rubecula)*	1
Jackdaw *(Corvus monedula)*	10
Lesser Black-backed Gull *(Larus fuscus)*	17
Herring Gull *(Larus argentatus)*	3
Mallard *(Anas platyrhynchos)*	10

Table 41. The abundance of ground vegetation species recorded at Fitzgerald's Park.

Vegetation Species	Abundance
Perennial Ryegrass *(Lolium perenne)*	207
White Clover *(Trifolium repens)*	36
Buttercup *(Ranunculus repens)*	12
Dandelion *(Taraxacum officinale)*	32
Daisies *(Bellis perennis)*	120
Greater plantain *(Plantago major)*	94
Petty Spurge *(Euphorbia peplus)*	9
Thyme-leaved Speedwell *(Veronica serpyllifolia)*	2
Horseweed *(Erigeron canadensis)*	1
Irish Ivy *(Hedera hibernica)*	34
Japanese Pachysandra *(Pachysandra terminalis)*	15
Arrow Bamboo *(Pseudosasa japonica)*	5
Witch Hazel *(Hamamelis x intermedia Jelena)*	1
Holly *(Ilex aquifolium)*	5
Bull Thistle *(Cirsium vulgare)*	2
Bracken *(Pteridium aquilinum)*	3
Red Clover *(Trifolium pratense)*	7
Nettles *(Urtica dioica)*	1

4.7 Shannon-Wiener Diversity Index

The Shannon-Wiener Diversity Index (H) was calculated for each urban site. This index inlcudes all data from taxa which were identified to the species-level; this includes birds, lichens, and ground vegetation. This survey has shown a large number of various taxa present at all 6 sites. All sites had a calculated H value greater than 2, indicating that there is a large number of species as well as a good level of evenness across all the urban sites surveyed in Cork city. However, UCC and Fitzgerald's Park are the only 2 sites which have a H value higher than 2.5. The results of a Chi-squared test have shown that there is no significant association between the calculated Shannon diversity indices and the type of urban site (p=0.224).

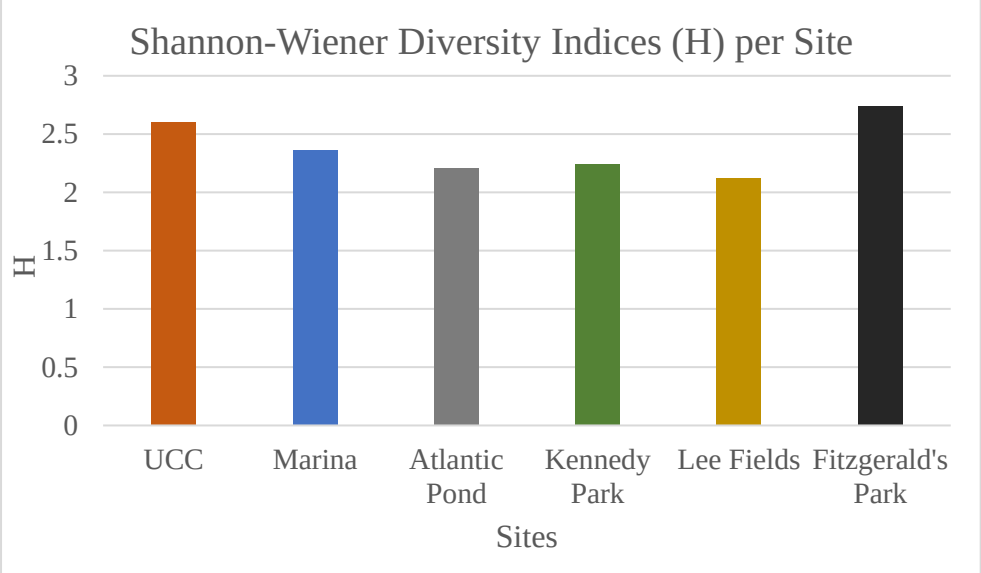


Figure 21. The caluclated H index for each of the 6 urban sites (X^2 (25) =30, p>0.05).

4.8 Community-Level Analysis

The biotic communites of all urban sites were compared using non-metric multidimensional scaling (NMDS). The abundance data per site is visualised by generating NMDS plots is SPSS. MANOVA (Mulitvariate Analysis of Variance) tests were then condcuted on the data to determine the statistical signficance.

4.8.1 Invertebrate NMDS

The invertebrate communities recorded for the urban sites are largely occupying different ordination space, meaning that the invertebrate communites differ among the 6 urban sites. However, the communtiies of UCC and the Marina street trees, as well as Fitzgerald's Park and the Lee fields, occupy a similar ordination plane. Although, the data appears to show that the communities mainly differ among the sites, these are the most similar in their community composition. There was a statistically significant variation in invertebrate communities between the 6 urban sites, meaning that the type of urban site impacts the invertebrate community composition ($F(35, 397.9) = 2.15$, $p < 0.001$; Wilk's $\lambda = 0.482$, $\eta^2 = 0.136$).

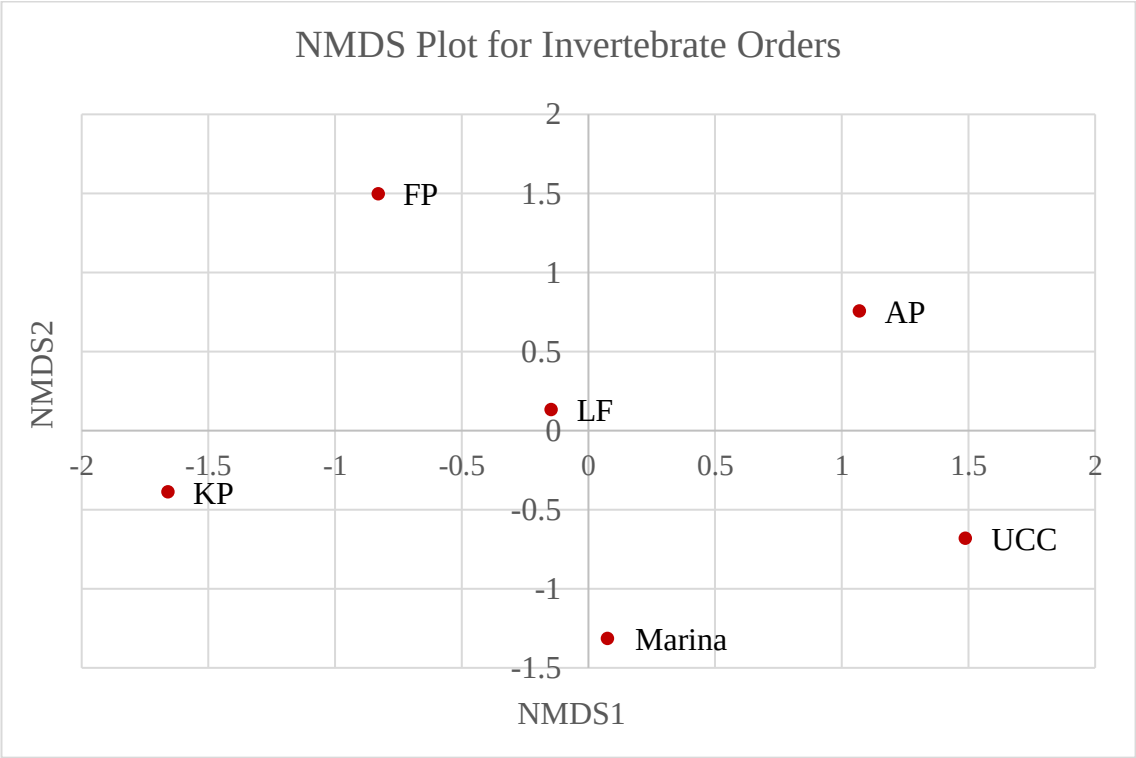


Figure 22. NMDS ordination plot for the mean abundance of invertebrate orders recorded at 6 sites in Cork city. Final stress from two-dimensional solution = 0.11478. RSQ = 0.8454. (UCC =UCC Arboretum; Marina =Marina Street Trees; AP =Atlantic Pond; KP =Kennedy Park; LF =The Lee Fields; FP =Fitzgerald's Park)

4.8.2 Lichen NMDS

The lichen species communities are grouped into 2 sites per plane which have similarities in their community composition. Similar communities are evident between Kennedy Park and the Marina street trees; UCC and Fitzgerald's Park; the Lee Fields and the Atlantic Pond. There was a statistically significant variation in lichen species communities between the 6 urban sites, meaning that the type of urban site impacts the lichen community ($F(50,422.9) = 2.62$, $p<0.001$; Wilk's $\lambda = 0.292$, $\eta^2 = 0.218$).

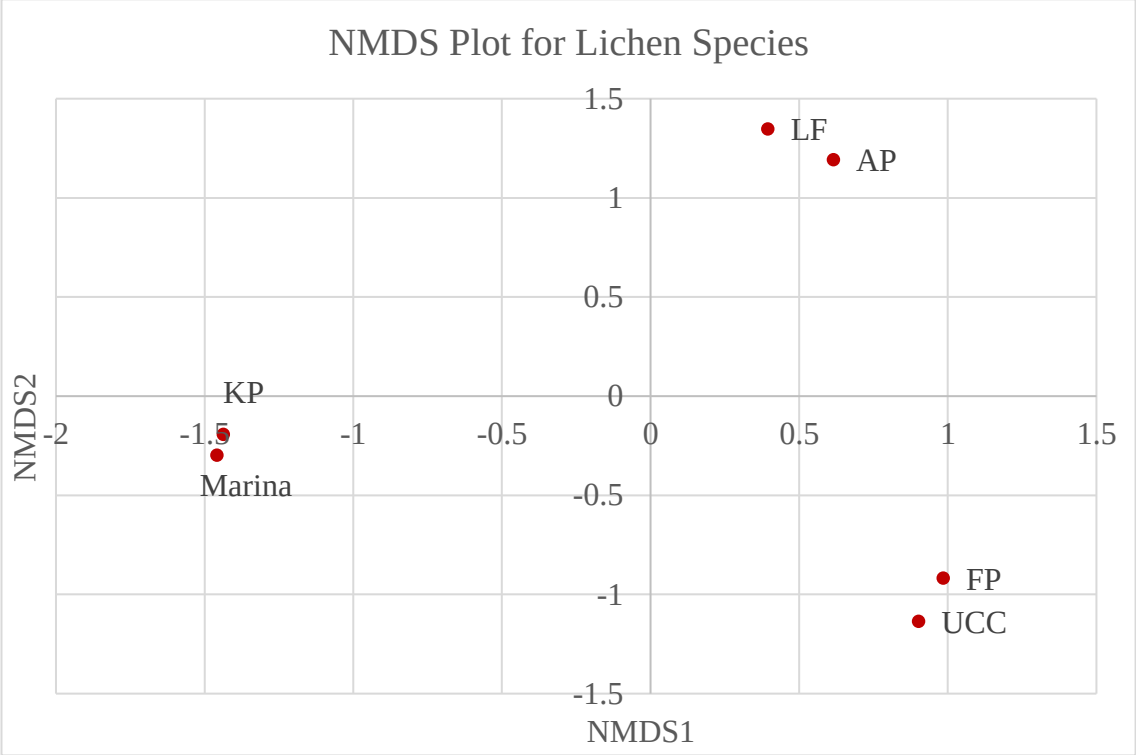


Figure 23. NMDS ordination plot for the mean abundance of lichen species recorded at 6 sites in Cork city. Final stress from two-dimensional solution = 0.01683. RSQ = 0.99836. (UCC =UCC Arboretum; Marina =Marina Street Trees; AP =Atlantic Pond; KP =Kennedy Park; LF =The Lee Fields; FP =Fitzgerald's Park)

4.8.3 Ground Vegetation NMDS

The UCC community of ground vegetation species differs the most from all other urban sites. The marina street trees also differ from the other sites, likely due to the increased levels of impervious surfaces. Similarities in community composition can be seen between the Atlantic Pond and the Lee fields, as well as between Kennedy Park and Fitzgerald's Park. There was a statistically significant variation in ground vegetation species communities between the 6 urban sites, meaning that the type of urban site impacts the vegetation species composition (F (195,313.3) =1.81, $p<0.001$; Wilk's λ =0.024, η^2 =0.527).

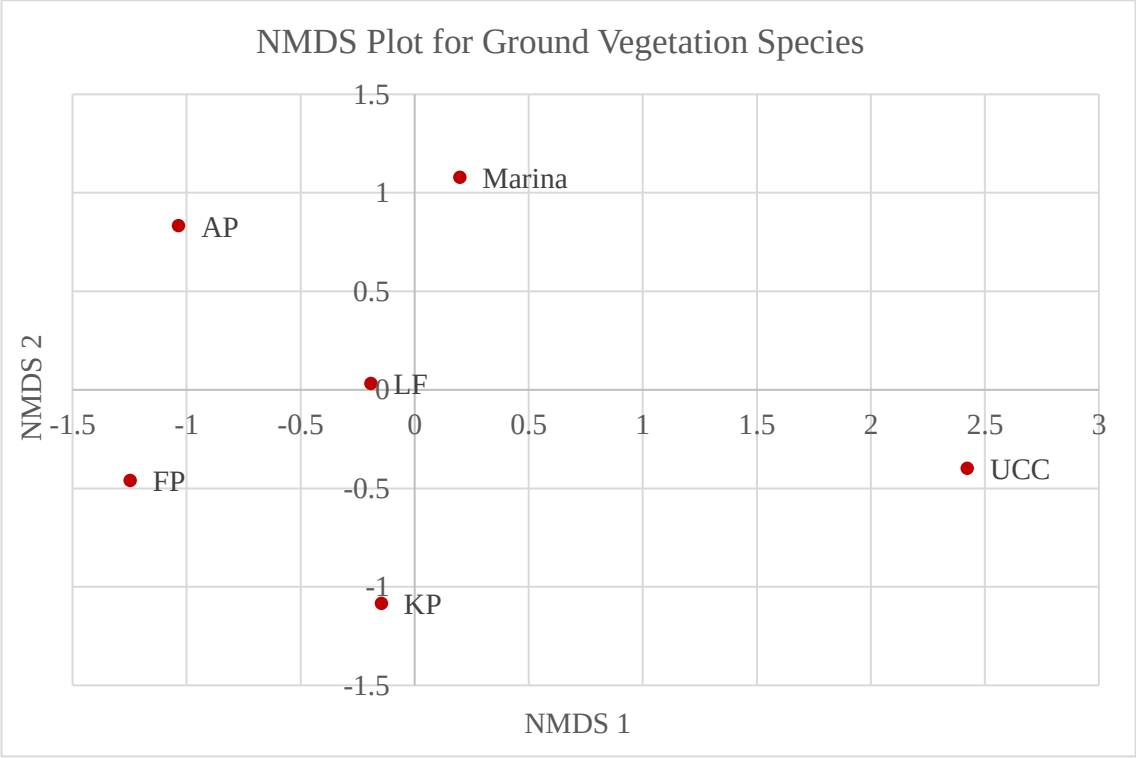


Figure 24. NMDS ordination plot for the mean abundance of ground vegetation species recorded at 6 sites in Cork city. Final stress from two-dimensional solution = 0.02368. RSQ = 0.99648. (UCC =UCC Arboretum; Marina =Marina Street Trees; AP =Atlantic Pond; KP =Kennedy Park; LF =The Lee Fields; FP =Fitzgerald's Park)

4.8.4 Bird NMDS

Similar to the ground vegetation NMDS plot, there is an evident difference between the Marina street trees, as well as UCC abundance versus the 4 urban parks. The street tree bird communities differ from the rest likely due to the increased level of impervious surfaces, traffic and higher urbanisation. Kennedy Park and the Atlantic Pond have a similar bird community structure, as well as Fitzgerald's Park and the Lee Fields. There was a statistically significant variation in bird species communities among between the 6 urban sites, meaning that the urban site type impacts the bird community abundance ($F(65,636.1) = 1.72$, $p<0.001$; Wilk's $\lambda = 0.281$, $\eta^2 = 0.224$).

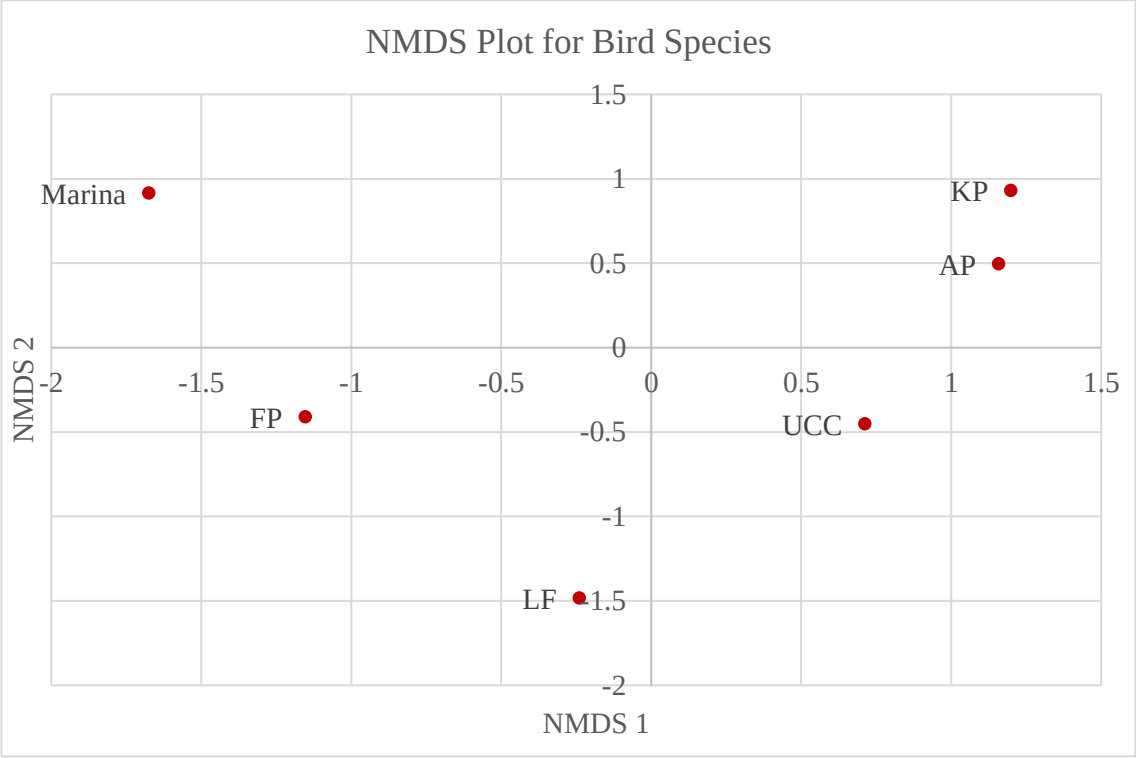


Figure 25. NMDS ordination plot for the mean abundance of bird species recorded at 6 sites in Cork city. Final stress from two-dimensional solution = 0.09677. RSQ = 0.92957. (UCC =UCC Arboretum; Marina =Marina Street Trees; AP =Atlantic Pond; KP =Kennedy Park; LF =The Lee Fields; FP =Fitzgerald's Park)

4.9 Regression Analyses

Regression analyses were performed to evaluate any correlations between abundance, species richness, or Shannon diversity and the mean microclimate conditions recorded. Daytime temperatures and light intensity were recorded for each experiment. All signficiant regression plots are presented in section 8.3 of the appendix. Although, there are some significant results presented below, it should be noted that the microclimate conditions recorded are affected by numerous external factors which could not all be investigated in this experiment. This was a major limitation of this section of the research, which could be further investigated in future studies. However, an overview of the results are displayed in the table below.

Additionally, hemispherical photographs were taken in Fitzgerald's Park with the intention of calculating the percentage canopy openness of trees being surveyed. These photographs can be seen in section 8.2 of the appendix. The percentage of canopy openness was calculated and regression analysis was used to investigate these values with microclimate conditions (seen in the table 42). This method of determining canopy openness is recorded regualrly in experiments investigating forest stands, for example. This research was conducted as an attempt to create a novel adaptation of the methods used in previous research. However, there are numerous external factors which would have to be investigated and assessed in order to gain accurate insight. This method could also be adapted for future use in urban biodiversity research.

There was a positive correlation between the mean daytime temperature (degrees Celsius) and inverterbate abundance in experiment 3 of the UCC arbroetum ($F(1,11)=7.86$, $p=0.017$). Regression analysis indicated that mean daytime temperature explained 4.17% of the variation in total invertebrates. There was also a positive correlation between mean daytime light intensity (lx) and invertebrate abundance in this experiment ($F(1,12)=8.297$, $p=0.014$). Mean daytime light intensity explained 40.88% of the variation in total invertebrate numbers.

In experiment 2 of the Atlantic Pond, there was a negative correlation between mean daytime light intensity (lx) and total species richness ($F(1,6)=7.36$, $p=0.035$). Regression analysis indicated that mean day time light intensity explained 55.07% of the variation in total species richness.

There was a negative correlation between mean daytime temperature and Shannon Diversity Indices in experiment 2 of Kenedy Park ($F(1,7) = 18.8$, $p = 0.003$). Regression analysis indicated that mean daytime temperature explained 72.87% of the variation in Shannon diversity indices. This experiment also showed a negative correlation between daytime light intensity (lx) and Shannon diversity indices ($F(1,7) = 9.34$, $p = 0.018$). Regression analysis indicated that mean day time light intensity explained 57.17% of the variation in Shannon diverstity indices and mean daytime temperature explained 72.87% of the variation in Shannon diversity indices.

In experiment 2 of the Lee Fields, daytime light intensity had a positive correlation with invertebrate abundance ($F(1,8)=7.72$, $p=0.029$). Regression analysis indicated that mean daytime light intensity explained 49.1% of the variation in total invertebrates.

Table 42. The resulting p-values of regression analyses per experiment, comparing the biodiversity and abundance values with microclimate conditions (temperature and light intensity). All significant p-values are highlighted in bold below.

Experiment 1A – UCC Arboretum	**Mean Daytime Temperature (Degrees Celsius)**	**Mean Daytime Light Intensity (lx)**
Invertebrate Abundance	0.41	0.37
Species Richness	0.68	0.72
Shannon Diversity Index	0.74	0.76
Experiment 1B – UCC Arboretum		
Invertebrate Abundance	0.83	0.91
Species Richness	0.07	0.22
Shannon Diversity Index	0.28	0.63
Experiment 1C – UCC Arboretum		
Invertebrate Abundance	**0.017**	**0.014**
Species Richness	0.87	0.75
Shannon Diversity Index	0.57	0.398
Experiment 2A – Street Trees		
Invertebrate Abundance	0.55	0.27
Species Richness	0.6	0.99
Shannon Diversity Index	0.58	0.97
Experiment 2B – Street Trees		
Invertebrate Abundance	0.37	0.23
Species Richness	0.71	0.29
Shannon Diversity Index	0.82	0.83

Experiment 3A – the Atlantic Pond		
Invertebrate Abundance	0.23	0.48
Species Richness	0.19	0.29
Shannon Diversity Index	0.93	0.89
Experiment 3B – The Atlantic Pond		
Invertebrate Abundance	0.63	0.65
Species Richness	0.08	**0.035**
Shannon Diversity Index	0.16	0.26
Experiment 4A – Kennedy Park		
Invertebrate Abundance	0.102	0.31
Species Richness	0.06	0.18
Shannon Diversity Index	**0.003**	**0.018**
Experiment 4B – Kennedy Park		
Invertebrate Abundance	0.059	0.706
Species Richness	0.83	0.48
Shannon Diversity Index	0.84	0.56
Experiment 4C – The Lee Fields		
Invertebrate Abundance	0.98	0.83
Species Richness	0.71	0.99
Shannon Diversity Index	0.35	0.24
Experiment 4B – The Lee Fields		
Invertebrate Abundance	0.29	**0.029**
Species Richness	0.21	0.39
Shannon Diversity Index	0.317	0.78
Experiment 5A – Fitzgerald's Park		
Invertebrate Abundance	0.87	0.88
Species Richness	0.3	0. 26
Shannon Diversity Index	0.59	0.408
Canopy Openness	0.14	0.18
Experiment 5C – Fitzgerald's Park		
Invertebrate Abundance	0.79	0.096
Species Richness	0.26	0.72
Shannon Diversity Index	0.51	0.67
Canopy Openness	0.94	0.42

5 Discussion

5.1 Why is this study important?

The recent COP15 meeting highlighted the need to restore as well as conserve ecosystems and biodiversity globally. Nations agreed on several measures that must be taken by 2030 to address the critical rate of biodiversity loss and for the restoration of ecosystems (Convention on Biological Diversity, 2022).

