The Ecology and Management of Ballybrack woods and Beaumont quarry: an exercise in urban greenspace management

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CARL Research Project

in collaboration with

Cork Nature Network

& Douglas Tidy Towns

CARL
COMMUNITY - ACADEMIC
RESEARCH LINKS
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- provide their services on an affordable basis;
- promote and support public access to and influence on science and technology;
- create equitable and supportive partnerships with civil society organisations;
- enhance understanding among policymakers and education and research institutions of the research and education needs of civil society, and
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Abstract

In this era of globalization, invasive alien species are quickly becoming one of the main drivers of environmental decline, and with more than half of the world's population living in urban centres, the management of biodiversity within this ecosystem is of increasing importance. One such invasive species which is highly prevalent in urban ecosystems is winter heliotrope (*Petasites fragrans* (Vill.) C.Presl, (Asteraceae), a clonal plant species that has become invasive in the UK and Ireland. Information on this plant is limited, especially in relation to how it should be managed. It is well documented that clonal plants can be some of the most difficult to manage effectively. The aim of this study is to determine how winter heliotrope should be managed and if this invasive species should be a top priority for park managers to eradicate. This was tested in a number of ways including mapping the species distribution in two urban parks, collecting quantitative data on the species itself using quadrats, and gathering further information from organisations and individuals who have dealt with plant in the past. Another feature of this project is the public's perception of invasive species in urban parks which was completed via questionnaire. Results found that densities of winter heliotrope were not affected by habitat or slope but were affected by canopy overhead and the presence of native broadleaved woodland. There were also significant differences in leaf height and diameter across zones. The questionnaires given to park users showed that alien species were not a priority and they were much more concerned with other aspects such as litter and antisocial behaviour. Finally, it was determined from interviews that park managers do not have access to sufficient information on invasive species or regulated long-term management plans in Ireland or elsewhere. This has highlighted the need for more comprehensive research into this area as a whole and specifically into invasives such as winter heliotrope.

1.0 Introduction

As with any island, Ireland has a long history with invasive alien species. In fact, around 33% of naturalised species in Ireland are not indigenous (Baars, 2011). Similar to other oceanic islands, Ireland does not have the native floras to satisfy a human population's needs when it comes to plants. This has resulted in the long-term transfer of alien species to islands from other separated regions, mainly continents (Mack & Lonsdale, 2002). Islands also tend to lack biotic diversity when compared to continents. This means that they have little protection from biotic barriers to naturalisation, which would reduce invasion (Mack & Moran, 1996). The incidence of this invasion has only increased with the escalation of globalisation and urbanisation over the last century, and with this comes an increased importance in the role of biodiversity

conservation and management in cities (Kowarik, 2011). This coupled with changing climatic conditions means that species which are not currently a threat may become a problem in the future (Baars, 2011; Culliney, 2005). Other vectors for invasive plant species to spread through include habitat fragmentation, homogenisation of species diversity, and landuse development (Lee *et al*., 2008).

Invasive species are particularly an issue in urban settings. Cities are not only an entry-point through which many invasive species arrive but are also a gateway for secondary release into surrounding landscapes (Alston & Richardson, 2006). The extensive infrastructure that is associated with urban centres act as corridors for invasive species to colonise new areas, through transport along the roads and the disturbed habitats which roads create (Hansen & Clevenger, 2005) Despite the fact that urban ecosystems are gateways for invasion, the dynamics of invasion science itself has not been readily applied to towns and cities, and the challenges facing the managers of these areas are often overlooked. The process of urban invasion differs greatly from invasion in other contexts and therefore managing alien species in an urban context poses a unique set of challenges (Gaertner *et al.,* 2017). Several elements of urban centres contribute to the success of invasive species within them, including the prevalence of impervious surfaces and disturbed ground, population size and density, and affluence (Kuhman *et al.,* 2010). Affluence in this case refers to the prevalence of importing exotic species for gardens and the general increase in trade that is associated with affluence (Sharma *et al.,* 2010).

Invasions from biological organisms, be it plants or animals, represent one of the biggest threats for the conservation of biodiversity, the provision of ecosystem goods and services, and the development of the economy worldwide, as well as their possible impacts on human health (Roiloa, 2020; Stout, 2011). The ecological impacts of invasive plant species can be both physical, such as displacement or disturbance, and chemical, such as altering soil pH (Teixiera *et al*., 2020). There is evidence that invasive alien species are better competitors as a result of either the possession of novel traits like those which confer with higher biological fitness, for example rapid growth rates, or an efficiency at accessing water sources (Stout, 2011).

The costs of these invaders include the damage inflicted on native habitats and species, monitoring existing populations, eradication and control schemes, and the cost of preventing initial introduction (Callahan, 2003). To put this into perspective, invasive alien species cost the US government roughly $120 billion annually, £1.7 billion to the UK and over €10 billion to the EU (Stout, 2011; Williams *et al*., 2010). However, it should be noted that not all alien

species have negative effects on the habitats they invade. For example, they can provide new crop species, improving diet and reducing preventable death from starvation, and are used as ornamental plants in gardens and parks (Alpern, 1992; Niemiera & Van Holle, 2009).

The impacts that invasive plant species have on human health can vary from very mild to deadly, however, in Ireland there are few invasive plants that have severe impacts (Stout *et al.*, 2011). One example of a plant that does impact health in Ireland is giant hogweed (*Heracleum mantegazzianum*). The sap from this plant causes phytophotodermatitis when it comes into contact with skin. This can cause quite severe slow-healing burns and scarring (Camm *et al*., 1976). In general, the impact that invasive alien species have on ecosystems and biodiversity is extremely hard to assess. Problems are often context and species specific, making it next to impossible to make general statements (Stout, 2011).

The lack of organization between policy makers, the commercial sector, and scientific researchers is the root of a widespread failure to create and execute a sustainable invasive species management practice (Stokes *et al*., 2006). Ideally, an eradication operation would involve all potentially invasive species destroyed upon arrival to the country, however, very few colonists meet this fate. Usually, no action is taken until a species is already established. In this case, the maximum amount of effort should be mounted against destroying the species foothold in the country (Mack and Lonsdale, 2002). Unlike weed control in agriculture, where the aim is to control all species except the crop, managers of invasive plant species are often trying to control one or many invasive species while trying to cause as little damage to native species and ecological species as possible. Management regularly involves the eradication of hundreds of invasive, non-indigenous plant species with very little knowledge on the effects the species is having on the land they manage. Often, it is unknown whether control of invasive alien species is possible or what the potential cost of eradication could be (Hiebert, 1997).

The European commission recognises the threat that invasive species pose and have developed a co-ordinated action plan at the European level in order to eradicate them effectively. This plan consists of prevention, early detection, and management, and its enforcement is aided by the European committee on invasive alien species, the invasive alien species expert group, the scientific forum on invasive alien species, and the working group in invasive alien species.

