Managing urban road verges for biodiversity - ecological impacts and social considerations

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Abstract

Urbanisation is one of the greatest threats to biodiversity, causing significant habitat loss and species declines. However, with appropriate management, urban green spaces such as road verges can support biodiversity and provide ecosystem services. To improve the provision of these benefits, suitable management needs to be identified.

The first objective was to investigate the impact of reducing mowing frequency of urban road verges on botanical and invertebrate communities through a controlled experimental trial. The second objective assessed residents’ perceptions of the trial on their road, along with a range of hypothetical road verge management scenarios. The final objective was to provide baseline information on how different urban road verges are managed across England and assess which factors influence decisions.

A reduction in mowing frequency over one season significantly increased vegetation height, Araneae and total invertebrate abundance. It did not alter botanical species richness, flowering abundance, forb abundance and the number of invertebrate orders, when compared to the established mowing regime. However, residents experiencing these changes significantly preferred road verges mown at the established, higher frequency, both when compared to the actual reduced mowing and to other hypothetical scenarios, despite recognising that current management may not be best for biodiversity.

With increasing budgetary constraints, road verge managers are considering or implementing alternative management such as reducing mowing frequency. Factors influencing management decisions include finance and resources, public perception and actions, safety, spatial context, biodiversity and environmental benefits, physical factors and departmental and councillor input.

These results indicate that urban road verge management involves a complex set of trade-offs, where win-win scenarios may not always be possible. It also highlights where more considered management could increase the benefits from what is a ubiquitous, but often

overlooked habitat, potentially playing an important role in cultivating greater connection to nature within the urban setting.

Declaration

I, the author, confirm that the Thesis is my own work.

Olivia C. Richardson
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Chapter 1: General Introduction

1.1 Urbanisation

Human activity has significantly impacted Earth's ecosystems, altering almost half of the world's terrestrial surface (Foley et al., 2005; Vitousek, 1997). Whilst urban land use is not the largest in extent (Asner et al., 2004), covering 652,825km^2 in 2000 (Seto, Güneralp, & Hutyra, 2012), by 2030 it is predicted to increase significantly, expanding by 1.2 million km^2 with about 60% of the world's population expected to live in these urban areas (United Nations, 2018; Seto, Güneralp, & Hutyra, 2012). Urban areas are the land use to be most altered by human activity (Karieva et al., 2007), with urbanisation contributing to global change, altering land use, biogeochemical cycles, climate and biodiversity (Grimm et al., 2008).

Urbanisation is one of the greatest threats to biodiversity, causing significant habitat loss and species declines (Seto et al., 2011; McDonald, Kareiva, & Forman, 2008; Grimm et al., 2008). However, the relationship between urbanisation and biodiversity is not straightforward as cities can support biodiversity, but at lower densities than non-urban areas (Aronson et al., 2014). Early research assessing the relationship between biodiversity and urbanisation from an urban-rural gradient perspective, indicated that at high levels of urbanisation, several species have experienced an associated decline, linked to increased habitat fragmentation, resulting in biotic homogenisation of urban habitats (Marzluff and Ewing, 2001; McKinney, 2006; McKinney, 2008). For moderate urbanisation levels, species richness has been found to increase for plants (~65% of studies), some invertebrates (~30% of studies) and small numbers of non-avian vertebrates (~12% of studies) (McKinney, 2008). However, whilst urban-rural gradient studies can inform debates regarding the broad scale implications of urbanisation they do not assess the heterogeneity of urban green spaces within cities (Beninde, Veith, & Hochkirch, 2015), and do not incorporate the influence of fine scale habitat features (McDonnell & Hahs, 2008). Recent research assessing biodiversity within cities at a finer, feature scale, indicated that habitat patch area and corridors ("functional habitat connecting two habitat patches") within an urban area had the strongest impact on biodiversity combined with vegetation structure (Beninde, Veith, & Hochkirch, 2015).

1.2 Urban green space

The use of the term urban green spaces has been broadly defined in previous studies with no clear definition (Taylor & Hochuli, 2017). For this purpose, urban green spaces are areas of urban vegetation which include, but are not limited to, parks, gardens, urban forests, sports grounds, cemeteries, green roofs and road verges. Urban green space can vary dramatically in extent, for example, covering between 1.9% to 46% for different European cities (Fuller & Gaston, 2009). It is well documented that urban green spaces have the potential to support high levels of biodiversity (Ives et al., 2016; Baldock et al., 2015; Aronson et al., 2014) and provide a number of ecosystem services, i.e. the benefits ecosystems provide to humans (Millennium Ecosystem Assessment, 2005; Bolund & Hunhammar, 1999). Benefits from urban green spaces include, provisioning services such as urban food production (Speak, Mizgajski, & Borysiak, 2015), regulating services such as the improvement of air quality through the removal of pollutants (Pugh et al., 2012; Nowak, Crane, & Stevens, 2006), carbon storage (Nowak et al., 2013), supporting services such as providing habitat for species (Baldock et al., 2019; Aronson et al., 2014) and cultural services with stress reduction (Ward Thompson et al., 2012) and increased wellbeing (White et al., 2013) linked to increased exposure to urban green space.

These ecosystem services have an impact on the quality of life of urban residents and can help to reduce the footprint of urban areas (Gaston, Ávila-Jiménez, & Edmondson, 2013; Bolund & Hunhammar, 1999). Whilst restoring urban ecosystem services can be financially beneficial (Elmqvist et al., 2015), it is not without its challenges. These include spatial constraints, a large number of managers of green space in urban areas (government, non-government organisations, householders and tenants) but with different management goals and public perception of urban ecosystem services (Gaston, Ávila-Jiménez, & Edmondson, 2013).

Despite these numerous benefits from green spaces, it is thought that people are becoming increasingly disconnected from nature, otherwise known as the “extinction of experience”, a consequence of a number of factors including urbanisation (Soga & Gaston, 2016; Miller, 2005). This may have negative consequences for health and wellbeing as there is an increasing body of evidence associating the exposure to nature with a number of health benefits including increased self reported psychological well-being (Fuller et al., 2007), quicker recovery times (Ulrich, 1984), reduced mortality from circulatory diseases (Mitchell & Popham, 2008), better mental health (Cox, Shanahan, et al., 2017), reduced allergies (Hanski et al., 2012) and improved cognitive functioning (Berman, Jonides, & Kaplan, 2008). Indeed, urban residents with a low exposure to nature were more likely to have worse mental health and perception of social cohesion than those living in rural areas (Cox et al., 2018). Other consequences resulting from the extinction of experience comprise changes in emotional connection, attitude and behaviour towards nature (Soga & Gaston, 2016). This highlights the importance of people engaging with nature and the creation of opportunities to maximise human interaction with nature (Soga & Gaston, 2016; Miller, 2005).

Clearly urban green space can provide numerous benefits to its residents and can support biodiversity (albeit at lower levels than many rural areas), so how should cities grow to accommodate the world's urbanising population and maximise these benefits whilst reducing negative impacts on biodiversity and ecosystem service provision? Future predictions of urbanisation typically focus on two extreme scenarios paralleling the idea of the land sharing versus land sparing debate typically used in agricultural studies (Lin & Fuller, 2013). This involves the idea of land sparing (increasing housing density in current urban areas with small areas of green space allowing other green areas to be undeveloped) and land sharing (maintaining current density but increasing urban areas and thus more spread of green space areas) (Lin & Fuller, 2013). Current estimates from 326 urban sites globally suggest that urban sprawl otherwise known as land sharing may currently be more common rather than urban densification or land sparing (Seto et al., 2011). Urban studies modelling the suitability of these two scenarios result in differing 'optimal' scenarios dependent on the focal outcome, especially the type of ecosystem service (Stott et al., 2015; Eigenbrod et al., 2011).

Land sparing has been shown to have positive outcomes for some taxa such as bats (Caryl et al., 2016), mammals (Villaseñor et al., 2017) and birds (Sushinsky et al., 2013) and has been advocated to be the optimal strategy for future urbanised areas based on findings for biodiversity (Geschke et al., 2018; Soga et al., 2014). However, this maybe at the expense of local residents interaction with nature as this scenario reduces access to green space (Fuller & Gaston, 2009), causes loss of some urban green space (Haaland & van den Bosch, 2015; Royal Horticultural Society, 2015; Pauleit, Ennos, & Golding, 2005) and may influence the 'extinction of experience', where residents have less interaction with nature (Soga et al., 2015; Miller, 2005). There is disparity in studies assessing engagement with nature in land sparing and land sharing areas with results from Soga et al., (2015) indicating people living in land sharing areas were found to visit green spaces more frequently than those living in land sparing areas whereas Shanahan et al., (2017) found similar patterns for time spent visiting green spaces and residents' connection to nature for both land sharing and land sparing areas. At high levels of urbanisation, land sparing is advocated to be the optimal strategy for increased bird and many ground beetle and butterfly population sizes (Geschke et al., 2018; Soga et al., 2014). However, at lower levels of urbanization, areas which have a mixture of both land sharing and land sparing are suggested to provide the greatest benefit to modelled biodiversity population sizes (Geschke et al., 2018; Soga et al., 2014). This may in some cases act as a compromise between people's interaction with nature and the potential reduction in negative impacts to biodiversity. As urbanisation increases, the quality of these urban green spaces may also become increasingly important for these interactions, including those of informal green spaces (Fuller & Gaston, 2009).

1.3 Road verges

An often overlooked type of urban green space, road verges (also known as 'nature strips' in Australia and 'sidewalk buffer', 'tree lawn' and 'parking strips' in the USA) comprise managed linear areas of land next to roads usually dominated by vegetation (typically grass as the understorey with sometimes shrubs and street trees) (Forman & Alexander, 1998). In the USA, roadsides cover an estimated 6.9 million hectares (Hopwood, Black, & Fleury, 2015) and similarly large areas are found in other developed countries such as the Netherlands (80,000 km in linear distance) (Noordijk et al., 2010) and Finland (140,000 hectares) (Saarinen et al., 2005). Road verges are likely to be found on a significant number of the UK's roads, of which there are 397,025 km in linear distance (Department for Transport, 2019). Even considering urban green space as a whole, road verges can be significant contributors, such as in Melbourne where it makes up 36.7% (Marshall, Grose, &

Williams, 2019a) and in Germany where a study found that 10-25% of total urban green space managed by park departments comprised of road verges (Weber, Kowarik, & Säumel, 2014a). This is likely to significantly increase as 25 million km of new roads are predicted to be built by 2050 globally, fragmenting landscapes further (Ibisch et al., 2016; Dulac, 2013).

Road verges are recognised to provide numerous ecosystem services as reviewed in Säumel, Weber, & Kowarik, (2015). For urban trees these include carbon sequestration (Nowak et al., 2013) and the removal of air pollutants (carbon monoxide, nitrogen dioxide, ozone, particulate matter and sulphur dioxide) (Tallis et al., 2011; Nowak, Crane, & Stevens, 2006). However, the influence of street trees on overall urban carbon storage value is unclear, as studies assessing urban green space often do not provide a breakdown of specific green spaces and their contributions. Herbaceous vegetation can also be effective at immobilizing particulate matter (Weber, Kowarik, & Säumel, 2014b). In addition, vegetation on road verges have the potential to be used for biomass production (Voinov et al., 2015; Pedroli et al., 2013), reduce noise from traffic (Van Renterghem, Botteldooren, & Verheyen, 2012), regulate temperature through transpiration and shade in the area surrounding the vegetation (Armson, Rahman, & Ennos, 2013; Gill et al., 2007), reduce water run off (Armson, Stringer, & Ennos, 2013a) and improve aesthetics (Weber, Kowarik, & Säumel, 2014a; Todorova, Asakawa, & Aikoh, 2004). The presence of vegetation on roadsides is thought to impact a number of road users; for drivers, views of nature when driving can reduce stress (Parsons et al., 1998) and for pedestrians this can improve the perceived 'accessibility' of an area (Foltête & Piombini, 2007). The presence of trees and other vegetation have also been suggested to influence property prices (Saphores & Li, 2012).

A highly visual element of green space, road verges may play a key role in urban residents' daily experiences of nature, as nature is experienced most frequently through a window at work and at home, rather than through direct experience (Cox, Hudson, et al., 2017). Indeed, views of nature outside of a window have shown to contribute to neighbourhood satisfaction and sense of wellbeing (Kaplan, 2001). Greater quantity and quality (through structural diversity) of street greenery can provide numerous health benefits such as social cohesion and reduced stress (de Vries et al., 2013), restorative effects (Honold et al., 2014), improved mental health (Taylor et al., 2015; van Dillen et al., 2012) and reduced risk of childhood asthma (Lovasi et al., 2008).

A major survey of roadside verges in England and Wales in 1977 revealed that roadside habitats can provide a breeding habitat for 20 UK mammal species, 6 reptile species, 40 bird species, 25 butterfly species, 8 bumblebee species, 5 amphibian species and are associated with 870 mostly native plant species, of which 35 are nationally rare (Way, 1977). Assessment of biodiversity on urban road verges has mainly focused on three taxa: plants, birds and invertebrates. Studies assessing urban road verges indicate that plant species are highly homogenized (Gong, Chen, & Yu, 2013; Wittig & Becker, 2010), but can also support rare species (Brown & Sawyer, 2012). The proportion of non-native plant species present on urban road verges is found to vary (Brown & Sawyer, 2012; Cilliers & Bredenkamp, 2000), and can be significantly greater than non-native plants found in near-natural habitats (Gong, Chen, & Yu, 2013). Whilst it could not be conclusively shown that road verges can act as dispersal corridors along an urban-rural gradient (Cilliers & Bredenkamp, 2000), impacts from the road such as exposure to nitrogen and other chemicals from vehicles as well as salt, is thought to influence native and non-native plant distributions (Brown & Sawyer, 2012). However, in a Japanese study road verges were found to have similar grassland quality to semi-natural grasslands (Koyanagi et al., 2012). Management of urban road verges has also been found to impact Hemiptera species richness, with high frequency mowing causing a negative impact (Helden & Leather, 2004).

Across four UK cities, urban road verges have been found to support significantly lower bee and hoverfly abundance than gardens and allotments, thought to be due to significantly lower floral abundance and species richness (Baldock et al., 2019). Bird species richness and abundance is significantly lower on urban road verges than other areas of urban green space such as parks and gardens, thought to be influenced by noise and traffic from the road (Carbó-Ramírez & Zuria, 2011). However, the type and structural complexity of vegetation present on the verge can be also be an important factor as established road verges with native tree species supported greater bird species richness and abundance than verges recently established with younger trees and verges with exotic tree species (White et al., 2005).

Despite supporting lower species richness and abundance for many taxa, as linear structures, road verges have the potential to be used as corridors by birds (Fernández-Juricic, 2000) and mammals (Munshi-South, 2012) connecting fragmented greenspaces such as urban parks within an urban landscape. Further investigation into the potential role of urban road verges as corridors is required as current research indicates this may not the case for all taxa, such as bats (Oprea et al., 2009).

In comparison to rural road verges, no significant difference in butterfly and diurnal moth species richness, and plant species richness has been found (Jantunen et al., 2006; Saarinen et al., 2005). This contrasts with Ray & George, (2009) which found significantly more plant species on urban road verges compared to rural verges in India. This contrast may be explained by the high number of non-native species found present in Ray & George, (2009). However, butterfly abundance and grassland cover was found to be significantly lower on urban road verges, thought to be due to more intensive management undertaken than on rural or highway verges (Saarinen et al., 2005).

Whilst road verges can support biodiversity, the proximity of this habitat to roads can cause numerous negative effects on biodiversity including species mortality (Baxter-Gilbert et al., 2015), pollution, noise and artificial lighting, heavy metal contamination, vehicular emissions, spread of invasive species (Valtonen, Jantunen, & Saarinen, 2006) and habitat fragmentation (Spellerburg, 1998; Forman & Alexander, 1998). Vehicular traffic emissions and the indirect impact of salt and grit alter plant communities on the verge, increasing the number of halophyte species (Truscott et al., 2005).

1.4 Road verge management and impacts on biodiversity

In many countries around the world, including Germany (Weber, Kowarik, & Säumel, 2014a), Finland (Saarinen et al., 2005) and the USA (Hopwood, Black, & Fleury, 2015), government bodies manage public road verges. For countries such as the USA and Australia there is some variation in who manages different elements of the road verge, with residents being responsible for road verge maintenance in Ann Arbor, Michigan (Hunter & Brown, 2012), the costs of street tree maintenance in Portland (Donovan & Butry, 2010) and in

Melbourne, Australia local residents voluntarily maintain or undertake planting on road verges otherwise known as verge gardening (Marshall, Grose, & Williams, 2019b). In the UK, under the Highways Act 1980, highway authorities comprising of local authorities, Highways England, Transport Scotland and the Welsh Government have the responsibility to maintain roadsides (Great Britain, 1980). Over the past 50 years, private companies are increasingly being contracted to undertake road verge maintenance (Dempsey, Burton, & Selin, 2016).

Road verge vegetation (grass verges, trees, hedges and shrubs) can be managed in a number of different ways providing a variety of different ecosystem services and biodiversity value (O'Sullivan et al., 2017; Säumel, Weber, & Kowarik, 2015). A baseline understanding of road verge management is essential in order to understand the impacts of current management on biodiversity and the potential for management change. However, little systematic information and research on urban road verge management is available, probably due to the large number of localised management teams and because road verges receive much less research attention than other forms of urban green space.

When making management decisions, a variety of factors need to be considered including economic, social, ecological and political factors to increase the chance of effective conservation management (Knight et al., 2011). To my knowledge, the only two studies which have assessed what factors need to be accounted for in road verge management are Way, (1973) and (O'Sullivan et al., 2017). In an urban road verge context, O'Sullivan et al., (2017) highlighted that cost, limitations of private contracts and public perception may influence management to maximise biodiversity and ecosystem services. According to UK county highway authorities in 1973, safety, amenity, weed control, drainage and an unobstructed highway were key reasons for management of rural road verges (Way, 1973). A greater understanding is needed of the factors that affect management within an urban context.

1.4.1 Mowing

The majority of studies assessing the impact of mowing on road verges have focused on rural road verges with only a few assessing urban road verges (O'Sullivan et al., 2017). Helden & Leather, (2004), the only exclusively urban study, indicated that areas that were mown less frequently had greater numbers of grassland Hemiptera. It has been suggested that a reduction in mowing frequency of urban road verges may increase the floral resources that may support pollinator-plant communities at a city scale (Baldock et al., 2019). Therefore, further investigation is required to assess the implications of a reduction in mowing frequency in an urban environment on multiple taxa.

Studies assessing the impact of a reduction in mowing frequency on rural road verges suggest that this significantly increased plant and flower visiting invertebrates species richness, with an optimal frequency of twice a year with cuttings being removed (Jakobsson et al., 2018; Auestad, Rydgren, & Austad, 2011; Noordijk et al., 2009; Parr & Way, 1988). In combination with the narrow width of verges, high frequency mowing also significantly decreases butterfly abundance (Saarinen et al., 2005). In contrast Halbritter et al., (2015) found no significant difference in butterfly abundance with different mowing frequencies. No significant difference in plant diversity was seen with different types of cutting machine (Parr & Way, 1988).

Careful timing of verge cutting is advocated, avoiding early spring to allow seedling establishment (Auestad et al., 2010; Parr & Way, 1988). Summer mowing has no significant effect on the number or distribution of birds on roadside verges (Laursen, 1981). When considering mowing timing and frequency, the impact on interactions between species such as ants and butterflies should be considered (Wynhoff et al., 2010). For management of butterflies and diurnal moths, it is recommended that mowing is avoided from mid June to September, so that food plants retain their flowers for insect egg-laying (Wynhoff et al., 2010; Valtonen, Saarinen, & Jantunen, 2006).

Partial mowing (leaving sections of grass unmown) during the summer has been found to increase species richness, diurnal moth diversity and butterfly abundance in comparison to full mowing (Valtonen, Saarinen, & Jantunen, 2006). Mosaic mowing (staggering or rotating mowing strategies) has been advocated as a potential measure to optimise species richness and abundance (Wynhoff et al., 2010; Auestad et al., 2010; Noordijk et al., 2009). This is something that requires further investigation and its impacts may well depend on the spatial scale of the mosaic. The amount of time an area is left uncut should be carefully considered, as leaving an area uncut can also reduce botanical species richness (Parr & Way, 1988).

The removal of grass arisings, shortly after mowing has been found to increase plant species richness (Noordijk et al., 2009; Parr & Way, 1988). There is debate as to the underlying cause creating this impact with Schaffers, Vesseur, & Sykora, (1998) indicating this is likely to be due to the removal of nutrients from the soil with the removal of the cuttings and Parr & Way, (1988) suggesting that this is due to a combination of the removal of cuttings reducing the smothering of underlying vegetation as well as the disturbance caused by this removal.

1.4.2 Herbicide use

Herbicides are typically used on road verges to control weeds (O'Sullivan et al., 2017; Way, 1977). The most commonly used herbicide on urban road verges is glyphosate, also known as Roundup (O'Sullivan et al., 2017; Woodburn, 2000). Glyphosate has high solubility and tightly binds to soil (Ramwell, Heather, & Shepherd, 2002). High rainfall after application is thought to increase the chance of glyphosate leaching from the soil (Borggaard & Gimsing, 2008; Vereecken, 2005; Ramwell, Heather, & Shepherd, 2002), but in comparison to other herbicides such as atrazine and duiron, lower concentrations of glyphosate were found in run off after rainfall (Ramwell, Heather, & Shepherd, 2002). Adverse impacts of glyphosate on aquatic species from runoff is thought to be unlikely as the toxicity exposure ratios have been found to be above the trigger value indicating that it was unlikely that the chemical was harmful (Ramwell, Heather, & Shepherd, 2002) .

As a method of weed control, glyphosate has been found to be effective, with one study indicating that with no glyphosate application in 5 European towns, weed coverage increased compared to when glyphosate was applied (Melander et al., 2009). The impacts of glyphosate on biodiversity on urban road verges is understudied, but more broadly, it has been shown that this can be dependent on taxa, with no impact or increased species richness found for vascular plants (Sullivan & Sullivan, 2003). Glyphosate impact on invertebrates was found to be taxa dependent (Sullivan & Sullivan, 2003), with detrimental responses found for species such as earthworms (Correia & Moreira, 2010), snails (Druart et al., 2011) and spiders (Evans, Shaw, & Rypstra, 2010).

Flazasulfuron is used for spot spraying and is advantageous in that it can be applied at very low rates (Grey & McCullough, 2012). However, it has been found that soil type (increased organic matter such as clay) and pH (over 7) increases its persistence within the soil (Grey & McCullough, 2012). In comparison to other commonly used herbicides, flazasulfuron application is also thought to have little impact on freshwater communities such as algae (Couderchet & Vernet, 2003).

1.4.3 Tree planting

When considering planting street trees, a number of factors such as tree type, variety of species, location of new trees and management method need to be considered. Tree species vary in their functional traits and thus their capacity to provide certain ecosystem services (Sæbø et al., 2012; Roloff, Korn, & Gillner, 2009). Planting a variety of different tree species may optimise these differing attributes (Bolund & Hunhammar, 1999).
Careful consideration should be made about the location of trees on roadsides as a modelled study suggested that trees may increase nitrogen dioxide and elemental carbon levels due to canopy cover reducing wind and trapping pollutants (Vos et al., 2013). The method used to plant and manage trees also should be assessed as management techniques (initial tree planting and tree maintenance using chainsaws) can release carbon back into the atmosphere which can culminate overall net gain of carbon by trees (Nowak et al., 2002). Recommendations to reduce carbon use include planting long-lived trees which need little maintenance and using wood from trees cut down in wood productions (Nowak et al., 2002).

1.4.4 Grassland restoration through wildflower seeding and planting

Semi-natural grasslands are considered habitats of conservation interest in Europe, supporting high species richness of flora and fauna (Wilson et al., 2012; Webb, Drewitt, & Measures, 2009; Öckinger & Smith, 2006; van Swaay, 2002). During the second half of the twentieth century, semi-natural grasslands declined to a significant extent, with 97% of its area lost in England and Wales between 1930 to 1984 (Fuller, 1987). Restoration of urban grasslands such as road verges has been identified as one method to increase biodiversity in grassland habitats (Klaus, 2013).

Planting local native species is a recommended measure to improve grassland quality (Staab et al., 2015; Rydgren et al., 2010). Urban green spaces, including road verges, planted with annual and perennial wildflower seed mixes significantly increased flower, bee and hoverfly abundance 1 to 2 years after seeding (Blackmore & Goulson, 2014). Road verges surrounded by suburban development and agricultural land, planted with native prairie forbs and grasses and mown every 2 to 4 years, supported greater species richness and abundance of bees than conventional verges (Hopwood, 2008).

Evidence assessing the effectiveness of different establishment techniques has focused on rural road verges. Selecting the most appropriate method is key as different methods such as seed sowing and soil seed bank impact plant species composition and frequency on road verges (Nordbakken et al., 2010). To increase species richness on road verges, both sowing local seeds and hay transfer have been shown to be effective methods of establishment (Rydgren et al., 2010; Nordbakken et al., 2010).

Understanding the soil characteristics of road verges is also essential for seedling survival. In a US highway setting, planting 9 native species in sandier soil increased the likelihood of survival compared to clay and silt soils (Haan, Hunter, & Hunter, 2012). Attention should be given to the soil properties of road verges proposed to be reseeded and plant species tolerant of those soil properties selected to maximise the potential of seedling success (Haan, Hunter, & Hunter, 2012).

As a low cost species, it has been suggested that seeding yellow rattle (*Rhinanthus* species), a hemi-parasitic plant, can be effective in reducing biomass, by reducing the growth of competitive plant species, allowing other plant species to establish (Ameloot, Hermy, & Verheyen, 2006; Bullock & Pywell, 2005). The optimal sowing rate of *Rhinanthus* species has not been established for road verges. However, Blackmore & Goulson, (2014) ascertained that *Rhinanthus minor* failed to establish when sown at 1 g m^{-2} and differing numbers of established *Rhinanthus* species were produced when Ameloot, Hermy, & Verheyen, (2006) sowed *Rhinanthus angustifolius* at 3g m^{-2} and *Rhinanthus minor* at 2.62g m^{-2}, which in some cases, was not large enough to reduce biomass. The productivity of the road verge and amount of biomass already present should be considered when selecting areas to sow yellow rattle, as highly productive verges with high biomass reduced the effectiveness of *Rhinanthus* species (Ameloot, Hermy, & Verheyen, 2006).

1.5 Public perception of urban road verges

Consideration of social values is key for effective ecological management (Bennett, 2016; Ives & Kendal, 2014), as human behaviour influences management through the decision making process to create the management plan and the human behaviour change required to successfully achieve the management (Schultz, 2011; Polasky, 2008; Mascia et al., 2003). Failure to consider these social values alongside other management factors can cause conflict with local residents and impact the effectiveness of implemented management (Knight et al., 2011; Brechin et al., 2002). It is therefore surprising that public perception of informal urban greenspaces such as road verges is understudied (Botzat, Fischer, & Kowarik, 2016). Studies focus primarily on street trees (such as Fernandes et al., 2019; Schroeder, Flannigan, & Coles, 2006; Sommer, Guenther, & Barker, 1990), with only a few studies focusing on herbaceous vegetation on the road verge (Botzat, Fischer, & Kowarik, 2016; Säumel, Weber, & Kowarik, 2015).

The presence of herbaceous vegetation has shown to be important on streets, with herbaceous vegetation presence significantly preferred to streets with no herbaceous vegetation (Bonthoux et al., 2019; Fischer et al., 2018). Members of the public have been found to have a high awareness of ecosystem services associated with roadside vegetation, with the most popular ecosystem services selected being aesthetic function, psychological well-being, air quality and habitats for animals and plants (Weber, Kowarik, & Säumel, 2014a).

However, previous studies that have assessed public perception of urban road verge management have shown there is disparity in preferences, with wild spontaneous vegetation being met with high approval by some people (Bonthoux et al., 2019; Weber, Kowarik, & Säumel, 2014a), and planted, maintained and ordered vegetation significantly preferred in other studies (Weber, Kowarik, & Säumel, 2014a; Todorova, Asakawa, & Aikoh, 2004). When presented in the form of hypothetical scenarios, tree presence and low and ordered vegetation with colourful flowers were most preferred (Todorova, Asakawa, & Aikoh, 2004). Highest preferences have also been shown for street scenarios which are the most biologically diverse (Fischer et al., 2018). When asked what factors influence these preferences, aesthetics, psychological benefits and orderliness were factors mentioned with regards to maintained vegetation (Weber, Kowarik, & Säumel, 2014a; Todorova, Asakawa, & Aikoh, 2004), whereas people who preferred wild spontaneous vegetation perceived ecological and economic concerns to be more important than orderliness (Weber, Kowarik, & Säumel, 2014a). However, these urban road verge preferences have focused predominately on hypothetical scenarios, with only one study (Weber, Kowarik, & Säumel, 2014a) assessing perceptions of actual wild vegetation based on one arterial road. Further investigation is needed to assess whether these preferences remain the same when different management is implemented in practice across a number of sites.

In other contexts such as highways, road verge vegetation has also been perceived to be an important part of the landscape (Fathi & Masnavi, 2014; Akbar, Hale, & Headley, 2003) with the exception of Froment & Domon, (2006), where wider landscapes such as agricultural and mountainous landscapes were perceived to be more important to road users than the road verge embankments in the foreground. When asked about current vegetation (predominately trees with shrubs and flowering herbs uncommon and in some locations, no road verge present at all) on highways, the majority of participants had a negative attitude (Fathi & Masnavi, 2014). The presence of a variety of vegetation types have been shown to be favoured, with trees in the background and shrubs and/or flowering herbs near the road

(Fathi & Masnavi, 2014; Lucey & Barton, 2011; Akbar, Hale, & Headley, 2003). The least desirable type of road verge management was found to differ between studies assessing hypothetical road verge scenarios. One study indicated a tidy, intensively mown grass sward was least desirable when the public were asked about hypothetical options during surveys conducted at motorway service stations and small cafes along A roads (Akbar, Hale, & Headley, 2003) and another, that unmown turf was undesirable when the public were shown hypothetical images online (Lucey & Barton, 2011).

When considering alternative road verge management on highways, results from Akbar, Hale, & Headley, (2003) indicate that public preference would be high to plant road verge vegetation with native species but when creating visual vegetation this should not be regardless of cost. When implementing a reduced mowing frequency regime in a highway context, Froment & Domon, (2006) indicated that the majority of participants appreciated the altered embankment when asked about the management change, but when asked to photograph views they appreciated, there were few images relating the altered embankment. Negative reactions to the management change were based on the perception that it would look untidy and neglected (Froment & Domon, 2006).

1.6 Aims and Objectives

The overall aim of this thesis is to gain a greater understanding of urban road verge management. This is done by assessing ecological implications, social considerations from a public perception perspective, and management practicalities, to assess the potential for particular management changes to enhance biodiversity and the scope for implementing them. The objectives are:

1. To investigate the impact of reducing mowing frequency of urban road verges on botanical and invertebrate communities.

- Does the abundance and number of invertebrate orders differ between urban road verges that are mown less frequently (every 6-8 weeks) compared to current management (every 3-4 weeks)?

- Does herbaceous plant diversity, forb abundance and flower abundance differ between urban road verges that are mown less frequently (every 6-8 weeks) compared to current management (every 3-4 weeks)?

2. To assess local resident's perceptions of a reduced mowing frequency trial taking place on their road and of other hypothetical scenarios.

- Do local residents' attitudes differ when comparing road verges on their road which are mown less frequently (every 6-8 weeks) and those managed typically (every 3-4 weeks)?
- What factors influence local residents' attitudes when comparing road verges which are mown less frequently (every 6-8 weeks) and those managed typically (every 3-4 weeks)?
- Do local residents' attitudes differ when comparing alternative hypothetical road verge scenarios to current management (mown every 3-4 weeks)?
- Does local residents' connection to nature influence attitudes towards different types of road verge management?
- Do local residents' attitudes differ regarding the ability of different road verge scenarios to support biodiversity?

3. To provide baseline information on how different urban road verges are managed around England and what factors affect management decisions.

- How are road verges currently managed in major towns and cities in England?
- What factors influence road verge management decisions?
- What resources do road verge managers use when making the decision to alter management practices?

Objective 1 was addressed through the implementation of a large scale mowing trial across urban areas in the city of Sheffield, UK., using a paired design where current management was maintained on one side of the road (mown every 3-4 weeks) and mowing frequency was halved (mown every 6-8 weeks) on the opposite side of the road. Botanical and invertebrate surveys were conducted over a single season (for some sites over two seasons).

This information was used to assess the impact of reducing the mowing frequency of urban road verges on invertebrate and botanical communities (Chapter Two).

Objective 2 was addressed by undertaking two questionnaires with local residents living on the roads where the mowing trial was implemented. An initial door to door questionnaire was conducted where local residents were asked about their attitudes towards the mowing trial that took place on their road and their attitudes towards each side of the roads ability (and therefore each treatment) to support biodiversity. Local residents were then provided a postal questionnaire to fill in during their own time and send back. Residents were asked their attitudes towards other alternative management scenarios, their attitudes regarding ability of alternative management scenarios to support biodiversity, what factors affect their attitudes and how connected they feel to nature using a nature relatedness scale. These responses were used to assess local residents' responses to a mowing trial taking place on their road and of other hypothetical scenarios (Chapter Three).

Objective 3 was addressed using semi-structured interviews with road verge managers (working for local authorities and contractors) from unitary authorities and metropolitan districts across England, UK. The interviews were focused around five broad questions relating to: (i) how road verges are classified, (ii) how they currently manage road verges, (iii) what factors influence road verge management decisions, (iv) how do they make their decisions about road verge management and (v) what alternative management have they used or considered on road verges in their area. These responses were used to create a baseline of current road verge management, identify current factors that influence management and what resources are used in management decisions (Chapter Four).

Chapter Two: To mow or not to mow? The impact of reduced mowing of urban road verges on plant and invertebrate communities.

Abstract

The management of urban green space often limits its ability to support biodiversity and provide ecosystem services. Discussions about how to optimise green space management often ignore road verges despite their large spatial extent. Urban road verges are typically managed to generate short grass swards which probably limits their biodiversity value, but the benefits of alternative management regimes are rarely assessed. Here we use a controlled paired experimental design to test if doubling the interval between cutting from every 3-4 weeks to every 6-8 weeks enhances plant species richness, forb abundance, the availability of floral resources for insect pollinators, the number of invertebrate orders and invertebrate abundance. Work was conducted on 16 roads located throughout urban Sheffield, England's 5th largest city, in 2016 and 2017. Many invertebrate groups exhibited trends towards increased abundance. Whilst these trends were only statistically significant for Araneae in late summer, total invertebrate abundance was significantly higher on verges with reduced mowing in the late summer compared to those with a typical mowing regime. Reduced mowing increased vegetation height but had negligible influence on botanical species richness and forb abundance whilst reducing the abundance of floral resources in late summer. These patterns probably arise due to strong grass growth, and large amounts of cut grass left in situ, suppressing floral development and recruitment from remnant seed banks. Removing arisings from cut verges may thus be required for plant communities at most sites to benefit from reduced mowing frequency. Our results highlight that reduced mowing of urban roadside verges can rapidly increase invertebrate abundance, thus potentially helping to mitigate the frequently documented low numbers of invertebrates in urban areas.

1. Introduction

By 2050, it is predicted that approximately 25 million kilometres of new roads will be built globally, an increase of 60% compared to road infrastructure in 2010 (Dulac, 2013). This rapid expansion of road creation creates a range of environmental pressures on ecosystems including global fragmentation (Ibisch et al., 2016), and thus, requires careful planning to minimise future environmental loss (Laurance et al., 2014). However, typically as a consequence of this road building is the creation of linear strips of vegetation alongside a road, known as road verges. Road verges can cover large areas of land, approximately 140,000 ha and 80,000 km in Finland and the Netherlands respectively (Noordijk et al., 2010; Saarinen et al., 2005). The UK has 397,025 km of road of which a large proportion are likely to be associated with road verges (Department for Transport, 2019). Whilst the close proximity of road verges to roads can have negative consequences for flora and fauna (Muñoz, Torres, & Megías, 2014; Forman & Alexander, 1998), for example from road mortality (Baxter-Gilbert et al., 2015) and vehicular nitrogen emissions (Truscott et al., 2005), road verges have been found to provide nectar resources and host plants for invertebrates (Ouin et al., 2004; Ries, Debinski, & Wieland, 2001) and the dispersal of grassland plants in fragmented landscapes (Tikka, Högmander, & Koski, 2001).

In a UK study, botanical surveys of road verges in 1977 revealed that 870 out of 2000 species of mainly native plants are associated with roadsides and 35 out of 257 species of these are nationally rare (Way, 1977). Rural roadside habitats (verges and intersections) have been identified as providing habitats for numerous pollinators (Way, 1977; Free et al., 1975) such as bees (Baldock et al., 2015; Hanley & Wilkins, 2014; Osgathorpe, Park, & Goulson, 2011), flies (Free et al., 1975), butterflies and diurnal moths (Valtonen, Saarinen, & Jantunen, 2007; Saarinen et al., 2005). In a rural setting, road verges have been found to support significantly more foraging bumblebees than in adjacent arable agricultural land (Hanley & Wilkins, 2014) and also act as a source of forage for long-tongued bumblebees (Osgathorpe, Park, & Goulson, 2011). It has also been suggested that rural road verges can provide the bare-ground needed for ground-nesting bumblebees (Hopwood, 2008).

Much of what we know about road verges as wildlife habitat is based on studies of rural road verges, but the high density of roads, and their associated verge areas in urban systems raises the important question of what contribution they can make to supporting biodiversity in urban areas, where habitat context and management may be rather different. Plant species on urban roads have been found to be highly homogenized (Gong, Chen, & Yu, 2013; Wittig & Becker, 2010), with impacts from the road such as chemicals from exhausts are thought to potentially impact native and non-native plant species distributions (Brown & Sawyer, 2012). In comparison to other areas of green space, urban road verges have been found to support significantly lower bird species richness and abundance than parks and gardens (Carbó-Ramírez & Zuria, 2011), and lower bee and hoverfly abundance than gardens and allotments (Baldock et al., 2019).However, urban road verges have the potential to act as corridors for birds (Fernández-Juricic, 2000) and small mammals (Munshi-South, 2012) connecting urban parks. Baldock et al., (2019) highlight that alternative management on urban road verges such as a reduction in mowing frequency may increase the robustness of plant-pollinator communities to species loss across cities by increasing floral abundance.

Urban green space management decisions such as the application of pesticides and mowing frequency can impact biodiversity (Aronson et al., 2017; Bertoncini et al., 2012). Current management of urban road verges is typically in the form of short mown grass, often with street trees, mown every 3-4 weeks, which does not maximise biodiversity and ecosystem service provision (O'Sullivan et al., 2017). With a reduction of local authority budgets by 28.6% since 2010 (National Audit Office, 2018) and the length of plant growing season set to increase due to climate change and increased levels of carbon dioxide (Reyes-Fox et al., 2014; Menzel et al., 2006), there is increasing interest into alternative cost-effective management strategies. Unlike most urban green spaces which are typically managed by many landowners, urban road verges are typically managed by one local authority or contractor, providing opportunity for change on a large scale (Gaston, Ávila-Jiménez, & Edmondson, 2013). In the UK, local authorities are responsible for managing road verges but increasingly, this maintenance is also contracted out to private companies (Dempsey, Burton, & Selin, 2016; Great Britain, 1980).

The reasons for current management in rural areas, are primarily safety and cost (Way, 1973; Parr and Way, 1988). Several studies have assessed the impact of different mowing techniques such as mowing frequency on biodiversity. A combination of mowing frequency and the removal of cuttings can significantly impact plant communities (Jakobsson et al., 2018). On rural road verges, an optimal frequency of mowing twice a year with the removal of cuttings is found to significantly increase plant species richness and abundance as well as arthropod and flower visiting invertebrate richness and abundance (Jakobsson et al., 2018; Noordijk et al., 2009, 2010; Parr & Way, 1988). The removal of cuttings after mowing has been found to significantly increase plant and invertebrate species richness, although there are conflicting views on the underlying cause of this (Auestad, Rydgren, & Austad, 2011; Noordijk et al., 2009; Parr & Way, 1988). Whilst it has been shown that potassium is lost from the soil when cuttings are removed, Parr & Way, (1988) suggest that the increase in plant species richness is more likely to be due to the disturbance whilst removing cuttings and the removal of the vegetation smothering growth rather than the nutrient loss. In contrast, Schaffers, Vesseur, & Sykora, (1998) indicated that this increase may be due to removal of nutrients from the soil. A greater reduction in mowing frequency from frequently mown verges (every 3 weeks) to every 6 weeks and verges not mown at all, significantly increased the density and species richness of flowering plant species but had no significant impact on butterfly abundance in a rural highway setting over one season (Halbritter et al., 2015).

Despite this knowledge indicating a reduction in mowing frequency of road verges in a rural setting has the potential to yield biodiversity benefits, most of these studies focus on the impacts on plant communities rather than invertebrates (Jakobsson et al., 2018). In addition, there is a lack of evidence for this in an urban context where typical management is more intensive (O'Sullivan et al., 2017), with only one study (Helden & Leather, 2004), assessing the impact of mowing on Hemiptera and plant species for urban road verges. Grassland Hemiptera species richness and abundance was negatively affected by more frequent mowing, with the species richness and abundance of grassland Hemiptera significantly lower when mown every 14 days in comparison to road verges mown every 40 days or once or less a year in an urban setting (Helden & Leather, 2004). However, the impact of mowing could not be separated from the species area relationship for plant species. This was thought to be due to plant diversity being unaffected by short term mowing, although it is unclear how long the mowing frequency had been in place for (Helden & Leather, 2004).

A reduction in management resulting in tall, structurally complex grasslands supports a greater abundance and diversity of many invertebrate groups compared to short, more intensively managed grasslands (Diehl et al., 2013; Langellotto & Denno, 2004; Morris, 2000; Lawton, 1983). The underlying causes of this are less well understood. It is commonly proposed that this may be linked to the niche concept, where a niche is “a n-dimensional hypervolume”, “every point in which corresponds to a state of the environment which would permit the species S_1 to exist indefinitely” (Hutchinson, 1957). Increased vegetation complexity is thought to increase the number of niches and resources for different species (Willis, Winemiller, & Lopez-Fernandez, 2005; MacArthur & MacArthur, 1961) such as altering microclimate (Gardiner & Hassall, 2009), food resources (Volkl et al., 1993) and habitat structures (Bell, Wheater, & Cullen, 2001). Therefore, we would expect to see that reducing the mowing frequency of urban road verges will significantly increase the abundance and richness of invertebrate species.

Management intensity such as mowing frequency is one of the numerous factors which influence grassland species richness including nutrient richness (Crawley et al., 2005), productivity (Vermeer & Berendse, 1983) and soil seed bank composition (Bakker & Berendse, 1999). Mowing causes damage to plants, thereby reducing the ability of less competitive plant species to grow and compete with plant species with more competitive features (Grime, 1973). Botanical species richness is thus influenced by what has been termed as ‘competitive exclusion’ where under very intensive mowing frequency, only certain plant species are able to persist under the increased disturbance (Grime, 1973). Under moderate mowing frequency less competitive plant species have the opportunity to grow as competitive species are restricted and therefore, plant species richness is predicted to increase (Grime, 1973, 2001). However, “many ecological processes take processes take place over relatively long time periods” (Franklin, 1989), with positive effects on urban grassland species richness shown with a reduction in mowing frequency over long timescales (Sehrt et al., 2020; Chollet et al., 2018; Rudolph et al., 2017; Bertoncini et al., 2012). Therefore, given the short timescale of the experiment, even if such changes were taking place we might not necessarily expect to see a difference in botanical species richness when the mowing frequency of urban road verges are reduced.

In order to address the question of how invertebrate and plant communities respond to altered mowing regimes in urban roadside verges we conducted a large scale mowing trial in Sheffield, UK, using a paired design, maintaining the current management (mowing every 3-4 weeks) on one side of the road and halving the mowing frequency (mowing every 6-8 weeks) on the opposite side of the road over a single season (or two seasons for a small subset of sites). We assessed effects on abundances of invertebrate orders, herbaceous plant diversity, and flower abundance.

2. Material and Methods

2.1 Site Selection

The study was conducted in Sheffield, South Yorkshire, UK (53°23’N, 1° 28’W), a city with 2.9 million square metres of grass verges managed on behalf of the City Council by contractors, Amey Plc (Amey Plc, 2015). Seventy-three percent of road verges managed by the contractor in Sheffield are classed as urban or suburban.

We selected 28 roads for use in the mowing trial using GIS road verge data from Sheffield City Council in ArcGIS 10.1 (Environmental Systems Research Institute (ESRI), 2015). Roads were chosen at random with the exception of two roads where there was a specific interest in understanding the response to a change in mowing frequency. Seven roads that had at least 200m sections of verges on both sides of the road were randomly selected from each of four quadrants covering urban Sheffield using urban data from Davies et al., (2008). Google Street View was then used to check that verges were still intact and not extensively damaged by parking or other activities, and the practicality of implementing the experimental design on each road was checked in discussion with mowing contractors. This led to the removal of three roads. Before the experiment started, we communicated the nature of the trial to local residents using three methods: (i) signs on lamp posts of affected roads, (ii) a summary leaflet delivered to every house on all mowing trial roads and (iii) a press release from Sheffield City Council.

2.2 Experimental design

We successfully established a controlled paired experimental design on 16 of these remaining 25 roads. Between April and October 2016 and 2017, one side of each road was mown as normal (every 3-4 weeks) and the other side of the road was mown every 6-8 weeks (Fig.2.1). On nine roads out of the original 25 roads, mowing trials were not established due to mowing contractors implementing mowing regimes incorrectly and local residents mowing the verges themselves. Grass cuttings were left on road verges after mowing took place, which is standard practice when managing verges.

Although intended as a two season experiment, feedback from local residents meant that it was only possible to continue the trial over a second season at two of the original sites.

Figure 2.1. Experimental treatment on a road verge. One side of the road was mown every 3-4 weeks (verge on the left) and the other side every 6-8 weeks (verge on the right).

2.3 Sampling

Botanical and invertebrate surveys were conducted using a 1 m wide transect along 100 m of road verge on each side of the road from July to September 2016 and June and August 2017. Transects were split into multiple sections when verges were not continuous, for example to allow tarmacked entrances to residents' driveways. The distance of the central line of each transect varied in its distance from the road edge according to verge width (0.5m from the edge when verges were 1m width, 1m from the edge for verges 1.1-2m width, 1.5m from the edge for verges 2-6m in width). One verge was wider than 6m and here we conducted two transects, one that was 1.5m from the edge of the road and the other was in the middle of the verge.

When possible, monthly visits to all roads for surveying were timed to occur just before mowing when the vegetation height was at its maximum, to avoid bias in the samples from mowing mortality (Skórka et al., 2013) and to aid botanical identification. The order in which the roads were surveyed was based on information from the mowers as to when the verges were scheduled to be cut. To prevent vegetation being trampled before botanical identification and measurements occurred, botanical sampling took place on the road verge first, then invertebrate sampling. Both survey types (botanical and invertebrate) were conducted on the same day or within a couple of days when possible (weather dependent).

2.3.1 Invertebrate sampling

Invertebrates were sampled using three techniques: (i) sweep net sampling, (ii) G-vacuum sampling and (iii) visual sampling, to provide as complete a representation as possible of invertebrates of all sizes (Sanders & Entling, 2011; Doxon, Davis, & Fuhlendorf, 2011; Brook et al., 2008; Standen, 2000).

Invertebrate surveys took place between 10:45 and 19:10 (the majority were between 10:45 and 17:00) at 13-17°C in sunny conditions (at least 60 % sunshine) and above 17°C when it is sunny or cloudy (Pollard,1977). Counts were not made when the temperature was less than 13°C (Butterfly Conservation, 2016; Pollard, 1977). Visual surveys were undertaken first to ensure that the data was not influenced by the removal of invertebrates from sweep net and vacuum sampling.

Sweep net sampling consisted of sweeping a 60 cm diameter x 1 m deep butterfly net with a 50 cm handle along the surface of the road verge vegetation at a 180° angle with the bottom edge of the net in contact with the vegetation, sweeping across the road verge from side to side from the transect point.

Vacuum sampling was conducted using a McCulloch GBV 325 garden vacuum adapted for invertebrate sampling by attaching a 48 cm long, 24 cm wide collecting net to the end of the vacuum inlet tube. At 30 random points on either side or in the middle of the transect, the tube attached to the running vacuum was placed on the ground, slightly tilted, for 10 seconds.

For both sweep net and vacuum sampling, the invertebrates caught in the nets were immersed in 100% IMS and later sieved into size fractions and identified to order where possible (Acari and Oligochaeta identified to subclass and Gastropoda, Collembola, Chilopoda and Diplopoda to class level) in the laboratory. Due to large numbers of Acari and Collembola, dominating the smallest size fraction of the vacuum samples, a subsample of one fifth of the smallest size fraction was identified and scaled for the whole sample.

The Pollard method (a fixed distance walk along a transect) was used to visually monitor the total number of bees, hoverflies and adult Lepidoptera (butterfly and day-flying moths) along a 100m transect up to 5m in front of the recorder on the road verge sites (Pollard & Yates, 1993; Pollard, 1977). These orders were used to create a proxy of ‘pollinators’ found on road verges. No standardized time limit to walk the 100m was used due to differing number of gaps ie pavements, drives and intersecting roads between road verge sections.

2.3.2 Botanical surveys

Along the 100 m transect, all forbs (all species apart from grasses, sedges and rushes) were identified to species where possible. This survey was split into three equal length sections. For each section all forb species were recorded, along with the percentage cover of flowering forbs (to the nearest 5%) and abundance of each species (using the DOMIN scale). The maximum natural standing vegetation height of the road verge was measured to the nearest 0.01 m at ten random points within the 100 m transect. During the botanical survey, three points were randomly measured at two of the three equal length sections and four points for a randomly selected other section of the survey.

2.4 Data Analysis

All analyses were conducted using R 3.5.3 (R Core Team, 2019). To assess for spatial autocorrelation between roads, a Mantel test was performed using the 'ade4' package in R (Dray & Dufour, 2007) with total invertebrate abundance data which indicated independence (r=0.28, *p*=0.07).

2.4.1 Effects of road verge mowing frequency on invertebrate abundance, order richness, botanical species richness, mean forb abundance and mean flowering index.

To test the effects of altered mowing frequency on the response variables only, t-test and Wilcoxon Signed rank tests were initially performed (Appendix 2.1).