The UN Environment Programme (2022) acknowledged at COP27 that biodiversity loss is already significantly affecting both regional and global changes to climate. Efforts to reduce forest degradation and increase ecosystem restoration could help to decrease greenhouse gas emissions (UN Environment Programme, 2022). These have highlighted the necessity to develop novel ways of tackling the biodiversity crisis to achieve these goals. Natural ecosystems need to be restored; similarly, urban environments need to be acknowledged as areas in which biodiversity can not only be restored, but also enhanced.

This study is highlighting a proportion of the taxa communities supported by urban trees in Cork city. The Cork City Heritage Plan (2015-2020) previously highlighted the importance of public spaces as urban environments that can harbour efficient levels of biodiversity (Cork City Council, 2015). The Council declared a Biodiversity emergency in 2019 and has since committed to clear strategies to support the maintenance of Irish wildlife (Cork City Council, 2021). However, with the implementation of a recent 'Cork City Heritage and Biodiversity Plan' which extends from 2021 to 2026, it is the prime time for novel research on biodiversity and urban green space in Cork city, as Cork City Council are promoting the conservation of our natural heritage in the community.

5.2 Do certain tree species harbour higher biodiversity levels in urban areas than others?

Statistical analyses have shown that there were no significant correlations between the species richness of each taxon (lichens, birds, vegetation) and tree species. This insignificance was consistent across all experiments and sites. Species richness is one of the simplest measures of species diversity, thus acting as a good basis for the understanding of taxa communities among tree species. This may be due to the limitations in the number of replicates per tree species, which is not unusual for observational data such as these. To efficiently address the hypothesis that tree

species impacts the taxa community composition, this research would benefit from the addition of more replicates per tree species. This would allow for a broader understanding of biotic composition of different tree species in Cork city. Regardless of these statistical results, the abundance data of various taxa for 102 trees acts as a good basis for the biodiversity supported by urban trees in Cork city. There is scope for this data to be used in future urban planning and alternative research projects, and the data will be added to a data repository such as 'Zonodo' for future applications.

5.3 Do taxa communities differ between urban sites?

Community-level analyses using NMDS plots have shown significant variations in the taxa communities among the 6 sites ($p<0.001$ for all taxa). These data suggest that the type of urban site is significantly associated with biotic community composition.

Figure 22 shows an NMDS ordination plot of the invertebrate communities of the 6 urban sites in Cork city. The plot shows that the invertebrate communities of the 6 sites are mostly dissimilar. Fitzgerald's Park and the Lee Fields appear to occupy the most similar ordination space, meaning that they have the most similar invertebrate communities overall. UCC arboretum and the Marina trees share a similar ordination space (yet they are not very close), meaning that they have a similar community of invertebrate Orders, when compared to some of the other sites. The invertebrates of the Atlantic Pond and Kennedy Park do not share a similar ordination space with any of the other sites, meaning that their lichen composition is quite unique when compared to the other sites. Overall, the invertebrate communities of urban sites vary immensely, and there does not appear to be a particular pattern arising from the data.

Figure 23 shows the NMDS plot for lichen communities in Cork city. This plot showed the most prominent similarities between sites. It is likely that many of the similarities seen in lichen communities are due to the location of the sites as a well as the type of urban green space. For example, UCC campus and Fitzgerald's Park are very close in their ordination space, and these two sites are very close in distance to each other. Similarly, Kennedy Park and the Marina street trees were both located on the very outskirts of Cork city centre, both of which occupied a very similar ordination space on the NMDS plot. Finally, the Atlantic Pond and the Lee Fields have shown proximity on the plot. Although these sites have the greatest

geographical distance between them, both sites are located the furthest on the outskirts of Cork city, near to a body of water. These similarities among certain sites are likely due to the sensitivity of lichens towards air quality, which is linked to urban location.

Figure 24 visualises the variance among sites in their ground vegetation composition. The UCC campus community of vegetation species differs the most from all other urban sites. The Marina street trees also have an individual community of vegetation when compared to the other sites. Similarities in community composition can be seen between the Atlantic Pond and the Lee fields, as well as between Kennedy Park and Fitzgerald's Park. The marina street trees were largely surrounded by impervious surfaces, more than any other urban site. Thus, this is likely the reason why this site had an alternative community of vegetation to the others. These data give evidence that the urban parks all harbour a similar composition of ground vegetation to each other, which could be due to factors such as park management or use as recreational space, for example.

Like the ground vegetation NMDS plot, there is an evident difference between the Marina and UCC's bird species abundance versus the 4 urban parks. Kennedy Park and the Atlantic Pond have a similar bird community structure, as well as Fitzgerald's Park and the Lee Fields. The largest number of bird species was present in the UCC campus, with the largest abundance values. The Marina street trees haad a low level of bird abundance, which is likely due to increased commercial activity, for example. The ordination of the Marina trees being dissimilar to the others could correlate to this.

5.4 Urban Tree Microclimates & Canopy Openness

The results for this section of the study were inconclusive, meaning that there is no clear answer to the proposed hypothesis that microclimate conditions impact the taxa communities of urban trees in Cork city. Although there were some significant results when regression analyses were conducted on the data, there were too many external factors and limitations that need to be considered; thus, the significant data cannot be taken as conclusive. Some more factors which need to be considered include, for example, tree age, size, weather conditions, location, proximity to water/buildings, etc.

The microclimate data collected in this experiment still acts as efficient supplementary data for the purpose of gaining a broader insight into the climate conditions associated with the recorded abundance data over this specific time-period. There is also scope for continued and focused research on this topic. For example, recent studies have shown that in urban habitats (where temperature is likely elevated), there will likely be an increased level of insect herbivores due to the accelerated development or decreased predation associated with this elevated temperature (Raupp *et al.*, 2010).

The method used in this study for the estimation of canopy openness in Fitzgerald's Park is a novel method adapted from common methods used in forest ecology. These methods were first adapted for biological use by Evans and Coombe (1959). This method is to be used irrespective of the larger scale analyses of 'Sky View Factor' (in more exposed urban environments) which are developed to distinguish between impervious surfaces, buildings, and canopy, for example using advanced dual-wavelength technology (Konarska *et al.*, 2021).

There has been a development of smartphone hemispherical photography, making this approach more accessible than before. Recent studies have shown that the use of smartphone hemispherical photography garners similar results to digital/film cameras (<10% overestimation or underestimation of canopy openness consistently) (Beeles *et al.*, 2022).

5.5 Can a biodiversity scale be developed for future use?

The development of a biodiversity scale would allow an easier comparison and analysis of biodiversity surveys between tree species and/or urban locations. A previous study by Cornelis and Hermy (2004) developed a biodiversity scoring system which classified habitat saturation and species richness into biodiversity classes for the comparison of urban parks in Flander, Belgium. Outlined below (table_) is a novel biodiversity scoring system, reminiscent of Cornelis and Hermy (2004), which is based on the combined data of the 102 trees surveyed across Cork city in this study.

Biodiversity is split into three classes, based on species richness, total invertebrates, and Shannon diversity indices. The limiting values of the classes were chosen based on the overall range of data collected in this study. Each class gets a value of 1 (Very

high) to 5 (very low), meaning that the sum of the 3 classes gives a total biodiversity score of 15 (maximum).

This scoring system could easily be applied for future biodiversity surveys in urban areas both within Ireland and globally. Alternatively, the biodiversity classes and limiting values could be altered depending on the data collected.

Table 43. Showing the proposed system of classification of species richness, total number of invertebrates, and Shannon diversity indices into biodiversity classes with corresponding biodiversity scores (Cornelis and Hermy, 2004).

Biodiversity Scores (1 – 5)	**Mean Species Richness**	**Mean Total Abundance***	**Shannon Diversity Index**
Very high (5)	2 +	100 +	2.5+
High (4)	1.5 - 2	75 – 100	1.5 – 2.5
Moderate (3)	1.25 – 1.5	50 – 75	1 – 1.5
Low (2)	1 - 1.25	25 - 50	0.5 – 1
Very low (1)	< 1	< 25	< 0.5

*Mean total abundance of individuals includes invertebrates, as well as lichens, birds, ground vegetation.

If this biodiversity scale was to be applied to this research, for example, the resulting biodiversity scores would be those represented in the table below. In this scenario, the biodiversity scoring system used the mean values of species richness and total abundance since each experiment had a different number of samples. This table could be adapted for use in the assessment of taxa communities of individual trees (regardless of species or site), which could be beneficial for use in urban planning and conservation within a city.

Table 44. This table represents the biodiversity scores given to each site, ranked from highest to lowest.

Sites	**Biodiversity Score**
Fitzgerald's Park	13
Kennedy Park	13
UCC Arboretum	11

Marina Street Trees	11
The Atlantic Pond	10
The Lee Fields	10

5.6 Potential Changes to the Methodology

There are several changes which could be made to the methodology of this research, which could aid in the achievement of some significant results which were not completed. An increased number of individuals (replicates) per tree species would increase the precision of the data. This would allow for the generation of potentially more comprehensive results pertaining to the taxa communities of different tree species. An assessment of native versus non-native tree species would be beneficial in an urban setting, as this type of research has been common previously in forest ecology research. This would generate an even better understanding of the type of tree species which would benefit the biodiversity of Cork city i.e., for the purpose of aiding Cork County Council and for urban development plans.

A lesser focus on microclimate data and canopy openness would have aided the research data. Considering the time and effort that was taken in the process of assessing these variables, it would have been more beneficial to increase the number of trees being surveyed, specifically in terms of tree species replicates (as mentioned above). This extra data would also have guided tree species data on a community-level. The microclimate data would benefit other more climate-focused research but was ultimately insignificant in the context of this experimental design and the findings. Reducing the number of variables being measured would allow for easier navigation of results pertaining to biotic communities across individual trees and urban settings.

There was a low representation of bird species at many sites, which is likely due to the timing of the experiments. The ‘point-count’ method used for recording bird species was conducted all throughout the summer months, as it was not possible to complete all bird observations before the end of the breeding season. An broader view of the bird species in Cork city would be aided by the assessment of bird diversity during the correct time of year. However, despite the low levels of abundance overall, there were 4 amber-listed bird species recorded several times in

this research. These included the House Sparrow, Herring Gull, Lesser Black-backed Gull and the Mallard.

5.7 Conclusions & Recommendations

In conclusion, this study supported the hypothesis that there is a wide range and abundance of species from various taxa harboured by Cork city's urban trees. The responses of biodiversity to urbanisation are complex, yet this study has shown that there is scope for enhanced biodiversity in cities in future. These urban trees include urban parks, urban green spaces such as the UCC campus, and individual trees in more commercial areas of the city. This information is important in the context of urban land management, planning, and policymaking. There were little to no differences found between urban tree species' ability to harbour other taxa overall. However, there was a significant difference in the taxa abundance recorded for each of the urban sites. In general, the 4 urban parks have shown the most similar lichen, bird, and vegetation composition to each other, when compared to UCC and the Marina street trees. The Marina and UCC taxa communities consistently have taxa communities which differ to the other sites (urban parks).

The diversity levels have been shown in the Shannon diversity indices which were calculated per site. All sites had a calculated H value greater than 2, indicating that there is a large number of species as well as a good level of evenness across all the urban sites surveyed in Cork city. UCC and Fitzgerald's Park are the only 2 sites which have a H value higher than 2.5. However, the results of a Chi-squared test have shown that there is no significant association between the calculated Shannon diversity indices and the type of urban site ($p=0.224$).

Although the taxa communities may be significantly different between the sites, each site has been shown to harbour very good levels diversity. My recommendation for urban land management involves the addition of a wider variety of different types of urban green spaces. The urban parks have the most similarities in taxa composition; thus, it would be beneficial to increase the number of street trees and alternative green spaces (besides urban parks). This would increase the complexity of the cork city urban habitat. Not only would this increase the abundance of different species present in Cork city, but there is also potential for increased connectivity amongst sites. Individual street trees are classified in this study as trees in more commercial

areas/surrounded by impervious surfaces. By increasing the number of street trees in these areas, the trees could potentially act as ‘ecological corridors’ in built-up areas. This could act to increase the variation in taxa communities in sites like the urban parks (which mainly have a similar community composition with each other) by increasing access from one urban green space to another for the biotic communities.

Cork City Council (2021) mentions in their ‘Cork City Green and Blue Infrastructure Plan’ that parks that are of low ecological value provide opportunity to enhance habitat structure and change the management plans. University campuses also provide many opportunities for the implementation of green spaces as well as having the added benefit of being near academics in the associated fields. Previous ecological studies have been conducted on universities globally, which have all demonstrated the capacity of university campuses to support biodiversity (Liu *et al.*, 2009).

The taxa data collected for each of the 102 trees surveyed as part of this research acts as a good baseline for the biodiversity supported by urban trees and green spaces in Cork city. This abundance data will benefit future urban planning and development in Cork city, as it provides a full set of information regarding the biodiversity in different urban sites or for individual trees within those sites. These data will be added to a data repository ‘Zenodo’ for future application. This data will also benefit the research community as a basis for future projects in Cork city and in other urban areas.

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What We Do Not Know: Cascades, Surprises, and Megadiversity Hot-Spots Figure 1. Biodiversity Is Both a Response Variable Affected by Global Change Drivers and

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8 Appendix

8.1 Microclimate

8.1.1 UCC Experiment A

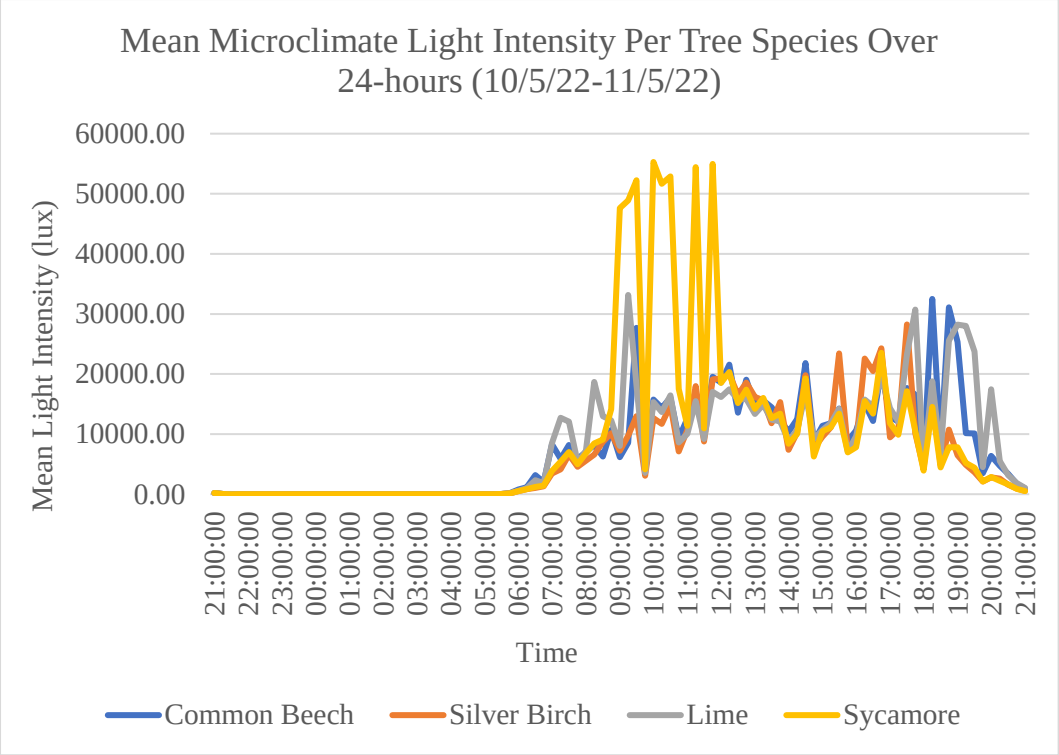


Figure 26. The mean light intensity recorded in the microclimate of each tree species using a HOBOware data logger. This temperature data was recorded for 24-hours between 10/05/22 and 11/05/22 on the UCC campus.

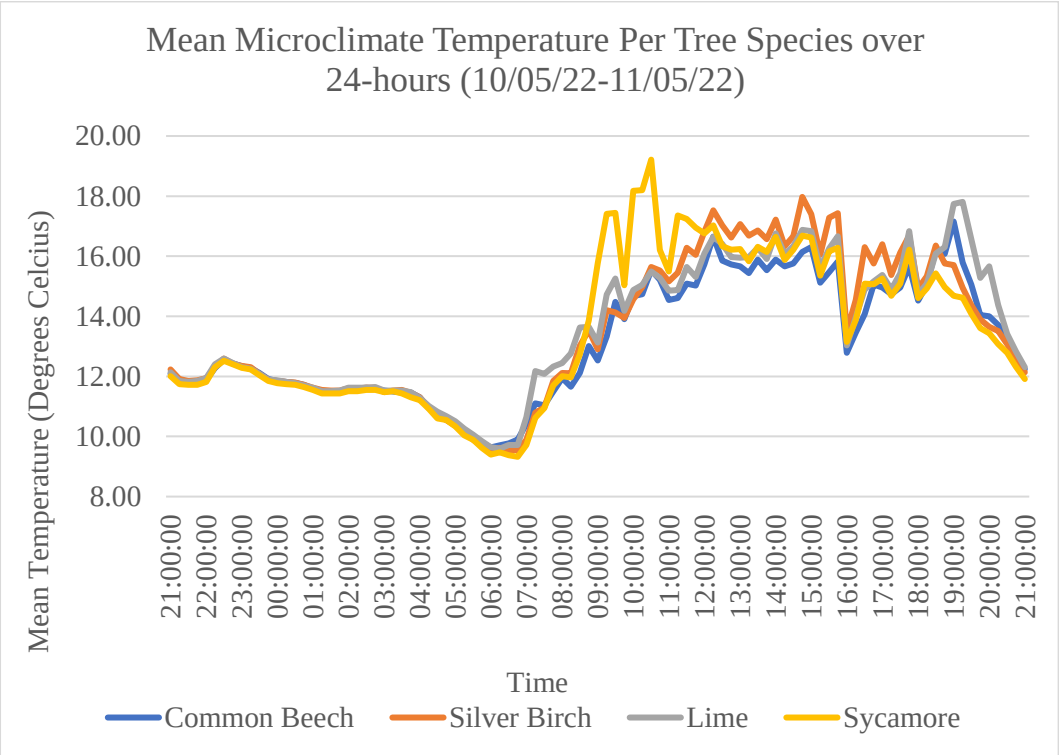


Figure 27. The mean temperature recorded in the microclimate of each tree species using a HOBOware data logger. This temeprature data was recorded for 24-hours between 10/05/22 and 11/05/22 on the UCC campus.

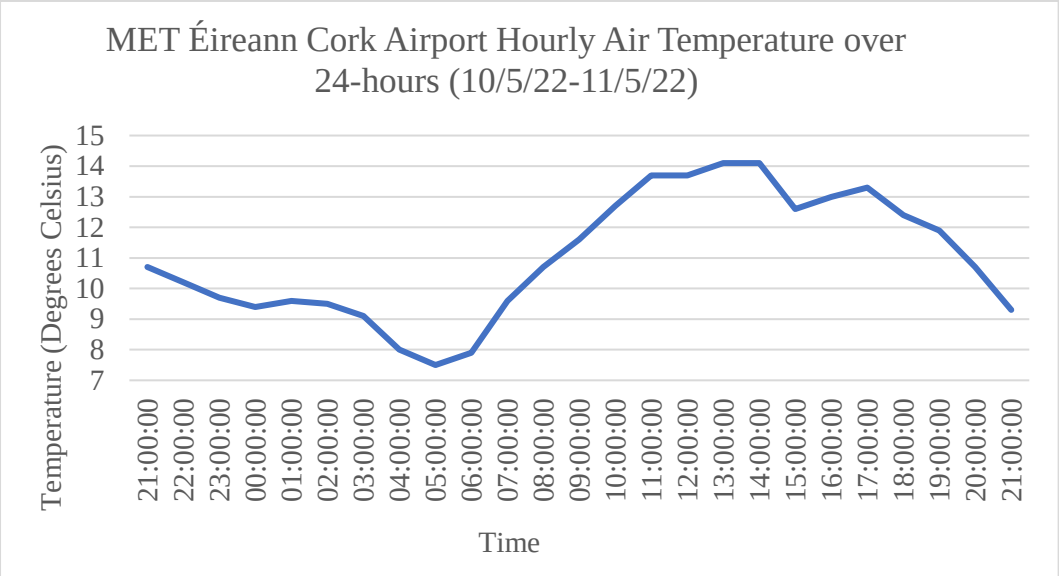


Figure 28. MET Éireann air temperature data recorded hourly at the Cork Airport weather station. This graph represents air temperature recorded between 9pm 10/5/22 and 9pm 11/5/22.

8.1.2 UCC Arboretum Experiment B

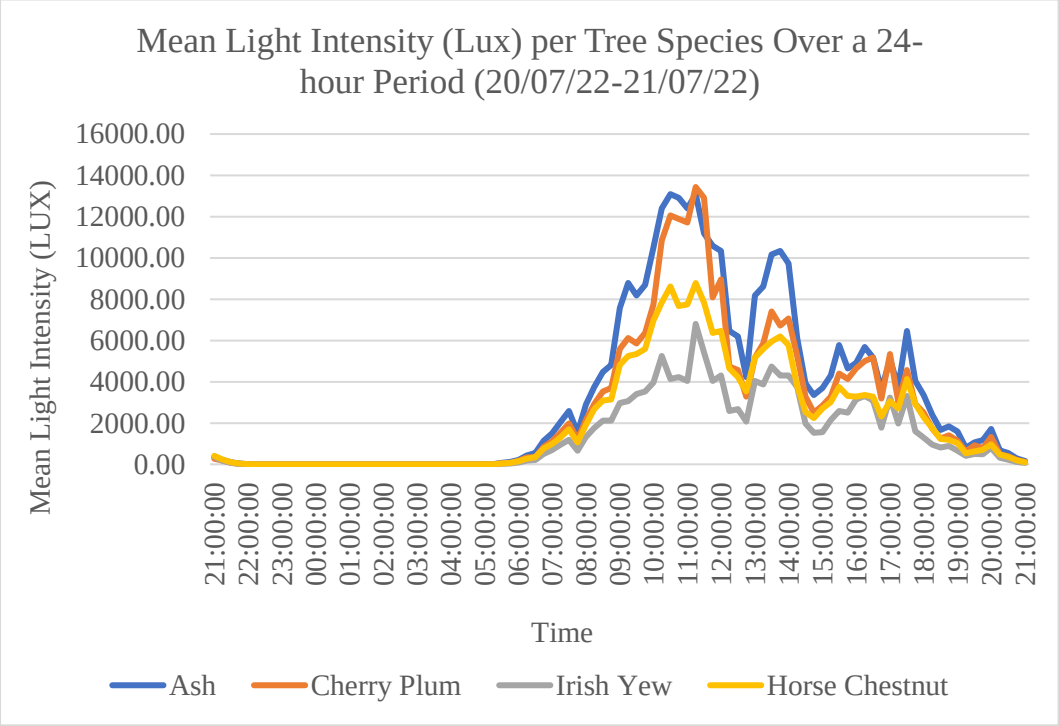


Figure 29. The mean light intensity recorded in the microclimate of each tree species over 24-hours. This data was recorded in 15-minute intervals between 9pm 20/7/22 and 9pm 21/7/22.

