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The University of Dublin

Building Habitats: An Analysis of Irish Tree Planting Projects in Urban Environments

Rachel Byrne

School of Natural Sciences

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University of Dublin, Trinity College

Declaration

I, Rachel Byrne, declare that this thesis is my own work except where stated through references or in the Acknowledgements and that it is 5,805 words in length.

Signed: Rachel Byrne

Date: 06/04/2022

Abstract

With CO_2 emissions increasing globally alongside rapidly decreasing forest cover, society is in a race against time to preserve and restore our natural habitat. In Ireland, we face the challenge of rebuilding our once dense native forest that has been exploited over the past 300 years. As the population growth of Ireland sees no sign of slowing, strategies must be implemented to merge the human and natural world and allow urban habitats to become greener as we attempt to regenerate our native woodland habitats. Many organisations and local authorities across Ireland are working to make this vision a reality by creating new woodland habitats and restoring old ones. This project investigated the challenges that urban planting projects may face when planting saplings in a busy metropolitan environment and if proximity to points of human activity influences their success. The prediction model revealed there is an increased risk of sapling damage and death the closer saplings are planted to these points of human activity. Further analysis determined that keeping saplings fenced, regardless of distance, will reduce the rate of damage and increase the rate of survival among the sapling populations. The ecological traits and ecosystem functions of the most common species identified in this survey were investigated and it was concluded that focusing on the ecosystem as a whole rather than the numbers of individuals being planted is the best approach going forward to ensure the future sustainability of these habitats. Importantly, there is a need for more large broadleaves and conifers to be planted to meet the aim of increased carbon capture. Finally, this project revealed the lack of research available for any organisations wishing to plan tree planting projects, particularly in urban environments.

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I would like to thank my supervisor, Professor Yvonne Buckley, for her inspiration and guidance throughout this challenging process. I would also like to thank Courtney Gorman and Alain Finn for their endless patience and programming advice over the past few months.

Thank you to Orla Farrell for her endless enthusiasm and infectious spirit, I do not doubt that Ireland is a greener place because of her inexhaustible passion to restore the beauty of our forests for the children of Ireland. I would also like to thank Diarmuid McAree of CRANN and Mick Burke of Dublin City Council for their wealth of knowledge.

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1. Introduction

1.1 Deforestation and Climate Change

The promotion of afforestation has become an integral part of tackling rising global CO_2 emissions. Throughout the 1990s, CO_2 emissions from deforestation were estimated to be at 5.8 $GtCO_2$/yr (IPCC, 2007). However, beyond carbon emissions, the removal of trees from our land has a variety of far-reaching consequences illustrated in the IPCC's 2019 Special Report. Deforestation can alter albedo causing a fluctuation in the Earth's temperatures; this reduces evapotranspiration which helps cool the air; contributing to the release of aerosols and biogenic volatile organic compounds which impact cloud formation; changing the roughness of the Earth's surface, affecting wind speed (IPCC, 2019).

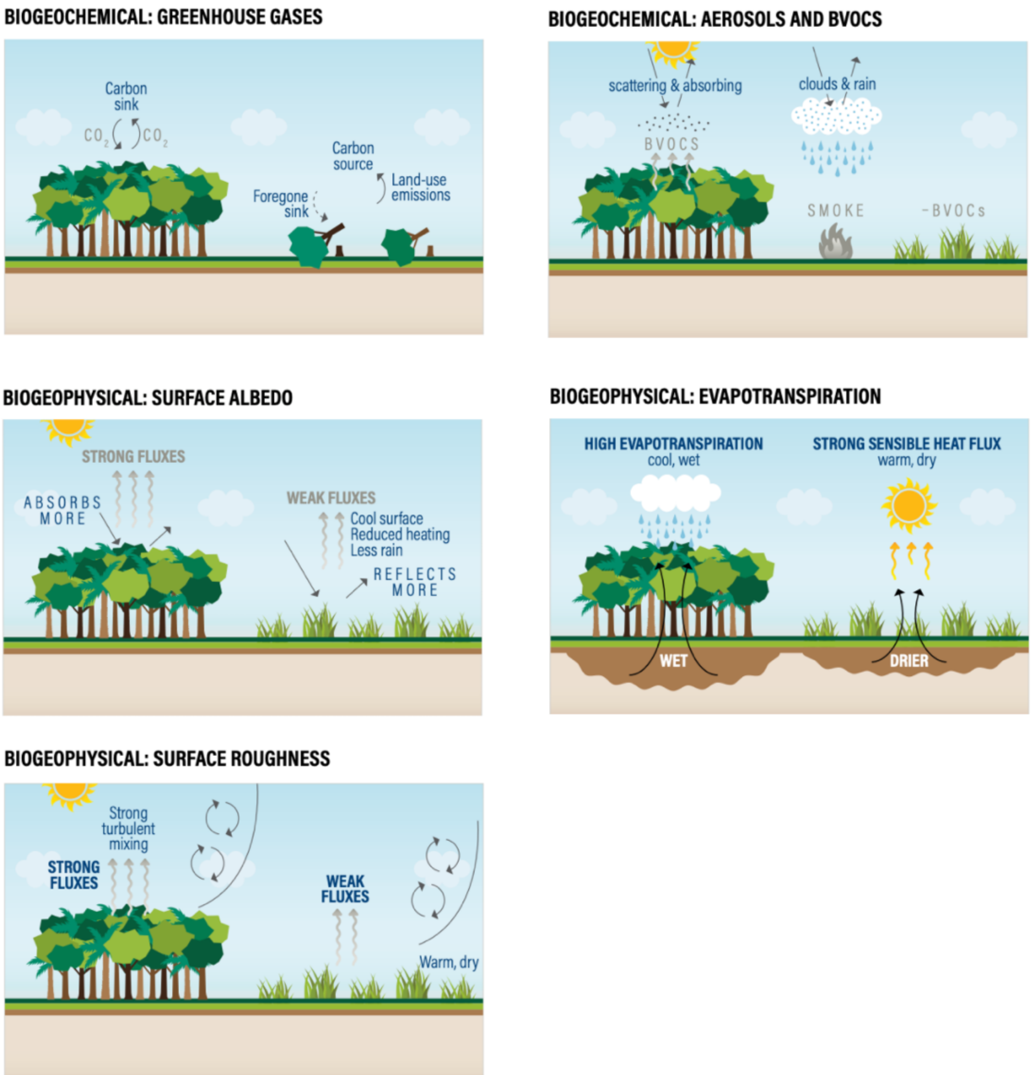


Figure 1. *Adapted from Wolosin, Harris (2018), Figure 2.* The Biogeochemical and Biogeophysical effects of Deforestation on the Earth's Climate.

The combination of the components listed, and their interactions are complex (Fig. 1), and the scale of their consequences is not yet fully understood, however modelling studies agree that continued deforestation across all continents would result in warmer, drier climates in the deforested areas (D'Almeida, C., *et al.* 2007, Davidson, E. A. *et al.* 2012, Mahmood, R. *et al.* 2013).

1.2 Tree Planting Projects as a Response to Deforestation

The rate of deforestation has slowed between 1990 and 2020, this is in part due to the increase in forest area resulting from afforestation policies (FAO, 2020). The IPCC has expressed the need to protect and restore our forests which will help contribute to the solution of the rising greenhouse gas emissions (IPCC, 2019). REDD+ is a framework developed by policymakers in response to the mounting concerns regarding global deforestation that offers financial incentives to governments, businesses, and communities to maintain and if possible, increase forest cover (COP 19, 2013). The emergence of afforestation policy frameworks such as REDD+ has also encouraged a wide range of citizen-led tree planting initiatives across the globe.