We modelled the effects of different road verge mowing frequencies on total invertebrate abundance, invertebrate order abundance, botanical species richness, mean forb abundance and mean flowering index (n=5 separate models) using generalized linear models (GLM) and generalized linear mixed effect models (GLMM) using the 'lme4' package (Bates et al., 2015) with a Gaussian distribution unless otherwise stated. Analyses were carried out for (i) the whole data set and (ii) separately for the most abundant invertebrate Orders (Acari, Araneae, Coleoptera, Collembola, Diptera, Gastropoda, Hymenoptera, Hemiptera, Lepidoptera, Psocoptera and Thysanoptera abundance). Data were split by season, with data collected in July 2016 and June 2017, collectively termed as 'early season' and data from September 2016 as 'late season'. As only two roads were sampled in August 2017, no 'late season' data for 2017 was included. Full models were retained following

Whittingham et al., (2006) as all covariates included within the models are of relevance to the study.

Fixed effects for the invertebrate models were mowing treatment, road, botanical species richness, mean flowering index (see below), mean road verge width and roadside tree density. Mean flowering index was calculated by converting the mid-point values of the DOMIN scale into a proportion of the coverage of the DOMIN scale (100%). These values were then multiplied with the percentage flowering cover for each species for each transect section, averaged for each species and the values summed from each transect section. Fixed effects used for the mean forb abundance and mean flowering index models included treatment, road verge width and tree density only. Mean forb abundance was calculated using the sum of the mean mid-point values of the DOMIN scale for each species to produce the mean forb abundance per side of the road. Vegetation height at the time of sampling was not included within the model as plants are more likely to be responding to the overall mowing regime than short term variation in vegetation height.

Due to convergence issues, early season data were fitted as generalized linear models (GLM) as road could not be included as a random effect so was included as a fixed effect. With the exception of Araneae, Gastropoda and Lepidoptera abundances, log transformed data with the normal error function was used where it provided the best fit to the model assumptions. For the late season data, generalized linear mixed effect models (GLMM) were fitted and residuals were checked for normality and heteroscedascity. Total invertebrate abundance, Araneae abundance, Acari abundance and Collembola abundance data were log transformed to meet model assumptions. Due to singular fit issues, Gastropoda, Lepidoptera and Thysanoptera abundances were fitted with a Poisson GLM. The resulting models were overdispersed and therefore the standard errors were corrected using a quasi-GLM model. The same fixed effects were used as for the early season data with the exception of road, which was included as a random effect in all GLMM models to incorporate variation between roads. Botanical species richness data was tested using combined data from the early and late season using a GLMM.

Invertebrate models were tested without mean vegetation height, with both treatment and mean vegetation height and without treatment to assess the implications as the realised vegetation height on different verges and at the specific time of sampling was quite variable, and mobile invertebrates may respond to this independently of mowing frequency (Appendix 2.2-2.4). As model assumptions were met and the resulting output did not differ between different model variations, models with just treatment are presented.

The effect of altering the mowing frequency on the number of 'pollinators' from the visual survey was tested for July, August and September 2016 using paired t-tests (for August and September 2016) or Wilcoxon Signed-Rank tests (for July 2016 data). As only two roads were included in the trial in 2017, this data was excluded from this 'pollinator' analysis.

3.Results

3.1 Effects of road verge mowing frequency on invertebrate abundance and order richness.

More than 155,700 invertebrates (comprised of 16 orders, 2 subclasses and 4 classes) were collected across 16 urban roads in Sheffield in July 2016, September 2016, June 2017 and August 2017 (Appendix 2.5 & 2.6).

There was no significant difference in the richness of invertebrate orders, nor in the abundances of Acari, Coleoptera, Collembola, Diptera, Gastropoda, Hymenoptera, Hemiptera, Lepidoptera, Psocoptera and Thysanoptera, between the two mowing frequencies for both seasons (Fig. 2.2C & D, Fig. 2.3A-B & E-F, Fig. 2.4A-F, Fig. 2.5A-F, Fig. 2.6A-D, Tables 2.1-2.3). In the early season, there was no significant difference in total invertebrate abundance and Araneae abundance with different mowing frequencies (Fig. 2.2A, Fig. 2.3C, Table 2.1). However, in the late season, there were significantly more invertebrates and Araneae on road verges mown every 6-8 weeks compared to road verges mown every 3-4 weeks (Fig. 2.2B, Fig. 2.3D, Table 2.2).

Significantly more Collembola were found on road verges with a higher flowering index in the late season, whilst no such effect was seen in the early season (Tables 2.1 & 2.2). Diptera and Hymenoptera responded similarly to site characteristics in the late season, with significantly lower abundances found on road verges with higher botanical species richness and significantly higher abundances on wider road verges (Table 2.2). Significantly more Psocoptera were found on road verges with a higher botanical species richness in the late season but had significantly lower abundances with greater mean road verge width (Table 2.2).

In the late season significantly fewer Gastropoda were found on wider road verges and significantly more Thysanoptera were found on road verges which had a greater mean flowering index (Table 2.3).

There was no significant difference in 'pollinator' abundance during the visual invertebrate surveys between road verge mowing treatments for all three months in 2016 (July 2016: Wilcoxon signed rank test, $V=2.5$, $p=0.42$; August 2016: paired t-test, $t=-1.55$, d.f.=13, $p=0.14$; September 2016: paired t-test, $t=0.37$, d.f.=13, $p=0.72$) (Fig.2.7).

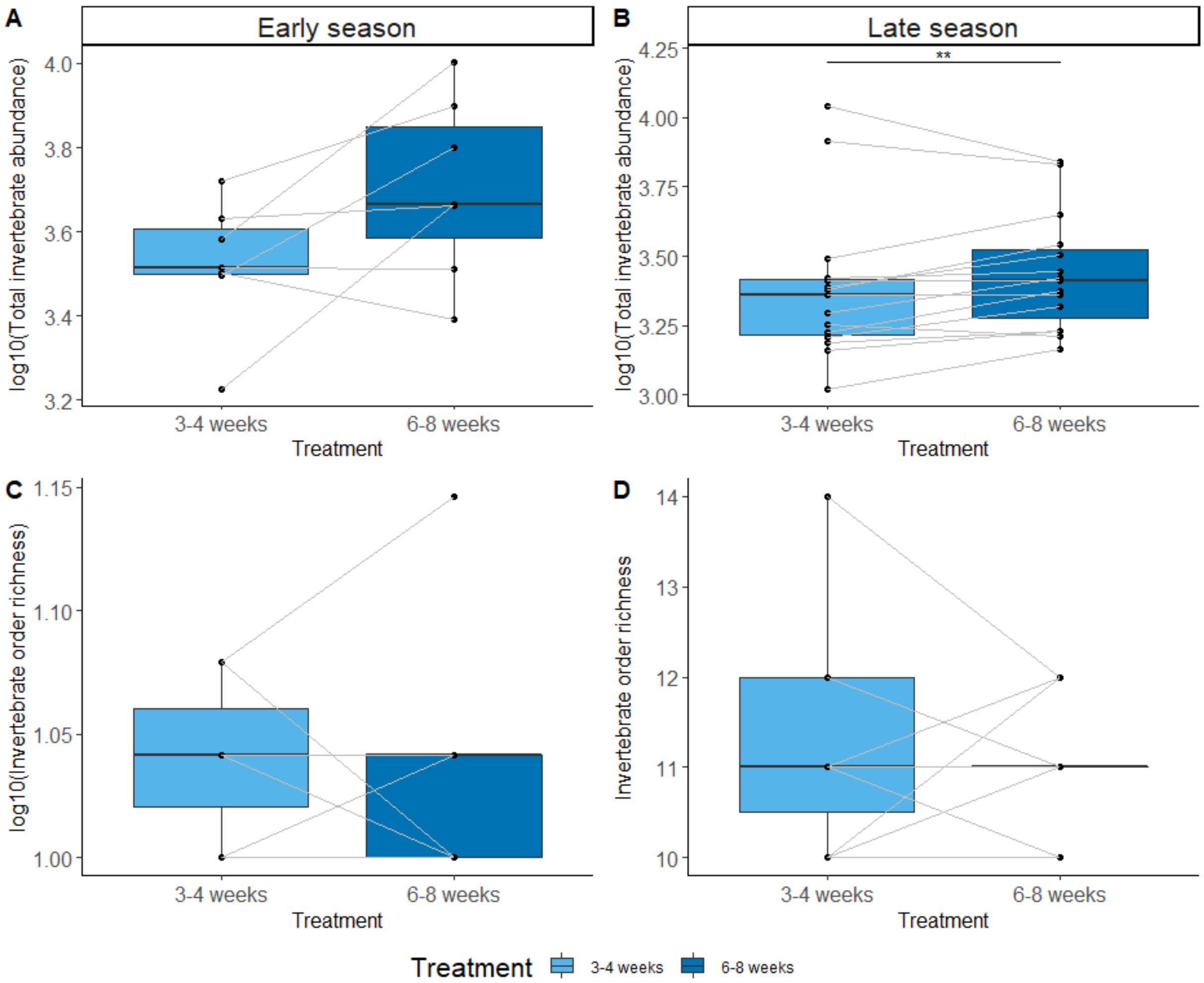

Figure 2.2. Box plots of $\log_{10}$ total invertebrate abundance in the early and late season (A-B), $\log_{10}$ invertebrate species richness in the early season (C) and invertebrate order richness in the late season (D) for the two mowing treatments (mown every 3-4 weeks and every 6-8 weeks) from sweep and G-vacuum sampling. The top and bottom of the box indicate the 25th and 75th percentile, the bold line the median and the grey lines the paired taxa or index for each road. Significant differences between mowing treatments from the GLM and GLMM are indicated (** P<0.01).

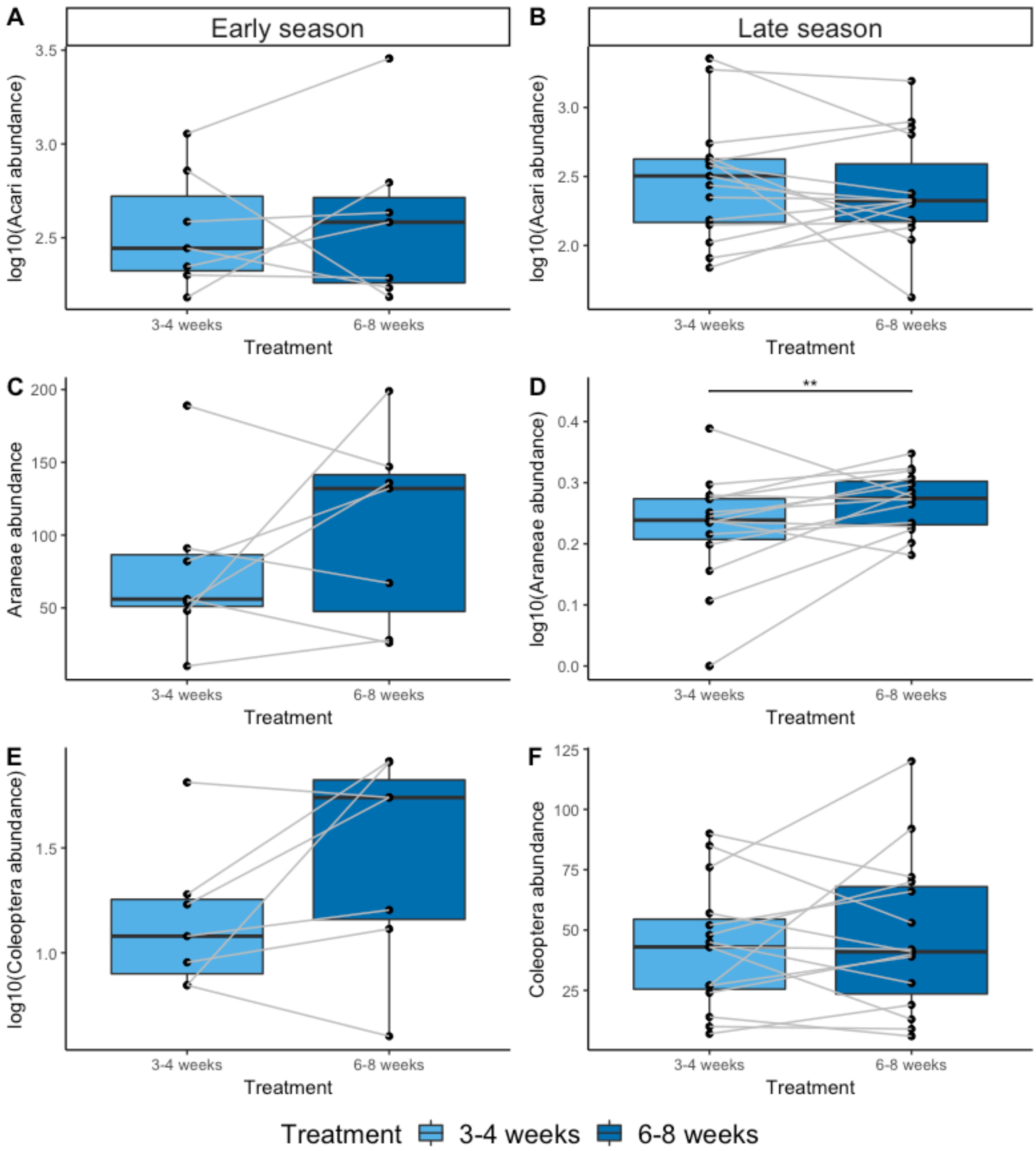

Figure 2.3. Box plots of $\log_{10}$ Acari abundance in the early and late season (A-B), Araneae abundance in the early season (C), $\log_{10}$ Araneae abundance in the late season (D), $\log_{10}$ Coleoptera abundance in the early season (E) and Coleoptera abundance in the late season (F) for the two mowing treatments (mown every 3-4 weeks and every 6-8 weeks) from sweep and G-vacuum sampling. The top and bottom of the box indicate the 25th and 75th percentile, the bold line the median and the grey lines, the paired taxa or index for each road. Significant differences between mowing treatments from the GLM and GLMM are indicated (** P<0.01).

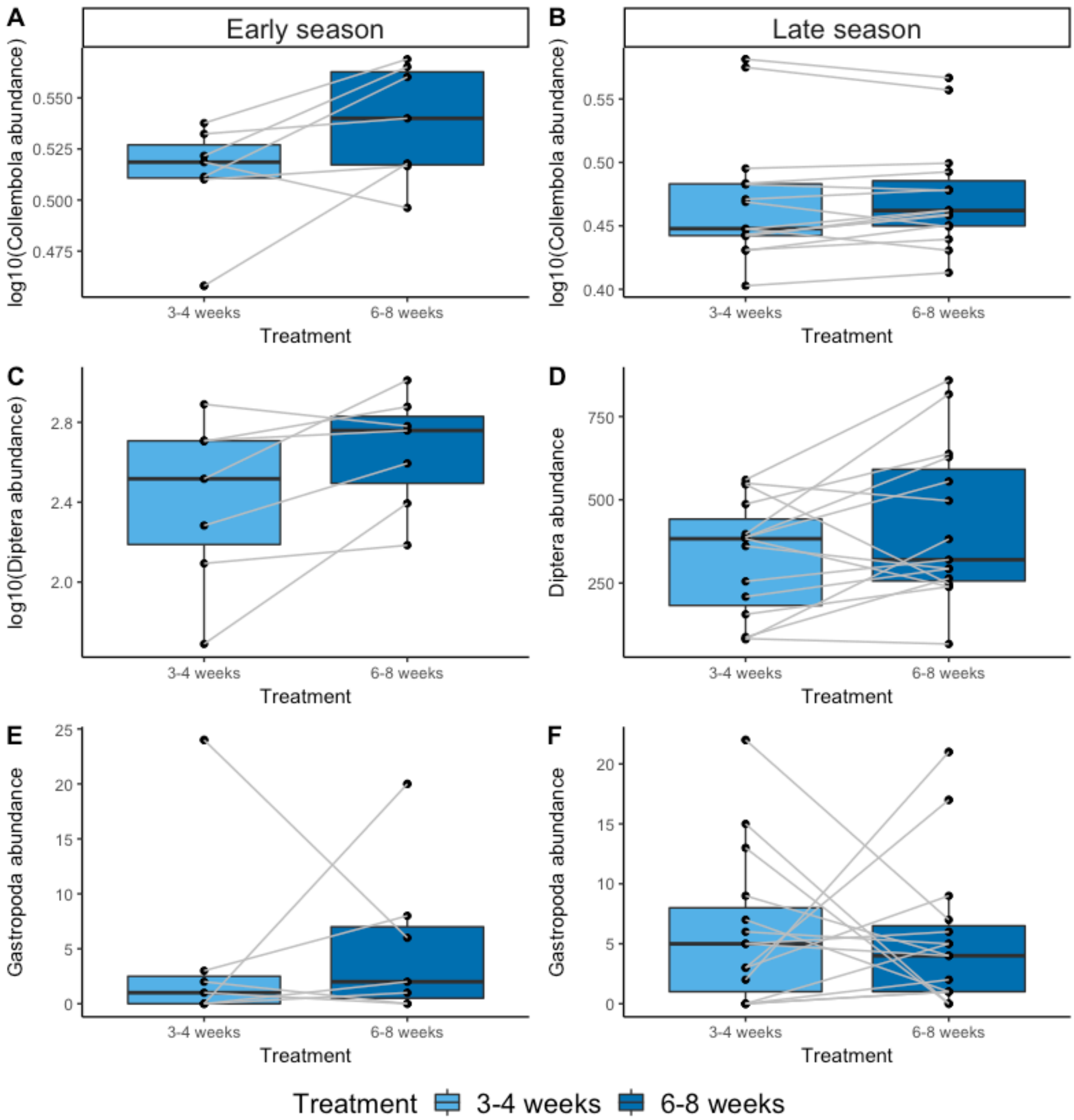

Figure 2.4. Box plots of log_{10} Collembola abundance in the early and late season (A-B), log_{10} Diptera abundance in the early season (C), Diptera abundance in the late season (D), Gastropoda abundance in the early and late season (E-F) for the two mowing treatments (mown every 3-4 weeks and every 6-8 weeks) from sweep and G-vacuum sampling. The top and bottom of the box indicate the 25th and 75th percentile, the bold line the median and the grey lines, the paired taxa or index for each road.

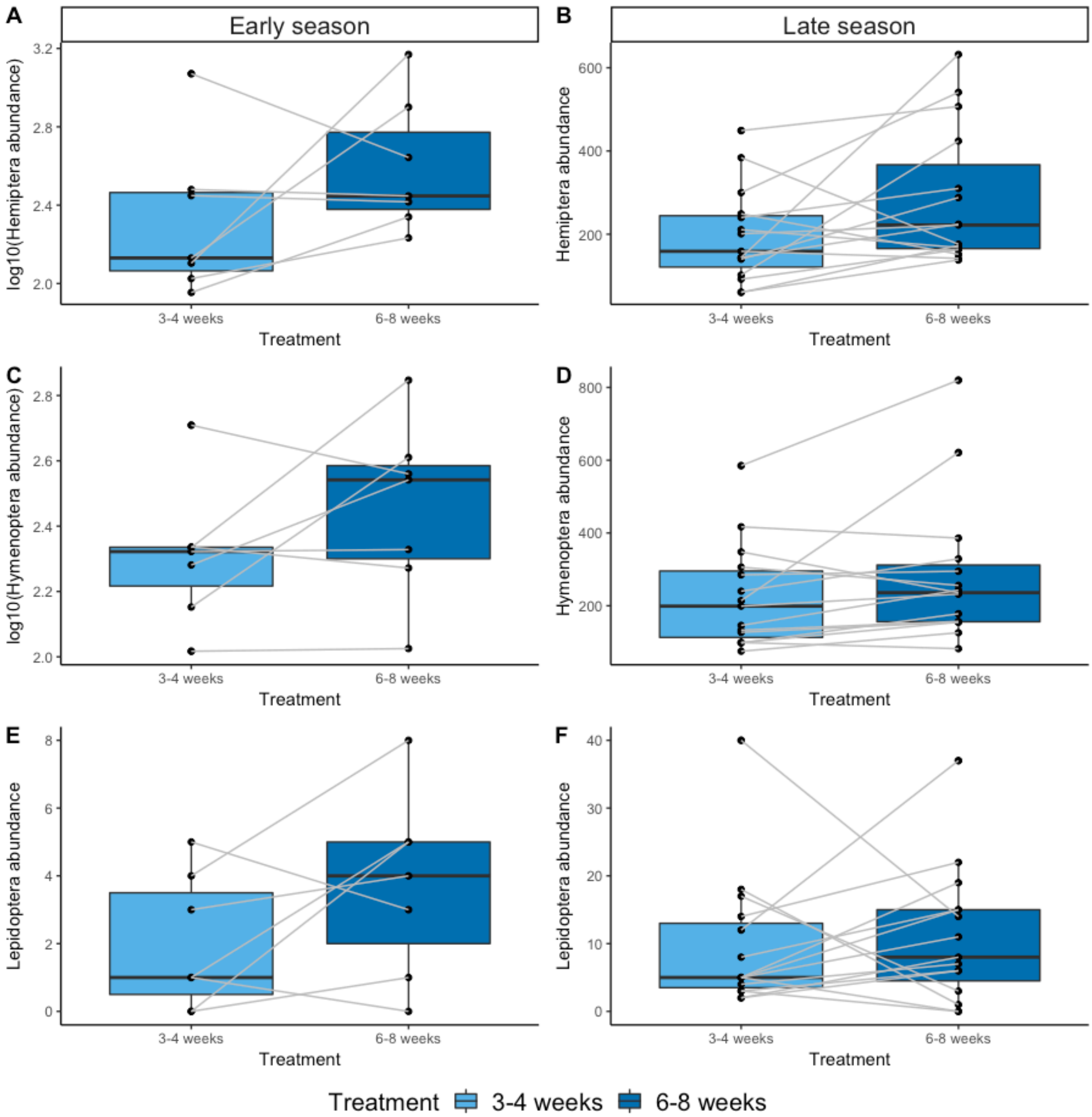

Figure 2.5. Box plots of $\log_{10}$ Hemiptera abundance in the early season (A), Hemiptera abundance in the late season (B), $\log_{10}$ Hymenoptera abundance in the early season (C), Hymenoptera abundance in the late season (D), Lepidoptera abundance in the early and late season (E-F) for the two mowing treatments (mown every 3-4 weeks and every 6-8 weeks) from sweep and G-vacuum sampling. The top and bottom of the box indicate the 25th and 75th percentile, the bold line the median and the grey lines, the paired taxa or index for each road.

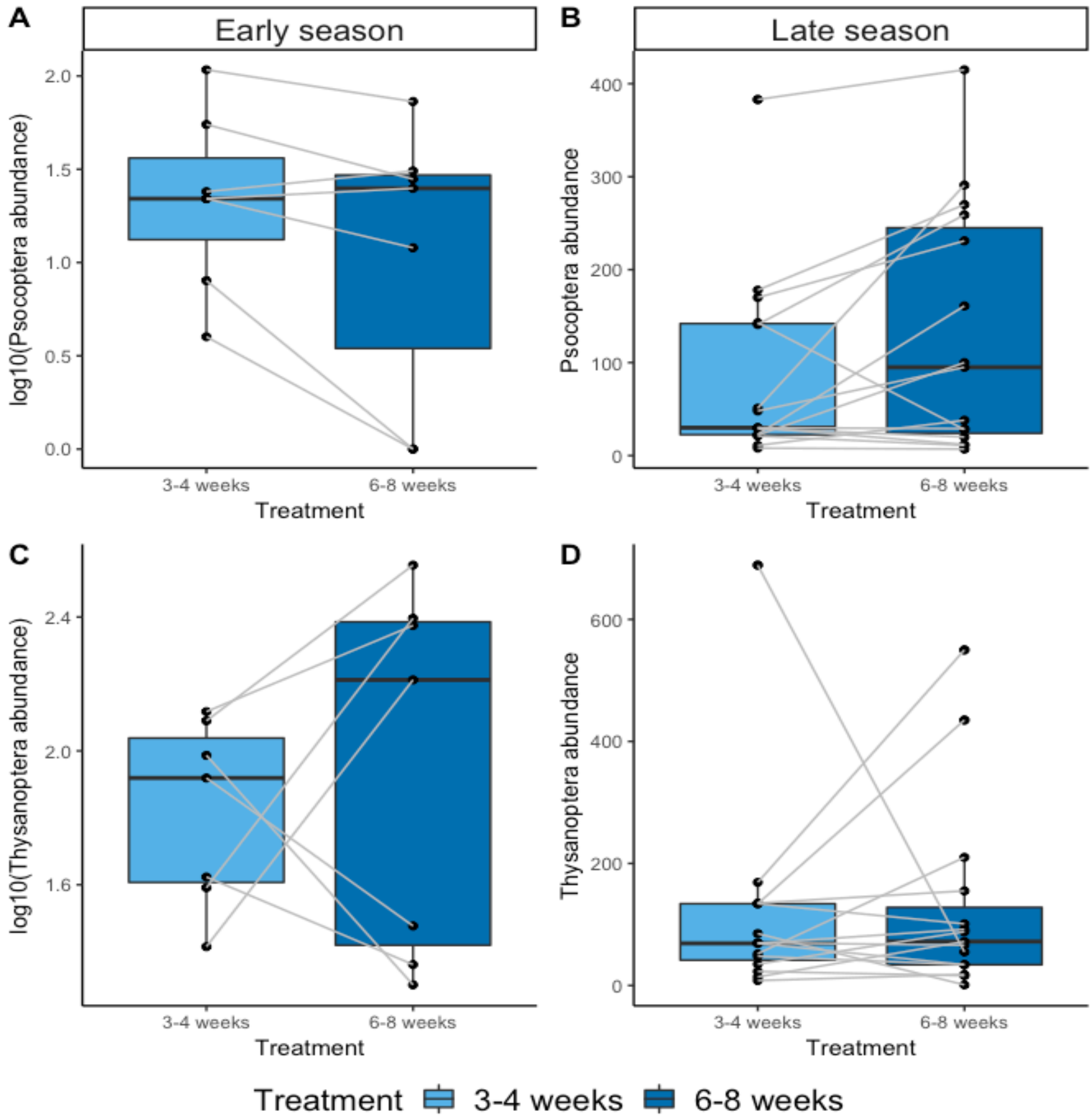

Figure 2.6. Box plots of log_{10} Psocoptera abundance in the early season (A), Psocoptera abundance in the late season (B), log_{10} Thysanoptera abundance in the early season (C) and Thysanoptera abundance in the late season (D) for the two mowing treatments (mown every 3-4 weeks and every 6-8 weeks) from sweep and G-vacuum sampling. The top and bottom of the box indicate the 25th and 75th percentile, the bold line the median and the grey lines, the paired taxa or index for each road.

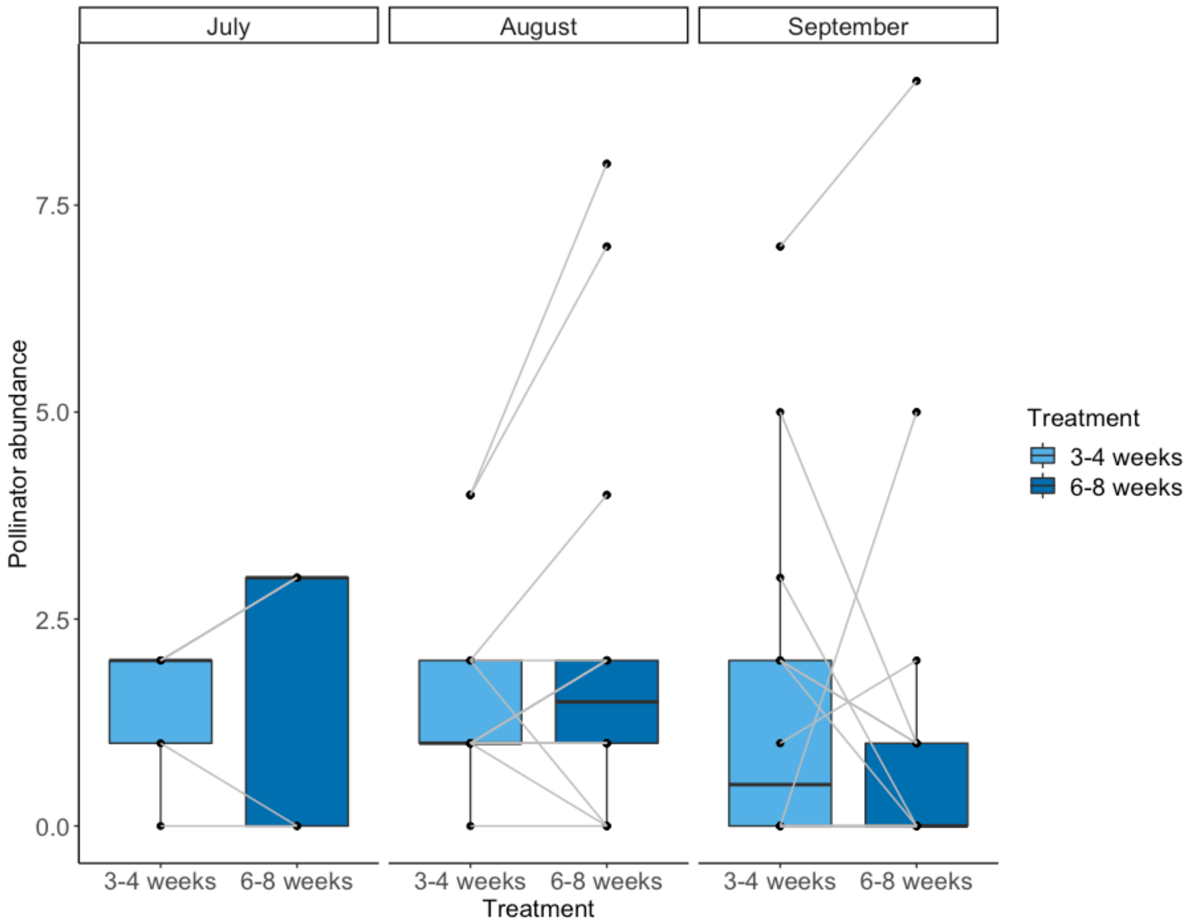

Figure 2.7. Boxplot of 'pollinator' abundance sighted on road verges mown every 3-4 weeks and every 6-8 weeks in July-September 2016 during visual invertebrate surveys. The top and bottom of the box indicate the 25th and 75th percentile, the bold line the median and the grey lines, the paired 'pollinator' sightings for the two mowing treatments on each road.

3.2 Effects of road verge mowing frequency on botanical species richness, mean forb abundance and mean flowering index.

Across all months in the growing season, 72 forbs were identified to species level, 9 to genus level and 4 to family level (Appendix 2.6-2.8). Mean vegetation height was significantly higher on road verges mown every 6-8 weeks compared to every 3-4 weeks in both the early season and late season (early season: Wilcoxon signed rank test, $V=308.5$, $p<0.001$; late season: paired t-test, $t=-3.97$, d.f.=149, $p<0.001$).

During both seasons, different mowing frequencies had no significant effect on mean forb abundance and botanical species richness (Fig.2.8A, B & E, Tables 2.4 & 2.5). However, whilst there was no significant difference in mean flowering index between mowing frequencies in the early season, road verges which were mown every 6-8 weeks had a significantly lower mean flowering index in the late season (Fig.2.8C & D, Tables 2.4 & 2.5).

Site characteristics had an impact on botanical species richness and mean forb abundance. Across both seasons, road verges with a higher tree density had significantly higher botanical species richness (Table 2.5). However, in the early season road verges with a higher tree density had a significantly lower mean forb abundance but this difference was not evident later in the season (Tables 2.4 & 2.5). Whilst road verge width had no significant difference in forb abundance in the early season, in the late season wider road verges had a significantly higher forb abundance (Tables 2.4 & 2.5).

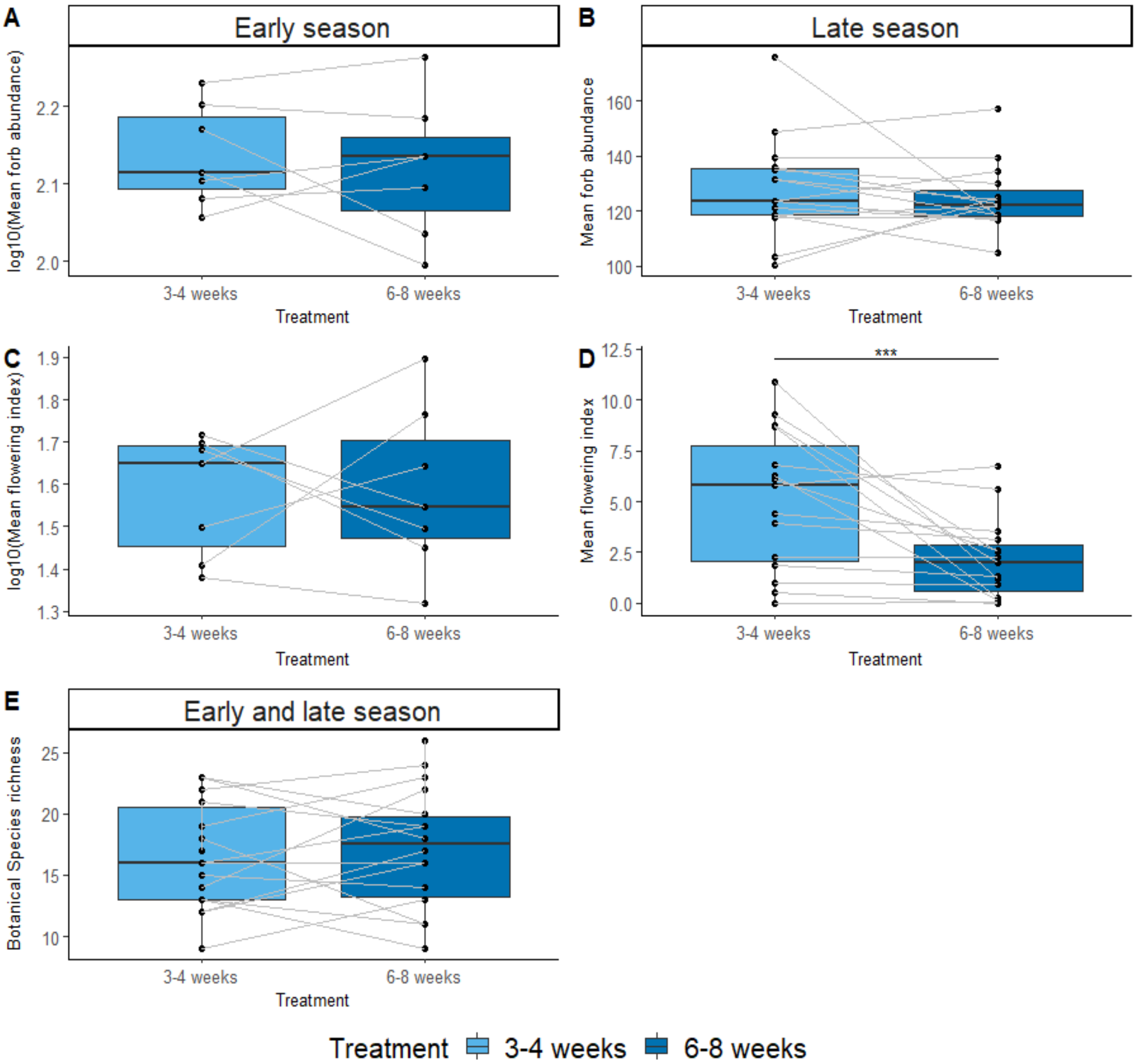

Figure 2.8. Box plots of log_{10} mean forb abundance in the early season (A) mean forb abundance in the late season (B), log_{10} mean flowering index in the early season (C), mean flowering index in the late season (D) and botanical species richness for both early and late season (E) for the two mowing treatments (mown every 3-4 weeks and every 6-8 weeks). The top and bottom of the box indicate the 25th and 75th percentile, the bold line the median and the grey lines, the paired botanical abundance or index for each road. Significant results from the GLM and GLMM are indicated (*** P<0.001).

Table 2.1. Results of GLMs testing for differences in invertebrate data between the two mowing treatments (every 3-4 weeks and every 6-8 weeks) for the early season (July 2016 and June 2017). Treatment is included in the models as a fixed factor. Parameter estimates and standard errors are presented.

Taxon or index	Treatment 6-8 weeks	Botanical species richness	Flowering index	Mean road verge width	Tree density
Total invertebrate abundance	0.20±0.09 p 0.16	-0.02±0.03 p 0.48	0.00±0.00 p 0.62	0.03±0.12 p 0.83	-8.22±5.68 p 0.28
Invertebrate order richness	-0.01±0.02 p 0.73	-0.00±0.01 p 0.93	0.00±0.00 p 0.24	0.00±0.03 p 0.91	0.04±1.25 p 0.98
Acari abundance	0.20±0.18 p 0.39	-0.02±0.05 p 0.73	-0.01±0.01 p 0.55	-0.15±0.24 p 0.59	-14.88±11.45 p 0.32
Araneae abundance	14.01±27.20 p 0.66	-2.14±7.77 p 0.81	1.45±1.43 p 0.42	36.26±35.75 p 0.42	-942.62±1721.66 p 0.64
Coleoptera abundance	0.13±0.19 p 0.56	0.02±0.05 p 0.70	-0.01±0.01 p 0.55	0.51±0.25 p 0.18	-10.07±11.90 p 0.49
Collembola abundance	0.22±0.11 p 0.19	-0.02±0.03 p 0.55	-0.00±0.01 p 0.97	0.06±0.15 p 0.74	-9.68±7.00 p 0.30
Diptera abundance	0.14±0.15 p 0.43	0.01±0.04 p 0.81	0.00±0.01 p 0.84	0.20±0.19 p 0.41	1.10±9.33 p 0.92
Gastropoda abundance	1.13±8.07 p 0.90	-0.50±2.31 p 0.85	0.18±0.43 p 0.72	-0.68±10.60 p 0.96	-2.54±510.74 p 1.00
Hymenoptera abundance	0.15±0.07 p 0.15	-0.02±0.02 p 0.33	0.01±0.00 p 0.17	0.04±0.09 p 0.70	-6.54±4.13 p 0.25
Hemiptera abundance	0.28±0.15 p 0.20	-0.03±0.04 p 0.52	0.02±0.01 p 0.13	-0.06±0.19 p 0.80	-4.91±9.38 p 0.65
Lepidoptera abundance	2.33±0.96 p 0.14	-0.63±0.27 p 0.15	0.05±0.05 p 0.39	-0.40±1.26 p 0.78	-53.02±60.87 p 0.48
Psocoptera abundance	-0.39±0.19 p 0.18	0.03±0.05 p 0.69	-0.00±0.01 p 0.72	0.15±0.25 p 0.61	9.31±12.11 p 0.52
Thysanoptera abundance	-0.00±0.16 p 0.99	0.09±0.05 p 0.19	0.02±0.01 p 0.10	-0.10±0.21 p 0.70	14.21±10.19 p 0.30

Table 2.2. Results of GLMMs testing for differences in invertebrate and botanical data between the two mowing treatments (every 3-4 weeks and every 6-8 weeks) for the late season (September 2016) with Site included as a random factor. Treatment is included in the models as a fixed factor. Parameter estimates and standard errors are presented and significant results are indicated in bold.

Taxon or index	Treatment 6-8 weeks	Botanical species richness	Flowering index	Mean road verge width	Tree density
Total invertebrate abundance	**0.09±0.03 p 0.01**	-0.001±0.01 p 0.34	0.01±0.01 p 0.12	-0.01±0.02 p 0.73	-0.99±0.82 p 0.23
Invertebrate order richness	-0.24±0.34 p 0.48	0.01±0.06 p 0.80	-0.03±0.07 p 0.64	-0.02±0.15 p 0.88	-4.00±3.76 p 0.29
Acari abundance	0.04±0.11 p 0.75	-0.03±0.02 p 0.19	0.04±0.02 p 0.10	0.02±0.06 p 0.78	0.02±1.97 p 0.99
Araneae abundance	**0.25±0.09 p<0.01**	-0.03±0.01 p 0.08	0.03±0.02 p 0.09	0.03±0.04 p 0.44	-0.38±1.00 p 0.70
Coleoptera abundance	3.93±9.06 p 0.66	-1.01±1.57 p 0.52	0.19±1.80 p 0.92	5.55±4.32 p 0.20	-181.51±115.28 p 0.12
Collembola abundance	0.06±0.03 p 0.06	-0.01±0.01 p 0.24	**0.01±0.01 p 0.04**	-0.00±0.02 p 0.80	-0.84±0.88 p 0.34
Diptera abundance	79.58±57.21 p 0.16	**-22.83±10.07 p 0.02**	-4.97±11.46 p 0.66	**73.00±27.65 p 0.01**	-743.95±750.06 p 0.32
Hymenoptera abundance	59.84±36.18 p 0.10	**-20.74±7.00 p<0.01**	-0.49±7.51 p 0.95	**44.33±19.24 p 0.02**	-876.13±593.79 p 0.14
Hemiptera abundance	80.43±57.59 p 0.16	-0.43±8.58 p 0.96	-1.37±10.65 p 0.90	7.03±23.42 p 0.76	-849.00±552.26 p 0.12
Psocoptera abundance	30.35±21.76 p 0.16	**10.02±4.60 p 0.03**	-3.90±4.64 p 0.40	**-33.74±12.63 p<0.01**	-519.64±477.16 p 0.28

Table 2.3. Results of standard errors corrected with a quasi-GLM model testing for differences in invertebrate and botanical data between the two mowing treatments (every 3-4 weeks and every 6-8 weeks) for the late season (September 2016) with Site included as a random factor. Treatment is included in the models as a fixed factor. Parameter estimates and standard errors are presented and significant results are indicated in bold.

Taxon or index	Treatment 6-8 weeks	Botanical species richness	Mean flowering index	Mean road verge width	Tree density
Gastropoda abundance	0.45±0.55 p 0.43	0.03±0.14 p 0.84	0.18±0.14 p 0.23	**-0.72±0.33 p 0.05**	-18.39±20.12 p 0.38
Lepidoptera abundance	0.29±0.50 p 0.57	0.08±0.13 p 0.53	0.05±0.08 p 0.54	-0.09±0.27 p 0.76	-30.44±20.42 p 0.17
Thysanoptera abundance	0.89±0.48 p 0.09	-0.18±0.10 p 0.11	**0.19±0.08 p 0.04**	-0.09±0.32 p 0.78	19.25±18.09 p 0.31

Table 2.4. Results of the log transformed GLMs testing for differences in botanical data between the two mowing treatments (every 3-4 weeks and every 6-8 weeks) for the early season (July 2016 and June 2017). Treatment is included in the models as a fixed factor. Parameter estimates and standard errors are presented and significant results are indicated in bold.

Taxon or index	Treatment 6-8 weeks	Mean road verge width	Tree density
Forb abundance	-0.01±0.02 p 0.77	-0.00±0.03 p 0.98	**-3.15± 1.11 p 0.05**
Flowering index	-0.02±0.02 p 0.51	0.05±0.02 p 0.10	-1.43± 1.03 p 0.24

Table 2.5. Results of GLMMs testing for differences in botanical data between the two mowing treatments (every 3-4 weeks and every 6-8 weeks) for the late season (September 2016) with Site included as a random factor. Treatment only was included in the models as fixed factors. Parameter estimates and standard errors are presented and significant results are indicated in bold.

Taxon or index	Treatment 6-8 weeks	Mean road verge width	Tree density
Botanical species richness	0.56±1.01 p 0.58	**0.97±0.50 p 0.05**	**36.70±14.68 p 0.01**
Forb abundance	-4.20± 3.44 p 0.22	**8.31±1.30 p<0.001**	41.77± 35.79 p 0.24
Flowering index	**-3.04±0.92 p<0.001**	0.49±0.36 p 0.17	-11.80±10.00 p 0.24

4. Discussion

This study provides one of the few assessments of the effects of altering mowing regimes, at field-scale, in urban road verges, on invertebrate abundance, the number of invertebrate orders, botanical species richness, forb abundance and mean flowering index. Overall few effects of altered mowing regime were observed, but there was evidence that reducing mowing frequency to every 6-8 weeks over one mowing season, significantly increased the total number of invertebrates present and specifically, Araneae abundance but significantly decreased the mean flowering index (mean number of floral resources) on the road verge in late summer.

4.1 Effects of road verge mowing frequency on invertebrate abundance and order richness.

Reducing the frequency of mowing urban road verges to every 6 to 8 weeks, significantly increased total invertebrate abundance and Araneae abundance across one growing season. There was no significant difference in invertebrate order richness, the abundance of the 10 remaining orders tested, and in the number of 'pollinators' viewed on the road verge. This partially agrees with our original hypothesis, that reducing the mowing frequency of urban road verges will significantly increase the abundance and richness of invertebrate species. These results are not directly comparable with other road verge studies assessing the impact of mowing frequency on total invertebrate abundance. These studies have focused mainly on much lower mowing frequencies in rural areas than in this urban study (i.e. no management, mown once a year or mown twice a year) (Noordijk et al., 2009, 2010).

Although Araneae were the only order to show a response to reduced mowing, total invertebrate abundance also significantly increased with reduced mowing frequency, both with and without Araneae included in the model in the late season (Appendix 2.9), suggesting modest, but more widespread trends in other orders too. Reducing mowing frequency, may have reduced the frequency of negative consequences mowing has on invertebrates, allowing invertebrate abundance to collectively increase (Morris, 2000). These negative effects include direct invertebrate mortality at all stages of development (Humbert et al., 2010; Johst et al., 2006; Gardiner & Hill, 2006), mortality of ground invertebrates from the mowing machine wheels (Humbert et al., 2010), the loss of host-plants (Valtonen & Saarinen, 2005), ant-hills (Morris, 2000) and spider web structures (Cattin et al., 2003) and the alteration of the microclimate of the grassland (Gardiner & Hassall, 2009).

Similarly to this study, an increase in mowing frequency has been shown to negatively impact Araneae abundance (Jones, 2010; Baines et al., 1998). Araneae abundance and species richness is often positively correlated with vegetation height and density (Baines et al., 1998; Downie, Butterfield, & Coulson, 1995; Hatley & Macmahon, 1980). An increase in vegetation height, as seen in this study caused by a reduction in mowing frequency, may have increased the structural diversity of the road verge, increasing the number of niches for Araneae, including web building sites (Bell, Wheater & Cullen, 2001) and aiding the dispersal of less mobile Araneae species (Cattin et al., 2003). Whilst the number of Araneae species respond favourably to increased litter/cutting depths creating greater litter complexity and diversity in microclimate and prey availability (Baines et al., 1998; Uetz, 1979), current knowledge suggests this does not affect Araneae abundance (Bell et al., 2002; Baines et al., 1998).

Our finding that there is no significant difference in all other order abundances between different mowing frequencies, concurs with the results of Halbritter et al., (2015) for Lepidoptera abundance on rural highways and contrasts with Helden & Leather, (2004) for Hemiptera abundance, which significantly increased with a reduction of mowing frequency in an urban landscape. However, the latter study compared already established mowing frequencies which may have been present over a number of years, which might have influenced grassland Hemiptera abundance (Helden & Leather, 2004). Indeed, the effect of increased total invertebrate and Araneae abundance was only found later in the season in our study, suggesting that the length of the mowing trial was important in allowing invertebrates to respond to the change.

We found no significant difference in pollinator abundance with different mowing regimes when viewed on the road verge. This contrasts with studies which found that flower visiting invertebrates (Garbuzov, Fensome, & Ratnieks, 2015) and wild bee abundance (Wastian, Unterweger, & Betz, 2016) significantly increases with a reduction in mowing frequency in urban areas. There is an increasing body of evidence indicating that urban pollinator abundance and arthropod diversity is positively correlated with flowering abundance (Gunnarsson & Federsel, 2014; Lowenstein et al., 2014; Pardee & Philpott, 2014; Noordijk et al., 2009, 2010). No significant difference in mean flowering index was found early in the season, but significantly decreased on verges mown every 6-8 weeks later in the season, suggesting that pollinators may not have had access to these floral resources from the less frequently mown side of the road. This may be due to the density of the grass cuttings left on the road verge. Reflowering plants later in the season have been suggested to be important for flower visiting invertebrates, providing additional nectar and pollen resources (Noordijk et al., 2009). In contrast to this study, Lerman et al., (2018) found mowing every 2 or 3 weeks can significantly increase bee abundance through the provision of additional floral resources.

Several of the botanical species present on road verges within the study, such as *Senecio jacobaea, Taraxacum* spp.*, Cirsium arvense* and *Hypochaeris radicata* have the capacity to provide high levels of nectar sugar per flower, which can act as an importance resource for invertebrates, particularly early in the growing season (Hicks et al., 2016; Larson, Kesheimer, & Potter, 2014). Whilst these species also have low levels of pollen per flower in comparison to other designed mixes, this ability to produce high levels of nectar sugar suggests that increasing the number of floral resources of these species could have the potential to benefit flower-visiting invertebrates on road verges (Hicks et al., 2016). A positive relationship was found between mean flowering index and Collembola and Thysanoptera in the late season of the study. Both Thysanoptera and Collembola are known to use flowers as a food resource, feeding on pollen, with some Collembola additionally feeding on nectar and Thysanoptera feeding on the plant cells (Kirk, 1995; Kevan & Baker, 1983). In addition, some species of Thysanoptera also live and reproduce within flowers (Mound et al., 1976). It is therefore surprising that the abundance of other orders which comprise of pollinating invertebrates such as Diptera and Hymenoptera, did not exhibit the same relationship with mean flowering index, and it is not obvious what might be driving this.

Plant species richness has also been found to correlate with number of pollinator visits and invertebrate abundances (Ebeling et al., 2008; Haddad et al., 2001), thought to be due to an increased number of resources and increased vegetation complexity, increasing the number of potential habitats (Lawton, 2003). Interestingly, Psocoptera abundance seemed to show a positive relationship with botanical species richness, with Diptera and Hymenoptera abundances found to have a negative relationship in the late season. This indicates that the relationship between plant species richness and invertebrate abundance is complex and differs between orders, although it is not obvious whether environmental, tropic or structural changes were responsible for these differing responses.

Road verge width caused mixed effects on different order abundances; a positive relationship with Diptera and Hymenoptera abundance and a negative relationship with Gastropoda and Psocoptera abundance. Most studies assessing the impact of road verge width on invertebrates have found positive impacts on butterfly abundance (Skórka et al., 2013; Munguira & Thomas, 1992) and diversity (Saarinen et al., 2005) contrasting our study. However, as Diptera and Hymenoptera are highly mobile orders similar to butterflies, it can be assumed that wider road verges further away from traffic, reducing mortality and impact from traffic related pollutants, may have a similar impact on Diptera and Hymenoptera. Interestingly, Gastropoda and Psocoptera had a negative relationship with road verge width, although it is not obvious what is causing this. The negative relationship between road verge width and Gastropoda is surprising, as snail dispersal can increase with increasing corridor width (Baur & Baur, 1992), which may suggest an increasing number of snails may travel along wider road verges, contrary to our results.