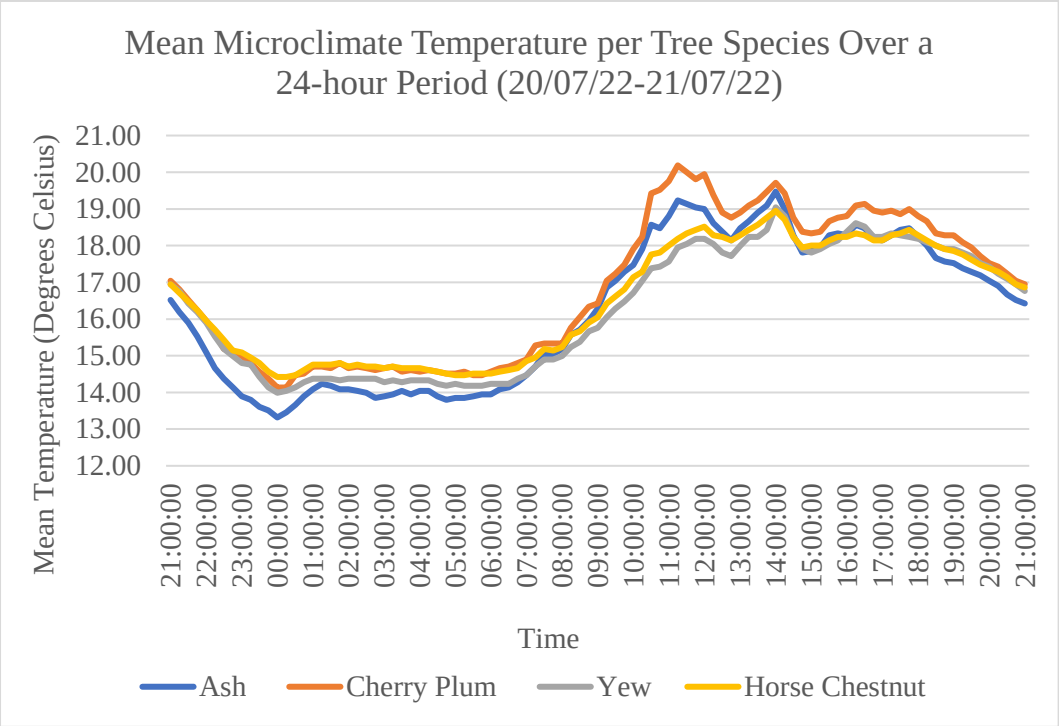


Figure 30. The mean temperature recorded in the microclimate of each tree species over 24-hours. This data was recorded in 15-minute intervals between 9pm 8/9/22 and 9pm 9/9/22.

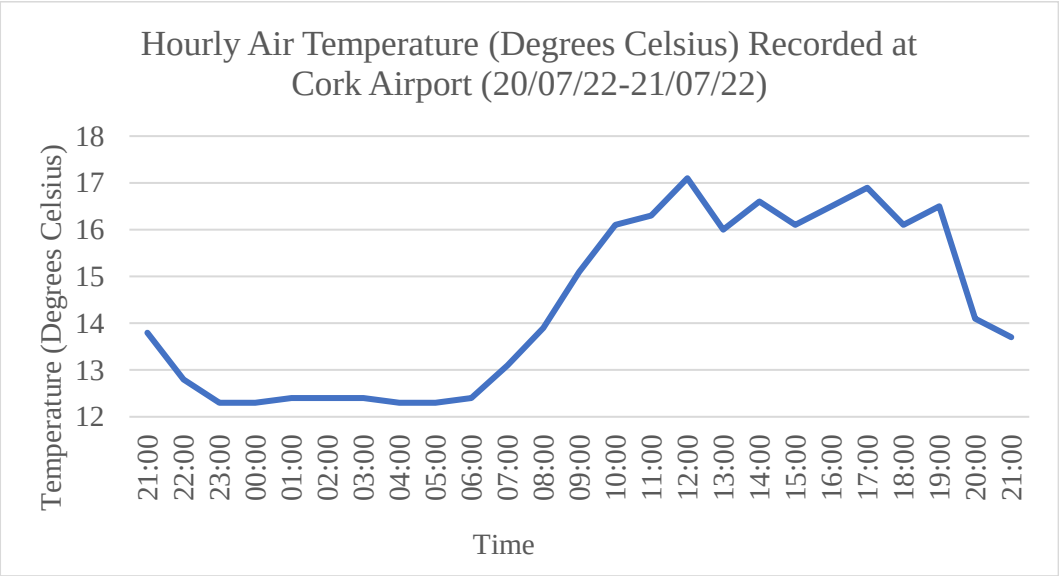


Figure 31. The hourly air temperature (Degrees Celsius) recorded at the MET Éireann Cork Airport weather station between 9pm 20/07/22 and 9pm 21/07/22.

8.1.3 UCC Arboretum Experiment C

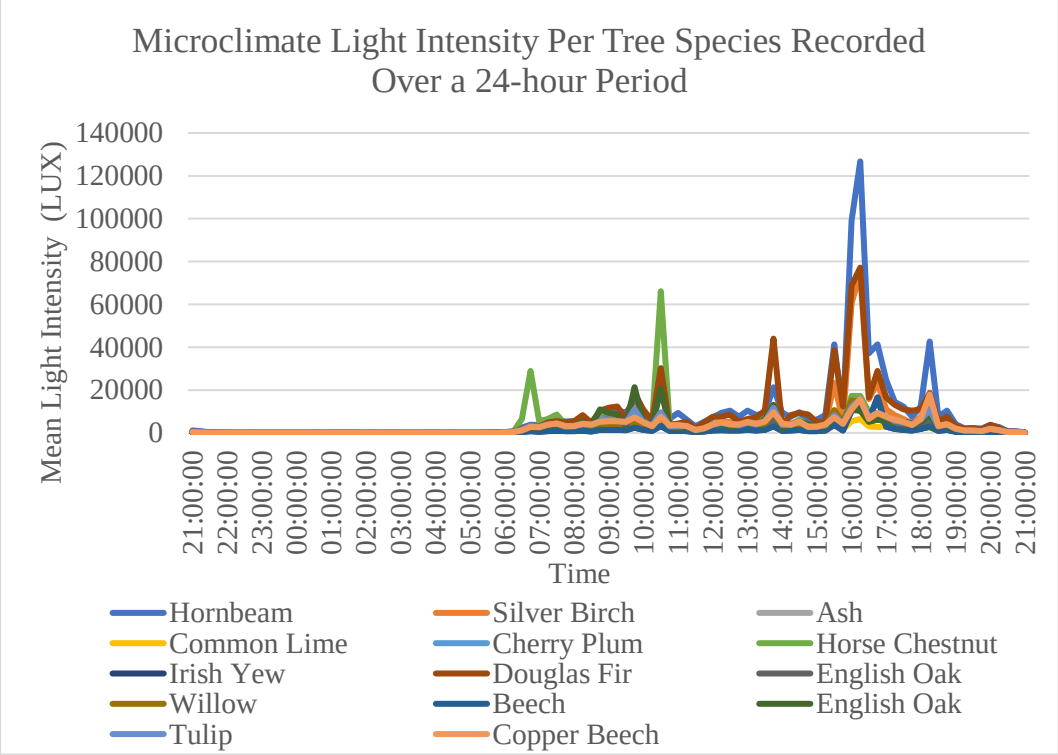


Figure 32. The light intensity (lx) recorded in the microclimate of each tree species in 15-minute intervals over a 24-hour period. This study was conducted between 9pm 18/07/22 and 9pm 29/07/22.

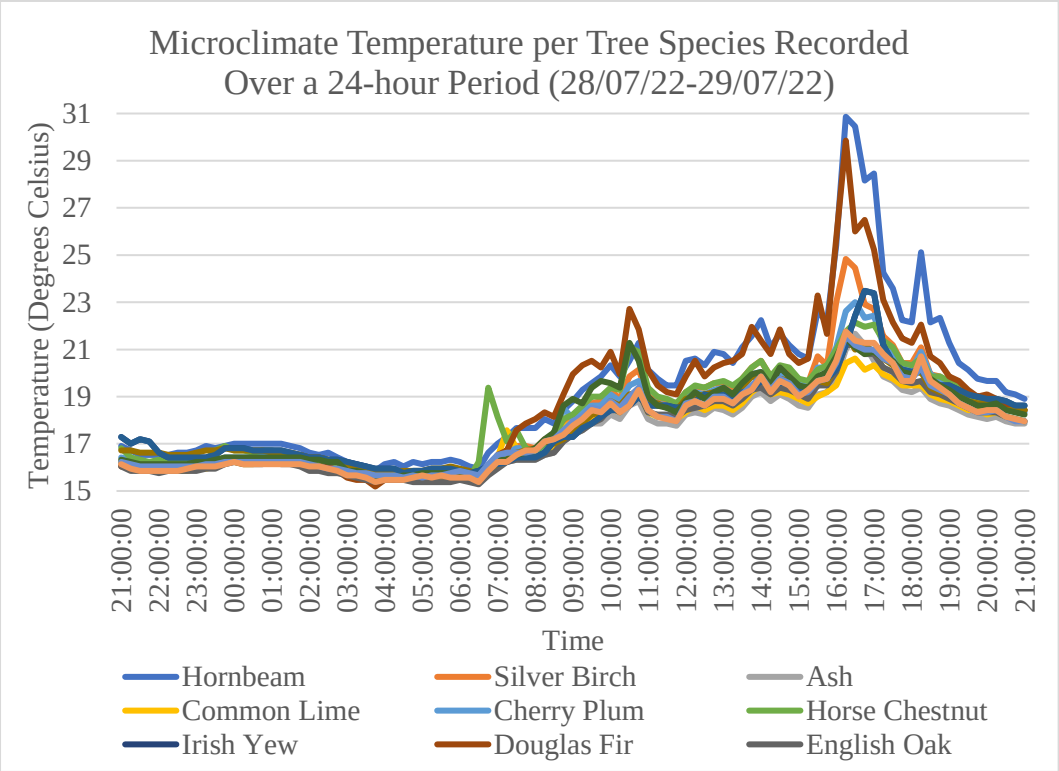


Figure 33. The temperature (degrees Celcius) recorded in the microclimate of each tree species in 15-minute intervals over a 24-hour period. This study was conducted between 9pm 28/07/22 and 9pm 29/07/22.

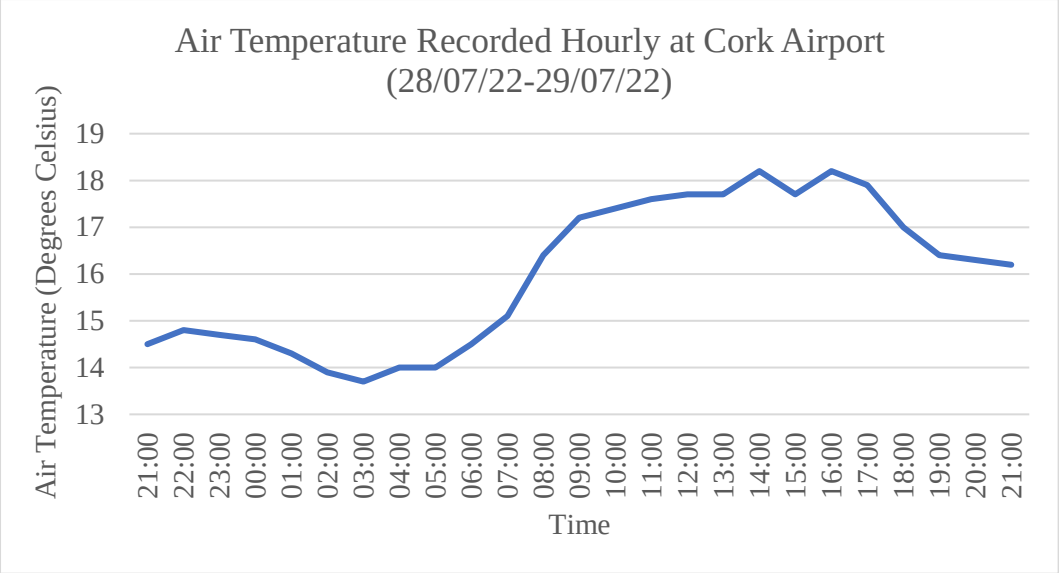


Figure 34. Hourly air temperature (Degrees Celsius) recorded by MET Éireann in the Cork Airport weather station between 9pm 28/07/22 and 9pm 29/07/22.

8.1.4 Marina Street Trees Experiment A

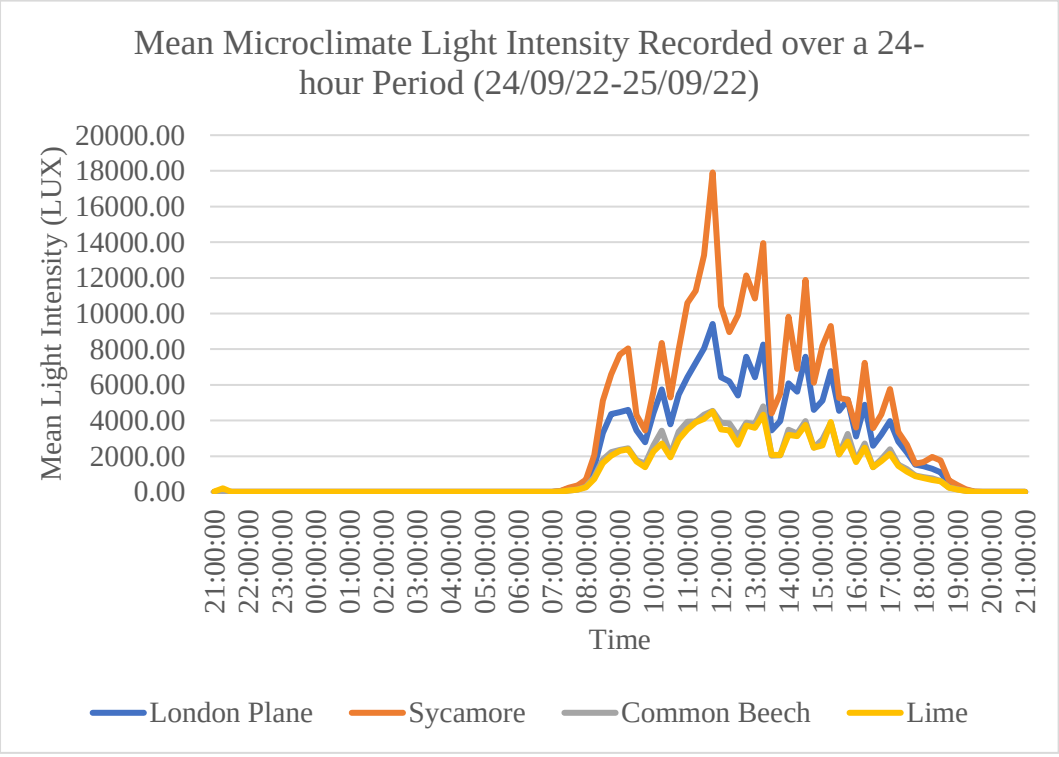


Figure 35. The mean light intensity (Lux) recorded in the microclimate of each tree species in 15-minute intervals over a 24-hour period. This study was conducted between 9pm 24/09/22 and 9pm 25/09/22.

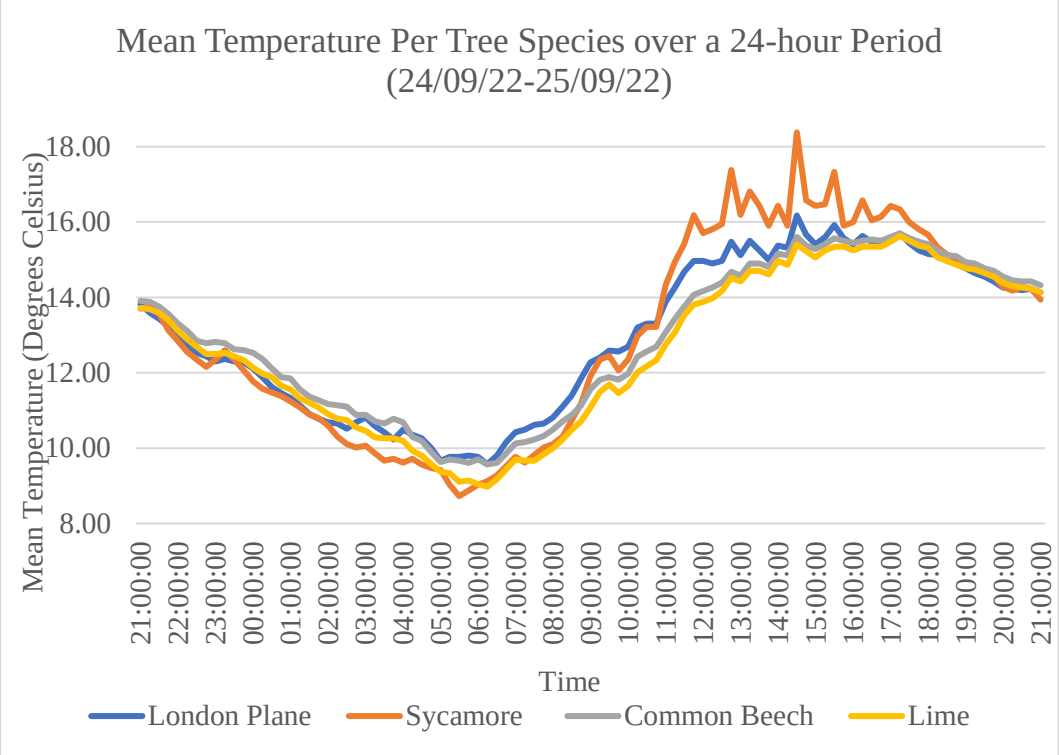


Figure 36. The mean temperature recorded in the microclimate of each tree species in 15-minute intervals over a 24-hour period. This study was conducted between 9pm 24/09/22 and 9pm 25/09/22.

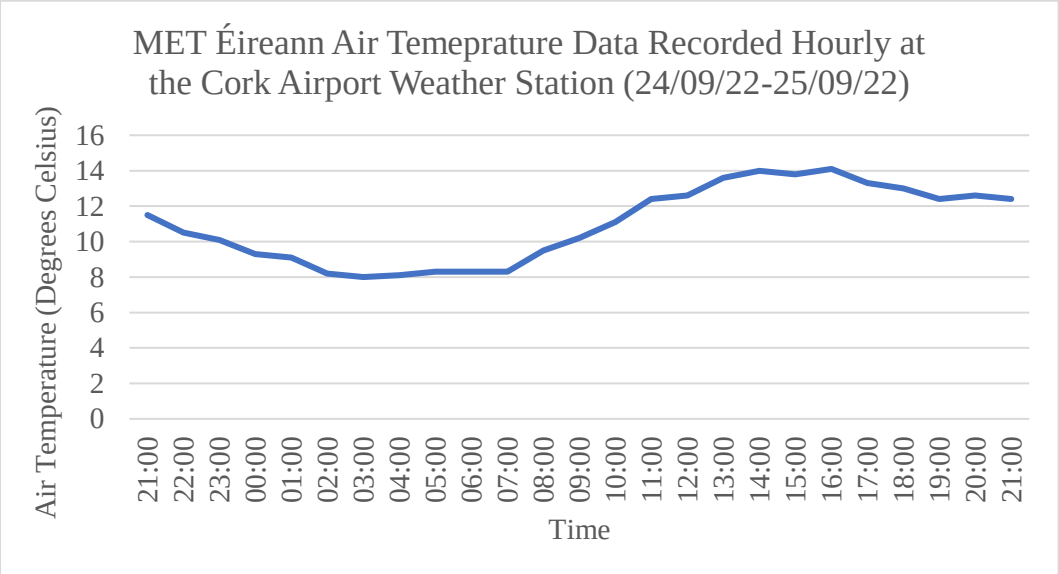


Figure 37. Hourly air temperature recorded by MET Éireann at the Cork Airport weather station over a 24-hour period (24th-25th September 2022).

8.1.5 Marina Street Trees Experiment B

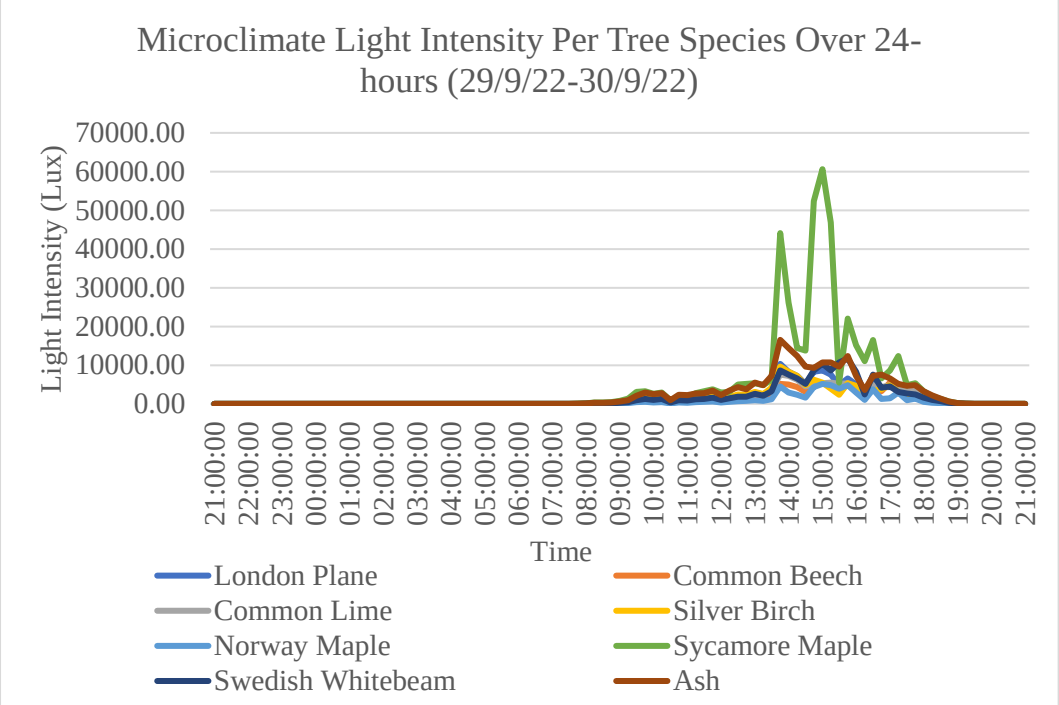


Figure 38. Light Intensity recorded in the microclimate of each tree species over 24-hours. This data was recorded in 15-minute intervals between 9pm 29/9/22 and 9pm 30/9/22.

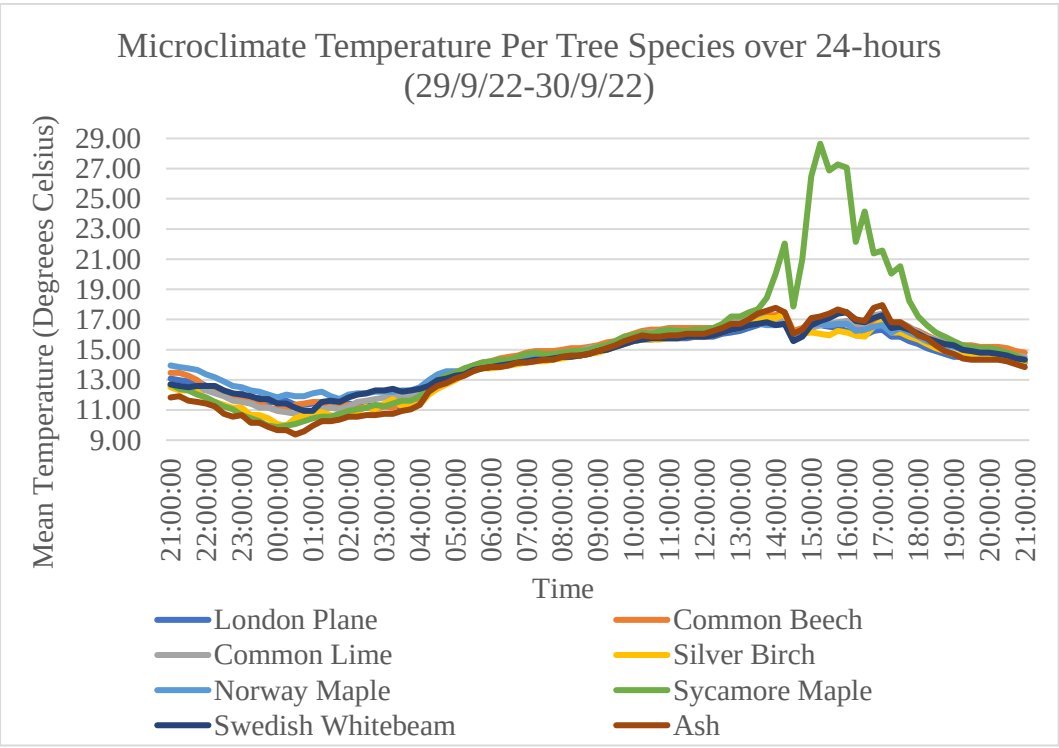


Figure 39. The temperature recorded in the microcliamte of each tree species over 24-hours. This data was recorded in 15-minute intervals between 9pm 29/09/22 and 30/09/22.