Since 1961, tree-planting organisations have reportedly planted close to 1.4 billion trees across 74 different countries, and the number of these organisations has risen by 288% in the past 30 years (Martin *et al.,* 2021). The aims of many of these tree-planting organisations were examined by Martin *et al.* in a review analysing the most frequently used words in organisations' mission statements (Fig. 2), the most common of which being "communities", "forest", "sustainable", "local", "conservation" etc.

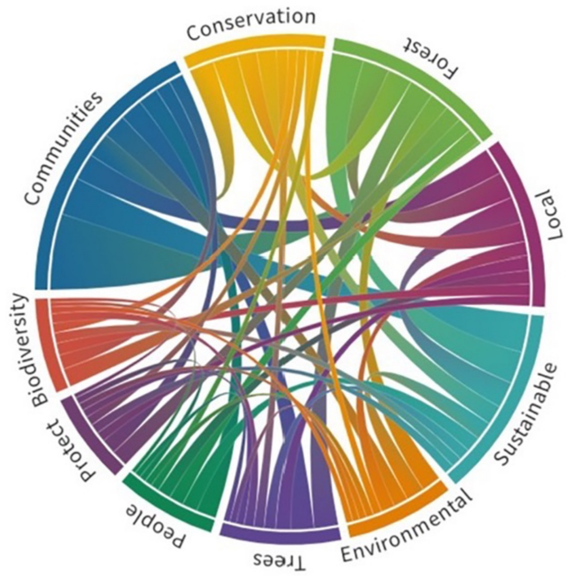


Figure 2: Word linkages between most frequently used words in mission statements for tropical tree-planting organisations. Thick lines represent two words that are frequently used together, thin lines indicate less frequent. (Source: Martin et al., 2021, Fig.3)

Martin *et al.* concluded that although 75% of organisations investigated specified forest restoration or wildlife conservation as their main goal for planting trees, they found a more prevailing utilitarian focus for the tree-plantings. The most common species planted were economically functional trees that provided timber, fruit, or agricultural services, further reflected in their mission statements where one-third of the 15 most used words were people-focused ("communities", "sustainable", "people", "development", "economic") (Martin *et al.,* 2021).

Whether these projects aim to increase biodiversity, encourage habitat restoration, produce timber or offset carbon, many tree planting organisations fail to keep detailed records of previous projects and so there is little to compare against in terms of strategy and execution of long-term results.

1.3 Reforesting Ireland

Due to extensive afforestation programmes, Ireland's forest cover has increased from 1% in the early 1900s to 11% at present (EPA, 2017), making Ireland's landscape one of the most rapidly evolving in Europe in terms of land-use changes (Wilson *et al.,* 2012). Habitat loss and fragmentation have become major issues due to the extensive agricultural presence across the country and other human drivers, resulting in a decline of biodiversity on the island since the early 2000s (Morrison R., & Bullock C., 2018). Due to the need for native tree restoration across the country, the Department of the Environment, Climate and Communications has proposed a target of 8,000 hectares of new forestry every year, with an objective of 70% conifers and 30% broadleaves (Department of the Environment, Climate and Communications, 2019). Several Irish tree planting organisations and local county councils have made it their mission to aid in the restoration of native Irish forests (CRANN, Easy Treesie, Trees on the Land, Hometree) and to "re-green" the island that was once rich in woodland.

1.4 The Ambiguity of Success & the Challenge of Creating a Sustainable Habitat

The measure of success for these projects appears ambiguous, with little mention in the documentation of various Irish tree planting organisations of how the organisations in question evaluate the success of the plantings including their long-term monitoring strategies. Therefore, it is unclear what many of these organisations deem a "successful" project. The lack of literature available on previous planting projects, particularly in Ireland, also makes it difficult to form a clear picture of the planting strategies that have been executed by these organisations. There are, however, suggestions on many of the websites of these organisations regarding how members of the public should approach planting trees such as instructions on how to plant a sapling, what you should consider before planting etc. (i.e., the height of the tree may grow, the location of planting etc.) (CRANN Ireland, 2004). Due to the variety of motivations listed previously for tree plantings, stakeholders must collaborate to clearly define the biophysical and socioeconomic goals of each planting project (Brancalion H. S., Holl D., 2020). Brancalion and Holl suggest a synthesised planning process to guarantee an increase in tree cover that includes guidelines such as addressing the underlying causes of deforestation, tailoring the planting strategy to the clearly defined project goals, and focusing on the forest or habitat as a whole and not just the trees. This last point highlights the need to consider species diversity when planning these projects. For these plantations to function as independent ecosystems, heterogeneity and age structure are important factors to consider (Di Sacco *et al.,* 2021).

The promotion of tree planting in local parks and recreational areas has increased with the knowledge that urban nature can have a positive effect on people's mental and physical health (Turner-Skoff J., Cavender N., 2019). With the growing need to integrate nature into our urban communities, it is important to be aware of how large amounts of human activity impact the success and survival of the saplings planted in these projects. Ensuring the plantations can grow into sustainable habitats that can provide shelter and food for wildlife as well as contributing ecosystem services to the humans that live and use these recreational spaces are crucial goals to aim towards. Due to the increasing urban populations, it is important to implement planting strategies that work well with busy urban environments.

1.5 Project Aims and Research Questions

This project aims to investigate and consider various factors that may affect the success of tree planting projects, with a focus on public parks where there is a large amount of footfall. The lack of standardised guidance for local tree planting projects presents an opportunity to create a baseline guide for future projects which can be developed and utilised to mitigate damage and death of saplings planted, as well as aid in creating a balanced habitat that can withstand a large amount of human activity while also providing shelter and nutrition for local wildlife.

The main research questions for this project are as follows:

i) Does proximity to points of human activity influence the damage or survival of saplings in public parks?
ii) Does having the saplings fenced/unfenced impact the damage or survival of the saplings?
iii) Are the species that are being planted contributing to a well-balanced habitat that can withstand the large amount of human activity in these areas?

2. Methods

2.1 Site Selection

The three chosen sites for this project are each located across three different jurisdictions in County Dublin: Dún Laoghaire Rathdown (DLR), Dublin City and Fingal (Fig. 3). The organisations that have been involved in planting trees at these sites are Easy Treesie, CRANN Ireland, and Dublin City Council.

Figure 3: Location of each of the three sites chosen across Dublin for this project; Stonebridge GAA Shankill, Seagrange Park Baldoyle, and Tolka Valley Park. Source: via QGIS.

Easy Treesie is a volunteer collective composed of schools and associations, that aims to plant one million trees in Ireland by 2023, with 240,029 trees planted as of March 2022 (Easy Treesie, 2022). The organisation focuses on the importance of schoolchildren as stewards of the planet and regularly hosts planting days across the country that teach children how to plant trees. Easy Treesie has been involved in planting trees at each of the sites examined in this project. CRANN Ireland is another voluntary organisation, and partner of Easy Treesie, that aims to "promote, protect and increase awareness about trees, hedgerows and woodlands in Ireland" (CRANN, 2022). CRANN was responsible for planting the majority of the trees at the Shankill site. Fingal County Council (Fingal CC) devised a tree strategy in 2011 (The Forest of Fingal) that aims to retain and protect existing trees in the area, care for those trees to maximise survival, and plant more trees (The Forest of Fingal, 2010). The management system adopted by Fingal CC involves continuous cover forest with trees of both mixed ages and species and they have been working with Dublin City Council to restore the lost Fingal Forest at Tolka Valley Park.