We found no significant difference in the number of invertebrate orders with different mowing frequencies. Whilst this study quantified invertebrate richness at order level only, identification to a higher taxonomic resolution such as order level can act as a suitable surrogate for finer scale taxonomic resolutions (Driessen & Kirkpatrick, 2019; Schipper et al., 2010; Biaggini et al., 2007). However, higher taxonomic resolutions may not detect more subtle environmental changes (Driessen & Kirkpatrick, 2019; Schipper et al., 2010). The strength of this ability to act as a surrogate can depend on the ratio of the number of orders to the number of lower taxonomic resolutions, with smaller ratios providing more effective surrogates as ecological traits are more likely to be similar (Driessen & Kirkpatrick, 2019; Schipper et al., 2010). Therefore, this suggests that our results may be conservative for invertebrate richness.

No significant difference in invertebrate order richness between the two mowing regimes, may also be indicative of the time scale of the study. At a finer taxonomic resolution, the response of species richness to a management change may be cumulative especially for species with low dispersal, as seen in other studies with effects seen after a longer duration (Woodcock et al., 2012; Noordijk et al., 2009; Morris & Lakhani, 1979).

4.2 Effects of road verge mowing frequency on botanical species richness, mean forb abundance and mean flowering index.

Reducing the mowing frequency had no significant difference on botanical species richness and forb abundance across the whole mowing season, which is not unexpected, given the timescale of the experiment, and suggests that any vegetation changes which might take place are not simply a result of species previously present but suppressed by mowing, immediately having the opportunity to increase in abundance. Whilst no significant difference in flowering index was found in the early season when reduced mowing took place, it was found to have a significantly negative impact on flowering index in the late season.

This contrasts with previous studies showing that reducing mowing frequency, or only cutting a couple of times a year, significantly increases botanical species richness (Noordijk et al., 2009; Parr & Way, 1988). However, these studies have focused on alternative mowing frequencies which are considerably less intensive than mowing frequencies commonly undertaken in urban environments. When comparing the effects of similar mowing frequencies, Halbritter et al., (2015) found significantly higher species richness and abundance of botanical communities when mown every 6 weeks compared to mowing every 3 weeks on rural highways. For public urban green spaces, a greater reduction in mowing frequency from every 4-5 weeks to once a year over 25 years, significantly increases plant species richness, functional and phylogenetic diversity, indicating that a reduction in mowing frequency can increase plant diversity in contrast to our findings (Chollet et al., 2018). However, this contrast may be due to a greater reduction in mowing and the longer time frame over which the mowing took place.

The short term change in mowing frequency in this experiment, altering vegetation height and structure over mainly one growing season, did not directly affect botanical species richness. This is perhaps not surprising, and is a similar result to those from other studies (Auestad, Rydgren, & Austad, 2011; Helden & Leather, 2004). Continuing the altered mowing regime over several years, would provide a more robust assessment of the response of botanical communities over time (Baasch, Tischew, & Bruelheide, 2010). However, in this case public response to the mowing trial by local residents, precluded running it over multiple seasons. This outcome in itself is important in that it suggests that the time taken for positive biodiversity responses to be evident following such management change may in itself be a barrier to implementation.

Botanical species richness, forb abundance and flowering index may have been affected by the presence of grass cuttings on the road verge, which when removed, has been shown to have a positive impact on botanical species richness (Parr & Way, 1988). Botanical species richness can potentially be affected by changes in both nutrient levels and disturbance caused by grass cuttings (Parr & Way, 1988). The higher volume of grass cuttings left on the road verge may have caused shading at ground level increasing competition for light (Jensen & Meyer, 2001), reducing levels of photosynthesis, increasing susceptibility to disease (Parr & Way, 1988), and therefore reducing chances of plant regrowth and reflowering later in the season. In addition, the removal of grass cuttings reduces the amount of nutrients such as potassium that can leach back into the soil from the cuttings, thus decreasing soil nutrient levels, which in turn can increase plant species richness due to the reduced dominance of some plants which typically reduce competition for light and space (Schaffers, Vesseur, & Sykora, 1998; Vermeer & Berendse, 1983; Bakelaar & Odum, 1978; Al-Mufti et al., 1977). The removal of cuttings shortly after mowing can also reduce biomass, creating gaps in the vegetation, which suppresses more dominant species, allowing the growth of other low-lying forb species (Klimeš & Klimešová, 2001; Parr & Way, 1988). When plant productivity is low, it is recommended to remove grass cuttings as soon as possible in order

to maintain species richness (Schaffers, Vesseur, & Sykora, 1998). As this study involved a paired design, nutrient levels on both sides of the road are likely to have been similar.
In relation to environmental effects, there was a positive relationship between mean road verge width and forb abundance (the mean abundance of each plant species recorded using the DOMIN scale on the road verge) in the late season. This may be due to the impact of disturbance and vehicular emissions experienced from the road. Indeed, Truscott et al., (2005) found that with increasing distance from the road, nitrogen concentrations from vehicular emissions decrease as well as the amount of bare ground and ruderal species present. This suggests that areas of the verge closer to the road may present a more stressed environment for plant growth. Therefore, wider verges may provide more opportunities for plant growth and increased forb abundance, at a greater distance from the road and its associated impacts. In the early season, tree density had a negative impact on forb abundance, perhaps due to shading from the tree canopy reducing light availability and therefore, forb growth. In the late season, tree density had a positive impact on botanical species richness, in agreement with Gamfeldt et al. (2013).

4.3 Management implications

We trialled reducing the mowing frequency of a number of urban road verges by half to investigate whether this change in management could enhance biodiversity whilst being cost-effective for the councils that manage urban road verges. Our study indicates that a reduction in mowing frequency to every 6-8 weeks significantly increases the total number of invertebrates but not other variables, suggesting that this management change can provide some enhancement of biodiversity, consistent with the management objectives of this study. In addition to the significant increase in total number of invertebrates that a reduction in mowing frequency can provide, this can have implications on anthropogenic emissions, reducing the amount of carbon dioxide emitted from mowers (Lerman & Contosta, 2019). When selecting the mowing frequency of a road verge, the habitat and productivity of the road verge should be taken into account, as this can cause the biodiversity benefits to differ (Tälle et al., 2018).

Whilst not tested within the study, we recommend the removal of arisings from road verges when reducing the mowing frequency, particularly on road verges with high nutrient richness, as this may have a positive impact on botanical species present on the road verge, which in turn may have a positive effect on invertebrate species (Noordijk et al., 2009, 2010; Parr & Way, 1988). The urban context of this however, can pose a challenge in terms of the disposal of the cuttings. The presence of litter and dog faeces within the cuttings causes concern for farmers to use as animal fodder, but there is potential in the use of cuttings for biomass (Hoyle et al., 2017).
Rotational or mosaic management, whereby a road verge is divided into two strips, with one part managed at a different frequency or time than the other, is frequently advocated as a potential alternative to support invertebrate communities (Auestad et al., 2010; Noordijk et al., 2009; Valtonen, Saarinen, & Jantunen, 2006). Leaving 10-20% of the grass uncut has been proven to increase Orthopteran density and species richness (Buri, Arlettaz, & Humbert, 2013), butterfly abundance (Bruppacher et al., 2016), arthropod abundance (Klink et al., 2019), wild bee abundance and species richness (Buri, Humbert, & Arlettaz, 2014) through increased access to food resources and shelter (Noordijk et al., 2009). The time frame of leaving this area uncut should be carefully considered as leaving an area uncut can also reduce botanical species richness (Parr & Way, 1988).Whilst this may provide a potential win-win scenario for invertebrates, the practicalities of this must be considered given the urban context of the study. Within this study, the urban road verge width varied between 1 to 6 metres, making the practicality of leaving a strip difficult at an operational level, and perhaps not more cost-effective in terms of the amount of time operatives spend on a road verge (Valtonen, Saarinen, & Jantunen, 2006).

As urban road verges are extremely visible, public perception must also be considered in order for acceptance of the alternative mowing regime to occur. Studies assessing public perception of road verge indicate that short, tidy vegetation which have signs of care are often favoured over more wild vegetation (Weber, Kowarik, & Säumel, 2014a; Nassauer, 1995). This public perception may conflict with reduced mowing strategies which can result in long vegetation which is more 'wild' in appearance. Therefore, consideration and communication with the public when implementing a different mowing regime is key.

We show that a reduction in mowing frequency on urban road verges can provide benefits to invertebrates even over just one growing season. With careful site considerations and communication with local residents, alternative management of urban road verges can provide enhancement of biodiversity and a reduction in anthropogenic emissions.

Chapter Three: Public responses relating to urban roadside verge management.

Abstract

Road verges have the potential to provide numerous ecosystem services and biodiversity benefits. However, typical management of road verges consists of frequently cut grass, which does not maximize these benefits. Whilst some work has examined public preferences for different forms of management, none of these studies have assessed the response of urban residents to actual changes in road verge management in their own residential setting.
In this study, we assess public responses to alternative road verge management that is assessed through (i) a trial reducing mowing frequency of road verges on residential roads, and (ii) different hypothetical road verge management scenarios. We also assess how responses are shaped by respondents' connection to nature, and attitudes regarding the ability of different road verge scenarios to support biodiversity. We use face to face and postal questionnaires with 235 local residents experiencing a reduced mowing frequency on 12 residential roads across urban Sheffield, UK.

This study shows that local residents prefer frequently mown short grass compared to road verges mown less frequently on their road and other hypothetical scenarios, even though it is perceived by residents to be worse for biodiversity than other alternative management scenarios. Participants who were opposed to a reduction in mowing were more likely be concerned with issues such as the presence of dog faeces and litter and have a preference for neat and tidy verges. Participants who were in favour of mowing less frequently were more likely to think that reduced mowing had a positive impact on wildlife. Participants with a higher connectedness to nature were more likely to rate biodiverse scenarios more favourably and more likely to agree that road verges should be managed for conservation. This research provides an evidence base to inform decision makers considering management changes to urban roadside habitats.

1. Introduction

By 2050, about 68% of the world's population is expected to live in urban areas (United Nations, 2018). As urbanisation continues to increase, causing global changes to ecosystem functioning, it is increasingly important to assess the ecosystem services that urban areas can provide (Seto et al., 2011; Grimm et al., 2008; Vitousek, 1997). Urban greenspaces provide numerous benefits (Bolund & Hunhammar, 1999), including to health and wellbeing (Cox, Shanahan, et al., 2017; White et al., 2013; Ward Thompson et al., 2012; Ulrich, 1986), social interaction (Sullivan, 2004) and air pollution reduction (Nowak, Crane, & Stevens, 2006). A combination of the densification of cities reducing access to green space (Fuller & Gaston, 2009), loss of some urban green space (Haaland & van den Bosch, 2015; Royal Horticultural Society, 2015; Pauleit, Ennos, & Golding, 2005) and increasing 'extinction of experience', where residents have less interaction with nature (Soga et al., 2016; Miller, 2005), threaten these benefits for urban residents.

Road verges (managed linear areas of land next to roads usually dominated by vegetation) are an often neglected but potentially important element of urban green space. Though very fragmented, they can, cumulatively, form a large total area, for example comprising 10-25% of urban green space managed by German park departments (Weber, Kowarik, & Säumel, 2014a) and 26.7% of urban public green space in Melbourne, Australia (Marshall, Grose, & Williams, 2019a). Much of people's experience of nature is from viewing natural areas from a window at work or home, suggesting that road verges, by virtue of their ubiquity, may be important in providing daily experiences of nature (Cox, Hudson, et al., 2017). Such experiences can lead to health benefits such as reduced stress (de Vries et al., 2013) and improved mental health (Taylor et al., 2015; van Dillen et al., 2012). In addition, if managed appropriately, road verges have the potential to provide other ecosystem services and biodiversity benefits (O'Sullivan et al., 2017; Säumel, Weber, & Kowarik, 2015), such as acting as wildlife corridors for birds (Fernández-Juricic, 2000) and mammals (Munshi-South, 2012). However, typical management of road verges consists of the use of frequent mowing to maintain a short grass sward, which does not maximise ecosystem services and can be detrimental to biodiversity (O'Sullivan et al., 2017). One of the factors favouring this management approach is likely to be managers' perceptions of public attitudes and aesthetic values (Richardson et al. in prep [Chapter Four]; Hoyle et al., 2017).

In the UK, local authorities have a statutory responsibility to maintain road verges (Great Britain, 1980). Since 2010, UK local authority budgets have been reduced by 28.6% (a reduction of 27% spent on open spaces), increasing pressure on the services local authorities provide (National Audit Office, 2018). This has led to an increased interest in alternative, more cost-effective, management practices. However, when considering altering management practices, public preferences as well as monetary and environmental benefits need to be incorporated into decision making (Bennett, 2016; Ives & Kendal, 2014).

Despite the ubiquity and public nature of urban road verges, public responses to informal urban green spaces is little studied, and such studies as do exist tend to focus on urban street trees, rather than the herbaceous ground vegetation on urban road verges (Botzat, Fischer, & Kowarik, 2016; Säumel, Weber, & Kowarik, 2015). When alternative forms of verge management have been presented to members of the public in an actual or hypothetical scenario, a diversity of vegetation forms is frequently favoured with the presence of urban trees being important to the public (Weber, Kowarik, & Säumel, 2014a; Todorova, Asakawa, & Aikoh, 2004). Streets which have herbaceous vegetation have been found to be significantly more valued by the public compared to streets with no herbaceous vegetation or the presence of trees only (Bonthoux et al., 2019; Fischer et al., 2018). Ordered and maintained vegetation is significantly preferred (Weber, Kowarik, & Säumel, 2014a; Todorova, Asakawa, & Aikoh, 2004), with brightly coloured flowers low in height preferred as ground vegetation compared to other alternatives such as traditional management of mown grass (Todorova, Asakawa, & Aikoh, 2004). Aesthetic values and psychological benefits appear to be primary factors driving this preference (Weber, Kowarik, & Säumel, 2014a; Todorova, Asakawa, & Aikoh, 2004). However, there is disparity in public preference, as "wild" vegetation is preferred by some members of the public (Weber, Kowarik, & Säumel, 2014a), and accepted when there are some visible signs of management (Bonthoux et al., 2019). Across five European cities, herbaceous vegetation with greatest botanical diversity was valued by members of the public most highly, compared to other hypothetical scenarios with lower botanical diversity (Fischer et al., 2018). These explicitly urban studies predominately focus on hypothetical scenarios apart from Weber, Kowarik, & Säumel, (2014), which asked participants about existing road verge vegetation present on one arterial road in Berlin. However, the research conducted to date has not assessed public responses towards actual changes in urban road verge management using a controlled experiment. Exploration of the factors that drive these changes has also been limited.

There are numerous theoretical frameworks (such as the Cognitive Hierarchy Model of Human Behaviour (Rokeach, 1973), Theory of Planned Behaviour (Ajzen, 1991) and the Values-Beliefs-Norm (VBN) theory (Stern, 2000; Stern & Dietz, 1994)) which have been proposed that suggest there are a number of underlying constructs that lead to pro-environmental attitudes and behaviour. Whilst varying in design, these theories typically propose that values (often divided into held values: "principles or ideas that are important to people, such as notions of liberty, justice or responsibility"(Lockwood, 1999) and assigned values: "expressed relative importance or worth of an object to an individual or group in a given context" (Brown, 1984)) and beliefs ("understandings about the state of the world; they are facts as an individual perceives them" (Dietz, Fitzgerald, & Swom, 2005)) form the underlying basis of behaviour. Values and beliefs are then thought to influence norms (" statements about how one ought to behave" (Dietz, Fitzgerald, & Swom, 2005)) and attitudes ("statements of people's positive or negative evaluations of a specific object or situation, and are typically expressed as likes or dislikes, or preferences" (Ives & Kendal, 2014)), all of which influence human behaviour (Stern, 2000; Stern & Dietz, 1994; Ajzen, 1991; Rokeach, 1973).

A greater understanding of values relating to environmental management, may also help green space managers anticipate what management practices may cause negative feedback from the public such as complaints and allow for more effective communication of management changes (Ives & Kendal, 2014; Seymour et al., 2010). As part of the VBN Theory, Stern & Dietz, (1994) proposed that environmental attitudes are underpinned by three types of values; a person's concern for themselves (egoistic), for other people above themselves (altruistic) and for all living things (biospheric). This idea has since been built upon, with Schultz, (2000) suggesting that environmental concern is associated with how a person sees themselves as part of nature and has since been defined as 'connectedness to nature'(Schultz, 2002). Indeed, Schultz et al., (2004) found a positive correlation for a person who feels connected to nature with biospheric values and a negative correlation to egoistic values. This supports Wilson's biophilia hypothesis that as humans evolved in nature, humans have an "innate tendency to focus on life and lifelike processes" (Wilson, 1984). Numerous scales have since been created to assess people's connectedness to nature such as the New Ecological Paradigm (Dunlap et al., 2000), Connection to Nature Scale (Mayer & Frantz, 2004) and the Nature Relatedness Scale (Nisbet, Zelenski, & Murphy, 2009), many of which are highly correlated with each other (Tam, 2013). Connectedness to nature scales are often positively associated with pro-environmental behaviours and attitudes (Whitburn, Linklater, & Abrahamse, 2019; Nisbet, Zelenski, & Murphy, 2009; Mayer & Frantz, 2004; Dunlap et al., 2000).

This extends to perceptions of alternative management strategies, with for example, conversion of mown amenity grassland in parks to urban meadows being perceived more positively by people with higher eco-centricity (ecological values and attitudes) (Southon et al., 2017). Such relationships may occur because such people are able to judge the species richness value of alternative habitats more accurately (Southon et al., 2018), and greater perceived biodiversity value of green-space is associated with more positive public perception (Lindemann-Matthies, Junge, & Matthies, 2010) and psychological well-being (Fuller et al., 2007). However, the relationship between public perception and species richness of a habitat, sometimes referred to as the people-biodiversity paradox, is complex (Pett et al., 2016) and other studies have found contrasting negative relationships between species richness and preferences (Qiu, Lindberg, & Nielsen, 2013).

Here we assess local residents' responses to a controlled experimental manipulation of road verge vegetation across the city of Sheffield, UK. We conducted a reduced frequency mowing trial using a controlled paired design on urban road verges which maintained the current mowing frequency (mown every 3-4 weeks) on one side of the road, whilst the mowing frequency was reduced by half (every 6-8 weeks) on the opposite side of the road. Residents living on these roads were interviewed after the trial had taken place to address five main questions: (i) Do local residents' attitudes differ when comparing road verges on their road which are mown less frequently (every 6-8 weeks) to those managed typically (every 3-4 weeks)?, (ii) what factors influence local residents' attitudes when comparing road verges which are mown less frequently (every 6-8 weeks) to those managed typically (every 3-4 weeks)?, (iii) Do local residents' attitudes differ when comparing alternative hypothetical road verge scenarios to current management (mown every 3-4 weeks)?, (iv) Does local residents' connection to nature influence attitudes towards different types of road verge management? and (v) do local residents' attitudes differ regarding the ability of different road verge scenarios to support biodiversity?

2. Methods

2.1 Mowing trial

The city of Sheffield (53°23'N, 1° 28'W) has a population of approximately 560,000 (Office for National Statistics, 2018) and has approximately 2.1 million square metres of urban and suburban road verges (Amey Plc, 2015).

Roads were selected for the mowing trial using a three step selection process: (i) Sheffield was split into four quadrants, (ii) roads with verges at least 200m in length were extracted from GIS shapefiles of road verges in Sheffield (Sheffield City Council, 2016a) and subsequently (iii) randomly selected from each quadrant. All selected roads had verges on both sides of the road that were being maintained as short mown grass. Street trees, if present, occurred in small numbers and generally at similar frequencies on both sides of the road.

The trial used a paired design whereby normal mowing frequency (every 3-4 weeks) was maintained on the road verge on one side of the road and reduced to every 6-8 weeks on the opposite verge throughout the 2016 growing season. The side of the road used for each mowing frequency was randomly selected and for ease of the mowing operatives undertaking the changes, was kept consistent for each road with the side of the road with even house numbers mown every 3-4 weeks and the side with odd house numbers mown every 6-8 weeks. Following current standard practice, cuttings were not removed from the road verges after mowing took place. This treatment was successfully implemented on 16 roads, but here we report on the results of social science surveys of local residents from 12 of these roads (those with sufficient domestic residences along the road) between January and March 2017.

It was necessary to inform people living on these roads about the experimental management changes taking place. To do this: (i) signs were put up on lamp posts of affected roads, (ii) a summary leaflet was delivered to every house and (iii) a press release was released by Sheffield City Council (Sheffield City Council, 2016b). This informed the public that it was a trial to look at the impacts on wildlife and people of cutting urban roadside verges less frequently and to assess whether reduced mowing could attract a wider range of wildlife. Care was taken not to directly mention the paired design indicating which side of the road was mown differently in order to avoid bias in the questionnaires.

2.2 Selection of survey methods

The mowing trial ran for a single growing season (March-October). Surveys were conducted in the winter following the trial. Given the weather at that time of year, in order to minimise the length of the interview process we conducted a short door to door questionnaire (Appendix 3.1) and a separate postal questionnaire (Appendix 3.2 & 3.3). Once the door-to-door questionnaire was completed with a resident, they were given the option to take the postal questionnaire to fill in during their own time and send back. Pre-addressed, stamped envelopes and a financial incentive (a prize draw for a gift voucher) were given with the postal questionnaire to increase response rates. All envelopes were coded in order to associate responses from the two questionnaires for further analysis.

The door-to-door questionnaire (approximately five minutes long) comprised 16 questions focused on residents' attitudes towards the mowing trial that had taken place on the road. The postal questionnaire (approximately 10 minutes long) comprised 19 questions, focused on three key themes; (i) residents' responses towards other alternative road verge management strategies (ii) biodiversity management on road verges and how responses were influenced by (iii) residents' connectedness to nature. Both questionnaires comprised a mixture of quantitative and qualitative questions assessing local residents' responses towards urban roadside verges. This mix was to allow participants to express their own views not restricted by a set of options and to measure the strength of these views quantitatively (McLafferty, 2010). Both questionnaire surveys were trialled (n=12) before they were conducted on the mowing trial roads and adapted accordingly to refine length and wording of questionnaires (White et al., 2005).

Surveys were conducted twice on the 12 roads from 11am to 6pm, once during the week and the other at the weekend, to reduce any employment status bias on participant recruitment. Every household was approached on both visits with the exception of locations where no roadside verge was present outside the house, a 'no cold calling' sign was present or where a response had already been received on the first visit. Survey visits were carried out by two interviewers (same sex and approximate age) with each taking one side of the road being surveyed. Prior training, discussion and trial deployment were undertaken by the two interviewers to ensure a consistent approach, particularly to open-ended questions.
Ethical approval for this study was granted by the ethics committee of the Department of Animal and Plant Sciences, University of Sheffield (reference number 011291). Potential participants were made aware that participation was completely voluntary and that they could withdraw at any time throughout the survey.

2.3 Door-to-door questionnaire

2.3.1 Residents' responses regarding the mowing trial on their road

In the first section of the door-to-door questionnaire, participants were asked 3 questions to establish how long the participant had lived on their street, whether they had noticed any differences on the verges on the different sides of their street the previous spring and summer and, if yes, what changes they had noticed. The wording avoided directly mentioning that a mowing trial had taken place. If the participant had not noticed a difference in the verges on their street, then they were not asked about the changes on their road verges and were only asked the remaining questions, about their side of the road. This ensured that information was still obtained about the aesthetic value of the road verge regardless of the mowing trial. To assess residents' attitudes regarding the mowing trial on their road, participants were asked to give a preference score (using an 11 point Likert scale: from 0= strongly dislike to 10=strongly like) for the road verge on their side of the road and the opposite side of the road

during the mowing trial. Participants were then asked to explain why they felt this way about each verge. The order in which the participant was asked about the verge on their side of the road and then the opposite side of the road was rotated for different residents to avoid any bias in opinion by asking the same question first (Bowling, 2005).
To establish whether the change in mowing frequency affected people's interactions with the verge, participants were asked "Did you do anything differently due to this change (for instance when viewing or using the street)? Please describe what."

In order to assess if local residents' attitudes differ regarding the ability of different road verge mowing frequencies to support biodiversity, participants were asked, "Based on your experience from last spring and summer, please give a score from 0 to 10 for how good you think the road verge on your side of the road and the opposite side of the road were for supporting a wide range of plants and animals such as insects, where 0 is very poor and 10 is very good." Again, participants were asked why they felt this way about each side of the road in two open ended questions.

Finally, in order to establish residents' general opinion about reducing the mowing frequency of road verges, participants were asked, "Over the spring and summer last year, the road verges on one side of the road was mown less frequently than normal. What do you think about mowing verges less frequently?"

2.4 Postal questionnaire

2.4.1 Road verge management scenarios

Photo elicitation was used to assess residents' aesthetic preference and perceived biodiversity value for five verge management scenarios (Fig.3.1). These were (A) a botanically diverse road verge of a similar height to the reduced mowing frequency used in the trial (from an high diversity urban meadow planting that has high abundance of floral resources and high biodiversity value; Norton et al., (2019)), (B) replacement of the verge with tarmac, (C) a short verge dominated by flowering white clover *Trifolium repens* (similar height to current management but with more floral resources used by bees; Blackmore & Goulson, 2014), (D) a verge mown every 3-4 weeks (current management) and (E) a road verge mown every 6-8 weeks (mowing trial management, which increases invertebrate abundance but has negligible impact on floral resources for pollinators; Richardson et al. in prep [Chapter Two]). These images thus capture current road verge management and a range of alternative management to herbaceous vegetation on road verges, including replacing the verge entirely with tarmac and differing diversity in vegetation structure and floral resources. Images of different road verge scenarios were created by altering the verge element of a single roadside scene using image editing software to ensure that all aspects of the image were identical apart from the verge type. For each image respondents were asked "Attached are a series of photographs showing five different types of road verges. Imagining that this is alongside a road in your area, please give a preference score for each road verge image from 0 to 10, where 0 is strongly dislike and 10 is strongly like" and "Looking at the same photographs as Question 1, please give a score from 0 to 10 for how good you think each of the five verge types are for supporting a wide range of plants and animals such as insects, where 0 is very poor and 10 is very good". Following each of these questions participants were asked, "Do you have any further comments about why you rated the images in this way?".

2.4.2 Factors affecting public responses towards urban roadside verge management

We used a five point Likert scale of agreement (strongly disagree to strongly agree) to assess participants' responses to seven statements regarding road verges which captured information on their assigned values: (i) "The appearance of a roadside verge doesn't matter to me", (ii) "Managing roadside verges for nature is important to me", (iii) "It is not important to manage roadsides to benefit nature", (iv) "Efforts to conserve urban nature should focus on parks not roadside verges" and attitudes:(v)"I would prefer roadside verges to be tarmacked", (vi) "I like roadside verges to look neat and tidy" and (vii) "I don't mind if vegetation on a verge is taller (i.e. up to 30cm/1 foot in height) if it is beneficial to nature". Opposing statements were used to ascertain whether participants' scores were consistent for the same theme (McLafferty, 2010).

2.4.3 Connectedness to nature

Nature relatedness was measured using the NR-6 scale (Nisbet & Zelenski, 2013) which consists of six statements (e.g. “I always think about how my actions affect the environment”) assessed using a 5-point Likert scale. This scale is based on two constructs: how people identify themselves as a part of nature and their experience in nature such as time outdoors (Nisbet, Zelenski, & Murphy, 2009). The higher the mean score (created from the scores of the six statements) from the scale, the more connected a person is deemed to be with nature (Nisbet, Zelenski, & Murphy, 2009).

2.5 Sociodemographic data

We collected socio-demographic data in both questionnaires for use in statistical analyses and to establish how representative the sample population was relative to the population of Sheffield. Age was recorded in 8 categories (18-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75-85 and 85+). Gender was recorded using three options (Female, Male and Other), but as there were no responses for the last option only two categories were used in the analysis. Ethnic group was recorded as 18 categories grouped into 5 broader categories (White, Mixed/multiple ethnic groups, Asian/Asian British, Black/African/Caribbean/Black British and other ethnic group), but most of these had very low sample sizes for the different ethnicity categories, so categories were merged to generate two levels: (i) White and (ii) Other. Employment situation was recorded as 7 categories (“I study full-time”, “I am retired”, “I am a housewife/househusband”, “I work full time”, “I work part time”, “I am unemployed/between jobs” and “I am freelance/self-employed”).

We asked participants to, “Please tick all qualifications that you have completed (please tick as many as apply)” out of 10 categories (O-levels, GCSE, A-level, BTEC, International Baccalaureate, Higher national certificates, Bachelor degree, Postgraduate degree (eg Masters), PhD and Other) and used this information to identify the participant’s highest level of qualification. When a participant put another qualification in the ‘other’ category, they were classified by the UK Government’s qualification classification system (GOV.UK, 2018). These were aggregated into five levels with qualifications equivalent to: (i) GCSE & O level or below, (ii) A level, (iii) Diploma, (iv) Bachelor degree and (v) Postgraduate degree.

We recorded the road name for each participant and used the postcode for each road to obtain the Index of Multiple Deprivation (IMD) (Ministry of Housing Communities & Local Government, 2017). This is a weighted index of 37 indicators organised across seven domains of deprivation that provide an overall deprivation metric ranging from 1 (most deprived area) to 32,844 (least deprived area) that provides a broad socio-demographic indicator (Department for Communities and Local Government, 2015b, 2015a). Respondents' IMD scores exhibited a distinct binary distribution and were thus classified as a two level categorical variable (0-16,000 and 16,000-32,000) (Appendix 3.4).

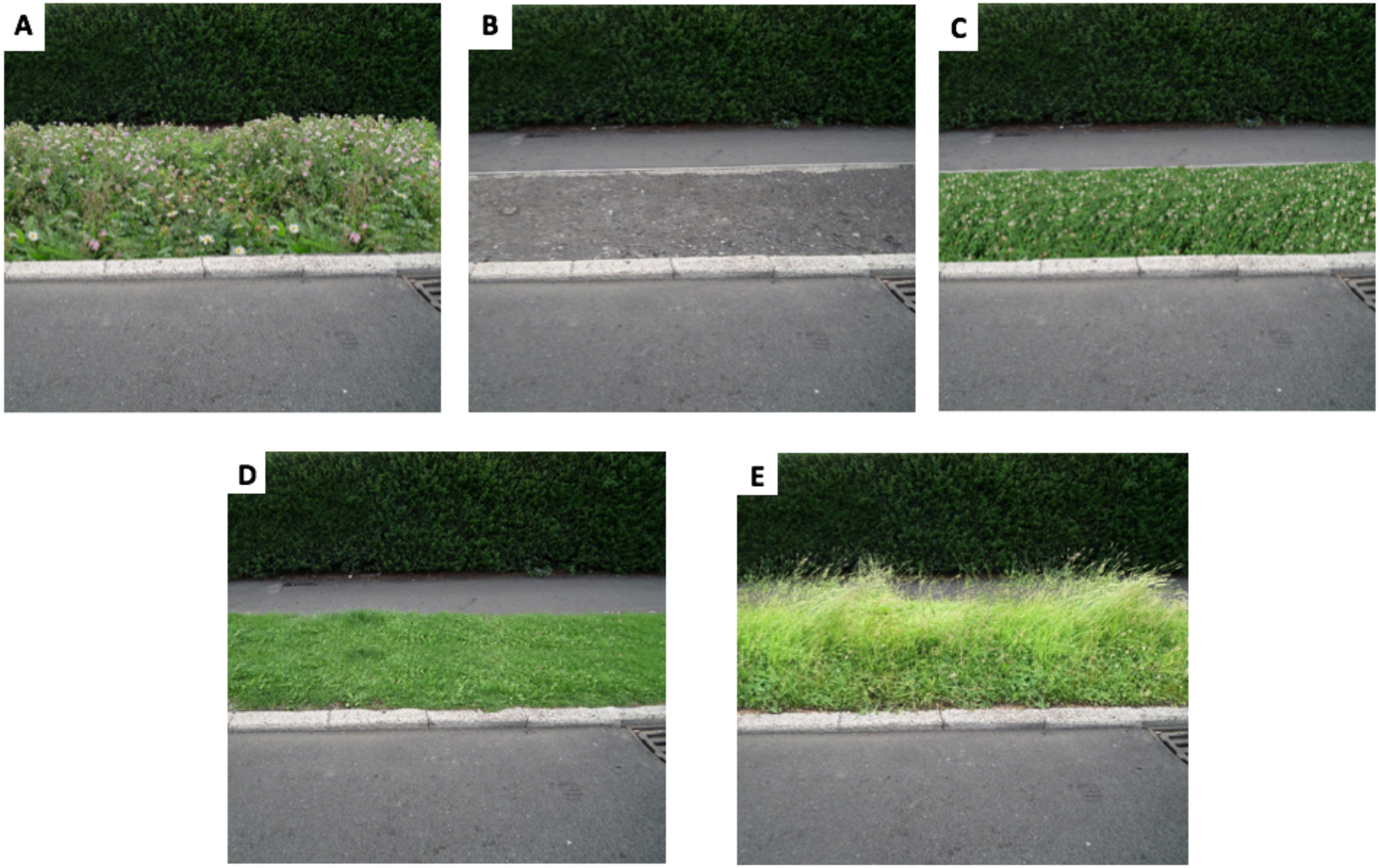

Figure 3.1. Five road verge management scenarios: (A) Floristically diverse vegetation (similar in height to Image E), (B) tarmacked road verge, (C) short road verge dominated by white clover *Trifolium repens*, (D) road verge mown every 3-4 weeks (current standard practice) and (E) road verge mown every 6-8 weeks.

2.6 Data analysis

Statistical analysis was conducted in R 3.4.1 (R Core Team, 2017). Our general approach was to construct full models without stepwise regression or use of information theoretic approaches following the advice of Cade, (2015) and Whittingham et al., (2006).

To assess for multicollinearity, all independent variables were analysed using variance inflation factor (vif) with the 'pedometrics' package in R (Samuel-Rosa, 2015). All predictor variables had VIF values lower than three indicating that our analyses are unlikely to be influenced by multicollinearity (Zuur, Ieno, & Elphick, 2010).

2.6.1 Residents' attitudes towards the mowing trial and road verge management scenarios

Global cumulative link mixed models were constructed (using the 'ordinal' package in R) (Christensen, 2019) to model participants' (i) preference score and (ii) perceived biodiversity value as a function of each of the five hypothetical road verge management scenarios with a nested design (participant nested within the site (road) where the participant lived as a random factor) with nature relatedness (as an interaction term with each road verge scenario) and sociodemographic variables (gender, age, ethnicity, employment status, final qualification and deprivation) as additional predictors. However, as these global models did not converge, employment situation was removed from the analysis as, a priori, it was thought to be the least useful variable in terms of explanatory power. As there were multiple responses from each participant providing Likert score values for each of the five hypothetical road verge management scenarios, participant was included as a random factor. Image D (current management mown every 3-4 weeks), 18-25 (age category), female (gender), other (ethnic group), 0-16,000 (Index of Multiple Deprivation) and A-level (highest level of qualification) were each used as the reference value for each category meaning that all other values within each category were compared to these reference categories. Aesthetic value and biodiversity value response variables (Likert scale from 0 to 10) were treated as ordered factors as required for the ordinal package. Kendall's Tau test was conducted to assess if there was a relationship between participants' aesthetic value of the road verge management scenarios and the perceived ability of different road verge management scenarios to support plants and animals.

To assess local residents' attitudes regarding the (i) aesthetic value and (ii) perceived biodiversity value of the reduced mowing regime (road verges mown every 6-8 weeks) compared to the regular mowing regime (mown every 3-4 weeks), an additional cumulative link mixed model was constructed with the same sociodemographic variables and a nested random factor of participant number within road name. However, as fitting the model failed for the analysis comparing perceived biodiversity value, the original Likert scale was collapsed to a five point scale (0-1 very poor, 2-3 poor, 4-6 neutral, 7-8 good and 9-10 very good). Reduced mowing frequency (treatment) was used as the reference value meaning that all responses are relative to this. As the nature relatedness scale question was only in the postal survey, this was not included in this analysis as this reduced the sample size of the aesthetic value and perceived biodiversity analyses by 47.6% and 48.5% respectively. Additional analyses were conducted including the average connectedness to nature values which indicated that nature relatedness did not affect preferences but due to the low sample size were not included in main results (Appendix 3.5).

2.6.2 Factors affecting attitudes for road verge scenarios

Qualitative questions asking, "Please explain why you feel this way?" relating to the choice of Likert scale responses were analysed using quantitative content analysis. Content analysis analyses texts such as interviews and questionnaires through the creation of themes or codes (Bryman, 2016; Krippendorff, 2013).

Themes were created inductively and deductively, through initially identifying themes from the scientific literature (Weber, Kowarik, & Säumel, 2014a; Lucey & Barton, 2011; Froment & Domon, 2006; Todorova, Asakawa, & Aikoh, 2004; Akbar, Hale, & Headley, 2003) and also from reading through the responses from the participants. All open ended questions were systematically read through and for each question a coding manual was created which describes the theme or code that relates to the text, with examples (Appendix 3.6). The headings or main categories under which the codes were clustered were used to create a coding schedule, a form used when coding the text (Bryman, 2016). The coding manual and schedule were repeatedly refined to ensure that the categories were mutually exclusive, easy to understand for other coders and featured all different aspects of the content (Bryman, 2016; Krippendorff, 2013).

To ensure that the coding was replicable, a second coder reviewed 25% of the qualitative data and using the coding manual, re-coded the responses. Cohen's kappa was used to measure agreement between the two coders, which provides values from 0-1 (values closer to 1 indicate more agreement) (Bryman, 2016). Interpretation of the Cohen's kappa results were based on guidelines from Krippendorff, (2013) whereby results were reliable when kappa was above 0.800 and treated with caution between 0.667 and 0.800. The coding schedule was revised accordingly.

A multiple correspondence analysis (MCA) was performed on the codes from Questions 5, 6 and 11 in the door to door questionnaire (Appendix 3.7-3.8) using the 'FactoMineR' and 'factoextra' packages (Kassambara & Mundt, 2017; Le, Josse, & Husson, 2008), to establish whether there was an association between participants opinions of mowing verges less frequently and the reasons for preference or lack of preference of reduced mowing when trialled on their road. Codes ("Consistently for", "Consistently neutral" and "Consistently against") created from the responses to Question 11 in the door to door questionnaire asking participants, "Over the spring and summer last year, the road verge on one side of the road was mown less frequently than normal. What do you think about mowing verges less frequently" were analysed with the combined codes from Questions 5 and 6 asking participants why they rated the verge mown every 3-4 weeks and the verge mown every 6-8 weeks. If the category was mentioned as important on one side of the road but not on the other, this category was coded as present for that individual. For the codes in Question 11, the categories that suggested the participant's opinion was dependent on another factor were merged where possible into the three main categories ("Consistently for", "Consistently neutral" and "Consistently against") and the remaining two categories were removed from the analysis due to low sample size. MCAs indicate associations between categorical variables, with variables mapped closely together indicating that they are similar and those which are far apart on the axes are negatively correlated. The categories "symmetrical verges", "same as normal", "safety" and "discouraged parking" were removed from the MCA before analysis as these categories were less than 5% of the data which may have skewed responses. Due to low response rates and answers provided not relating to the questions asked, it was not possible to run the same analysis for the following qualitative questions; Questions 9 and 10 of the door-to-door questionnaire and Question 4 of the postal questionnaire.

2.6.3 Factors affecting public responses towards urban roadside verge management

2.6.3.1 Exploratory factor analysis

Exploratory factor analysis was undertaken on the responses from Question 5 of the postal questionnaire using the 'pysch' package (Revelle, 2019) to assess if there are underlying relationships between variables and to establish if this can be used to group several statements into common factors. For statements that had opposing sentiments, the Likert scale responses were reverse coded before analysis, to ensure that values such as strongly agree and strongly disagree were consistent across all statements.

Bartlett's Test of Sphericity ($p<0.05$)(Bartlett, 1940) and the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (minimum KMO threshold of >0.5)(Kaiser & Rice, 1974) were performed on the responses to test if the data was suitable for factor analysis. To determine the number of factors required for the exploratory factor analysis, scree plot and parallel analysis were conducted on the data. Exploratory analysis models were conducted using a maximum likelihood estimation with an oblique rotation (oblim), using 0.30 as a cut off for factor loadings as recommended in Fabrigar et al., (1999). To establish the measure of fit of the exploratory factor analysis models, a number of fit indices were calculated including Root Mean Square Error of Approximation (RMSEA), Standardized root mean residual (SRMR), Tucker-Lewis nonnormed fit index (NNFI) and Comparative fit index (CFI). For NNFI and CFI, the threshold for a good model fit was defined as >0.95, for RMSEA, <0.06 and for SRMR <0.08 (Hu & Bentler, 1999). Cronbach's alpha was used to measure the internal reliability of the proposed factors using a threshold of $\alpha>0.70$ (Hair et al., 2006).

2.6.3.2 Residents' responses towards road verge conservation analysis

The results of the exploratory factor analysis indicated that five out of the seven statements in Question 5 reliably formed one factor or index; (i) "Managing roadside verges for nature is important to me", (ii) "I would prefer roadside verges to be tarmacked", (iii) "I don't mind if vegetation on a verge is taller (ie up to 30cm/1 foot) if it is beneficial to nature", (iv) "It is not important to manage roadsides to benefit nature" and (v) "Efforts to conserve urban nature should focus on parks not road verges". These statements all related to participant's assigned values and attitudes towards road verge conservation. The Likert scale responses from each statement to be used for the index were summed, generating a single score for each participant for the index. High values for the conservation index indicated that the participant was strongly motivated to manage road verges for conservation.

Using this index from the exploratory factor analysis, we modelled participant's assigned values and attitudes towards road verge conservation using a generalized linear mixed effect model (GLMM) using the 'lme4' package (Bates et al., 2015) with a Gaussian distribution. Fixed effects used were age, gender, ethnicity, final qualification, deprivation and nature relatedness and road was used as a random factor. 18-25 (age category), female (gender), other (ethnic group), 0-16,000 (Index of Multiple Deprivation) and A-level (highest level of qualification) were used as the reference value for each sociodemographic category.

3. Results

In total 235 face-to-face questionnaires were completed (a response rate of 25.7%) and 129 postal questionnaires were returned (54.9% response rate). Sample sizes varied slightly for each question as some questionnaires were incomplete.

3.1 Residents' attitudes regarding the mowing trial on their road

Participants significantly preferred road verges which had the typical mowing frequency (every 3-4 weeks) when compared to road verges mown less frequently (every 6-8 weeks) (P<0.001, Fig 3.2). Sociodemographic variables had no impact on the mowing frequency preference with the exception of participants between the ages of 55-64 and 85+ who had a significantly negative reaction ($P<0.05$, Table 3.1).

3.2 Factors that affect residents' attitudes regarding the mowing trial on their road

The qualitative answers from Question 11 of the door to door questionnaire indicated that the majority (60.7%) of respondents were consistently against mowing less frequently and the remaining respondents were equally consistently neutral (19.6%) or consistently for mowing less frequently (19.6%) when asked what do you think about mowing less frequently (Table 3.2).

When respondents were asked to explain why they felt this way about the road verges on their side of the road and the opposite side of the road for Questions 5 and 6 of the door to door questionnaire, a number of aesthetic value themes were mentioned the most frequently, including neat and tidy vegetation (71.4%), a positive perception of short vegetation height and/or negative perception of long vegetation height (55.4%), the presence of litter and/or dog poo (33.9%) and vehicular parking negatively impacting road verge aesthetics (17.9%) (Table 3.2). Other themes also classed as aesthetic value were not mentioned as frequently including, a standalone mention of how the road verge appears (14.3%), signs of care (7.1%), the road verge looking the same as normal (3.6%), the perception that the respondent would like symmetrical verges (3.6%) and the positive perception of long vegetation height and negative perception of short vegetation height mentioned by only 1.8% of respondents (Table 3.2).

When wildlife was mentioned, the most frequently mentioned theme was the perception that the mowing trial had a positive impact on wildlife and plants on road verges which is beneficial and/or there was an appreciation that the road verge mown normally may not have been as good for wildlife and plants (16.1%) (Table 3.2). All other themes relating to wildlife; mowing trial had no impact on wildlife and plants on road verges (3.6%), had a negative impact on wildlife and plants on road verges (1.8%) and supported problematic wildlife and plants (1.8%) were mentioned less frequently (Table 3.2).

Themes other than aesthetic value and wildlife were mentioned infrequently with accessibility across the road verge and council resources mentioned by 10.7% each, lack of knowledge about the trial and safety concerns mentioned by 5.4% of respondents each and discouraging vehicular parking accounting for 3.6% of mentions by respondents (Table 3.2).

In the qualitative answers 23.3% of the variance was explained in the first two dimensions from the multiple correspondence analysis (MCA). Results from the MCA indicate that respondents who were consistently in favour of mowing less frequently were more likely to think that the mowing trial had a positive impact on wildlife (Fig 3.3). The presence of litter and dog faeces, and neat and tidy vegetation, were more likely to be associated with respondents who were against mowing less frequently. Wildlife was less likely to be mentioned by respondents who were against mowing less frequently. The categories relating to “signs of care”, “thought the mowing trial had no impact on wildlife”, “likes long vegetation height” and was “neutral about mowing less frequently” were not well represented in the first two dimensions indicating that this data should be treated with caution.

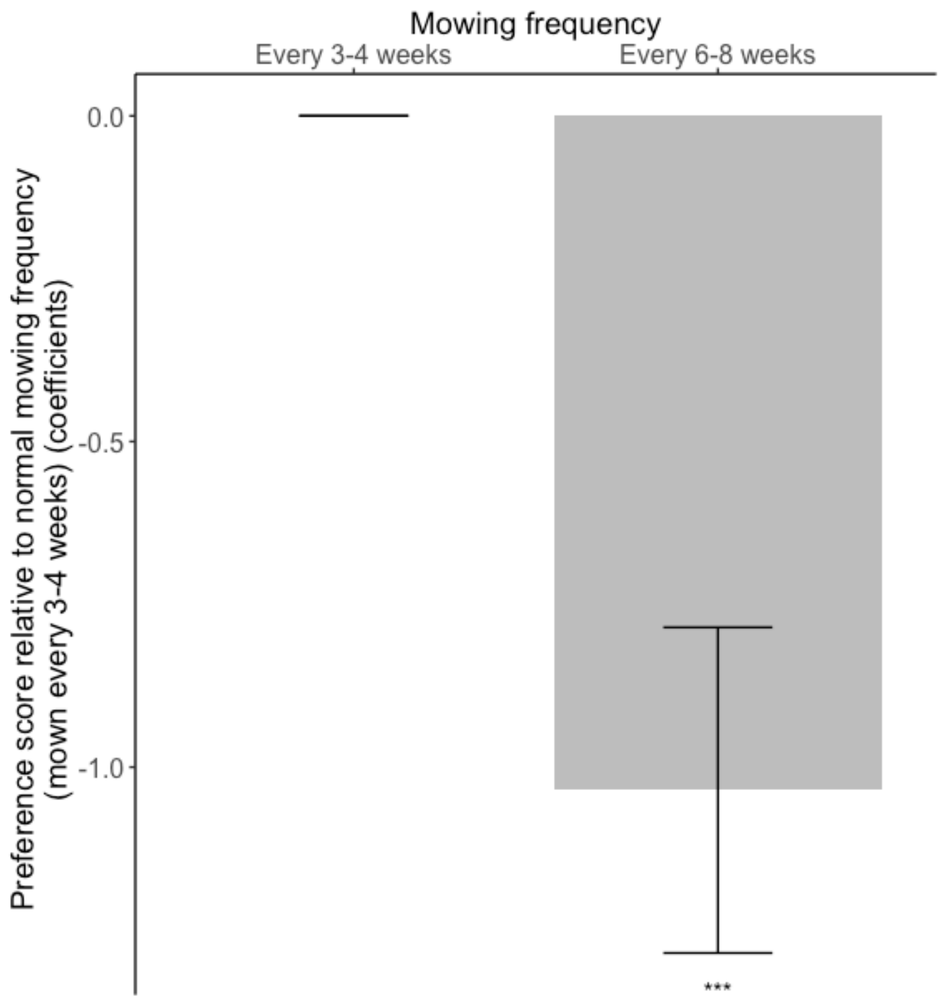

Figure 3.2 Coefficients for local residents preference scores to a mowing trial taking place on their road where one side of the road is mown normally (every 3-4 weeks) and the other side of the road is mown less frequently (every 6-8 weeks using a cumulative link mixed model. Standard error and significance levels (***P<0.001) are shown. Residents were asked the following question, “During the spring and summer last year, a mowing trial was taking place on your road. Thinking back to that time, please give a preference score from 0 to 10 for the road verge on your side of the road and the opposite side of the road, where 0 is strongly dislike and 10 is strongly like”.

Table 3.1 Results from the global cumulative linked mixed model asking "During the spring and summer last year, a mowing trial was taking place on your road. Thinking back to that time, please give a preference score from 0 to 10 for the road verge on your side of the road and the opposite side of the road, where 0 is strongly dislike and 10 is strongly like". Data reported are parameter estimates, standard error, z-value and P-value. Preference for typical mowing frequency (every 3-4 weeks) was used as the reference intercept, so all results are compared to these values. Values in bold indicate that they have a significant effect on mowing preference.

Variables	**Parameter estimate ± standard error**	**z-value**	**P-value**
Reduced mowing frequency	**-1.04±0.25**	**-4.14**	**<0.001**
Age (25-34)	-1.65±1.43	-1.15	0.25
Age (35-44)	-1.53±1.31	-1.17	0.24
Age (45-54)	-1.83±1.33	-1.38	0.17
Age (55-64)	**-2.93±1.34**	**-2.19**	**0.03**
Age (65-74)	-2.09±1.31	-1.59	0.11
Age (75-85)	-1.99±1.33	-1.49	0.14
Age (85+)	**-3.25±1.46**	**-2.22**	**0.03**
Gender (male)	0.17±0.27	0.65	0.52
Ethnicity (white)	-0.17±0.76	-0.22	0.83
Index of Multiple Deprivation (16,000-32,000)	-0.02±0.33	-0.07	0.94
Final qualification (GCSE)	-0.05±0.42	-0.12	0.91
Final qualification (Diploma)	-0.32±0.49	-0.66	0.51
Final qualification (Bachelor degree)	0.40±0.50	0.80	0.43
Final qualification (Postgraduate degree)	0.46±0.46	1.00	0.32

Table 3.2. The themes, descriptions and percentage of people mentioning each theme identified in the content analysis from Question 11 and combined codes from Questions 5 and 6 of the door to door questionnaire. In Question 11, participants were asked “Over the spring and summer last year, the road verges on one side of the road was mown less frequently than normal. What do you think about mowing verges less frequently?” and from Question 5 and 6, “During the spring and summer last year, a mowing trial was taking place on your road. Thinking back to that time, please give a preference score from 0 to 10 for the road verge on your side of the road and the opposite side of the road, where 0 is strongly dislike and 10 is strongly like. Please explain why you feel this way about the verge on your side of the road?” and “During the spring and summer last year, a mowing trial was taking place on your road. Thinking back to that time, please give a preference score from 0 to 10 for the road verge on your side of the road and the opposite side of the road, where 0 is strongly dislike and 10 is strongly like. Please explain why you feel this way about the verge on the opposite side of the road?” respectively. These themes were used in the multiple correspondence analysis (MCA).