However, there is no legislation preventing species moving within Europe at the same level (Regulation (EU) 1143/2014 on Invasive Alien Species)

One of the lesser-known invasive species in Ireland is Winter Heliotrope (*Petasites fragrans* or *Petasites pyrenaicus*) which is the focus of this project. Although *P. fragrans* is considered invasive, it is not listed under international or domestic legislation (tii.ie). The genus consists of 18 species which have a broad distribution across the Northern Hemisphere (biodiversityireland.ie). Taxonomically, *Petasites* is a hard group to describe because of the flower's conservative structure and the large amount of variability of the leaves. This genus is also capable of forming fertile hybrids, therefore there are several different classifications of the genus (Tys *et al.,* 2015). Winter heliotrope can survive in a variety of diverse habitats including riparian, urban and inland habitats and are a common feature of disturbed ground (biodiversityireland.ie). Native to Northern Africa, Italy and Sardinia, winter heliotrope was introduced to Ireland as an ornamental garden plant in the mid 1800's and is now relatively common throughout the island of Ireland (Preston *et al., 2002*). *P. fragrans* is a clonal plant meaning it reproduces asexually and the offspring produced remain attached to the parent plant until they become established on their own (Dong et al., 2014). All individuals in Ireland and the UK are male, with no females known (Preston *et al., 2002*). Clonal species are one of the most invasive forms of plants in the world and include other invasive species present in Ireland such as Japanese knotweed (Keser *et al*., 2014). However, in comparison to Japanese knotweed, winter heliotrope seems to have a much milder invasive impact and, in some contexts, can be considered a desirable plant species, for example as a source of nectar during winter for some pollinators (Reynolds, 2002).

The issue with winter heliotrope is that very little is known about the plant in an invasive context in Ireland or elsewhere. There is very little peer reviewed literature on managing the plant. This perhaps stems from the fact that invasive alien species in Ireland did not always receive the level of serious study that they deserved. One book by Reynolds (2002), claims that invasive plants in Ireland, especially "casual invaders" were often glossed over and dismissed. These "casual invaders" make up over half of the current population of non-native species in Ireland. Any literature that had been written may have been unpublished or simply ignored. In contrast, for more than a century, Britain has been studying invasive alien flora. This is partly the consequence of a more urbanised society and landscape, with many invasives having been introduced as a result of extensive and intensive long-term global commerce (Reynolds, 2002).

The aim of this research project is to determine the best way to manage the invasive alien species winter heliotrope (*Petasites fragrans*), that is accessible to the general public, specifically to the managers of parks and other recreational areas in Cork city, Ireland. This

will be achieved by first conducting interviews of individuals and organisations who have had experience managing winter heliotrope in Ireland, with a strong focus on Cork city and surrounding county. This information will then be compiled into a literature review along with any peer-reviewed and grey literature that is available. Physical mapping of winter heliotrope in two urban parks located in Cork city will take place along with a quantitative survey of the species. The final aspect of this project will be to conduct a survey of individuals who use the park regularly, to establish whether they perceive winter heliotrope as a major issue. As a result, this project aims to create a straightforward management plan of winter heliotrope for tidy towns committees, park managers and possibly more.

2.0 Method

This study was conducted at two recreational urban parks in Cork City, Ireland (*Fig. 1).*

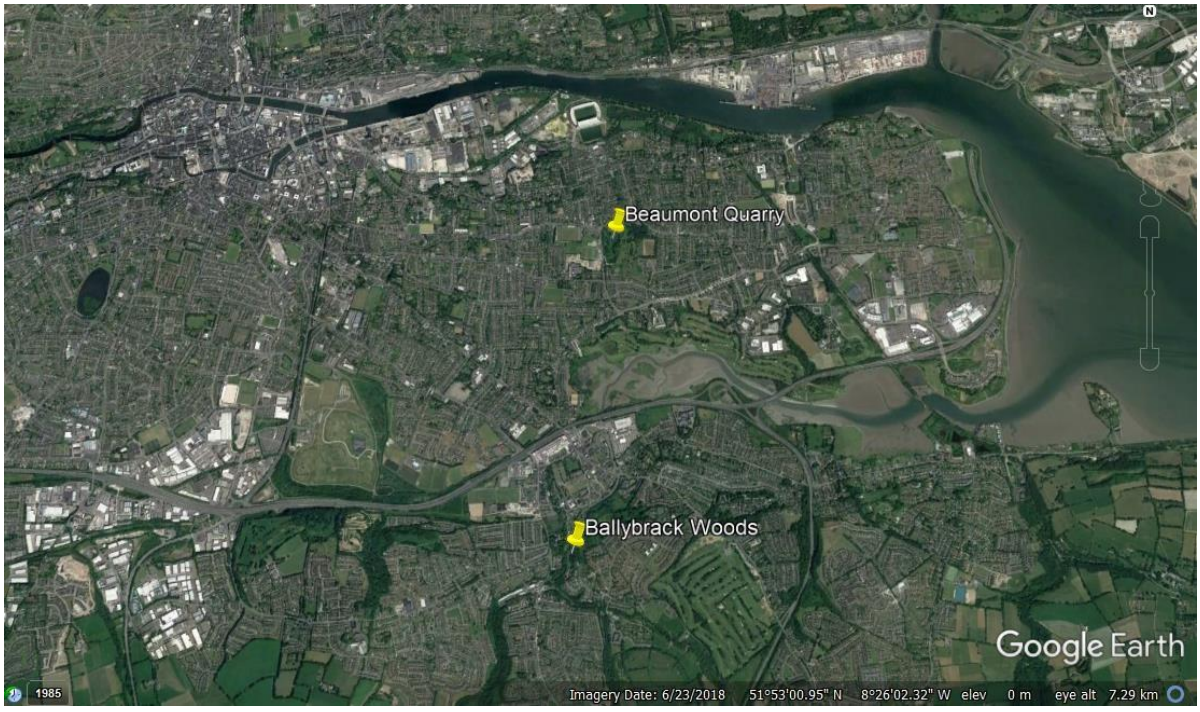

Figure 1. An aerial image of Ballybrack Woods and Beaumont quarry in Cork city, Ireland.

2.1 Ballybrack woods

The first of these parks is Ballybrack woods, known locally as the Mangala, which is located at 51°52’15.15” N, 8°26’11.66” W and is roughly 0.01km^2 in size (*Fig. 2*).

Figure 2. An aerial image of Ballybrack Woods (the Mangala), Ardarrig, Cork city, Ireland.