The three sites were chosen due to their shared similarities of being the location of significant tree plantings by the organisations mentioned, the presence of public recreational sports areas and consequential heavy footfall, and the absence of chemical fertilisers and pesticides. The project at Shankill GAA began 5 years ago and was part of a local initiative to plant one tree for every resident in Shankill (11,000). The site sees varying levels of footfall, with the highest activity period being weekends due to ongoing GAA matches at the site. However, it remains a popular area for exercise throughout the week. The busiest activity point is situated around the changing facilities where many saplings have been planted. Seagrange Park, Baldoyle was the original site of the Easy Treesie project where >3,300 trees have been planted to date (Easy Treesie, 2022). Adjacent to the plantings are multiple soccer pitches and basketball courts where the highest level of activity is on the weekend, but like Shankill, is a popular spot for walks throughout the week. Tolka Valley Park was once Fingal Forest and was repurposed in the 1970s and used as a city landfill (Irish Times, 2013). The landfill has since been developed into a public park and Dublin City Council has worked alongside Fingal County Council to replant the land with chiefly native trees. Located on the site is a pitch and putt public golf course which sees its heaviest footfall on the weekends. The site remains busy throughout the week with joggers, walkers and cyclists that enjoy the scenic greenway route.

2.2 Fieldwork

Initial site visits were carried out between May and August 2021 to get familiarised with the vegetation and project details for each location. Data were collected at each of the three sites between January and February 2022. Five belt transects, measuring 30m x 2m, were taken at each of the three sites surveyed (for GPS coordinates, see Appendix 1). The location of the transects was selected randomly covering both fenced and exposed areas. For each sapling along the transects, species were identified using a taxonomic key and height was measured with a metre stick and measuring tape. Survival status of the saplings was determined by scratching the twigs with a penknife and if it was moist and green underneath the sapling was listed as alive. It was also noted whether each sapling was damaged and if the transect was fenced or exposed. A total of 1,153 saplings were surveyed across the three sites. The Field Key to Winter Twigs (John Poland, 2018) was used on the field to identify the winter saplings to species level.

Using Google Earth (2022), the distance from each transect to the closest activity point was measured and recorded. At the Shankill site, the closest activity points included walking paths and changing facilities for the GAA pitch. At Seagrange Park, the closest activity points included walking trails and the side-lines of the soccer pitch. The Tolka Valley Park activity points included walking/cycling trails and the golf course fairway.

2.3 Statistical Analysis

All statistical analysis was performed using R version 4.1.2 (RStudio Team, 2022).

To test whether proximity to a point of human activity influenced the survival of saplings, a mixed-effects model was created and implemented in *lme4. Survival* (binary response variable), *distance* from an activity point (fixed effect), *species* (fixed effect) and *height* (fixed effect) were included in the models with *site* as a random effect, including *transect* nested within *site.* To determine the significance of the fixed terms, various models were constructed by modifying the fixed effects, and compared using likelihood-ratio testing (ANOVA() analysis of variance). To test whether proximity to a point of human activity influenced damage to the saplings, a mixed-effects model was implemented in *lme4* with *Damage* as the binary response variable. All other methodology for this model is the same as the survival model, including the same fixed effects and likelihood-ratio testing.

To test if the fencing status (i.e., fenced, or exposed) influenced the damage and survival of the saplings, a chi-squared test was used to determine if the proportions of either fenced or exposed trees were significantly different. A chi-squared test was chosen due to the comparison of two categorical variables (*damage, fenced*) (*survival, fenced).* The alternative hypothesis for this test was fencing influences the damage and survival status of the saplings.

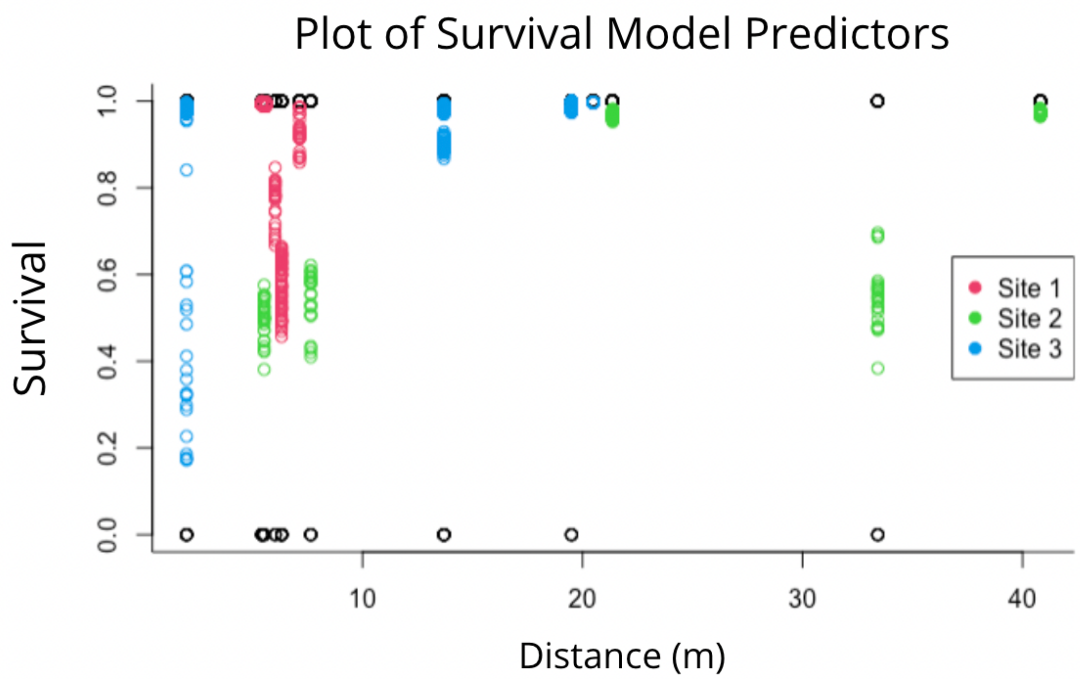
To determine the species diversity and evenness of the sites, species richness for each site was calculated including the Shannon's Diversity Index and Shannon's Equitability Index. An analysis of the most common species found on the sites was carried out and it was investigated if the planting configurations are sufficient for habitat restoration.

3. Results

3.1 Survival

The survival rate of all trees surveyed across all sites was high, at 94%, while 6% of the trees planted had not survived. The most effective model to predict the chances of survival in relation to distance included *distance* and *height* as fixed effects and no interaction with *species.* The model shows that the chance of survival reduces if the saplings are located closer to human activity points (Fig. 4).

The chances of survival are also influenced by the fencing status (fenced/exposed) of the saplings (Fig. 5). This is demonstrated in Fig. 4 where it can be seen that at ~33m there is an average chance of just under 60% survival, this transect is exposed (as can be seen in Fig. 5) and the significance of fencing will be further examined in Section 3.3.



0= Dead 1 = Alive

Figure 4: Plot of survival model predictors (coloured points) including the original data collected (◯). The plot shows that by increasing the distance from the human activity points the chances of survival increase.