THEME	**DESCRIPTION**	**Percentage of people mentioning this theme (Number of responses) n=56**
Over the spring and summer last year, the road verges on one side of the road was mown less frequently than normal. What do you think about mowing verges less frequently? :		
Consistently against mowing less frequently	The respondent has a consistently negative reaction towards mowing verges less frequently or specifically says that it should be mown frequently or more frequently or regularly or at the same frequency as that before the trial started. This also includes if the respondent mows the verge themselves, suggesting they prefer the verge to be mown frequently. EXAMPLE: "Don't think it's a good idea"	60.7% (34)
Consistently neutral	The respondent is either consistently indifferent or doesn’t know or not sure about mowing verges less frequently and uses specific words to indicate this such as ‘doesn’t really matter to me’, ‘not concerned’, “don’t bother me” and/or didn’t “notice” the mowing trial and/or didn’t think it “made a difference” to them. In addition, code this if doesn’t provide a strong opinion and just provides a balanced response. EXAMPLE: "Doesn't make much difference to me"	19.6% (11)

Consistently for mowing less frequently	The respondent has a consistently positive reaction to mowing verges less frequently using positive words on the whole such as, ‘fine’, ‘alright’, ‘okay’, ‘no problem with that’. EXAMPLE: "Good idea. Think they came too often last year. Don't need to be that much”	19.6% (11)
During the spring and summer last year, a mowing trial was taking place on your road. Thinking back to that time, please give a preference score from 0 to 10 for the road verge on your side of the road and the opposite side of the road, where 0 is strongly dislike and 10 is strongly like. Please explain why you feel this way about the verge on your side of the road? Please explain why you feel this way about the verge on the opposite side of the road? :		
AESTHETIC VALUE: Neat and tidy vegetation	Positive language regarding ‘neat’ and/or ‘tidy’ vegetation or infers that it looks orderly and negative language such as ‘untidy’ and/or ‘scruffy’ and/ or ‘messy’ and/or ‘unkempt’ directly mentioned or infers that the consequences of mowing such as left grass cuttings/arisings cause a ‘mess’. This does not include vegetation with regards to be cared for or vegetation being damaged by vehicular parking. EXAMPLE: “Looked neater and well kept”	71.4% (40)
AESTHETIC VALUE: Positive perception of short vegetation height and/or negative perception of long vegetation height	Vegetation height mentioned in relation to the mowing trial. Words may include ‘short’ or ‘mown’ using positive language and/or ‘long’ or “uncut” or “overgrown” using negative language directly or infers that it needs to be cut regularly and/or mentions that the respondent/ other residents had cut the verge themselves. EXAMPLE: “really annoyed. Left long and had to cut it myself”	55.4% (31)
AESTHETIC VALUE: Litter/dog poo	The road verge had litter or rubbish or any objects that are being described as if they have been thrown away and could be classed as litter. In addition, if the word, ‘clean’ or ‘unclean’ is used. In addition, include if the response directly mentions dog poo or any variations of dog poo such as dog mess/dog faeces/dogs fouling/dog muck/dog dirt or any words that imply that dog owners don’t pick up dog poo. EXAMPLE: “Risk of more dog poo in grass"	33.9% (19)
AESTHETIC VALUE: Vehicular parking negatively impacts road verge aesthetics	The visual appearance of road verges has been impacted by vehicular parking, damaging the grass verge. EXAMPLE: “Not that nice when people have parked on it”	17.9% (10)
WILDLIFE: Mowing trial had a positive impact on wildlife and plants on road verges which is beneficial and/or appreciation that the road verge mown normally may not have been as good for wildlife and plants	Thought the mowing trial has had a positive impact on wildlife/plants and/or this is expressed using positive language. This includes if the respondent appreciates wildlife on the road verge and/or appreciates that elements of the road verge such as wildflowers can benefit wildlife. This does not include if trees are mentioned, as the management of trees remained the same during the mowing trial. EXAMPLE: “Did improve amount of flowers we got on verge”	16.1% (9)
AESTHETIC VALUE:	A standalone mention of how the road verge appears.	14.3% (8)

Other	EXAMPLE: “Well sort of look neat and tidy but I guess a little bit dull”	
Accessibility across the verge	Access for people getting to/from a location or a vehicle or moving items such as a wheelie bin by crossing or using the road verge. This also includes being able to see what is in the verge. EXAMPLE: “Anyone getting out of the car have to walk along verge”	10.7% (6)
Council resources	Road verge management is dependent on council resources, including the mention that the trial would save money or the council money and implies that as residents pay council tax, the council should maintain the grass verge. EXAMPLE: “Served no purpose but to save money”	10.7% (6)
AESTHETIC VALUE: Signs of care	The road verge is ‘cared for’ and/or ‘looked after’ and/or ‘inhabited’ or it looks like it is maintained or kept by someone. In addition, negative language relating to signs of care such as ‘no-one cares’ and/or ‘unkept’ or it looks like it isn’t maintained by someone. This is different from neat and tidy vegetation in that a road verge can be maintained but doesn’t necessarily mean that it looks neat and tidy. EXAMPLE: “Had been kept, tidy, maintained”	7.1% (4)
Lack of knowledge about the trial	Didn’t know why the mowing trial had taken place and/ or “didn’t notice” the mowing trial. EXAMPLE: “Looked a bit scruffy and people didn't really know why it had been done”	5.4% (3)
Safety	Any mention of safety concerns or hazards such as restricted vision caused by the road verge and directly uses the words ‘dangerous’ or ‘slipping’ with regards to the road verge. EXAMPLE: “Thought It was very dangerous”	5.4% (3)
AESTHETIC VALUE: Looked same as normal	The road verge looked the same as normal. EXAMPLE: “Don't have any strong things. Just normal as you are used to seeing it”	3.6% (2)
AESTHETIC VALUE: Symmetrical verges	Would like verges on both sides of the road or on same side of the road to be consistently mown at the same time and/or dislikes asymmetrical verges- verges that were cut at different times. EXAMPLE: ‘Some people cut down, others didn't. Wasn't consistent’	3.6% (2)
Discouraging vehicular parking	Suggestion that the presence of long vegetation/flowers deters parking on verges using language which suggests this is a positive consequence. EXAMPLE: “Grass might help stop parking"	3.6% (2)
WILDLIFE: Mowing trial had no impact on wildlife and plants on road verges	Thought that there was no difference and/or no impact of the mowing trial on wildlife and plants on road verges. EXAMPLE: “It looked untidy. Didn't notice any difference in wildlife e.g. butterfly. Any different. Didn't see anything but then you don't see things on your own front doorstep”	3.6% (2)
AESTHETIC VALUE: Positive perception of long vegetation height and/or negative	Vegetation height mentioned in relation to the mowing trial. Words may include ‘long’ or ‘uncut’ or ‘overgrown’ using positive language and/or ‘short’ or ‘cut’ using negative language or infers that the vegetation doesn’t need to be cut regularly.	1.8% (1)

perception of short vegetation height	EXAMPLE: “Would prefer overgrown greenspace to not greenspace”	
WILDLIFE: Mowing trial had a negative impact on wildlife and plants on road verges	Thought that the mowing trial had a negative impact on wildlife and plants. EXAMPLE: “Thought It was very dangerous. I'm a childminder. Not good for wildlife as got more wildlife on my verge”	1.8% (1)
WILDLIFE: Mowing trial supported problematic wildlife and plants on the road verge	Thought that the mowing trial would increase problematic wildlife and plants such as ‘pests’. EXAMPLE: “From public perspective, will just increase pests”	1.8% (1)

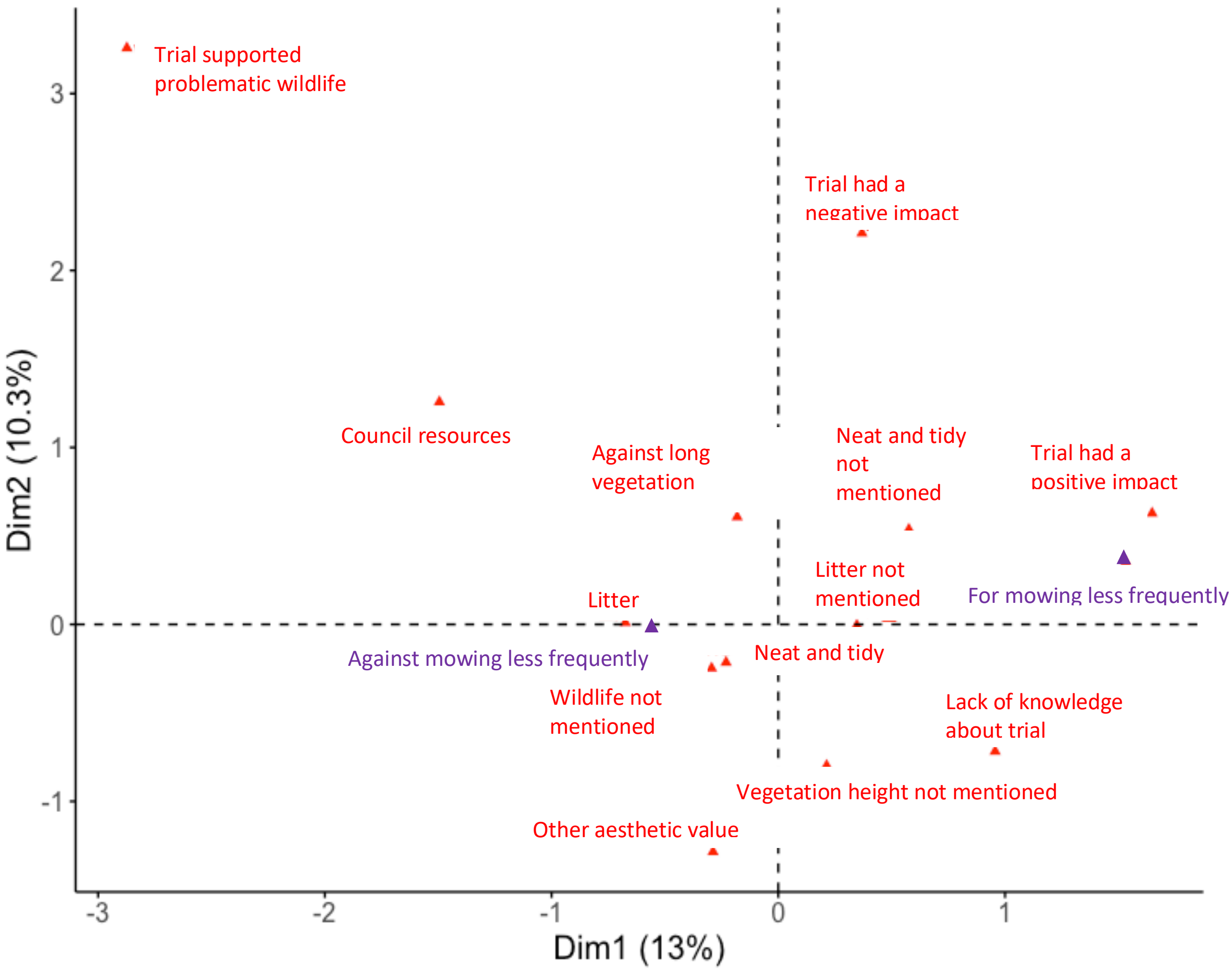

Figure 3.3 A multiple correspondence analysis (MCA) plot showing the top 15 subcategories which explain the most variation across the first two dimensions. The opinions “For mowing less frequently” and “Against mowing less frequently” (indicated in purple) are plotted against subcategories identified from qualitative answers (indicated in red).

3.3 Road verge management scenarios

Participants significantly preferred Image D (road verge mown every 3-4 weeks) to all other image scenarios (Images A-C & E) (Fig 3.4, Table 3.3). Relative to Image D, Image A (floristically diverse vegetation) & E (road verge mown every 6-8 weeks) were the images with the lowest preference scores ($P<0.001$) (Table 3.3). Although marginally non-significant, Image C (short road verge dominated by white clover) was the most favoured road verge management scenario after Image D ($P=0.064$). Participants aged 65-85 had a significantly negative reaction (Table 3.3). Participants' nature relatedness score had a significantly positive impact on preferences for Images A & E ($P<0.01$ and $P<0.05$ respectively) (Fig 3.4, Table 3.3).

3.4 Attitudes towards perceived biodiversity benefits

Participants thought that the road verge mown every 6-8 weeks would support a significantly wider range of plants and animals than road verges mown every 3-4 weeks ($P<0.05$, Fig 3.5A, Table 3.4). Sociodemographic variables had no impact on this perception of how good the different road verges were for supporting a wide range of plants and animals (Table 3.4).

Participants rated Images A (floristically diverse vegetation) and E (road verge mown every 6-8 weeks) significantly higher in relation to supporting a wide range of plants and animals when compared with Image D ($P<0.05$ and $P<0.01$ respectively) (Fig 3.5B, Table 3.5). Relative to Image D, Image B (tarmacked verge) was thought to be significantly worse at supporting a wide range of plants and animals ($P<0.001$) (Fig 3.5B, Table 3.5). Apart from participants aged 75-85 who had a significantly negative reaction, sociodemographic variables made no significant difference to perception of how good the road verge scenarios were for plants and animals (Table 3.5).

A relationship between aesthetic value and perceived biodiversity value was statistically significant but there was not a strong association. ($r_\tau=0.275$, $P<0.001$).

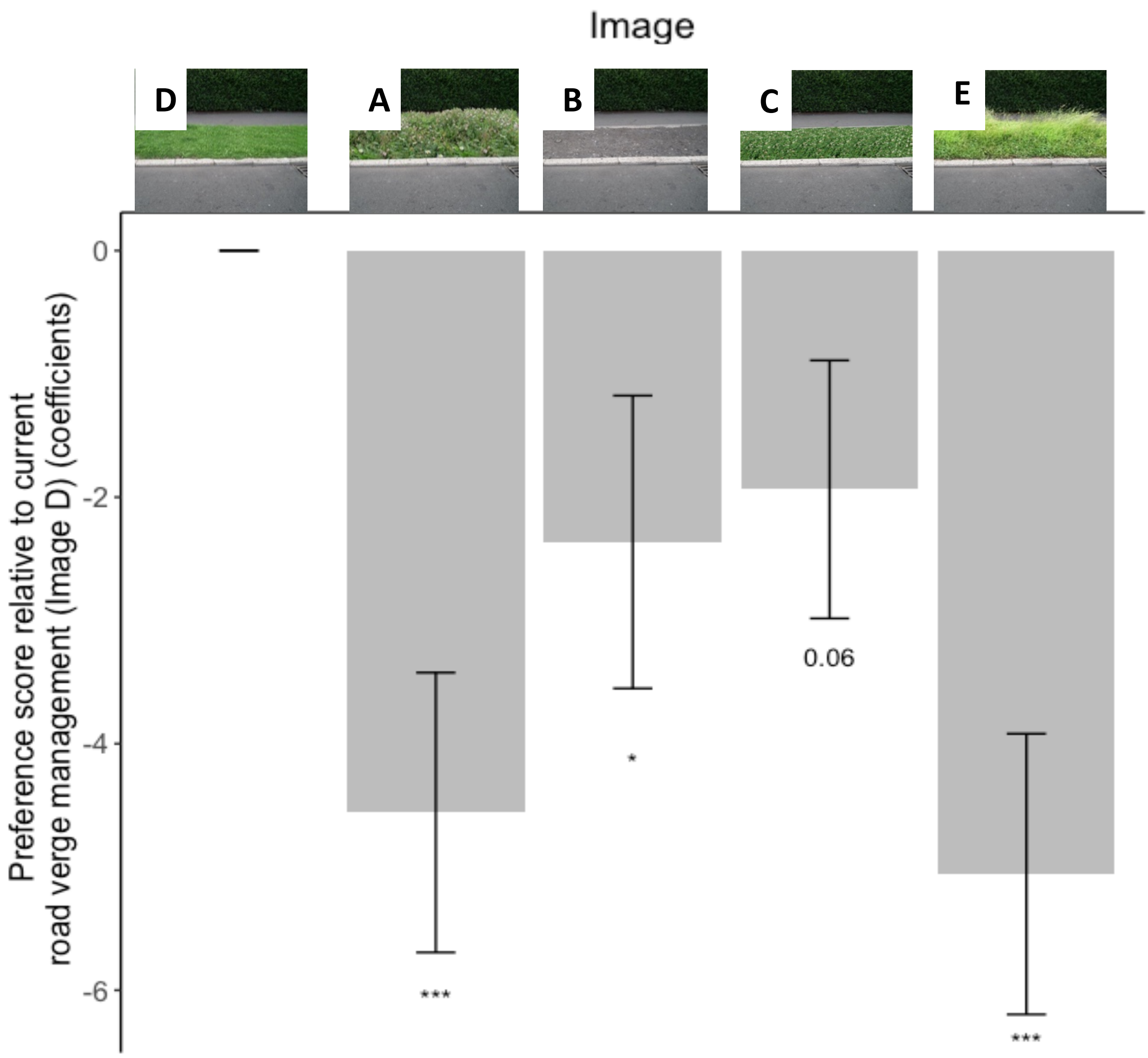

Figure 3.4 Coefficients for local residents preference scores to different road verge images (A-E) when compared with the current road verge management (Image D) using a cumulative link mixed model. Standard error and significance levels (*P<0.05; ***P<0.001) are shown. Residents were asked the following question: “Attached are a series of photographs showing five different types of road verges. Imagining that this is alongside a road in your area, please give a preference score for each road verge image from 0 to 10, where 0 is strongly dislike and 10 is strongly like”.

Table 3.3 Results from the global cumulative linked mixed model asking, “Attached are a series of photographs showing five different types of road verges. Imagining that this is alongside a road in your area, please give a preference score for each road verge image from 0 to 10, where 0 is strongly dislike and 10 is strongly like”. Data reported are parameter estimates, standard error, z-value and P-value. Preference for Image D (typical mowing frequency every 3-4 weeks) was used as the reference intercept, so all results are compared to these values. Values in bold indicate a significant effect on image preference.

Variables	Parameter estimate ± standard error	z-value	P-value
Image A	**-4.56±1.14**	**-4.02**	**<0.001**
Image B	**-2.36±1.19**	**-1.99**	**0.05**
Image C	-1.94±1.05	-1.85	0.06
Image E	**-5.06±1.14**	**-4.44**	**<0.001**
Nature relatedness	-0.14±0.21	-0.64	0.52
Age (25-34)	-1.57±1.10	-1.42	0.16
Age (35-44)	-1.84±1.08	-1.71	0.09
Age (45-54)	-1.79±1.07	-1.67	0.09
Age (55-64)	-1.88±1.07	-1.75	0.08
Age (65-74)	**-2.08±1.05**	**-1.97**	**0.05**
Age (75-85)	**-2.89±1.07**	**-2.71**	**0.01**
Age (85+)	-1.80±1.26	-1.43	0.15
Gender (Male)	0.07±0.19	0.39	0.69
Ethnicity (White)	0.34±0.68	0.51	0.61
Index of Multiple Deprivation (16,000-32,000)	0.21±0.32	0.66	0.51
Final qualification (GCSE)	0.35±0.31	1.16	0.25
Final qualification (Diploma)	0.31±0.30	1.06	0.29
Final qualification (Bachelor degree)	-0.23±0.31	-0.74	0.46
Final qualification (Postgraduate degree)	0.07±0.28	0.23	0.82
Image A: Nature relatedness	**0.92±0.30**	**3.03**	**<0.01**
Image B: Nature relatedness	-0.30±0.32	-0.93	0.35
Image C: Nature relatedness	0.43±0.28	1.54	0.12
Image E: Nature relatedness	**0.71±0.30**	**2.37**	**0.02**

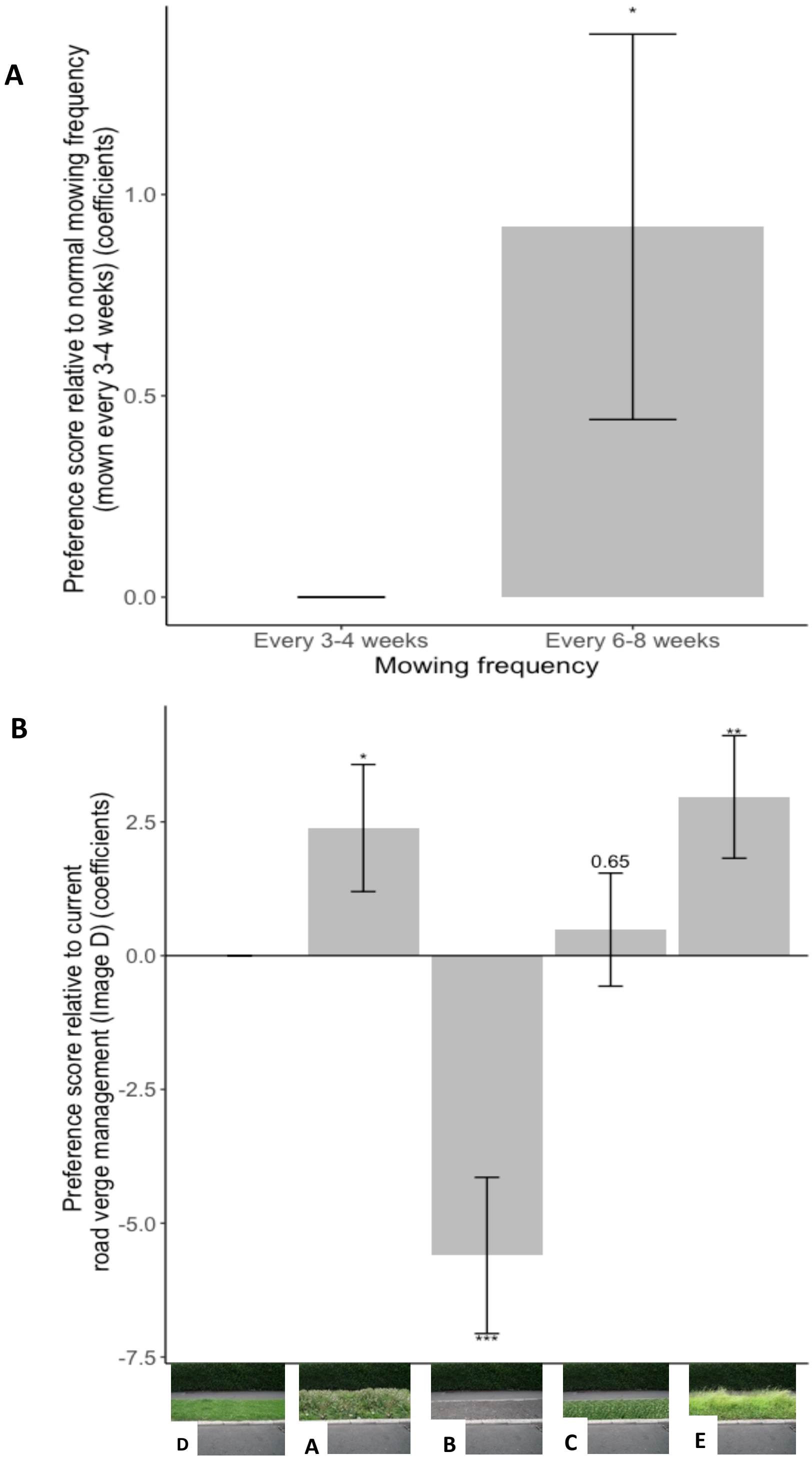

Figure 3.5 Coefficients for local residents' (A) attitudes towards the ability of road verges with different mowing regimes (every 3-4 weeks and every 6-8 weeks) to support biodiversity and (B) attitudes towards different road verge images' (A-E) ability to support biodiversity when compared with the current road verge management (Image D) using a cumulative link mixed model. Standard error and significance levels (*P<0.05; **P<0.01;

***P<0.001) are shown. Residents were asked the following question (A), "Based on your experience from last spring and summer, please give a score from 0 to 10 for how good you think the road verge on your side of the road and the opposite side of the road were for supporting a wide range of plants and animals such as insects, where 0 is very poor and 10 is very good" and (B) Looking at the same photographs as Question 1, please give a score from 0 to 10 for how good you think each of the five verges types are for supporting a wide range of plants and animals such as insects, where 0 is poor and 10 is very good".

Table 3.4 Results from the global cumulative linked mixed model asking “During the spring and summer last year, a mowing trial was taking place on your road. Thinking back to that time, please give a score from 0 to 10 for how good you think the road verge on your side of the road and the opposite side of the road are for supporting a wide range of plants and animals such as insects, where 0 is poor and 10 is very good”. Data reported are parameter estimates, standard error, z-value and P-value. Attitudes regarding typical mowing frequency (every 3-4 weeks) was used as the reference intercept, so all results are compared to these values. Values in bold indicate a significant effect on mowing preference.

Variables	**Parameter estimate ± standard error**	**z-value**	**P-value**
Reduced mowing frequency	**0.92±0.48**	**1.92**	**0.05**
Age (25-34)	0.12±1.99	0.06	0.95
Age (35-44)	0.80±1.84	0.43	0.66
Age (45-54)	-0.34±1.71	-0.20	0.84
Age (55-64)	-0.27±1.67	-0.16	0.87
Age (65-74)	0.52±1.64	0.32	0.75
Age (75-85)	0.03±1.67	0.02	0.99
Gender (male)	-0.12±0.52	-0.23	0.81
Ethnicity (white)	1.42±2.12	0.67	0.50
Index of Multiple Deprivation (16,000-32,000)	-1.38±0.80	-1.72	0.08
Final qualification (GCSE)	1.47±1.20	1.22	0.22
Final qualification (Diploma)	1.28±1.23	1.04	0.30
Final qualification (Bachelor degree)	2.03±1.23	1.65	0.10
Final qualification (Postgraduate degree)	2.14±1.26	1.69	0.09

Table 3.5 Results from the global cumulative linked mixed model asking, “Looking at the same photographs as Question 1, please give a score from 0 to 10 for how good you think each of the five verges types are for supporting a wide range of plants and animals such as insects, where 0 is poor and 10 is very good”. Data reported are parameter estimates, standard error, z-value and P-value. Attitudes regarding Image D (typical mowing frequency every 3-4 weeks) was used as the reference intercept, so all results are compared to these values. Values in bold indicate that they have a significant effect on perceived benefit for supporting plants and animals.

Variables	**Parameter estimate± standard error**	**z-value**	**P-value**
Image A	**2.38±1.19**	**2.01**	**0.05**
Image B	**-5.60±1.46**	**-3.84**	**<0.001**
Image C	0.49±1.06	0.46	0.65
Image E	**2.97±1.15**	**2.59**	**0.01**
Nature relatedness	0.09±0.29	0.32	0.75
Age (25-34)	-1.90±2.06	-0.92	0.36
Age (35-44)	-2.67±2.00	-1.34	0.18
Age (45-54)	-3.17±1.96	-1.62	0.11
Age (55-64)	-3.05±1.98	-1.54	0.12
Age (65-74)	-3.41±1.94	-1.75	0.08
Age (75-85)	**-4.85±1.97**	**-2.46**	**0.01**
Age (85+)	-3.69±2.72	-1.36	0.18
Gender (Male)	0.31±0.38	0.82	0.41
Ethnicity (White)	1.41±1.16	1.23	0.22
Index of Multiple Deprivation (16,000-32,000)	0.07±0.66	0.10	0.92
Final qualification (GCSE)	-0.01±0.63	-0.01	0.99
Final qualification (Diploma)	1.01±0.60	1.69	0.09
Final qualification (Bachelor degree)	-0.69±0.68	-1.01	0.31
Final qualification (Postgraduate degree)	0.02±0.59	0.03	0.97
Image A: Nature relatedness	0.22±0.32	0.70	0.48
Image B: Nature relatedness	0.05±0.38	0.12	0.91
Image C: Nature relatedness	0.25±0.28	0.87	0.39
Image E: Nature relatedness	-0.12±0.30	-0.41	0.69

3.5 Factors affecting the public responses towards urban road verge management

3.5.1 Exploratory factor analysis

The statements from Question 5 in the postal questionnaire (Appendix 3.9) were suitably correlated (Chi-squared=195.18, $p<0.001$, df=21) and had a large enough sample size (MSA=0.78) for factor analysis. The scree plot (Appendix 3.10) and parallel analysis indicated that two factors would be the most suitable for the exploratory factor analysis. The exploratory factor analysis model with 2 factors indicated that each statement loaded onto one of two factors (statements 5b, 5c,5e,5f,5g loaded onto Factor 1 and statements 5a and 5d loaded onto Factor 2) with all statements loading greater than 0.30. The fit indices for the two factor model indicated a good fit (Table 3.6). However, as Factor 2 was below the threshold of Cronbach's Alpha (Table 3.6) indicating Factor 2 was unreliable and factors should ideally have 3-5 items per factor as recommended in Fabrigar et al., (1999), an exploratory factor analysis was conducted with 1 factor. Factor loadings for statements 5a and 5d were below the 0.3 threshold with one factor (Table 3.7) and therefore were removed from exploratory factor analysis. The 1 factor model without the two statements provided a good fit and had good internal reliability (Table 3.6).

Table 3.6 Fit indices (Root Mean Square Error of Approximation (RMSEA), Standardized root mean residual (SRMR), Tucker-Lewis nonnormed fit index (NNFI) and Comparative fit index (CFI)) and Cronbach's Alpha for the two exploratory factor analysis models.

Exploratory factor model	RMSEA	SRMR	NNFI	CFI	Cronbach's Alpha
1 factor model (without 5a and 5d)	0	0.03	1	1	0.79
2 factor model	0	0.03	1	1	Factor 1: 0.79 Factor 2: 0.43

Table 3.7 Factor loadings from the final 1 factor exploratory factor analysis model. Statements with factor loadings greater than 0.30 are indicated in bold.

Statement	Factor 1
5a: The appearance of a roadside verge doesn't matter to me	-0.15
5b: Managing roadsides for nature is important to me	**0.76**
5c: I would prefer roadside verges to be tarmacked	**0.49**
5d: I like roadside verges to look neat and tidy	-0.22
5e: I don't mind if vegetation on a verge is taller (i.e. up to 30cm/1 foot in height) if it is beneficial to nature	**0.79**
5f: It is not important to manage roadsides to benefit nature	**0.46**
5g: Efforts to conserve urban nature should focus on parks not roadside verges	**0.85**

3.5.2 Residents' responses towards road verge conservation analysis

Participants' nature relatedness score had a significantly positive impact on participant's assigned values and attitudes towards road verge conservation (using an index) but there was no significant difference for any of the participant's sociodemographic variables (Table 3.8). Final qualification was marginally insignificant (p=0.08) in the analysis regarding participant's assigned values and attitudes towards road verge conservation (Table 3.8).

Table 3.8 Results of the GLMM testing for differences in participant's assigned values and attitudes towards road verge conservation using a conservation index. Road was included as a random factor. Parameter estimates and standard errors are presented and significant results are indicated in bold.

Variables	**Parameter estimate± standard error**	**P-value**
Age (25-34)	-0.47±5.72	0.86
Age (35-44)	1.03±5.63	
Age (45-54)	-1.64±5.48	
Age (55-64)	-2.03±5.53	
Age (65-74)	-1.17±5.42	
Age (75-85)	-1.75±5.45	
Age (85+)	0.22±6.76	
Gender (Male)	0.36±1.07	0.73
Ethnicity (White)	1.53±3.17	0.63
Index of Multiple Deprivation (16,000-32,000)	-0.16±1.47	0.91
Final qualification (GCSE)	-2.82±1.77	0.08
Final qualification (Diploma)	-1.63±1.74	
Final qualification (Bachelor degree)	1.79±1.87	
Final qualification (Postgraduate degree)	1.56±1.73	
Nature relatedness	**1.73±0.65**	**0.01**

3.6 Sociodemographic information

Respondents under 18-24 represented a smaller percentage (3.9% for the face-to-face and 0.8% for postal questionnaires) of both questionnaire responses than would be expected for UK and Sheffield populations (8.7% and 14.2% respectively)(Table 3.9)(Office for National Statistics, 2018a). The proportion of females responding to the questionnaires was slightly more than the typical UK and Sheffield populations (50.7% and 50.3% respectively) (Table 3.9)(Office for National Statistics, 2018a). For both face-to-face and postal questionnaires, white was the dominant ethnicity, with other ethnicities only comprising of a small proportion of responses (6.5% and 3.2%) (Table 3.9). The dominant employment situations for both questionnaires were retired people (34.5% for face-to-face questionnaires and 45.5% for postal questionnaires) and people that work full time (33.6% and 28.5% for face-to-face and postal questionnaires), suggesting that there is unlikely to be a bias in responses based on the time of day or day of the week (Table 3.9). Respondents had a range of highest level of qualifications, with the most common being GCSE, O Level or below (40.1% for face-to-face questionnaires and 37.1% for postal questionnaires) (Table 3.9).

3.7 Recollection of the mowing trial

Questionnaires asking attitudes and assigned values relating to the mowing trial were conducted in the winter after the mowing trial took place. This may have influenced attitudes and assigned values as participants may have remembered the trial differently from memory compared to when it was taking place. To control for this, we assessed whether the respondents remembered the mowing trial at the beginning of the questionnaire. Whilst some qualitative responses were related to the current conditions on the road (ie winter conditions), these were few in number. Indeed, the length of time after the responses had taken place may have ensured that the reactions shown were long term views from the mowing trial across the whole growing season rather than just initial reactions.

Table 3.9 Summary statistics (percentage and number of responses) for sociodemographic variables for both door to door and postal questionnaires.

Variable	Face-to-face questionnaire	Postal questionnaire
Age		
18-24	3.9 % (n=9)	0.8% (n=1)
25-34	11.6 % (n=27)	5.9% (n=7)
35-44	16.8% (n=39)	12.6% (n=15)
45-54	17.2% (n=40)	21.0% (n=25)
55-64	17.7% (n=41)	20.2% (n=24)
65-74	19.8% (n=46)	25.2% (n=30)
75-85	10.8% (n=25)	14.3% (n=17)
85+	2.2% (n=5)	2.5% (n=3)
Gender		
Male	43.55% (n=101)	44.6% (n=54)
Female	56.5% (n=131)	55.4% (n=67)
Ethnicity		
White	93.1% (n=216)	96.8% (n=120)
Other	6.5% (n=15)	3.2% (n=4)
Employment situation		
Study full time	0.4% (n=15)	0.0% (n=0)
Retired	34.5% (n=80)	45.5% (n=56)
Housewife/househusband	7.8% (n=18)	4.9% (n=6)
Work full time	33.6% (n=78)	28.5% (n=35)
Work part time	15.5% (n=36)	13.0% (n=16)
Unemployed/between jobs	6.0% (n=14)	2.4% (n=3)
Freelance/self-employed	1.7% (n=4)	5.7% (n=7)
Highest level of qualification		
GCSE & O level or below	40.1% (n=93)	37.1% (n=46)
A level	19.8% (n=46)	15.3% (n=19)
Diploma	11.2% (n=26)	14.5% (n=18)
Bachelor degree	13.4% (n=31)	12.9% (n=16)
Postgraduate degree	15.5% (n=36)	20.2% (n=25)

4. Discussion

We demonstrate that (i) road verges managed at the current mowing frequency (mown every 3-4 weeks) were preferred by residents both when compared to a reduced mowing frequency (every 6-8 weeks) experienced on their road and to other hypothetical road verge scenarios and (ii) current management was considered less likely to support a wide range of plants and animals on road verges than either the reduced mowing implemented on their road, or other, hypothetical, scenarios involving taller vegetation.

Participants who were consistently against mowing less frequently were more likely to be concerned by factors such as dog faeces and litter presence, to prefer neat and tidy verges, and were less likely to mention wildlife as a factor. Participants who were consistently in favour of mowing less frequently were more likely to think that the mowing trial had a positive impact on wildlife. Sociodemographic variables did not influence participants' assigned values and attitudes towards road verge conservation but a participant's nature relatedness score did have a significantly positive impact on their assigned values and attitudes towards road verge conservation.

4.1 Residents' attitudes regarding the mowing trial on their road and factors affecting residents' attitudes

Participants significantly preferred road verges mown every 3-4 weeks compared to road verges mown every 6-8 weeks when a mowing trial took place on their road. Our findings suggest that participants preferred highly managed vegetation compared to more wild, longer vegetation, supporting the results of previous studies (Weber, Kowarik, & Säumel, 2014a; Hofmann et al., 2012; Lucey & Barton, 2011). These results support the idea that positive preference for short, maintained lawn like vegetation is widespread across Western countries and seen as a cultural norm (Ignatieva et al., 2017; Kaufmann & Lohr, 2002; Nassauer, 1995).

Evidence from the qualitative answers suggested that neat and tidy vegetation and, to a lesser extent, concern about litter and dog faeces, were aesthetic values more likely to be important for people who were against mowing road verges less frequently. This accords with the idea that most people find orderliness and signs of human control and care to be important (Weber, Kowarik, & Säumel, 2014a; Lucey & Barton, 2011; Özgüner & Kendle, 2006; Hands & Brown, 2002; Nassauer, 1995).

Perceived effects of verge management on wildlife appear to contribute to people's attitudes to the mowing trial. Participants who were in favour of mowing less frequently were more likely to think that the mowing trial had a positive impact on wildlife. Whilst it is not clear specifically what this positive impact on wildlife was thought to be, vegetation complexity such as vegetation height is thought to be a potential cue to perceived plant species richness (Southon et al., 2018) and therefore, this may have influenced the perception that the mowing trial may be beneficial for wildlife. People who were against mowing less frequently were also less likely to mention wildlife, perhaps suggesting that while they do not consider reduced mowing to be detrimental to wildlife, this factor does not influence their attitudes.

An important element of this study was that the management change was real and taking place on the road outside participants' houses. As a result, outcomes may be influenced by 'place attachment', which is defined as, "an affective bond or link between people and specific places" (Hidalgo & Hernández, 2001). People who are more attached to a certain place have been linked with negative attitudes to changes in condition in the area they are attached to (Kyle et al., 2004). In this case, it may be that negative reactions to reduced mowing were strengthened by such an effect, particularly relative to hypothetical scenarios. Time may also be an important factor. Our study examined the response to a management change which had only occurred over one mowing season, so provided a strong contrast with the familiar norm. It is possible, that over time people's expectations would change, and management that is unpopular now, would become more acceptable. However, there is a lack of knowledge regarding the long term perceptions of road verge management changes, with the only study, Everett et al., (2018) indicating there was no clear change in public attitudes and perceptions to introduced bioswales over time in Portland, USA. Further research assessing whether attitudes change over time to a management change is required.

Another potential complicating factor is that participants had been provided with information that the mowing trial was taking place and why. While such basic information for the public was a necessity for such an experiment as this, we were careful that no additional information relating to cost implications or biodiversity benefits were provided. The converse of this is that if such management changes were to be adopted operationally, the provision of additional information may influence the perception of alternative management (Ramer et al., 2019; Southon et al., 2017; Lucey & Barton, 2011). Indeed, Southon et al., (2017), found that the provision of information relating to the benefits of the management change increased the acceptance of longer urban wildflower meadows in UK parks. In a US study, assessing whether information influences the perception of management, the use of facts in video format increased the acceptance of flowering meadows and decreased the desirability of mown grass but when presented information in paper format, acceptance for unmown turf was significantly lower (Lucey & Barton, 2011). Information provided to residents needs to be carefully framed as statements about specific species which the residents see negatively may influence perceptions of the management change (Ramer et al., 2019). This may indicate that additional information may increase the acceptability of some alternative management strategies, but not others.

4.2 Responses regarding hypothetical road verge management scenarios

Consistent with the preferences from the actual mowing trial, current management (mown every 3-4 weeks) was significantly preferred compared to all other hypothetical scenarios offered to participants, with the option depicting a grass verge mown less frequently, with long grass, rated the least favourable. Similarly, a floristically diverse road verge, but with similar vegetation height was the next least preferred scenario when compared to current management. Jiang & Yuan, (2017), a Chinese study assessing public perceptions and preferences of wildflower meadows using questionnaires and photographs, demonstrated that people had a lower preference for urban meadows than short lawns and natural grasslands. However, they also found that natural grasslands were preferred over short lawns, contrasting our results. These contrasting views may be influenced by the setting, with the natural grassland image used from a national park compared to the residential background within our study. Our images of floristically diverse tall vegetation and of long grass were edited so that they appeared the same height, but they differed in species composition and flower abundance. This suggests that participants rating the former more positively than the latter are consistent with earlier studies that indicate flowers and flower colour diversity positively influences aesthetic response (Hoyle et al., 2018; Graves, Pearson, & Turner, 2017; Todorova, Asakawa, & Aikoh, 2004).

The contrast between our results and those of some other studies (Gobster et al., 2007) may be partly contextual. In a park setting, Southon et al., (2017) demonstrated wildflower meadows to be more favourable to members of the public than short amenity grassland and Garbuzov et al., (2015) found that the majority of participants found taller grass from reduced mowing to be suitable. In a motorway/highway setting, one study showed that one of the least favourable options for participants was tidy, frequently mown, grass (Akbar, Hale, & Headley, 2003), whilst another study indicated found that the reduced management of sloped embankments on highways were infrequently noticed but when noticed, were received, in general, positively (Froment & Domon, 2006). In inner city areas, wild road verge vegetation can met with high approval (Weber, Kowarik, & Säumel, 2014a), although this specific study's participants were members of the public rather than specifically residents living on the road, directly experiencing a management change. This may suggest that alternative management with a more natural, wild appearance may be more favourably received when not directly outside residents' houses.

Although marginally a non-significant preference in our results, our scenario of a road verge dominated with low lying forb species such as *Trifolium repens* was rated the next best option after current management. This concurs with the results of Ramer et al., (2019), where participants strongly supported the implementation of flowering lawns in US parks. Although a much less well studied option than longer meadow vegetation, such low growing floristically more diverse verges may be a plausible alternative approach. Participants in Ramer et al. (2019) identified aesthetics as the main benefit, with 56% having no concerns about this type of management.

Interestingly, although participants preferred short grass to a vegetation-free 'verge' (the verge area being tarmacked), such an option was, nonetheless, preferred to the two scenarios with tall vegetation (floristically diverse, or just grass). Whilst viewing an image of a section of road verge may elicit a different response compared to viewing a whole street without vegetation, Bonthoux et al., (2019) which showed images of a road verge along the length of a whole street and Fischer et al., (2018) depicting the area around a street tree, both concluded that all vegetated streets were preferred over streets without vegetation.

Participants with a higher connectedness to nature were more likely to rate hypothetical scenarios of floristically diverse tall vegetation and long grass more favourably, as well as have a significantly positive impact on their assigned values and attitudes towards road verge conservation. These findings support Southon et al., (2017) demonstrating that people who have high ecocentric values are more likely support urban meadows. Urban meadows and mowing road verges less frequently provide greater biodiversity benefits than Image D, short, highly managed vegetation (Norton et al., 2019; Richardson et al., in prep [Chapter Two]). This is further supported by our finding that participants' connectedness to nature had a positive impact on their attitudes and assigned values towards road verge conservation. Collectively, these results supports the idea that there is a relationship between people who have a high connectedness to nature and pro-environmental attitudes and behaviour (Whitburn, Linklater, & Abrahamse, 2019; Gosling & Williams, 2010; Kaltenborn & Bjerke, 2002), therefore supporting Schultz, (2000)'s idea that environmental concern can be linked with how a person sees themselves as part of nature and Wilson (1984)'s 'biophilia' hypothesis. Activities that encourage connectedness to nature, such as engagement with nature may increase the likelihood of pro-environmental behaviour (Schultz, 2011).

Older people had a significantly negative perception of reduced mowing and other alternative scenarios relative to current management, similar to Ramer et al., (2019). In addition, older people were more likely to rate other scenarios to be worse at supporting wildlife relative to current management. This may be because they are more inclined to perceive mown grass as a cultural norm (Ignatieva et al., 2017). Landscapes perceived to be more natural were found to be relatively unimportant for older people in Zube, Pitt, & Evans, (1983) and Bjerke, Østdahl, Thrane, & Strumse (2006) found people older than their 40s had a lower preference for high vegetation density in Norwegian urban parks. Young adults and people of ethnicities other than white were not well represented within our study but, given the nature of the sampling design, this was unavoidable as every house was visited on the mowing trial roads.

4.3 Attitudes towards perceived biodiversity benefits

Reduced mowing frequency were generally perceived to be better at supporting biodiversity, both by residents on their own road and in hypothetical scenarios. Visual factors such as vegetation height and colour diversity have been proposed as potential cues for people to assess species richness (Hoyle et al., 2018; Southon et al., 2018). Our results partially support this idea, with the tallest vegetation perceived to provide the most biodiversity benefits. However, there was no clear link with colourfulness: of the two tall vegetation scenarios, the grass-only option was rated highest for biodiversity benefit. No strong relationship was found between aesthetic value and perceived biodiversity, a finding consistent with Qiu, Lindberg, & Nielsen, (2013). Participants' connectedness to nature did not impact attitudes towards scenarios to support wildlife. Previous studies find people are good at identifying general types of wildlife (Hoyle et al., 2018) but not as good at identifying species (Dallimer et al., 2012), perhaps indicating that for perceived wildlife support, traits related to connectedness to nature were not required. However, Southon et al., (2018) found that connectedness to nature was positively associated with increased accuracy identifying plant species richness.

4.4 Management Implications

Our results indicate that a reduction in mowing frequency of urban road verges was perceived negatively by local residents experiencing the change over a growing season. This is also reflected in preferences of alternative hypothetical scenarios, indicating that residents prefer the status quo of short, highly maintained grass verges, despite the recognition that this is not the best option to support biodiversity. This has implications for road verge managers who are looking to alter management, as our results indicate that the management option of reducing the mowing frequency of urban road verges may not be viewed positively by local residents, at least on short timescales. There is a possible indication in our results that road verges with low lying flowering forbs may be a potentially acceptable alternative to current management with respect to public aesthetic preference.

Further investigation into the design and composition of such road verges for biodiversity and aesthetic value is required.

The issues of public response found in our study suggest there may be a need for ways of influencing attitudes towards alternative management strategies. In particular (i) incorporating 'signs of care' and (ii) public involvement in, and information about the benefits of management changes.

Results from this study indicate that orderliness is a key factor for local residents, supporting studies which have shown that people are more willing to accept more 'wild' vegetation if there are cues to care, signs that deliberate management has taken place (Hofmann et al., 2012; Özgüner & Kendle, 2006; Hands & Brown, 2002; Nassauer, 1995). Relating to the mowing trial, this sign of management could be something as small as strimming a small section next to the pavement or road to prevent encroachment. Arisings left on the road verge were mentioned negatively in some of the qualitative answers of this study (Appendix 3.6), indicating that perhaps a more visible sign of care could be the removal of arisings from the grass verge. However, it is recognised that this may be difficult from a logistic perspective and may potentially add to costs, contrary to the intended financial benefits of a management change (Richardson et al., in prep [Chapter Four]).

Greater incorporation of public assigned values and attitudes to proposed management changes through consultation is recommended as alternative management strategies are increasingly proposed as part of cost-effective measures. Presenting the facts regarding cost savings and environmental benefits to members of the public has been shown to increase acceptance of alternative management strategies (Southon et al., 2017; Lucey & Barton, 2011).

We show that current road verge management, mowing every 3-4 weeks, is the preferred management, when compared to reduced mowing, despite potential ecological and cost benefits of the latter. These results point to the importance of investigating strategies to inform and engage local residents and devise management strategies that show elements of care.

Chapter Four: Road verge management in England and factors that influence management decisions

Abstract
With appropriate management, road verges, including those in urban areas can provide a number of different ecosystem services and biodiversity value. However, there is a lack of systematic information about how urban road verges are typically managed and what factors influence that management. We address this gap in knowledge through 37 semi-structured interviews with road verge managers (local authorities and contractors) from unitary authorities and metropolitan districts across 8 regions in England, UK to investigate current road verge management practice, factors affecting that, and the resources used to make decisions. Nearly half (48.7%) of councils managed road verges in house, with the remaining partially or fully contracting out management. Alternative management techniques commonly used were the reduction of mowing frequency and wildflower planting. Road verge managers identified seven factors that affect management: (i) financial considerations and resources, (ii) public perception and public actions, (iii) safety, (iv) biodiversity and wider environmental benefits, (v) physical factors, (vi) spatial context and (vii) departmental and councillor input. Financial and resource factors were key in influencing management, as 70.6% of road verge managers indicated their budgets had decreased significantly. Safety factors and public perception were also strong factors influencing road verge management. When making a management decision, road verge managers most commonly gained knowledge from people within the council and other local authorities. Changes in management as a consequence of budgetary cuts may provide an opportunity to maximise biodiversity benefits. Our findings have implications for road verge managers and those developing alternative management strategies.

1. **Introduction**

Urban green spaces can provide a number of ecosystem services (Bolund & Hunhammar, 1999), including carbon storage (Davies et al., 2011), air pollution reduction (Sæbø et al., 2012; Nowak, Crane, & Stevens, 2006), psychological benefits (White et al., 2013; Fuller et al., 2007), and social interaction (Sullivan, 2004) as well as supporting high levels of species richness (Ives et al., 2016; Baldock et al., 2015; Aronson et al., 2014). However, increasing urbanisation and population density can threaten urban green space (Haaland & van den Bosch, 2015). Therefore, managing green space to maximise the provision of ecosystem services, particularly in urban areas is key (Gaston, Ávila-Jiménez, & Edmondson, 2013) and furthermore, the restoration of these services has been found to be financially beneficial (Elmqvist et al., 2015).

Managing urban green space for ecosystem services is complex with multiple land owners and managers involved over a fragmented environment (Andersson et al., 2014; Gaston, Ávila-Jiménez, & Edmondson, 2013). Current urban green space management practices have been found to have little interaction between green space actors at different scales (Andersson et al., 2014; Ernstson et al., 2010; Borgström et al., 2006). Local groups have been found to be important in ecosystem service management but are often not involved in decision making (Ernstson et al 2010; Andersson et al., 2014). In recent years, numerous alternative concepts have been proposed for environmental management to increase the resilience of urban ecosystems to change, focusing on multiple benefits.

Ecosystem stewardship can be defined as, "a strategy to respond to and shape social-ecological systems under conditions of uncertainty and change to sustain the supply and opportunities for use of ecosystem services to support human well-being" (Chapin et al., 2010). Rather than management to maintain previous conditions, ecosystem stewardship focuses on the principles of using uncertainty as an opportunity to increase resilience by reducing risks, preserving diversity and engaging local residents and stakeholders in adapting management (Chapin et al., 2010). Measures undertaken by different environmental stewards ("individuals, groups or networks of actors" (Bennett et al., 2018)) to manage and maintain the landscape collectively with links to government, can provide urban ecosystem service delivery (Connolly et al., 2014; Krasny et al., 2014).