This park was once the grounds of an estate known as Ballybrack owned by the Lane family. It is possible that the presence of winter heliotrope in the park may have been the result of its introduction by the Lane family for its flowers in winter. This could mean that the plant has been a feature there since the house was built circa 1820. The present-day park consists of semi-natural and highly modified woodland, scrub, freshwater streams, and wet grassland. The stream running through the park is a small tributary of the Douglas river known as the Ballybrack stream. The bedrock at this location is Old Red Sandstone and the soil is generally acidic. There are also several areas where the stream banks have been reinforced with limestone which may have an effect on the stream's ecology.

2.2 Beaumont quarry

The second park in which this study was conducted was Beaumont Quarry, located at 51°53'28.18" N, 8°25'56.36" W. This park, situated in the Ballintemple area of Cork city, is an abandoned limestone quarry and is roughly 0.3km^2 in size (*Fig. 3.*).

Figure.3. Aerial image of Beaumont Quarry, Ballintemple, Cork city, Ireland.

The quarry fell out of use in the 1960's, leaving it to revegetate naturally, and has since been acquired by Cork Nature Network, who manage it. The park consists of calcareous grassland, exposed limestone, scrub, broad-leaved woodland, and a large array of invasive alien species. There are also several rare species within the quarry such as common toadflax (*Linaria vulgaris*), pale flax (*Linum bienne*) and little robin (*Geranium purpureum*) (https://corknaturenetwork.ie/beaumont-quarry/). Little robin is classified as an endangered species by the National Biodiversity Data centre.

2.3 Mapping

The first aspect of this project was mapping. As time could not be considered in how fast the winter heliotrope is spreading within these two parks, it was determined that this study would map patches of winter heliotrope so that future research using a temporal factor could be achieved. In Ballybrack woods, the winter heliotrope was present in three very obvious areas which were split into zones. Within each zone the number of patches was counted, and each patch was measured.

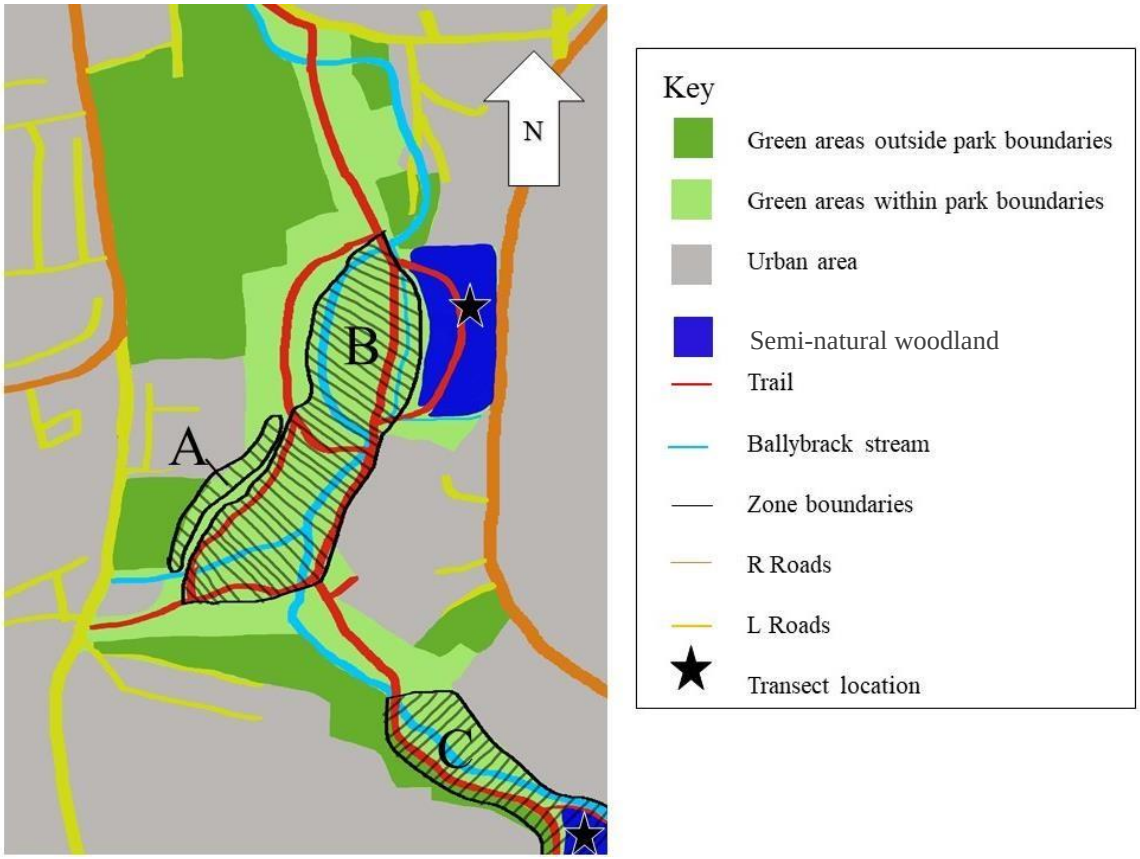

Figure 4. Map of Ballybrack Woods

The above map of Ballybrack woods (*Fig. 4.*) shows the main area of the park in light green with zones A, B, and C marked in a black outline. Transects located in areas of broadleaved native woodland are indicated by a black star.

The first zone (zone A) was located on the western border of the park. The majority of this zone was located on a steep eastward facing slope and was interspersed with bramble (*Rubus fruticosus*), nettle (*Urtica dioica*) and fern (*Pteridium aquilinum*) and some trees including beech (*Fagus sylvatica*), oak (*Quercus robur*) and ash (*Fraxinus excelsior*).

Zone B was focused around the central green area of the park. Many of the patches in this zone were located in close proximity to the streams flowing through the park and so were present on waterlogged soil. This was the largest of the three zones and so, had the most extensive collection of winter heliotrope patches at the Ballybrack location.

The final zone, zone C, was located at the southeast entrance of the park. It is notable for its proximity to the newest concrete path running through park which was built circa. 2013. This zone showed the most variability in habitat type, with several steeply sloped areas, riparian

areas and constructed paths. Other notable plant species in this zone included sycamore (*Acer pseudoplantanus*) and Japanese knotweed (*Fallopia japonica*).