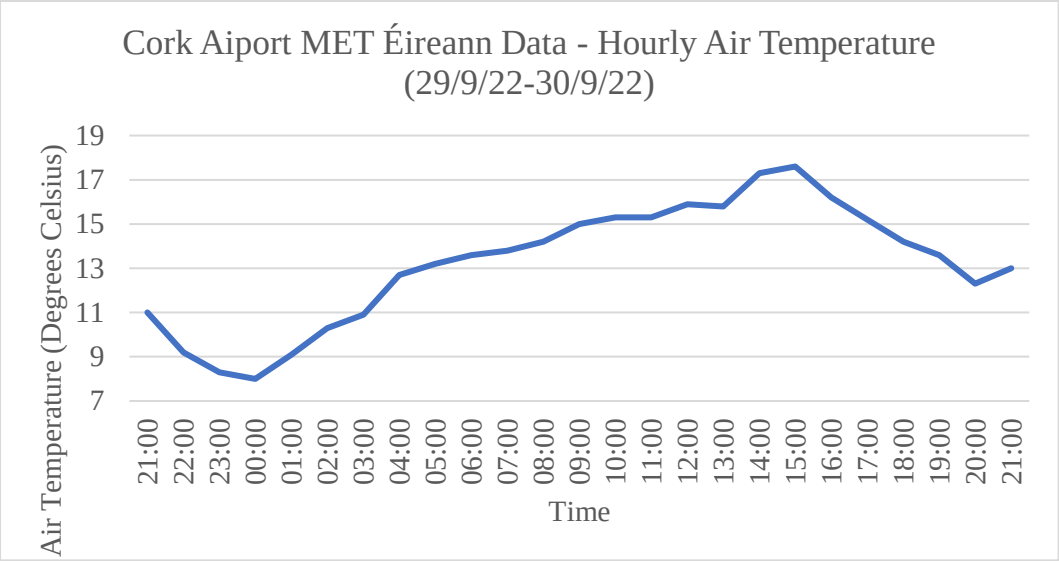


Figure 40. MET Éireann air temperature data recorded at the Cork Airport weather station over 24-hours. This graph represents data recorded hourly between 9pm 29/9/22 and 9pm 30/9/22.

8.1.6 The Atlantic Pond Experiment A

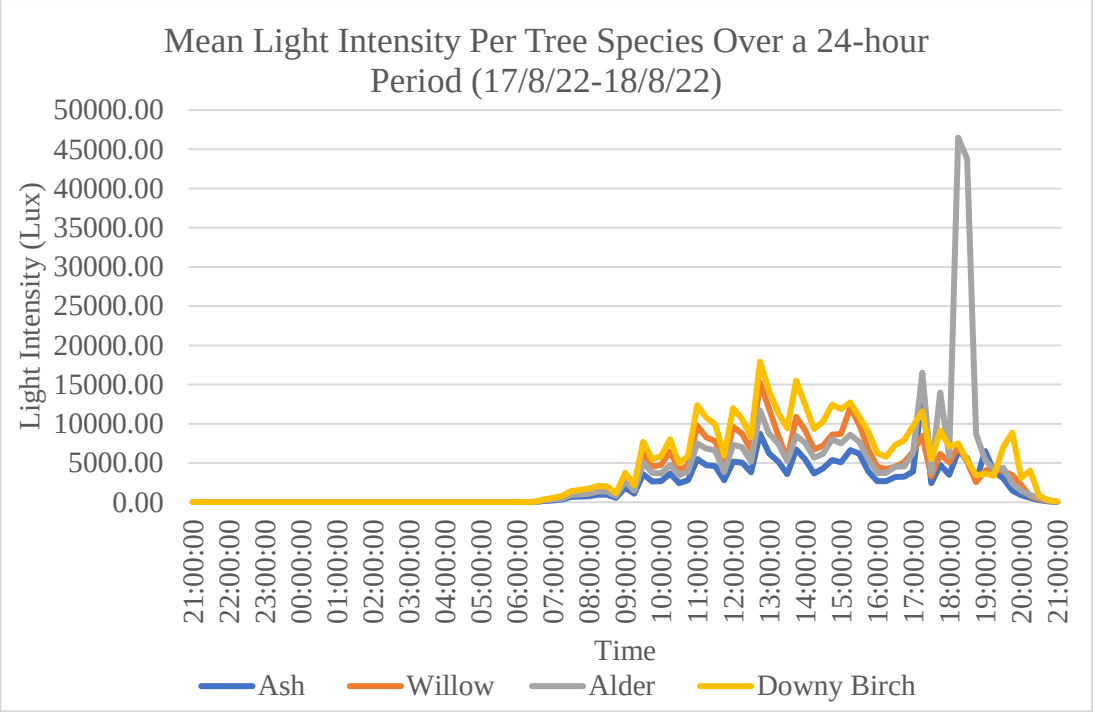


Figure 41. Mean light intensity (lx) recorded in the microclimate of each tree species over 24-hours. This data was recorded in 15-minute intervals between 9pm 17/8/22 and 9pm 18/8/22.

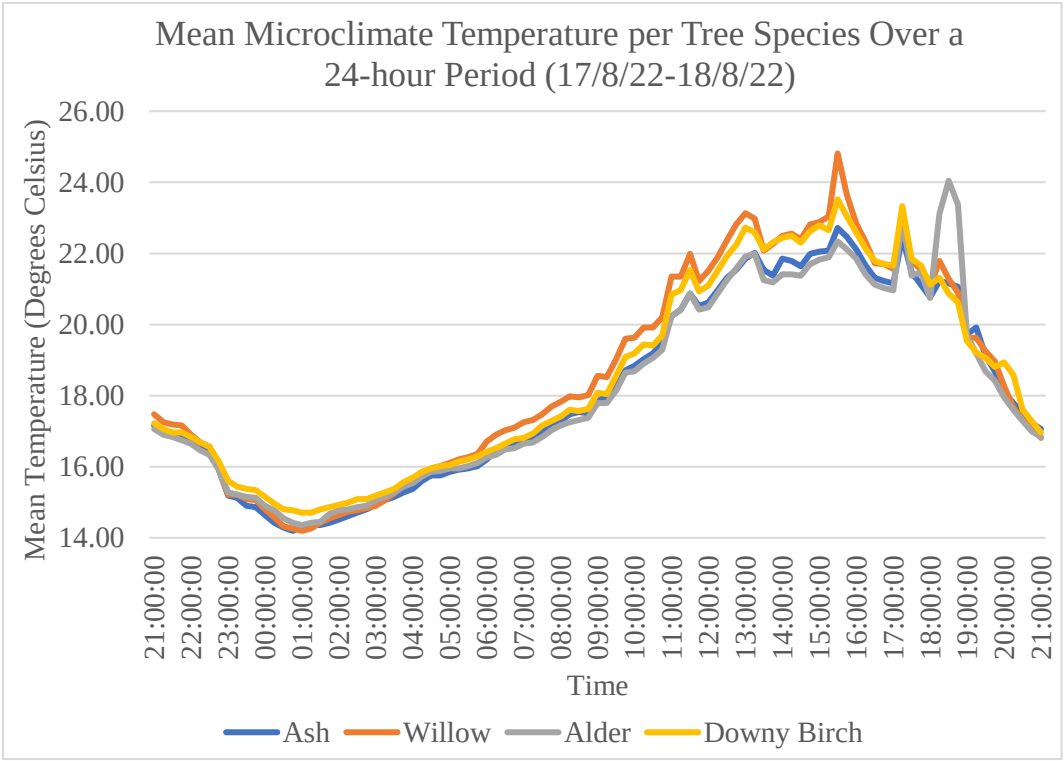


Figure 42. Mean temperature recorded in the microclimate of each tree species over 24-hours in the Atlantic Pond urban park. This data was recorded in 15-minute intervals between 9pm 17/8/22 and 9pm 18/8/22.

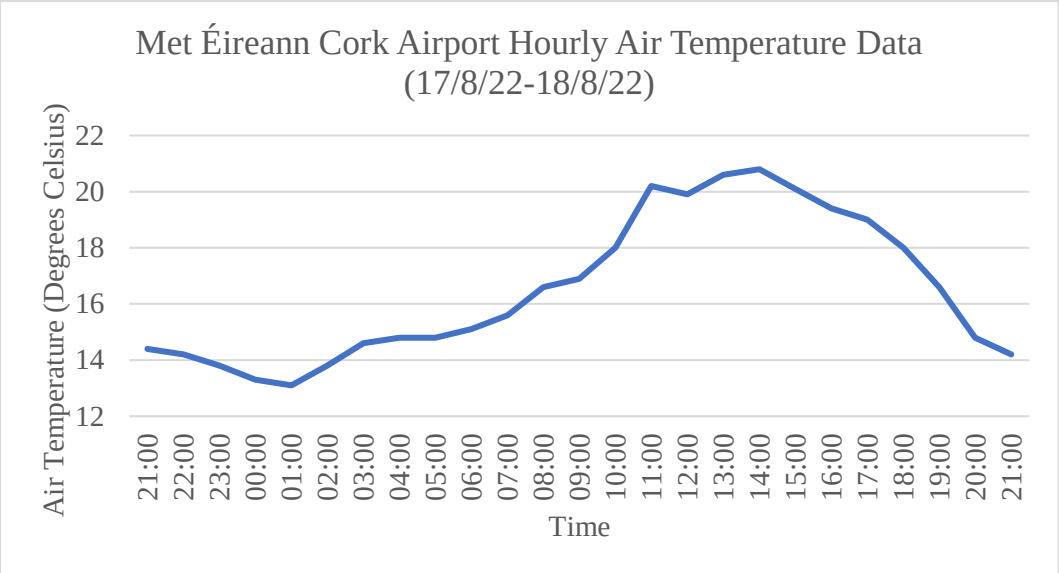


Figure 43. MET Éireann air temperature data recorded at the Cork Airport weather station. This graph represents the temperature data recorded hourly over 24-hours, between 9pm 17/8/22 and 9pm 18/8/22.

8.1.7 The Atlantic Pond Experiment B

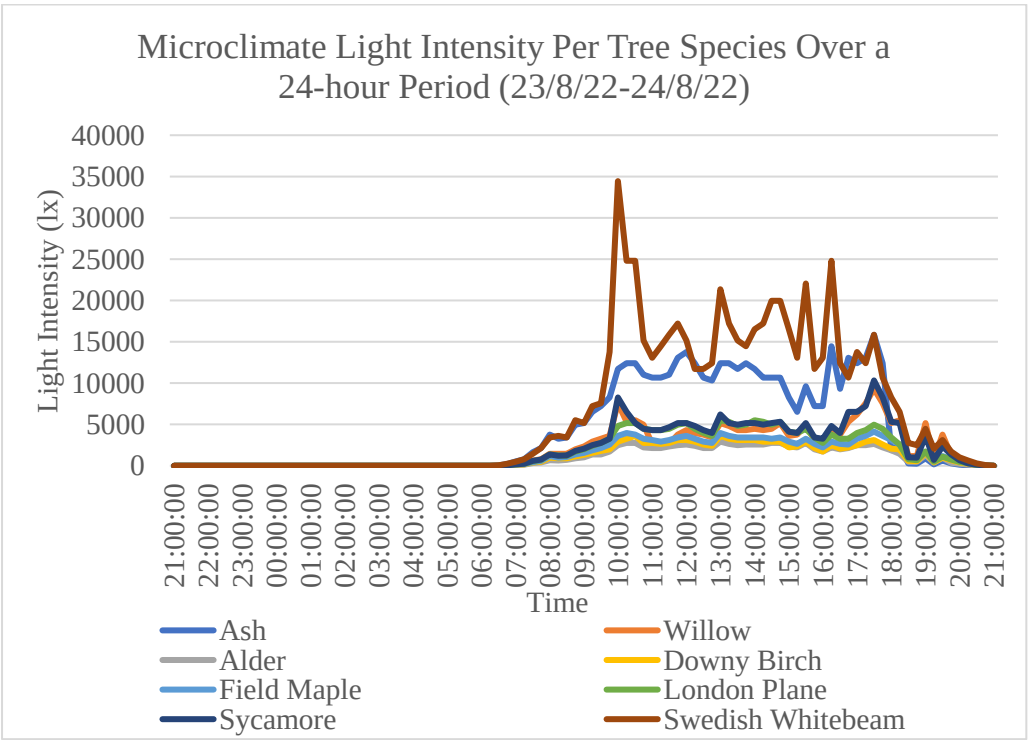


Figure 44. The light intensity recorded in the microclimate of each tree species. This data was recorded in 15-minute intervals for 24-hours.

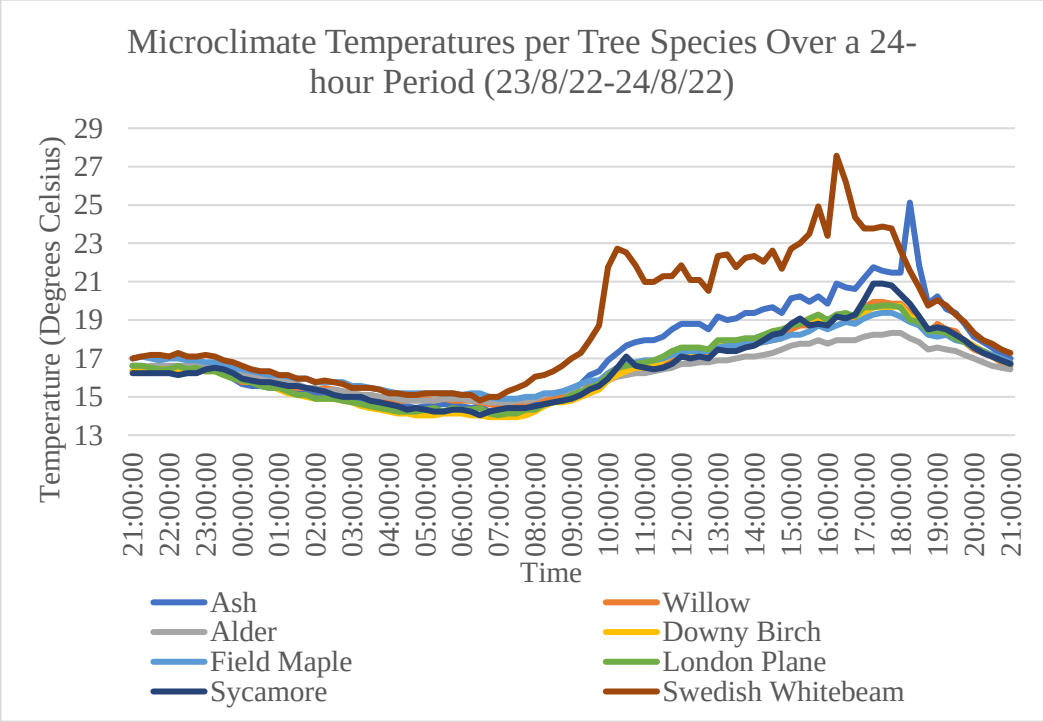


Figure 45. The microclimate temperature data recorded in 15-minute intervals over 24-hours between 28/8/22 and 24/8/22.

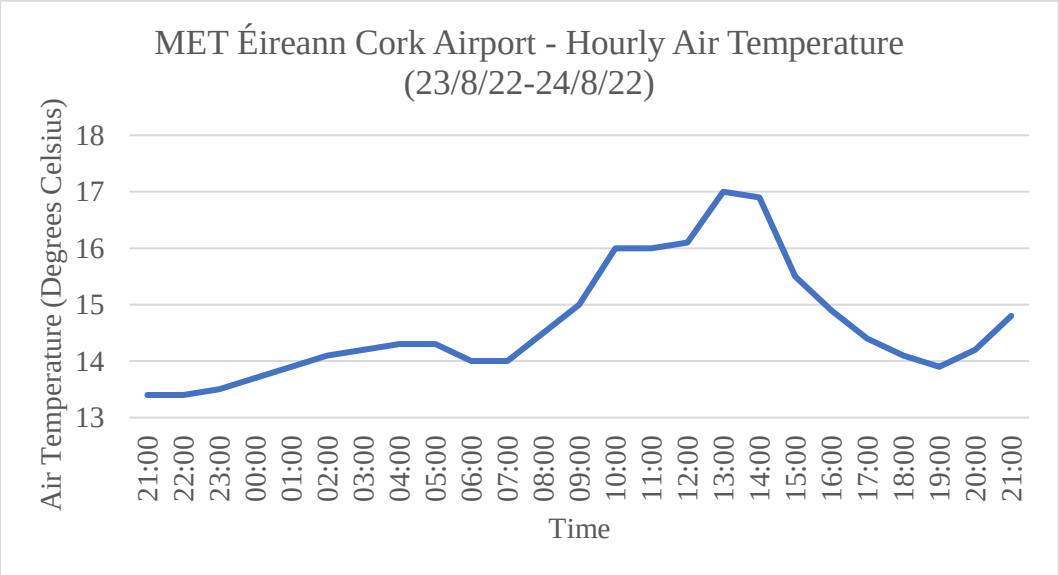


Figure 46. The MET Éireann Cork Airport weather station air temperature data recorded hourly between 9pm 23/8/22 and 9pm 24/8/22.

8.1.8 Kennedy Park Experiment A

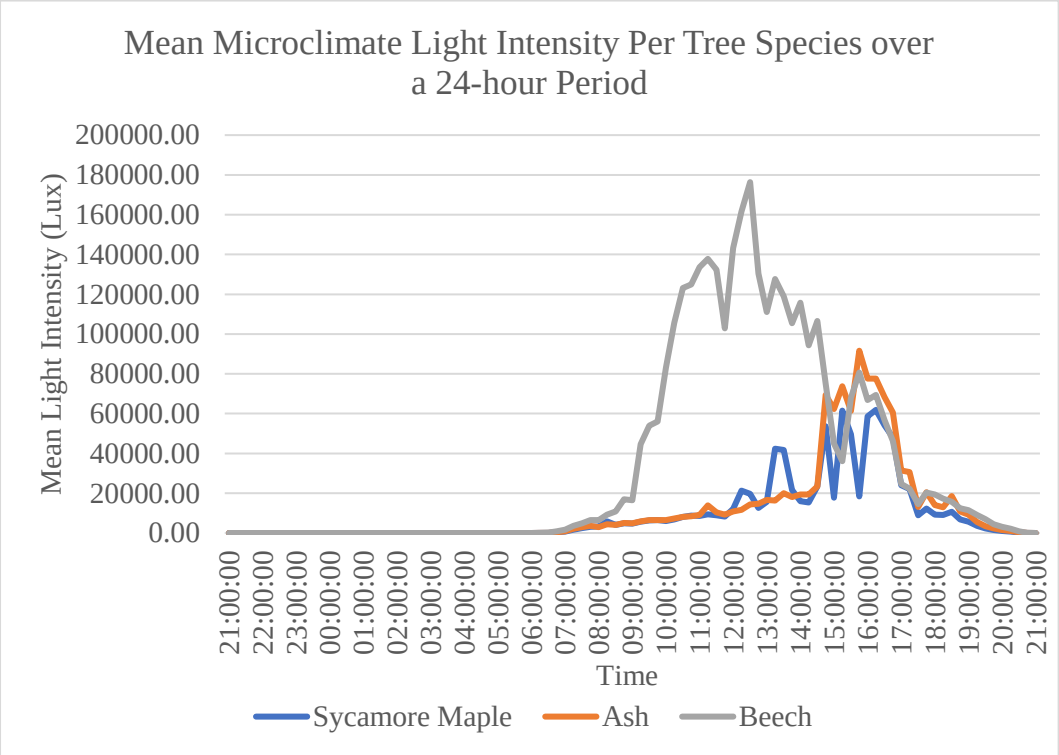


Figure 47. Mean light intensity (lx) recorded in the microclimate of each of the 3 tree species over 24-hours in Kennedy Park. This data was recorded in 15-minute intervals between 9pm 26/8/22 and 9pm 27/8/22.

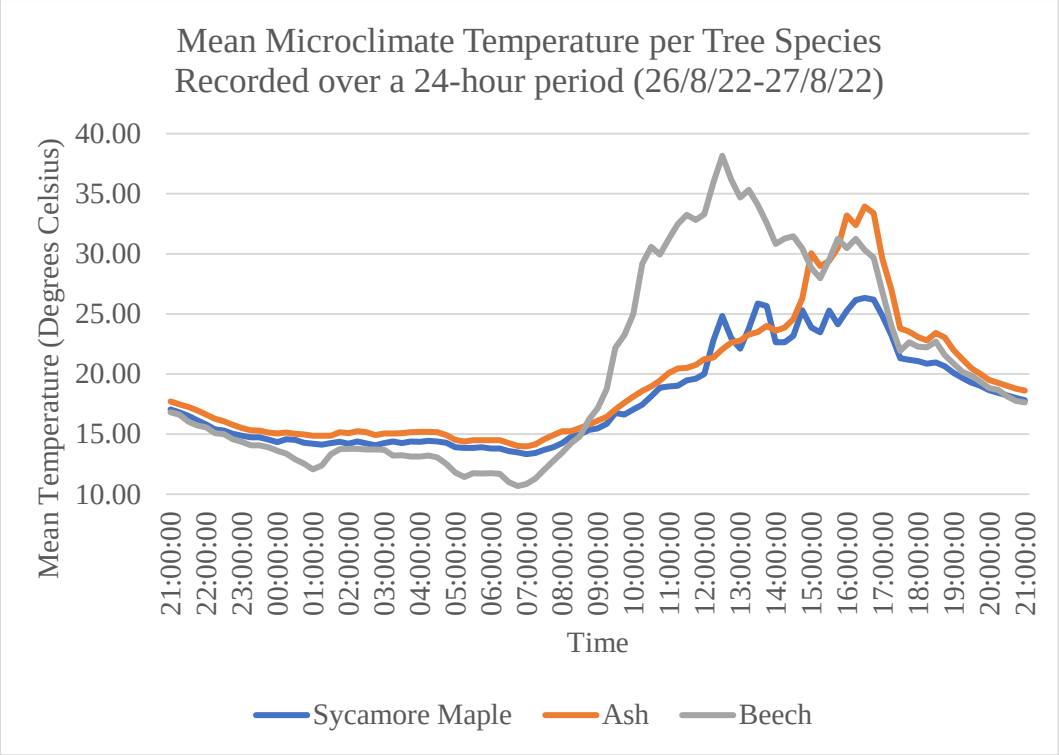


Figure 48. Mean temperature (degrees Celsius) recorded in the microclimate of each of the 3 tree species over 24-hours in Kennedy Park. This data was recorded in 15-minute intervals between 9pm 26/8/22 and 9pm 27/8/22.

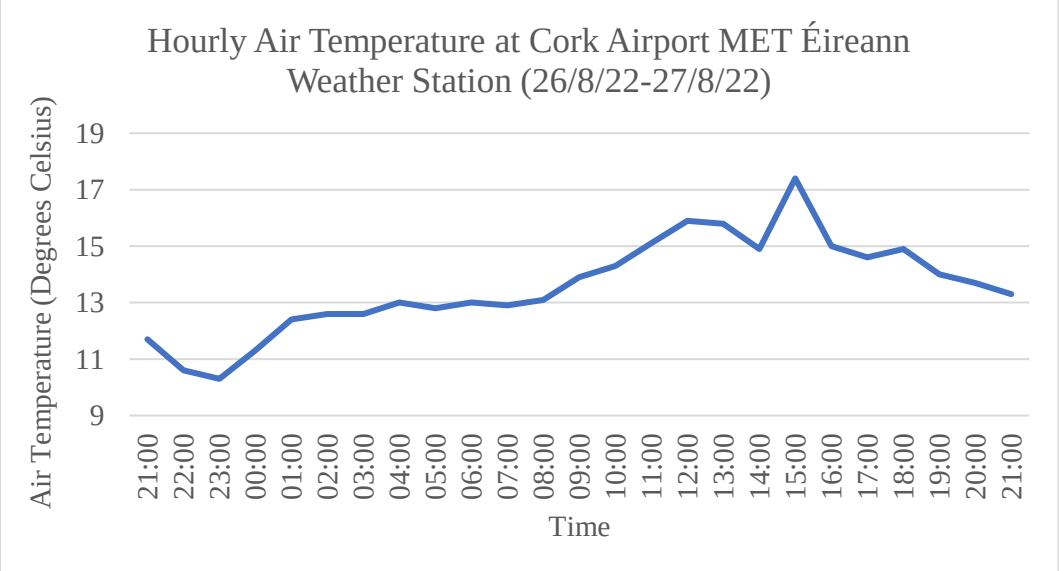


Figure 49. MET Éireann air temperature data recorded hourly at the Cork Airport weather station. This graph is the data recorded between 9pm 26/8/22 and 9pm 27/8/22.