Often described as an “umbrella concept” for numerous terms including ecosystem services, resilience and green infrastructure (Lafortezza et al., 2018; Nesshöver et al., 2017; Kabisch et al., 2016), nature-based solutions are, “solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions” (European Commission, 2020). This focuses on maximising the benefits of current ecosystems through restoration and enhancement as well as developing new ecosystems (Cohen-Shacham et al., 2016).

An advocated step to increase success for both of these concepts, focuses on the idea that numerous actors are involved in management decision making (Nesshöver et al., 2017; Chapin et al., 2010). Instead of management overseen by government, adaptive co-management are, “flexible community-based systems of resource management tailored to specific places and situations and supported by, and working with, various organizations at different levels”(Kofinas, 2009; Olsson, Folke, & Berkes, 2004). This concept focuses on the ideas that management is flexible, involves individuals and organizations between and across multiple scales, and requires monitoring, partnership and social learning (Armitage et al., 2009; Kofinas, 2009).

A highly conspicuous but understudied area of urban green space are road verges, areas of vegetation directly next to roads. Collectively, these can be large areas, covering 80,000 km linear distance in the Netherlands (Noordijk et al., 2010), and areas of 140,000 hectares in Finland (Saarinen et al., 2005) and an estimated 6.9 million hectares of roadsides in the USA (Hopwood, Black, & Fleury, 2015). In urban areas this is also the case, with road verges in a German study comprising 10-25% of total urban green space managed by park departments (Weber, Kowarik, & Säumel, 2014a) and 36.7% of urban green space in Melbourne, Australia (Marshall, Grose, & Williams, 2019a).

A number of different management methods can be employed to manage road verge vegetation and when taking into consideration all elements of road verge vegetation (grass verges, trees, hedges and shrubs), these different options can provide a variety of different ecosystem services and be of differing biodiversity value (O'Sullivan et al., 2017; Säumel, Weber, & Kowarik, 2015). To understand the current outcomes, and potential for management change, a baseline understanding of what management is typically undertaken and how widespread these types of management are, is needed. However, because verges are typically managed locally, to our knowledge there is little systematic information and research in this area.

Public road verges are managed by government bodies in many countries around the world, including Germany (Weber, Kowarik, & Säumel, 2014a), Finland (Saarinen et al., 2005) and the USA (Hopwood, Black, & Fleury, 2015). Under the Highways Act 1980, highway authorities and in local areas, councils in the UK have the responsibility to maintain roadsides (Great Britain, 1980). Since the 1970s, road verge maintenance has been increasingly being contracted out to private companies, with contract lengths varying from 3- 25 years (Dempsey, Burton, & Selin, 2016). Therefore, understanding the perspectives of road verge managers is crucial to identifying opportunities and constraints of both current and future management.

For effective conservation management, decisions need to consider not only ecological information, but additional management factors such as economic, social and political factors (Knight et al., 2011). Whilst there have been a number of studies assessing urban green space management from the perspective of the public (e.g Fischer et al., 2018; Southon et al., 2017; Weber, Kowarik, & Säumel, 2014a), few have investigated the perspective of urban green space managers (Shams & Barker, 2019; Barnes et al., 2018; Ignatieva et al., 2017; Hoyle et al., 2017). Studies that have assessed green space managers' perceptions of what factors need to be accounted for in management decisions, highlight that practicality (Ignatieva et al., 2017), aesthetic and public reaction (Hoyle et al., 2017), locational context (Hoyle et al., 2017) and economic factors and resources (Ordóñez et al., 2019; Hoyle et al., 2018) play a key role. However, these results derive almost exclusively from management of greenspace other than roadsides. One exception is a study conducted in 1973 with county councils around England and Wales, which indicated that safety, amenity, weed control, drainage and an unobstructed highway were key reasons for management of rural road verges (Way, 1973).

Previous research assessing management practices by conservation decision makers has indicated that a number of sources can influence the decision to implement a management action and often, this is not evidence-based (Matzek et al., 2014; Cook et al., 2012; Sutherland et al., 2004). Instead, personal experience and knowledge is commonly used with time and access to resources being cited as factors limiting the use of scientific evidence (Matzek et al., 2014; Pullin & Knight, 2005).
Whilst there are a number of studies focusing on the ecological impacts of different roadside verge management, there is little research about how widespread different management techniques are, how the road verge managers (councils and contractors) select management options for roadside habitats and what drivers influence this. This study focuses on urban road verges in the UK, and aims to address three questions: (i) how are road verges currently managed, (ii) what factors influence road verge management decisions and (iii) what resources do road verge managers use when making the decision to alter management practices? These questions are examined through evidence derived from semi-structured interviews with road verge managers of major towns and cities in England, UK.

2. Methods

2.1 Study design

Highway authorities are responsible for managing roadside verges in Great Britain (Great Britain, 1980). Highways England, Transport Scotland and the Welsh Government manage motorways and major (trunk) 'A' roads but as 96.9% of the total road length in Great Britain is managed by local authorities (county councils, unitary authorities, metropolitan districts with some District, Parish or Community Councils), each of whom have the authority to manage road verges based on their own chosen methods, this study focused on local authorities using key informant sampling (Plantlife, 2019; Young et al., 2018; Department for Transport, 2018). Interviewees included both local authority managers and, since many local authorities contract out road verge management, contractors.

Urban areas were initially identified using population estimates data for major towns and cities (defined by the Office for National Statistics as an area with a 'resident or workday population of at least 75,000 people') in England and Wales from mid 2016 (Office for National Statistics, 2016a, 2018b). Wales and Scotland have devolved powers and funding, and were excluded from this study (Cabinet Office et al., 2019). Large towns and cities managed by unitary authorities and metropolitan districts in England were initially selected from these data and were categorized by region within England (Appendix 4.1) (Ministry of Housing Communities & Local Government, 2016; Office for National Statistics, 2016b). Unitary authorities and metropolitan districts were selected as they are responsible for all services in their area, and thus would provide a good representation of road verge management within that area (Ministry of Housing Communities & Local Government, 2016). London was excluded from this initial selection due to its large population size, making it difficult to compare with other towns and cities in England. This selection provided 69 councils all of whom were contacted.

Councils and contractors were invited to participate using a two-step process: (i) the relevant council was rung to identify a suitable decision maker/s and gain contact details and then (ii) the decision maker was then emailed with details about the research project and the consent form to allow them to make an informed decision to participate. To identify the appropriate decision maker, contact was requested for either the person in charge of road verge management or someone equivalent to a Grounds Maintenance Operational Manager. From personal communication with a large contractor, the role of a Grounds Maintenance Operational Manager was identified as the most appropriate person to speak with regarding management decisions, so this role was used as an example when asking for the appropriate decision maker if there was not someone specifically identified as in charge of road verge management. Potential interviewees were given the option to take part in the interview face to face, by telephone or by Skype.

In total 38 managers agreed to be interviewed, representing 37 local authorities. Distribution of these was relatively even across the regions of England (Fig 4.1).
Most interviews (36) took place by telephone and one interview took place face to face. The interviews were recorded using a Sony ICD-UX560 Digital Stereo Voice Recorder when permission was given by the participant, to allow for more accurate analysis of the interview. Participants were aware throughout that their identity, their organisation, and their responses would not be revealed. Interview protocols and subsequent handling of data were approved by the University of Sheffield Research Ethics Committee (reference number 016197).

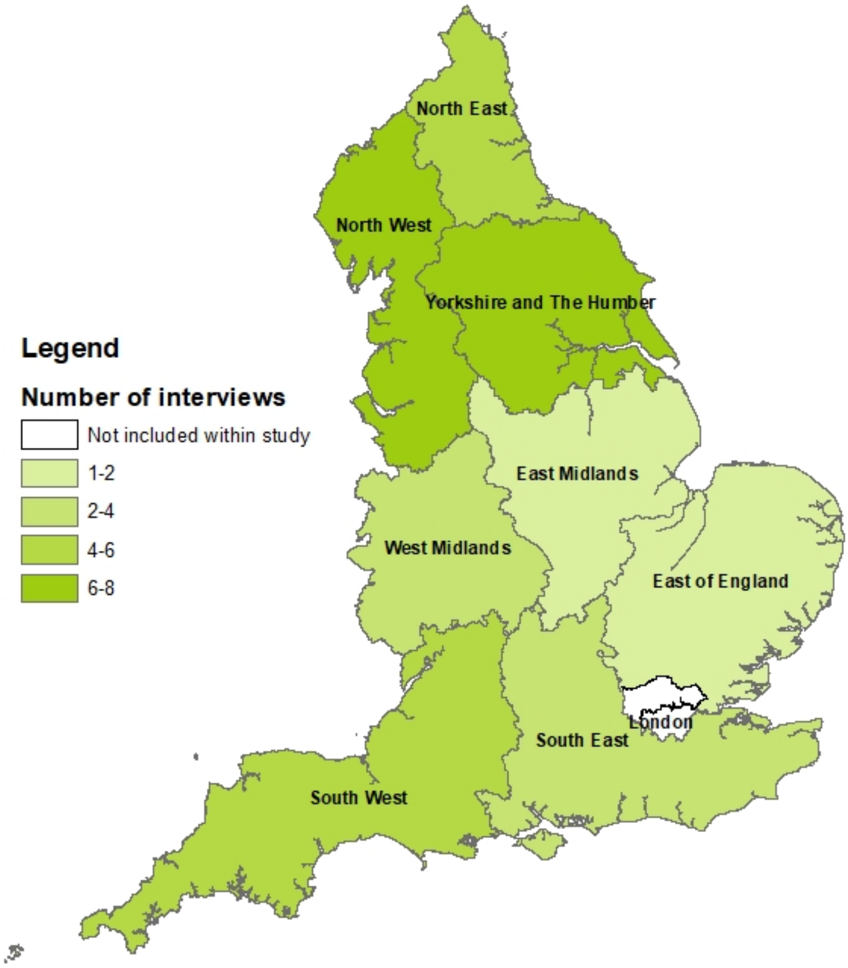

Figure 4.1. The number of semi-structured interviews conducted with road verge managers by geographic area in England, UK. Contains National Statistics data © Crown copyright and database right [2018]. Contains OS data © Crown copyright and database right [2018].

2.2 Semi-structured interviews

Semi-structured interviews involve asking broad open ended questions and then use of an interview guide which acts to provide follow up questions (Bryman, 2016). This avoids bias in what the interviewer thinks is a key question, allowing themes and questions to be identified based on the interviewee (Bryman, 2016).

Initial themes of factors that may affect road verge management decisions were identified through reading the scientific literature, reading through council webpages on road verges and from personal observations working in a research partnership, involving academics, an NGO and a road verge management contractor (O'Sullivan et al., 2017; Parr & Way, 1988; Way, 1973).

To gain an understanding of the background information about the decision maker's experience working in greenspace management and the council/contractor's organisation, participants were asked four to six initial questions, dependent upon whether they are the contractor/or contract out the work to another company. These questions were based on the experience and time in role of the interviewees and some background information if they contracted out the management of roadside verges.

Five broad questions were then initially asked, "How are different road verges classified in your organization?", "Considering the different types of road verges, please could you briefly describe to me how you currently manage road verges in your area?", "What are the main factors that influence why you manage road verges in this way?", "How do you make your decisions about road verge management?" and "Has any alternative management been used or considered on road verges in your area?" Follow up questions were then asked using an interview schedule (Appendix 4.2) which listed potential follow up questions if something was, or wasn't, mentioned in the response from the initial questions (Young et al., 2018). The order of the follow up questions varied with each decision maker dependent on the topic of conversation at the time.

2.3 Data Analysis

All audio recordings were transcribed using the software Trint (https://trint.com). Qualitative content analysis was used to analyse the interview data. Using NVivo for Mac (v12), transcripts were coded by themes within each general question. Initial themes created before the interviews were then revised accordingly. Road verge managers were coded numerically (RM), to retain anonymity.

Roles for road verge managers fell into four categories: (i) Council- Operational and/or strategy (managing staff and responsible for maintaining greenspace and/or responsible for strategy/development for the service), (ii) Council- Contractual (supervises contracts when all of grounds maintenance is contracted out), (iii) Council- External communications (engagement with third parties relating to green space management) and (iv) Contractors- Operational and/or strategy (managing staff and responsible for maintaining greenspace and/or responsible for strategy/development for the contract they have been contracted to). Relevant experience was defined as previous experience working in greenspace management prior to their current role managing greenspace. Experience working in green space management ranged from 6-43 years and were divided into three broad categories: 0-15 years, 16-30 years and 31-45 years. Relevant green space qualifications were broken down into two main categories: (i) relevant greenspace qualifications (if mentions qualifications in subject areas such as arboriculture, horticulture, landscape, environmental management, ecology, environmental geoscience and countryside management), (ii) no and/or other qualifications (if no qualifications are mentioned or qualifications that aren't directly related to greenspace).

3. Results & Discussion

3.1 Council and road verge manager background

The majority (68.4%) of road verge managers' role was to manage staff and to be responsible for the strategy and/or maintaining greenspace whereas 18.4% of road verge managers were council workers who dealt with managing road verge maintenance contracts, 7.9% were contractors, 2.6% managed highway contracts and only 2.6% dealt with external communications as their primary role (Table 4.1).

With the exception of two road verge managers whose experience working in green space management was from their current role and one whose role involved highway management, all road verge managers had extensive green space management experience, with the majority working in greenspace management between 16-30 years (36.8%) and 31-45 years (36.8%) respectively. Half (55.3%) of road verge managers had formal qualifications ranging from City and Guilds and Diplomas to Masters degrees relating to relevant aspects of green space (Table 4.1).

Almost half of councils (48.7%) managed all elements of road verge management, with 27.0% partially contracting out road verge management and 13.5% of councils contracting out all road verge management (Table 4.2). In addition, in 10.8% of councils the work is either contracted out to a local authority trading company (LATC) the council owns, or responsibility for road verges is assigned to parish councils (smaller authorities within the local council area), but these parish councils then contract the work to the original council (Table 4.2). This is in keeping with examples elsewhere of council services that are being contracted out to private companies both in the UK (Dempsey, Burton, & Selin, 2016) and Sweden (Randrup, Östberg, & Wiström, 2017). However, it contrasts with the findings of Fongar et al., (2019) who reported that only 7% of Norwegian green space managers contracted out to private services.

Most councils who did contract out work, used different contractors; only two contractors were used by more than one council (two in each case). Contractors that manage all elements of road verge management have contracts ranging from 7 to 25 years, with 55.56% of these being between 10 to 25 years. Contractors who manage just certain elements of road verges, have contracts which range from being on an ad hoc basis to 10 years. This suggests that contractors which manage all road verge management may have longer term contracts than those who manage elements of road verge management.

Table 4.1. Summary of road verge managers' job roles and background in greenspace management

Manager identifier	Job role	Relevant experience	Time working in greenspace management (years)	Relevant greenspace qualifications
RM2 and RM26	Council- Operational and/or Strategy	Yes	0-15	No and/or other qualification
RM5 and RM30	Council- Operational and/or Strategy	Yes	0-15	Yes
RM13, RM17, RM29 and RM31	Council- Operational and/or Strategy	Yes	16-30	No and/or other qualification
RM1, RM3, RM15, RM21,RM25B and RM28	Council- Operational and/or Strategy	Yes	16-30	Yes
RM6, RM8, RM18, RM23, RM34-35	Council- Operational and/or Strategy	Yes	31-45	No and/or other qualification
RM4, RM10, RM12, RM19, RM24 and RM27	Council- Operational and/or Strategy	Yes	31-45	Yes
RM9	Council- Contractual	Yes	0-15	No and/or other qualification
RM11 and RM36	Council- Contractual	From current role	0-15	No and/or other qualification
RM32	Council- Contractual	Yes	0-15	Yes
RM16	Council- Contractual	Yes	16-30	No and/or other qualification
RM37	Council- Contractual	Yes	16-30	Yes
RM22	Council- Contractual	Yes	31-45	Yes
RM33	Council- External communications	Yes	0-15	Yes
RM7 and RM20	Contractor- Operational and/or Strategy	Yes	16-30	Yes
RM14	Contractor- Operational and/or Strategy	Yes	31-45	Yes
RM25A	Council-Contractual (Highways)	No	0-15	No

Table 4.2. Councils divided by the type of road verge management: council managing all elements of road verge management, partially contracted out (councils contract out some element(s) of management such as hedges, rural verges, high speed roads, selective weed control and wildflower sowing), fully contracted out (to a single contractor) and councils contracted out to manage their own verges (through a local authority trading company or from parishes being given the responsibility to manage road verges within their parish).

Manager identifier	Road verge management
RM1, RM2, RM4, RM5, RM10, RM12, RM13, RM17, RM18, RM21, RM23-26, RM28, RM29 and RM33	All elements managed by the council
RM3, RM6, RM9, RM15, RM19, RM27, RM30, RM31, RM34 and RM35	Partially contracted out
RM7, RM11, RM22, RM32 and RM37	Fully contracted out
RM14, RM16, RM20 and RM36	Councils contracted out to manage their own verges

Councils who did contract out road verge management (partially or completely) were asked about whether there are any opportunities to change the terms of their contracts. All said there was the opportunity to do so. All councils that fully contract out the maintenance of road verges have performance requirements that contractors have to meet, with the majority of those road verge managers (88.9%) mentioning that these relate in part to height specifications or frequency of cut of the grass verge. Two councils (RM22 and RM7) mention additional requirements which include, the frequency of shrub bed maintenance, wildflowers, vehicle overrun and the verge having a uniform appearance. The majority of managers (88.9%) mention that councils that partially contract out road verge maintenance do have performance criteria, but this varies widely from having informal requirements where the council says if they aren't happy to ensuring that 95% of the work issued to them is completed. If performance criteria aren't met when management is fully or partially contracted out, the majority of contractors will be asked to redo the work (47.4%) and/or may be given a financial penalty (42.1%) dependent on the severity of the issue and whether the work is rectified.

When asked how different road verges are classified in their organisation, 45.9% managers indicated that they are responsible to maintain not only urban road verges, but also rural verges.

3.2 How do you currently manage road verges in your area and has any alternative management been used or considered?

3.2.1 Mowing

Councils and contractors classified and managed road verges in a variety of different ways. Based on the responses from managers, where possible, road verges were very broadly grouped into 8 classifications, with mowing frequencies varying widely from not being cut at all to 32 times a year (Table 4.3). Rural road verges were mown the least frequently and city centre areas such as roundabouts, sponsored islands and grass around sheltered housing had the highest mowing frequencies (Table 4.3). 59.5% of the managers indicated that they had reduced the frequency of mowing, 13.5% mentioned that they only cut the edges of the road in some areas and 18.9% mentioned that in some areas, the road verges were not cut at all. Only in one instance was the mowing frequency mentioned to have increased. This increased from 6 times a year to 10 times a year over the last 2 years due to the parish council taking over management (RM14). 18.9% of managers said they were considering reducing mowing frequency, one manager (RM22) was thinking of just cutting the edges of the road and two managers (RM15 and RM36) said that they were considering leaving areas uncut.

Mowing was typically conducted between March/April and October/November, with the exceptions of two managers (RM16 and RM20) indicating that they may start in February and another two managers (RM7 and RM21) saying that they may finish mowing in December dependent on the weather. Road verges that were mown once a year were most likely to be cut at the end of July-August (RM7, RM30 and RM37), but two managers did indicate that they also would mow in late September and late October to end of November (RM30 and RM35). When mown twice a year, the first cut was most likely to be between March-May with May mentioned most frequently and the second cut was between August to October with September mentioned the most frequently according to 24.3% of road verge managers.

There was general agreement across the managers (70.3%) that cut and collect grass cuttings was not undertaken on any road verge types with the exception in some instances, of high profile areas and roundabouts (10.8%), as well as conservation areas and relaxed mowing areas (18.9%).

Table 4.3. The variety and most frequently mentioned mowing frequencies according to road verge type.

Road verge type	Mowing frequency range (times a year)	Most frequently mentioned mowing frequency (times a year)	Percentage of road verge managers mentioning each road verge type (%)
Rural	Not cut at all-4	1 and 2	37.8
Rural at junctions requiring site lines	2-6	4	13.5
High speed roads (ring roads, arterial roads and dual carriageways	1-6	2	29.7
Central reservations	4	4	2.7
Built up and urban areas	8-20	8-11	37.8
Amenity grass and standard verges	2-16	10 and 14	24.3
City centre areas, roundabouts, sponsored islands and grass around sheltered housing	14-32	28	13.5
All verges managed the same	7-16	12	21.6

From these results, it is clear that different councils have a wide variety of mowing frequencies, often dependent on where the road verge is located. The most frequently mentioned mowing frequency for rural verges and high speed roads of once to twice a year, has shown to be beneficial for plant and invertebrate species richness and abundance, compared to road verges not cut at all (Noordijk et al., 2009, 2010; Parr & Way, 1988). However, greater increases in abundance and species richness for both invertebrates and plants have been found when grass cuttings were removed from the verge, which currently only occurs in select locations in a minority of the councils interviewed (Jakobsson et al., 2018; Noordijk et al., 2009, 2010; Parr & Way, 1988). The most frequently mentioned timings of mowing for both once and twice a year may be beneficial for wildlife as no cutting in early spring increases the chance of plants to set seed and avoidance of mowing from mid June to September can allow invertebrate egg laying on plants (Auestad et al., 2010;

Jantunen et al., 2006; Parr & Way, 1988). Therefore, to increase biodiversity on rural road verges and high speed roads, an increase in cut and collecting grass cuttings is recommended.

There is a lack of evidence for the optimal mowing frequency in urban areas where, as demonstrated in Table 4.3, mowing occurs at much higher frequencies. However, a reduction in mowing frequency in urban road verges has shown to significantly increase grassland Hemiptera species richness and abundance (Helden & Leather, 2004) and total invertebrate abundance and Araneae abundance (Richardson et al., in prep [Chapter 2]). As a large number of managers indicated that they had or were considering reducing mowing frequency, then this may be a beneficial management action for biodiversity.

3.2.2 Herbicide use

The majority of managers (73.0%) mentioned that herbicides are used on road verges, around street furniture and/or obstacles, on pavements and hard surfaces and when weeds are present. Glyphosate or a glyphosate based product was the most popular herbicide used, accounting for 92.6% of councils/contractors that use herbicides. Chikara and Katana (manufactured by Belchim Crop Protection with an active ingredient of 25% weight per weight flazasulfuron) (Belchim Crop Production, 2019) were also used by managers (11.1% and 3.7% respectively) who apply glyphosate. The frequency of herbicide application varied from reactive application to being used all year around, with the most commonly used frequencies being reactive application (18.5%), once a year (25.9%) and twice a year (22.2%, being used typically in the early spring and late summer). Three managers indicated that they had considered or are currently considering using a growth retardant to suppress grass growth (RM20, RM24 and RM28). In one case, herbicides were applied around trees as an alternative to strimmers as strimmer use caused damage to young trees (RM10). For the same reason, another council was also considering this type of herbicide use (RM12).

Clearly, glyphosate is the most frequently used herbicide by the local authorities and contractors interviewed, supporting O'Sullivan et al., (2017). This is also similar for amenity areas in the UK whereby 72% of herbicides applied are glyphosate (Garthwaite, Parrish, &

Couch, 2016). However, this contrasts herbicide use in Sweden, where municipalities do not apply herbicides on managed lawns (Ignatieva et al., 2017). Whilst there is a lack of evidence explicitly assessing the impacts of herbicides on road verges on biodiversity, more broadly the effect of exposure to glyphosate can be variable amongst taxa (Sullivan & Sullivan, 2003). For some types of invertebrates, negative effects have been found (Helander, Saloniemi, & Saikkonen, 2012) including a reduction in growth and weight (Druart et al., 2011; Correia & Moreira, 2010) and change in behaviour and survival (Evans, Shaw, & Rypstra, 2010). Therefore, the limited use of glyphosate as demonstrated with the most commonly used applications being reactive, once a year and twice a year, is likely to be of benefit to biodiversity. As highlighted in O'Sullivan et al., (2017), reduced herbicide use may also provide cost savings. Whilst the timing of herbicide use wasn't mentioned by the managers, this should be carefully considered, with herbicide application conducted when there is no forecast of rain, as heavy rain can cause herbicide run off from road verges, which may lead to contamination of nearby water courses (Ramwell, Heather, & Shepherd, 2002).

3.2.2 Shrub bed and street tree maintenance

Shrub beds were typically pruned in the winter, according to 40.5% of managers, with the most frequently mentioned frequency being once a year (29.7%). Some managers indicated that additional cuts may be done for health and safety (21.6%) and in three cases, for highly visual areas or sponsored sites. Shrub beds were pruned twice a year according to three managers (RM2, RM21 and RM32) with two other managers (RM33 and RM37) indicating that they had a schedule to manage some shrub beds differently and 16.2% indicating that they did additional prunes in the summer. About a third (32.4%) of managers stated that shrub beds were visited multiple times throughout the year, to conduct maintenance such as mulching (16.2%), litter removal (18.9%) and weeding (13.5%), with chemically treating shrub beds (16.2%). Three managers (RM6, RM7 and RM13) indicated that shrub bed maintenance is done on an ad hoc basis, managed reactively. In some areas, shrub bed removal was taking place according to 21.6% of managers, with two road verge managers (RM7 and RM21) indicating this was due to anti-social behaviour and a fear of crime. However, two road verge managers indicated that they are planting some shrub beds out, with one indicating this is to prevent antisocial behaviour (RM11 and RM21). One road verge manager (RM30) indicated that they are looking into coppicing shrub beds.

Most managers (81.1%) had the management of street trees under their remit, and almost all of these managers (80.3%) mentioned that they inspected trees, with frequencies ranging from 3 times a year to every 10 years. The most commonly mentioned inspection frequency was every 3 years and every 5 years. Two road verge managers (RM14 and RM34) mentioned that inspection frequency was risk-dependent with lower risk trees inspected every 5-10 years or every 3 years and higher risk trees were done annually or every 1-2 years. Management for health and safety was carried out by 46.7% of managers, on a risk basis, with only 16.7% of managers mentioning that street trees were proactively managed. Five managers (RM7, RM21, RM23, RM26 and RM28) directly mentioned that such management will be carried out if the tree is dead, diseased or dangerous, with tree removal on this basis, if required. Two managers (RM7 and RM31) directly mention that if a tree is removed, another will be planted in the same place or alternative where possible and another manager (RM28) indicated that they have a 2 for 1 replacement policy. Some road verge managers indicated that that there were no resources for replanting, with a few saying replanting was only possible with external funding (RM12, RM29 and RM33).

Maintenance interventions on street trees that were mentioned included pollarding (13.3% of road verge managers), maintenance of epicormic growth (20%), crown lifting (6.7%), crown reduction (6.7%), deadwood thinning (3.3%), removal of basal growth (6.7%) and in one instance tree pit bases were sprayed with herbicides (RM20). One road verge manager indicated that they were currently writing a tree strategy to establish targets based on tree stock (RM28) and another (RM3) mentioned that they were using a risk based approach with ash dieback in trees where trees were removed if they displayed symptoms of ash dieback. The introduction of a proactive tree officer and a reactive tree officer was being considered by one manager (RM18).

3.2.3 Wildflower seeding and planting

Wildflower planting was quite a widespread practice: 83.8% of managers said that they had planted wildflowers, with planting locations specifically mentioned being roundabouts and gateways (16.2%), central reservations (RM6, RM34 and RM35), islands (RM9 and RM19) and a bypass (RM10). When asked what had been their biggest success in managing road verges, 20.6% of managers asked said wildflowers.

A number of techniques were mentioned to be used to establish wildflowers including, plug planting (RM10, RM30 and RM37), preparing the ground and chemically treating it to remove weeds before sowing (RM8 and RM9), using yellow rattle (RM8 and RM30) as well as coir matting and turf with wildflowers (RM3 and RM32). Grass meadows, where wildflowers weren't deliberately planted but naturally grew in areas that were left were also mentioned by four managers (RM5, RM10, RM12 and RM30). Annual and perennial wildflower mixes had been used by six managers (RM17, RM19, RM21, RM27, RM29 and RM31), with only five managers (RM22, RM23, RM28, RM33 and RM34) having just planted annual wildflower mixes and one planting just perennial mixes (RM30). A mixture of non-native and native wildflowers has been planted according to two managers (RM6 and RM37), with one manager mentioning that whilst they have planted local native wildflowers, community groups have also planted non-native species such as sunflowers (*Helianthus annuus)*. Specific planted wildflowers mentioned in the interviews included daisies (*Asteraceae)*, poppies (*Papaveroideae)* and cornflowers (*Centaurea cyanus)* (RM9, RM11 and RM35). Pictorial Meadow seed mixes were mentioned the most frequently (RM12, RM21, RM22, RM30), with other mixes; Beeline, Euroflor, Rigby Taylor and Emorsgate mentioned only once (RM13, RM14, RM19 and RM30). Three managers who currently do not have wildflowers on road verges (RM16, RM18 and RM25) said that they were considering planting some wildflowers.

There was the perception (RM17, RM18, RM31 and RM37) that wildflower success on road verges was dependent on soil quality, with low quality soil perceived to be beneficial for wildflower establishment. High nutrient soils, human trampling and type of seed mix used were also thought to be potential causes of wildflower failure for another council (RM23).

Soil type was also perceived to be key, with some wildflowers planted according to the acidity of the soil (RM17) and the failure of wildflowers for another council attributed to heavy clay soil (RM29).

> *In the last two or three years, on some of those sites where we didn't want to lose the interest, we put some, …local perennials …, mixes in, which haven't really been particularly successful. … a lot of it, is just down to the … land in this area, …. We have a very heavy clay soil … that's not conducive to … a lot of … traditional what you might think of, as meadow land and farmland ...* (RM29).

The results of this study show that wildflowers are a widely used management practice on road verges, with a fifth of managers asked perceiving it to be successful. Methods of wildflower establishment varied widely suggesting that there is no established method widely used by managers. The success of these different methods was not mentioned by managers, so it is not possible to establish how effective these are. Whilst our understanding of successful establishment methods for urban road verges is limited with regards to the scientific literature, sowing local seeds and hay transfer have been shown to be effective on rural road verges (Rydgren et al., 2010; Nordbakken et al., 2010). Of the type of wildflowers mentioned, there appears to be no distinct preference between the use of annual and perennial wildflowers and native and non-native plants. To improve the native diversity of urban grasslands, the use of local native species on road verges has been recommended (Staab et al., 2015; Rydgren et al., 2010). However, in relation to increasing biodiversity this is not clear cut. Indeed, a combination of native and non-native wildflower mixes significantly increased the number of flowers, bees and hoverflies in an urban setting (Blackmore & Goulson, 2014). Further research into the long term impacts of different wildflower types on biodiversity is needed. Supporting the results of Haan, Hunter, & Hunter, (2012), several managers indicated that soil characteristics impacted the success of wildflower seeding and planting on urban road verges. To increase success, it is recommended to identify the soil characteristics of the chosen verges before selecting the seed mixes and plants.

3.2.4 Alternative management

In addition to what might be thought of as typical management, the presence of roadside nature reserves were identified by a number of road verge managers (RM15, RM16, RM20, RM30 and RM32). The management of these reserves varied between areas, ranging from the first cut being missed (RM30) to being maintained every 5 years undertaking cut and collect and ad hoc management (RM15). The provenance of these reserves were often not known by the managers with only one manager (RM15) identifying that the reserves were inherited from Sites of Nature Conservation Interest (SNCI). One manager indicated that new verges have been recently added based on consultation with their biodiversity officer (RM32).

Two managers also mentioned that on some verges, there were hay meadow areas which were only mown once a year but cut and collected (RM30 and RM37). When asked if they work with any different organisations when implementing wildlife friendly road verge management, 43.2% of managers said that they did and this involved working with NGO's such as a Wildlife Trust (21.6%), local groups such as volunteers (13.5%), universities (5.4%) and other organisations such as suppliers and a lobbying group (13.5%).

When asked if there has been any discussion for using grass cuttings for biomass as an alternative management, none of the managers said that they currently do this. Four managers indicated that they had looked into this type of management but hadn't used it due to the amount of investment required and/or due to the issue of trying to dry the grass which they perceived to have a high water content (RM6, RM22, RM27, RM35 and RM35). Another reason for not doing this, identified by 18.9% of the managers, was that it would require a cut and collect which they do not currently operate and would add to the cost. One manager (RM1) indicated that they haven't got an anaerobic digestor in the area to apply this method and the litter within the cuttings would be classed as contaminants, making it difficult to dispose of. However, three managers are currently thinking of using this approach, with one of the managers having recently trialled it to assess the benefit of its use, and another writing a bid to do this as a carbon capture scheme in which cuttings could be used as a fuel source with the potential to power some electrified fleet vehicles and tools (RM3, RM7 and RM25).

Other alternative management schemes that were being considered included replacing grass with hard surfaces on traffic islands or very small verges, and replacing grass with low growing flowering species that would only need to be mown 4 times a year and with clover that would only need to be mown 1-2 times a year (RM28 and RM36).

Whilst not a widely adopted management action, roadside nature reserves had been created which involved low frequency mowing of the road verge, typically once a year. To increase biodiversity on the roadside nature reserves, mowing twice a year with the removal of cuttings is recommended, to benefit plant and invertebrate species richness and abundance (Jakobsson et al., 2018; Noordijk et al., 2009, 2010; Parr & Way, 1988). As it was unknown when the roadside nature reserves were created, this indicates that this was not a recent change.

The use of road verge cuttings for biomass had been considered by a number of managers but had not been implemented by any contractor or council. The constraints identified by managers preventing its use including how to remove waste from the road verge, and investment required such as a cut and collect machinery and an anaerobic digestor, supports the challenges mentioned in Meyer, Ehimen, & Holm-Nielsen, (2014). Given the current pressure on resources highlighted by managers (see 3.3.1), management changes to use grass cuttings for biomass may be unlikely, at least in the short term. However, the idea of replacing grass with low growing flowering species such as clover is likely to require less investment. Whilst not currently tested in a real life scenario for urban road verges, Richardson et al., in prep [Chapter Three] identified that whilst not significant, hypothetical low growing flowering road verges was the next preferred road verge management option after current typical management. This may be applicable in other areas of green space, as in a park setting, Ramer et al.,(2019) found that 95.4% of visitors would support flowering lawns.

3.3 What are the main factors that influence why you manage road verges in this way?

3.3.1 Financial considerations and resources

All managers mentioned that road verge management was influenced by finances and resources. Indeed, 35.3% of managers indicated that their greatest success in managing road verges was being able to manage current management with their available budget and resources. When asked if they knew the cost per square metres for road verge maintenance or the general cost of road verge maintenance, 40.5% of managers were aware of approximate or actual costs, 29.7% didn't know how much it would cost when asked during the interview, 19.9% weren't able to provide the information as it was hard to separate road verge costs from the overall budget and four managers indicated that they were not able to provide the information as it was commercially sensitive (RM9, RM11, RM23 and RM32). As road verge maintenance involves different types of management, it was not possible to provide meaningful comparisons of the costs for different management.

A number of alternative management regimes were mentioned with the aim of reducing costs and saving time. There were contrasting views by managers as to whether planting wildflowers reduces costs and maintenance time or not, with six managers (RM9, RM12, RM13, RM18, RM20 and RM25) indicating that they thought it was labour intensive and/or expensive, whereas three other managers (RM8, RM16 and RM21) thought that planting wildflower saves on maintenance costs and time.

> *… I think what people don't realise is that actually you still need to go in and it's probably, they're just as labour intensive as you still need to go in and weed out the docks and all the, … encroaching … stuff you don't want in there. So, … I think they just didn't work and it was easier to turn them back to grass than it was to try and to keep them going.* (RM25B).

One manager who was considering planting wildflowers said it would be dependent on costs (RM24) and three managers who have already planted wildflowers indicated that continuation of the practice was unlikely for financial reasons (RM23, RM28 and RM29).

Implementing traffic management to allow safe access for management and maintenance of verges on high speed roads was mentioned to be costly (RM21) and "resource hungry" (RM5) and as a consequence some managers have altered verge management to allow for safe working on such road verges. One manager (RM13) reduced the mowing frequency and another planted wildflowers on traffic managed roads to reduce maintenance time (RM28). An additional cost saving approach, identified by two managers was that they mowed just a strip near the curb rather than the entire width of the road verge (RM18 and RM22).

A number of managers (21.6%) indicated that they had reduced shrub bed maintenance as a consequence of budget cuts, with other managers also indicating that they were replacing some shrub beds with grass (RM9), not replacing shrubs when they died (RM33) and bringing shrub beds into coppicing routines (RM30). One manager indicated that it was not possible to do differential management for different types of shrubs given the extent of shrubs across their city (RM2). With this lack of resources, hedge management was also impacted, with one road verge manager (RM1) indicating that they cut the hedges less frequently and another used a tractor mounted flail to manage rather than hand cutting (RM25). As a consequence of reduced resources, weed spraying road verges altered for two councils; one council used weed spraying instead of trimming to stop grass encroachment (RM36) and another council only did follow up weed treatment when resources allowed rather than when was necessary (RM26).

Damage caused by parking on road verges was also highlighted as a challenge by several managers (RM11, RM16, RM17, RM24 and RM36) with one manager (RM24) indicating that they did not have the funding to reinstate the road verges and two others suggesting that they had to install deterrents such as wooden posts or alternatives such as grasscrete (RM11 and RM25). One manager (RM11) thought that the public would be happy to concrete over verges to provide more parking.

Finances were identified as one of the barriers to implementation of cutting and collecting grass cuttings and the use of growth retardants, both of which were potential management changes considered by managers (RM1, RM9, RM14, RM18 and RM24). Indeed, one manager indicated that they were aware of what management they should be doing, but not always able to do that with the resources available (RM5). In addition, managers indicated that the cuttings may be contaminated, making it difficult to dispose of once collected (RM1, RM7 and RM33) and they do not have the resources to facilitate it (RM13 and RM29).

Due to a lack of funding to employ both a tree team and a grass cutting team, tree specialists within the council also undertook mowing operations according to one manager (RM21). Three managers indicated that the availability of different types of products such as growth retardants (RM28) and having the right machinery with suitably skilled operatives (RM7, RM8 and RM17) were important for management and the development of new approaches. One manager indicated that they used a robot mower to reduce time cutting banks (RM15) and another manager indicated that they haven't got the funds to change machinery to a rotary mower which may be better at withstanding damage from objects left in the area (RM26). Two managers mentioned that they used sponsorship packages as additional revenue to develop roundabouts and enhance beds (RM1 and RM17).

When asked how much their budget has changed in the last couple of years, 70.6% of managers indicated that in the last couple of years they had a significant decrease in budget and reduced numbers of staff. Only four managers (RM5, RM11, RM32 and RM36) said that their budgets hadn't changed. Due to road verges being managed by different departments, it was not possible to extract a meaningful collective percentage of budget lost; 14.7% of managers didn't know or weren't able to provide the information about budgets cuts and one manager indicated this was difficult to say as highways was merged with other green spaces (RM17).

There is agreement amongst the managers (70.6%) that management had been changed as a consequence of this budget cut, with one manager (RM16) indicating that money is used for normal maintenance rather than road verge enhancements. A number of managers (59.5%) mentioned that they had reduced the mowing frequencies of road verges, with another two managers (RM14 and RM36) suggesting that they may also make this change due to budget cuts. Five managers (RM4, RM9, RM12, RM19 and RM34) indicated that this reduction in mowing frequency also meant that they had to change their machinery with two managers (RM23 and RM24) suggesting that reduced mowing puts a strain on some types of machines.

> *… since then we've now reduced down to a frequency of six cuts per year on our highway verge, which has meant that the grass gets considerably long at times of high vigour, …, which has resulted in us needing to change our machinery. So we now use front and front deck rotary or flail mowers and triple flail mowers to cut the verges.* (RM12).

Some verges were not cut at all according to two managers (RM5 and RM6). One manager said that additional road verge nature reserves were also added to make cost savings as well as for biodiversity reasons (RM32).

Other effects of budget cuts on tree management identified by single managers included having no budget for tree planting (RM12); loss of 'in house' tree specialists (RM12); and scope only for reactive management of trees (RM1). There were also instances of the application of more herbicides due to reduction in street cleaning (RM3) and use of herbicides instead of trimming (RM4) as consequences of budget reductions, along with cessation of cut and collect management of roadside nature reserves (RM30). Although cutting herbicide use to make savings, had been tried by one council, the change had caused problems and herbicide use had been reinstated (RM32). Hedges were also cut less frequently in one instance (RM1).

Wildflower maintenance was also influenced, with two managers (RM1 and RM33) indicating that they've stopped maintaining wildflowers due to lack of resource. One manager (RM36) indicated that they may consider changing some small verges into hard surfaces as "*they are expensive to maintain for what they are offering back*".

Finance was universally important for all management decisions. Just under half of managers were able to provide actual or approximate costs of management, with the remaining either unable to provide this information or did not know. For those managers who did not know the costs or were unable to separate specific road verge costs from other areas of urban green space, this may make management decisions more difficult as cost-benefit analyses would not be able to be conducted to establish the effectiveness of management (Cook et al., 2017). A number of management actions were mentioned with the aim of saving time and reducing costs. There were conflicting views on whether planting wildflowers would save time and costs, with a few managers highlighting that the time needed for ongoing maintenance required for wildflowers did not save costs and time. This mirrors the perception of UK park managers who also perceived that wildflowers did not save costs (Hoyle et al., 2017). For management that was costly such as traffic management, actions were undertaken with the aim of reducing the number of maintenance visits required and time taken such as just maintaining a strip of the road verge. Parking on road verges was highlighted to be an issue due to the costs of reinstating the verges and adding parking deterrents. Whilst the perception that the public may be happy for verges to be concreted verges for parking may be valid for some cases, on the whole, members of the public have been shown to prefer the presence of road verges with vegetation than streets without vegetation (Bonthoux et al., 2019; Fischer et al., 2018). Finances were mentioned to be a barrier for the use of additional management and machinery such as cut and collecting the road verge, as well as the cost of the disposal of the cuttings classed as contaminated. This mirrors Hoyle et al., (2017) where UK park managers also indicated this to be a constraint.

A large proportion of managers highlighted that they had experienced a significant decrease in budget over the last couple of years. This contrasts with Randrup, Östberg, & Wiström, (2017) who found that only 18.6% of Swedish municipal green space managers said that had experienced a reduction in budget over a period of three years. As a consequence of this budget cut, a number of alternative management techniques were employed from reducing mowing frequency, reactive tree management and reduced maintenance of wildflowers.

3.3.2 Public perception and public actions

There was agreement (91.9%) that public perception influences road verge management, with three of the managers (RM8, RM12 and RM27) indicating that one of the biggest challenges was managing public expectations with the available resources. One manager (RM22) suggested the council’s biggest success when managing road verges was when they received a low level of complaints. Some managers perceived that the public like neat and tidy road verges (RM19, RM23 and RM37) with councillors receiving a lot of complaints about untidy verges (RM30). Managers suggest that the public like well maintained verges which are nicely cut (RM12, RM18, RM19 and RM21), disliking litter presence (RM2, RM6, RM9 and RM23).

> *Clean and green environment that means you want clean streets, empty litter bins, nice cut verges ,… the aesthetics of where you live, you want to get that feel good factor, …, maintain trees. You want everywhere to look clean and pleasant … and when you open your front door, or whilst you're walking in your neighbourhood, so that's why … we manage the areas that we do to the standards we do.* (RM21).

This perception of maintenance extends to grass cuttings left after mowing, with some road verge managers receiving complaints about grass cuttings (RM11 and RM31) and other managers indicating that the public would like areas to be cut and collected (RM6 and RM26).

Public perception of mowing frequencies and the length of grass were also mentioned frequently by managers. It was perceived that the public like short grass (RM3, RM5 and RM12) with managers receiving complaints when the grass grew taller (RM4, RM10, RM12 and RM28) or when the public thought it should be cut (RM2 and RM31). When management regimes are altered to a reduced mowing frequency, 53.9% of the managers that alter the frequency mentioned that they received complaints. Two road managers (RM5 and RM30) indicated that complaints were about the verge looking scruffy and uncared for, in one case people saying that this was causing house prices to drop (RM5). One road verge manager (RM33) found that when members of the public contacted the council about the road verge campaign to reduce mowing and the council stopped cutting in response, the council received a large number of complaints as the road verge manager thought the public perceived the change to look different from the actual reality. However, when the change has been in place for a number of years, managers thought the public became more accepting, with a reduction in the number of complaints over time (RM1, RM5, RM9, RM12, RM19, RM24, RM30 and RM35).

> *But …, when we did the relaxed areas initially, we did have …, people complaining… once it got to a certain length, but I think now, … the complaints have …, subsided. Because people …, are aware now that we've come along, why they're left, …, and then when we come along to cut the areas, and I think, …. It's kind of ……well known now that …, these areas … are managed in such a way and why they're managed.* (RM35).

Additionally, gradual changes in mowing frequency were reported by two road verge managers (RM32 and RM33) as not prompting any big influx in complaints from the public. There are exceptions though. One manager said they were still receiving complaints about reduced frequency in areas where the change had been in place for 10 years (RM25).

Wildflower planting was, unsurprisingly, perceived to be a positive influence on public perception (RM6, RM8, RM12, RM15, RM21, RM31, RM34 and RM35), and a number of managers (RM5, RM8, RM16, RM34, RM35) who said that they planted or were considering planting wildflowers in their area identified making the verges more aesthetically pleasing as the reason. However, there were also some (though fewer) instances of negative comments about verges looking long, unkempt, affecting sightlines and collecting litter (RM9, RM28 and RM35). One manager (RM9) indicated that the appearance of the wildflower plantings may be good in the first year but decline subsequently.

Three managers (RM5, RM10 and RM30) thought that the public perceive and like wildflower areas to be colourful. However, this may be at odds with the effect produced when local naturally occurring wildflowers grew naturally when the grass verge was left uncut, with one manager (RM5) having to rebrand areas of uncut verges from wildflower meadows to grass meadows as it was not what the public perceived as wildflower area. Indeed, two managers (RM6 and RM29) thought that the public would perceive local natural wildflowers as not particularly interesting or just as weeds. This in part concurs with other managers who indicate that the public complain about naturally occurring plants such as dandelions (RM15 and RM28), ragwort (RM10) and plants that are perceived to be weeds (RM6).

Public perception also affected shrub bed management. Some shrub beds had been removed according to three managers (RM21, RM27 and RM28), as a result of their appearance being less attractive, or on the basis of people's fear of crime in the area.

Public opinion in relation to herbicide spraying was not mentioned by many managers, and where it was, responses were quite area specific, e.g. instances of people wanting a reduction of weed spraying in one area (RM2), or conversely complaints when spraying was stopped in another were identified (RM32). However, one manager (RM19) made the point that selective weed killing could help to improve the appearance of the area.

Several points were made about the influences on, and potential to change, public perceptions of changes in verge management. Two managers (RM8 and RM12) considered that some public expectations may be due to people comparing changes negatively with previous long standing management practice but, equally some people also appreciate that these changes in management could benefit biodiversity (RM12), with members of the public in one area encouraging the council to adopt reduced mowing based on Plantlife's road verge campaign (RM30). Three managers identified a role for education (RM10, RM28 and RM37), with one advocating for a trained person (e.g. from a Wildlife Trust) to provide evidence of the potential benefits of the management change (RM37). Better provision of information to the public via signs and website may also influence perceptions (RM7 and RM37). One approach identified by several managers (RM2, RM7, RM12 and RM37) was that a strip of grass next to the highway or footpath being mown, where the rest is unmown, can provide a sign that this is deliberate management and care, rather than neglect.

In addition to management by the councils or contractors based on public perception, some of the interviews revealed that members of the public were also taking management action themselves. On an individual basis, some residents were mowing their own verges (RM6 and RM33). Whilst these managers did not express any strong opinions regarding this, one manager mentioned that as a consequence of residential mowing, they had received insurance claims from residents who damaged their own machines mowing the verges

(RM6). Collectively as volunteer groups, members of the public planted and maintained wildflowers themselves (RM6) and working with the council (RM10, RM16 and RM24). In one case, a group of volunteers surveyed road verges for wildlife (RM35).

The perceptions of what road verge managers think the public prefers, supports previous research indicating that people appreciate areas that are orderly and show signs of care (Weber, Kowarik, & Säumel, 2014a; Özgüner & Kendle, 2006; Nassauer, 1995). This also mirrors what public perception is perceived to be by UK park managers (Hoyle et al., 2017). This perception extends to vegetation height on the road verge, as many managers received complaints about reductions in mowing frequency. This is supported by Richardson et al., in prep [Chapter Three], which indicated that local residents significantly preferred grass verges mown more frequently with factors influencing this preference associated with neat and tidy verges without the presence of litter. However, it also interesting to note that over time, some managers perceived a change in attitude with fewer complaints. Future research assessing this change in attitude over time may provide further insight into the factors driving this change.

The popularity of wildflowers noted by several managers corroborates other studies which indicate that members of the public have a positive response to planted wildflowers (Southon et al., 2017; Todorova, Asakawa, & Aikoh, 2004) and to flowers and flower colour diversity (Hoyle et al., 2018; Graves, Pearson, & Turner, 2017; Todorova, Asakawa, & Aikoh, 2004). Suggested strategies to engage the public with road verge management through education and showing cues of care may influence the perception of management. Indeed, previous studies have shown the provision of additional information may be effective at influencing the perception of a management change (Ramer et al., 2019; Southon et al., 2017; Lucey & Barton, 2011) and management actions such as mowing a strip of grass indicating signs of care can increase the willingness of the public to accept more wild vegetation (Hofmann et al., 2012; Hands & Brown, 2002; Nassauer, 1995). Our results highlight that local residents may also take personal action with regards to managing road verges themselves, similar to residents in Australia (Marshall, Grose, & Williams, 2019b). In addition, in a few instances, collaboration was mentioned between the council and residents, suggestive of environmental stewardship. It is, however, interesting to note that whilst the managers who mentioned residential engagement in management appeared to neutral about this, there was also a consequence for one manager in the form of insurance claims.

3.3.3 Safety

Safety was mentioned as an important factor when considering road verge management according to 91.9% of managers. Many managers (27.0%) specifically highlighted that road verge management needs to ensure that sightlines are maintained for motorists, enabling visibility at junctions and corners and to ensure that vegetation does not encroach onto the highway or pavement. If an area is deemed to be dangerous or with sight lines that need to be kept open, then it is mown more frequently (RM1, RM3, RM4 & RM33).

When reduced mowing is implemented or is being considered, many managers highlighted that they consider this in relation to health and safety, mindful of potential insurance risks and highway safety (RM8 and RM14) and indeed also receive many calls about highway safety (RM27). Two managers (RM10 and RM19) mentioned that in their reduced mowing frequency areas, a strip of grass is mown for safety purposes and site views. In particularly dry weather, some road verge managers considered that the longer grass left may cause a fire risk (RM8 and RM37) and another manager (RM7) reported that they received complaints with people perceiving that reduced mown areas could become a fire risk.

