APPENDIX W ENVIRONMENT BIODIVERSITY DATA SETS W4

DICKLEBURGH AND RUSHALL NEIGHBOUR CLERK@ HOOD PLAN
REGULATION 14 PRE-SUBMISSION

Introduction

The biodiversity team undertook a wide range of studies, embracing national and international developments and areas of debate, in addition to the examination of existing legislation and the intentions, plans and projects of local and national bodies which might impact upon the Parish of Dickleburgh & Rushall.

A broad examination of ancient maps was made and comparisons made with the contemporary landscape following extensive surveys of the naturally occurring features within the Parish boundary.

The '*Have Your Say*' open days and questionnaires highlighted the importance placed on wildlife by residents and we followed up on the anecdotal reference to certain features by capturing actual data from old, recent and new wildlife surveys. Surveys were conducted by local enthusiasts and volunteers, conservationists, and the team itself.

Bat surveys were completed and continue using the Parish's own Bat monitor, working in conjunction with the British Trust for Ornithology in Thetford.

It is intended that this survey work will be ongoing. A permanent Biodiversity Body is planned, and this will dovetail with the existing Commons Committee working with local and national wildlife bodies. A website is planned so that all existing and new data, surveys and so on are made permanently available to the public.

This document illustrates some of the survey data conducted, features extracts from certain publications and makes reference to a cross-section of the study materials used in the preparation of the Plan.

Biodiversity data sets

The Biodiversity Data Appendix is divided into several separate sections, as follows:

Section1 Wildlife Reports & Data 1

- Bats

Extract from a bat survey 2019
Specimen of one of the Parish Bat Surveys September019
2019's bat survey sites and results and extracts from new mammal/insect surveys
Sonogram of Pipistrelle Bats on Dickleburgh Moor Sept 2020

Maps

Habitat and Land Use Summary from NBIS May 2019

Section 2 Wildlife Reports & Data 2

- General Wildlife

Bird List for Dickleburgh Moor from 2018
Dickleburgh & Rushall Species sighted 2017/2018
Survey of moths -Dickleburgh 2017-2019
General Wildlife Survey - Langmere & Dickleburgh 2019
Dickleburgh's Wild Birds 2000-2001

Dickleburgh Species Results from NBIS

Section 3 Wildlife Reports & Data 3

- Specific Sites
County Wildlife Sites in the Parish: General Overview of each site
County Wildlife Site Survey 2019 for St.Clement's Common
County Wildlife Site Survey 2018 for St.Clement's Common

Section 4:

Hedges, Trees, Verges & Habitat
Hedgerow Surveys for the Parish, sample summary
Specimen of a typical completed Hedgerow Survey within the Parish
Norfolk County Council Verge Cutting Plans
Verges Conservation & Verge Management
Norfolk County Council Biodiversity Action plan for Hedgerows
Map illustrating interlinking corridors of hedgerows.
Ecologist's notes on habitat loss etc.
Local Government Association Workshop - Environmental Net Gain
Regulations
Hedgerow Regulations & Definitions

Relevant Publications
Tree Planting & Air Quality Academic Paper

Miscellaneous
Quiet Lane Proposal Document for the Parish
Dark Skies - links to Various articles and papers relating to health and light pollution
Trees - notes on Tree Preservation Orders for South Norfolk County Council
References to other wildlife data held in archive
Miscellaneous Additional Research
Research: Dickleburgh and Rushall NP Biodiversity – insect decline

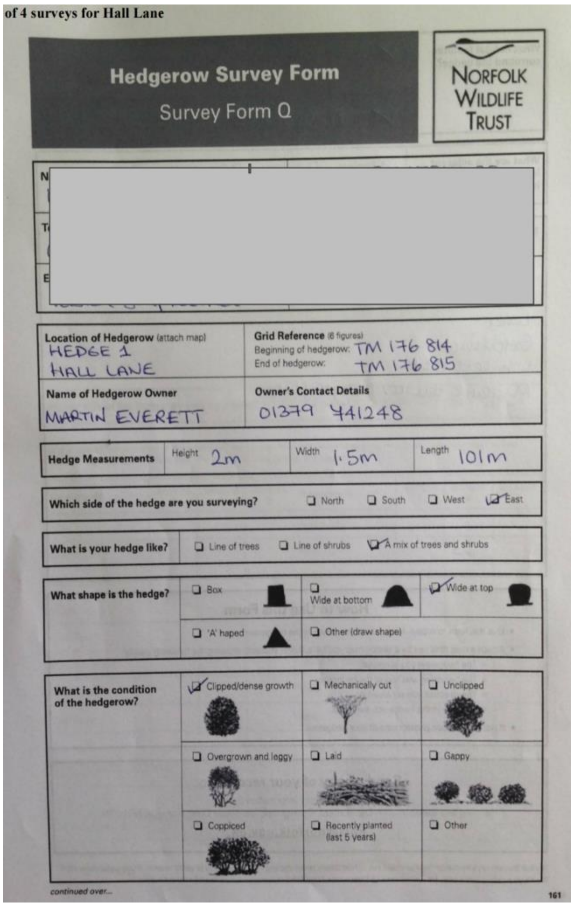
Hedges, Trees, Verges & Habitat

Hedgerow Surveys for the Parish, sample summary

Dickleburgh & Rushall Hedgerow Surveys: Page 1

Place	Grid Ref	Ditch?	Trees in hedgerow?	Verge?	No. Of species	Meets criteria of 'important' status?	Survey sent to NWT?
Hall Lane Hedge1	TM176814 TM176815	Y	Y	Y	6	Y	Y
Hall Lane Hedge 2 Common Road	TM175815 TM176816	Y	Y	Y	4	Y	Y
Hall Lane Hedge 3	TM175816	Y	Y	Y	5	Y	Y
Hall Lane Hedge 4	TM175818	Y	Y	Y	6	Y	Y
Langmere Road (north side)	TM176819 TM178818	Y	Y	Y	7	Y	Y
Langmere Road (south side)	TM176819 TM178818	Y	Y	Y	6	Y	Y
Langmere Road (north & south)	TM178818 TM181189	N	Y	Y	7	Y	Y
Vaunces Lane (east and west)	TM191825 TM192821	Y	Y	Y	7	Y	Y
Rectory Lane (east & west)	TM177823 TM178819	Y	Y	Y	7	Y	Y
Harvey Lane (south side)	TM172821 TM176819	Y	Y	Y	8	Y	y

Specimen of completed Hedgerow Survey within the Parish


of 4 surveys for Hall Lane

Hedgerow Survey Form
Survey Form Q
Norfolk Wildlife Trust

[redacted]

Location of Hedgerow (attach map): HEDGE 1 HALL LANE
Grid Reference (8 figures): Beginning of hedgerow: TM 176 814; End of hedgerow: TM 176 815
Name of Hedgerow Owner: MARTIN EVERETT
Owner's Contact Details: 01379 441248
Hedge Measurements: Height 2m; Width 1.5m; Length 101m
Which side of the hedge are you surveying? ☐ North ☐ South ☐ West ☑ East
What is your hedge like? ☐ Line of trees ☐ Line of shrubs ☑ A mix of trees and shrubs
What shape is the hedge? ☐ Box ☐ Wide at bottom ☑ Wide at top ☐ 'A' haped ☐ Other (draw shape)
What is the condition of the hedgerow? ☑ Clipped/dense growth ☐ Mechanically cut ☐ Unclipped ☐ Overgrown and leggy ☐ Laid ☐ Gappy ☐ Coppiced ☐ Recently planted (last 5 years) ☐ Other