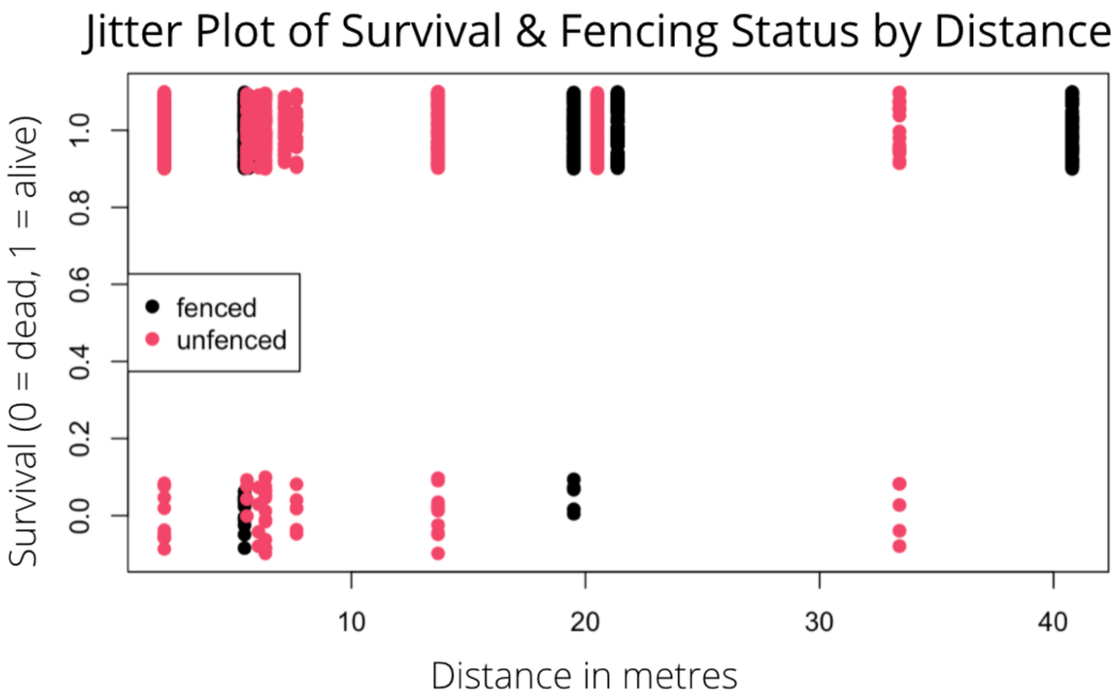
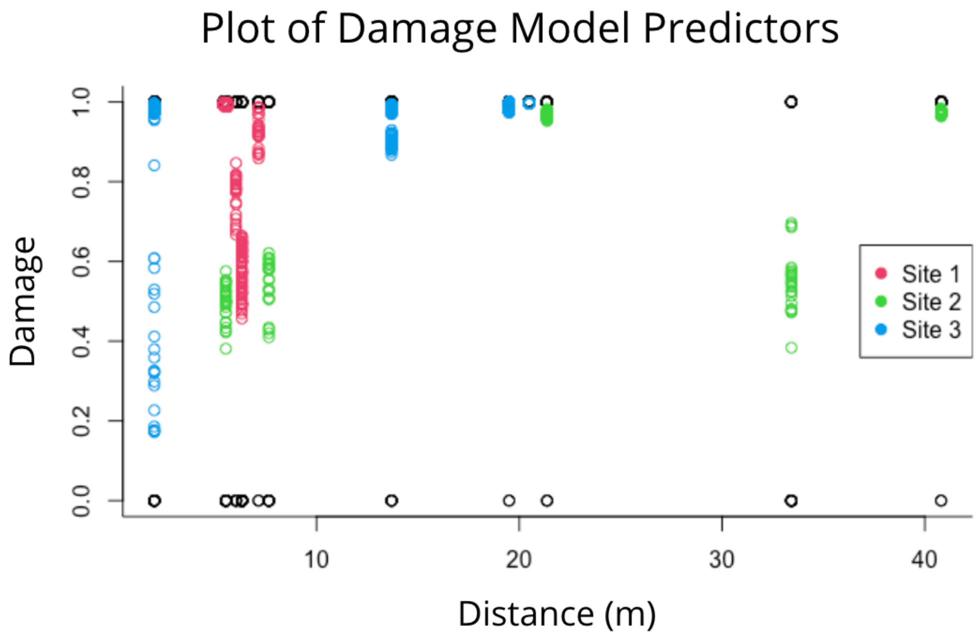


Figure 5: Plot demonstrating the survival status of the saplings in the transects that were fenced or exposed. This plot highlights the status of saplings that didn't survive were predominantly exposed.

3.2 Damage

The percentage of damaged trees surveyed was 10% with 90% remaining undamaged. As with the survival model, the most effective model to predict the chances of damage in relation to distance included *distance* and *height* as fixed effects and no interaction with *species.* The model shows that the chance of the saplings being damaged increases if the saplings are located closer to human activity points (Fig. 6).

Similarly to sapling survival, the chances of damage are also influenced by the fencing status (fenced/exposed) of the saplings (Fig. 7). This is demonstrated in Fig. 6 at ~33m where there is an average chance of just under 60% of being undamaged despite the long distance from the point of activity. This transect is exposed (as can be seen in Fig. 7), the effects of which can be seen in Section 3.3.



0 = Damaged   1 = Undamaged

Figure 6: Plot of damage model predictors (coloured points) including the original data collected (○). The plot shows that by increasing the distance from the human activity points the chances of the saplings being damaged decreases.

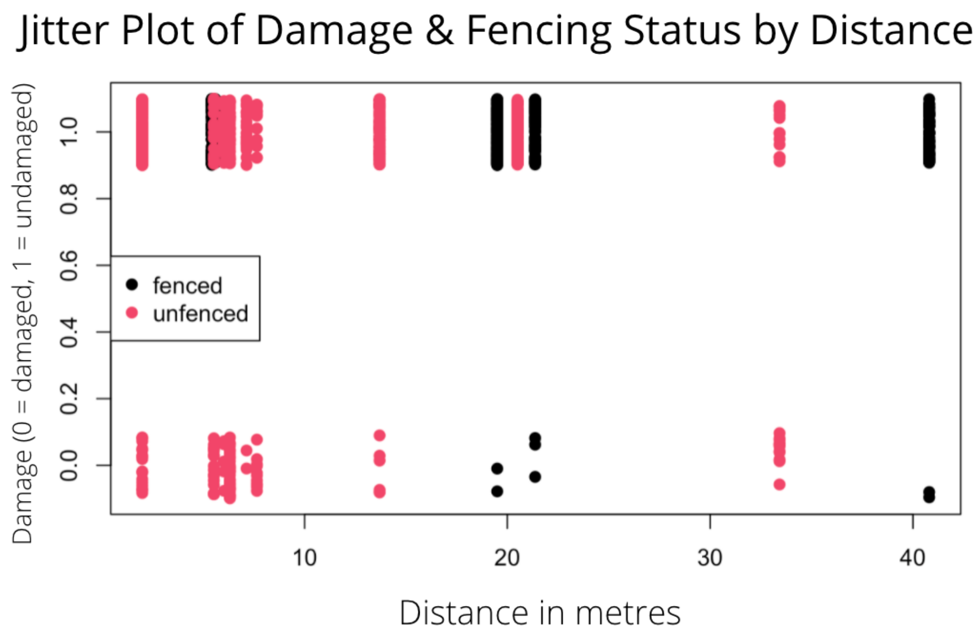


Figure 7: Plot demonstrating the damage status of the saplings in the transects that were fenced or exposed. This plot highlights the status of saplings that were damaged were predominantly exposed.

3.3 Fencing

Of all the trees surveyed across all three sites, 41.4% of trees counted were confined in fenced areas and 58.6% were exposed. The chi-square test performed to test the relationship between sapling damage and fencing returned a p-value < 0.0001 therefore we can reject the null hypothesis that the variables *damage* and *fencing* are independent and accept that fencing does influence sapling damage (Table 1), (Fig. 8).