8.1.9 Kennedy Park Experiment B

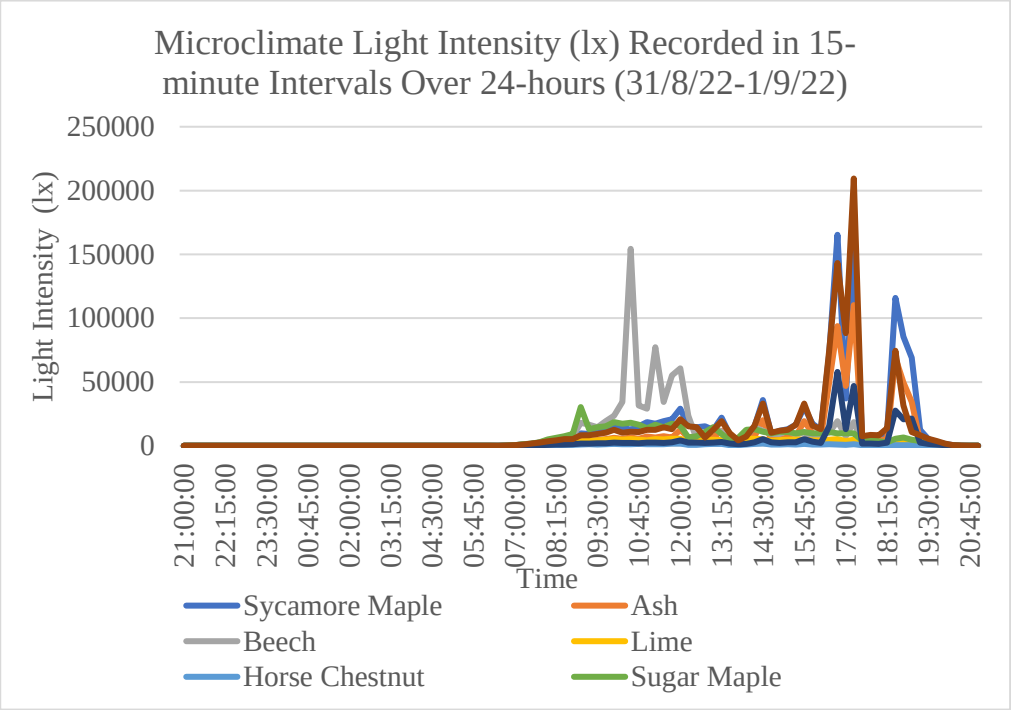


Figure 50. The light intensity (lx) recorded in the microclimate of each tree species over 24-hours. This data was recorded in 15-minute intervals between 9pm 31/8/22 and 9pm 1/9/22.

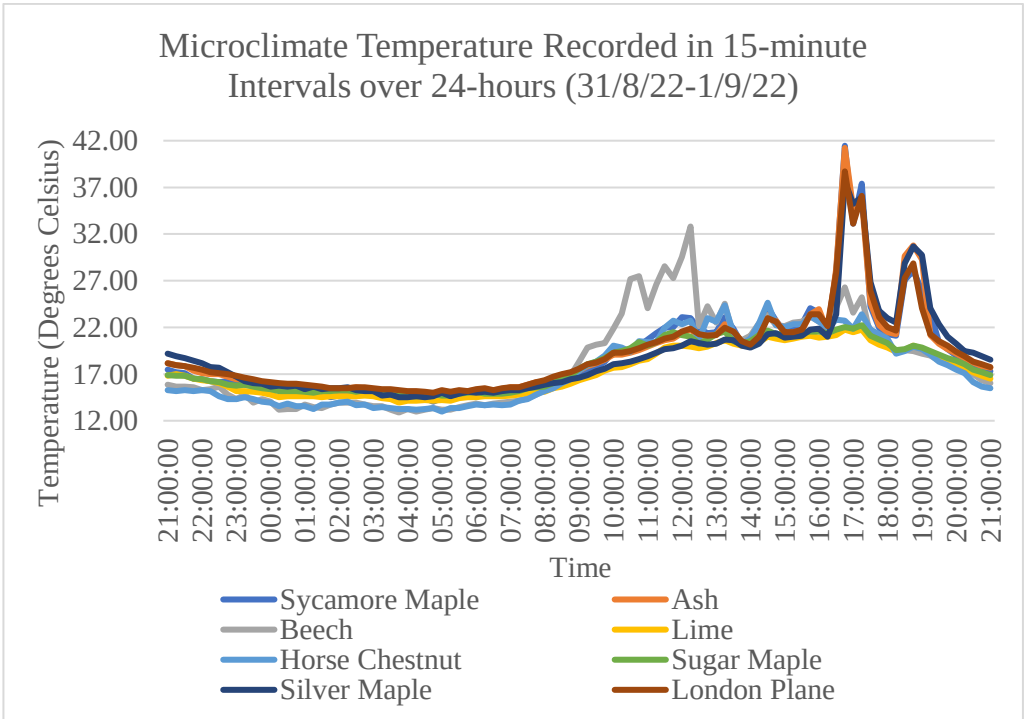


Figure 51. The temperature recorded in the microclimate of each tree species over 24-hours. This data was recorded in 15-minute intervals between 9pm 31/8/22 and 9pm 1/9/22.

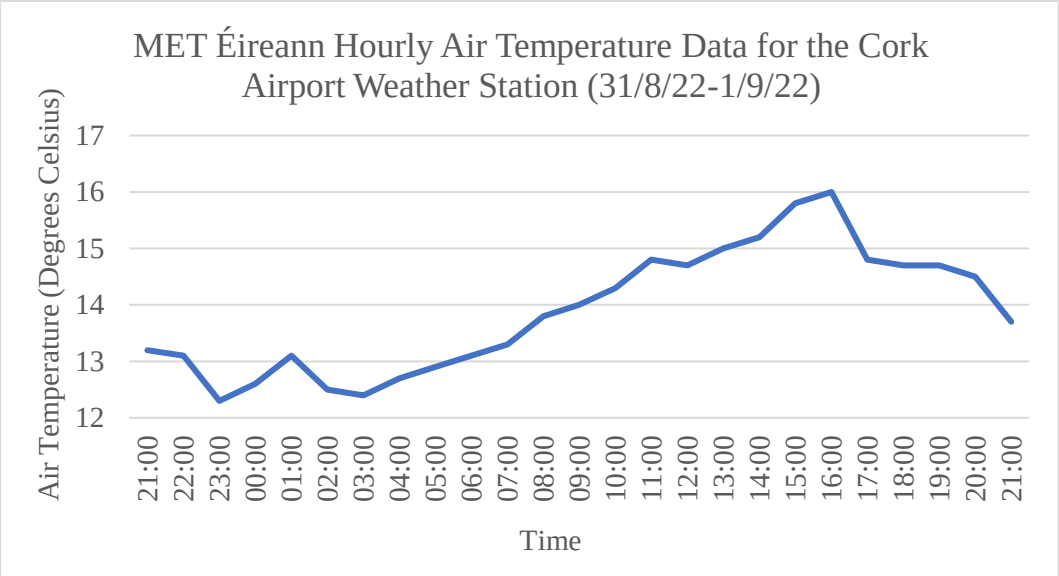


Figure 52. Historical MET Éireann Cork Airport air temperature. This graph represents the data recorded hourly between 9pm 31/8/22 and 9pm 1/9/22.

8.1.10 The Lee Fields Experiment A

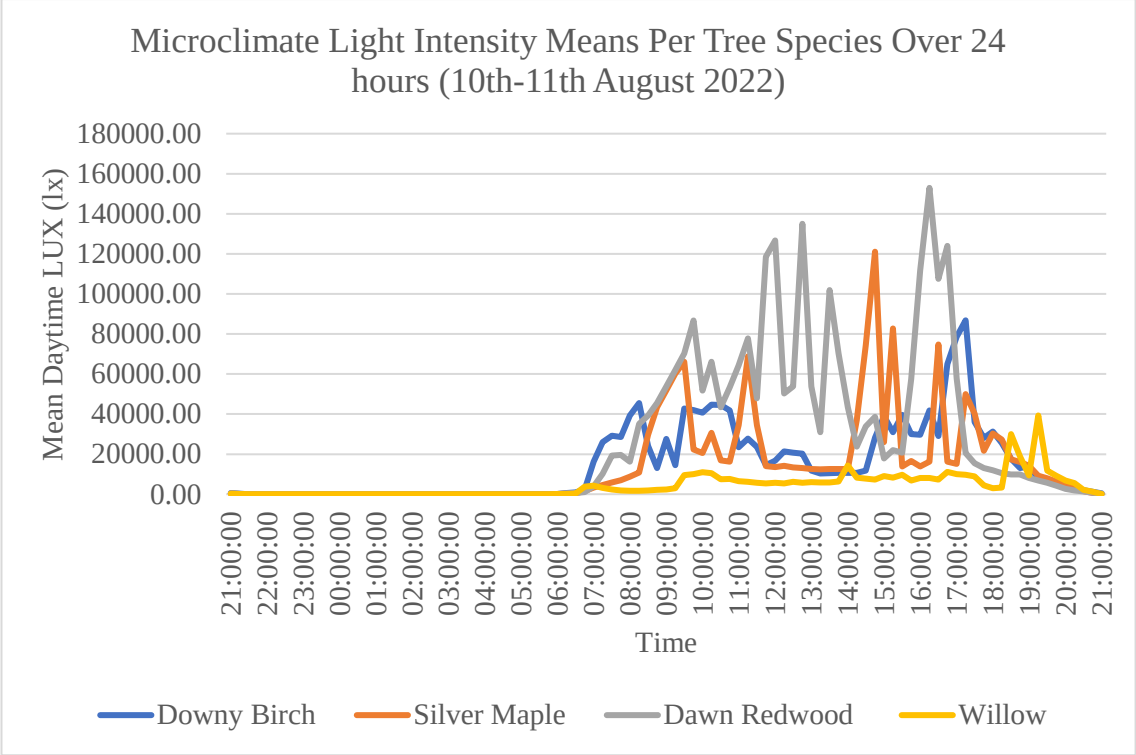


Figure 53. Mean microclimate light intensity (lx) of each tree species recorded every 15 minutes between 9pm 10/8/22 and 9pm 11/8/22.

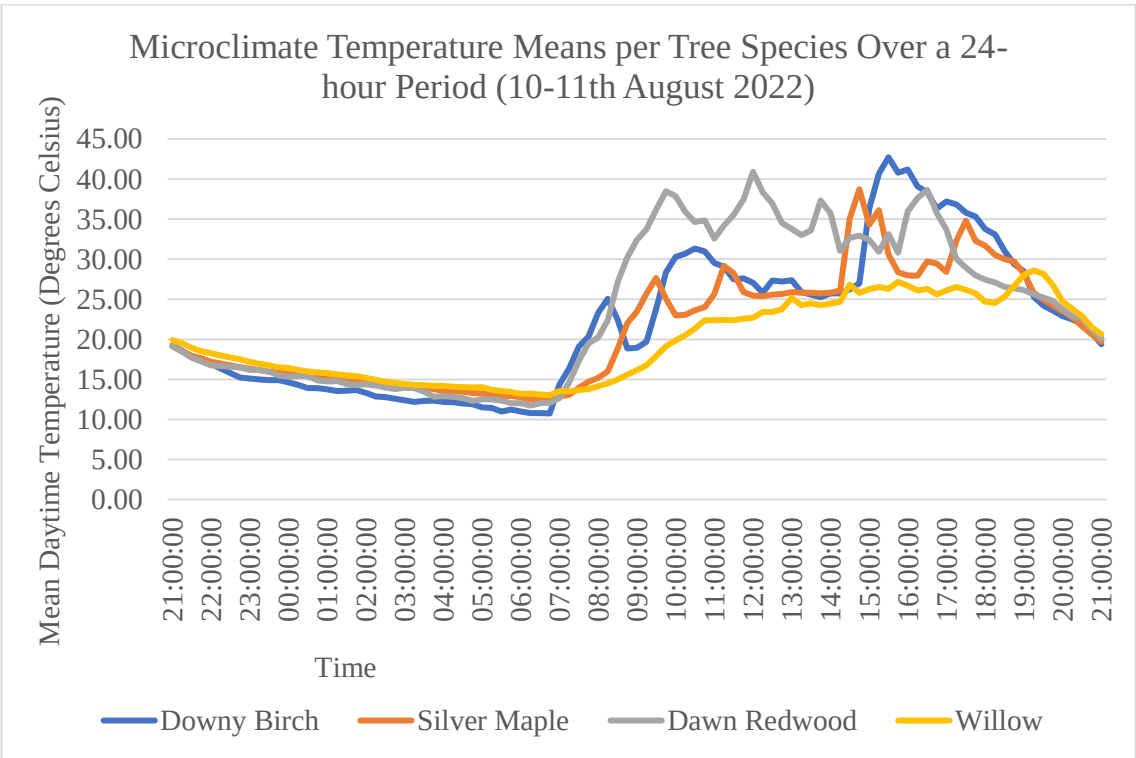


Figure 54. Mean Microclimate temperatures of each tree species recorded every 15 minutes between 9pm 10/8/22 and 11/8/22.

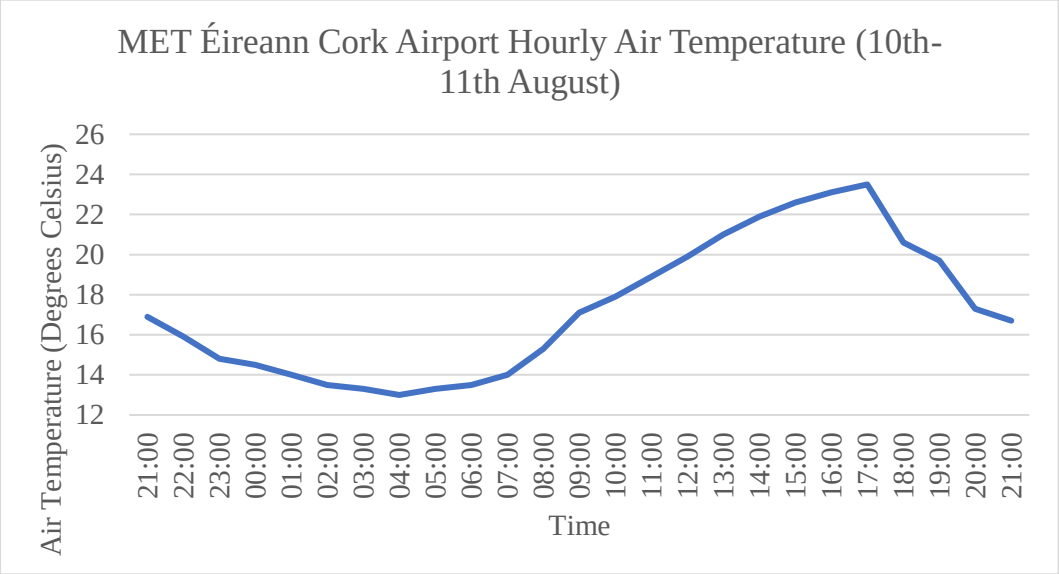


Figure 55. The hourly air temperature (degrees Celsius) recorded by MET Éireann at the Cork Airport weather station between 9pm 10/8/22 and 9pm 11/8/22.

8.1.11 The Lee Fields Experiment B

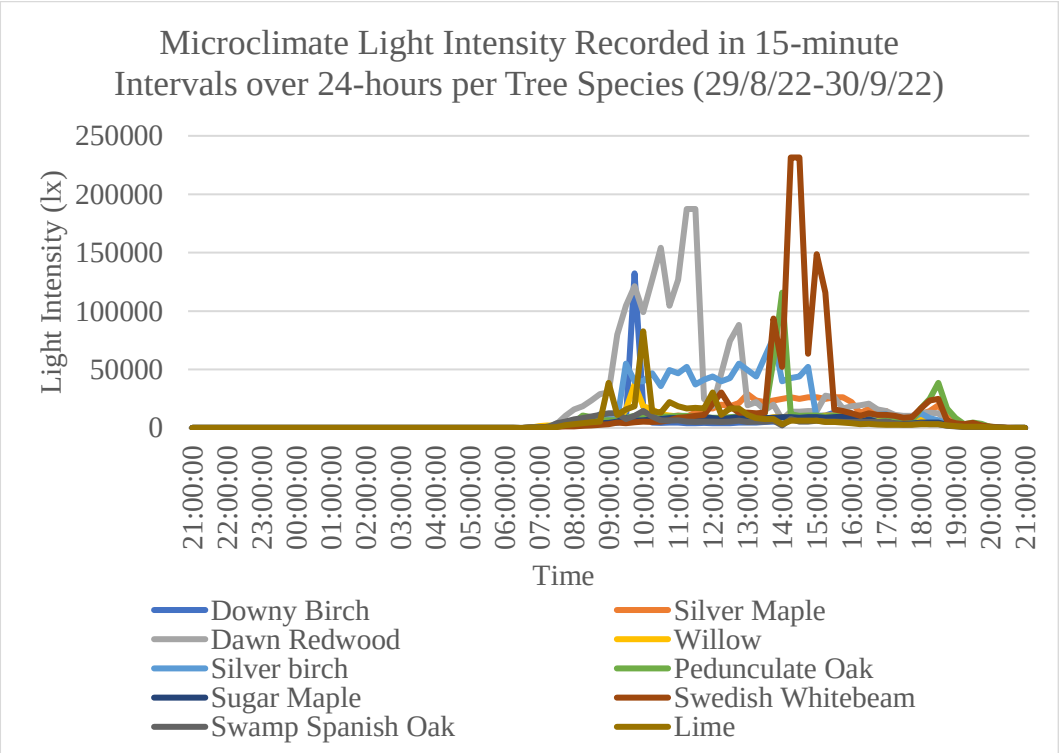


Figure 56. Light intensity data recorded in the microclimate of each tree species over 24-hours. This data was recorded in 15-minute intervals between 9pm 29/8/22 and 9pm 30/8/22.

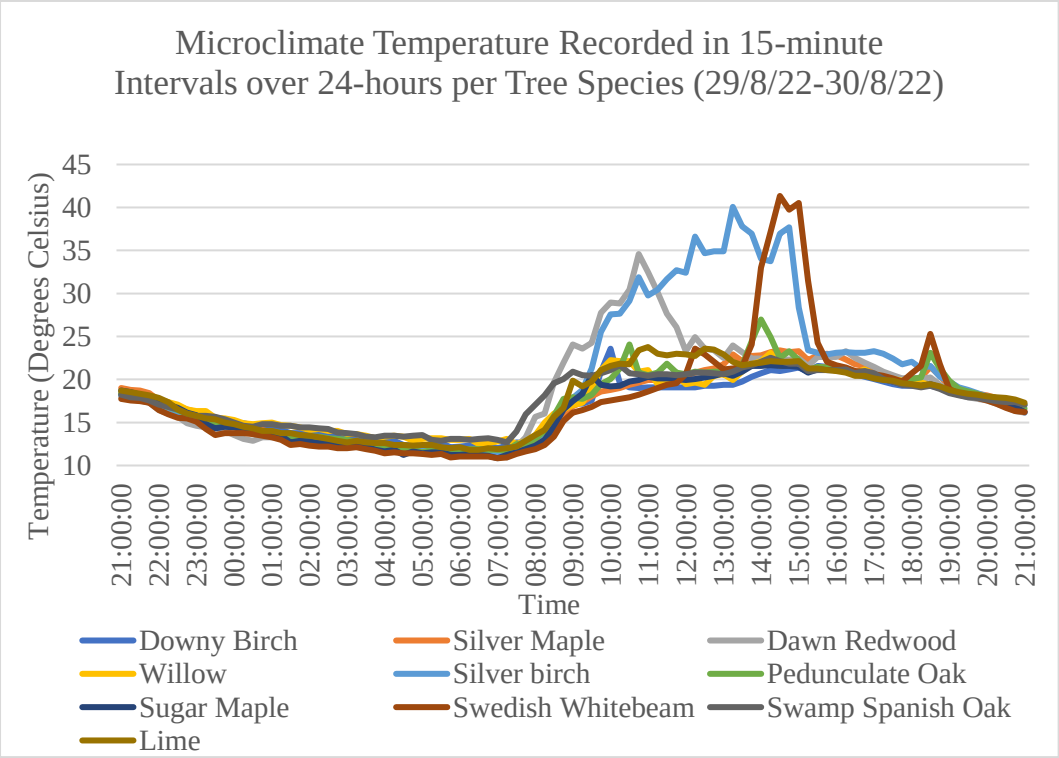


Figure 57. The temperature in the microclimate of each tree species, recorded over 24-hours. This data was recorded in 15-minute intervals between 9pm 29/8/22 and 9pm 30/8/22.

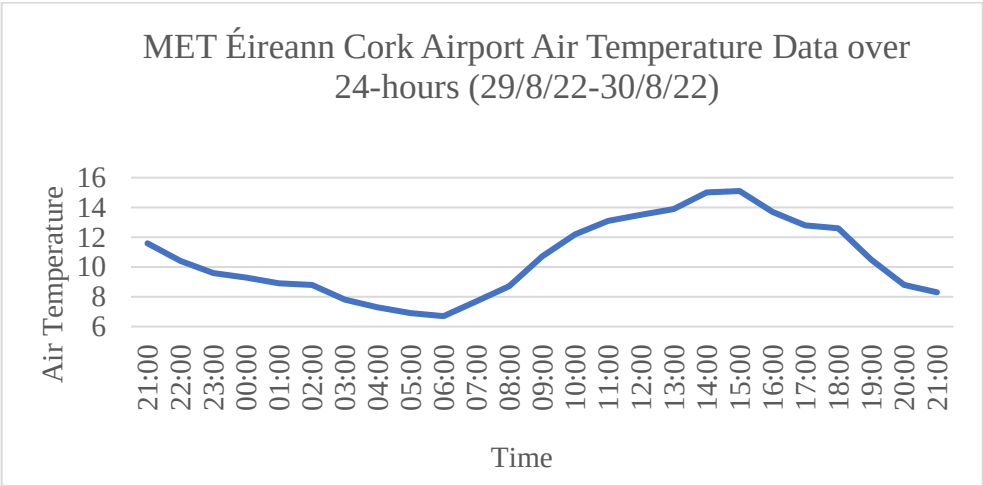


Figure 58. Historical hourly air temperature data recorded in the Cork Airport MET Éireann weather station. This graph represents data between taken 9pm 29/8/22 and 9pm 30/8/22.

8.1.12 Fitzgerald's Park Experiment A

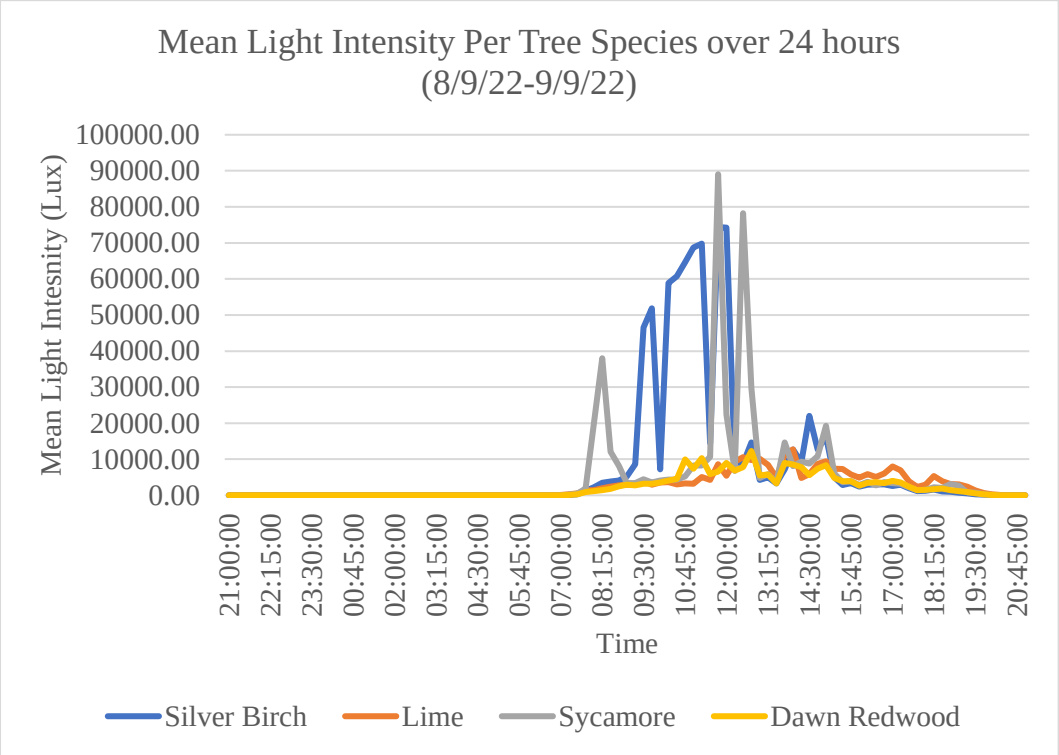


Figure 59. The mean light intensity recorded in the microclimate of each tree species over 24-hours. This data was recorded in 15-minute intervals between 9pm 8/9/22 and 9pm 9/9/22.