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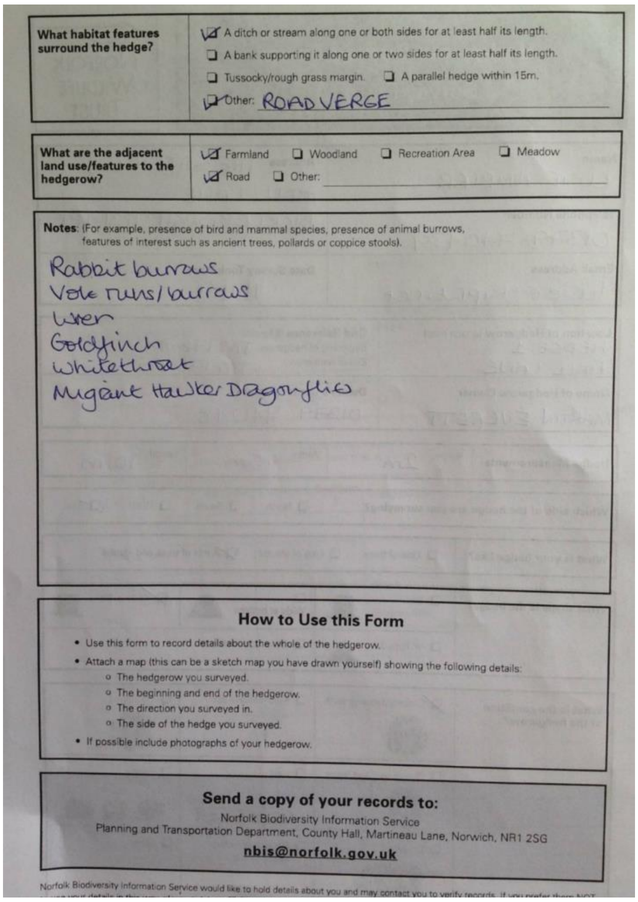
What habitat features surround the hedge? ☑ A ditch or stream along one or both sides for at least half its length. ☐ A bank supporting it along one or two sides for at least half its length. ☐ Tussocky/rough grass margin. ☐ A parallel hedge within 15m. ☑ Other: ROAD VERGE

What are the adjacent land use/features to the hedgerow? ☑ Farmland ☐ Woodland ☐ Recreation Area ☐ Meadow ☑ Road ☐ Other:

Notes: (For example, presence of bird and mammal species, presence of animal burrows, features of interest such as ancient trees, pollards or coppice stools).
Rabbit burrows
Vole runs/burrows
Wren
Goldfinch
Whitethroat
Migrant Hawker Dragonflies

How to Use this Form
- Use this form to record details about the whole of the hedgerow.
- Attach a map (this can be a sketch map you have drawn yourself) showing the following details:
  - The hedgerow you surveyed.
  - The beginning and end of the hedgerow.
  - The direction you surveyed in.
  - The side of the hedge you surveyed.
- If possible include photographs of your hedgerow.

Send a copy of your records to:
Norfolk Biodiversity Information Service
Planning and Transportation Department, County Hall, Martineau Lane, Norwich, NR1 2SG
nbis@norfolk.gov.uk

Hedgerow Woody/Climbing Plant Survey Form

Survey Form R

NORFOLK WILDLIFE TRUST

	Address
Email Address	**Date Survey Took Place** 1/9/19

Location of Hedgerow (attach map) HEDGE1 HALL LANE	**Grid Reference** (6 figures) Beginning of hedgerow: End of hedgerow:

Which side of the hedge are you surveying? ☐ North ☐ South ☐ West ☑ East

Make a note of the presence of the species. If the species has been allowed to grow into a tree, use the following key:
N = newly planted, S = standard tree, P = pollard, D = dead tree, A = ancient tree.

Tree/shrub	Section 1	Section 2	Section 3	Tree/shrub	Section 1	Section 2	Section 3
Ash				Field maple	✓		
Beech				Field rose			
Blackthorn				Gorse			
Broom				Guelder rose			
Buckthorn				Hawthorn	✓	✓	
Butcher's-broom				Hawthorn (Midland)			
Cherry Plum				Hazel			
Crab apple				Holly			
Dog rose	✓	✓		Hornbeam			
Dogwood				Oak (pedunculate)			
Elder				Oak (sessile)			
Elm (small leaved)				Rowan			
Elm (wych)				Silver birch			

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Tree/shrub	Section 1	Section 2	Section 3	Tree/shrub	Section 1	Section 2	Section 3
Small-leaved lime				Wild service			
Spindle				Willow (goat)			
Sycamore		S		Willow (grey)			
Wild cherry				Yew			
Wild plum							
Wild privet							

Please tick if any of the following climbing plants are present.

Climbing plant	Section 1	Section 2	Section 3	Climbing plant	Section 1	Section 2	Section 3
Bittersweet / Woody nightshade				Ivy		✓	
Bramble	✓	✓		Large bindweed			
Black bryony	✓	✓		Traveller's joy			
Hedge bindweed		✓		White bryony			
Honeysuckle							
Hop							

How to Use this Form

- Attach a map (this can be a sketch map you have drawn yourself) showing the following details:
  - The hedgerow you surveyed.
  - The beginning and end of the hedgerow.
  - The direction you surveyed in.
  - The side of the hedge you surveyed.
- Attach survey form Q, page 161 showing the character of the whole hedge.
- Decide how many 30m sections of hedge you are going to survey. Mark the survey sections on the map.
- The best time to carry out this survey is between April and October, when leaves are on the hedgerow plants.
- Identify all the woody species present. If the species has been allowed to grow into a tree, show this on the survey form using the following key: N = newly planted, S = standard tree, P = pollard, C = coppice, D = dead tree, A = ancient tree.
- Identify all the climbing plant species present, just tick the box to indicate they are present.

Send a copy of your records to:

Norfolk Biodiversity Information Service
Planning and Transportation Department, County Hall, Martineau Lane, Norwich, NR1 2SG
nbis@norfolk.gov.uk

Norfolk Biodiversity Information Service would like to hold details about you and may contact you to verify records. If you prefer them NOT to use your details in this way, please tick here ☐ Please note if you tick this box your survey record cannot be used

Hedgerow Woody/Climbing Plant Survey Form

Survey Form R

NORFOLK WILDLIFE TRUST

Name	**Address**
Telephone Number	
Email Address	**Date Survey Took Place** 1/9/19

Location of Hedgerow (attach map) HEDGE1 HALL LANE	**Grid Reference** (6 figures) Beginning of hedgerow: End of hedgerow:

Which side of the hedge are you surveying? ☐ North ☐ South ☐ West ☑ East

Make a note of the presence of the species. If the species has been allowed to grow into a tree, use the following key:
N = newly planted, S = standard tree, P = pollard, D = dead tree, A = ancient tree.

Tree/shrub	Section 1	Section 2	Section 3	Tree/shrub	Section 1	Section 2	Section 3
Ash				Field maple	✓		
Beech				Field rose			
Blackthorn				Gorse			
Broom				Guelder rose			
Buckthorn				Hawthorn	✓	✓	
Butcher's-broom				Hawthorn (Midland)			
Cherry Plum				Hazel			
Crab apple				Holly			
Dog rose	✓	✓		Hornbeam			
Dogwood				Oak (pedunculate)			
Elder				Oak (sessile)			
Elm (small leaved)				Rowan			
Elm (wych)				Silver birch			

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Hedgerow Flowering Plant / Fern Survey Form

Survey Form S

NORFOLK WILDLIFE TRUST

Name	**Address**
Telephone Number	
Email Address	**Date Survey Took Place** 1/9/19

Location of Hedgerow (attach map) HEDGE 1 HALL LANE	**Grid Reference** (6 figures) Beginning of hedgerow: End of hedgerow:

Which side of the hedge are you surveying? ☐ North ☐ South ☐ West ☑ East

Key: Q1 = quadrat 1 Q2 = quadrat 2 DAFOR

Species	Section 1 Q1	Section 1 Q2	Section 2 Q1	Section 2 Q2	Section 3 Q1	Section 3 Q2	Species	Section 1 Q1	Section 1 Q2	Section 2 Q1	Section 2 Q2	Section 3 Q1	Section 3 Q2
AGRIMONY	F	F	O				SMOOTH MEADOWGRASS		O				
COCKS FOOT			O	O			UPRIGHT HEDGE PARSLEY		R				
COMMON KNAPWEED	F	F	F	A			YARROW	O		O	O		
FALSE BROME				O			YORKSHIRE FOG		O	O			
FALSE OAT-GRASS	O	O		O									
CREEPING BENT	O		O										
FESCUE SP	O		O										
GROUNDIVY	O		O										
RIBWORT PLANTAIN	O	O											
ROUGH MEADOWGRASS	F		O										