Table 1: Results of the chi-squared test testing the relationship between damage and fencing. The p-value was highly significant with a value of <0.00001

Pearson's Chi-squared Test *Data: tree damage and tree fencing*					
X-squared	60.882	**Degrees of Freedom**	1	**p-value**	6.061^{-15}

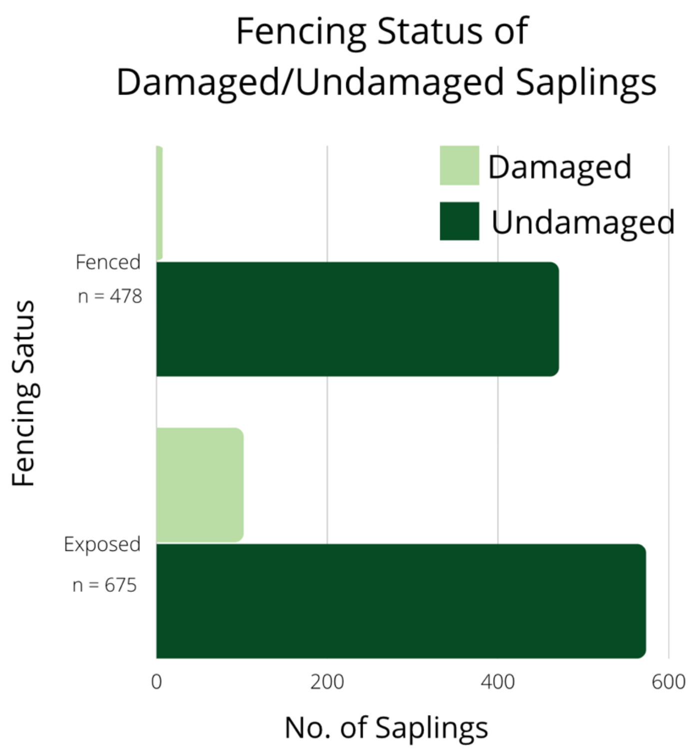


Figure 8: Fencing status of saplings and how many of them were damaged/undamaged in each category; fenced (n = 478) and exposed (n = 675). The proportion of exposed saplings that were damaged is visibly higher than those that were fenced. (See appendix 2 for contingency table).

The chi-squared test carried out to test the relationship between survival and fencing returned a p-value of 0.0008352 indicating that the null hypothesis can be rejected (*survival* and *fencing* are independent) and the alternative hypothesis that fencing does have an impact on sapling survival can be accepted (Table 2), (Figure 9).

Table 2: Results of the chi-squared test testing the relationship between survival and fencing. The p-value was significant with a value of 0.00085352.

Pearson's Chi-squared Test *Data: tree survival and tree fencing*					
X-squared	11.161	**Degrees of Freedom**	1	**p-value**	0.00085352

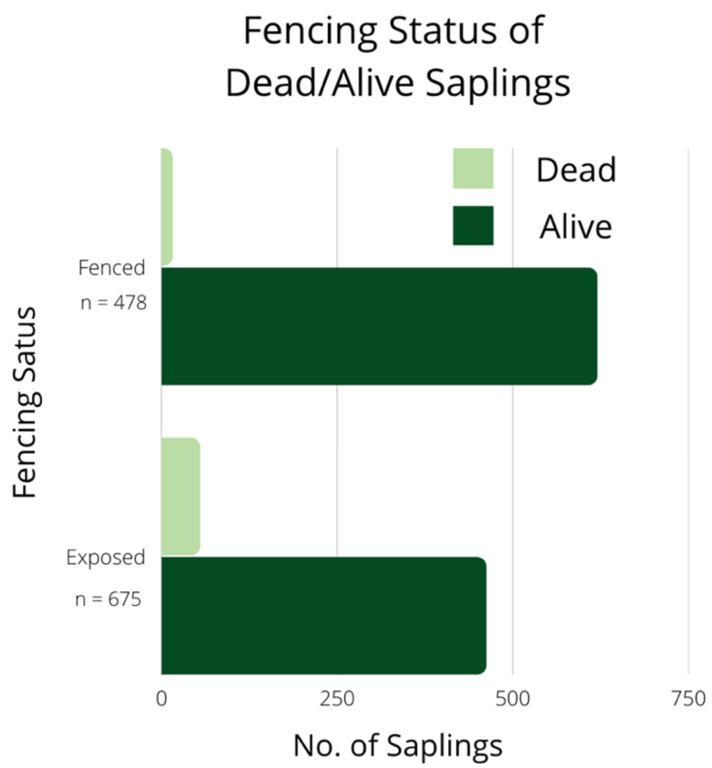


Figure 9: Fencing status of saplings and how many of them were dead/alive in each category; fenced (n = 478) and exposed (n = 675). The proportion of exposed saplings that are dead is visibly higher than those that are fenced. (See appendix 2 for contingency table).

3.4 Species Diversity & Evenness

In total 1,153 saplings were counted, identified, and measured across all sites and 22 unique species were identified (see Appendix 3 for full species list). At Site 1, 17 individual species were identified from the transects and the site shows 62% maximum possible diversity (Table 3). Six individual species were identified on Site 2 and the site shows 56% of the maximum possible diversity. Thirteen individual species were identified on the Site 3 transects and the site shows 72% of maximum possible diversity. Site 3, therefore, has the greatest evenness of species.

Table 3: Species Richness for each site including the calculated Shannon's Diversity Index (H’) & Shannon's Equitability for each of the three sites.

Site	Species Richness	H’	Equitability
1	17	1.766	0.623
2	6	1.001	0.559
3	13	1.848	0.720
All Sites	22	-	-

Native species were the most abundant of all species counted across all sites (Fig. 10), of the ten most common species counted only two were non-natives (Field maple *Acer campestre,* and Sycamore *Acer pseudoplantanus*). The three most common species found were common alder (*Alnus glutinosa*) (total of 206), downy birch (*Betula pubescens*) (total of 189), and silver birch (*Betula pendula*) (total of 175).

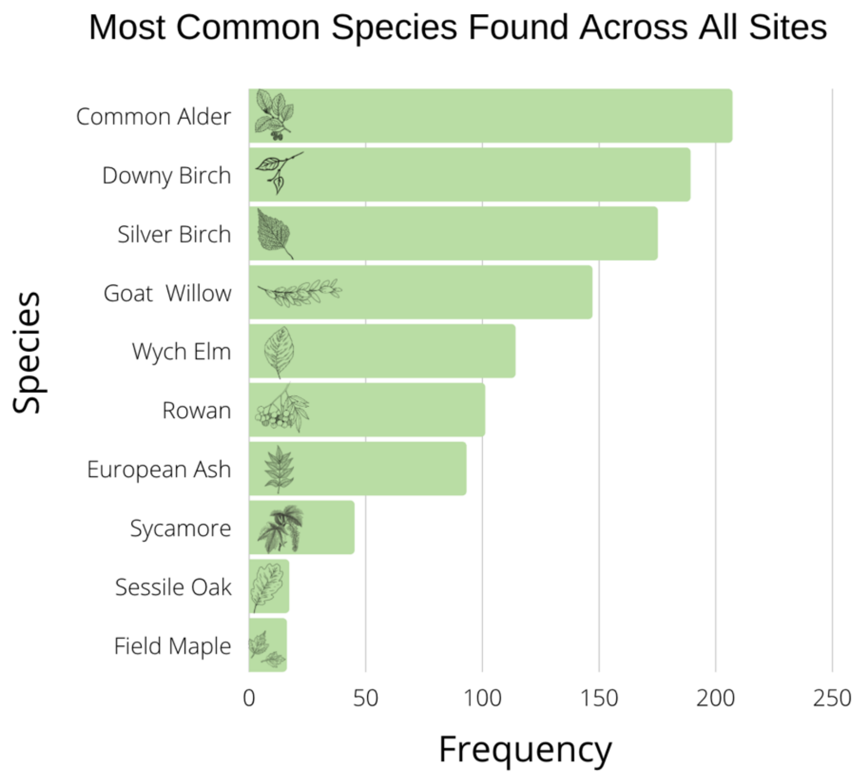


Figure 10: Frequency chart of the 10 most common species that were found and counted across all sites (common names). Alder, Birch, and Willow were counted the most frequently.