> *So, ... we just cut once a year ... . We've moved it forward a little bit because it was, … the weather was so hot, it was getting so dry. … the wildflowers went over earlier so we … put an earlier cut on, early on in August … because also a risk of … fire. It was at the time when … we were seeing that … there were areas of …, up on the … bottom of the Moors, and stuff burning in Manchester … . We had a couple of fires in our kind of … long grass areas that we'd left. So … , it was to prevent arson.* (RM37).

Shrub management is undertaken if the shrubs are causing road safety issues or obstructing pedestrians or motorists according to some managers (16.2%). In some cases, shrub beds have been removed or redesigned to prevent anti-social behaviour such as drug-taking or people hiding in shrub beds (RM6, RM7 and RM21). Street tree management was mentioned to be based on risk and safety in a number of areas (46.0%), with trees identified through inspections or complaints as being dead, diseased or dangerous being a priority for management. One manager (RM30) highlighted that hedges are also cut more often if they pose a safety risk.

Managing road verges based on safety requires consideration of both motorists safety and that of the operatives undertaking the work. The use of strimmers were identified by two managers (RM7 and RM22) to put operatives at risk to hazards and traffic, with one manager using herbicide application (RM22) as an alternative measure to reduce risk. Based on the news regarding a trial involving Monsanto, the manufacturers of the herbicide Roundup at the time of the interview, one manager (RM8) indicated that they try to minimise operatives' contact with glyphosate. Three managers altered management or avoided types of management to reduce the safety risks either by the introduction on wildflowers to reduce maintenance where risks existed (RM21) or by not removing the grass cuttings after mowing has taken place (RM1 and RM33).

> *… roadside verges can be hazardous … places for people to work so the more we're … keeping people there to collect cuttings [to] do something with the cuttings, extra vehicles, it all adds to the potential safety risk (RM1).*

On high speed roads, where there are high volumes of traffic, 40.5% of managers stated that traffic management involving lane closures was needed when road verge management takes place. Several of these mentioned difficulties in implementing management as a consequence; it influences when management can take place (RM29), the type of machinery used (RM31) and makes additional management difficult such as remedial action for planted wildflowers on the high speed roads (RM28).

> *It's health and safety. Where we can and can't work at different times of,… day and, … the cost of road closures* (RM29).

Safety being regarded as an important factor which affects road verge management is unsurprising, with legislation and guidance in place regarding health and safety such as the Highways Act, 1980 (Great Britain, 1980) and with many managers referencing Chapter 8 of the Traffic Signs Manual (Department for Transport/Highways Agency et al., 2009a, 2009b, 2016). As an important priority, many elements of road verge management were highlighted to involve safety including street tree maintenance, mowing frequency for fire risk, shrub management and road closures for high speed road maintenance. However, a few managers indicated that this can cause operational issues, such as the time of day work can take place. These safety measures were identified to be for the safety of both the general public using the road and the operatives working on the road have to be considered. Indeed, Bortolini et al., (2016) found that pruning and grass cutting, especially on banks were one of the riskiest tasks when managing urban green spaces.

3.3.4 Biodiversity and wider environmental benefits

The majority of managers (75.7%) mentioned that biodiversity influenced road verge management. A number (RM3, RM5, RM15, RM30, RM32, RM37) agreed that their councils would like to maintain road verges to provide biodiversity benefits. A couple of managers mentioned that they had dedicated roadside nature reserves (for further information see 3.2.4).With regards to policy, two managers (RM15 and RM30) suggested that their council will make an extra effort due to the NERC Act and local authorities signing up to initiatives like the National Pollinator Strategy. Two other managers also mentioned that their councils were trying to develop pollinator strategies, one of which was developing at the time and another had tried with other councils but due to budget cuts, people didn’t have time to be involved (RM30 and RM33). However, as two managers (RM7 and RM31) highlighted, managing for biodiversity can be difficult if this conflicts with other factors such as cost, manageability and public perception.

> *And we'd like to think that we could improve biodiversity but it's difficult when you've got contractual obligations …to make those changes whether it's in the timing of the cut, the frequency of the cut and you've got the residents and all the other factors*

that … impact on us. If it's a rural verge, with few visitors to the area, you could do an awful lot. (RM7).

There was a general perception amongst the managers that a reduction in maintenance may have a positive effect on biodiversity. One manager highlighted that they tried not to over maintain road verges that were perceived to have biodiversity value (RM37). Whilst a change in management reducing the frequency of mowing was primarily done from a cost saving perspective in many cases, 30.8% of managers who had made this management change directly mentioned that they thought this change would also provide biodiversity benefits. Two managers who reduced the mowing frequency on some of their verges said they saw species such as orchids (RM30) and the other thought that there was a wider range on flora present (RM7).

Mowing a strip of verge rather than the whole verge was also perceived to increase habitat cover to support urban pollinators according to one road verge manager (RM22). One manager (RM30) indicated that they perceived bringing shrub beds into coppicing routines to also provide biodiversity benefits. Reducing the frequency of cutting of hedges or timing the cut outside of bird nesting season was also perceived to be beneficial according to a number of managers (RM1, RM15 and RM34). The management of some areas was reduced or the timing altered for specific species, with some areas weren't mown at all due to the presence of orchids (RM24, RM29 and RM35) and some rural, upland verges were mown later in the year to allow for nest and foraging areas for Twite that were known to be in the area (RM3 and RM6).

In addition to reducing the frequency of management, some managers identified additional management which they perceived to provide value to biodiversity. Two of the managers (RM8 and RM10) cut and collect grass cuttings from reduced frequency mowing areas or planted wildflower areas, as they thought this would reduce the fertility of the soil and keep the verge species rich.

Everything gets quite long so we do … a cut and collect service for them … which helps … the further continuation of seeds … and growth in that area. (RM10)

Planting wildflowers was thought to promote biodiversity, with two managers specifically mentioning that they thought it would benefit pollinators (RM4, RM10, RM19, RM21, RM28 and RM35). One manager (RM27) highlighted that when some new road verges were created in their area, balancing ponds and French drains were installed which they perceived to be beneficial for species such as voles and newts.

One manager (RM17) highlighted that their council had piloted planting trees as part of a drainage system with aim of reducing flood risk, highlighting that road verges can be perceived to provide wider environmental benefits than just biodiversity value. This is supported by a comment from another manager (RM12) who thought that reducing mowing frequency also may reduce the emissions from the mowers.

However, whilst road verges can be managed to maximize biodiversity benefits, four managers (RM14, RM15, RM29 and RM37) noted that road verges can also support invasive non-native species such as Japanese Knotweed *Fallopia japonica*, Giant Hogweed *Heracleum mantegazzianum* and Himalayan Balsam *Impatiens glandulifera*, which they manage using herbicides. In addition, management such as a reduction in mowing or rotovating areas for wildflowers resulted in the increase of species that were perceived to be problematic such as Ragwort *Senecio spp.* and Fat Hen *Chenopodium album* for two managers (RM14 and RM21).

> *… the verges being left to its own devices which, can obviously benefit wildlife although it can obviously be detrimental. … one of the problems we do have is increasing amounts of … ragwort.* (RM14).

A high proportion of managers thought that biodiversity influenced management. Efforts to promote biodiversity were considered at a policy level by three managers, with mention of the NERC Act and pollinator strategies were being devised or had been attempted. However, it was acknowledged by two managers that efforts to conserve biodiversity may conflict with other factors such as cost. A reduction in management which would provide cost-savings was thought to have a positive impact on biodiversity and indeed, two managers indicated that they saw the positive effects of this change. This supports previous studies which have shown reduced mowing can provide biodiversity benefits on rural road verges (Auestad, Rydgren, & Austad, 2011; Noordijk et al., 2009; Parr & Way, 1988) and urban road verges (Richardson et al., in prep [Chapter Two]). The timing of management was mentioned to be considered in some instances to avoid the bird nesting season and plant flowering periods. Delaying mowing to avoid spring has shown to be beneficial for seedling establishment (Auestad et al., 2010; Parr & Way, 1988). Additional management actions such as cut and collecting the grass cuttings and planting wildflowers was perceived to improve biodiversity. This supports previous studies which suggests that botanical species richness can increase with the removal of grass cuttings (Parr & Way, 1988). Whilst this will be dependent on the seed mix used, wildflower meadows have been shown to provide biodiversity benefits (Norton et al., 2019). A reduction in management was also perceived to provide wider benefits such as a reduction in emissions from the mowing equipment which is evidenced by Lerman & Contosta, (2019). This also highlights that nature-based solutions and to a certain extent ecosystem stewardship, in this study exemplified by the use of trees to reduce flood risk, are not concepts widely mentioned by managers. However, increasing biodiversity can increase problematic or invasive non-native species which then require management to maintain.

3.3.5 Physical factors

Weather affected road management, with 78.4% of managers mentioning consistently that it influences the frequency of mowing and the time of year that mowing starts and finishes as it impacts grass growth. Various other aspects of management are also affected by weather including wildflower success (RM4 and RM28), tree maintenance (RM17 and RM27) and the application of herbicides (RM19 and RM20). If there is a lot of rain, this makes it difficult to manage grass cutting and if mild, this can cause increased grass growth (RM10, RM23 and RM24). Shrub management and leaf fall collection may also be affected as this is typically done in winter once mowing has ceased (RM15 and RM16).

One manager (RM12) highlighted that with global warming, summers will probably become wetter and warmer for longer periods and so adaptation of road verge management methods will be required. During warm weather conditions in the summer, when it is very dry for a prolonged period such as during the summer of 2018, this can reduce the number of cuts as grasses stopped growing (RM1, RM6, RM7, RM22 and RM33), but one manager (RM6) notes that it was a "40 year event".

> *It … would vary dependent on the year, obviously this year with the … prevailing weather that we've had, we have actually removed a couple of cuts off … the profile because the grass just wasn't growing*. (RM22).

Another major influence on management are physical practicalities, such as soil type, nutrients, slope and size influence road verge management, cited by about half the managers (56.8%). For examples relating to soil characteristics such as soil type and nutrients, see 3.2.3. Road verges that were identified to be steep and difficult to mow were in some cases, mown less frequently or by specific machines (RM17, RM22 and RM37), with one manager (RM36) strimming sloped verges rather than mowing. Equally, the opportunity to alter management on road verges was dependent on width (RM3 and RM19), with one manager (RM3) stipulating that nature areas with reduced mowing frequencies within their council were chosen on the basis that many verges were not wide enough to do anything apart from cutting them. The logistics of undertaking cut and collect for grass cuttings based on the width of the verges and extent of verges that would need to be collected was identified as one of the barriers for its use (RM5, RM19 and RM30). Larger areas were also more likely to be chosen as a location for a reduced mowing regime, according to one manager (RM35).

However, management issues still occur when cuttings are left on the verge, with one manager (RM11) stating when managing road verges, they need to ensure that vegetation doesn't block gullies allowing surface water to gather. This was also identified as a potential concern for two managers (RM14 and RM26) when considering a reduction in mowing frequency. In addition, one manager (RM10) had the perception that when the grass cuttings rots down to detritus, this can also allow dispersal of "weed" seeds, causing issues for weed spraying contractors. In relation to tree planting, services beneath roads were also identified as an issue for locating potentially suitable tree pits (RM33).

Weather appeared to influence all forms of management for the majority of managers. Unusual weather such as the warm summer of 2018 as highlighted by a few managers, influenced management, with a reduction in mowing frequency. Climate change and increased levels of carbon dioxide are predicted to increase the length of the growing season according to previous studies, and therefore adaptation of management strategies to the weather may become increasingly important (Reyes-Fox et al., 2014; Menzel et al., 2006). This may also include considering tree characteristics such as drought tolerance and winter hardiness when selecting new trees to plant as highlighted in O'Sullivan et al., (2017). Physical characteristics of the verge influenced operational delivery, with steep verges difficult to mow and the width of the verges constraining the use of other forms of management. This is supported in Valtonen, Saarinen, & Jantunen, (2006) where it highlighted that leaving a strip of road verge unmown would be logistically difficult due to the width of the road verge.

3.3.6 Spatial context

The spatial context of the road verge, such as whether it was in a residential area or a city centre area influenced the type of management implemented according to 32.4% of managers. In highly visual, valued areas, some managers stated that maintenance was increased (RM17), with shrubs cut more often (RM3), and in large areas wildflowers were planted (RM34).

Indeed, on high profile central reservations, two managers (RM6 and RM34) planted wildflowers as they can provide a big impact whilst reducing maintenance. Two managers (RM9 and RM24) identified that street trees may be inspected more often in areas which have high footfall and traffic.

> *So, if, … you've got some of our, … highway trees, that are in … an area where there's a, …lot of high footfall and a lot of … vehicles, you'd probably look to inspect it within every 2 years.* (RM24).

Public perception also had a role to play as several managers (RM5, RM12, RM22 and RM35) indicated that reduced mowing frequency wasn't undertaken in residential areas as due to perception:

> *But we did have to choose our, … spots for that and on roadside verges within, say housing estates and built up areas …, we decided not to leave the grass uncut in those areas because …, people just would not accept it in those areas.* (RM5).

The location of the road verge influenced management practices with increased maintenance undertaken in high profile visual areas and reduced management occurring away from residential areas. Whilst not explicitly mentioned in the majority of cases referring to spatial context, this type of management is likely to be driven by public perception, as previous research has indicated that people like management that is orderly and shows signs of care (Hofmann et al., 2012; Özgüner & Kendle, 2006; Nassauer, 1995). This supports statements by park managers in Hoyle et al., (2017), who indicated that this influenced where perennial meadow plantings may be perceived to be most suitable. For management that may require additional financial investment such as wildflowers, sowing seeds or planting in areas of high visibility may maximise the number of people exposed to this management. However, in areas with a high density of people, this may also increase the risk of incidents, increasing the need for safety management.

3.3.7 Departmental and councillor input

Within the department managing road verges, preferences and internal politics can influence management. Four managers (RM3, RM15, RM18 and RM23) indicated that road verge management was done in this way as it is an established pattern of management and is what they've always done:

> *…, it's just historic. I think it's historic information, historic work. … that's been … passed down and it's just revised as and when needed. … if a new verge ….[and] a new roads … is built and it needs roadside management, we just … look at it and measure it up … and build it into a schedule.* (RM18).

Managers and/or service heads' preferences can influence decisions made about road verges (RM4, RM5, RM12 and RM35), such as one road verge manager saying that they don't have a program of spraying obstacles in the highway as the person didn't like the appearance (RM12) and another suggesting that it is dependent on the manager in charge (RM4). Internal politics between departments who are in charge and the other who maintains road verges were also mentioned as a factor influencing road verge management by one manager (RM6).

The service that delivers road verge management responds to requests from councillors, although one manager said the ability to respond to everything that they want has been reduced with a reduction in resources (RM18, RM28 and RM29). Councillors became involved in management decisions when they received complaints from the public according to 27.0% of managers. Councillor preference can also influence management as three managers indicated that some councillors prefer "traditional form of maintenance" of short mown grass with two managers indicating that this preference prevented support for reduced mowing changes (RM2, RM9 and RM20). Due to council policy herbicides were not used according to one manager (RM16). Indeed, three managers also indicated that councillors raised issues about people parking on the grass or when people have made a mess throwing rubbish out of their car (RM17, RM21 and RM34).

> *… I would think probably …, one of the key issues … raised by councillors is, where people park their cars on roadside verges and it spoils the grass and it makes it muddy and, … So parking on grass is always a problem and … we do get requests to see whether we could take the grass out or, sometimes it's the grass is no longer there. … But that's more of … where it's on an estate rather than, by a main road*. (RM17).

As well as becoming involved when there are complaints, councillors were also mentioned to fund wildflower schemes (RM4 and RM15), provide support regarding management and new ideas (RM10, RM20 and RM25) and suggest alternative management such as planting wildflowers or having a strip of vegetation that is mowed on the verge (RM6, RM11, RM23, RM32 and RM33). The decisions for two of these alternative types of management, one resulting in the application of weed spraying being stopped and the other to stop mowing based on the road verge campaign, were reversed after complaints from the public (RM32 and RM33).

Influences on management strategies came from managers, service heads and councillors within the council, with personal preference and management based on an established pattern identified to be drivers for some decisions according to managers. Whilst personal experience was not directly mentioned by many managers, it does suggest that some managers use personal experience to make decisions, supporting the findings of previous research (Matzek et al., 2014; Pullin & Knight, 2005). Danish green space managers have also been found to base management decisions on personal preference and experiences (Molin & Konijnendijk van den Bosch, 2014). Input from councillors involved responding to complaints as well as providing support and suggestions for alternative management. Councillor preference for conventional forms of maintenance in the form of short grass highlighted by three managers suggests that some councillors may have similar preferences to that of members of the public (Richardson et al., in prep [Chapter Three]). Whilst councillors were willing to support alternative forms of management as evidenced by examples from two managers, these decisions may be influenced by complaints from the public, a finding also supported in Hoyle et al., (2017).

4. How do you make your decisions about road verge management?

4.1 Resources and sources of information used in decision making

A number of different resources and sources of information were found to be used when making decisions about road verge management, using both communication with people and written forms of information. 51.4% of the managers directly mentioned that they speak to people within the council or organisation who had relevant expertise and knowledge when making decisions about road verge management.

Area related information from within the council and externally was also used when making decisions, with five managers citing that they used complaints data (RM12 and RM35) or police data (RM16) or highways data on highway safety and information from local naturalist groups (RM3) or reviewed what they were able to afford (RM9) when making decisions. In addition three managers also directly mentioned that they would assess how a change may impact the existing verges, aesthetics and the machinery currently used based on their local knowledge, with one manager mentioning that they would do some site visits to assist the process (RM3, RM24 and RM27). Indeed, one manager indicated that they had been doing trials of different grass cutting in one area and taking pictures which would be used to help make the decision which method might be implemented (RM10).

Most (78.4%) managers mentioned that they speak to other local authorities through such means as greenspace forums and seminars (RM1, RM9, RM10, RM11, RM13 and RM32), Association for Public Service Excellence (APSE) activities (27.0% of road verge managers), Green Flag and In Bloom (RM25 and RM28) and most commonly, directly contacting them (46.0%). In one instance, a road verge manager learnt that a nearby local authority had reduced their mowing frequency and had received a number of complaints and as a consequence, they introduced changes more slowly (RM33). Four managers (RM6, RM8, RM15 and RM36) indicated that although they don't directly speak to other local authorities, they will visit other areas or look on their website to see what other local authorities are doing. Two managers (RM7 and RM37) mentioned that they collaborate with other organizations such as the Wildlife Trust and a University to identify areas where they can potentially change management.

As well as using verbal information from people to help make decisions, other resources are used. Literature such as trade magazines (e.g Horticultural Weekly and pitchcare.com)(RM22, RM29, RM31 and RM37), Wildlife Trust and Plantlife guidance (RM30 and RM31) and technical guidance (e.g Chapter 8 and the new highways code of practice) (RM6, RM11, RM25 and RM36) have been cited as sources of information from numerous managers. In addition, two managers (RM8 and RM28) specifically mentioned the internet and another (RM1) using information from a campaign by the "gardener chap on telly".

When asked what sort of information they would like to use but are not able to, 18.9% thought that there wasn't any additional information that they needed at the moment as they had the knowledge they required, while 21.6% said they didn't need any further information but would speak to colleagues within their council or other local authorities if they wanted further information. Several managers (16.2%) couldn't think of anything that they would like to use. Of those managers who wanted information which they currently were not able to use, five managers (RM3, RM6, RM7, RM18 and RM30) said that they would like to use technology or data about their areas to optimize management. This included gathering information about local factors, using data to establish where people complain about grass, using robotic mowers on high risk areas and using data from vehicles to allow route optimization (RM3, RM6, RM7 and RM18). Additional information on the environmental and health impacts of reducing mowing frequency or not cutting road verges to inform decision making and for changing people's perception was also suggested by three road verge managers (RM5, RM12 and RM20). One manager (RM4) said that they would like information on the long term effects when road verges are mown less frequently and another indicated having some public education about how long it takes to create a flower rich meadow would also be useful (RM30). There were additional suggestions about information relating to biodiversity, including when to cut they are unable to cut and collect (RM30), what plants would be suitable to encourage wildlife (RM11) and what the impacts are of cut and collect and dogs on nutrient levels in urban areas (RM33). Further guidance relating to health and safety of grass cutting machines and case studies of good practice were also suggested to be useful (RM24 and RM34).

Information used to make urban road verge management decisions were from a number of sources. Whilst information was used from the literature and local data such as complaints, the most popular method to gain information was from personal interaction with people within their council or organisation or other local authorities. There was no mention of the use of scientific peer reviewed literature by any of the managers interviewed. This supports the findings of previous studies, that conservation managers more often used knowledge from other colleagues and scientific literature was not frequently used (Fabian et al., 2019; Matzek et al., 2014). These results indicate that the most effective way for disseminating information to road verge managers, is likely to be through personal contact or at seminars such as APSE supporting Seavy & Howell, (2010). Future avenues for research are highlighted by some of the managers interviewed, including the use of technology to improve management, the environmental and health impacts of alternative management, the long term impacts of such management and further guidance on how best to manage for biodiversity.

4.2 How decisions are made within the council

The management level at which decisions are made within the council is dependent on the scale of the decision required. For low level, localised decisions, these are managed by the service team, according to four managers (RM1, RM19, RM35 and RM36). For changes in management, the service managers provide suggestions or proposals (directly mentioned by 18.9% of road verge managers) and consult with councillors or the cabinet member/portfolio holder about the proposed changes (43.2% of managers). Four managers specifically mentioned that local residents would be consulted if a management change is likely to impact them (RM18, RM22, RM23 and RM31). These changes in management would then have to be approved by the executive or Cabinet of the council, before they could be implemented, according to 46.0% of managers.

One manager (RM4) indicated that they have a commissioning department who creates the specifications of how the road verges are managed but indicated this was a new process and the department managing the road verges have the knowledge and experience. For the councils that fully contract out management or who are contracted out to manage their own verges, three managers said that management was based on what was in the contract (RM7, RM9 and RM11), one said it was based on the organisation that made the decisions and another said it was a discussion between the team doing the grounds maintenance and the local authority (RM14 and RM16).

Our study highlights that localised management decisions are typically made by the road verge management, with larger scale decisions made with input from councillors, the cabinet and in some cases local residents. This suggests that in the context of urban road verge management, concepts such as adaptive co-management which promote flexible decision making with individuals and organizations across multiple scales are not currently being applied.

5. Conclusions

Our findings provide the first comparative assessment of current urban road verge management in England, deriving from semi-structured interviews with 38 road verge managers, representing 37 urban local authorities across England. In these areas, almost half the authorities did road verge management in house (48.7%) while the remainder contracted it out in some form. Contractors who fully managed road verges typically had relatively long contracts ranging from 7-25 years, suggestive that if appropriate management was implemented, this could have long term benefits. A reduction in mowing frequency and the introduction of wildflowers were the most commonly used types of alternative management, both of which have the potential to enhance biodiversity (Norton et al., 2019; O'Sullivan et al., 2017).

Seven main factors were reported to affect road verge management: (i) financial considerations and resources, (ii) public perception and public actions, (iii) safety, (iv) biodiversity and wider environmental benefits, (v) physical factors, (vi) spatial context and (vii) departmental and councillor input. Financial and resource factors had a major influence on management, particularly as just under three-quarters of road verge managers indicated that they had a significant decrease in budget. Safety reasons were of primary concern and public perception was also frequently mentioned to influence management decisions. When making decisions about road verge management, the most frequently used sources of information were speaking to other people within their department and other local authorities, rather than other forms of information. Councillors provided input mainly when there were complaints from members of the public, but also provided support and ideas regarding management. If a large scale management decision had to be made, this would have to involve the executive or cabinet of the council. Whilst it was not possible within this study to identify key costs involved in road verge management, to develop this knowledge further, a detailed cost-benefit analysis for different management strategies across different councils would provide further insight.

This knowledge of current management and the factors that affect management has implications for other road verge managers as well as those developing alternative management strategies. Changes in management as a consequence of budgetary cuts may provide an opportunity to maximise biodiversity benefits and the provision of ecosystem services. This study illustrates the complexity of environmental management decisions in an urban landscape, and the need for interdisciplinary working to overcome current management constraints.

Chapter Five: General Discussion

5.1 Main findings

This thesis aimed to provide a greater understanding of urban road verge management assessing the ecological implications of reducing mowing frequency by half (Chapter Two), public perception of a change in mowing frequency and other hypothetical scenarios (Chapter Three) and to create an baseline of current road verge management in England (Chapter Four). These three chapters assess the potential for particular management changes to enhance biodiversity, and the scope for implementing them.

The first objective (Chapter Two) was to investigate the impact of a reduced mowing regime on botanical and invertebrate communities on urban road verges. To achieve this, a city wide mowing trial was conducted on 16 roads in Sheffield, UK using a paired design, whereby one side of the road was mown every 3-4 weeks (current management) and the opposite side of the road was mown every 6-8 weeks. Botanical and invertebrate surveys were conducted to assess the impact on plant species richness, forb abundance, availability of floral resources, the number of invertebrate orders and invertebrate abundance. The results showed that over one mowing season, total invertebrate abundance and Araneae abundance significantly increased when mowing frequency was reduced by half, but there was no significant difference in botanical communities and other invertebrate orders. This has wider implications for road verge managers who have or are considering changing mowing frequencies as our results indicate that a reduction in mowing frequency in urban areas even over one growing season, can provide some biodiversity benefits.

The second objective (Chapter Three) was to assess public responses of a changed mowing regime that they have experienced as well as other hypothetical scenarios. In addition, I investigated how local residents' responses are shaped by attitudes regarding the ability of different road verge scenarios to support biodiversity. Face to face and postal questionnaire surveys were conducted with 235 local residents who had experienced a reduced mowing frequency road verge trial on their road in Sheffield, UK. The results indicated that local residents prefer frequently mown short grass verges compared to verges with reduced mowing frequency and other hypothetical scenarios despite perceiving that other scenarios are more biodiverse. This study provides evidence that local residents prefer the 'status quo' of short highly managed vegetation when experiencing an actual management change, and in comparison to other hypothetical scenarios.

The third objective (Chapter Four) was to establish an understanding of current urban road verge management practice in England, what factors influence management decisions and how road verge managers make those decisions. Semi-structured interviews were conducted with 38 road verge managers (contractors and people working for unitary authorities and metropolitan districts) across 8 regions in England, UK. The results showed that alternative management strategies such as reducing mowing frequency and wildflower sowing and planting were commonly used. Road verge managers identified seven factors that affect management: (i) financial considerations and resources, (ii) public perception and public actions, (iii) safety, (iv) biodiversity and wider environmental benefits, (v) physical factors, (vi) spatial context and (vii) departmental and councillor input. When making a management decision, road verge managers most commonly gained knowledge from people within the council and other local authorities. Greater collaboration with other stakeholders such as local conservation bodies and academic researchers may provide a wider knowledge exchange which could be used when devising alternative management strategies.

5.2 Current management and factors affecting management

Altering management can enhance biodiversity and the provision of ecosystem services in road verges (O'Sullivan et al., 2017). However, to improve these methods, an understanding of how widespread these practices are and of other methods being explored is needed. To my knowledge, the results from the third objective of this thesis provide the first baseline of current urban road verge management for unitary authorities and metropolitan districts in England, UK. Almost half the councils interviewed managed all elements of road verges themselves, supporting studies showing that some green space management is contracted out. However, a larger percentage was contracted out by English councils than Swedish and Norwegian green space managers (Fongar et al., 2019; Randrup, Östberg, & Wiström, 2017; Dempsey, Burton, & Selin, 2016). The most popular alternative types of management from typical management were a reduction in mowing frequency and the planting or seeding of wildflowers for financial and aesthetic reasons. Both of these management types can provide biodiversity benefits if implemented appropriately with careful consideration of sown species diversity (Norton et al., 2019; Noordijk et al., 2009, 2010; Parr & Way, 1988).

Road verge managers identified seven factors that affect management: (i) financial considerations and resources, (ii) public perception and public actions, (iii) safety, (iv) biodiversity and wider environmental benefits, (v) physical factors, (vi) spatial context and (vii) departmental and councillor input. Financial and resource factors were key in influencing management, as 70.6% of road verge managers indicated their budgets had decreased significantly. Safety factors and public perception were also strong factors influencing road verge management. This highlights that management decisions are multifaceted (Hoyle et al., 2017; Knight et al., 2011), with sometimes conflicting factors involved. Changes in management as a consequence of budgetary constraints may provide a greater opportunity for alternative management to be considered which may benefit biodiversity if it meets other key objectives such as being cost-effective and compliant with health and safety.

To improve understanding how effective management changes such as these are, detailed cost-benefit analyses are required (Cook et al., 2017). This is essential as costs and resources were regarded to be important by all road verge managers within this study, with 70.6% reporting to have had a significant budget cut in recent years. Undertaking this task would not be without challenges, as only 40.5% of road verge managers were able to say approximate or actual costs of road verge management when asked, some due to barriers of commercial sensitivity and others due to management being incorporated with other areas of green space. However, this disconnect may make it difficult for managers taking decisions on the ground to judge the impacts of those on overall costs.

The results also showed that road verge managers more commonly speak to other colleagues within their council or organisation or other local authorities when requiring sources of information to make a decision than using other resources such as relevant literature. Whilst road verge managers' primary focus is not conservation, these results support that of previous studies which show that conservation managers make decisions mainly based on experience (Fabian et al., 2019; Matzek et al., 2014; Pullin et al., 2004). This suggests that the best method to communicate information regarding alternative management that is beneficial to biodiversity is through personal contact with road verge managers (Seavy & Howell, 2010). For maximum impact, this may be through conferences or using already known contact networks identified in this study, such as APSE.

Although all councils from major towns and cities in England were contacted, the managers who agreed to take part were self-selecting and may be more inclined to agree to take part if they were interested in speaking about their work. Baselines from other countries managed by local authorities may provide further insight into how typical road verge management is and of additional opportunities.

5.3 Reducing the mowing frequency of urban road verges

The first two objectives of this study focus primarily on the impact of reducing the mowing frequency of urban road verges. Altering mowing frequencies is a commonly used management strategy, as indicated in Chapter Four, where 59.5% road verge managers mentioned that they had reduced the mowing frequencies of road verges. When asked what sort of information they would like to be able to use but are not able to, three road verge managers explicitly said that they would like additional information on the environmental and health benefits of reducing mowing frequency or not cutting road verges to inform decisions and members of the public. Chapter Two provides some evidence for the effects of this management change in an urban context, indicating that over one mowing season a reduction in mowing significantly increased the number of Araneae and the total number of invertebrates later in the growing season. This may be due to the reduction in negative consequences caused by mowing (Morris, 2000), allowing invertebrate abundance to increase. The increase in structural diversity from reduced mowing may have increased the number of niches for Araneae (Cattin et al., 2003; Bell, Wheater, & Cullen, 2001). However, no change was found in botanical species richness and forb abundance, and reduced mowing significantly reduced the abundance of floral resources later in the growing season. This latter observation may be due to the increased abundance of cuttings left on the road verge after mowing (Parr & Way, 1988), but could also reflect the fact that the forbs that are successful in short mown sward are not easily able to respond to reduced mowing by growing taller and therefore flowering visibly in the longer, grass dominated, vegetation.

These results contrast that of Tälle et al., (2018) which suggested that different mowing frequencies of European grasslands produced similar effects for biodiversity. However, the studies analysed within this meta-analysis compared mowing frequencies ranging from every 5th year to 4 times a year, frequencies lower than those compared in this study. Previous research papers assessing higher urban mowing frequencies have shown that over one mowing season, mowing had little effect on flower species richness (Garbuzov, Fensome, & Ratnieks, 2015) but a reduction in mowing increased the number of flowering plants (Lerman et al., 2018; Garbuzov, Fensome, & Ratnieks, 2015). However, none of these studies assess this for urban road verges. Few studies to date have focused on the impact of mowing on invertebrates on road verges, with a particular dearth of knowledge in an urban road verge setting, with the only exclusively urban study assessing one order, Hemiptera (Jakobsson et al., 2018; Helden & Leather, 2004). My results highlight that reducing the mowing frequency of grasslands over one mowing season can increase invertebrate abundance, a positive conservation measure given reported population declines for many invertebrates (Hallmann et al., 2017; Potts et al., 2010), including those in urban areas (e.g. Dennis et al., 2017; Jones & Leather, 2012; Van Dyck et al., 2009). It is however, important to note that whilst my results show that there is an increase in invertebrate abundance, this does not necessarily mean that there are more species present, as the invertebrates collected may comprise of high numbers of the same species.

This increase in invertebrate abundance however, comes with a caveat, as the very nature of a road verge habitat means that there will also be implications on invertebrate mortality from traffic (Keilsohn, Narango, & Tallamy, 2018; Baxter-Gilbert et al., 2015). However, assuming that the total percentage mortality remains constant as invertebrate abundance increases, there may still be a net gain in the number of invertebrates as there will be more live invertebrates as well as those killed by traffic. It was not within the scope of this study to assess whether the invertebrates used the road verge as a habitat to reproduce and overwinter such as found in Schaffers, Raemakers, & Sýkora, (2011) or were using the road verge just for its floral resources. Further research investigating this may help to establish whether road verge enhancements benefit those using it as a habitat and therefore a net gain, or is primarily used by invertebrates from other areas of green space for its floral resources.

Whilst increased numbers of invertebrates found on the road verges can be seen positively, members of the public can also have a negative perception of invertebrates such as flies, wasps, mosquitoes and cockroaches (Leandro & Jay-Robert, 2019) and therefore, may consider increases in abundance to be problematic. These types of invertebrates can be viewed with fear, anxiety and in some cases are considered harmful pest species (Baldwin et al., 2008; Kellert, 1993).

Despite these possible benefits for invertebrate abundance, the results of the second objective (Chapter Three) indicated that local residents preferred the current management, of frequently mown short grass, to road verges that were managed less frequently, despite the fact that residents perceived the latter to be better at supporting biodiversity. Whether or not people liked reduced mowing was mainly due to aesthetics, with residents who were against mowing less frequently more likely to be associated with the idea that verges should be neat and tidy and free from litter and dog faeces. Residents who were in favour of mowing less frequently were more likely to think that the mowing trial had a positive impact on wildlife. This is supported by some road verge managers in Chapter Four who mentioned that when reduced mowing was first implemented, they received a high number of complaints. These findings mirror that of previous studies which suggest that short, highly maintained vegetation is preferred and seen as a social norm, with members of the public valuing orderliness and signs of care (Ignatieva et al., 2017; Weber, Kowarik, & Säumel, 2014a; Hofmann et al., 2012; Lucey & Barton, 2011; Özgüner & Kendle, 2006; Hands & Brown, 2002; Nassauer, 1995).

Whilst other studies have also assessed public perception of different types of road verge management, these have been entirely hypothetical and therefore, this study provides a novel assessment of public perception when they actually experience the management change on the road they live on as well as other hypothetical scenarios. These results pose a challenge for road verge managers who may be considering management changes which may not meet the expectations of the public from an aesthetic point of view. The portrayal of road verges in the media may support a perception that changes in management such as a reduction in mowing frequency will produce colourful, attractive wildflowers as shown in images in articles (Norfolk, 2019; Heath & Bevis, 2019). However, as highlighted by road verge managers in Chapter Four, the creation of such wildflower meadows can be complex (both wildflower planting and "grass meadows" created from reduced mowing frequency) and therefore is not as simple as suggested in some articles.

However, this preference may also be contextual in relation to other urban green spaces and highways. In a park setting, wildflower meadows and reduced mown grass were viewed positively (Southon et al., 2017; Garbuzov, Fensome, & Ratnieks, 2015) and in a highway setting, frequently mown tidy vegetation was one of the least favoured option (Akbar, Hale, & Headley, 2003). Therefore wilder, less managed, vegetation may not be favoured when in a residential setting outside residents' doors but may be more acceptable in other green spaces. This may also be related to the length of time since the change in management has taken place; eight road verge managers interviewed in Chapter Four, who had been implementing a reduced mowing frequency over a number of years, suggested that people were more accepting of this change over a longer period of time.

To my knowledge, this is the first study to assess the impact of reducing the mowing frequency of urban road verges incorporating both the ecological and social impacts. The results show that reducing mowing frequency of urban road verges over one growing season, does not provide a win-win scenario contrasting with Garbuzov, Fensome, & Ratnieks, (2015) as, whilst there seem to be some biodiversity benefits over this time frame, local residents largely prefer current management, despite perceiving it to be less good at supporting biodiversity.

Although originally planned as a two season experiment, due to feedback from local residents it was only possible to continue the mowing trial on two sites which were away from residential housing. Whilst it was not possible to statistically test differences in mowing frequencies for the roads in 2017 due to the small sample size, the data from the two roads appeared to show similar patterns to the results in Chapter Two with no clear difference in invertebrate orders, plant species richness and mean forb abundance, but with substantially more invertebrates and Araneae present on the road verges mown less frequently for both June and August 2017. However, Collembola, Hemiptera, Hymenoptera and Thysanoptera abundance were greater in road verges mown less frequently during June and August 2017, with Gastropoda abundance appearing to increase on both roads in August 2017. In addition, the mean flowering index appeared to be higher on road verges mown less frequently during June and August 2017, with a noticeable decrease in the flowering index from June to August for both roads and both mowing frequencies. Given this data are from two roads, it is not possible to draw definitive conclusions based upon this.

Having most sites subject to the changed mowing regime for only a single season was clearly a potential limitation on the response, particularly of the flora (Chapter Two). Ideally, future studies would be able to assess reduced mowing frequency over a greater time periods, to allow longer term changes to take place. Such work could not only test for biological changes (Baasch, Tischew, & Bruelheide, 2010) but also potentially for changes in public acceptability as suggested by managers' comments in Chapter 4. However, to achieve the longer trial period, given what this study found in terms of residents' responses, such work might have to be carried out in non-residential areas, making the latter test much more difficult.

In addition, future trials would ideally involve identification of invertebrates to a finer taxonomic resolution. This could provide greater insight into how invertebrate communities respond to this change, such as identifying which invertebrates are most influenced by reduced mowing, allowing the use of some taxa to act as bioindicators of environmental change (Gerlach, Samways, & Pryke, 2013) or using the functional traits of invertebrates such as body size and feeding guild to assess how this may impact ecosystem processes (Brousseau, Gravel, & Handa, 2018; Moretti et al., 2017; Reiss et al., 2009). In addition, studying these effects on invertebrates and botanical communities across multiple cities, would provide evidence on the generality of the results in different geographical contexts (Groffman et al., 2017).

5.4 Wildflowers

Chapter Four identified that wildflower seeding and planting was a popular form of alternative maintenance both in implementation and resulting public perception. This was also perceived to be favourable in relation to public perception in an urban park setting and to provide biodiversity benefits (Norton et al., 2019; Southon et al., 2017). However, the results from Chapter Three indicate that this may be contextual as images of wildflower meadow vegetation, of a similar height to a reduced mowing frequency, and viewed in an urban residential road verge setting were perceived negatively when compared to typical frequently mown grass verges. Whilst the seed mixes and height of wildflowers chosen as well as soil type will differ between councils, in Chapter Four there were contrasting views relating to the practicalities and cost of implementing wildflowers. Some road verge managers indicated that wildflowers were labour intensive, and/or expensive, in comparison to typical grass verges and as a consequence some thought they were unlikely to continue using this management. Some of these challenges were mirrored by park managers in Hoyle et al. (2017).

However, as research has shown that flowers and flower colour diversity can positively influence aesthetic response (Hoyle et al., 2018; Graves, Pearson, & Turner, 2017; Todorova, Asakawa, & Aikoh, 2004), low lying wildflower verges may provide an potential alternative option. This was an option that was currently being considered by one of the road verge managers in Chapter Four. Whilst not significant, the image depicting a low lying wildflower verge with white clover was the next preferred management option after typical management in Chapter Three. This supports in part Ramer et al., (2019) who found that 95.4% of visitors would support flowering lawns in a park context. Selection of plant species which are low in height may reduce maintenance costs in relation to mowing as there would be less vegetation growth, reducing the mowing frequency required to maintain current standards and a lower volume of cuttings may be produced. As a consequence of this potential reduction in mowing frequency, flowers would not be cut as frequently and therefore, flowering may occur for a longer period of time. Studies have found that there is a positive correlation between urban pollinator abundance and arthropod diversity with flowering abundance (Gunnarsson & Federsel, 2014; Lowenstein et al., 2014; Pardee & Philpott, 2014; Noordijk et al., 2009, 2010). Inclusion of a range of flowering species which have the ability to provide high levels of nectar and pollen, such as those identified in Hicks et al., (2016) may therefore support pollinating species. Further investigation into the design and effects of implementation of different seed mixes is required. If successful, this may be applied in other areas of green space.

5.5 Wider considerations

5.5.1 Cut and collect

The removal of arisings from road verges after mowing has been shown to have a positive impact on botanical species richness, as it thought to decrease nutrient richness and creates gaps in the vegetation allowing the growth of low lying forb species (Klimeš & Klimešová, 2001; Schaffers, Vesseur, & Sykora, 1998; Parr & Way, 1988). Whilst this was not possible to implement in Chapter Two for operational reasons, it would be valuable for further studies to assess the use of this management when reducing mowing frequency of urban road verges. The results of Chapter Three indicated that generally residents preferred road verges that were neat and tidy and some local residents mentioned in the qualitative answers that they did not like cuttings being left on the verge, suggesting that this management of cut and collect may be favourable to residents, showing signs of care (Nassauer, 1995). However, the results of Chapter Four indicated that this is not possible at a practical level, with none of the road verges managers interviewed currently undertaking this management with the exception of high-profile areas, conservation areas and some relaxed mowing areas. Reasons provided involved the cost of maintenance and the difficulty in disposing of the cuttings as they may be contaminated, mirroring UK park managers in Hoyle et al., (2017).

The use of cuttings for biomass has been identified as a potentially feasible method with high production potential but with some practicality issues, such as waste removal from the road verge before cuttings are collected, alternative equipment that may be required to collect cuttings from road verges and issues relating to grass within the anaerobic digesters such long grass becoming stuck in the stirring equipment causing faults (Voinov et al., 2015;

Meyer, Ehimen, & Holm-Nielsen, 2014). In Chapter Four, road verge managers that had investigated this potential highlighted that the high water content of the grass and the amount of investment needed for equipment currently did not make this feasible. Continued research through biomass harvesting trials such as those undertaken in Lincolnshire, UK (Lincolnshire Wildlife Trust, 2019), may make this option more feasible, which in turn may benefit biodiversity and the provision of ecosystem services.

5.5.2 Engagement with the public

Conservation actions are inextricably linked with human behaviour and therefore greater engagement with the public is required to try to increase pro-environmental behaviour (Schultz, 2011). Chapter Three indicated that people with a greater connection to nature were more likely to be accepting of biodiverse road verge management alternatives. This is supported by previous studies suggesting that a greater connection to nature may be an explanatory factor for people who exhibit pro-environmental behaviour (Whitburn, Linklater, & Abrahamse, 2019; Gosling & Williams, 2010; Kaltenborn & Bjerke, 2002). Engagement in activities that promote connectedness to nature may influence behaviour change (Schultz, 2011).

Evidence from Southon et al., (2017) and Lucey & Barton, (2011) showed that providing information on management changes can play a role in altering perceptions in an urban park context and for some hypothetical scenarios respectively. Chapter Four indicated that five road verge managers indicated that more information on the environmental and health benefits of altered management changes would be useful to provide to the public and councillors. Whilst it was not possible to implement for this study due to a lack of knowledge relating to biodiversity benefits in an urban road verge context, future research should focus on assessing whether the provision of information regarding an alternative management regime (such as the biodiversity information from Chapter Two) before implementation influences public perception of the actual road verge management change. In addition, further expansion of this knowledge base through measurement of additional environmental and health variables of alternative management strategies in urban road verges could also have a valuable role to play.

5.5.3 Road verges and other areas of green space

Local authority budgets for open spaces have been reduced by 27% since 2010 (National Audit Office, 2018). This is supported by 70.6% of road managers in Chapter 4 who indicated that they had experienced a significant decrease in their budgets. Given council budgets are currently restricted, should greater investment be given to road verges or other areas of green space that councils maintain such as parks?

Other areas of green space such as parks have been found to support higher bird and pollinator species richness than urban road verges (Baldock et al., 2019; Carbó-Ramírez & Zuria, 2011; Fernández-Juricic, 2000), with species less likely to be exposed to the same negative impacts as experienced on a road verge (Trombulak & Frissell, 2000) such as traffic mortality (Baxter-Gilbert et al., 2015), vehicular pollution (such as NO_X and NH_3)(Truscott et al., 2005) and de-icing salts (Cunningham et al., 2008; Bryson & Barker, 2002). The implementation of alternative management in parks which may require more investment such as urban meadows has been found to provide biodiversity benefits (Norton et al., 2019; Garbuzov, Fensome, & Ratnieks, 2015) and are well received by members of the public (Southon et al., 2017; Garbuzov, Fensome, & Ratnieks, 2015).
However, due to the proximity of road verges to roads, safety is a key priority for road verge managers to ensure that sightlines are maintained as highlighted in Chapter Four. Therefore, a certain level of management has to occur regardless of council budget. As reviewed in O'Sullivan et al., (2017) and Säumel, Weber, & Kowarik, (2015), urban road verges can provide a number of biodiversity and ecosystem services. Urban road verges also have the potential to act as corridors for birds and small mammals from areas of green space such as parks (Munshi-South, 2012; Fernández-Juricic, 2000), thus potentially supporting species using parks as a habitat. As nature is most commonly viewed through a window, road verges are likely to be a key part of people's daily experience of nature (Cox, Hudson, et al., 2017). Evidence from this thesis (Chapter Three) and other studies indicate that people prefer the presence of vegetation on roads than roads without vegetation present (Bonthoux et al., 2019; Fischer et al., 2018). Therefore, this suggests that members of the public would broadly be against the management option of tarmacking over road verges. Indeed, there is also great interest in the management of road verges to increase

biodiversity as evidenced by Plantlife's road verge campaign where over 85,000 people have signed a petition to campaign councils to 'cut less, cut later' (Plantlife, 2019).

As indicated in Chapter 2, cost saving measures such as reducing mowing frequency can have a positive impact, significantly increasing invertebrate abundance on the urban road verges. Therefore, even measures that do not require investment can increase invertebrate abundance. However, greater benefits may be gained if cuttings were removed from the road verges when reduced mowing occurs (Jakobsson et al., 2018; Noordijk et al., 2009, 2010; Parr & Way, 1988) which would require investment in additional machinery. Therefore, even though current council budgets are restricted, limiting opportunities for greater investment, there is a case that road verges should be considered as well as parks when providing investment.

5.5.4 Synthesis and recommendations for practitioners

Considering the combined results of this study, it is clear that there are a number of synergies and tensions that need to be considered by managers when managing urban road verges for both biodiversity and people. Reducing the mowing frequency of urban road verges is a commonly used type of alternative management undertaken for mainly financial reasons, as evidenced in Chapter Four, and from the results of Chapter Two, a reduction of mowing frequency, even over a short time period can also provide some biodiversity benefits. However, from a social perspective, results from Chapter Three indicated that in a residential setting, local residents preferred short, highly managed vegetation on road verges compared to less frequently mown verges. This mirrors how managers perceived public preference regarding road verges in Chapter Four. This conflict between biodiversity and public preferences over a relatively short timeframe, therefore, needs to be considered when planning alternative management. Despite this, Chapter Four indicates that some managers received fewer complaints when reduced mowing was undertaken over a longer period, suggesting that this conflict may lessen over time. Regardless of public preference of this type of management, the results of Chapter Three suggested that local residents perceived less frequently mown road verges to be better at supporting biodiversity than those which are frequently mown, supporting the findings found in Chapter Two.

Wildflower planting on road verges is another widely applied type of alternative management which was noted to be popular with the public by managers in Chapter Four. This contrasts with the results of Chapter Three which indicated that local residents preferred short, frequently mown grass to a hypothetical verge with wildflowers. The context of the location and wildflower composition may influence this contrast. Despite the popularity of wildflowers noted in Chapter Four, this is not a win-win scenario as the cost of wildflowers was a limiting factor for implementation highlighted by managers.

Based on the findings of this thesis and taking into consideration the synergies and tensions relating to management, the following recommendations are provided for road verge managers:

1. If undertaking alternative road verge management such as reducing mowing frequency, the context of the proposed location should be considered in the planning stages, particularly if in a populated area. To maximise public acceptance of a management change, where possible, public consultation and engagement should be undertaken providing evidence and reasoning behind the management change and why the change will be beneficial as this has been shown to influence preferences (Ramer et al., 2019; Southon et al., 2017; Lucey & Barton, 2011). If practical, actions should also be undertaken such as mowing a small strip near the pavement or road, which may provide 'signs of care' to the public by indicating that the management is deliberate (Hofmann et al., 2012; Hands & Brown, 2002; Nassauer, 1995). When presenting management plans to councillors or decision makers, it should be highlighted that acceptance of management by the public may take time.
2. Investigate the potential of changing verge composition to low-lying forbs in areas where alternative management such as reduced mowing may not be readily accepted by the public or possible from a safety perspective. This may benefit invertebrates (Smith et al., 2015) (particularly pollinators if comprised of botanical species with high levels of nectar and pollen), may be supported by members of the public (Ramer et al., 2019) and may reduce mowing maintenance costs.

3. Consider using alternative management strategies which provide biodiversity benefits across the urban landscape as this has the potential to increase habitat connectivity for pollinators using other areas of green space (Phillips et al., 2020; Baldock et al., 2019).
4. Looking to the future, with technological advances (and should local authority budgets allow it) the use of a cut and collect mowing system would be recommended. This would deliver numerous ecosystem services including biodiversity benefits (Schaffers, Vesseur, & Sykora, 1998; Parr & Way, 1988), indicate signs of care which may increase public acceptance of management and provide fuel from the use of cuttings for biomass.

5.6 Conclusion

When managing urban road verges for biodiversity, a number of factors need to be considered in decision making including ecological, economic, social and political factors (Knight et al., 2011). This thesis illustrates some of these factors and the complexities involved in trying to improve biodiversity on urban road verges. The main results show that: i) reducing the mowing frequency of urban road verges over just one growing season, increased total invertebrate abundance, ii) typical high frequency mowing is preferred by local residents compared to reduced mowing and other hypothetical scenarios in an urban residential setting despite residents recognising that current management is not the best form of management to support biodiversity and iii) financial considerations and resources, public perception and public actions, safety, spatial context, biodiversity and wider environmental benefits, physical factors and departmental and councillor input all influence management decisions.

With increasing budgetary constraints, road verge managers are considering or implementing alternative management strategies such as the reduction of mowing frequency which provide potential opportunities to maximise biodiversity benefits. However, multiple factors need to be considered when considering this management change as management may not always provide win-win scenarios. Considering the management of urban road verges from multiple perspectives is important to identify nature-based solutions from urban green spaces such as road verges.