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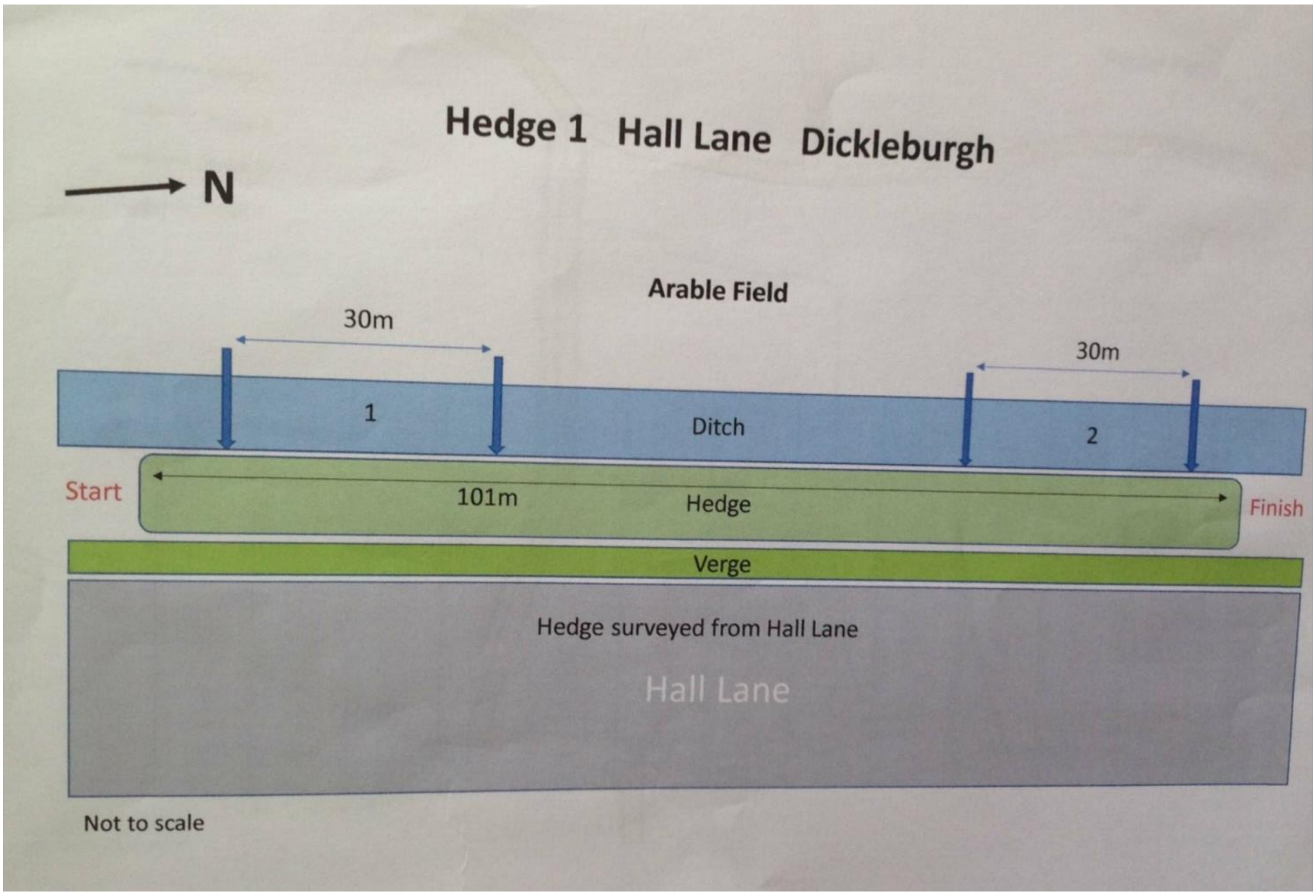

Hedge 1 Hall Lane Dickleburgh
N
Arable Field
30m
30m
1
Ditch
2
Start
101m
Hedge
Finish
Verge
Hedge surveyed from Hall Lane
Hall Lane
Not to scale


LANGMERE ROAD
Poplar Farm
Hedge 1
Hedge 2
Hedge 3
Hedge 4
LANGMERE ROAD
HALL LANE
The Gatehouse
COMMON ROAD
Blackthorn Farm

Note: NBIS forms used for surveys and in conjunction with the NBIS document 'Surveying Hedgerows'

Norfolk County Council Verge Cutting

Coronavirus: Visit our coronavirus updates page for the latest advice and information.

Norfolk County Council   Services ▾   Sign in   Find services and information...   Search

Home > News > Balance of safety and nature driving verge cutting plans

Balance of safety and nature driving verge cutting plans

13 May 2019

With the annual verge cutting programme getting underway today (Monday 13 May) the need to balance supporting nature, and keeping roads safe, is again the focus for Norfolk County Council.

More than 11,000 miles of roads are under the care of the County Council. Verges along the majority of roads are cut twice between May and September each year.

Cllr Martin Wilby, Norfolk County Council Cabinet member for Highways, Infrastructure and Transport, said: "We only cut verges for safety reasons, not appearance. Safety will always be a top priority on our roads and making sure verges are cut for visibility every year is a vital piece of the work we do to keep our roads safe.

"I'm very proud of the work we've been doing over more than 20 years to support the now 112 roadside nature reserves we have across the county. A real success story has been the Sulphur Clover Project, where we have worked with Norfolk Wildlife Trust and the Norfolk Farming and Wildlife Group (FWAG) to increase the number of sites this rare plant grows. For over 10 years sulphur clover seed has been harvested from roadside nature reserves, and with the help of landowners the seed has been given new homes on the clay soils of South Norfolk where the plant can grow well."

Up to around 1 metre of verge from the edge of the road is cut in most areas with wider areas around corners and junctions cut to make sure visibility is maintained. In urban areas roadside verges are usually cut five times a year, and areas maintained on the county council's behalf by other local councils may see more frequent cuts. Highways England maintain the A11 and A47.

Actions to support rare species on our roadsides are continuing. One-hundred and twelve roadside nature reserves maintained by the county council, in partnership with Norfolk Wildlife Trust, are home to a range of vulnerable plants. In these reserves cutting takes place once in or around September each year. Rare species such as crested cow-wheat, sulphur clover, and Breckland speedwell, are protected by roadside nature reserves. In Norfolk, there are also verges designated for toad migratory routes and rare fungi.

"The grassland and hedgerows along our road networks also play a vital role as corridors for wildlife to move along and help connect our increasingly isolated 'islands' of good habitat where wildlife still thrives. Without any cutting many of the rarer plant species would not survive and so with sensitive management and careful planning the needs of both road safety and looking after wildlife can both be met.

"We are fortunate in Norfolk still to have many road verges rich not just in flowers but also in bees, butterflies and other pollinators bringing wider benefits to adjacent farmland."

And the highway teams' work to support flora and fauna along Norfolk newest road, the Broadland Northway, is proving a success. Barn owls have been seen on the platform of one of the owl boxes, and bats are using the green bridge carrying Marriott's Way over the dual carriageway and have also been recorded in one of the new bat houses. The wildlife ponds are thriving, and wildflowers are blooming alongside the 6,700 trees and 181,000 shrubs planted along the 12 mile route.

Ed Stocker, Norfolk County Council Ecologist, said: "Activities such as road improvements, tree and hedgerow maintenance, surface water drainage and gritting all have to consider protected species, protected areas and biodiversity in general.

"From 2019 we will be working more closely with Norfolk Wildlife Trust staff and volunteers to survey and protect the most important wildflowers. We are currently replacing the roadside nature reserve posts that mark out the sections to be left out of the main mowing schedule, and these are clearly labelled so do look out for these as you travel around the county."