4. Discussion

4.1 Sapling Survival

Overall, the survival rate across all sites was high (at 96%), making the planting projects very successful in terms of survival. The survival model demonstrates that by increasing the distance from human activity points chances of survival increase, allowing us to reject the null hypothesis that there is no relationship between survival and distance.

It must be noted that untrained volunteers are recruited to plant most of the saplings for the tree planting organisations e.g., school children and company workers. This can ultimately result in disturbance to the saplings due to the way they have been planted which may affect their long-term survival. For example, at Site 1 several saplings were planted against walls, fences, and paths and as the trees grow their roots may damage the structures they grow around. This may ultimately result in their removal. In future projects volunteers should be advised to plant at least 1m from any structure that may be affected by the growing trees and their root systems. Long-term monitoring of sapling survival will be necessary to determine if the survival rate will remain this high. The factors mentioned such as the proximity of saplings to walls etc. may impact the rate of survival in the future when the trees reach a certain size.

Decreased survival because of proximity to human activity is difficult to confirm. It is easier to visually determine if a sapling has been damaged by humans, but it can be more challenging to determine why a sapling has not survived (i.e., death could be due to edaphic factors, weather conditions etc.). Therefore, damage appears to be the most effective way of measuring the effects of sapling proximity to human activity.

4.2 Sapling Damage

The damage rate of 10% across all sites examined is relatively low, however, a lot of this damage is avoidable. Most of the damage to the saplings occurred in the transects closest to the points of human activity, although the transects that were fenced off saw a much lower damage rate than those that were exposed regardless of location.

The most notable area of damage was located on Site 1 (Shankill). The transects carried out in the proximity of the changing facilities revealed a large amount of damage to the saplings, several of these saplings had also died. The saplings planted at this location were unfenced and therefore, many had been trampled, snapped, and vandalised (Fig. 11 & 12). These findings demonstrate the importance of keeping the saplings fenced, particularly when planting next to hubs of human activity until they reach a more mature growth stage. When planning future planting projects, planting proximity to points of human activity is worth considering based on the results of this study. If there is a desire to increase tree cover around these activity points, protecting the saplings should be a priority if the damage rates are to be reduced.

Figure 11 (left) & **12** (right): Site 1 saplings physically deformed and snapped. Located beside changing facilities which see the heaviest amount of footfall at that site. For further images please refer to Appendix 4.

At Site 2 (Baldoyle), there was notable damage to the saplings planted along the side-lines of the football pitch which were all unfenced. This is most likely a result of the vulnerable saplings being hit by fast-flying footballs and being damaged by people gathering on the sidelines. A possible solution to this issue in the future could be to plant more mature trees at the edge of a pitch to protect the younger saplings that are planted behind them, acting as a line of defence. Alternatively keeping the saplings fenced that are close to the side-lines of the pitch may significantly reduce the chance of damage. These methods of protection could be compared and tested in future studies to determine the most effective form of protection.

4.3 Fencing

There is a strong relationship between the fencing status of the saplings and whether the trees are damaged/undamaged (Table 1). Despite the results indicating that the chance of damage/death will increase the nearer the saplings are planted to an activity point, fenced saplings near these points remained predominantly undamaged and survival was high. Two transects at Site 1 (Shankill) were carried out in a fenced area that was close to a busy road and pathway (Fig. 13). This road sees heavy traffic and footfall during the week due to the presence of two primary schools situated along Stonebridge Road. No saplings were damaged in this transect and the few saplings that didn't survive are suspected to have died in the drought that struck the area in the Summer of 2020. Therefore, it is assumed that human activity had no impact on these saplings despite their proximity to an activity point. A similar observation was made at Site 2 (Baldoyle), where there was a fenced area adjacent to the soccer pitch. Very little damage was recorded on the fenced transects despite their proximity to the pitch (Fig. 14) and survival on these transects was 100%, highlighting the benefit of fencing until the trees have reached maturity.

Not all saplings that were recorded as damaged were dead, many had begun the recovery process and were sprouting new buds (Fig. 15). To guarantee their survival and prevent further damage, particularly for those located next to walkways or other hubs of activity, it would be beneficial to keep these areas fenced in future projects.

Figure 13: Image taken at Site 1 of an area of fenced saplings adjacent to a busy road and walkway. All of the saplings here were undamaged and survival was high. There was no evidence of human interference that was seen closer to the GAA pitch.

Figure 14: Image taken at Site 2 (Baldoyle). This grove of fenced saplings (right) had very low damage and 100% survival despite being within proximity to the soccer pitch (left background).

Figure 15: Image taken at Site 1 on a transect that was located next to a busy walkway (seen in the background). Keeping these saplings fenced may have significantly reduced the damage to the saplings on this transect and prevented any further damage to the saplings planted here in the future.

There is, however, an issue of cost in relation to constructing adequate fencing to protect the saplings. Many of these projects are reliant on the donations of sponsors, with a cost of €10 to plant a single sapling (CRANN Ireland, 2022), and proper fencing can be a costly addition to the balance sheets. A search for local fencing suppliers shows the average pricing for 10m of low-rise steel fencing is €117, and €55 for one panel of 1.2m (H) wooden fencing (TimberTrove, 2022). If the non-profit organisations incorporated the cost of pricing into each tree donation it may discourage people from donating a tree due to the price rise. A cost-benefit analysis would be beneficial to carry out to investigate if the cost of fencing would mitigate the funds lost on the saplings that don't survive in the unfenced areas.

The studies that have been conducted on the effectiveness of fencing in tree planting projects have seemingly only focused on protection against herbivory, more data need to be collected regarding fencing and human activity to form a more definitive judgement regarding its effectiveness.

4.4 Species Evenness and the Importance of a Balanced, Functional Habitat

The lowest species richness was recorded at Site 2 (Baldoyle) with *Betula spp.* dominating the site. Overall, the diversity of species planted at each site could be improved to promote the development of independently functioning ecosystems. It is important to keep in mind the broader idea of the habitat we aim to create when carrying out these projects and not just the idea of increasing tree cover. By only focusing on the trees that are planted it is easy to lose sight of the diverse range of other plant species that are crucial to a functioning habitat (epiphytes, lianas, herbs) (Brancalion *et al.,* 2020).

Homogeneity was particularly noticeable at Site 3 (Tolka Valley Park), which had been predominantly planted by Dublin City Council. Despite the site having the most variation of species and the highest species evenness, many of the trees occurred in patches of monoculture (Fig. 16). A lot of these patches of homogenous species were planted along transects similar to those measured out for this project, making them much simpler to count and identify but not contributing much in terms of biodiversity to the site. These transects had a much more homogenous vegetation composition and structure that lacked signs of other organisms that form the mutualistic relationships crucial to habitat recovery. Therefore, tree planting projects not only have the responsibility to focus on the growth and survival of the trees being planted, but they must also carefully consider the non-tree species that will aid in the establishment of a multifaceted and independently functioning habitat.