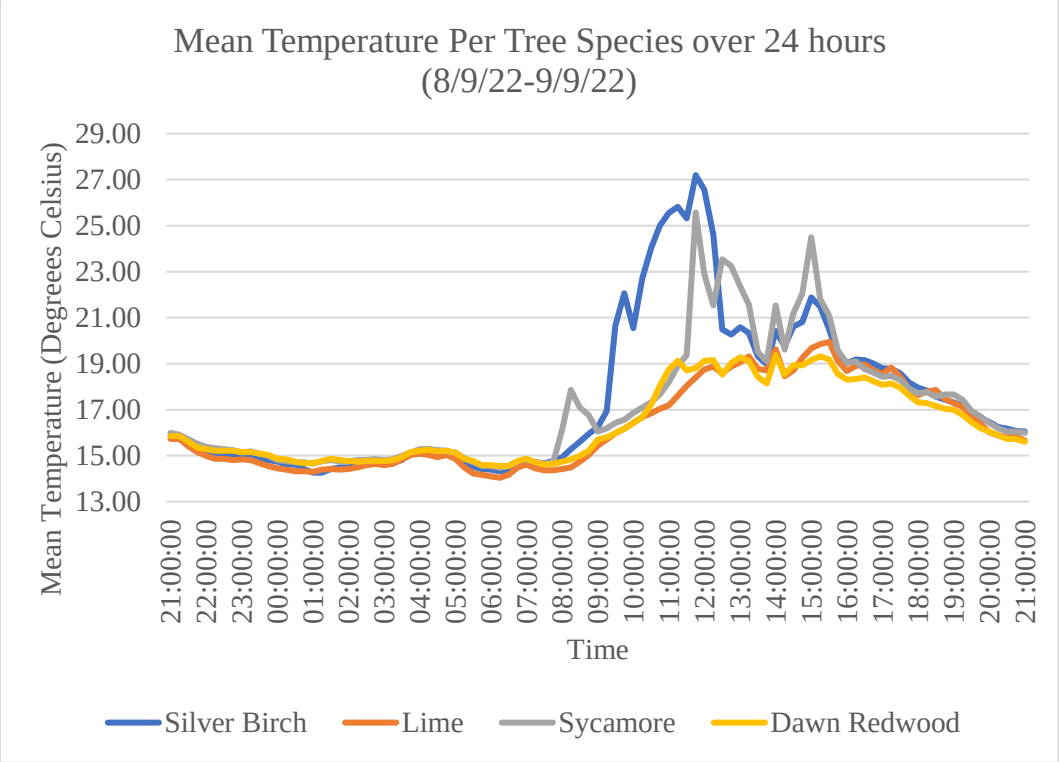


Figure 60. The mean temperature recorded in the microclimate of each tree species over 24-hours. This data was recorded in 15-minute intervals between 9pm 8/9/22 and 9pm 9/9/22.

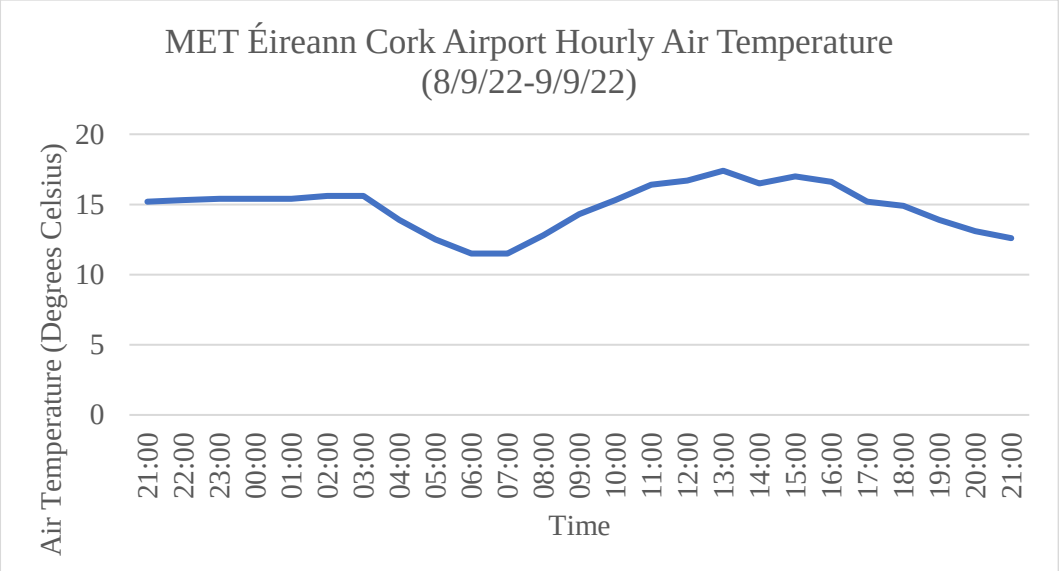


Figure 61. MET Éireann air temperature data recorded hourly at the Cork Airport weather station. This graph represents air temperature data recorded between 9pm 8/9/22 and 9pm 9/9/22.

8.1.13 Fitzgerald's Park Experiment B

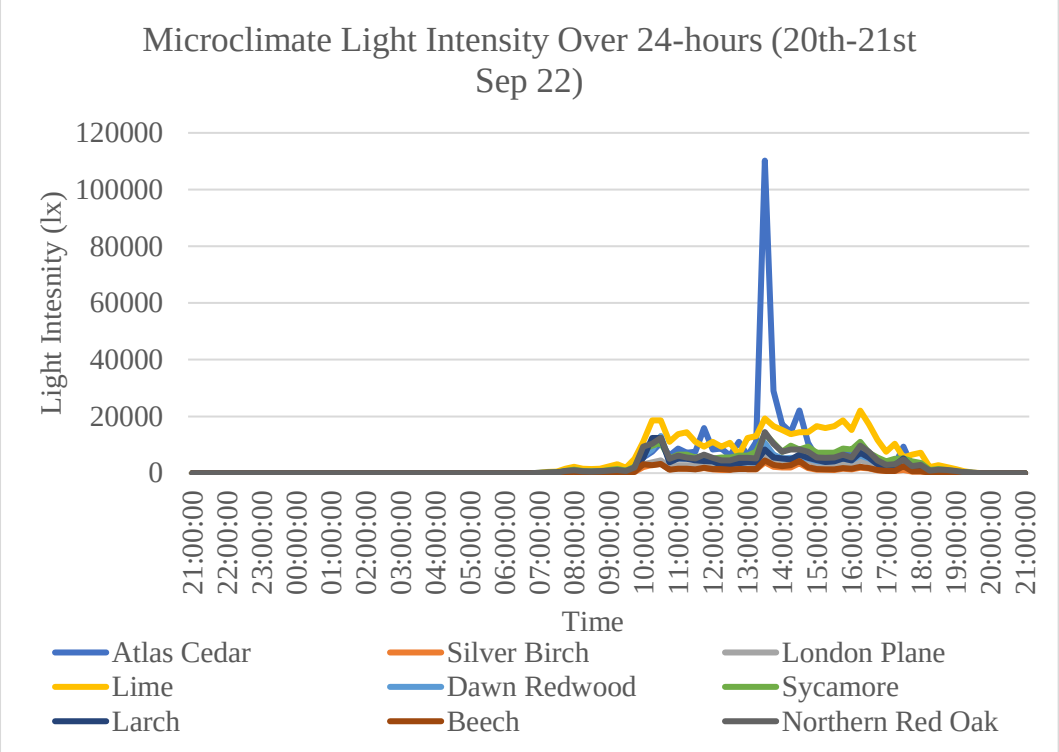


Figure 62. Microclimate light intensity recorded in 15-minute intervals over 24-hours between 9pm 20/9/22 and 9pm 21/9/22.

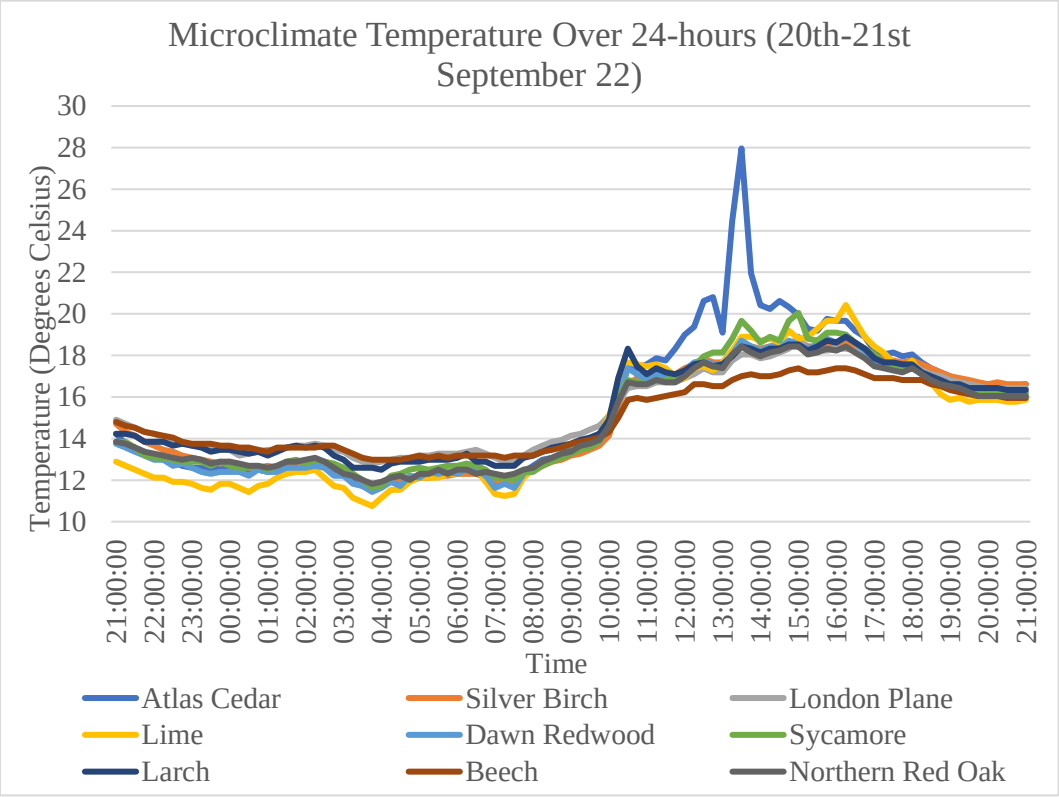


Figure 63. Microclimate temperature data recorded at each tree being surveyed in Fitzgerald's Park in 15-minute intervals over 24-hours (20/9/22-21/9/22).

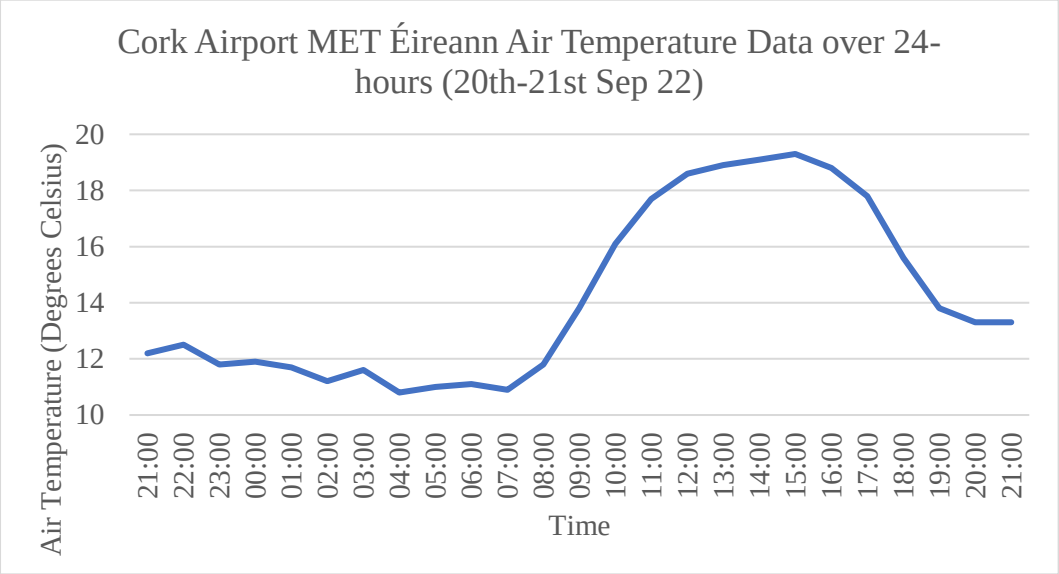


Figure 64. Hourly air temperature data recorded in the Cork Airport MET Éireann weather station over 24-hours between 20/9/22 and 21/9/22.

8.2 Hemispherical Photography

8.2.1 Fitzgerald's Park Experiment A

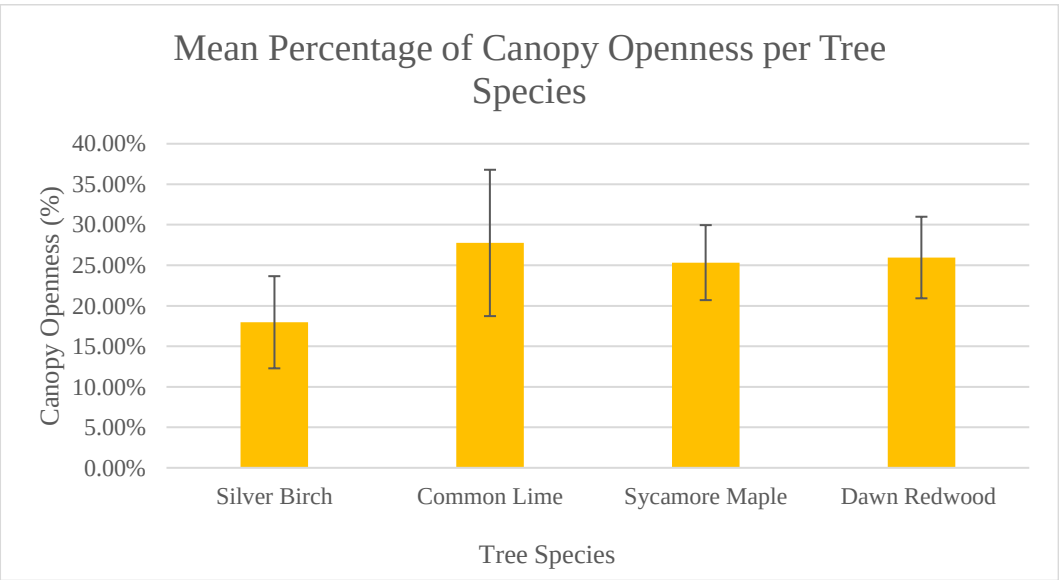


Figure 65. The calculated mean canopy openness of each tree species in Fitzgerald's Park ($H = 1.974$, $df = 3$, $p>0.05$).



Figure 66. These three hemispherical images were taken of all three Silver Birch trees in Fitzgerald's Park experiment A. The top of the camera is aligned with the

geographical North and the camera was set up in the South cardinal of each tree. The calculated percentages of canopy openness (in order of images top to bottom) were 28.56%, 16.26% and 9.08%.





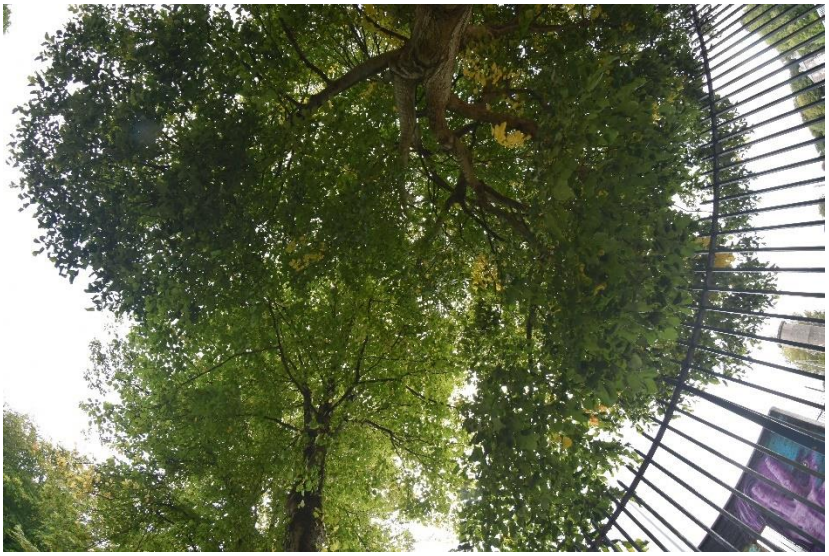


Figure 67. These three hemispherical images were taken of all three Lime trees in Fitzgerald's Park experiment 1. The top of the camera is aligned with the geographical North and the camera was set up in the South cardinal of each tree.. The calculated percentages of canopy openness (in order of images top to bottom) were 32.07%, 40. 79% and 10.41%





Figure 68. These three hemispherical images were taken of all three Sycamore Maple trees in Fitzgerald's Park experiment 1. The top of the camera is aligned with the geographical North and the camera was set up in the South cardinal of each tree. The calculated percentages of canopy openness (in order of images top to bottom) were 21.53%, 34.54% and 19.91%.



Figure 69. These three hemispherical images were taken of all three Dawn Redwood trees in Fitzgerald's Park experiment 1. The top of the camera is aligned with the

geographical North and the camera was set up in the South cardinal of each tree. The calculated percentages of canopy openness (in order of images top to bottom) were 23.05%, 35.67% and 19.06%.

8.2.2 Fitzgerald's Park Experiment B

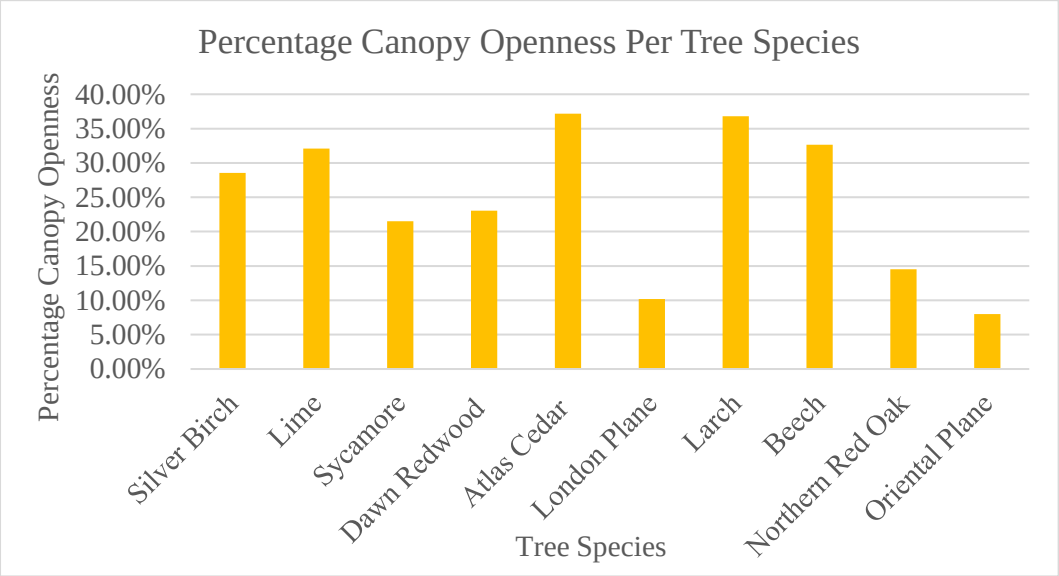


Figure 70. Bar chart showing the percentage canopy openness of each tree species, calculated using Gap Light Analyser software and hemispherical photography. The results of a Chi-square test showed no significance ($p < 0.05$).



Figure 71. Hemispherical photograph of an Atlas Cedar in Fitzgerald's Park. The top of the camera is aligned with the geographical North and the camera was set up in the South cardinal of the tree. The calculated canopy openness is 37.15%. Photo: Caoimhe Marron, 2022.



Figure 72. Hemispherical photograph of a Beech tree in Fitzgerald's Park. The top of the camera is aligned with the geographical North and the camera was set up in the South cardinal of the tree. The calculated canopy openness is 32.63 %. Photo: Caoimhe Marron, 2022.



Figure 73. Hemispherical photograph of a Larch tree in Fitzgerald's Park. The top of the camera is aligned with the geographical North and the camera was set up in the South cardinal of the tree. The canopy openness of this tree was estimated to be 36.82 %. Photo: Caoimhe Marron, 2022.



Figure 74. Hemispherical photograph of a London Plane tree in Fitzgerald's Park. The top of the camera is aligned with the geographical North and the camera was set

up in the South cardinal of the tree. The calculated canopy openness is 10.19 %Photo: Caoimhe Marron, 2022.



Figure 75. Hemispherical Photograph of a Northern Red Oak tree in Fitzgerald's Park. The top of the camera is aligned with the geographical North and the camera was set up in the South cardinal of the tree. The calculated canopy openness of this tree is 42.52 %. Photo: Caoimhe Marron, 2022.



Figure 76. Hemispherical photograph of an Oriental Plane tree in Fitzgerald's Park. The top of the camera is aligned with the geographical North and the camera was set up in the South cardinal of the tree. The calculated canopy openness of this tree is 8.01 %. Photo: Caoimhe Marron, 2022.

8.3 Significant Regression Analyses

8.3.1 UCC Experiment C

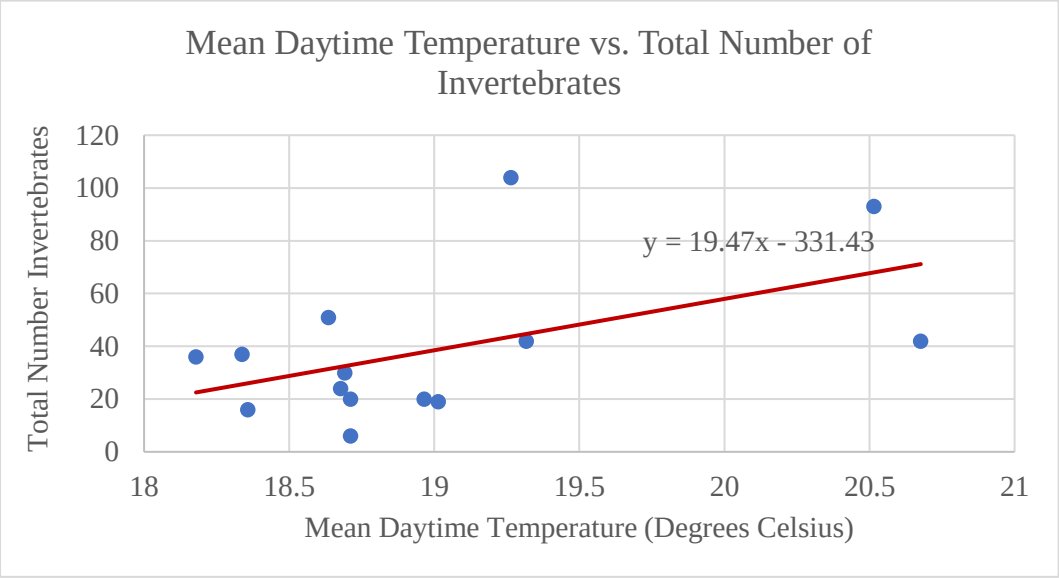


Figure 77. Scatter plot showing the positive correlation between the mean daytime temperature (degrees Celsius) and the total number of invertebrates recorded at each tree ($F(1,11)=7.86$, $p=0.017$). Regression analysis indicated that mean daytime temperature explained 4.17% of the variation in total invertebrates.