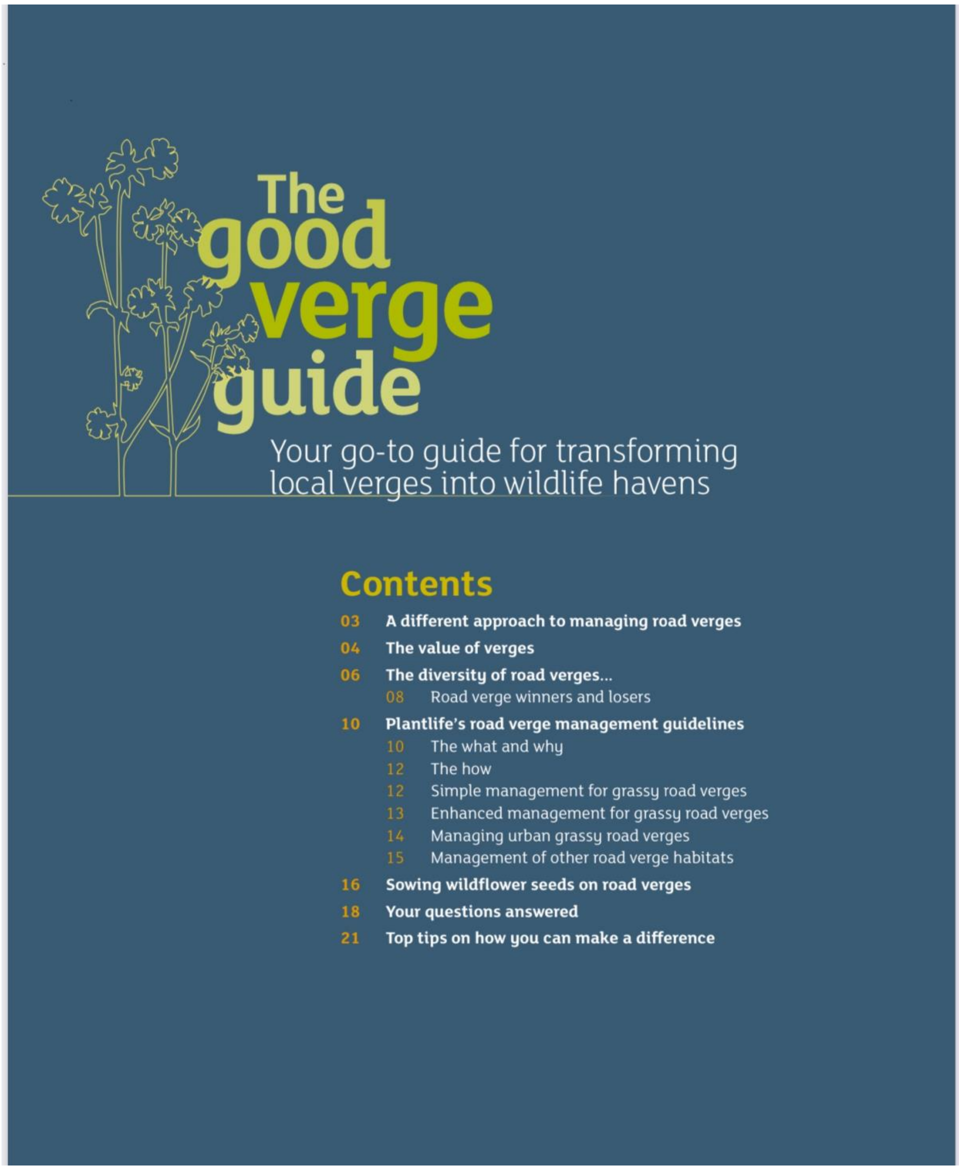
Further information is available on our Grass cutting page.

Grass cuttings are not collected on all but the roadside nature reserves as the cost of collection and disposal is considerable.

https://www.norfolk.gov.uk/news/2019/05/balance-of-safety-and-nature-driving-

Verges Conservation & Verge Management

An extract from the Plantlife organisation's Good Verge Guide



The good verge guide

Your go-to guide for transforming local verges into wildlife havens

Contents

The full guide is located at:
https://www.plantlife.org.uk/uk/our-work/publications/good-verge-guide-different-approach-managing-our-waysides-and-verges

Reference has also been made to the organisation's information on plant species and rare verge plant species (some of which are present in the Parish):

https://www.plantlife.org.uk/uk/discover-wild-plants-nature/plant-fungi-species

and

https://www.plantlife.org.uk/application/files/4514/9261/2387/Road_verges_report_19_April_FINAL.pdf

Significant progress is being made across the country which suggests we are on the right track with our ambitions for verges. According to *Plantlife*, 'Seven in 10 English councils are using mowing or management regimes alongside roads in their area to boost wildflowers and wildlife such as bees that depend on them, data gathered by the PA news agency suggests.'

https://uk.news.yahoo.com/councils-transform-road-verges-wildflowers-000100711.html?utm_source=Plantlife+email+updates&utm_campaign=54718fbe07-RV_Feb2021&utm_medium=email&utm_term=0_ce964b84b6-54718fbe07-285770565&mc_cid=54718fbe07&mc_eid=02dd4597cb&guccounter=1

And also to its library of specialist publications:
https://www.plantlife.org.uk/uk/our-work/publications

Plus, various publications relating to different habitats:

https://www.plantlife.org.uk/uk/discover-wild-plants-nature/habitats

https://uk.news.yahoo.com/councils-transform-road-verges-wildflowers-000100711.html?utm_source=Plantlife+email+updates&utm_campaign=54718fbe07-RV_Feb2021&utm_medium=email&utm_term=0_ce964b84b6-54718fbe07-285770565&mc_cid=54718fbe07&mc_eid=02dd4597cb&guccounter=1

Norfolk County Council Biodiversity Action plan for Hedgerows

NORFOLK BIODIVERSITY ACTION PLAN

HEDGEROWS

Ref 1/H5	Tranche 1	Habitat Action Plan 5
Plan Author:	Norfolk County Council (Gerry Barnes)	
Plan Co-ordinator:	Farmland BAP Topic Group	
Plan Leader:	Norfolk County Council	
Date:	Stage:	
31 Dec 1998	Version 1	
January 2006	Version 2	
November 2009	Version 3	

A hedgerow is defined as any boundary line of trees or shrubs over 20m long and less than 5m wide, and where any gaps between the trees or shrub species are less than 20m wide. Any bank, wall, ditch or tree within 2m of the centre of the hedgerow is considered to be part of the hedgerow habitat, as is the herbaceous vegetation within 2m of the centre of the hedgerow. All hedgerows consisting predominantly (ie, 80 % or more cover) of at least one woody native species are covered by this habitat. Climbers such as honeysuckle and bramble are recognised as integral to many hedgerows; however, they require other woody plants to be present to form a distinct, woody boundary feature and as such are not included in the definition of woody species. The definition is limited to boundary lines of trees or shrubs, and excludes banks or walls without woody shrubs on top of them.

1. CURRENT STATUS

National Status

- The 2007 Countryside Survey found that there are 547,000km of woody linear features in England (see http://www.countrysidesurvey.org.uk/pdf/reports2007/england2007/CS-England-Results2007-Chapter05.pdf). Of this total, it is estimated that approximately 525,000km meet the BAP definition as given above.

Norfolk Status

- Norfolk is a particularly good area for hedges because of the rich diversity of its landscapes, both man-made and natural. It contains a wide variety of soil types, ranging from acid sands and gravels, through rich loams and alluvium, to heavy clay. It lies astride the conventional boundary between the 'planned' and the 'ancient' countryside: in the west of the county, field patterns were largely created by planned post-medieval enclosure, but in the south and east, they have much earlier origins. Moreover, although the county suffered badly from the intensification of agriculture in the second half of the twentieth century, in most districts substantial numbers of hedges still remain.

- It has been calculated that, in 1973, Norfolk had about 16,500km of hedge, roughly 4km per km^2 (Farmland Tree Survey, NCC).

2. CURRENT FACTORS CAUSING LOSS OR DECLINE IN NORFOLK

- The perceived increases in farm efficiencies facilitated by hedgerow removal are still a factor in hedgerow loss.

- Degradation of hedgerow flora and fauna by drifted and even deliberate applications of agri-chemicals is a major but unquantified factor.

- Ill-timed cutting affects breeding birds and winter food supplies for birds and other wildlife, and annual cutting limits flowering and fruiting, also affecting food supplies for a wide range of wildlife.

- Arable cultivation too close to hedges and more efficient field drainage are probably major factors in the declining hedgerow and hedgerow tree quality.

- Climate change.

- The difficulty of establishing new hedges on banks, in Norfolk's drought prone springs. Rabbits and deer can also create problems with hedges.

- Loss to development.