In Beaumont quarry accurate mapping of patch size and number was not possible due to the size and inaccessibility of the site. Winter heliotrope also covered far larger areas that were not visibly distinguishable and so a more general map was created for this park (Fig. 5)

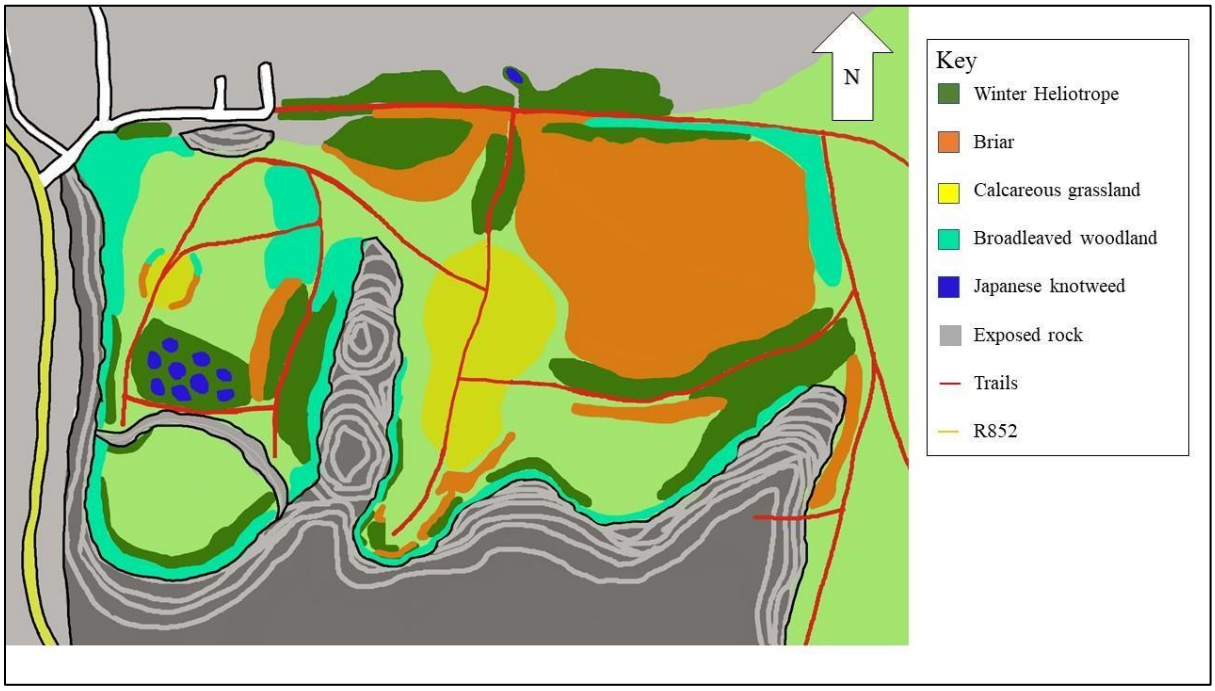

Figure 5. Map of Beaumont Quarry

2.4 Transects and Quadrats.

There were also two areas of semi-natural woodland in Ballybrack woods, which seem to have been left relatively untouched and may be original features from when the park was parkland in Ballybrack House estate. During initial observations in the park, it was determined that there were no visible signs of invasive species within these areas. Three 10m long, 20m wide, line transects were completed in both of these zones of old forest to determine if winter heliotrope was present. Fig *6.* shows one of these forested areas.

Fig. 6. Area of broadleaved semi natural woodland in Ballybrack Woods, Ardarrig, Cork.

The next step in Ballybrack woods consisted of a quantitative survey of the patches of winter heliotrope within each zone. Quadrats were employed in order to achieve this. Thirty quadrats were thrown in each of the three zones (n=90) and several aspects were recorded. These aspects included plant height (cm), leaf diameter (cm), leaf density (%), Canopy (variability in shading), Slope (none, gentle, moderate, steep), aspect (north, south, east, west), herbivory (leaf punctures, leaf mines, leaf holes), and other plants within the quadrat to determine if winter heliotrope creates a monoculture.

2.5 Statistics

Several statistical analyses were completed in order to determine if winter heliotrope had a preferred habitat as there is little to no literature to support the subject. The first of these tests consisted of a comparison of the size of patches between zones and therefore slightly different habitat types. The second compared the density of winter heliotrope between the three different zones. Thirdly the plant height was compared between zones and the fourth analysis compared leaf diameter between zones. As the data gathered was non-parametric, a Kruskal-Wallis test was performed at the 5% significance level using SPSS.

Statistical tests were also used to compare the density of winter heliotrope under varying degrees of shade. These were 0= no shading, 1= minimal shading, 2= moderate shading, and 3= dense shading. The effect of slope on the density of winter heliotrope was also tested using four different levels: 0= no slope, 1=gentle slope, 2= moderate slope, 3= steep slope. These were then compared to recorded densities using a Kruskal-Wallis test at the 95% confidence interval and post hoc analysis to determine which level, if any, had an effect on density.

A Kruskal Wallis test was also used to determine whether the aspect of the slope had an effect on the density of winter heliotrope at the 95% confidence level. In order to do this the cardinal directions north, south, east, and west were numbered 1,2,3, and 4 respectively and compared to density.

2.6 Questionnaires

2.6.1 Public Questionnaires

As Ballybrack woods is an urban park that connects much of Douglas' residential area to the town centre, there is a large number of locals commuting through the park. In order to determine whether locals were concerned with invasive alien species, a questionnaire was composed and given to members of the public who were walking through the park. The data was collected over three separate days in November 2020 and questionnaires usually took 5 minutes to complete. The questionnaire was completely anonymous and did not include any financial incentives. It consisted of six questions covering socio-demographic information, park usage, opinions on the park's amenities and the park user's recognition of plant species (*Table 1*).

In order for the public to recognise all species mentioned in the final question, photographs of the six invasive and problematic native species were presented as part of the questionnaire. Recognition of these species was measured by asking members of the public to categorise them from most problematic to least problematic.

Table 1. Breakdown of questionnaire given to members of the public in Ballybrack Woods.

Category	Factor	Description/question	Scale
Demographic information	Age	How old are you?	0-24
			25-49
			50-74
			75+
	Sex	What sex are you?	Male
			Female
Park usage	Frequency of visit	How often do you come to the park?	Once a day
			A few times a week
			Once a week
			Once a month
	Function of the park	Why do you come to the park?	Commuting
			Exercise
			Dog walking
			Nature
		What aspects of the park do you like?	Peace and quiet
			Wildlife
			Natural environment
		What aspects of the park don't you like?	Litter
			Anti-social behaviour
			Management
			Lack of information/facilities
			Alien species
Recognition of plant species	Awareness of invasives vs. natives	Which specides do you notice/recognise as "bad species"?	Sycamore
			Bramble
			Giant Hogweed
			Nettle
			Japanese hogweed
			Winter Heliotrope

2.6.2 Questionnaires to organisations and individuals who have interacted with winter heliotrope.

As there is little to no literature on the management of winter heliotrope in Ireland or elsewhere in the northern hemisphere, and very little known about the species in general, a series of questionnaires and interviews were conducted with those who have past experience managing

the species either as individuals or with organisations such as Tidy Towns, Transport Infrastructure Ireland (formerly the National Road Authority of Ireland), Cork city and county councils, Cork Nature Network, and the Botanical Society of Britain and Ireland to name a few. In total 17 individuals and organisations were asked to participate in the survey.