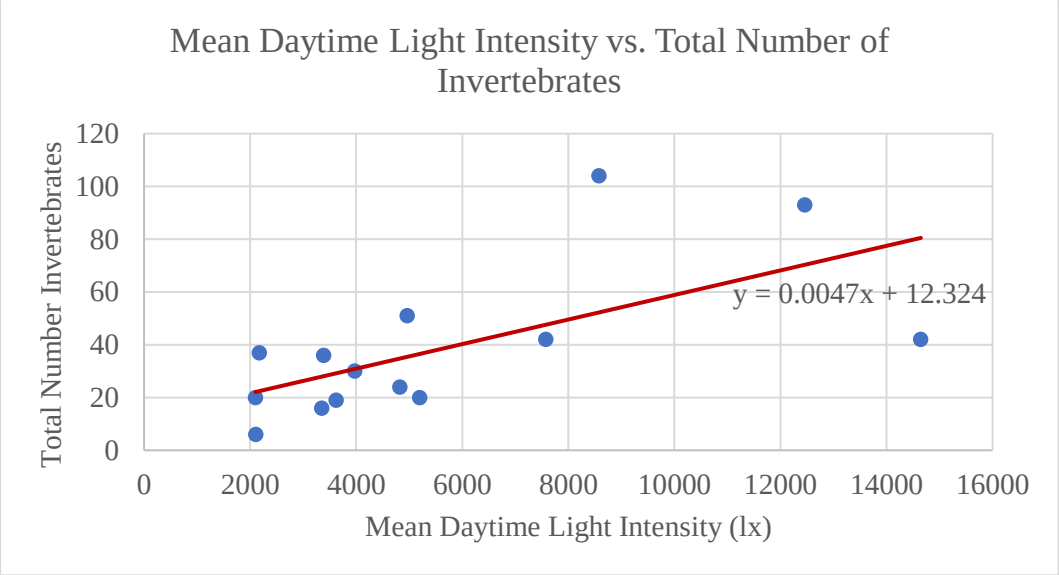


Figure 78. Scatter plot showing the positive correlation between mean daytime light intensity (lx) and the total number of invertebrate individuals counted for each tree ($F(1,12)=8.297$, $p=0.014$). Regression analysis indicated that mean daytime light intensity explained 40.88% of the variation in total invertebrate numbers.

8.3.2 Atlantic Pond Experiment B

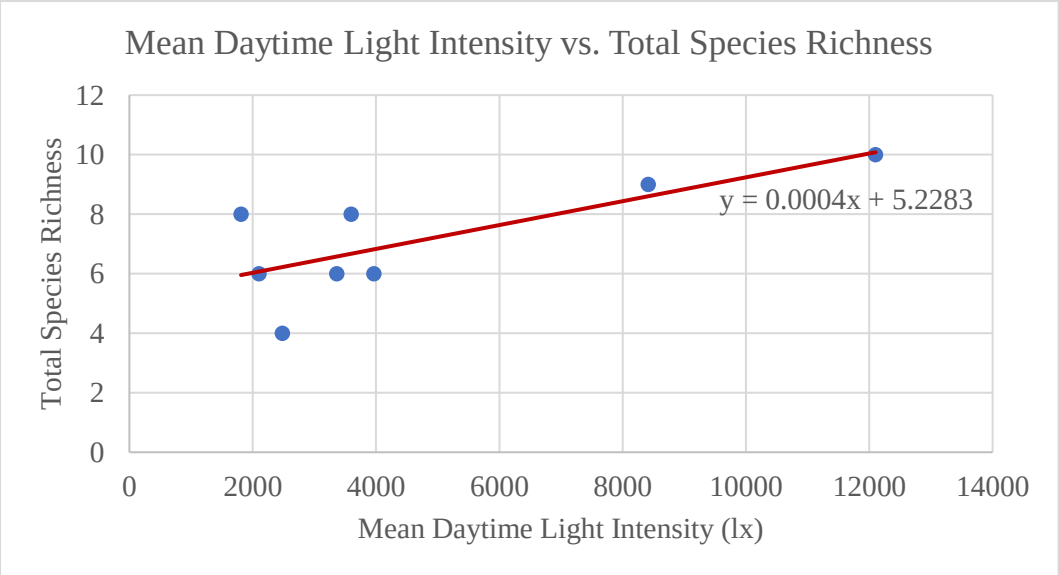


Figure 79. Scatter plot showing the positive correlation between mean daytime light intensity (lx) and total species richness ($F(1,6)=7.36$, $p=0.035$). Regression analysis indicated that mean day time light intensity explained 55.07% of the variation in total species richness.

8.3.3 Kennedy Park Experiment A

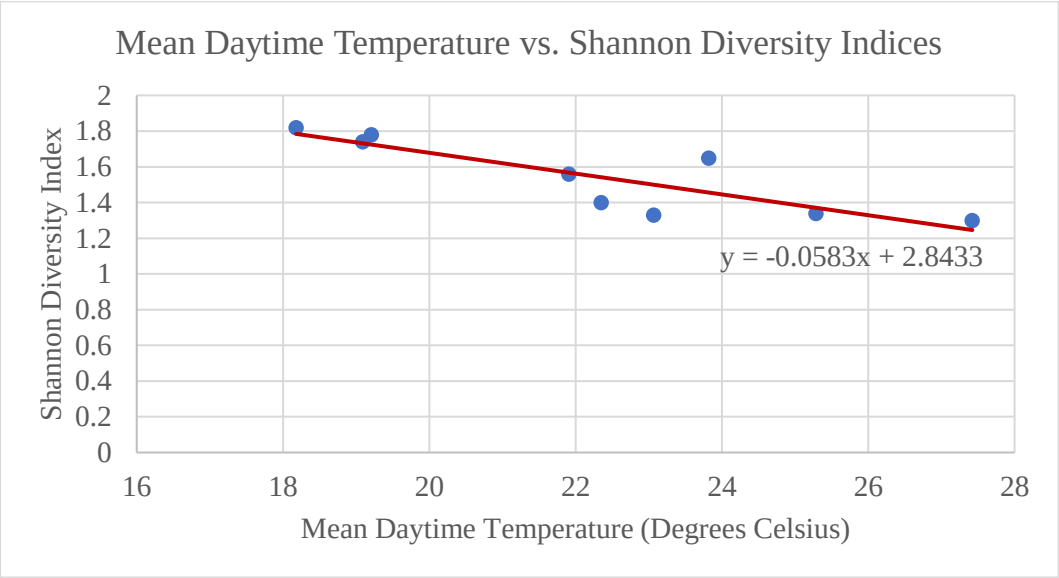


Figure 80. Scatter plot showing the negative correlation between mean daytime temperature and Shannon Diversity Indices ($F(1,7) = 18.8$, $p = 0.003$). Regression analysis indicated that mean daytime temperature explained 72.87% of the variation in Shannon diversity indices.

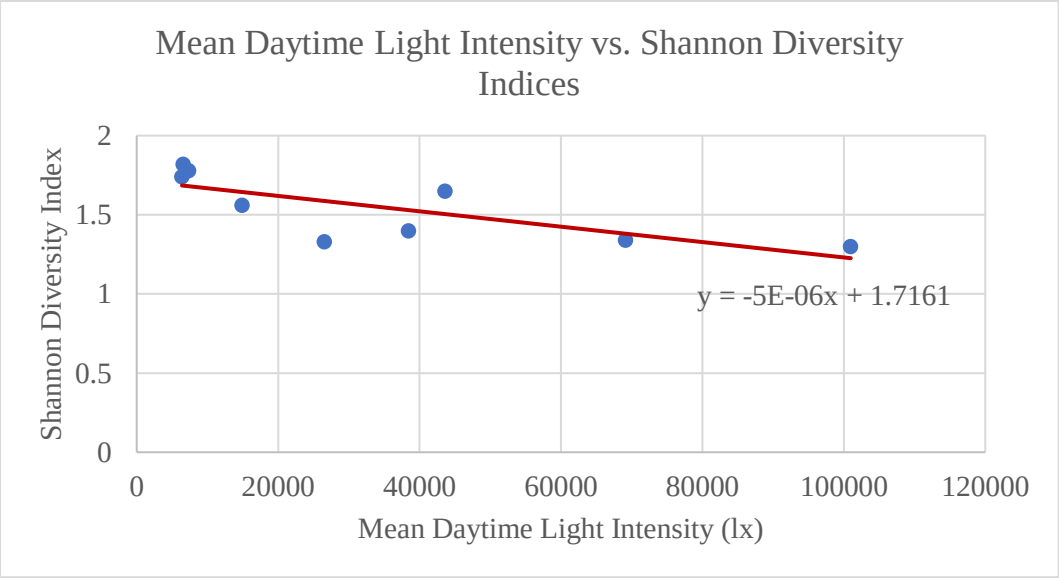


Figure 81. Scatter plot showing the negative correlation between daytime light intensity (lx) and Shannon diversity indices ($F(1,7) = 9.34$, $p = 0.018$). Regression analysis indicated that mean day time light intensity explained 57.17% of the variation in Shannon diverstity indices.

8.3.4 Lee Fields Experiment B

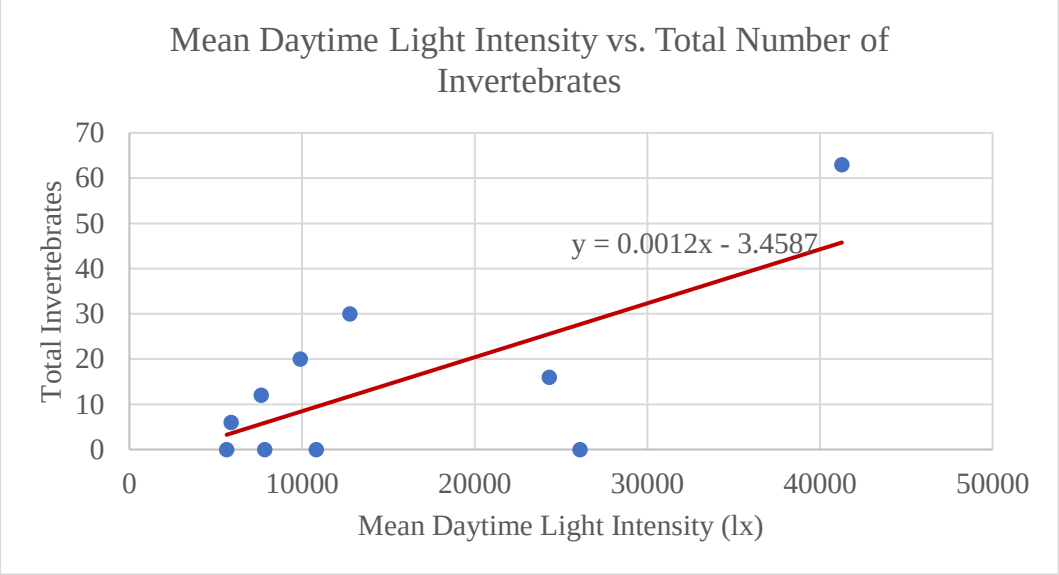


Figure 82. Scatter plot showing the mean daytime light intensity plotted against the total number of invertebrate individuals counted for each tree ($F(1,8)=7.72$, $p=0.029$). This plot includes a trendline demonstrating the moderately strong positive correlation. Regression analysis indicated that mean daytime light intensity explained 49.1% of the variation in total invertebrates.

8.4 Taxa Abundance Data

8.4.1 UCC

Table 45. A table of all abundance data recorded across 4 taxa for all samples in experiment A of the UCC arboretum.

Invertebrate Orders	**Sycamore 1**	**Sycamore 2**	**Sycamore 3**	**Beech 1**	**Beech 2**	**Beech 3**	**Lime 1**	**Lime 2**	**Lime 3**	**Birch 1**	**Birch 2**	**Birch 3**
Diptera	42	20	97	44	36	13	103	26	19	42	9	32
Coleoptera	0	1	1	0	0	0	1	0	0	3	0	0
Lepidoptera	0	0	0	0	1	0	0	1	0	0	0	1
Hymenoptera	0	0	0	0	0	0	0	0	1	0	0	0
Dermaptera	0	0	0	0	0	0	0	0	0	1	0	0
Isopoda	0	60	0	0	0	1	1	50	0	0	0	2
Lichen Species	**Sycamore 1**	**Sycamore 2**	**Sycamore 3**	**Beech 1**	**Beech 2**	**Beech 3**	**Lime 1**	**Lime 2**	**Lime 3**	**Birch 1**	**Birch 2**	**Birch 3**
A. calcarea	10	2	0	0	3	7	0	20	9	0	6	0
P. perlatum	0	0	0	0	0	8	0	0	0	0	0	0
C. candelaris	0	0	0	0	0	5	0	0	0	0	0	0
F. carpeta	0	0	0	0	0	1	0	0	0	0	0	0
T. flexuosa	0	0	0	0	0	0	0	0	0	0	0	0
R. farinacea	0	14	13	18	0	0	0	0	0	1	0	18
O. parella	10	0	0	0	0	5	8	0	2	0	0	0
Bird Species	**Sycamore 1**	**Sycamore 2**	**Sycamore 3**	**Beech 1**	**Beech 2**	**Beech 3**	**Lime 1**	**Lime 2**	**Lime 3**	**Birch 1**	**Birch 2**	**Birch 3**
Jackdaw *(Coloeus)*	0	0	0	0	0	0	0	0	0	1	1	0
Wood Pigeon *(Columba palumbus)*	0	1	1	0	4	0	1	1	2	1	1	0
Crow *(Corvus)*	0	0	0	1	0	0	0	0	0	0	0	0
Magpie *(pica pica)*	1	0	0	0	0	0	2	1	0	0	0	0
Robin *(Erithacus rubecula)*	0	0	0	1	0	0	0	1	0	0	0	0
Great Tit *(Parus major)*	0	0	0	0	0	0	0	0	2	0	0	0
Dunnock *(Prunella modularis)*	0	0	0	0	0	0	0	2	2	0	0	0
Rook *(Corvus frugilegus)*	3	0	0	0	0	0	0	2	0	0	0	0
House Sparrow (*Passer domesticus*)	0	1	0	0	0	0	0	0	3	0	0	0
Vegetation Species	**Sycamore 1**	**Sycamore 2**	**Sycamore 3**	**Beech 1**	**Beech 2**	**Beech 3**	**Lime 1**	**Lime 2**	**Lime 3**	**Birch 1**	**Birch 2**	**Birch 3**
Nettles *(Urtica dioica)*	1	0	2	1	0	0	0	0	0	0	0	0
Oxeye daisy *(Leucanthemum vulgare)*	5	0	0	0	0	0	0	0	0	0	0	0
Buttercup *(Ranunculus repens)*	13	1	0	1	0	0	0	2	2	2	0	15
Sticky chickweed *(Cerastium glomeratum)*	2	0	0	1	2	0	0	4	0	0	0	0
Bracken *(Pteridium aquilinum)*	1	0	0	0	0	0	0	0	0	0	0	0
Ryegrass *(Lolium perenne)*	21	15	20	21	22	13	22	25	18	6	1	25
Germander Speedwell *(Veronica chamaedrys)*	6	0	0	0	2	0	8	0	0	0	0	3
Broadleaf Dock *(Rumex obtusifolius)*	1	0	0	0	0	0	0	0	0	0	0	0
Spear Thistle *(Cirsium vulgare)*	1	0	0	0	0	0	0	0	0	0	0	0
Curled Dock *(Rumex crispus)*	0	2	0	0	1	1	0	1	0	0	0	0
Dandelion *(Taraxacum officinale)*	0	1	1	0	0	2	4	0	1	2	3	0
Harebell *(Campanula rotundifolia)*	0	2	0	2	0	0	0	0	0	0	0	0
Daisies *(Bellis perennis)*	0	0	2	0	1	0	3	0	0	2	0	0
White Clover *(Trifolium repens)*	0	0	3	0	0	7	0	0	0	2	0	0
Greater plantain *(Plantago major)*	0	0	0	0	2	0	1	0	0	0	0	0
Wood aven *(Geum urbanum)*	0	0	0	0	0	0	0	0	1	0	0	0
Irish Ivy *(Hedera hibernica)*	0	0	0	0	0	0	0	1	2	1	0	0
Cow Parsnip *(Heracleum maximum)*	0	0	0	0	0	0	0	0	8	0	0	0
Pink Sorrel *(Oxalis articulata)*	0	0	0	0	0	0	0	0	0	1	0	0

Table 46. The abundance of 4 taxa recorded in experiment B of the UCC Arboretum.

Lichen Species	**Ash 1**	**Ash 2**	**Cherry Plum 1**	**Cherry Plum 2**	**Irish Yew 1**	**Irish Yew 2**	**Horse Chestnut 1**	**Horse Chestnut 2**
A. calcarea	0	17	14	0	6	2	17	11
P. perlatum	0	0	10	13	0	0	0	5
F. carpeta	0	0	0	2	16	0	0	5
R. farinacea	0	0	2	0	0	0	0	0
Invertebrate Orders	**Ash 1**	**Ash 2**	**Cherry Plum 1**	**Cherry Plum 2**	**Irish Yew 1**	**Irish Yew 2**	**Horsechestnut 1**	**Horsechestnut 2**
Diptera	39	18	12	3	11	7	90	33
Coleoptera	0	0	0	0	0	0	2	0
Lepidoptera	0	1	0	0	0	0	0	3
Hymenoptera	1	0	1	0	0	0	0	0
Dermaptera	0	0	0	0	0	0	1	0
Isopoda	0	1	0	2	3	0	0	0
Araneae	2	2	1	1	2	0	0	1
Bird Species	**Ash 1**	**Ash 2**	**Cherry Plum 1**	**Cherry Plum 2**	**Irish Yew 1**	**Irish Yew 2**	**Horse Chestnut 1**	**Horse Chestnut 2**
Magpie *(pica pica)*	2	0	0	0	0	0	0	0
Rook *(Corvus frugilegus)*	0	1	0	0	0	0	0	1
Herring Gull *(Larus argentatus)*	0	2	0	0	0	2	5	0
Robin *(Erithacus rubecula)*	0	0	1	1	0	0	0	1
Wood Pigeon *(Columba palumbus)*	0	0	0	0	0	2	2	1
Jackdaw *(Corvus monedula)*	0	0	0	0	0	0	1	2
Coal Tit (Periparus ater)	0	0	0	0	0	0	0	2
House Sparrow (*Passer domesticus*)	0	0	0	0	0	1	0	0
Vegetation Species	**Ash 1**	**Ash 2**	**Cherry Plum 1**	**Cherry Plum 2**	**Irish Yew 1**	**Irish Yew 2**	**Horse Chestnut 1**	**Horse Chestnut 2**
Perennial Ryegrass *(Lolium perenne)*	25	25	16	20	1	10	16	2
Dandelion *(Taraxacum officinale)*	0	8	2	1	1	1	2	0
Common Nipplewort *(Laspana communis)*	0	1	0	0	0	0	0	0
Cow Parsnip *(Heracleum maximum)*	0	1	0	0	0	0	1	0
Buttercup *(Ranunculus repens)*	0	2	1	1	0	0	0	0
Ground Elder *(Aegopodium podagraria)*	0	1	0	0	0	0	0	0
Tansy Ragwort *(Jacboaea vulgaris)*	0	1	0	0	0	3	0	0
Daisies *(Bellis perennis)*	0	1	0	0	0	0	0	0
Irish Ivy *(Hedera hibernica)*	0	1	2	8	21	0	0	0
Clustered Dock *(Rumex conglomeratus)*	0	0	1	2	1	0	1	1
Greater Birdsfoot Trefoil *(Lotus pedunculatus)*	0	0	5	0	0	0	0	0
Common Selfheal *(Prunella vulgaris)*	0	0	1	1	0	0	0	0
Old Man's Beard *(Clematis vitalba)*	0	0	0	6	0	0	0	0
White Clover *(Trifolium repens)*	0	0	0	3	0	2	0	0
Fox-and-Cubs *(Pilosella aurantiaca)*	0	0	0	1	0	0	0	0
Greater plantain *(Plantago major)*	0	0	0	0	3	0	0	0
Herb Robert *(Gernaium robertianum)*	0	0	0	0	1	0	0	0
Baby's Tears *(Soleirolia soleirolii)*	0	0	0	0	0	14	0	0
Spear Thistle *(Cirsium vulgare)*	0	3	0	0	0	0	0	0

Table 47. The abundance of 4 taxa recorded in experiment C of the UCC arboretum.

Lichen Species	**Hornbeam**	**Lodgepole Pine**	**Sessile Oak**	**Willow**	**Tulip**	**Copper Beech**	**English Oak**
A. calcarea	20	0	0	0	5	11	0
P. perlatum	0	2	0	14	2	1	0
C. candelaris	0	0	0	0	0	0	12
F. carpeta	3	0	3	0	0	2	0
O. parella	0	0	0	1	3	3	0
C. aurantia	0	0	0	0	2	0	5
Invertebrate Orders	**Hornbeam**	**Lodgepole Pine**	**Sessile Oak**	**Willow**	**Tulip**	**Copper Beech**	**English Oak**
Diptera	19	29	36	17	50	22	14
Coleoptera	0	0	0	1	1	0	2
Lepidoptera	0	1	1	0	0	2	1
Hymenoptera	0	0	0	2	0	0	0
Isopoda	0	0	0	0	0	0	3
Bird Species	**Hornbeam**	**Lodgepole Pine**	**Sessile Oak**	**Willow**	**Tulip**	**Copper Beech**	**English Oak**
Jackdaw *(Corvus monedula)*	0	0	0	0	1	0	0
Magpie *(pica pica)*	0	0	0	0	1	0	1
Robin *(Erithacus rubecula)*	0	0	0	1	0	0	0
Wood Pigeon *(Columba palumbus)*	0	0	2	0	1	0	0
Rook *(Corvus frugilegus)*	0	0	0	1	0	0	0
Vegetation Species	**Hornbeam**	**Lodgepole Pine**	**Sessile Oak**	**Willow**	**Tulip**	**Copper Beech**	**English Oak**
Irish Ivy *(Hedera hibernica)*	0	0	2	0	0	0	0
Perennial Ryegrass *(Lolium perenne)*	0	1	25	0	22	21	25
Buttercup *(Ranunculus repens)*	0	1	1	0	4	2	2
Germander Speedwell *(Veronica chamaedrys)*	0	0	2	0	7	0	4
Yellow Pimpernel *(Lysimachia nemorum)*	0	0	0	0	6	0	0
Tansy Ragwort *(Jacboaea vulgaris)*	0	0	0	0	1	0	0
White Clover *(Trifolium repens)*	0	0	0	0	0	2	0
Daisies *(Bellis perennis)*	0	0	0	0	0	1	0
Spear Thistle *(Cirsium vulgare)*	0	0	0	0	0	1	0
Common Selfheal *(Prunella vulgaris)*	0	0	0	0	0	2	0
Herb Robert *(Gernaium robertianum)*	0	0	0	0	0	2	0
Short-fruited Willowherb *(Epilobium obsurum)*	0	0	0	0	0	2	0
Wall-lettuce *(Lactuca muralis)*	0	0	0	0	0	1	0
Greater plantain *(Plantago major)*	0	0	0	0	0	0	4

8.4.2 Marina

Table 48. The abundance of 4 taxa recorded in experiment A of the Marina Street Trees.

Lichen Species	**London Plane 1**	**London Plane 2**	**Beech 1**	**Beech 2**	**Lime 1**	**Lime 2**	**Sycamore 1**	**Sycamore 2**
A. calcarea	15	8	20	20	8	0	20	20
P. perlatum	0	0	0	0	0	2	0	0
F. carpeta	0	0	0	0	0	16	0	0
Invertebrate Orders	**London Plane 1**	**London Plane 2**	**Common Beech 1**	**Common Beech 2**	**Common Lime 1**	**Common Lime 2**	**Sycamore 1**	**Sycamore 2**
Diptera	4	22	21	22	10	25	3	1
Coleoptera	0	1	0	0	0	0	0	0
Hymenoptera	0	1	2	1	0	2	0	2
Dermaptera	0	0	0	0	0	0	0	2
Isopoda	0	0	0	0	0	0	10	0
Araneae	0	1	0	0	0	0	0	0
Bird Species	**London Plane 1**	**London Plane 2**	**Common Beech 1**	**Common Beech 2**	**Common Lime 1**	**Common Lime 2**	**Sycamore 1**	**Sycamore 2**
Wood Pigeon *(Columba palumbus)*	0	0	1	1	0	1	0	0
Mallard *(Anas platyrhynchos)*	0	0	0	0	0	0	0	0
Jackdaw *(Corvus monedula)*	2	2	0	0	0	0	0	0
Vegetation Species	**London Plane 1**	**London Plane 2**	**Common Beech 1**	**Common Beech 2**	**Common Lime 1**	**Common Lime 2**	**Sycamore 1**	**Sycamore 2**
Dandelion *(Taraxacum officinale)*	3	0	0	0	3	1	4	5
Perennial Ryegrass *(Lolium perenne)*	25	5	0	0	37	1	5	4
Irish Ivy *(Hedera hibernica)*	0	0	19	19	0	0	0	0
Herb Robert *(Gernaium robertianum)*	0	0	10	0	0	0	0	0
Nettles *(Urtica dioica)*	0	0	4	5	0	0	0	0
Old Man's Beard *(Clematis vitalba)*	0	0	2	4	0	0	0	0
Holly *(Ilex aquifolium)*	0	0	2	11	0	0	0	0
Greater plantain *(Plantago major)*	0	0	0	0	0	2	1	1
Hairy Bolesia *(Bowlesia incana)*	0	0	0	0	0	0	5	0
Baby's Tears *(Soleirolia soleirolii)*	0	0	0	0	0	0	2	0
Wall-lettuce *(Lactuca muralis)*	0	0	0	0	0	0	1	0
White Clover *(Trifolium repens)*	0	0	0	0	0	0	0	18
Daisies *(Bellis perennis)*	0	0	0	0	0	0	0	2

Table 49. The abundance of 4 taxa recorded in experiment B of the Marina Street Trees. There were no bird species recorded in this experiment.