- Use of inappropriate species and genotypes.

- Elm disease and premature die-back of other tree species (particularly oak, eg. from Acute Oak Decline and Sudden Oak Death) have caused significant losses of mature trees. (Regular trimming preserves elm as a hedged species where it was previously hedge or has regenerated from suckers from failed mature trees.)

3. CURRENT ACTION IN NORFOLK

- The Hedgerows Regulations 1997 require landowners to consult District Councils prior to removing a hedge.

- Cross-compliance under the Single Payment Scheme underpins the Hedgerow Regulations and requires hedgerow cutting to be avoided between 1 March and 31 July except for roadside hedges. Farmers are also required not to cultivate or apply fertilisers, manures or pesticides within 2m of the centre of a hedgerow on fields over 2ha.

- Defra's agri-environment schemes provide incentives for hedgerow management. Funding through HLS is available for hedge planting and restoration where hedges are a feature of the landscape, while ELS offers incentives for on-going maintenance.

- Norfolk County Council provides comprehensive advice and grants, currently at 40% up to a maximum of £3,200 (total cost £8,000) for hedge planting and gapping up. This programme has been developed over the past 30 years.

- Norfolk FWAG provides comprehensive independent advice on farmland conservation, including sources of grants.

- Landowners are obliged to seek a felling licence for hedgerow trees from the Forestry Commission.

- A survey of the hedges in over 200 parishes was undertaken between 1995 and 2003, in a joint project between Norfolk County Council and the School of History at UEA.

4. ACTION PLAN OBJECTIVES AND PROPOSED TARGETS

National

- Maintain the net extent of hedgerows across the UK.
- Maintain the overall number of individual, isolated hedgerow trees and the net number of isolated veteran trees.
- Ensure that between 2005 and 2010 hedgerows remain, on average, at least as rich in native woody species.
- Achieve favourable condition of 243,000 km (35%) of hedgerows by 2010 and 348,000 km (50%) by 2015. (Target does not include Northern Ireland.)
- Reverse the unfavourable condition of over-managed hedgerows across the UK by reducing the proportion of land managers who trim most of their hedgerows annually to 60% by 2010 (applicable to England only).
- Halt further decline in the condition of herbaceous hedgerow flora in Great Britain by 2010 (and improve their condition by 2015). (Target does not include Northern Ireland.)
- Improve the condition of the hedgerow tree population by increasing numbers of young trees (1-4 years) in Great Britain to 40,000 by 2010 and 80,000 by 2015. (Target does not include Northern Ireland.)
- Achieve a net increase in the length of hedgerows of an average of 800 km per year in Great Britain to 2010 and 2015 (Target does include Northern Ireland.)

Norfolk

- Reduce the loss of hedgerows through removal to a negligible proportion of the resource.
- In parts of the county where trees in the hedgerow are a charismatic and traditional feature, ensure the establishment of replacement hedgerow trees.
- Re-create 100 new hedgerow pollards per year, from young trees where these are a characteristic or traditional feature of the landscape.
- Ensure all roadside hedgerows associated with Roadside Nature Reserves (RNRs) are in favourable management by 2012.
- Establish 60km of new hedgerows per annum from 2009-2014.
- Plant 1km per year of new Scots pine hedges in the Brecks.
- Ensure willow pollards are maintained with no net loss on the roads and the broads and fens where they are a characteristic feature.

Hedgerows - Norfolk Action Plan

NATIONAL ACTION		NORFOLK ACTION	LEAD	PARTNERS
5.1	**Policy and Legislation**			
5.1.1	Ensure that grants for hedgerow management, restoration and establishment are available to farmers. Consider standardising payments across land management schemes.	Encourage farmers to put forward sufficient number of quality applications to agri-environment schemes.	FWAG, LAs, NE	Landowners
5.1.2	Ensure that development plans contain policies to promote the protection and management of hedges and seek to minimise adverse effects on hedges from planning proposals.	Ensure that new Local Development Frameworks contain policies to promote the protection and management of hedges.	LAs	
5.2	**Site Safeguard and Management**			
5.2.1	Encourage the retention and favourable management of hedgerows	Identify and encourage the positive management of Norfolk hedgerows that are part of, link or enhance Natura 2000 sites, SSSIs or County Wildlife Sites.	NE	LAs
5.2.2	Encourage favourable management of ASR roadside hedges.	Identify roadside hedgerows, particularly those associated with RNRs, and encourage favourable management.	NCC	Farmers
5.3	**Advisory**			
5.3.1	Promote the use of practices that can protect hedges from fertilisers and pesticides.	Prepare and distribute a leaflet highlighting the impacts of agri-chemicals on hedgerows and the hedge bottom environment, and ways of mitigating these.	FWAG	NCC, NE
5.3.2	Consider the development of hedge management skills through training, especially for contractors.	Establish a directory of hedge trimming contractors.	NCC	FWAG, NE
		Organise one training event a year.	NCC	FWAG, NE

Hedgerows - Norfolk Action Plan

NATIONAL ACTION		NORFOLK ACTION	LEAD	PARTNERS
		Suggest that educational institutions teaching agriculture-related subjects include hedges and their management in appropriate courses. Undertake guided farm walks to introduce the concept of hedgerows, and promote favourable management.	Easton College FWAG, NCC, NE	
5.4 **5.4.1**	**Future Research and Monitoring** Carry out sample surveys at 10 year intervals throughout UK to determine regional trends in status of hedges.	Produce GIS layer of Norfolk hedge survey and make this widely available to LAs and other interested parties. Continue survey work as required.	UEA, NCC UEA, NCC	
5.5 **5.5.1**	**Communications and Publicity** Continue to promote an awareness among the public and land managers of the importance of hedgerows and their associated features for wildlife, of the continuing loss of hedgerows, and of the need for management to maintain biodiversity.	Undertake guided walks and hold events. Produce guidance material.	NCC, NE, FWAG NCC, UEA	
5.6 **5.6.1**	**Links with other Action Plans** None given.	Hedgerows are associated with a wide range of BAP habitats, including woodland habitats such as orchards, wood-pasture and deciduous mixed woodlands. Many BAP species are also associated with hedgerows, including soprano pipistrelle, barbastelle and a variety of birds such as tree sparrow.	Farmland BAP Topic Group, Woodland BAP Topic Group	

Abbreviations

FWAG	Farming and Wildlife Advisory Group
LA	Local authority
NCC	Norfolk County Council
NE	Natural England
UEA	University of East Anglia

NORFOLK DISTRIBUTION

MANAGEMENT GUIDANCE

(*This guidance is a general summary; for more detailed information or advice, please consult the references or contacts below.*)

Appropriate tree planting, by area

Claylands

- If it is on an existing line, and that line is straight:

  Mainly hawthorn, with ash, blackthorn and occasional field maple. Other species only in ones or twos. Oak and ash as trees.

- If on a curving/irregular line, but not on a parish boundary/roadside:

  Hawthorn with blackthorn for bulk of hedge. Include large amounts of dogwood, hazel, field maple, ash, crab apple and holly.

- If on a roadside/parish boundary:

  A high percentage of hazel, dogwood, field maple - with a smaller proportion of hawthorn/blackthorn and a scattering of ash, crab apple, holly, hornbeam, spindle, purging buckthorn and goat willow as required.

Breckland

- If in an area where pine rows dominate:

  Scots pine.

- Elsewhere, but not on a parish boundary/roadside:

  Mostly hawthorn, with some ash and blackthorn.

- If on a roadside or parish boundary:

  Mostly hawthorn, with ash, blackthorn and occasional field maple, privet, crab apple and very occasional hazel.

North-West Norfolk

- Most, especially all the dead straight ones:

  Hawthorn, with some blackthorn and ash.

- If curving or on a roadside or parish boundary:

  Hawthorn, with some blackthorn and ash with occasional field maple, dogwood and hazel.

North-East Norfolk

- If on an existing line, and that line is straight:

  Mostly hawthorn, with blackthorn, field maple.

- If curving or on a roadside or parish boundary:

  Hawthorn, with blackthorn, field maple and occasional crab apple, hazel, spindle, ash and holly.

Fens

- Willow hedges might be a possibility, but advice should be sought.