The questions were emailed to all participants with instructions to answer either via email or videocall. The questions covered a range of topics including the timeline of winter heliotrope in their location, the impacts they have noticed it has had on other flora and fauna, the habitats it occupies, and any management types that they may have performed against the plant as can be seen in Table 2 below.

Table 2. Breakdown of questionnaire given to individuals and organisations who manage winter heliotrope.

Category	Factor	Description/question	Scale
Spread	Arrival	When did WH arrive at a particular location & how quickly has it spread into new areas?	Dates
	Timeframe	How quickly has it spread into new areas?	Years/Months
Impacts	Effects on other plants	Does it displace native species or simply live alongside them?	Displace
			Coexist
	Effects on invertebrates	How is WH beneficial to other species- do they attract pollinating insects?	Good for other species
			Bad for other species
Habitats	Preferred habitats	What kind of habitats does it seem to prefer?	Grassland
			Woodland
			Roadside verges
			Hedgerows
			Damp areas
			Riverbanks
			Disturbed ground
Management	What active management efforts have been made in the past	Have people tried to manage the plant in different way. Were the effective?	Herbicide treatment
			Mowing/cutting
			Digging up/removal of plants
			Smothering the plant
	What factors may limit WH in the future?	Do other plant species prevent it colonising new areas, is it sensitive to climatic extremes, do patches naturally grow and decline over time?	Other plants
			Climatic extremes
			Natural decline over time

2.7 Literature Review

In order to accurately determine how winter heliotrope and urban parks in general are managed in Ireland, a literature review was conducted. This consisted of reviewing literature around the subjects of urban forestry, urban park management plans in Ireland and abroad and collating this information with that gathered from the organisations and individuals who responded to the questionnaire (*Table 2*).

3.0 Results

3.1 Transects and Quadrats

Transects within areas of semi natural broadleaved woodland in Ballybrack woods showed no evidence of the presence of winer heliotrope or any other invasive alien species.

Other plant species including Buttercup (*Ranunculus repend*), Nettles (*Urtica dioica*), Bramble (*Rubus fruticosus*), several species of grass (Poaceae), Bracken Fern (*Pteridium aquilinum*), Hawthorn (*Crataegus monogyna*), Ivy (*Hedera helix*), Hart's tongue fern (*Asplenium scolopendrium*), Dandelion (*Taraxacum officinale*), Giant Hogweed (*Heracleum mantegazzianum*), Thistle (*Cirsium vulgare*), Sticky-back (*Galium aparine*), Hairy Bittercress (*Cardamine hirsuta*), and Dock (*Rumex obtusifolius*) were all recorded within patches of *P. fragrans*. Only 4% of all quadrats recorded no other plant species living amongst the winter heliotrope. The most common species found was buttercup found in over half (52%) of the 90 quadrats, the next most common species recorded were bramble and grass at 38% and 26% respectively. Other common species included nettle (11%), ivy (9%), fern (8%), and stickyback (5%). The remaining species were recorded in less than 3% of quadrats. An example of some of these species can be seen in Fig 8.

Zone A was the smallest distinct area of winter heliotrope in Ballybrack Woods. This zone is distinguishable by its location on a wooded slope which was relatively well drained and heavily shaded. Bramble was the most common plant within patches of winter heliotrope in this zone with 97% of quadrats from this area containg the plant. Zone A also had the lowest level of species richness recorded in the park with a total of 8 different species in 30 quadrats. Buttercup was less present in this zone when compared to zones B and C.

Zone B was the largest and most diverse of the three zones in terms of habitat and had the most consistency in which plants were present. This zone consists of several areas in close proximity to water ways. These areas were often shaded by stands of decidouos trees and shrubs. There is also a large area of maintained grassland in the centre of the zone. The most common plant in Zone B within patches of winter heliotrope was buttercup with 63% of quadrats thrown in this area containing buttercup.

Finally, Zone C was notable for its proximity to the newest paved area meaning that a large proportion of this section was fragmented verge habitat. The area is well drained and includes

both open and sheltered ground. The most common species recorded in this zone was buttercup with 73% of quadrats from this area containg this species, a far greater amount than any other species within this section with the next highest percentage being just 6% for bramble, bracken fern, and sticky-back

Fig. 8. Quadrat 26 from Zone B Ballybrack Woods showing a variation of other plant species growing within winter heliotrope including buttercup, grass, and hairy bittercress.

Three variations of herbivory on the leaves of winter heliotrope were also recorded. Only 4% of quadrats contained leaves that showed no signs of herbivory. Leaf punctures were the most comon type of herbivory recorded with 76% of quadrats containing punctured leaves. Leaf cutting was also very common with over half of quadrats (56%) containing this herbivory type. The least common form of herbivory was leaf mining found in only 4% of quadrats. Evidence of leaf cutting and leaf punctures can be seen in Fig. 9.

Fig. 9. Quadrat from Ballybrack Woods showing evidence of herbivory in the form of leaf cutting and leaf punctures.

3.2 Statistical analyses

The first statistical test aimed to determine whether there was a significant difference in the size of patches of winter heliotrope between the three zones, A, B, and C. Statistical analysis confirmed that there was no significant difference in patch size between the three zones at the 5% significance level. There were, however outliers in zone A, the wooded slope zone, where two of the patches were far greater in size than the other patches (*Fig. 10a)*.

Secondly, a statistical test was completed to determine if there was a differnce in the density of winter heliotrope across the three zones: A,B, and C. The Independent-Samples Kruskal Wallis

test found at the 5% alpha level that there was no difference in the denstity of winter heliotrope across the three zones despite their varying habitats. These results are represented in a boxplot (*Fig.10b*).

Thirdly, a Kruskal Wallis test compared plant height across the zones. This found that plant height was significantly different across zones. A Tukey test was completed to determine which zone was different and it found that zone B was the outlier. These results are represented viually as a boxplot in Fig 10c. Zone C also had the greatest variation outside of it inter quartile range.

The fourth analysis compared the leaf diameter between zones using a Kruskal Wallis test. This showed that diameter was statistically different across the zones. A post hoc analysis was performed to see which zone or zones was significantly different and this was represented graphically using a boxplot (*Fig. 10d*). It was determined that leaf diameter in zone C was significantly larger when compared to the other two zones.