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Appendices

Appendix 2.1.

Table. Results of t-tests and Wilcoxon Signed-Ranked tests testing the differences in invertebrate and botanical data between the two mowing treatments (every 3-4 weeks and every 6-8 weeks) for the early season (July 2016 and June 2017) and late season (September 2016). Significant results are indicated in bold.

	Early season			Late season		
Taxa or index	**t/v**	**df**	**p**	**t/v**	**df**	**p**
Mean vegetation height	**V=308.5**		**<0.001**	**t= -3.97**	**149**	**<0.001**
Total invertebrate abundance	t=-2.29	6	0.06	V=34		0.15
Invertebrate order richness	t=0	6	1	t=0.49	14	0.63
Acari abundance	t=-0.90	6	0.4	V=78		0.33
Araneae abundance	t=-1.10	6	0.31	**V=23**		**0.04**
Coleoptera abundance	t=-1.89	6	0.11	t=-0.60	14	0.56
Collembola abundance	**t=-2.53**	**6**	**<0.05**	V=51		0.64
Diptera abundance	t=-1.78	6	0.13	t=-1.92	14	0.07
Gastropoda abundance	t=-0.24	6	0.82	t=0.19	14	0.85
Hymenoptera abundance	t=-1.29	6	0.24	V=27		0.06
Hemiptera abundance	t=-0.83	6	0.44	t=-2.03	14	0.06
Lepidoptera abundance	t=-1.69	6	0.14	t=-0.42	14	0.68
Psocoptera abundance	t=1.76	6	0.13	t=-2.12	14	0.05
Thysanoptera abundance	t=-1.60	6	0.16	V=48		0.52
Botanical species richness	V=8.5		0.39	t=-0.48	14	0.64
Mean forb abundance	t=0.34	7	0.75	V=62		0.57
Mean flowering index	t=-0.54	7	0.61	V=109		**<0.01**

Appendix 2.2

Table. Results of the log transformed GLMs testing for differences in invertebrate data between the two mowing treatments (every 3-4 weeks and every 6-8 weeks) for the early season (July 2016 and June 2017). Mean vegetation height is included in the models as a fixed effect. Araneae abundance standard errors are corrected with a quasi-GLM model. Coleoptera, Psocoptera and Thysanoptera are fitted with a log transformed Gaussian GLM and Gastropoda and Lepidoptera abundance is fitted with a Gaussian GLM. Parameter estimates and standard errors are presented. Significant results are indicated in bold.

Taxon or index	Mean vegetation height	Botanical species richness	Flowering index	Mean road verge width	Tree density
Total invertebrate abundance	0.01± 0.01 p 0.26	-0.02± 0.03 p 0.54	-0.00± 0.01 p 0.99	-0.15± 0.22 p 0.58	-7.45± 7.08 p 0.40
Invertebrate order richness	0.00± 0.00 p 0.61	-0.00± 0.01 p 0.69	0.00± 0.00 p 0.26	-0.02± 0.04 p 0.67	-0.06± 1.19 p 0.97
Acari abundance	0.02± 0.01 p 0.09	-0.04±0.03 p 0.32	-0.01±0.01 p 0.16	-0.51±0.19 p 0.11	-14.55±5.95 p 0.13
Araneae abundance	0.00±0.02 p 0.89	0.08±0.13 p 0.63	0.03±0.03 p 0.33	0.11±0.59 p 0.87	31.29±42.85 p 0.54
Coleoptera abundance	0.01±0.01 p 0.33	0.01±0.05 p 0.80	-0.01±0.01 p 0.36	0.26±0.31 p 0.49	-9.87±9.82 p 0.42
Collembola abundance	0.01± 0.01 p 0.29	-0.02± 0.04 p 0.60	-0.00± 0.01 p 0.69	-0.13± 0.26 p 0.66	-8.85± 8.38 p 0.40
Diptera abundance	0.02± 0.00 p 0.06	-0.00± 0.02 p 0.91	-0.00±0.00 p 0.69	-0.10± 0.12 p 0.51	1.25±3.89 p 0.78
Gastropoda abundance	-0.39±0.45 p 0.48	0.28±2.03 p 0.90	0.25±0.37 p 0.57	9.33±13.73 p 0.57	26.96±435.27 p 0.96
Hymenoptera abundance	0.00±0.01 p 0.67	-0.02± 0.03 p 0.66	0.01±0.01 p 0.43	0.02± 0.23 p 0.93	-5.72± 7.28 p 0.51
Hemiptera abundance	0.01±0.02 p 0.77	-0.02± 0.07 p 0.84	0.02±0.01 p 0.32	-0.04± 0.48 p 0.94	-3.22±15.24 p 0.85

Lepidoptera abundance	0.16±0.05 p 0.10	-0.70±0.24 p 0.10	0.02±0.04 p 0.74	-3.07±1.61 p 0.20	-45.45±51.11 p 0.47
Psocoptera abundance	-0.03±0.01 p 0.08	0.04±0.04 p 0.43	0.00±0.01 p 0.77	0.64±0.27 p 0.14	8.13±8.52 p 0.44
Thysanoptera abundance	0.01±0.01 p 0.33	0.07±0.03 p 0.18	0.02±0.01 p 0.07	-0.34±0.24 p 0.29	13.64±7.50 p 0.21

Appendix 2.3

Table. Results of GLMMs testing for differences in invertebrate and botanical data between the two mowing treatments (every 3-4 weeks and every 6-8 weeks) for the late season (September 2016) with Site included as a random factor. Treatment and mean vegetation height are included in the models as fixed factors. Parameter estimates and standard errors are presented and significant results are indicated in bold.

Taxon or index	Treatment 6-8 weeks	Botanical species richness	Flowering index	Mean vegetation height	Mean road verge width	Tree density
Total invertebrate abundance	**0.09± 0.04 p 0.05**	-0.01±0.01 p 0.40	0.01±0.01 p 0.15	-0.00±0.01 p 0.89	-0.01±0.02 p 0.73	-1.06±0.84 p 0.21
Invertebrate order richness	-0.21±0.40 p 0.59	0.01±0.06 p 0.85	-0.03±0.07 p 0.69	-0.01±0.08 p 0.86	-0.01±0.16 p 0.93	-4.02±3.84 p 0.30
Acari abundance	0.11±0.15 p 0.46	-0.02±0.02 p 0.52	0.04±0.03 p 0.15	-0.05±0.04 p 0.13	0.03±0.07 p 0.63	-0.40±1.78 p 0.82
Araneae abundance	**0.18±0.09 p 0.05**	-0.02±0.01 p 0.19	0.02±0.02 p 0.15	0.03±0.02 p 0.13	0.01±0.04 p 0.86	-0.46±1.04 p 0.66
Coleoptera abundance	0.06±10.30 p 1.00	-0.91±1.60 p 0.57	-0.16±1.86 p 0.93	1.83±2.35 p 0.44	4.81±4.45 p 0.28	-170.04±118.86 p 0.15
Collembola abundance	0.08±0.04 p 0.07	-0.01± 0.01 p 0.47	0.01±0.01 p 0.06	-0.01±0.01 p 0.37	-0.01±0.02 p 0.66	-1.06±0.94 p 0.26
Diptera abundance	117.25±61.57 p 0.06	**-21.93±9.86 p 0.03**	-2.60±11.16 p 0.82	-20.30± 14.83 p 0.17	**82.78±27.26 p<0.01**	-832.68±780.70 p 0.29
Hymenoptera abundance	16.46±40.06 p 0.68	**-20.02±6.59 p<0.01**	-4.13±7.27 p 0.57	**20.86±10.20 p 0.04**	**40.65±18.16 p 0.03**	-771.43±560.44 p 0.17
Hemiptera abundance	18.93±61.26 p 0.76	4.32±8.32 p 0.60	-8.89±10.32 p 0.39	**24.33±11.18 p 0.03**	-8.07±23.30 p 0.73	-865.48±490.91 p 0.08
Psocoptera abundance	9.31±28.15 p 0.74	**9.48±4.83 p 0.05**	-5.71±5.08 p 0.26	9.99±7.92 p 0.21	**-29.71±13.26 p 0.03**	-463.17±472.37 p 0.33

Appendix 2.4

Table: Results of standard errors corrected with a quasi-GLM testing for differences in invertebrate and botanical data between the two mowing treatments (every 3-4 weeks and every 6-8 weeks) for the late season (September 2016) with Site included as a random factor. Treatment and mean vegetation height are included in the models as fixed factors. Parameter estimates and standard errors are presented and significant results are indicated in bold.

Taxon or index	Treatment 6-8 weeks	Botanical species richness	Mean flowering index	Mean road verge width	Mean vegetation height	Tree density
Gastropoda abundance	-0.12±0.74 p 0.88	-0.00±0.15 p 0.98	0.15±0.15 p 0.34	-0.65±0.34 p 0.09	0.24±0.22 p 0.31	-17.93±19.65 p 0.39
Lepidoptera abundance	0.33±0.61 p 0.60	0.09±0.14 p 0.54	0.06±0.09 p 0.55	-0.10±0.30 p 0.75	-0.03±0.22 p 0.90	-30.08±21.60 p 0.20
Thysanoptera abundance	0.67±0.57 p 0.28	-0.19±0.11 p 0.11	0.16±0.09 p 0.11	-0.03±0.34 p 0.92	0.15±0.21 p 0.48	23.26±20.41 p 0.28

Appendix 2.5.

Table. Invertebrate abundance and order richness across all sampling sites for both treatments in the early and late season

Year	Month	Site	Treatment	Total invertebrate abundance	Invertebrate order richness	Acari abundance	Collembola abundance	Diptera abundance	Hymenoptera abundance	Hemiptera abundance
2016	Early season	Bawtry Road	3-4 weeks	5251	11	152	2810	329	512	1178
2016	Early season	Bawtry Road	6-8 weeks	7929	11	623	5084	1025	363	440
2017	Early season	Bochum Parkway	3-4 weeks	3830	10	1134	2108	124	142	127
2017	Early season	Bochum Parkway	6-8 weeks	10065	11	2858	4725	153	408	1477
2016	Early season	Crowder Avenue	3-4 weeks	3131	11	222	1764	507	191	302
2016	Early season	Crowder Avenue	6-8 weeks	6326	11	383	4291	755	348	280
2017	Early season	Ecclesfield Road	3-4 weeks	1683	12	278	743	49	216	135
2017	Early season	Ecclesfield Road	6-8 weeks	4618	14	171	1973	248	703	796
2016	Early season	Greystones Grange Road	3-4 weeks	4268	11	385	2552	512	217	281
2016	Early season	Greystones Grange Road	6-8 weeks	4577	10	431	2933	574	187	261
2016	Early season	Greystones Hall Road	3-4 weeks	3281	12	200	1725	777	210	106
2016	Early season	Greystones Hall Road	6-8 weeks	3255	10	193	1929	604	213	171
2016	Early season	Whirlowdale Road	3-4 weeks	3174	10	721	1996	192	104	90
2016	Early season	Whirlowdale Road	6-8 weeks	2467	10	153	1363	393	106	219

2016	Late season	Blackbrook Avenue	3-4 weeks	1679	12	405	495	383	98	92
2016	Late season	Blackbrook Avenue	6-8 weeks	2378	11	715	663	239	178	163
2016	Late season	Bochum Parkway	3-4 weeks	1974	12	550	584	209	285	144
2016	Late season	Bochum Parkway	6-8 weeks	2637	11	788	790	293	295	224
2016	Late season	Bowden Wood Crescent	3-4 weeks	11056	12	2268	6519	397	348	384
2016	Late season	Bowden Wood Crescent	6-8 weeks	6943	11	636	4864	817	236	176
2016	Late season	Colley Avenue	3-4 weeks	2450	10	69	1108	550	240	240
2016	Late season	Colley Avenue	6-8 weeks	3197	11	200	1284	497	329	310
2016	Late season	Crowder Avenue	3-4 weeks	1048	11	81	337	255	75	61
2016	Late season	Crowder Avenue	6-8 weeks	1469	11	135	388	320	126	138
2016	Late season	Ecclesfield Road	3-4 weeks	8215	14	1886	5730	88	99	102
2016	Late season	Ecclesfield Road	6-8 weeks	6761	12	1557	4040	264	155	424
2016	Late season	Elm Lane	3-4 weeks	2400	11	105	595	388	214	449
2016	Late season	Elm Lane	6-8 weeks	3470	12	212	744	555	621	507
2016	Late season	Greystones Grange Road	3-4 weeks	1451	11	153	633	156	127	211
2016	Late season	Greystones Grange Road	6-8 weeks	1694	10	208	793	239	155	168
2016	Late season	Greystones Hall Road	3-4 weeks	1535	10	141	499	361	146	201
2016	Late season	Greystones Hall Road	6-8 weeks	1701	12	146	563	293	243	222

2016	Late season	Herries Road	3-4 weeks	2591	11	434	878	546	417	144
2016	Late season	Herries Road	6-8 weeks	2589	11	110	651	248	386	632
2016	Late season	Lindsay Avenue	3-4 weeks	1601	10	319	590	387	133	60
2016	Late season	Lindsay Avenue	6-8 weeks	2081	11	153	755	628	157	173
2016	Late season	Middlewood Road North	3-4 weeks	2293	10	223	1343	83	99	249
2016	Late season	Middlewood Road North	6-8 weeks	2300	10	215	1439	67	82	152
2016	Late season	Ridgeway Road	3-4 weeks	1789	12	412	637	81	199	159
2016	Late season	Ridgeway Road	6-8 weeks	1634	11	42	496	382	232	142
2016	Late season	Southey Hill	3-4 weeks	3106	11	379	907	560	585	300
2016	Late season	Southey Hill	6-8 weeks	4463	11	239	1022	859	820	541
2016	Late season	Whirlowdale Road	3-4 weeks	2641	11	273	1092	487	306	140
2016	Late season	Whirlowdale Road	6-8 weeks	2779	11	211	1013	638	256	288

Appendix 2.6

Table. Summary statistics for the raw data used within the GLM and GLMM models. Mean and standard error are presented for each variable for each mowing frequency (every 3-4 weeks and every 6-8 weeks) for the early and late season of the mowing trial.

	Mean± 1 s.e			
	Early season		**Late season**	
Taxon or Index	**3-4 weeks**	**6-8 weeks**	**3-4 weeks**	**6-8 weeks**
Total invertebrate abundance	3.52±4.18	5.61±1.01	3.06±7.17	3.07±4.46
Invertebrate order richness	11.00±0.31	11.00±0.53	11.20±0.28	11.07±0.15
Acari abundance	4.42±1.36	6.87±3.67	5.13±1.69	3.71±1.03
Araneae abundance	75.71±21.30	105.00±24.83	68.13±16.29	81.60±9.70
Coleoptera abundance	19.43±7.80	43.71±12.34	43.20±6.71	47.33±8.31
Collembola abundance	1.96±2.52	3.19±5.70	1.46±4.95	1.30±3.41
Diptera abundance	3.56±9.76	536.00±113.73	3.29±4.47	4.23±5.99
Gastropoda abundance	4.29±3.31	5.29±2.71	6.00±1.66	5.53±1.58
Hymenoptera abundance	2.27±5.01	3.33±7.41	2.25±3.70	2.85±5.11
Hemiptera abundance	3.17±1.47	5.21±1.78	1.96±2.94	2.84±4.23
Lepidoptera abundance	2.00±0.76	3.71±1.02	9.53±2.58	10.93±2.57
Psocoptera abundance	34.71±13.70	24.43±9.34	85.87±26.38	131.13±33.88
Thysanoptera abundance	77.29±15.99	0.02±0.51	115.60±42.85	128.47±41.07
Botanical species richness	16.14±1.71	16.86±1.78	14.73±1.02	15.13±1.07
Mean forb abundance	138.46±7.95	134.41±10.71	128.38±4.76	124.68±3.13
Mean flowering index	39.38±4.53	42.28±7.56	5.09±0.89	2.14±0.52
Mean vegetation height (cm)	12.05±0.93	31.49±9.13	10.17±0.74	11.75±0.68
Mean road verge width (m)	2.15±0.67	2.57±0.63	2.40±0.44	2.48±0.33
Tree density	0.07±0.02	0.07±0.02	0.05±0.01	0.05±0.01

Appendix 2.7

Table. Botanical data and road verge characteristics data collected across all sampling sites for both treatments in the early and late season.

Year	Month	Site	Treatment	Botanical species richness	Mean forb abundance	Mean flowering index	Mean vegetation height	Mean road verge width	Tree 'density'
2016	Early season	Bawtry Road	3-4 weeks	12	120.70	52.05	14.94	1.58	0
2016	Early season	Bawtry Road	6-8 weeks	16	124.42	35.07	44.81	1.6	0
2017	Early season	Bochum Parkway	3-4 weeks	23	169.93	44.58	11.69	5.7	0.11
2017	Early season	Bochum Parkway	6-8 weeks	26	183.63	78.63	23.94	5.18	0.08
2016	Early season	Crowder Avenue	3-4 weeks	12	113.77	24.00	12.32	1.45	0.07
2016	Early season	Crowder Avenue	6-8 weeks	14	136.47	20.84	14.73	1.5	0.07
2017	Early season	Ecclesfield Road	3-4 weeks	21	159.37	25.65	14.96	1.05	0
2017	Early season	Ecclesfield Road	6-8 weeks	19	152.83	58.00	76.93	3.25	0
2016	Early season	Greystones Grange Road	3-4 weeks	18	148.47	49.90	12.47	1.15	0.12
2016	Early season	Greystones Grange Road	6-8 weeks	11	108.33	28.13	11.86	1.1	0.15
2016	Early season	Greystones Hall Road	3-4 weeks	13	126.92	48.03	8.56	0.8	0.11
2016	Early season	Greystones Hall Road	6-8 weeks	16	136.38	31.36	9.51	1.05	0.1
2016	Early season	Whirlowdale Road	3-4 weeks	14	130.08	31.46	9.41	3.3	0.07
2016	Early season	Whirlowdale Road	6-8 weeks	16	98.80	43.95	38.63	4.3	0.1
2016	Late season	Blackbrook Avenue	3-4 weeks	13	131.77	4.38	7.77	1.5	0.13
2016	Late season	Blackbrook Avenue	6-8 weeks	11	123.88	3.53	11.31	1.5	0.15
2016	Late season	Bochum Parkway	3-4 weeks	23	149.03	5.79	13.92	5.7	0.11
2016	Late season	Bochum Parkway	6-8 weeks	20	157.05	6.76	13.7	5.18	0.08
2016	Late season	Bowden Wood Crescent	3-4 weeks	12	121.27	10.86	9.73	1.4	0
2016	Late season	Bowden Wood Crescent	6-8 weeks	12	117.23	1.17	8.28	1.3	0
2016	Late season	Colley Avenue	3-4 weeks	13	118.80	8.75	12.53	1.03	0
2016	Late season	Colley Avenue	6-8 weeks	9	121.60	1.98	12.84	1.07	0
2016	Late season	Crowder Avenue	3-4 weeks	12	103.45	6.07	7.77	1.45	0.07
2016	Late season	Crowder Avenue	6-8 weeks	15	122.27	2.60	13.09	1.5	0.07

2016	Late season	Ecclesfield Road	3-4 weeks	17	100.35	0.00	4.8	1.05	0
2016	Late season	Ecclesfield Road	6-8 weeks	19	125.25	0.04	7.46	3.25	0
2016	Late season	Elm Lane	3-4 weeks	18	131.48	6.25	14.682	3.9	0.04
2016	Late season	Elm Lane	6-8 weeks	11	118.67	0.15	16.91	3.35	0
2016	Late season	Greystones Grange Road	3-4 weeks	16	135.97	0.98	9.34	1.15	0.12
2016	Late season	Greystones Grange Road	6-8 weeks	14	122.60	0.89	10.87	1.1	0.15
2016	Late season	Greystones Hall Road	3-4 weeks	11	118.47	1.83	9.12	0.8	0.11
2016	Late season	Greystones Hall Road	6-8 weeks	16	104.64	1.31	12.72	1.05	0.1
2016	Late season	Herries Road	3-4 weeks	16	175.97	9.27	11.91	6.25	0
2016	Late season	Herries Road	6-8 weeks	16	118.30	2.50	14.96	2.51	0
2016	Late season	Lindsay Avenue	3-4 weeks	12	123.40	6.82	10.41	2.4	0
2016	Late season	Lindsay Avenue	6-8 weeks	17	116.80	5.58	10.83	3	0
2016	Late season	Middlewood Road North	3-4 weeks	22	117.70	0.53	6.85	2.2	0.1
2016	Late season	Middlewood Road North	6-8 weeks	24	117.77	0.00	8.65	2.1	0.04
2016	Late season	Ridgeway Road	3-4 weeks	9	135.10	8.68	12.27	1.32	0
2016	Late season	Ridgeway Road	6-8 weeks	13	130.03	0.25	13.16	3.37	0
2016	Late season	Southey Hill	3-4 weeks	13	123.43	3.92	13.22	2.6	0
2016	Late season	Southey Hill	6-8 weeks	11	134.53	3.12	12.46	2.66	0
2016	Late season	Whirlowdale Road	3-4 weeks	14	139.53	2.23	8.23	3.3	0.07
2016	Late season	Whirlowdale Road	6-8 weeks	19	139.53	2.24	9.08	4.3	0.1

Appendix 2.8

Table. Raw botanical data collected during the early and late season in 2016 and 2017. Plant species, flowering index and the mid-range value of the DOMIN scale are presented for 3 transects for each road for each mowing treatment (every 3-4 weeks and every 6-8 weeks).

Year	Season	Road	Treatment	Transect	Species	Latin name	Flowering index	DOMIN Mid range value
2017	Early season	Bochum Parkway	3-4 weeks	2	Autumn Hawkbit	Leontodon hispidus	0	0.5
2017	Early season	Bochum Parkway	3-4 weeks	1	Bee Orchid	Ophrys apifera	0.3	0.3
2016	Late season	Ecclesfield Road	6-8 weeks	2	Bittercress	Cardamine sp	0	0.3
2016	Early season	Whirlowdale Road	3-4 weeks	2	Black Medick	Medicago lupulina	0.5	0.5
2016	Late season	Ecclesfield Road	3-4 weeks	3	Bramble	Rubus fruticosus	0	0.3
2017	Early season	Ecclesfield Road	6-8 weeks	2	Broad leaved Willowherb	Epilobium montanum	0.25	0.5
2016	Early season	Bawtry Road	6-8 weeks	1	Broad-leaved Dock	Rumex obtusifolius	0	0.3
2016	Early season	Bawtry Road	3-4 weeks	3	Buck's-horn Plantain	Plantago coronopus	0	0.5
2017	Early season	Bochum Parkway	6-8 weeks	1	Bush Vetch	Vicia sepium	2	2.5
2016	Late season	Greystones Grange Road	3-4 weeks	3	Buttercup	Ranunculus sp	0	2.5
2016	Late season	Ecclesfield Road	6-8 weeks	2	Buttercup family	Ranunculaceae	0	2.5
2016	Late season	Ecclesfield Road	3-4 weeks	2	Carrot family	Apiaceae	0	2.5
2016	Early season	Bawtry Road	3-4 weeks	2	Cat's-ear	Hypochaeris radicata	12.6	18
2016	Late season	Middlewood Road North	3-4 weeks	1	Cleavers	Galium aparine	0	0.5
2016	Early season	Greystones Grange Road	3-4 weeks	3	Common Bird's-foot-trefoil	Lotus corniculatus	0.125	2.5
2016	Late season	Bowden Wood Crescent	6-8 weeks	2	Common Chickweed	Stellaria media	0	0.5
2016	Late season	Middlewood Road North	3-4 weeks	1	Common Dog-violet	Viola riviniana	0	0.3

2016	Early season	Whirlowdale Road	3-4 weeks	1	Common Field Speedwell	Veronica persica	0.285	0.3
2016	Late season	Bochum Parkway	3-4 weeks	3	Common Knapweed	Centaurea nigra	0	0.5
2016	Early season	Crowder Avenue	6-8 weeks	1	Common Mouse-ear	Cerastium fontanum	0.015	0.3
2016	Early season	Bawtry Road	3-4 weeks	2	Common Ragwort	Senecio jacobaea	0	2.5
2017	Early season	Bochum Parkway	6-8 weeks	1	Common Sorrel	Rumex acetosa	0.5	0.5
2016	Early season	Bowden Wood Crescent	6-8 weeks	2	Cow Parsley	Anthriscus sylvestris	0	0.3
2016	Early season	Greystones Grange Road	3-4 weeks	2	Crane's-bills	Geranium sp	0.2	0.5
2016	Early season	Bawtry Road	6-8 weeks	3	Creeping Buttercup	Ranunculus repens	0	0.5
2016	Late season	Blackbrook Avenue	6-8 weeks	2	Creeping Cinquefoil	Potentilla reptans	0	2.5
2016	Late season	Bowden Wood Crescent	3-4 weeks	3	Creeping Thistle	Cirsium arvense	0	0.3
2016	Late season	Lindsay Avenue	6-8 weeks	2	Curled Dock	Rumex crispus	0	0.3
2016	Early season	Bawtry Road	3-4 weeks	2	Daisy	Bellis perennis	2.5	2.5
2016	Early season	Bawtry Road	3-4 weeks	2	Dandelion	Taraxacum agg	6.3	63
2016	Early season	Bowden Wood Crescent	3-4 weeks	1	Danish Scurvygrass	Cochlearia danica	0	0.3
2016	Early season	Bawtry Road	3-4 weeks	2	Dove's foot Crane's bill	Geranium molle	1.5	2.5
2016	Early season	Greystones Grange Road	3-4 weeks	3	Fox and Cubs	Pilosella aurantiaca	0.35	0.5
2016	Late season	Ecclesfield Road	3-4 weeks	1	Garlic Mustard	Alliaria petiolata	0	7.5
2016	Late season	Elm Lane	3-4 weeks	3	Geranium family	Geraniaceae	0	0.3
2016	Late season	Ecclesfield Road	6-8 weeks	1	Germander Speedwell	Veronica chamaedrys	0	0.3
2016	Late season	Middlewood Road North	6-8 weeks	2	Geum	Geum sp	0	0.5
2017	Early season	Bochum Parkway	6-8 weeks	1	Goat's Beard	Tragopogon pratensis	0	0.3
2016	Late season	Middlewood Road North	6-8 weeks	3	Goosefoot	Chenopodium sp	0	

2017	Early season	Ecclesfield Road	3-4 weeks	3	Great Willowherb	Epilobium hirsutum	0.5	0.5
2016	Early season	Crowder Avenue	3-4 weeks	1	Greater Plantain	Plantago major	0	0.5
2016	Late season	Herries Road	6-8 weeks	2	Ground Ivy	Glechoma hederacea	0	0.3
2016	Late season	Herries Road	3-4 weeks	2	Groundsel	Senecio vulgaris	0.1	0.5
2016	Early season	Greystones Hall Road	6-8 weeks	1	Hairy Bitter-cress	Cardamine hirsuta	0.3	0.3
2016	Early season	Bawtry Road	6-8 weeks	1	Hedge Mustard	Sisiymbrium officinale	0	0.3
2016	Late season	Greystones Hall Road	6-8 weeks	3	Hemlock	Conium maculatum	0	0.3
2016	Late season	Middlewood Road North	6-8 weeks	2	Herb-Robert	Geranium robertianum	0	2.5
2016	Early season	Crowder Avenue	6-8 weeks	1	Hoary Plantain	Plantago media	0	7.5
2016	Early season	Bawtry Road	6-8 weeks	1	Hogweed	Heracleum sphondylium	2.25	7.5
2016	Early season	Greystones Grange Road	3-4 weeks	1	Knotgrass	Polygonum aviculare	2	2.5
2016	Early season	Greystones Grange Road	3-4 weeks	2	Lady's Mantle	Alchemilla vulgaris	0	0.5
2016	Late season	Ecclesfield Road	3-4 weeks	2	Lesser Burdock	Arctium minus	0	0.3
2016	Late season	Blackbrook Avenue	3-4 weeks	1	Lesser Hawkbit	Leontodon saxatilis	0	0.5
2016	Early season	Bawtry Road	6-8 weeks	1	Lesser Trefoil	Trifolium dubium	0.3	0.3
2016	Early season	Whirlowdale Road	6-8 weeks	2	Long-stalked Crane's-bill	Geranium columbinum	0.3	0.3
2017	Early season	Ecclesfield Road	3-4 weeks	2	Marsh Thistle	Cirsium palustre	0.5	0.5
2016	Early season	Whirlowdale Road	6-8 weeks	1	Meadow Buttercup	Ranunculus acris	0.3	0.3
2017	Early season	Bochum Parkway	3-4 weeks	3	Mouse-ear-hawkweed	Pilosella officinarum	0.3	0.3
2016	Late season	Elm Lane	3-4 weeks	3	Mugwort	Artemisia vulgaris	0.3	0.3
2016	Late season	Ecclesfield Road	3-4 weeks	2	Mustard family	Brassicaceae	0	0.3
2016	Late season	Ecclesfield Road	3-4 weeks	1	Nettle	Urtica dioica	0	0.3
2016	Late season	Blackbrook Avenue	3-4 weeks	1	Oxeye Daisy	Leucanthemum vulgare	0	0.5

2016	Early season	Bowden Wood Crescent	3-4 weeks	3	Pineappleweed	Matricaria discoidea	0	0.3
2016	Late season	Ecclesfield Road	6-8 weeks	2	Plume thistle	Cirsium sp	0	0.3
2016	Late season	Bochum Parkway	3-4 weeks	1	Red Campion	Silene dioica	0	0.5
2016	Late season	Bochum Parkway	3-4 weeks	1	Red Clover	Trifolium pratense	2.7	18
2016	Early season	Bawtry Road	3-4 weeks	2	Ribwort Plantain	Plantago lanceolata	11.7	18
2016	Early season	Greystones Hall Road	6-8 weeks	2	Rough Chervil	Chaerophyllum temulum	0	0.3
2016	Late season	Lindsay Avenue	6-8 weeks	3	Scentless Mayweed	Tripleurospermum inodorum	0.3	0.5
2016	Early season	Bowden Wood Crescent	6-8 weeks	1	Selfheal	Prunella vulgaris	2.5	2.5
2016	Early season	Crowder Avenue	3-4 weeks	1	Shepherd's Purse	Capsella bursa-pastoris	0.3	0.3
2016	Early season	Bawtry Road	3-4 weeks	2	Smooth Sow-thistle	Sonchus oleraceus	0	0.5
2016	Late season	Whirlowdale Road	3-4 weeks	1	Sowbread	Cyclamen hederifolium	0.5	0.5
2016	Early season	Bawtry Road	6-8 weeks	1	Spear Thistle	Cirsium vulgare	0.25	0.5
2016	Early season	Crowder Avenue	3-4 weeks	2	Speedwell	Veronica sp	0.5	0.5
2016	Late season	Elm Lane	3-4 weeks	2	Spring Vetch	Vicia lathyroides	0	0.5
2016	Late season	Ridgeway Road	6-8 weeks	1	Upright Hedge-parsley	Torilis japonica	0	0.3
2016	Late season	Bochum Parkway	3-4 weeks	1	Vetch	Vicia sp	0	2.5
2016	Late season	Bowden Wood Crescent	3-4 weeks	3	Wavy Bitter-cress	Cardamine flexuosa	0.5	0.5
2016	Early season	Bawtry Road	3-4 weeks	2	White Clover	Trifolium repens	2	2.5
2016	Early season	Bawtry Road	3-4 weeks	2	White Dead-nettle	Lamium album	0	0.3
2016	Late season	Ecclesfield Road	6-8 weeks	3	Willowherb	Epilobium sp	0	0.3
2016	Early season	Greystones Grange Road	3-4 weeks	1	Wood Avens	Geum urbanum	2.25	7.5
2017	Early season	Bochum Parkway	3-4 weeks	3	Woolly Thistle	Cirsium eriophorum	0	0.3

2016	Early season	Bawtry Road	3-4 weeks	3	Yarrow	Achillea millefolium	3.75	7.5

Appendix 2.9

Table. Results of the log transformed GLMM testing for differences in total invertebrate abundance without Araneae abundance between the two mowing treatments (every 3-4 weeks and every 6-8 weeks) for the late season (September 2016) with Site included as a random factor. Treatment is included in the models as fixed factors. Parameter estimates and standard errors are presented and significant results are indicated in bold.

Taxon or index	Treatment 6-8 weeks	Botanical species richness	Flowering index	Mean road verge width	Tree density
Total invertebrate abundance without Araneae abundance	**0.08± 0.03 p 0.02**	-0.01±0.01 p 0.34	0.01±0.01 p 0.12	-0.01±0.02 p 0.76	-0.96±0.82 p 0.24

Appendix 3.1
Face-to-face questionnaire

Urban roadside green space research: Project Information Sheet

We are conducting research on urban roadside green space, and how it can be improved for people and for wildlife. As a part of this we are interested in what people think about the roadside environment in their own area, and different ways of managing it.
As part of this work we are conducting short questionnaire surveys with people from a number of areas across the city. We would be grateful if you would please complete this survey about your views on roadside green space. The questionnaire will take about 5 minutes to complete.

- Your responses will be kept strictly anonymous, and we will not record your name, just the side of the road you live on and the street name.
- We will ask a few general questions about you (which are used to ensure we have a representative sample), but you can leave these out if you choose to.
- Your participation is completely voluntary and you can withdraw from the survey at any time.

If you have any questions now, then please feel free to ask. If you have any questions or you would like to find out more about the project, please contact:

Olivia Richardson
Department of Animal and Plant Sciences
Alfred Denny Building
Western Bank
Sheffield, S10 2TN
email: ocrichardson2@sheffield.ac.uk

This research has received ethics approval by the Department of Animal and Plant Sciences at the University of Sheffield. The work is part of a wider project called Living Highways, which aims to improve the biodiversity and benefits to people from urban roadside greenspace, in partnership with the Sheffield and Rotherham Wildlife Trust and Amey plc. This questionnaire research is being conducted independently by the University.
If you need any more information about the project or something is unclear, then please do ask us.

Please keep this copy of the project information for reference.

Thank you for taking part in this survey!

Urban roadside green space research survey: Consent Form

I understand that:

- My responses will be kept strictly anonymous, and the survey will not record my name, only the side of the road I live on and the street name.
- I will be asked a few general questions about myself (which are used to ensure the researchers have a representative sample), but I can leave these out if I choose to.
- My participation is completely voluntary and I can withdraw from the survey at any time.

I am over 18 years of age and I agree to take part in the survey: ☐

Sometimes information collected for one specific project can be useful for other research in the future.
Would you be happy for the results (which are all anonymous) from the survey to be kept and potentially be used for other research by the same research team in the future?

Yes ☐ No ☐

Section A. Road verge change

1. **How long have you lived on this street?**

   …………………………………………………………….

2. **Last spring and summer did you notice any differences on the verges on the different sides of this street?**

   Yes ☐ No ☐

NOTE TO INTERVIEWER: Go straight to Question 4 if no change noted and from now on only ask about their side of the road (NOT THE OPPOSITE SIDE OF THE ROAD SECTION).

3. **What changes did you notice on the road verge?**

   ………
   ………

4. **During the spring and summer last year, a mowing trial was taking place on your road. Thinking back to that time, please give a preference score from 0 to 10 for the road verge on your side of the road and the opposite side of the road, where 0 is strongly dislike and 10 is strongly like.**
   NOTE TO INTERVIEWER. REMINDER: If answered NO in Question 2, just ask about their side of the road for Question 4 and 5. For Question 5, just ask, 'Please explain why you feel this way about the verge on your side of the road?' Don't ask Questions 6 and 7 in this scenario.

	0 Strongly Dislike	1	2	3	4	5 Neither like or dislike	6	7	8	9	10 Strongly like
Your side of the road	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Opposite side of the road	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

NOTE TO INTERVIEWER: Please rotate the order of Question 5 and 6 each time the question is asked.

5. **Please explain why you feel this way about the verge on your side of the road?**

   ………
   ………

6. **Please explain why you feel this way about the verge on the opposite side of the road?**

   ………
   ………

7. **Did you do anything differently due to this change (for instance when viewing or using the street)? Please describe what.**

………

NOTE TO INTERVIEWER: If answered NO in Question 2, can ask Question 8 and 9 but only ask about their side of the road. Do not ask Question 10, but do ask Question 11 onwards.

8. **Based on your experience from last spring and summer, please give a score from 0 to 10 for how good you think the road verge on your side of the road and the opposite side of the road were for supporting a wide range of plants and animals such as insects, where 0 is very poor and 10 is very good.**

	0 Very poor	1	2	3	4	5 Neither	6	7	8	9	10 Very good
Your side of the road	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Opposite side of the road	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

9. **Please explain why you think this about the verge on your side of the road?**

………

10. **Please explain why you think this about the verge on the opposite side of the road?**

………

11. **Over the spring and summer last year, the road verges on one side of the road was mown less frequently than normal. What do you think about mowing verges less frequently?**

………

………

Section B. Demographic questions. NOTE TO INTERVIEWER: Tell the participant that you will now be asking some demographic questions. Remind them that they have the option to not to answer any question at any point during the survey. These questions are on a separate piece of paper to show respondents.

12. On average over the course of a year, how often do you visit the countryside?

☐ Daily ☐ A few times a week ☐ Weekly ☐ Fortnightly

☐ Monthly ☐ Every few months ☐ Once or twice a year ☐ Never

13. What is your age?

☐ 18-24 ☐ 25-34 ☐ 35-44 ☐ 45-54

☐ 55-64 ☐ 65-74 ☐ 75-85 ☐ 85+

13. What is your gender?

☐ Female ☐ Male ☐ Other

14. What is your ethnic group? Please tick the one box which best describes your ethnic group or background.

A White

- ☐ English/Welsh/Scottish/Northern Irish/British
- ☐ Irish
- ☐ Gypsy or Irish Traveller
- ☐ Any other white background, please describe…………………..

B Mixed/multiple ethnic groups

- ☐ White and Black Caribbean
- ☐ White and Black African
- ☐ White and Asian
- ☐ Any other Mixed/multiple ethnic background, please describe…………………

C Asian/Asian British

- ☐ Indian
- ☐ Pakistani
- ☐ Bangladesh
- ☐ Chinese
- ☐ Any other Asian background, please describe……………………………………

D Black/African/Caribbean/Black British

- ☐ African
- ☐ Caribbean
- ☐ Any other Black/African/Caribbean background, please describe………………..

E Other ethnic group

- ☐ Arab
- ☐ Any other ethnic group, please describe…………………….

15. What is your employment situation? (Tick as many as apply)

- ☐ I study full-time
- ☐ I am retired
- ☐ I am a housewife/ househusband
- ☐ Other
- ☐ I work full time
- ☐ I work part time
- ☐ I am unemployed/between jobs
- ☐ I am freelance/ self- employed

16. Please tick all the qualifications that you have completed. (Please tick as many as apply)

- ☐ O-levels
- ☐ GCSE
- ☐ A-level
- ☐ BTEC
- ☐ International Baccalaureate
- ☐ Other (please specify) ________________________
- ☐ Higher national certificates
- ☐ Bachelor degree
- ☐ Postgraduate degree (eg Masters)
- ☐ PhD

Thank you for completing this survey!

Road information

Date of survey …………… Road name ………………………………………………………………………

Side of the road the respondent lives on (MOW/NO- MOW)……………………………………………

Code…………………………………………

Appendix 3.2 Postal Questionnaire

Urban roadside green space: Project Information Sheet

Thank you for answering the door to door questionnaire. We would like to find out more about your opinions on the roadside environment and how they are managed. We would be grateful if you could please complete this additional survey about urban roadside verge management. This will take about 10 minutes to complete.

- Your responses will be kept strictly anonymous, and we will not ask for your name, but this questionnaire will be linked to the door to door questionnaire you've answered.
- We will ask a few general questions about you (which are used to ensure we have a representative sample), but you can leave these out if you choose to.
- Your participation is completely voluntary and you can withdraw from the survey at any time.

Please fill in the questionnaire and send it back using the attached, addressed, stamped envelope. By filling in this questionnaire, you will be put into a prize draw with a chance to win **£50 worth of Amazon vouchers**.

To be entered into the prize draw:

1. Please write your email address on the separate sheet provided with the questionnaire.
2. Post both the separate sheet and the completed questionnaire back in the same envelope provided.

Your email address will be not be associated with your answers and will only be used to inform you if you have won the prize draw.

If you have any questions or you would like to find out more about the project, please contact:

Olivia Richardson
Department of Animal and Plant Sciences
Alfred Denny Building
Western Bank
Sheffield, S10 2TN
email: ocrichardson2@sheffield.ac.uk

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Thank you for taking part in this survey!

Urban roadside green space: Consent Form

Please read the project information provided on the previous page.
I understand that:

- My responses will be kept strictly anonymous, and the survey will not record my name, but this questionnaire will be linked to the door to door questionnaire I've answered.
- I will be asked a few general questions about myself (which are used to ensure the researchers have a representative sample), but I can leave these out if I choose to.
- My participation is completely voluntary and I can withdraw from the survey at any time.

I am over 18 years of age and I agree to take part in the survey: ☐

Sometimes information collected for one specific project can be useful for other research in the future.
Would you be happy for the results (which are all anonymous) from the survey to be kept and potentially be used for other research by the same research team in the future?

Yes ☐ No ☐

Section A: Roadside environment

1. **Attached are a series of photographs showing five different types of road verges. Imagining that this is alongside a road in your area, please give a preference score for each road verge image from 0 to 10, where 0 is strongly dislike and 10 is strongly like.**

	0 Strongly Dislike	1	2	3	4	5 Neither like or dislike	6	7	8	9	10 Strongly like
A	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
B	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
C	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
D	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
E	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

2. **Do you have any further comments about why you rated the images in this way?**

....
....
....
....
....

3. **Looking at the same photographs as Question 1, please give a score from 0 to 10 for how good you think each of the five verge types are for supporting a wide range of types of plants and animals such as insects, where 0 is very poor and 10 is very good.**

	0 Very poor	1	2	3	4	5 Neither	6	7	8	9	10 Very good
A	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
B	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
C	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
D	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
E	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

4. **Do you have any further comments about why you rated the images in this way?**

....
....
....
....
....

5. **This question is a series of statements about urban roadside management. Please select the response that best describes how you feel about the statement.**

	Strongly disagree	Partially disagree	Neither agree or disagree	Partially agree	Strongly agree
The appearance of a roadside verge doesn't matter to me	☐	☐	☐	☐	☐
Managing roadside verges for nature is important to me	☐	☐	☐	☐	☐
I would prefer roadside verges to be tarmacked	☐	☐	☐	☐	☐
I like roadside verges to look neat and tidy	☐	☐	☐	☐	☐
I don't mind if vegetation on a verge is taller (i.e. up to 30cm / 1 foot in height) if it is beneficial to nature	☐	☐	☐	☐	☐
It is not important to manage roadsides to benefit nature	☐	☐	☐	☐	☐
Efforts to conserve urban nature should focus on parks not roadside verges	☐	☐	☐	☐	☐

6. **What advantages if any, do you think roadside vegetation (i.e. trees and other plants) has in urban areas?**

....

....

7. **What disadvantages if any, do you think roadside vegetation has in urban areas?**

....

....

8. **Do you/another person in your household/a person you employ manage the vegetation outside of your house?**

Yes ☐ No ☐

If you answered no to Question 8, skip Question 9 and go to Question 10.

9. **Please describe all management of the vegetation by people in your house or in your employment (including its frequency) and why is this done?**

....

....

10. **Please tick which activities you do on your street and the number of times you do each activity in an average week?**

Activity	**Please tick if you do this activity (✓)**	**How many times in an average week do you do this activity?**
Running		
Walking the dog		
Walking to the bus stop/shops		
Walking to the car		
Playing games on the street		
Watching other people		
Cycling		
Driving along the road		
Talking to neighbours		
Managing vegetation		
Watching nature		
Other		

11. **Are there any activities that members of your household do on your street that you haven't already ticked? Please list these.**

....
....

12. **This section is a series of statements about the environment. Please rate the extent to which you agree with each statement.**

	Strongly disagree	**Partially disagree**	**Neither**	**Partially agree**	**Strongly agree**
My ideal holiday spot would be a remote wilderness area	☐	☐	☐	☐	☐
I always think about how my actions affect the environment	☐	☐	☐	☐	☐
My connection to nature and the environment is a part of my spirituality	☐	☐	☐	☐	☐
I take notice of wildlife wherever I am	☐	☐	☐	☐	☐
My relationship to nature is an important part of who I am	☐	☐	☐	☐	☐
I feel very connected to all living things and the earth	☐	☐	☐	☐	☐

13. **Do you have any final comments which you would like to make in relation to urban roadside verge management, which hasn't been covered in this survey?**

………

………

Section B: Demographic questions. If you are the same person who answered the door to door survey, you can skip these questions.

14. **On average over the course of a year, how often do you visit the countryside?**

☐ Daily ☐ A few times a week ☐ Weekly ☐ Fortnightly

☐ Monthly ☐ Every few months ☐ Once or twice a year ☐ Never

15. **What is your age?**

☐ 18-24 ☐ 25-34 ☐ 35-44 ☐ 45-54

☐ 55-64 ☐ 65-74 ☐ 75-85 ☐ 85+

16. **What is your gender?**

☐ Female ☐ Male ☐ Other

17. **What is your ethnic group? Please tick the one box which best describes your ethnic group or background.**

A White

- ☐ English/Welsh/Scottish/Northern Irish/British
- ☐ Irish
- ☐ Gypsy or Irish Traveller
- ☐ Any other white background, please describe…………………..

B Mixed/multiple ethnic groups

- ☐ White and Black Caribbean
- ☐ White and Black African
- ☐ White and Asian
- ☐ Any other Mixed/multiple ethnic background, please describe…………………

C Asian/Asian British

- ☐ Indian
- ☐ Pakistani
- ☐ Bangladesh
- ☐ Chinese
- ☐ Any other Asian background, please describe…………………………………….

D Black/African/Caribbean/Black British

- ☐ African
- ☐ Caribbean
- ☐ Any other Black/African/Caribbean background, please describe………………..

E Other ethnic group

- ☐ Arab
- ☐ Any other ethnic group, please describe…………………….

18. **What is your employment situation?** (Tick as many as apply)

- ☐ I study full-time
- ☐ I am retired
- ☐ I am a housewife/ househusband
- ☐ Other
- ☐ I work full time
- ☐ I work part time
- ☐ I am unemployed/between jobs
- ☐ I am freelance/ self- employed

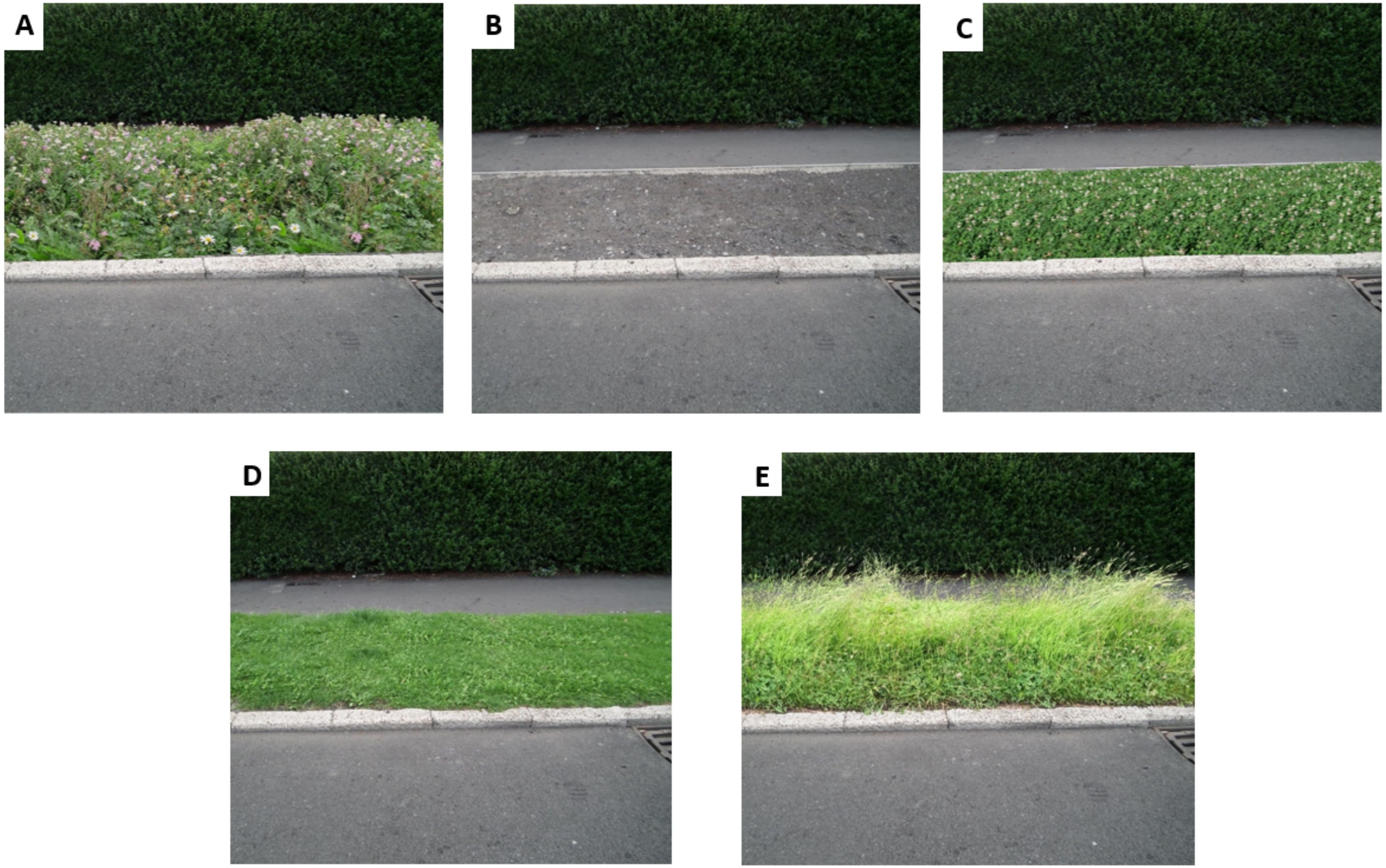
19. **Please tick all qualifications that you have completed.** (Please tick as many as apply)

- ☐ O-levels
- ☐ GCSE
- ☐ A-level
- ☐ BTEC
- ☐ International Baccalaureate
- ☐ Other (please specify) ________________________
- ☐ Higher national certificates
- ☐ Bachelor degree
- ☐ Postgraduate degree (eg Masters)
- ☐ PhD

Thank you for completing this survey!