CONTACTS

Environment Operations Section
Planning and Transportation Department
Norfolk County Council
County Hall
Martineau Lane
Norwich — Tel: 01603-222764
NR1 2SG — Email: gerry.barnes@norfolk.gov.uk

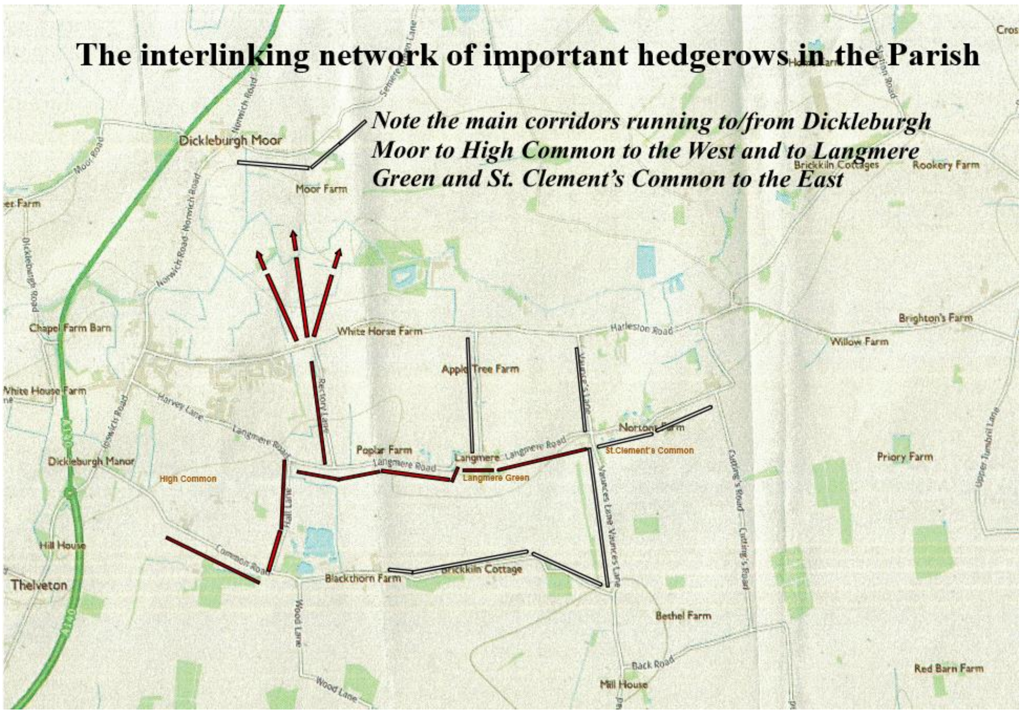
Norfolk Farming and Wildlife Advisory Group (FWAG)
Beeches Farm
Slopers Road
Downham
Wymondham — Tel: 01603-814869
NR18 0SD — Email: norfolk@fwag.org.uk

Natural England
Dragonfly House
2 Gilders Way
Norwich
NR3 1UB — Tel: 01603-674920

REFERENCES

Barnes, G. and Williamson, T. (2006). *Hedgerow History: Ecology, History and Landscape Character.* Macclesfield: Windgather Press Ltd.

Map illustrating a network of 'important' and ancient hedges and verges in the heart of the Parish which provide interlinking corridors to three County Wildlife Sites



Ecologist’s notes on habitat loss etc.

Notes on habitat loss, mitigation etc., provided by Katy Utting, Ecologist

Any loss of ancient habitats, including trees hedgerows, grassland and ditches, is to a large extent irreplaceable in that the length of time required to establish complex ecological interactions that exist between plants, animals, fungi, and micro-organisms will take centuries to establish. Certain species take so long to return to sites that their presence can be used to identify a site as indeed ancient. Any attempts to mitigate against the loss of historical landscape features should be sited adjacent to existing sites of this kind. This will ensure a source of organisms to colonise new sites and support the colonisation of species that have limited capacity to migrate across geographic barriers. It would be recommended to begin to establish areas within the locality where space adjacent to veteran and ancient sites can be extended to facility expansion of these sites.

Deadwood is another essential and often overlooked habitat that supports its own unique ecosystems. Not all deadwood is equal, and a log pile, although valuable, does not compensate for standing deadwood that can be used as a source of food and home for numerous under-represented organisms. Where possible dead should remain in situ or moved to a suitable situation as close to the original site as possible.

Extreme weather events are on the rise, all opportunities to liaise with landowners and establish environmental schemes to protect wildlife and, act for the common good and support ecosystem services should be encouraged. A catchment-wide assessment of opportunities to create wetlands and floodplain meadows to help mitigate flood risk and seasonal droughts should be actively sort. Increasingly outdated farming techniques that arose in response to post-war, food security fears and short-sighted environmental policy that called for unlimited intensification failed to recognise the importance of basic ecological essentials such as biodiversity, soil health, clean water as well as the human need for connectivity to the land. Current areas of land that would best serve the community being removed from damaging agricultural practices should be sought and alternative land use considered. Numerous organisations can advise on how best to plan habitat creation initiatives and where funding may be obtained to support such work.

References:

Natural Histories Meadows George Peterken

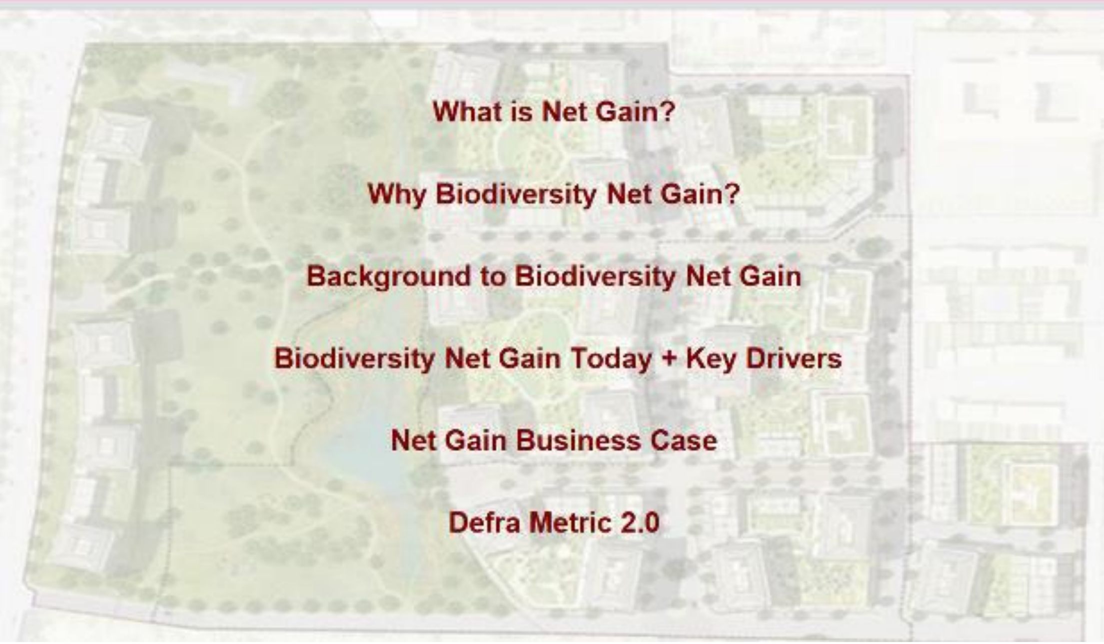
Deadwood https://www.woodlandtrust.org.uk/media/47652/wood-wise-autumn-2019-life-in-deadwood.pdf

Hedgerows by John Wright

Floodplain Meadows a Technical Handbook Emma Rothero published by OU Press

Natural Flood Management - www.catchmentbasedapproach.org

Local Government Association Workshop - Environmental Net Gain



https://www.local.gov.uk/sites/default/files/documents/Biodiversity%20Net%20Gain%20Dec%2018.pdf

Regulations

Hedgerow Regulations

Document Generated: 2020-08-03

Status: *This is the original version (as it was originally made). This item of legislation is currently only available in its original format.*

SCHEDULE 1 Regulations 2(3) and 4

ADDITIONAL CRITERIA FOR DETERMINING "IMPORTANT" HEDGEROWS

PART I

INTERPRETATION

In this Schedule—

"building" includes structure;