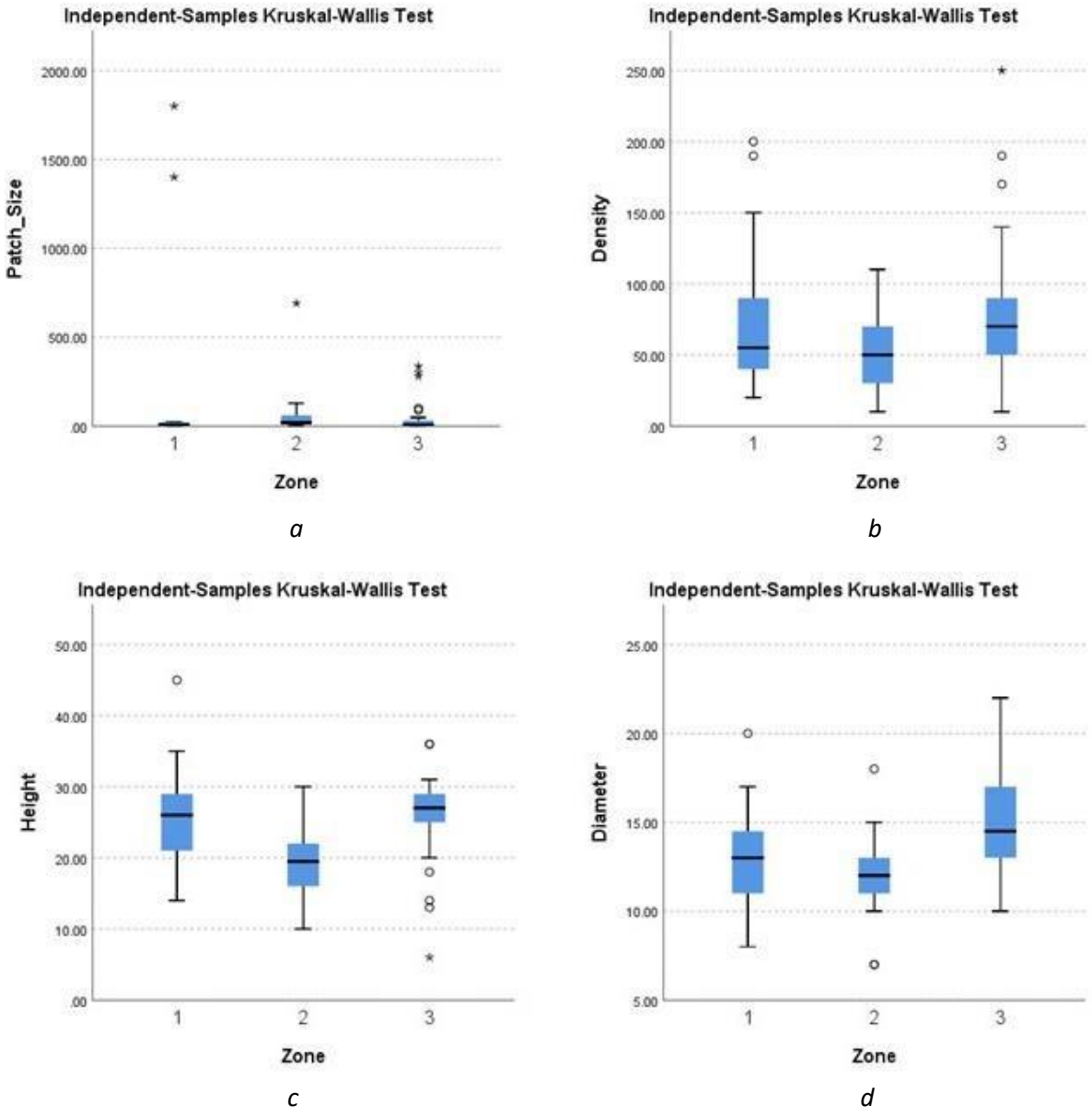

Figure 10. Boxplots showing (a) the difference patch size (m) across the three zones of Ballybrack woods; (b) the difference in density (%) across the three zones (c) the difference in the height (cm) of winter heliotrope across the three zones; (d) the difference in leaf diameter (cm) across the three zones;. Outliers are denoted by circles. As the software used does not accept categorical data, zones A, B, and C were converted to 1, 2, and 3, respectively.

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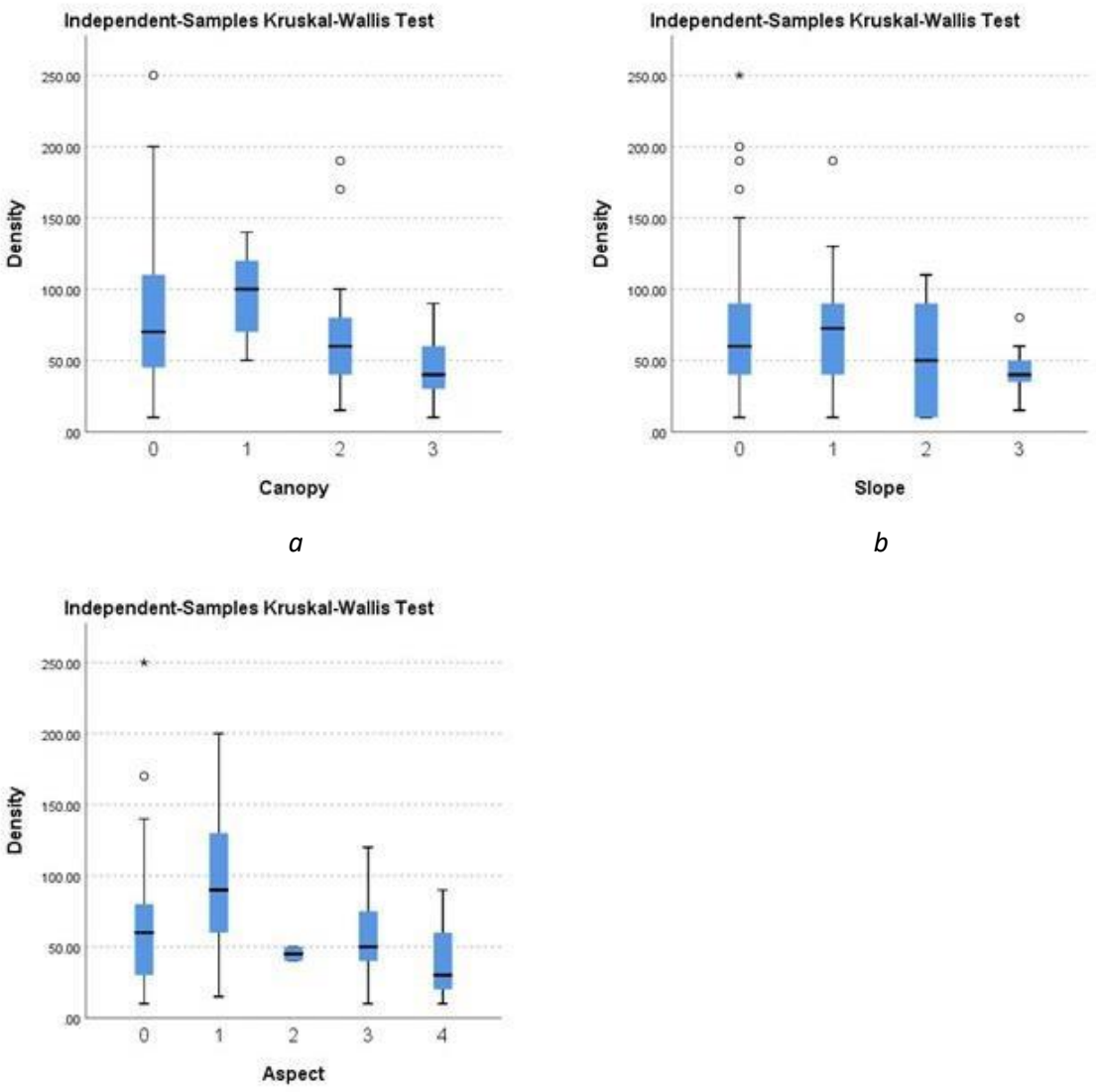