Appendix 3.3
Images for Question 1 and 3 in the postal questionnaire survey

Images for Question 1 and 3



Appendix 3.4
Histogram of questionnaire respondents

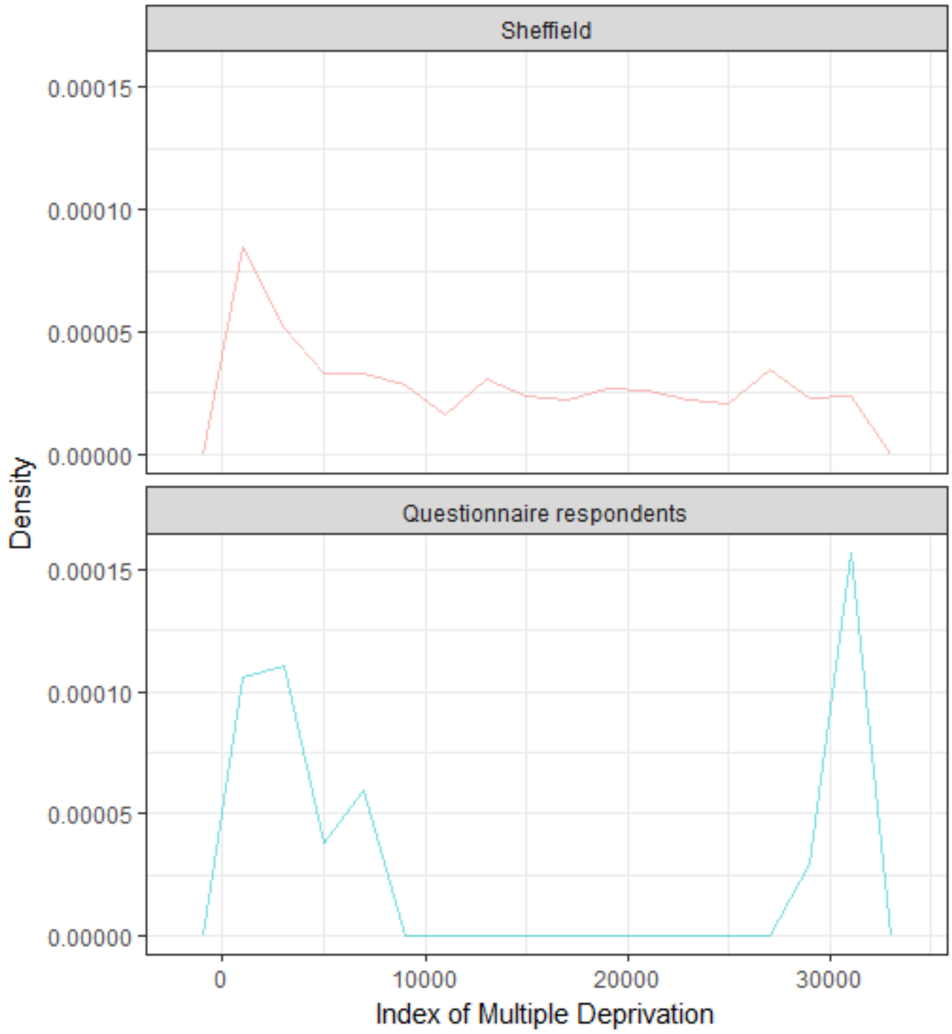


Figure . Histogram of questionnaire respondents and the population of Sheffield's Index of Multiple Deprivation (IMD). The Index of Multiple Deprivation ranks areas from 1 (most deprived area) to 32, 844 (least deprived area).

Appendix 3.5
Additional analyses assessing local resident's perception of aesthetic value and perceived biodiversity value of the reduced mowing regime (road verges mown every 6-8 weeks) compared to the regular mowing regime (mown every 3-4 weeks) on their road including nature relatedness as an interaction term.

Table. Results from the global cumulative linked mixed model asking "During the spring and summer last year, a mowing trial was taking place on your road. Thinking back to that time, please give a preference score from 0 to 10 for the road verge on your side of the road and the opposite side of the road, where 0 is strongly dislike and 10 is strongly like". Data reported are parameter estimates, standard error, z-value and P-value. Preference for typical mowing frequency (every 3-4 weeks) was used as the reference intercept, so all results are compared to these values. Mean nature relatedness values were included as an interaction term. Values in bold indicate that they have a significant effect on mowing preference.

Variables	Parameter estimate ± standard error	z-value	P-value
Reduced mowing frequency	-1.72±1.47	-1.17	0.24
Nature relatedness	0.14±0.27	0.52	0.61
Age (45-54)	0.27±0.63	0.42	0.67
Age (55-64)	**-1.41±0.72**	**-1.96**	**0.05**
Age (65-74)	-0.50±0.62	-0.81	0.42
Age (75-85)	-0.79±0.73	-1.08	0.28
Age (85+)	-1.69±1.31	-1.29	0.20
Gender (male)	0.28±0.37	0.75	0.45
Ethnicity (white)	0.42±0.93	0.45	0.65
Index of Multiple Deprivation (16,000-32,000)	-0.17±0.45	-0.36	0.72
Final qualification (Bachelor degree)	0.39±0.66	0.59	0.56
Final qualification (Diploma)	-0.74±0.64	-1.16	0.25
Final qualification (GCSE)	-0.20±0.59	-0.34	0.74
Final qualification (Postgraduate degree)	0.04±0.62	0.06	0.95
Reduced mowing frequency: nature relatedness	0.15±0.38	0.39	0.70

Table. Results from the global cumulative linked mixed model asking "During the spring and summer last year, a mowing trial was taking place on your road. Thinking back to that time, please give a preference score from 0 to 10 for how good you think the road verge on your side of the road and the opposite side of the road are for supporting a wide range of plants and animals such as insects, where 0 is poor and 10 is very good". Data reported are parameter estimates, standard error, z-value and P-value. Preference for typical mowing frequency (every 3-4 weeks) was used as the reference intercept, so all results are compared to these values. Mean nature relatedness values were included as an interaction term. Values in bold indicate that they have a significant effect on mowing preference.

Variables	**Parameter estimate ± standard error**	**z-value**	**P-value**
Reduced mowing frequency	2.30±1.61	1.43	0.15
Nature relatedness	0.20±0.31	0.65	0.52
Age (45-54)	-0.73±0.68	-1.08	0.28
Age (55-64)	-0.61±0.75	-0.81	0.42
Age (65-74)	-0.70±0.66	-1.06	0.29
Age (75-85)	-0.60±0.79	-0.76	0.45
Age (85+)	-2.48±1.58	-1.57	0.12
Gender (male)	0.59±0.39	1.51	0.13
Ethnicity (white)	0.29±0.95	0.30	0.76
Index of Multiple Deprivation (16,000-32,000)	-0.23±0.53	-0.43	0.67
Final qualification (Bachelor degree)	**1.71±0.72**	**2.39**	**0.02**
Final qualification (Diploma)	0.85±0.65	1.31	0.19
Final qualification (GCSE)	0.71±0.64	1.12	0.26
Final qualification (Postgraduate degree)	0.30±0.66	0.45	0.65
Reduced mowing frequency: Nature relatedness	-0.35±0.42	-0.85	0.40

Appendix 3.6
Content Analysis coding schedule and background provided to the second coder

Content Analysis Coding Schedule

Background

This content analysis involves assigning codes to some open ended responses I received in two questionnaires about urban roadside verge management, by themes.

To give some context, a mowing trial took place in the summer of 2016 on randomly selected roads around Sheffield. A paired design was used where one side of the road was mown every 6-8 weeks (less frequently than usual) and the other side (every 3-4 weeks- this is typical management). Residents were made aware of the trial through leaflets through their door, a press release and signs on lamp posts. I conducted botanical and invertebrate surveys on these road verges in 2016 which some residents saw me doing. Residents living on these roads were then interviewed in early 2017 to assess their views about the mowing trial and about other hypothetical scenarios.

The questions

There are 2 open ended questions which I am analysing and the question asked is written at the top for each question. All these questions apart from Q2 are focusing on **WHY** the respondent has chosen to rate an image/a side of the road in a certain way so **please refer back to the question when looking at the responses, to critically decide whether the response is answering the question. If the response is just repeating a preference (which they will have provided a score for before answering this part of the question), then do not code this.**

- Q1 is regarding the impact of the mowing trial taking place on their road. For each person interviewed, they responded about their side of the road and the opposite side of the road. I've then worked out which side was mown regularly and less frequently, so each part of this response is related to what actually happened on the different sides of the road. This can be seen in the spreadsheet under the mowing frequency column. Each person's response has two rows: one for reduced frequency mowing and another for normal frequency mowing. Please base your coding on information provided about both sides of the road. **For this question, it is important to make sure that the responses are related to the mowing trial.**

- Q2 asks residents what do they think about mowing verges less frequently. For this question, **I'm just interested in their reaction/opinion about mowing verges less frequently so please just code this and not information relating to other issues.**

The task

I've provided you with 25% of the responses for each of these questions. Please read through all the categories for the question from this schedule before starting to code a particular question. Read the responses in the spreadsheet and try to assign each response with the relevant theme/code that is appropriate.

If the response **matches** one/more of the categories below, please put a **1** under the corresponding column for that category/categories in the spreadsheet. For all questions, it is fine if the same response has more than one category associated with it ie if in one response it mentions both neat and tidy and signs of care (which are both about aesthetic value), you can code both of these by putting a 1 under both columns A and C. If the response **isn't relevant/answering the question**, please do not code this and put a note under the column 'Coding notes' why. This will allow me to check that I've coded responses based on a reproducible logic.

Q1 (Q5 and Q6 from the door to door questionnaire). During the spring and summer last year, a mowing trial was taking place on your road. Thinking back to that time, please give a preference score from 0 to 10 for the road verge on your side of the road and the opposite side of the road, where 0 is strongly dislike and 10 is strongly like.
->Please explain why you feel this way about the verge on your side of the road?
-> Please explain why you feel this way about the verge on the opposite side of the road?
When coding this question, please only code statements related to the mowing trial, not other general comments. Each person's response is shown over two rows as each person has responded about the regularly mown side of the road (see normal in mowing frequency column) and the reduced mowing frequency side of the road (see reduced in the mowing frequency column). Please base your coding on the information provided from both sides of the road. **If the person doesn't know and/or isn't answering the question and/or is not saying why** they rated that side of the road, please do not code this response and put a comment why under the column 'Coding notes'.

A. **1. Aesthetic value- neat and tidy vegetation**
   If the response mentions positive language regarding 'neat' and/or 'tidy' vegetation or infers that it looks orderly. Do not include in this category if the response refers to vegetation with regards to be cared for or is this relates to vegetation being damaged by vehicular parking.
   Examples: "**Looked neater** and well kept", "**Tidy** and visible" and "keep **neat and tidy**".

   2. Aesthetic value- messy and unkempt vegetation
   If the response mentions regarding 'untidy' and/or 'scruffy' and/ or 'messy' and/or 'unkempt' directly using negative language or infers that the consequences of mowing such as left grass cuttings/arisings cause a 'mess'. Do not include in this category if the response refers to vegetation with regards to be cared for or is this relates to vegetation being damaged by vehicular parking.
   Examples: "It **looked untidy**", "looked **unkempt**" and "It looked a **mess".**

B. **1. Aesthetic value- positive perception of short vegetation height and/or negative perception of long vegetation height**
   If the response mentions that the respondent mentions vegetation height in relation to the mowing trial. Words may include 'short' or 'mown' using positive language and/or 'long' or "uncut" or "overgrown" using negative language directly or infers that it needs to be cut regularly and/or mentions that the respondent/ other residents had cut the verge themselves.
   Examples: "really annoyed. **Left long** and had to cut it myself", "**No advantage to leaving things uncut**" & "Not desperately concerned about how often they **mow as long as not a meadow"**.

2. Aesthetic value-positive perception of long vegetation height and/or negative perception of short vegetation height

If the response mentions that the respondent mentions vegetation height in relation to the mowing trial. Words may include ‘long’ or ‘uncut’ or ‘overgrown’ using positive language and/or ‘short’ or ‘cut’ using negative language or infers that the vegetation doesn’t need to be cut regularly.

Examples: “Would **prefer overgrown** greenspace to not greenspace”.

C. 1. Aesthetic value- positive perception of signs of care

If the response mentions that the road verge is ‘cared for’ and/or ‘looked after’ and/or ‘inhabited’ or it looks like it is maintained or kept by someone. This is different from neat and tidy vegetation in that a road verge can be maintained but doesn’t necessarily mean that it looks neat and tidy.

Examples: “ looked neater and **well kept**”, “Had been **kept**, tidy, **maintained**” and “Looked tidy and **maintained**”.

2. Aesthetic value- negative perception in relation to signs of care.

If the response mentions that the road verge is ‘no-one cares’ and/or ‘unkept’ or it looks like it isn’t maintained by someone. This is different from neat and tidy vegetation in that a road verge can be maintained but doesn’t necessarily mean that it looks neat and tidy.

Examples: “looked a bit more **unloved”, “Not looked after at all**” and “People do tend to tend their own, otherwise it looks like a horrible estate **and not cared for”**.

D. Aesthetic value- litter/dog poo

If the response mentions that the road verge had litter or rubbish or any objects that are being described as if they have been thrown away and could be classed as litter. In addition, if the word, ‘clean’ or ‘unclean’ is used, include as this code. In addition, include if the response directly mentions dog poo or any variations of dog poo such as dog mess/dog faeces/dogs fouling/dog muck/dog dirt or any words that imply that dog owners don’t pick up dog poo.

Examples: “Risk of more **dog poo** in grass”, “All messed up. Paper and everything all own. **Paper. Napkins**” & “verges constantly untidy with **rubbish** and everything”.

E. Aesthetic value- symmetrical verges

If the response suggests that the resident would like verges on both sides of the road or on same side of the road to be consistently mown at the same time and/or dislikes asymmetrical verges- verges that were cut at different times.

Examples: ‘Looked a **bit asymmetrical**. Not that that was a problem but one side shorter than other’, ‘**Some people cut down, others didn't. Wasn't consistant**’ & ‘Didn't like the look of verges being cut, lady across road cut hers. Felt guilty as ruined trial. We were about to cut hers. We would have liked to have known what was happening. Think results will have got muddled up with Amey stuff. Didn't notice one was done, **both sides never cut at the same time’**.

F. **Aesthetic value- Looked same as normal**
If the response suggests that the road verge looked the same as normal.
Examples: "Don't have any strong things. Just **normal as you are used to seeing it**" & "Never looked **any different to what it normally looked like".**

G. **Aesthetic value- Vehicular parking negatively impacts road verge aesthetics**
If the response mentions the visual appearance of road verges has been impacted by vehicular parking, damaging the grass verge.
Examples: "**Not that nice when people have parked on it**", "Having people **parking on grassy parts churns it all up**" & "**What spoils it is people parking on it for main road**".

H. **Aesthetic value- Other**
If the response makes a standalone mention of how the road verge appears.
*Examples: "*Well sort of look neat and tidy but I guess a **little bit dull**" & "The council do a job regularly mowing it. Nice length and **green**".

I. **Mowing trial had a positive impact on wildlife and plants on road verges which is beneficial and/or appreciation that the road verge mown normally may have not been as good for wildlife and plants.**
If the response mentions that the mowing trial has had a positive impact on wildlife/plants and/or this is expressed using positive language. Also include if the respondent appreciates wildlife on the road verge and/or appreciates that elements of the road verge such as wildflowers can benefit wildlife. Do not include if trees are mentioned, as the management of trees remained the same during the mowing trial.
Examples: "Did **improve amount of flowers** we got on verge", "**We were quite interested in the bugs and things. Gave son chance to look for bugs**" & normal: "**Looks neat but not as good for the wildlife.**"

J. **Mowing trial had a negative impact on wildlife and plants on road verges and/or supported problematic wildlife and plants**
If the response suggests that the respondent thought that the mowing trial had a negative impact on wildlife and plants and/or supported wildlife/plants that they considered to be problematic and/or unfavourable. Include if the response suggests that some wildlife and plants are viewed as 'pests' and/or wildlife and plants are perceived negatively.
Example: "Thought It was very dangerous. I'm a childminder. **Not good for wildlife as got more wildlife on my verge"**.

K. **Mowing trial supported problematic wildlife and plants on the road verge.**
If the response suggests that the respondent thought that the mowing trial would increase problematic wildlife and plants such as 'pests'.
Example: "From public perspective, **will just increase pests**".

L. Mowing trial had no impact on wildlife and plants on road verges

If the response suggests that the respondent thought that there was no difference and/or no impact of the mowing trial on wildlife and plants on road verges.

Examples: "It looked untidy. **Didn't notice any difference in wildlife e.g. butterfly. Any different**. Didn't see anything but then you don't see things on your own front doorstep"& "Looked a mess. We went out and cut the verge ourselves. Still get foxes going up and down street. **Bird life not affected at all**. Used to have thrushes and woodpeckers anymore. Why don't have it? Built a fire station and that killed them off. Used to get lots of squirrels and they have gone".

M. Safety

If the responses includes any mention of safety concerns or hazards such as restricted vision caused by the road verge and directly uses the words 'dangerous' or 'slipping' with regards to the road verge.

Examples: "Thought It was very **dangerous" &** "**Hazard as couldn't see traffic**".

N. Accessibility across the verge

If the response mentions access for people getting to/from a location or a vehicle or moving items such as a wheelie bin by crossing or using the road verge. This also includes being able to see what is in the verge.

Examples: "**Anyone getting out of the car have to walk along verge"**, "Grass uncomfortably long **for people crossing the road"** and "**Other side could see what you were walking on most of time".**

O. Discouraging vehicular parking

If the response suggests the presence of long vegetation/flowers deters parking on verges using language which suggests this is a positive consequence.

Examples: "Grass might help **stop parking**"& "Not as **many cars park on it".**

P. Lack of knowledge about the trial

If the response mentions that the respondent didn't know why the mowing trial had taken place. Also include if the respondent "didn't notice" the mowing trial.

Examples: "Looked a bit scruffy and **people didn't really know why it had been done**", "**Not many residents know what was happening**, and suspect they cut their own verge" & "Didn't like the look of verges being cut, lady across road cut hers. Felt guilty as ruined trial. We were about to cut hers. **We would have liked to have known what was happening**. "

Q. Council resources

If the response mentions that road verge management is dependent on council resources. This includes the mention that the trial would save money or the council money and implies that as residents pay council tax, the council should maintain the grass verge.

Examples: "Served no purpose but **to save money"** & **"**Had to cut it myself. It's what **I pay my council tax for**".

Q2 (Q11 from the door to door questionnaire). Over the spring and summer last year, the road verges on one side of the road was mown less frequently than normal. What do you think about mowing verges less frequently?

A. Consistently against mowing less frequently

If the response suggests that the respondent has a consistently negative reaction towards mowing verges less frequently such as 'outrageous' or 'against it' or 'don't think it's a good idea' or specifically says that it should be mown frequently or more frequently or regularly or at the same frequency as that before the trial started. This also includes if the respondent mows the verge themselves, suggesting they prefer the verge to be mown frequently.

Examples: "**Don't think it's a good idea**", "will just keep in which is distate which **is not very good so need doing more frequently" &** "Don't think they mow them that often, **wouldn't want them to do less than now but don't need to do more."**

B. Consistently neutral

If the response suggests that the respondent is either consistently indifferent or doesn't know or not sure about mowing verges less frequently and uses specific words to indicate this such as 'doesn't really matter to me', 'not concerned', "don't bother me" and/or didn't "notice" the mowing trial and/or didn't think it "made a difference" to them. In addition, code this if doesn't provide a strong opinion and just provides a balanced response.

Examples: "**Doesn't make much difference to me**", "**No opinion** to be honest" & **"Don't know honestly".**

C. Consistently for mowing less frequently

If the response suggests that the respondent has a consistently positive reaction to mowing verges less frequently using positive words on the whole. This can include words such as, 'fine', 'alright', 'okay', 'no problem with that'.

Examples: "Good idea. **Think they came too often last year. Don't need to be that much"**, "**Happy enough with that**. Could encourage people" & **"**Think **it's alright**".

D. Preference for mowing less frequently is context specific

If the response suggests that the respondents opinion about mowing road verges less frequently is context specific, and so is dependent on different factors. Please code the responses which match this description using the subcategories below.

D1. Dependent on vegetation height

If the response suggests that the respondent could accept road verges being mown less frequently depending on vegetation height. This includes descriptions of heights that the respondent wouldn't like to see such as 'up to knees' and/or 'ankle length'.

Examples: "Suppose if mowed occasionally, better than not at all. Lots of calls on councils, sympathetic as only so much money. Wouldn't like **to see it being knee high again**", "Quite happy with them less frequently but **wouldn't like to see it grow**

2 ft high- would struggle with wheelie bin!" & "don't really mind as long as **not past ankle length** so doesn't look messy".

D2. Dependent on wildlife benefits
If the response suggests that they wouldn't mind changing the mowing frequency of road verges if it is beneficial for wildlife.
Examples: "It **is encourages wildlife I don't mind**", "Happy to verges to be used to their full potential. Very upset by tree felling program. **Wouldn't mind if it helps wildlife**" & "**If found better for wildlife then great which I think was the purpose".**

D3. Dependent on location
If the response suggests that the acceptability of changing the mowing frequency of road verges is dependent on the location where the road verges are present.
Examples: "can understand why it is a good idea **but not good around here**" &"Obviously attracts more bugs and wildlife is good thing. **Depends where".**

D4. Dependent on subsequent management
If the response suggests that they wouldn't mind changing the mowing frequency of road verges depending on subsequent management after mowing such as removal of grass arisings or the method of cutting operations including symmetrical verges.
Examples: "Not against it, **if there are going to allow some sort of cleaning up operations** or allow meadow flowers to grow", "I think it **depends on how is done**".

D5. Dependent on cost saving
If the response suggests that they wouldn't mind a reduction in mowing frequency of road verges if the reduced mowing frequency saves money.
Examples: "I think **if that's what you have to do for cost** then that's fine" & "**Think it's okay to mow less if saves money for council**, sure they would understand".
D6. Dependent on knowledge/awareness of the management decision
If the response suggests that the respondent's preference for mowing road verges less frequently is dependent on the management decision being explained to the local residents.
Examples: "If knew **why it was being done** that would help" & "I'm happy if it's **properly explained** particularly to the people adjacent to the verges".

E. Mowing frequency irrelevant as parking impacts the ability to mow
If the response mentions that the mowing frequency is irrelevant (and does not provide an opinion on mowing frequency) as parking impacts the ability to mow and/or it should be converted into concrete/tarmac.
Example: "Can't do anything here, **can't mow it, all parked on**".

F. Mowing frequency irrelevant as road verges should be concreted/tarmacked.

If the response mentions that the mowing frequency is irrelevant (and does not provide an opinion on mowing frequency) because the respondent thinks the road verge should be converted into concrete/tarmac.
Examples: “Depends on weather, just leave grass where it's mown. Tread it in the house sometimes. **Not bothered how often they mow it, should just asphault it”,** “Very filthy. **Want digging up and making car standings**” &“ My preference. When resurfacing, dug up all soil and grass and put planings down and then replanted it. It looks like a sink estate/quagmires. **Would prefer for it all to be taken up and tarmacked over so doesn't create a mess and not an eyesore**. By Penistone Road, allow central reservation to not mow, planted in a meadow plants, would imagine that would have an effect as near industries. To me, just a matter of area I live looking 'smart' rather than churned up WW1 battlefield if you like. On the other estates ie Rotherham where I used to live, no parking looks like quagmires. Parked up not a blade of grass on it. Gardens/gulley down there is ecosystems not disturbed down there foxes etc. That's where you will get the development of life cycle. Bit of grass outside.. your research say”.

Appendix 3.7

Table. The themes, descriptions and number of people mentioning each theme identified in the content analysis from combined codes from Questions 5 and 6 of the door to door questionnaire. In Questions 5 and 6, participants were asked, "During the spring and summer last year, a mowing trial was taking place on your road. Thinking back to that time, please give a preference score from 0 to 10 for the road verge on your side of the road and the opposite side of the road, where 0 is strongly dislike and 10 is strongly like. Please explain why you feel this way about the verge on your side of the road?" and "During the spring and summer last year, a mowing trial was taking place on your road. Thinking back to that time, please give a preference score from 0 to 10 for the road verge on your side of the road and the opposite side of the road, where 0 is strongly dislike and 10 is strongly like. Please explain why you feel this way about the verge on the opposite side of the road?" respectively.

THEME	**DESCRIPTION**	**Number of responses (n=106)**
AESTHETIC VALUE: Neat and tidy vegetation	Positive language regarding 'neat' and/or 'tidy' vegetation or infers that it looks orderly. This does not include vegetation with regards to be cared for or vegetation being damaged by vehicular parking. EXAMPLE: "Looked neater and well kept"	26
AESTHETIC VALUE: Messy and unkempt vegetation	'Untidy' and/or 'scruffy' and/ or 'messy' and/or 'unkempt' mentioned directly using negative language or infers that the consequences of mowing such as left grass cuttings/arisings cause a 'mess'. This does not include vegetation with regards to be cared for or vegetation being damaged by vehicular parking. EXAMPLE: "looked unkempt"	36
AESTHETIC VALUE: Positive perception of short vegetation height and/or negative perception of long vegetation height	Vegetation height mentioned in relation to the mowing trial. Words may include 'short' or 'mown' using positive language and/or 'long' or "uncut" or "overgrown" using negative language directly or infers that it needs to be cut regularly and/or mentions that the respondent/ other residents had cut the verge themselves. EXAMPLE: "really annoyed. Left long and had to cut it myself"	32
AESTHETIC VALUE: Positive perception of long vegetation height and/or negative perception of short vegetation height	Vegetation height mentioned in relation to the mowing trial. Words may include 'long' or 'uncut' or 'overgrown' using positive language and/or 'short' or 'cut' using negative language or infers that the vegetation doesn't need to be cut regularly. EXAMPLE: "Would prefer overgrown greenspace to not greenspace"	1
AESTHETIC VALUE: Positive perception of signs of care	The road verge is 'cared for' and/or 'looked after' and/or 'inhabited' or it looks like it is maintained or kept by someone. This is different from neat and tidy vegetation in that a road verge can be maintained but doesn't necessarily mean that it looks neat and tidy. EXAMPLE: "Had been kept, tidy, maintained".	3

AESTHETIC VALUE: Negative perception of signs of care	The road verge is ‘no-one cares’ and/or ‘unkept’ or it looks like it isn’t maintained by someone. This is different from neat and tidy vegetation in that a road verge can be maintained but doesn’t necessarily mean that it looks neat and tidy. EXAMPLE: “Not looked after at all"	2
AESTHETIC VALUE: Litter/dog poo	The road verge had litter or rubbish or any objects that are being described as if they have been thrown away and could be classed as litter. In addition, if the word, ‘clean’ or ‘unclean’ is used. In addition, include if the response directly mentions dog poo or any variations of dog poo such as dog mess/dog faeces/dogs fouling/dog muck/dog dirt or any words that imply that dog owners don’t pick up dog poo. EXAMPLE: “Risk of more dog poo in grass"	21
AESTHETIC VALUE: Symmetrical verges	Would like verges on both sides of the road or on same side of the road to be consistently mown at the same time and/or dislikes asymmetrical verges- verges that were cut at different times. EXAMPLE: ‘Some people cut down, others didn't. Wasn't consistent’	2
AESTHETIC VALUE: Looked same as normal	The road verge looked the same as normal. EXAMPLE: “Don't have any strong things. Just normal as you are used to seeing it”	2
AESTHETIC VALUE: Vehicular parking negatively impacts road verge aesthetics	The visual appearance of road verges has been impacted by vehicular parking, damaging the grass verge. EXAMPLE: “Not that nice when people have parked on it”	11
AESTHETIC VALUE: Other	A standalone mention of how the road verge appears. EXAMPLE: “Well sort of look neat and tidy but I guess a little bit dull”	10
WILDLIFE: Mowing trial had a positive impact on wildlife and plants on road verges which is beneficial and/or appreciation that the road verge mown normally may not have been as good for wildlife and plants	Thought the mowing trial has had a positive impact on wildlife/plants and/or this is expressed using positive language. This includes if the respondent appreciates wildlife on the road verge and/or appreciates that elements of the road verge such as wildflowers can benefit wildlife. This does not include if trees are mentioned, as the management of trees remained the same during the mowing trial. EXAMPLE: “Did improve amount of flowers we got on verge”	9
WILDLIFE: Mowing trial had a negative impact on wildlife and plants on road verges and/or supported problematic wildlife and plants	Thought that the mowing trial had a negative impact on wildlife and plants and/or supported wildlife/plants that they considered to be problematic and/or unfavourable. This includes if the response suggests that some wildlife and plants are viewed as ‘pests’ and/or wildlife and plants are perceived negatively. EXAMPLE: “Thought It was very dangerous. I'm a childminder. Not good for wildlife as got more wildlife on my verge”	1
WILDLIFE:	Thought that the mowing trial would increase problematic wildlife and plants such as ‘pests’.	1

Mowing trial supported problematic wildlife and plants on the road verge	EXAMPLE: “From public perspective, will just increase pests”	
WILDLIFE: Mowing trial had no impact on wildlife and plants on road verges	Thought that there was no difference and/or no impact of the mowing trial on wildlife and plants on road verges. EXAMPLE: “It looked untidy. Didn't notice any difference in wildlife e.g. butterfly. Any different. Didn't see anything but then you don't see things on your own front doorstep”	2
Safety	Any mention of safety concerns or hazards such as restricted vision caused by the road verge and directly uses the words ‘dangerous’ or ‘slipping’ with regards to the road verge. EXAMPLE: “Thought It was very dangerous”	3
Accessibility across the verge	Access for people getting to/from a location or a vehicle or moving items such as a wheelie bin by crossing or using the road verge. This also includes being able to see what is in the verge. EXAMPLE: “Anyone getting out of the car have to walk along verge”	8
Discouraging vehicular parking	Suggestion that the presence of long vegetation/flowers deters parking on verges using language which suggests this is a positive consequence. EXAMPLE: “Grass might help stop parking"	2
Lack of knowledge about the trial	Didn’t know why the mowing trial had taken place and/ or “didn’t notice” the mowing trial. EXAMPLE: “Looked a bit scruffy and people didn't really know why it had been done”	3
Council resources	Road verge management is dependent on council resources, including the mention that the trial would save money or the council money and implies that as residents pay council tax, the council should maintain the grass verge. EXAMPLE: “Served no purpose but to save money”	6

Appendix 3.8

Table. The themes, descriptions and number of people mentioning each theme identified in the content analysis from Question 11 of the door to door questionnaire. In Question 11, participants were asked “Over the spring and summer last year, the road verges on one side of the road was mown less frequently than normal. What do you think about mowing verges less frequently?”

THEME	DESCRIPTION	Number of responses
Consistently against mowing less frequently	The respondent has a consistently negative reaction towards mowing verges less frequently or specifically says that it should be mown frequently or more frequently or regularly or at the same frequency as that before the trial started. This also includes if the respondent mows the verge themselves, suggesting they prefer the verge to be mown frequently. EXAMPLE: "Don't think it's a good idea"	124
Consistently neutral	The respondent is either consistently indifferent or doesn’t know or not sure about mowing verges less frequently and uses specific words to indicate this such as ‘doesn’t really matter to me’, ‘not concerned’, “don’t bother me” and/or didn’t “notice” the mowing trial and/or didn’t think it “made a difference” to them. In addition, code this if doesn’t provide a strong opinion and just provides a balanced response. EXAMPLE: "Doesn't make much difference to me"	53
Consistently for mowing less frequently	The respondent has a consistently positive reaction to mowing verges less frequently using positive words on the whole such as, ‘fine’, ‘alright’, ‘okay’, ‘no problem with that’. EXAMPLE: "Good idea. Think they came too often last year. Don't need to be that much”.	41
Preference is context specific dependent on:		
Vegetation height	The respondent could accept road verges being mown less frequently depending on vegetation height. This includes descriptions of heights that the respondent wouldn’t like to see such as ‘up to knees’ and/or ‘ankle length’. EXAMPLE: “Suppose if mowed occasionally, better than not at all. Lots of calls on councils, sympathetic as only so much money. Wouldn't like to see it being knee high again”	5
Wildlife benefits	They wouldn’t mind changing the mowing frequency of road verges if it is beneficial for wildlife. EXAMPLE: “If found better for wildlife then great which I think was the purpose”.	5
Location	The acceptability of changing the mowing frequency of road verges is dependent on the location where the road verges are present. EXAMPLE: “can understand why it is a good idea but not good around here”	5
Subsequent management	They wouldn’t mind changing the mowing frequency of road verges depending on subsequent management after mowing such as removal of grass arisings or the method of cutting operations including symmetrical verges.	9

	EXAMPLE: “Not against it, if there are going to allow some sort of cleaning up operations or allow meadow flowers to grow”	
Cost saving	They wouldn’t mind a reduction in mowing frequency of road verges if the reduced mowing frequency saves money. EXAMPLE: “I think if that's what you have to do for cost then that's fine”	5
Knowledge/awareness of the management decision	The respondent’s preference for mowing road verges less frequently is dependent on the management decision being explained to the local residents. EXAMPLE: “If knew why it was being done that would help”	5
Mowing frequency irrelevant as parking impacts the ability to mow	The mowing frequency is irrelevant (and does not provide an opinion on mowing frequency) as parking impacts the ability to mow and/or it should be converted into concrete/tarmac. EXAMPLE: “Can't do anything here, can't mow it, all parked on”.	2
Mowing frequency irrelevant as road verges should be concreted/tarmacked.	The mowing frequency is irrelevant (and does not provide an opinion on mowing frequency) because the respondent thinks the road verge should be converted into concrete/tarmac. EXAMPLE: “Depends on weather, just leave grass where it's mown. Tread it in the house sometimes. Not bothered how often they mow it, should just asphault it”	4

Appendix 3.9
Likert scale responses to statements relating to urban roadside verge management from Question 5 in the postal questionnaire

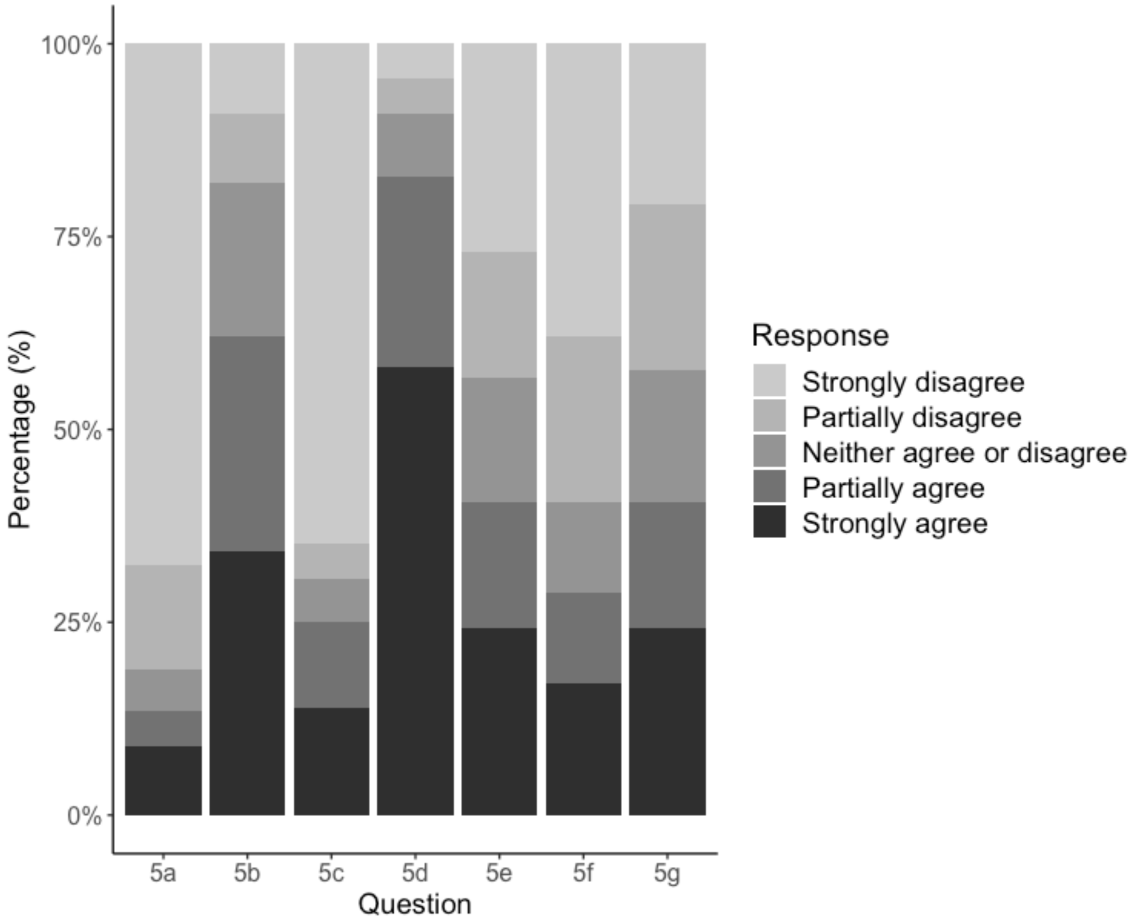


Figure. Likert scale responses (ranging from strongly disagree, partially disagree, neither agree or disagree, partially agree and strongly agree) to statements relating to urban roadside verge management. The statements for Question 5 of the postal questionnaire were 5a: "The appearance of a roadside verge doesn't matter to me", 5b: "Managing roadside verges for nature is important to me", 5c:"I would prefer roadside verges to be tarmacked", 5d: "I like roadside verges to look neat and tidy", 5e: "I don't mind if vegetation on a verge is taller (i.e. up to 30cm/ 1 foot in height) if it is beneficial to nature, 5f: "It is not important to manage roadsides to benefit nature" and 5g: "Efforts to conserve urban nature should focus on parks not roadside verges".

Appendix 3.10
Parallel analysis scree plot from Question 5 in the postal questionnaire

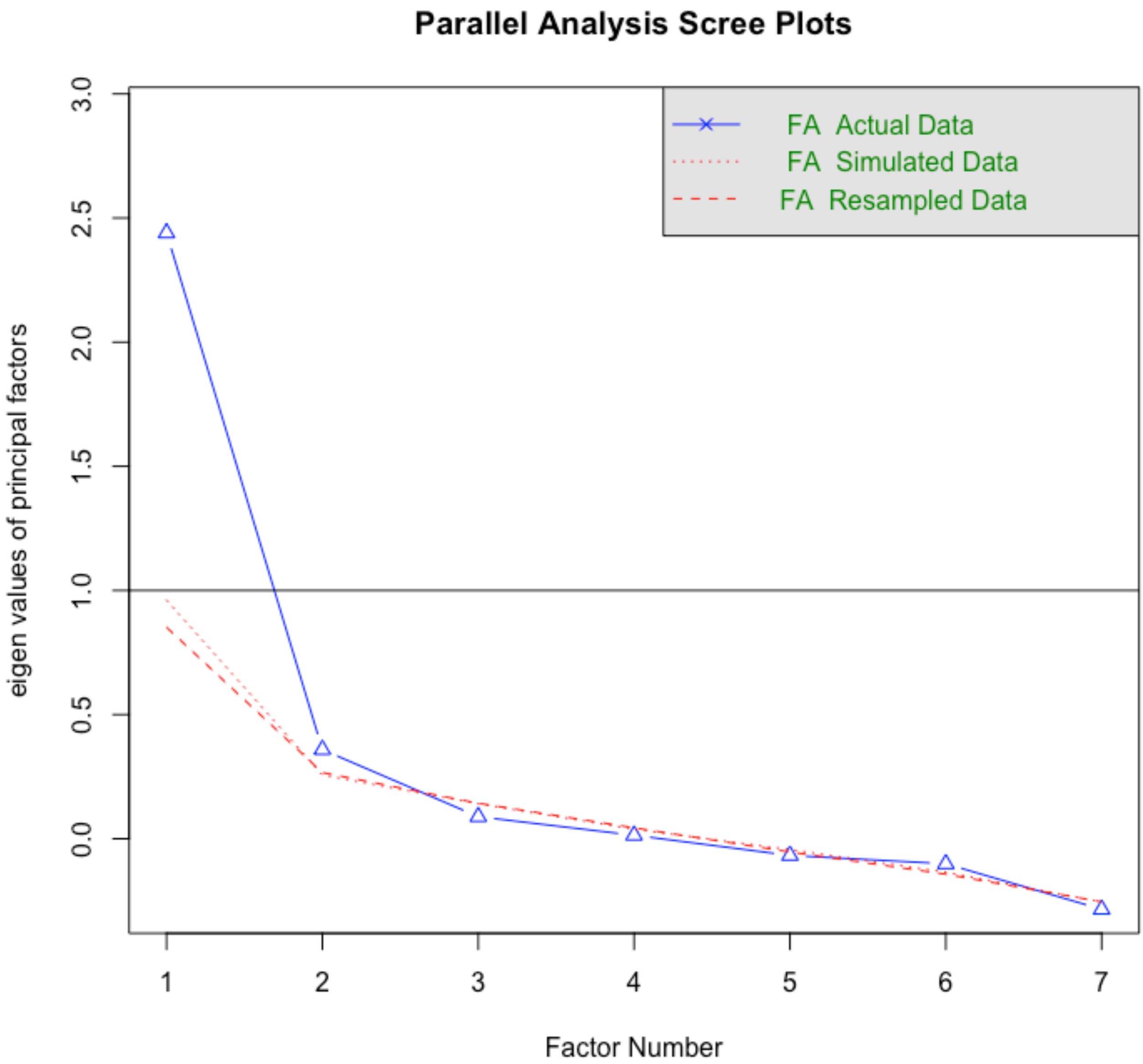


Figure. Parallel Analysis Scree Plot for the statements from Question 5 of the postal questionnaire.

Appendix 4.1

71 major towns and cities by population size, type of council and region (Office for National Statistics, 2016a, 2018b; Ministry of Housing Communities & Local Government, 2016).

Major town/city	Population Estimate	Name of council	Type of council	Official region
Derby	262971	Derby City Council	Unitary authorities	East Midlands
Nottingham	308273	Nottingham City Council	Unitary authorities	East Midlands
Leicester	408570	Leicester City Council	Unitary authorities	East Midlands
Bedford	92407	Bedford Borough Council	Unitary authorities	East of England
Peterborough	174102	Peterborough City Council	Unitary authorities	East of England
Southend-on-Sea	181711	Southend-on-Sea Borough Council	Unitary authorities	East of England
Luton	225033	Luton Borough Council	Unitary authorities	East of England
South Shields	76083	South Tyneside Borough Council	Metropolitan district	North East
Stockton-on-Tees	83925	Stockton-on-Tees Borough Council	Unitary authorities	North East
Hartlepool	89608	Hartlepool Borough Council	Unitary authorities	North East
Darlington	92392	Darlington Borough Council	Unitary authorities	North East
Gateshead	121367	Gateshead Borough Council	Metropolitan district	North East
Sunderland	175595	Sunderland City Council	Metropolitan district	North East
Middlesbrough	176625	Middlesbrough Borough Council	Unitary authorities	North East
Newcastle upon Tyne	282708	Newcastle Upon Tyne City Council	Metropolitan district	North East
Bury	79259	Bury Borough Council	Metropolitan district	North West
Chester	87507	Cheshire West and Chester Council	Unitary authorities	North West
Wigan	87654	Wigan Borough Council	Metropolitan district	North West
Birkenhead	89525	Wirral Borough Council	Metropolitan district	North West
Southport	93199	Sefton Borough Council	Metropolitan district	North West
Salford	94828	Salford City Council	Metropolitan district	North West
St Helens	104296	St Helens Borough Council	Metropolitan district	North West
Stockport	109637	Stockport Borough Council	Metropolitan district	North West
Rochdale	110194	Rochdale Borough Council	Metropolitan district	North West

Oldham	116866	Oldham Borough Council	Metropolitan district	North West
Blackburn	118145	Blackburn with Darwen Borough Council	Unitary authorities	North West
Blackpool	144857	Blackpool Council	Unitary authorities	North West
Warrington	171058	Warrington Borough Council	Unitary authorities	North West
Bolton	175933	Bolton Borough Council	Metropolitan district	North West
Manchester	548991	Manchester City Council	Metropolitan district	North West
Liverpool	571733	Liverpool City Council	Metropolitan district	North West
Chatham	80965	Medway Council	Unitary authorities	South East
Bracknell	82839	Bracknell Forest Borough Council	Unitary authorities	South East
Gillingham	108985	Medway Council	Unitary authorities	South East
Slough	155749	Slough Borough Council	Unitary authorities	South East
Milton Keynes	182265	Milton Keynes Council	Unitary authorities	South East
Portsmouth	229907	Portsmouth City Council	Unitary authorities	South East
Brighton and Hove	242858	Brighton and Hove City Council	Unitary authorities	South East
Reading	255651	Reading Borough Council	Unitary authorities	South East
Southampton	271173	Southampton City Council	Unitary authorities	South East
Weston-Super-Mare	87584	North Somerset Council	Unitary authorities	South West
Bath	100575	Bath and North East Somerset Council	Unitary authorities	South West
Poole	158835	Poole Borough Council	Unitary authorities	South West
Swindon	189553	Swindon Borough Council	Unitary authorities	South West
Bournemouth	201708	Bournemouth Borough Council	Unitary authorities	South West
Plymouth	267918	Plymouth City Council	Unitary authorities	South West
Bristol	567111	Bristol City Council	Unitary authorities	South West
Walsall	70240	Walsall Borough Council	Metropolitan district	West Midlands
Shrewsbury	73276	Shropshire Council	Unitary authorities	West Midlands
West Bromwich	76950	Sandwell Metropolitan Borough Council	Metropolitan district	West Midlands
Dudley	82814	Dudley Borough Council	Metropolitan district	West Midlands
Solihull	107078	Solihull Borough Council	Metropolitan district	West Midlands
Sutton Coldfield	108325	Birmingham City Council	Metropolitan district	West Midlands

Telford	147105	Telford and Wrekin Borough Council	Unitary authorities	West Midlands
Wolverhampton	240937	Wolverhampton City Council	Metropolitan district	West Midlands
Stoke-on-Trent	274810	Stoke-on-Trent City Council	Unitary authorities	West Midlands
Coventry	362690	Coventry City Council	Metropolitan district	West Midlands
Birmingham	1140754	Birmingham City Council	Metropolitan district	West Midlands
Scunthorpe	82334	North Lincolnshire Council	Unitary authorities	Yorkshire and The Humber
Grimsby	88099	North East Lincolnshire Council	Unitary authorities	Yorkshire and The Humber
Halifax	91271	Calderdale Borough Council	Metropolitan district	Yorkshire and The Humber
Barnsley	96082	Barnsley Borough Council	Metropolitan district	Yorkshire and The Humber
Wakefield	103351	Wakefield City Council	Metropolitan district	Yorkshire and The Humber
Rotherham	110200	Rotherham Borough Council	Metropolitan district	Yorkshire and The Humber
Doncaster	113043	Doncaster Borough Council	Metropolitan district	Yorkshire and The Humber
York	161875	City of York Council	Unitary authorities	Yorkshire and The Humber
Huddersfield	169928	Kirklees Borough Council	Metropolitan district	Yorkshire and The Humber
Kingston upon Hull	288301	Hull City Council	Unitary authorities	Yorkshire and The Humber
Bradford	350178	Bradford City Council	Metropolitan district	Yorkshire and The Humber
Leeds	500155	Leeds City Council	Metropolitan district	Yorkshire and The Humber
Sheffield	541763	Sheffield City Council	Metropolitan district	Yorkshire and The Humber

Appendix 4.2
The interview schedule used when conducting interviews with road verge managers

Background questions

"I'm just going to ask a few brief preliminary questions about your background before the main interview."

1. What is your current role within this organisation? What are your **main** responsibilities in this role?

2. Please could you briefly describe your experience working in greenspace management and any relevant professional qualifications?

3. How long have you worked in greenspace management?

4. If possible, please could you give an estimate for the area of roadside verges that your organization manages in your network/county/boundary? Please provide units.

5. (If speaking to a contractor)- How long is your company's contract managing road verges? During this contract, have they been or are there any opportunities to change the terms of the contract?

6. (If speaking to a contractor)- Are there performance criteria/ requirements for the road verge management you undertake? If yes, are there any consequences if these criteria aren't met?

7. (If speaking to a council worker)- Do you contract out the management of road verges to other companies? If yes, what is the company's name and how long is their contract managing road verges? During this contract, have they been or are there any opportunities to change the terms of the contract?

8. (If speaking to a council worker and answered yes to Question 7)- Are there performance criteria/ requirements for the road verge management that you contract out to the company? If yes, are there any consequences if these criteria aren't met?

Four broad introductory questions:

1. **How are different road verges classified in your organization?**

2. **Considering the different types of road verges, please could you briefly describe to me how you currently manage road verges in your area?**

Prompt questions

When the response is **descriptive about current management**, if the following isn't mentioned, follow up with a question:

- How frequently do you mow the road verges?
- What time of the year are road verges typically cut?
- Is a cut and collect machine used to remove cuttings?
- Do you use herbicides? If so, what type and how frequently are they applied?
- What is your organisations' approach to shrub beds? Does this involve setting specific targets for shrub beds? How do you manage shrub beds?
- What is your organisations' approach to trees? Does this involve setting specific targets for trees? How do you maintain trees?
- Have you planted any wildflowers?
- How long has your organisation been doing this management for?

3. **What are the main factors that influence why you manage road verges in this way?**

Prompt questions

- Once they have mentioned certain themes, say:

  "*Please could you tell me more about how …. impact the way you manage road verges*?"

  Possible themes: Public perception
  Safety
  Costs
  Physical attributes ie slope
  Wildlife/conservation (hopefully already answered in the question above)
  Personal/collective experience
  Sources of information/experience
  Other people: Council/councillors
  Machinery
  Other benefits such as flood risk and pollution

4. How do you make your decisions about road verge management?

Prompt questions

- When you have to make a decision about road verge management, are there any resources or sources of information that your company uses?
- Do you speak to other councils or organisations about what is good practice in road verge management?
- What sort of information would you like to use but are not able?
- What kind of sources of information (if any) would be useful when making decisions regarding roadside verge management?
- How much input do councillors (councils if contractors) provide when it comes to roadside verge management decisions?

5. Has any alternative management been used or considered on road verges in your area?

If specific **alternative/previous management strategies** are mentioned, follow up with:

- Previously, …… was managed by…….. Please could you explain in your own words, why did this management change?
- You mentioned that ………. has been considered before, could you possibly tell me more about the method and why this method wasn't applied?
- Has there been any discussion for using grass cutting for biomass?

If **wildlife or conservation** is/isn't mentioned in the response, follow up with:

- Do you have any road verges that are managed with consideration to conservation? If so, how many and how are they managed?
- If yes, are you aware of how the creation of the verges managed with consideration to conservation came about?
- Do you work with any different organisations when implementing wildlife friendly roadside verge management?

Questions if I have time:

- What has been your biggest challenge in managing road verges?
- What has been your biggest success?
- Do you happen to know the cost per square metres for road verge maintenance?
- Has your budget been changed in the last couple of years? If so, how much has it changed by?