"Record Office" means—

(a) a place appointed under section 4 of the Public Records Act 1958(**1**) (place of deposit of public records),

(b) a place at which documents are held pursuant to a transfer under section 144A(4) of the Law of Property Act 1922(**2**) or under section 36(2) of the Tithe Act 1936(**3**), including each of those provisions as applied by section 7(1) of the Local Government (Records) Act 1962(**4**), or

(c) a place at which documents are made available for inspection by a local authority pursuant to section 1 of the Local Government (Records) Act 1962;

"relevant date" means the date on which these Regulations are made;

"Sites and Monuments Record" means a record of archaeological features and sites adopted—

(a) by resolution of a local authority within the meaning of the Local Government Act 1972(**5**), or

(b) in Greater London, by the Historic Buildings and Monuments Commission(**6**);

"standard tree"—

(a) in the case of a multi-stemmed tree, means a tree which, when measured at a point 1.3 metres from natural ground level, has at least two stems whose diameters are at least 15 centimetres;

(b) in the case of a single-stemmed tree, means a tree which, when measured at a point 1.3 metres from natural ground level, has a stem whose diameter is at least 20 centimetres;

"woodland species" means the species listed in Schedule 2; and

"woody species" means the species and sub-species listed in Schedule 3, and any hybrid, that is to say, any individual plant resulting from a cross between parents of any species or sub-species so listed, but does not include any cultivar; and

references to the documents in paragraph 6(3)(b) and (4) are to those documents as at the relevant date, without taking account of any subsequent revisions, supplements or modifications.

(1) 1958 c. 51.
(2) 1922 c. 16; section 144A was inserted by the Law of Property (Amendment) Act 1924 (c. 5), Schedule 2.
(3) 1928 c. 2.
(4) 1962 c. 56.
(5) 1972 c. 70.
(6) The Commission was established by section 32 of the National Heritage Act 1993 (c. 47).

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PART II

CRITERIA

Archaeology and history

1. The hedgerow marks the boundary, or part of the boundary, of at least one historic parish or township; and for this purpose "historic" means existing before 1850.

2. The hedgerow incorporates an archaeological feature which is—

(a) included in the schedule of monuments compiled by the Secretary of State under section 1 (schedule of monuments) of the Ancient Monuments and Archaeological Areas Act 1979(7), or

(b) recorded at the relevant date in a Sites and Monuments Record.

3. The hedgerow—

(a) is situated wholly or partly within an archaeological site included or recorded as mentioned in paragraph 2 or on land adjacent to and associated with such a site; and

(b) is associated with any monument or feature on that site.

4. The hedgerow—

(a) marks the boundary of a pre-1600 AD estate or manor recorded at the relevant date in a Sites and Monuments Record or in a document held at that date at a Record Office; or

(b) is visibly related to any building or other feature of such an estate or manor.

5. The hedgerow—

(a) is recorded in a document held at the relevant date at a Record Office as an integral part of a field system pre-dating the Inclosure Acts(**8**); or

(b) is part of, or visibly related to, any building or other feature associated with such a system, and that system—

(i) is substantially complete; or

(ii) is of a pattern which is recorded in a document prepared before the relevant date by a local planning authority, within the meaning of the 1990 Act(**9**), for the purposes of development control within the authority's area, as a key landscape characteristic.

Wildlife and landscape

6.—(1) The hedgerow—

(a) contains species listed or categorised as mentioned in sub-paragraph (3); or

(b) is referred to in a record held immediately before the relevant date by a biological record centre maintained by, or on behalf of, a local authority within the meaning of the Local Government Act 1972(**10**), and in a form recognised by the Nature Conservancy Council for England, the Countryside Council for Wales(**11**) or the Joint Nature Conservation Committee(**12**), as having contained any such species—

(7) 1979 c. 46.
(8) *See* the Short Titles Act 1896 (c. 14).
(9) *See* section 1 of the Town and Country Planning Act 1990, as amended by the Local Government (Wales) Act 1994 (c. 19).
(10) *See* the definition of "local authority" in section 270(1), as amended by the Local Government Act 1985 (c. 51), Schedule 17 and the Local Government (Wales) Act 1994, Schedule 1, paragraphs 1 and 57.
(11) *See* section 128(1) of the Environmental Protection Act 1990 (c. 43); subsection (1) of section 128 was amended by the National Heritage (Scotland) Act 1991 (c. 28).
(12) *See* section 128(4) of the Environmental Protection Act 1990.

(i) in the case of animals and birds, subject to sub-paragraph (2), within the period of five years immediately before the relevant date.

(ii) in the case of plants, subject to sub-paragraph (2), within the period of ten years immediately before the relevant date;

(2) Where more than one record referable to the period of five or, as the case may be, ten years before the relevant date is held by a particular biological record centre, and the more (or most) recent record does not satisfy the criterion specified in sub-paragraph (1)(b), the criterion is not satisfied (notwithstanding that an earlier record satisfies it).

(3) The species referred to in sub-paragraph (1) are those—

(a) listed in Part I (protection at all times) of Schedule 1 (birds which are protected by special penalties), Schedule 5 (animals which are protected) or Schedule 8 (plants which are protected) to the Wildlife and Countryside Act 1981(**13**);

(b) categorised as a declining breeder (category 3) in "Red Data Birds in Britain" Batten LA, Bibby CJ, Clement P, Elliott GD and Porter RF (Eds.), published in 1990 for the Nature Conservancy Council and the Royal Society for the Protection of Birds (ISBN 0 85661 056 9); or

(c) categorised as "endangered", "extinct", "rare" or "vulnerable" in Britain in a document mentioned in sub-paragraph (4).

(4) The documents referred to in sub-paragraph (3)(c) are—

(a) of the books known as the British Red Data Books:

(1) "Vascular Plants" Perring FH and Farrell L, 2nd Edition, published in 1983 for the Royal Society for Nature Conservation (ISBN 0 902484 04 4);

(2) "Insects" Shirt DB (Ed.), published in 1987 for the Nature Conservancy Council (ISBN 0 86139 380 5); and

(3) "Invertebrates other than insects" Bratton JH (Ed.), published in 1991 for the Joint Nature Conservation Committee (ISBN 1 873701 00 4); and

(b) of the books known as the Red Data Books of Britain and Ireland:

"Stoneworts" Stewart NF and Church JM, published in 1992 for the Joint Nature Conservation Committee (ISBN 1 873701 24 1).

7.—(1) Subject to sub-paragraph (2), the hedgerow includes—

(a) at least 7 woody species;

(b) at least 6 woody species, and has associated with it at least 3 of the features specified in sub-paragraph (4);

(c) at least 6 woody species, including one of the following—

black-poplar tree *(Populus nigra* ssp *betulifolia)*;

large-leaved lime *(Tilia platyphyllos)*;

small-leaved lime *(Tilia cordata)*;

wild service-tree *(Sorbus torminalis)*; or

(d) at least 5 woody species, and has associated with it at least 4 of the features specified in sub-paragraph (4),

and the number of woody species in a hedgerow shall be ascertained in accordance with sub-paragraph (3).

(**13**) 1981 c. 69. Schedule 5 is amended by S.I.1988/288, 1989/906, 1991/367 and 1992/2350.

(2) Where the hedgerow in question is situated wholly or partly in the county (as constituted on 1st April 1997) of the City of Kingston upon Hull, Cumbria, Darlington, Durham, East Riding of Yorkshire, Hartlepool, Lancashire, Middlesbrough, North East Lincolnshire, North Lincolnshire, Northumberland, North Yorkshire, Redcar and Cleveland, Stockton-on-Tees, Tyne and Wear, West Yorkshire or York(**14**), the number of woody species mentioned in paragraphs (a) to (d) of sub-paragraph (1) is to be treated as reduced by one.

(3) For the purposes of sub-paragraph (1) (and those of paragraph 8(b))—

(a) where the length of the hedgerow does not exceed 30 metres, count the number of woody species present in the hedgerow;

(b) where the length of the hedgerow exceeds 30 metres, but does not exceed 100 metres, count the number of woody species present in the central stretch of 30 metres;

(c) where the length of the hedgerow exceeds 100 metres, but does not exceed 200 metres, count the number of woody species present in the central stretch of 30 metres within each half of the hedgerow and divide the aggregate by two;

(d) where the length of the hedgerow exceeds 200 metres, count the number of woody species present in the central stretch of 30 metres within each third of the hedgerow and divide the aggregate by three.