a

b

c

Figure 11. Boxplot showing (a) the variation in density (%) under variations in canopy. Zero represents no canopy, 1=slight canopy, 2= moderate canopy, and 3=full canopy. Densities exceed 100% due to multiple layers of winter heliotrope within quadrats. (b) the variation in density (%) across variations slope where 0= no slope, 1=gentle slope, 2=medium slope, and 3=steep slope. (c) the variation in density with different aspects where 0=no aspect, 1=northern aspect, 2=southern aspect, 3=eastern aspect and 4=western aspect. Outliers are represented by circles. As the software used (SPSS) does not accept categorical data, canopy cover, slope and aspect were converted to numerical data.

The sixth test performed was an Independent-Sample Kruskal Wallis test to determine if canopy had an effect on the density of winter heliotrope. It was determined that the density of *P. fragrans* was affected by the presence of a canopy. A post hoc analysis adjusted with the Bonferroni correction was performed in order to determine which severities of canopy were

significantly different. It found there were statistically significant differences in density between no canopy (0) and full canopy (3) and between slight canopy (1) and full canopy (3). A boxplot of these results can be seen in Fig. 11a.

A further statistical test was performed to determine if slope had an effect on the density of winter heliotrope. A Kruskal Wallis test confirmed that there was no statistically significant difference between the density of winter heliotrope within quadrats across the three zones, and the severity of the slope. These results are represented in a boxplot in Fig.11b.

The final test was conducted to determine whether winter heliotrope was affected by aspect. It was determined that aspect had no significant effect on the density of the plant at the 5% significance level. A post-hoc analysis showed that there was, however, a significant difference between North (1) and East (3). *P. fragrans* showed no proclivity to grow more on south facing slopes, as many plants do. This result is represented in a boxplot in Fig. 11c.

3.3 Questionnaires

3.3.1 Public questionnaire

The public questionnaire had 11 participants in total. Though the sample is small, participants varied in age with a majority of people being between the ages of 25 and 49 (63%). The ratio of gender in participants was biased towards females (63% females, 36% male). It is worth noting that many of the participants in the survey selected more than one option for the questions, so percentages often exceed 100%.

Frequency of usage of the park did not vary much between participants, with almost all (72%) of the participants using the park daily and the rest (27%) coming several times a week.

The majority (91%) of the participants use the park to exercise with just over half (55%) using the park to commute from the residential areas to work and the shopping facilities in Douglas shopping centre. The remaining contributors were availing of the park's nature (27%) and dog walking opportunities (27%).

Participants conveyed that they enjoyed a variety of aspects in the park including the wildlife (46%), the peace and quiet (36%), and being surrounded by the natural environment (36%). Included in both the peace and quiet option and the natural environment option, two participants said they enjoyed the sounds of the river. Two mothers interviewed stated that they liked the paved walkway as it was good for children on bikes and in prams.

When asked what elements of the park participants disliked, the majority chose litter (46%) and anti-social behaviour (55%). Many participants specified that dog-fouling and alcohol cans in particular were elements of concern in Ballybrack. Others were concerned about antisocial behaviour in the form of young people drinking and loitering in the evenings and at night in the park, even going so far as to not use the park in the evenings for their own safety. Another aspect of the park that several (27%) did not like was the lack of information and amenities available. Several of the older participants mentioned the lack of benches around the park where they could sit and rest during their walk, while other raised concerns over the lack of adequate lighting to make them feel safe while walking in the evenings or at night, especially in the winter months. Park management was not a concern of the participants. No participants mentioned the presence of alien species in the park as something of concern.

The final question which related directly to invasive and "problem" native species found that everyone who took part in the survey knew Japanese knotweed to be a "bad" species but not one participant knew of, or found winter heliotrope to be bad. Other species which were of most concern to participants were nettles (27%), giant hogweed (18%), and bramble (9%). Two of the three participants who said nettles were a "bad" species also said that they were not concerned by them as they knew to avoid them. Many who mentioned Japanese knotweed claimed to have heard that it was a bad plant but not why it was bad, saying similar about giant hogweed.

It is worthy to note that six people approached would not stop to answer the questionnaire as they were on their way to work from their lunchbreak. Another nine people refused to answer the questionnaire due to the Covid-19 restrictions in place at the time.

3.3.3 Questionnaire results from members of organisations and individuals who have managed winter heliotrope

Of the 17 surveys sent to individuals and organisations who have interacted with winter heliotrope in Ireland, there were a total of three replies. One participant who has completed many habitat surveys in the Cork area stated that winter heliotrope was the most pervasive nonnative species in East Cork, with perhaps the exception of the sycamore. The arrival of winter heliotrope to the participants respective areas was relatively unknown, however one participant speculated that the plant arrived with the coming of the railway to the area in 1862. Participants indicated that the plant can survive in a number of habitats with the exception of maintained grassland, wetlands or bogs, and woodland. The plants affinity for disturbed ground

was also noted. One participant stated that winter heliotrope has poor competitive ability to colonise existing swards but is good at excluding other species once established. No form of effective management was mentioned by any involved, however one claimed that the density of smallscale patches could be lessened by repeatedly digging up the plant over a number of years. Another participant had avoided attempts at management due to the uncertainty of the outcome. Finally, participants had mixed answers in terms of the attractiveness of winter heliotrope to pollinators in winter. One contributor said that they had not noticed winter pollinators visiting the plant, while another said that they had heard that the plant was good for pollinators but were uncertain if this was a true statement. The third participant who has the most experience with the plant stated that its flowering period does not overlap with most pollinators flight periods in Ireland but has noticed winter and early spring flying bumblebees visiting.