Figure 16: Image taken at Site 3 (Tolka) of a transect of singular species planted by Dublin City County Council. This was a common occurrence throughout the park. Note the high-density planting compared to Fig. 13, this can impact the light penetration resulting in a lack of growth and species diversity in the shrub layer and was also a common sight with the council plantings.

The differences in planting configuration are apparent between the non-profit planting initiatives and the county councils. Each site had saplings planted by their respective county council, Easy Treesie and CRANN Ireland. One stark contrast was the height of the saplings planted by the county councils (the average height of trees planted by the councils being 3m). During an interview conducted on 14th May 2021 with Diarmuid McAree of CRANN Ireland, Mr McAree had observed that planting saplings over 1m in height decreased their chances of survival. At Site 1, several observable mature saplings that were planted by the DLR county council had not survived. Studies have shown that tree size affects a tree's rate of establishment, and it takes longer for larger trees that are transplanted to become established due to the longer time needed for root re-establishment (Watson, 2005). The age structure of the trees planted by the councils is also largely homogenous with little to no age variation in the established sapling communities at each of the sites. Age structure is another aspect of habitat restoration that needs careful consideration when designing tree planting projects in order to replicate the natural succession of woodland habitats. In contrast to the councils planting large batches of saplings that are similar in age, CRANN and Easy Treesie continue to plant saplings at previous sites which aid in creating the desired age variation found in natural woodland. The lack of revisitation by the county councils to the sites was also highlighted by their failure to remove the stakes supporting many of the trees. Stakes can be seen growing into the bark of the maturing trees planted by the councils, CRANN and Easy Treesie do not use stakes in their planting strategy and so this was not an issue with any of the saplings planted by these organisations.

When designing these projects, it's important to have clear aims developed from the initial phases. If the aim is to naturally regenerate a site, the most effective tree-planting approach is to plant the fewest trees needed with the required functional traits to complement the habitat (Di Sacco *et al.,* 2020). The key to a resilient and biodiverse habitat is to promote mutualistic interactions (e.g., tree-fungi relationships), seed-dispersing animals, and pollinators. The ecological functionality and ecosystem services of the most common species planted at the sites varied with many proving suitable to be planted in areas of such exposure to human activity.

Alnus glutinosa, the most common species counted on all three sites, is a fast-growing medium broadleaf with a lifespan of roughly 60 years. This species is self-pruning and robust, capable of withstanding the late Spring frost without suffering (Teagasc, 2020). These traits make the species a good choice for planting around areas of high human activity. This was reflected in the survey where only seven *A. glutinosa* were either damaged or dead despite it being the most common species to be planted. Due to its symbiotic relationship with the bacteria *Frankia alni, A. glutinosa* can form nitrogen-fixing nodules that enhance the soil's fertility (Teagasc, 2020). The catkins that grow on this species act as an early source of nectar and pollen for bees, the seeds are eaten by finches, and the leaves are consumed by caterpillars and moths (Woodland Trust, 2022).

Birches (*Betula pendula* and *Betula pubescens*) are a medium broadleaf pioneer species with the ecological functionality of improving soil due to their deep root systems. These root systems accommodate the mycorrhizal associations with many species of fungi (*Amanita muscaria, Leccinum scarbum, Cantharellus cibarius*) and support 334 species of insects and other invertebrates that feed on them (Trees for Life, 2022). The *Betula* were the most frequent trees to be recorded as dead or damaged in this survey. Until recently both species were not recommended to be planted in afforestation projects by Teagasc due to their poor stem quality and poor survival and growth rates (a result of foreign seed importation) (Teagasc, 2022). However, the Birch Improvement Programme funded by the National Council for Forest Research and Development, has been working to develop a sustainable supply of improved and healthy Birch seed and plant material. Due to the more delicate nature of Birches and the frequency at which they were recorded to be damaged on this survey, future planting projects should consider keeping their birch saplings fenced to allow for greater survival and reduce the chance of damage, particularly when being planted close to points of human activity.

Sorbus aucuparia is a medium broadleaf that produces scarlet berries which are a source of nutrients to birds in the Autumn, who then disperse the seeds. The summer flowers attract pollinators like beetles and bees. The species is also resistant to frost and wind and is a good tolerator for poor, thin soil making this hardy sapling a good choice for exposed areas that may see a lot of activity. *Salix caprea* is another species suitable to be planted in urban environments such as the ones examined in this study. This tree can withstand heavily polluted environments and has been shown to have the ability to remove heavy metals like Cadmium and Zinc from sites that have been polluted (Enescu C.M. *et al.,* 2016). *S. caprea* is a host to several lichen species and its catkins provide pollen and nectar in the early Spring to insects, bees, and birds.

Many of the species that have been planted on each site have functional traits that make them appropriate to be planted on sites that see the levels of disturbance recorded in this study, however, when selecting species to plant in these areas it's important to be aware of the species susceptibility to damage to aid in the decision of which saplings should be fenced for protection. There is a notable imbalance of species on each site, particularly at Site 2 which recorded the lowest maximum possible diversity. To ensure that these habitats will be well-balanced and functional long into the future, focusing less on the number of trees that are being planted and more on the quality of the habitat i.e., what each species contributes, is a more effective method of habitat restoration.

Carbon capture is listed as a goal of many Irish tree planting projects. The survey carried out revealed most of the species planted were medium broadleaves, however, studies have shown that large broadleaf and large conifer species are the most effective at storing carbon and removing pollution from the atmosphere (Hand K., Doick K., 2021). Therefore, there needs to be more of a balance between medium and large conifers and broadleaves and careful consideration needs to be put into the long-term goals of each tree planting project i.e., medium species are fast-growing and will show short term results in terms of numbers, but the larger species will benefit the environment more in the long term (Fig. 17, Fig. 18).

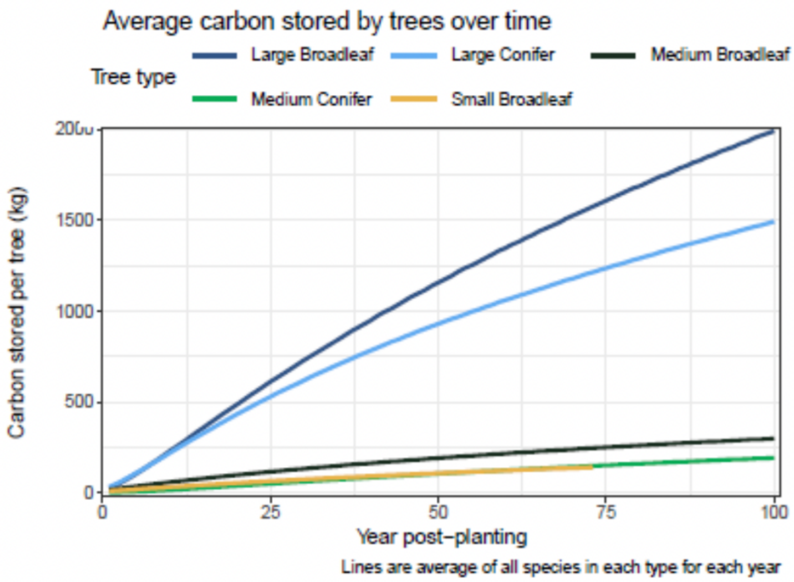


Figure 17: Figure demonstrating the higher amounts of carbon by large broadleaves and conifers each year after planting (Source: Hand K.. Doick K., Forest Research, 2021. Fig. 1).