Lichen Species	**Silver Birch**	**Norway Maple**	**Swedish Whitebeam**	**Ash**
A. calcarea	20	0	2	20
P. perlatum	0	0	16	0
C. candelaris	0	2	0	0
F. carpeta	0	5	2	0
T. flexuosa	0	0	4	0
Invertebrate Orders	**Silver Birch**	**Norway Maple**	**Swedish Whitebeam**	**Ash**
Diptera	102	3	10	21
Hymenoptera	3	1	3	2
Dermaptera	1	0	0	10
Isopoda	2	0	5	1
Vegetation Species	**Silver Birch**	**Norway Maple**	**Swedish Whitebeam**	**Ash**
White Clover *(Trifolium repens)*	4	0	0	0
Nettles *(Urtica dioica)*	9	4	0	0
Old Man's Beard *(Clematis vitalba)*	6	5	0	0
Red Clover *(Trifolium pratense)*	2	0	0	0
Buttercup *(Ranunculus repens)*	1	0	0	0
Perennial Ryegrass *(Lolium perenne)*	18	0	20	4
Dandelion *(Taraxacum officinale)*	2	0	7	11
Greater plantain *(Plantago major)*	1	0	2	11
Holly *(Ilex aquifolium)*	0	17	0	0
Irish Ivy *(Hedera hibernica)*	0	13	0	0
Daisies *(Bellis perennis)*	0	0	11	11

8.4.3 Urban Parks

Table 50. The abundance of 4 taxa recorded in experiment A of the Atlantic Pond.

Invertebrate Orders	**Ash 1**	**Ash 2**	**Ash 3**	**Willow 1**	**Willow 2**	**Willow 3**	**Alder 1**	**Alder 2**	**Alder 3**	**Downy Birch 1**	**Downy Birch 2**	**Downy Birch 3**
Diptera	67	5	50	10	19	29	46	31	110	5	24	51
Coleoptera	0	0	0	0	0	0	0	0	0	0	0	1
Lepidoptera	0	0	0	0	1	0	0	1	0	0	0	0
Hymenoptera	1	0	2	2	0	1	0	0	0	6	0	1
Dermaptera	0	0	1	0	0	0	0	0	0	0	0	0
Isopoda	0	2	2	0	0	0	0	0	0	1	0	0
Araneae	0	1	10	1	0	2	0	0	1	2	0	0
Bird Species	**Ash 1**	**Ash 2**	**Ash 3**	**Willow 1**	**Willow 2**	**Willow 3**	**Alder 1**	**Alder 2**	**Alder 3**	**Downy Birch 1**	**Downy Birch 2**	**Downy Birch 3**
Wood Pigeon *(Columba palumbus)*	0	0	0	1	0	3	2	2	0	1	2	2
Lesser Black-backed Gull *(Larus fuscus)*	1	0	0	0	0	0	0	0	0	0	0	0
Magpie *(pica pica)*	0	0	0	1	0	0	0	0	0	0	0	0
Tree Species	**Ash 1**	**Ash 2**	**Ash 3**	**Willow 1**	**Willow 2**	**Willow 3**	**Alder 1**	**Alder 2**	**Alder 3**	**Downy Birch 1**	**Downy Birch2**	**Downy Birch 3**
A. calcarea	2	0	0	5	5	4	8	1	16	5	2	0
P. perlatum	17	0	0	0	5	8	2	0	0	10	7	15
X. parietina	0	0	0	0	4	0	0	0	0	0	0	0
C. candelaris	0	0	0	0	0	0	1	13	9	10	7	0
F. carpeta	1	0	0	0	8	10	0	0	0	10	2	5
O. parella	1	0	0	0	0	0	8	0	0	0	0	0
Vegetation Species	**Ash 1**	**Ash 2**	**Ash 3**	**Willow 1**	**Willow 2**	**Willow 3**	**Alder 1**	**Alder 2**	**Alder 3**	**Downy Birch 1**	**Downy Birch 2**	**Downy Birch 3**
Greater Plantain *(Plantago major)*	4	3	0	4	4	17	7	10	0	0	4	0
White Clover *(Trifolium repens)*	4	0	0	0	0	0	0	0	0	0	0	0
Dandelion *(Taraxacum officinale)*	2	0	0	2	2	0	0	1	2	2	0	2
Perennial Ryegrass *(Lolium perenne)*	30	3	7	40	30	25	14	15	28	38	21	21
Bracken *(Pteridium aquilinum)*	0	3	3	0	0	0	0	0	0	0	0	0
Clustered Dock *(Rumex conglomeratus)*	0	1	0	0	0	0	0	0	0	0	0	0
Irish Ivy *(Hedera hibernica)*	0	6	7	0	0	0	0	0	0	0	0	0
Nettles *(Urtica dioica)*	0	4	4	0	0	0	0	0	0	0	0	0
Germander Speedwell *(Veronica chamaedrys)*	0	0	0	0	2	0	0	0	0	0	0	0
Lambsquarters *(Chenopodium album)*	0	0	0	0	1	0	0	0	0	0	0	0
Daisy *(Bellis perennis)*	0	0	1	1	0	2	1	1	2	0	0	1
Thyme-leaved Speedwell *(Veronica serpyllifolia)*	0	0	0	0	0	0	0	2	2	0	0	0
Baby's Tears *(Soleirolia soleirolii)*	0	0	0	0	0	0	0	0	0	0	0	1
Buttercup	0	0	3	0	0	0	0	0	7	0	0	0

Table 51. The abundance of 4 taxa recorded in experiment B of the Atlantic Pond.

Invertebrate Orders	**Field Maple**	**London Plane**	**Sycamore**	**Sugar Maple**	**Swedish Whitebeam**
Diptera	112	135	26	20	18
Coleoptera	0	0	0	0	0
Lepidoptera	0	0	0	0	0
Hymenoptera	0	0	1	0	6
Dermaptera	0	0	0	0	0
Isopoda	0	0	0	0	0
Araneae	0	0	0	0	0
Lichen Species	**Field Maple**	**London Plane**	**Sycamore**	**Sugar Maple**	**Swedish Whitebeam**
A. calcarea	0	9	0	0	5
P. perlatum	0	0	0	10	15
X. parietina	0	0	0	0	0
R. farinacea	0	0	0	0	9
C. candelaris	13	2	0	2	9
F. carpeta	0	0	0	5	6
O. parella	0	0	0	0	1
Bird species	**Field Maple**	**London Plane**	**Sycamore**	**Sugar Maple**	**Swedish Whitebeam**
Wood Pigeon *(Columba palumbus)*	0	0	2	0	2
Magpie *(pica pica)*	0	0	0	0	0
House Sparrow (*Passer domesticus*)	0	4	0	0	0
Vegetation Species	**Field Maple**	**London Plane**	**Sycamore**	**Sugar Maple**	**Swedish Whitebeam**
Dandelion *(Taraxacum officinale)*	4	0	1	0	2
Greater plantain *(Plantago major)*	6	0	18	0	2
Perennial Ryegrass *(Lolium perenne)*	11	2	15	24	26
Irish Ivy *(Hedera hibernica)*	0	32	0	0	0
Clustered Dock *(Rumex conglomeratus)*	0	1	0	0	0
Buttercup *(Ranunculus repens)*	0	3	0	0	0
Nettles *(Urtica dioica)*	0	2	0	0	0
Germander Speedwell *(Veronica chamaedrys)*	0	0	0	16	0
Tansy Ragwort *(Jacboaea vulgaris)*	0	0	0	2	0

Table 52. The abundance of 4 taxa recorded in experiment A of Kennedy Park.

Invertebrate Orders	**Sycamore 1**	**Sycamore 2**	**Sycamore 3**	**Ash 1**	**Ash 2**	**Ash 3**	**Beech 1**	**Beech 2**	**Beech 3**
Diptera	30	105	50	5	10	5	9	26	5
Coleoptera	0	0	0	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0	1	3	0
Hymenoptera	2	2	3	2	3	0	2	0	0
Dermaptera	0	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0	0
Araneae	0	0	0	0	0	0	0	1	0
Tree Species	**Sycamore 1**	**Sycamore 2**	**Sycamore 3**	**Ash 1**	**Ash 2**	**Ash 3**	**Beech 1**	**Beech 2**	**Beech 3**
Rook *(Corvus frugilegus)*	0	1	3	0	0	0	0	0	0
House Sparrow (*Passer domesticus*)	0	0	0	0	0	0	0	3	0
Wood Pigeon *(Columba palumbus)*	0	0	0	0	0	0	0	0	1
Tree Species	**Sycamore 1**	**Sycamore 2**	**Sycamore 3**	**Ash 1**	**Ash 2**	**Ash 3**	**Beech 1**	**Beech 2**	**Beech 3**
A. calcarea	0	7	0	0	15	1	20	20	20
P. perlatum	5	8	7	4	1	15	0	0	0
C. candelaris	12	19	14	16	6	0	0	0	0
F. carpeta	0	1	0	0	0	0	0	0	0
T. flexuosa	0	0	0	0	0	0	0	0	0
R. farinacea	6	20	10	14	4	0	0	0	0
O. parella	0	0	0	4	0	0	0	0	0
Vegetation Species	**Sycamore 1**	**Sycamore 2**	**Sycamore 3**	**Ash 1**	**Ash 2**	**Ash 3**	**Beech 1**	**Beech 2**	**Beech 3**
Greater Plantain *(Plantago major)*	6	8	2	8	12	2	0	0	4
Perennial Ryegrass *(Lolium perenne)*	25	25	12	23	11	11	16	25	25
Dandelion *(Taraxacum officinale)*	0	2	5	1	1	5	9	3	3
White Clover *(Trifolium repens)*	0	0	0	2	0	0	10	14	3
Germander Speedwell *(Veronica chamaec*	0	0	0	0	0	1	0	0	0
Creeping Cinquefoil *(Potentilla reptans)*	0	0	0	0	0	4	0	0	0

Table 53. The abundance of 4 taxa recorded in experiment B of Kennedy Park.

Invertebrate Orders	**Silver Maple**	**Sugar Maple**	**Horse Chestnut**	**Common Lime**	**London Plane**
Diptera	7	0	13	50	0
Coleoptera	1	0	0	2	0
Lepidoptera	2	0	0	0	0
Hymenoptera	3	0	2	2	0
Dermaptera	0	0	1	1	0
Isopoda	0	0	0	0	0
Araneae	0	0	0	0	0
Bird Species	**Silver Maple**	**Sugar Maple**	**Horse Chestnut**	**Common Lime**	**London Plane**
Wood Pigeon *(Columba palumbus)*	3	4	5	0	0
Jackdaw *(Corvus monedula)*	0	0	0	0	3
Tree Species	**Silver Maple**	**Sugar Maple**	**Horse Chestnut**	**Common Lime**	**London Plane**
A. calcarea	8	2	3	3	5
P. perlatum	11	0	0	6	0
C. candelaris	0	0	1	0	0
X. parientina	12	0	12	18	0
F. carpeta	0	0	0	0	0
T. flexuosa	0	7	0	0	0
R. farinacea	9	1	8	9	0
O. parella	0	0	0	11	0
Vegetation Species	**Silver Maple**	**Sugar Maple**	**Horse Chestnut**	**Common Lime**	**London Plane**
Perennial Ryegrass *(Lolium perenne)*	22	22	17	16	14
White Clover *(Trifolium repens)*	1	1	4	13	1
Dandelion *(Taraxacum officinale)*	5	0	3	0	6
Greater Plantain *(Plantago major)*	2	7	6	1	9

Table 54. The abundance of 4 taxa recorded in experiment A of the Lee Fields.

Invertebrate Orders	**Birch 1**	**Birch 2**	**Birch 3**	**Silver Maple 1**	**Silver Maple 2**	**Silver Maple 3**	**Dawn Redwood 1**	**Dawn Redwood 2**	**Dawn Redwood 3**	**Willow 1**	**Willow 2**	**Willow 3**
Diptera	0	10	0	10	113	105	50	65	10	10	23	12
Coleoptera	0	2	0	0	0	0	0	0	0	2	0	0
Lepidoptera	0	0	0	0	0	0	0	0	0	0	0	0
Hymenoptera	0	3	0	2	9	5	10	5	4	3	1	0
Dermaptera	0	0	0	5	0	5	3	10	0	0	0	0
Isopoda	0	0	0	13	0	30	0	0	0	0	0	0
Araneae	0	1	0	0	1	2	0	0	0	1	0	0
Tree species	**Downy 1**	**Downy 2**	**Downy 3**	**Silver Maple 1**	**Silver Maple 2**	**Silver Maple 3**	**Dawn Redwood 1**	**Dawn Redwood 2**	**Dawn Redwood 3**	**Willow 1**	**Willow 2**	**Willow 3**
Rook *(Corvus frugilegus)*	0	1	0	0	0	0	0	0	0	2	1	0
Herring Gull *(Larus argentatus)*	0	0	0	0	0	0	0	0	0	0	1	0
Tree Species	**Downy 1**	**Downy 2**	**Downy 3**	**Silver Maple 1**	**Silver Maple 2**	**Silver Maple 3**	**Dawn Redwood 1**	**Dawn Redwood 2**	**Dawn Redwood 3**	**Willow 1**	**Willow 2**	**Willow 3**
A. calcarea	5	0	10	20	18	0	3	0	9	18	20	10
P. perlatum	16	0	7	8	0	14	0	0	0	5	0	0
C. candelaris	5	4	3	0	0	6	2	0	0	0	0	0
F. carpeta	9	0	0	1	0	0	0	0	5	0	0	0
R. farinacea	0	0	0	0	0	6	0	0	5	0	0	0
O. parella	0	0	2	0	0	0	0	0	0	0	0	0
Vegetation Species	**Downy 1**	**Downy 2**	**Downy 3**	**Silver Maple 1**	**Silver Maple 2**	**Silver Maple 3**	**Dawn Redwood 1**	**Dawn Redwood 2**	**Dawn Redwood 3**	**Willow 1**	**Willow 2**	**Willow 3**
Perennial Ryegrass *(Lolium perenne)*	27	25	21	36	20	14	26	19	14	21	12	15
Buttercup *(Ranunculus repens)*	6	0	0	1	0	8	2	5	1	1	10	2
Greater plantain *(Plantago major)*	2	0	0	4	6	0	1	0	0	2	0	0
Dandelion *(Taraxacum officinale)*	4	0	0	3	4	6	8	6	2	4	0	0
Daisies *(Bellis perennis)*	1	0	0	3	7	1	0	0	0	0	0	0
White Clover *(Trifolium repens)*	0	0	0	1	3	0	4	0	22	0	8	8
Bracken *(Pteridium aquilinum)*	0	5	5	0	0	0	0	0	0	0	0	0
Nettles *(Urtica dioica)*	0	0	3	0	0	0	0	0	0	0	0	0

Table 55. The abundance of 4 taxa recorded in experiment B of the Lee Fields. There were no bird species observed.

Invertebrate Orders	**Sugar Maple**	**English Oak**	**Swamp Spanish Oak**	**Lime**	**Birch**	**Swedish Whitebeam**
Diptera	16	0	1	0	0	10
Coleoptera	0	0	0	0	0	2
Lepidoptera	0	0	0	0	0	0
Hymenoptera	0	0	0	0	0	7
Dermaptera	0	0	5	0	0	0
Isopoda	0	0	0	0	0	0
Araneae	0	0	0	0	0	1
Lichen Species	**Sugar Maple**	**English Oak**	**Swamp Spanish Oak**	**Lime**	**Birch**	**Swedish Whitebeam**
A. calcarea	2	3	11	6	5	5
P. perlatum	12	20	0	17	20	2
C. candelaris	0	0	0	0	9	2
F. carpeta	3	2	0	5	0	0
R. farinacea	0	0	0	0	6	0
C. aurantia	0	0	0	2	0	0
X. parietina	0	0	0	2	0	3
O. parella	0	2	0	3	0	0
Vegetation Species	**Sugar Maple**	**English Oak**	**Swamp Spanish Oak**	**Lime**	**Birch**	**Swedish Whitebeam**
Perennial Ryegrass *(Lolium perenne)*	11	21	25	25	19	25
Dandelion *(Taraxacum officinale)*	8	2	4	0	8	6
Greater Plantain *(Plantago major)*	5	10	0	0	0	3
Buttercup *(Ranunculus repens)*	8	3	0	0	4	4
Clustered Dock *(Rumex conglomeratus)*	0	4	0	0	0	0
Broadleaf Dock *(Rumex obtusifolius)*	0	0	11	2	0	0
Irish Ivy *(Hedera hibernica)*	0	0	0	2	0	0
Nettles *(Urtica dioica)*	0	0	0	2	0	0
Daisies *(Bellis perennis)*	0	0	0	0	0	1
White Clover *(Trifolium repens)*	0	0	0	1	0	0

Table 56. The abundance of 4 taxa recorded in experiment A of Fitzgerald's Park. There were no bird species observed.

Invertebrate Orders	**Birch 1**	**Birch 2**	**Birch 3**	**Lime 1**	**Lime 2**	**Lime 3**	**Dawn Redwood 1**	**Dawn Redwood 2**	**Dawn Redwood 3**	**Sycamore 1**	**Sycamore 2**	**Sycamore 3**
Diptera	10	13	22	8	20	1	4	6	10	112	33	0
Coleoptera	0	0	0	0	0	0	0	0	0	1	0	0
Lepidoptera	0	0	0	0	0	0	0	0	0	0	0	0
Hymenoptera	4	3	4	1	2	1	4	2	0	1	5	0
Dermaptera	0	0	0	0	0	1	3	1	0	0	0	0
Isopoda	0	0	1	3	0	12	4	0	0	0	2	0
Araneae	0	0	0	3	0	0	0	1	0	0	0	0
Tree Species	**Birch 1**	**Birch 2**	**Birch 3**	**Lime 1**	**Lime 2**	**Lime 3**	**Dawn Redwood 1**	**Dawn Redwood 2**	**Dawn Redwood 3**	**Sycamore 1**	**Sycamore 2**	**Sycamore 3**
Rook *(Corvus frugilegus)*	4	4	0	0	1	0	1	1	2	0	1	2
Wood Pigeon *(Columba palumbus)*	1	2	0	1	0	0	1	0	3	0	5	0
Robin *(Erithacus rubecula)*	0	0	1	0	0	0	0	0	0	0	0	0
Jackdaw *(Corvus monedula)*	0	0	1	0	0	0	0	0	0	1	1	3
Mallard *(Anas platyrhynchos)*	0	0	0	3	0	0	0	0	0	0	0	0
Lesser Black-backed Gull *(Larus fuscus)*	0	0	0	0	1	0	0	2	0	0	0	0
Lichen Species	**Birch 1**	**Birch 2**	**Birch 3**	**Lime 1**	**Lime 2**	**Lime 3**	**Dawn Redwood 1**	**Dawn Redwood 2**	**Dawn Redwood 3**	**Sycamore 1**	**Sycamore 2**	**Sycamore 3**
A. calcarea	2	2	0	12	10	0	0	0	0	1	2	20
P. perlatum	0	0	0	0	0	0	0	0	0	0	0	0
X. parietina	0	0	0	0	0	0	0	0	0	0	0	0
C. candelaris	0	0	5	0	0	0	13	8	20	5	5	0
F. carpeta	0	0	9	0	0	0	0	1	0	20	14	3
R. farinacea	0	0	0	0	0	0	0	0	0	0	16	0
O. parella	0	0	0	0	0	0	0	0	0	0	0	0
Vegetation species	**Birch 1**	**Birch 2**	**Birch 3**	**Lime 1**	**Lime 2**	**Lime 3**	**Dawn Redwood 1**	**Dawn Redwood 2**	**Dawn Redwood 3**	**Sycamore 1**	**Sycamore 2**	**Sycamore 3**
Irish Ivy *(Hedera hibernica)*	14	0	13	1	2	0	0	0	0	0	0	0
Japanese Pachysandra *(Pachysandra terminalis)*	15	0	0	0	0	0	0	0	0	0	0	0
Arrow Bamboo *(Pseudosasa japonica)*	0	5	0	0	0	0	0	0	0	0	0	0
Witch Hazel *(Hamamelis x intermedia Jelena)*	0	1	0	0	0	0	0	0	0	0	0	0
Greater plantain *(Plantago major)*	0	1	2	0	2	3	9	17	8	5	7	6
Dandelion *(Taraxacum officinale)*	0	1	0	5	5	0	0	0	1	11	1	1
Holly *(Ilex aquifolium)*	0	0	5	0	0	0	0	0	0	0	0	0
Petty Spurge *(Euphorbia peplus)*	0	0	3	0	5	0	0	0	0	0	0	0
Bull Thistle *(Cirsium vulgare)*	0	0	2	0	0	0	0	0	0	0	0	0
Perennial Ryegrass *(Lolium perenne)*	0	0	0	6	5	11	6	6	19	21	19	15
White Clover *(Trifolium repens)*	0	0	0	6	0	4	10	0	0	0	0	8
Buttercup *(Ranunculus repens)*	0	0	0	7	0	0	0	0	0	0	0	0
Bracken *(Pteridium aquilinum)*	0	0	0	3	0	0	0	0	0	0	0	0
Red Clover *(Trifolium pratense)*	0	0	0	0	7	0	0	0	0	0	0	0
Nettles *(Urtica dioica)*	0	0	0	0	1	0	0	0	0	0	0	0
Daisies *(Bellis perennis)*	0	0	0	0	3	2	15	17	3	3	3	35

Table 57. The abundance of 4 taxa recorded in experiment B of Fitzgerald's Park.

Invertebrate Orders	**Atlas Cedar**	**London Plane**	**Larch**	**Beech**	**Northern Red Oak**	**Oriental Plane**
Diptera	21	27	0	28	31	19
Coleoptera	0	0	0	0	1	0
Lepidoptera	0	0	0	0	0	0
Hymenoptera	0	0	0	6	0	1
Dermaptera	0	0	0	0	0	0
Isopoda	0	0	0	0	0	10
Aranideae	1	0	0	1	0	0
Lichen Species	**Atlas Cedar**	**London Plane**	**Larch**	**Beech**	**Northern Red Oak**	**Oriental Plane**
A. calcarea	15	9	1	11	0	20
P. perlatum	15	0	0	2	20	0
X. parietina	0	0	0	0	0	0
C. candelaris	0	0	0	0	0	0
F. carpeta	0	0	0	0	20	0
R. farinacea	0	0	0	0	0	0
L. muralis	1	0	0	0	0	0
O. parella	0	0	0	0	0	0
Bird species	**Atlas Cedar**	**London Plane**	**Larch**	**Beech**	**Northern Red Oak**	**Oriental Plane**
Wood Pigeon *(Columba palumbus)*	0	0	0	4	1	0
Rook *(Corvus frugilegus)*	0	3	2	0	2	0
Jackdaw *(Corvus monedula)*	0	1	0	2	1	0
Mallard *(Anas platyrhynchos)*	0	0	0	14	0	0
Herring Gull *(Larus argentatus)*	0	0	1	9	0	0
Vegetation Species	**Atlas Cedar**	**London Plane**	**Larch**	**Beech**	**Northern Red Oak**	**Oriental Plane**
Perennial Ryegrass *(Lolium perenı*	31	27	9	21	10	1
White Clover *(Trifolium repens)*	7	0	0	1	0	0
Buttercup *(Ranunculus repens)*	1	0	0	0	0	4
Dandelion *(Taraxacum officinale)*	1	0	0	2	1	3
Daisies *(Bellis perennis)*	0	3	17	4	8	7
Greater plantain *(Plantago major)*	0	0	4	6	21	3
Petty Spurge *(Euphorbia peplus)*	0	0	0	1	0	0
Thyme-leaved Speedwell *(Veronic*	0	0	0	0	0	2
Horseweed *(Erigeron canadensis)*	0	0	0	0	0	1
Irish Ivy *(Hedera hibernica)*	0	0	0	0	0	4