4.0 Discussion

This study resulted in a number of significant findings and brought to light a number of issues in how urban parks are managed. The statistical analyses of data gathered in Ballybrack woods showed that patch size and the density of winter heliotrope did not vary between zones, despite the fact that zone C has been disturbed relatively recently (2013/2014) by the construction of the new paths. It implies that recent disturbance has not overly promoted the growth of winter heliotrope in this area, however it is not known whether winter heliotrope already existed in this zone previous to construction. The differences in location also had no effect on the height of the plants, despite the fact that the zones consist of relatively different habitats, showing that winter heliotrope does not discriminate between habitats for that characteristic. Leaf diameter, however, was significantly bigger in zone C when compared to zone A. This shows that soil disturbance leads to larger leaves but not a greater density of plants, so though it may look like a monoculture has been created, that is not necessarily true. As was expected following observation in the park, the slope and aspect did not have an effect on the density of winter heliotrope whereas canopy did. Results showed that greater densities of canopy above patches of winter heliotrope reduced the density of the plant, but it is interesting to note that areas with a small amount of shading (1) showed a higher density of winter heliotrope than areas with no shading (0).

With these results in mind, the effect that removal of this species would have on the parks should be considered. Data was also collected on other species that are growing within the patches of winter heliotrope and it was found that biodiversity of other plant species within

these patches is quite high. Species such as Buttercup (*Ranunculus repend*), Fern (*Pteridium aquilinum*), Grasses (Poaceae), and Ivy (*Hedera helix*) and more can all be found growing within the winter heliotrope. *P. fragrans* also provides food for many invertebrates during winter while other nutritious, deciduous leaves are gone, and only less palatable evergreen options remain.

There are, of course, options for eradication, one of which that was obvious from this study is the presence of broadleaved woodland. The transects performed showed that no winter heliotrope, or in fact any alien species, were present in the areas of Ballybrack that were composed of native woodland, but a habitat such as this would take years to develop. It is also true that the areas of native woodland that already exist in the park are rarely visited by residents, who prefer to stay on the concrete paths, and so the park may no longer be a desirable to them if it was changed in this manner.

Chemical eradication is another effective method of removing winter heliotrope but can be costly and may take several iterations in order to remove completely. Eradication in this form would also harm other species which are growing throughout the winter heliotrope leaving a burned effect on these areas, which would not be aesthetically pleasing for park visitors.

Eradication could also lead to the spread of other problem species into the gap that has been created with removal (Prior *et al.,* 2018). Species such as bramble could potentially take over. Though this is a native species, it creates monocultures that few plant and animals can penetrate and so reduces biodiversity (https://dev.soilsforlife.org.au/what-is-a-weed/). There is also the potential for other, more vigorous invasive species which are already present in the parks to invade, such as Japanese knotweed. This would create a more expensive and long-lasting issue than what is currently present.

The scientific community are often biased towards large, untouched natural landscapes like national parks, however access to green spaces within cities is highly important (Razak *et al.,* 2016). Urban areas cover less than 6% of the Earth's surface but contain 4.1 billion people (Alberti *et al.,* 2003: https://ourworldindata.org/urbanization, 2017). Various studies show that the presence of natural areas can exponentially improve mental and physical health and create social opportunities for residents (Aerts *et al.,* 2018; Wood *et al*., 2017).

There are several different papers which give a list of varying lengths for best practice management of urban green spaces (Grey, 1995; Steidle-Schwahn, 2006), however the majority of these can be boiled down to just three factors which must be balanced to create the perfect

urban park: economy, ecology, and society (Miller, 1996). It is perhaps the only habitat type in which the needs of humans is on par with the needs of the environment, and because this is a human-based ecosystem, the perception and desires of urban residents should form an integral part of the management of biodiversity (Savard *et al*., 2000). Studies have found that if land managers fail to include public input and account for public opinion, they risk the loss of public support for the control of invasive species (Nimmo & Miller, 2007) and potentially government support and funding due to lack of interest in environmental issues.

With this in mind, a survey was conducted to ask members of the public what aspects of the park they were concerned about and none said that the presence of invasive species was a concern. When asked directly about invasive species, it became clear that no one who used the park was aware of winter heliotrope as a threat. This begs the question whether the management of winter heliotrope should be a priority for park management at all. Removal would likely have no effect on the public, while possibly promoting the growth of species which are even more problematic for the environment or native species that are not aesthetically pleasing. This would create a positive feedback event in which new problematic species that have filled the niche left behind by winter heliotrope, negatively affect the public's view, which then negatively effects the economic side of the park and so on.

From speaking to several park managers and reviewing the literature it became clear that park managers receive little guidance in how to manage an urban green space. For the majority of cases, green spaces are not addressed in the legislation of the country and therefore, bodies such as the county and city councils who are in charge of public parks tend to have different approaches to management (Randrup & Persson, 2009). A study by Randrup *et al*. (2017) found that less than half of green space managers in cities had a strategic management plan for the areas they manage. Many of these urban green areas are also created with no plan in place as how they are to be managed in the long term, a concept highlighted in a paper by Wild *et al*. (2008) which they term place-making versus place-keeping. Adaptive place-keeping methods ensure that ecological, social, and economical quality are managed long term and the benefits from such a scheme can be enjoyed by future generations. Well managed areas promote a dynamic and continuous process whereby place keeping enhances the result of place making as a sustainable, valuable asset within its local context (Dempsey & Burton, 2012). Failure to maintain such areas will cause them to degenerate over time with litter, vandalism, damage to amenities, and park users no longer feeling safe being the first signs that park management and maintenance practices are failing (Dempsey & Burton, 2012: Randrup & Persson, 2009). This

problem, however, does not fall solely on park managers. Maintenance budgets are constantly being reduced and capital is becoming less available because of this lack of support at the governmental level.

It has become clear that though winter heliotrope is a problem species, it is perhaps not such a problematic species as previously thought. More research should be conducted into how this species affects others within the same ecosystem such as the density and variety of invertebrates in patches of winter heliotrope when compared to areas of native species such as ivy or bramble. It would also be interesting to see if winter heliotrope provides food for pollinators in winter, one of the reasons it was introduced to the British Isles in the first place. It would also benefit further study to interview more members of the public to get a more accurate insight into their knowledge of invasive alien species. Testing similar habitats which do not contain winter heliotrope may also give insight into whether there is a significant difference in the density and diversity of other plant species when compared to those containing winter heliotrope. Finally, in order to create an accurate map of Beaumont quarry it may be beneficial to use a drone or similar tool to access areas that are difficult to reach as a temporal baseline for future study.

In conclusion lesser-known invasive species such as winter heliotrope, though seen as a threat to Irish species, may in fact not be as problematic as previously thought but this should be taken as a case-by-case basis, not a general rule. This study has highlighted the need for a more defined and structured plan in how urban green spaces need to be managed in Ireland and potentially the rest of the world. Clearer regulations have to come from a governmental source and must be available to all, not just parks run by government bodies. These regulations must keep in mind, not only the economic side of park management but also scientific research and the communities who use these areas because only then is a park going to survive and thrive in the long term.

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