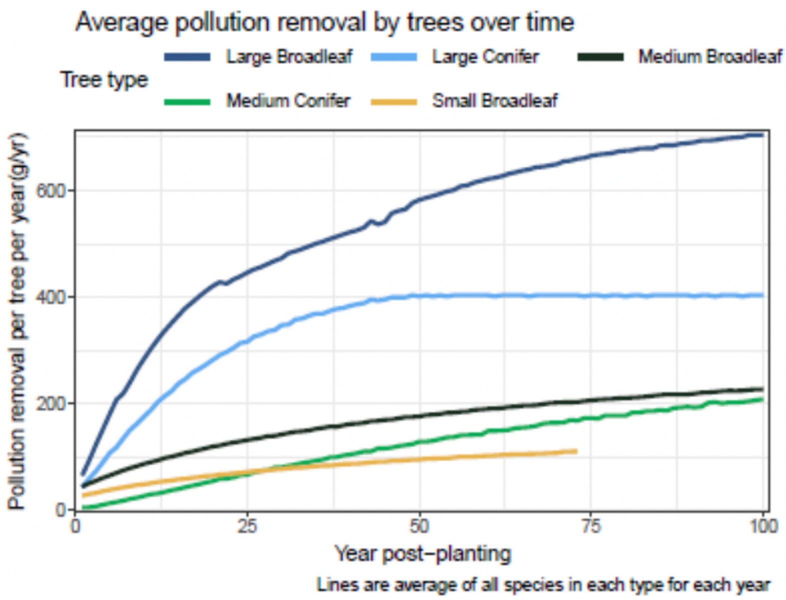


Figure 18: Figure demonstrating the amount of average pollution removed by trees over time, with large broadleaves and large conifers being the most effective (Source: Hand K., Doick K., Forest Research, 2021. Fig. 4).

4.5 Future Applications

Due to the limitations and time constraints of the study, the research needs further development to confirm and explore the findings of this project. This study, however, can act as a starting point for a more in-depth analysis of each aspect that was investigated. To create a broader picture of the effect of human activity on sapling survival and damage, a wider study across Ireland would add more clarity to the results as only three sites have been included in the initial project. Adopting a social aspect to the study would be an interesting addition by surveying areas of varying socio-economic status and interviewing the residents regarding their sentiments toward tree planting and what they think trees contribute to their community.

For future studies, a broader analysis of the effect of fencing in multiple locations and an examination of the effectiveness of different types of fencing (e.g., wire, wood, tubing) would be beneficial to determine the most efficient way, both financially and functionally, of protecting future saplings against human interference.

A full analysis of functional traits for the most common species used by Irish planting organisations could help build a planting strategy for these projects that could benefit and promote healthy balanced ecosystems long into the future. Regarding Irish tree planting projects who focus on restoring native woodland, a full ecological trait analysis of Irish native trees would be useful and could prove cost-effective.

A wider comparison of planting and monitoring strategies by local county councils and independent tree planting organisations could also aid in finding a balance between the most effective strategies that each body executes.

Due to the lack of literature on the topic, it was difficult to compare this project's findings against other projects with the same goals, therefore the more research carried out on the effects of human activity on survival and damage of saplings, and how fencing plays a role in that, a clearer baseline guide can be drawn up for planting projects in the future to ensure that these habitats can thrive for the future generations they're being planted for.

5. Concluding Remarks

This project aimed to highlight how proximity to human activity is affecting the damage and survival rate of saplings planted in public recreational areas of which there hasn't been largely documented in the literature. The results from this study show that proximity to points of human activity does increase the chance of saplings being damaged and decreases their chance of survival. It is possible, however, to mitigate this risk by keeping the sections of saplings fenced if they are situated close to activity points. The results from this study show that fenced saplings suffer much less damage than those that remain exposed.

The diversity of species planted at each of the three sites was not optimum, with *Alnus glutinosa, Betula spp.* and *Salix caprea* making up most individuals counted. Focusing less on the numbers of individual saplings planted and aiming for more species will increase the outcome of a functional habitat. Careful consideration of functional traits is required to ensure the saplings can withstand the high levels of human activity found at these locations.

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7. Appendices

Appendix 1

Table A1.1: Name of each site, transect number and corresponding GPS co-ordinates. Each transect measured 30m in length and 2m in width.

Site Name	Transect	GPS Co-ordinates
Shankill GAA, Stonebridge Road, Dun Laoghaire Rathdown	1	53°14'09.58" N, 6°08'04.90" W – 53°14'09.04" N, 6°08'03.52" W
	2	53°14'09.04" N, 6°08'03.26" W – 53°14'08.58" N, 6°08'01.84" W
	3	53°14'07.10" N, 6°08'00.62" W – 53°14'07.56" N, 6°08'02.07" W
	4	53°14'03.03" N, 6°07'54.59" W – 53°14'02.16" N, 6°07'55.34" W
	5	53°14'01.80" N, 6°08'01.01" W – 53°14'02.51" N, 6°08'02.15" W
Seagrange Park, Baldoyle, Fingal	6	53°23'46.23" N, 6°08'03.09" W – 53°23'47.20" N, 6°08'03.59" W
	7	53°23'46.22" N, 6°08'04.94" W – 53°23'45.27" N, 6°08'05.28" W
	8	53°23'44.21" N, 6°08'05.59" W – 53°23'43.24" N, 6°08'05.79" W
	9	53°23'43.21" N, 6°08'04.13" W – 53°23'44.15" N, 6°08'03.76" W
	10	53°23'42.08" N, 6°08'04.64" W – 53°23'43.07" N, 6°08'04.54" W
Tolka River Valley Park, Dublin City	11	53°22'38.04" N, 6°18'25.00" W - 53°22'37.79" N, 53°22'37.79" N
	12	53°22'36.07" N, 6°18'22.07" W - 53°22'36.01" N, 6°18'21.01" W
	13	53°22'33.94" N, 6°18'01.95" W - 53°22'33.86" N, 6°18'03.54" W
	14	53°22'35.82" N, 6°18'05.02" W - 53°22'35.09" N, 6°18'05.98" W
	15	53°22'33.27" N, 6°17'51.74" W - 53°22'33.24" N, 6°17'50.09" W

Appendix 2

Table A2.1: Contingency table reporting the number of saplings damaged/not damaged and whether they were fenced or exposed.

	Fenced	**Exposed**
Damaged	7	102
Not Damaged	471	573
Column Total	**478**	**675**

Table A2.2: Contingency table reporting the number of saplings alive/dead and whether they were fenced or exposed.

	Fenced	Exposed
Alive	462	620
Dead	16	55
Column Total	478	675

Appendix 3

Table A3.1: List of all species identified in all transects carried out across all three sites

Full Species List	
Black Cherry Plum	*Prunus cerasifera Nigra*
Blackthorn	*Prunus spinosa*
Common Alder	*Alnus glutinosa*
Deodar Cedar	*Cedrus deodara*
Douglas Fir	*Pseudotsuga menzesii*
Downy Birch	*Betula pubescens*
Elder	*Sambucus nigra*
European Ash	*Fraxinus excelsior*
European Beech	*Fagus sylvatica*
Field Maple	*Acer campestre*
Goat Willow	*Salix caprea*
River Birch	*Betula nigra*
Rowan	*Sorbus aucuparia*
Scots Pine	*Pinus sylvestris*
Sessile Oak	*Quercus patraea*
Silver Birch	*Betula pendula*
Silver Maple	*Acer saccharinum*
Small-leaved Lime	*Tilia cordata*
Sycamore	*Acer pseudoplantanus*
Unknown Sp	*Unknown sp*
Whitebeam	*Sorbus aria*
Wych Elm	*Ulmus glabra*

Appendix 4

Fig. A3.1 & A3.2: Further images of the damaged saplings that were planted around the changing facilities at Site 1.