(4) The features referred to in sub-paragraph (1)(b) and (d) (which include those referred to in paragraph 8(b)) are—

(a) a bank or wall which supports the hedgerow along at least one half of its length;

(b) gaps which in aggregate do not exceed 10% of the length of the hedgerow;

(c) where the length of the hedgerow does not exceed 50 metres, at least one standard tree;

(d) where the length of the hedgerow exceeds 50 metres but does not exceed 100 metres, at least 2 standard trees;

(e) where the length of the hedgerow exceeds 100 metres, such number of standard trees (within any part of its length) as would when averaged over its total length amount to at least one for each 50 metres;

(f) at least 3 woodland species within one metre, in any direction, of the outermost edges of the hedgerow;

(g) a ditch along at least one half of the length of the hedgerow;

(h) connections scoring 4 points or more in accordance with sub-paragraph (5);

(i) a parallel hedge within 15 metres of the hedgerow.

(5) For the purposes of sub-paragraph (4)(h) a connection with another hedgerow scores one point and a connection with a pond or a woodland in which the majority of trees are broad-leaved trees scores 2 points; and a hedgerow is connected with something not only if it meets it but also if it has a point within 10 metres of it and would meet it if the line of the hedgerow continued.

8. The hedgerow—

(a) is adjacent to a bridleway or footpath, within the meaning of the Highways Act 1980(**15**), a road used as a public path, within the meaning of section 54 (duty to reclassify roads used as public paths) of the Wildlife and Countryside Act 1981(**16**), or a byway open to all traffic, within the meaning of Part III of the Wildlife and Countryside Act 1981(**17**), and

(**14**) In relation to the City of Kingston upon Hull, North and North East Lincolnshire and the East Riding of Yorkshire, *see* S.I. 1995/600; to Darlington and Durham, *see* S.I. 1995/1772; to Hartlepool, Middlesbrough, Redcar and Cleveland and Stockton-on-Tees, *see* S.I. 1995/1747; to Lancashire, *see* S.I. 1996/1868; and to North Yorkshire and York, *see* S.I. 1995/610.
(**15**) 1980 c. 66. *See* the definition of "bridleway" and "footpath" in section 3.
(**16**) 1981 c. 69.
(**17**) *See* the definition in section 66(1).

(b) includes at least 4 woody species, ascertained in accordance with paragraph 7(3) and at least 2 of the features specified in paragraph 7(4)(a) to (g).

DICKLEBURGH AND RUSHALL QUIET LANES

July 2020

A walk around the Parish linking villages and beauty spots

This proposal is to create a walk linking footpaths, bridal ways and quiet lanes to create a pleasant walk around the Parish that takes the walker, cyclist or rider to and through the commons, the moor, and the villages of this parish.

Dickleburgh and Rushall Quiet Lanes proposal

A WALK AROUND THE PARISH LINKING VILLAGES AND BEAUTY SPOTS

THE PROPOSAL

During the period of lockdown, as a consequence of the Covid 19 pandemic, we saw, across the Parish, a far greater number of people walking the quieter lanes and enjoying access to the Commons, Dickleburgh Moor and some of the attractive footpaths and bridle paths in the Parish. Two households initially approached the Parish Council (PC) asking if there was a possibility of designating Langmere Road as a Quiet Lane as the footfall on the road had increased significantly and people were clearly enjoying the tranquility of the occasion. It was decided that if the PC were to invest in a Quiet Lanes proposal then we should look at the prospect of creating a circular walk around and through the parish – linking key features and the villages.

The Roads involved involved	Footpaths (fp) and Bridle ways (bw)
Harvey Lane	Langmere Road to Rushall Church (incorporating part of fp 10)
Langmere Road	Harleston Road to Air station road (fp 11)
Air Station Road 12)	Lonely Lane (Rushall) to Lonely Lane (Dickleburgh) (bw 23/fp
Lonely Lane (Rushall)	Lonely Lane to Rectory Lane (fp 2)
Rectory Lane (Langmere)	Lonely Lane to Rectory Road (via the Bottle bank fp 2)Rectory Road to Harvey Lane via the Dickleburgh Village Centre

PAGE 1

Quiet lanes work best when they are part of a network of designated lanes which can link local residents to, for example, the local shop or school, and connect lanes around a village centre or to a nearby village. Quiet lanes are about appreciating the beauty and tranquility of country lanes rather than travelling along them from A to B as quickly as possible in a car. By helping to protect the character and tranquility of the countryside from traffic, reducing the intimidating effects of traffic on rural roads, building community links and encouraging healthy recreational activities, Quiet Lanes play a valuable role in improving peoples quality of life.

CPRE's Guide to Quiet Lanes 2003

The views of households affected by the proposal

130 households (all those on or around the proposed routes) were contacted via a leaflet, regarding the proposal. Wherever possible, face to face conversations were held, outlining the routes and purposes of the Quiet Lanes initiative. The proposal has received almost universal backing from the households contacted (one hesitant objection has been received).

The proposed Quiet Lanes in pictures.

1. Possible start of the quiet network. The entry into Harvey Lane.

The logic of this is that it is the beginning of the road. It starts from the junction of Ipswich Road and would bring the Quiet Lanes initiative into the heart of the village of Dickleburgh. If the route started here it would incorporate the entrance to Dickleburgh Primary school.

2. Alternative start point. The Village Centre, Harvey Lane. There is no pavement available along most of this section of road and therefore the Quiet Lane initiative would make it safer for pedestrians, cyclists and horse riders.

3. Junction of Harvey Lane and Hall Lane. Hall Lane is also a candidate for designation as a Quiet Lane. The residents on Hall Lane have requested that this be looked at. This particular junction is a significant spot for a wide variety of bats including some rare and endangered breeds, including Brown

long-eared bat, Daubenton's bat, Leisler's bat, Noctule and Serotine bats.

4. Junction with Rectory Lane. This would see the joining of three Quiet Lanes, enabling the walker, cyclist, horse rider to head North up Rectory Lane and cross the Moor or continue on Langmere Road toward the Commons and Rushall Village.

5. Scenes along Langmere Road. Langmere Road is blessed with open vistas and secret views.

6. Junction of Lakes Road and Langmere Road at St. Clements Common.

7. St. Clements Common.

8. Footpath linking proposed Quiet Lanes in Rushall.

9. Entrance to Air Station Road.

Entrance to Rectory Lane from Rectory Road and Footpath 2.

Map showing existence of the roads in 1750 (Map curtesy of Norfolk Archive Library)

The roads in question are all heritage roads.

Management of the Quiet Lane Verges

> ***"Throughout the spring and summer the wild flowers of our country roads and lanes delight all who walk or drive them – or rather one would think that they delight everyone, but this is clearly not entirely so because each year, at the height of their glory, mile upon mile of them are ruthlessly cut."***
>
> **John Burton, Country Life, 1973.**

The majority of verges along the proposed quiet lanes are already at Wildlife verge qualification. Those that are not would, given their location and longevity, gain Heritage verge status and should be managed appropriately in line with the Roadside verge management identified in the Dickleburgh and Rushall Neighbourhood Plan.

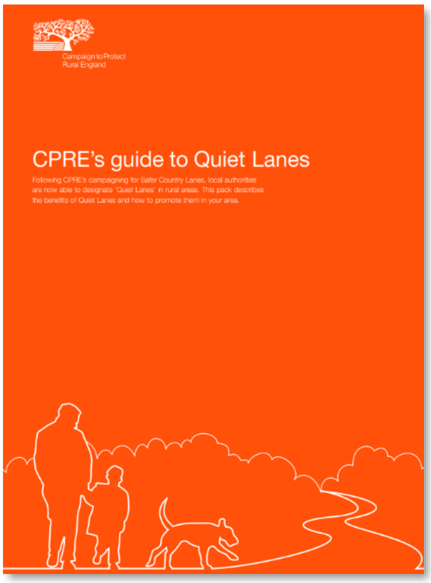
Damage to the Quiet Lane Verges.

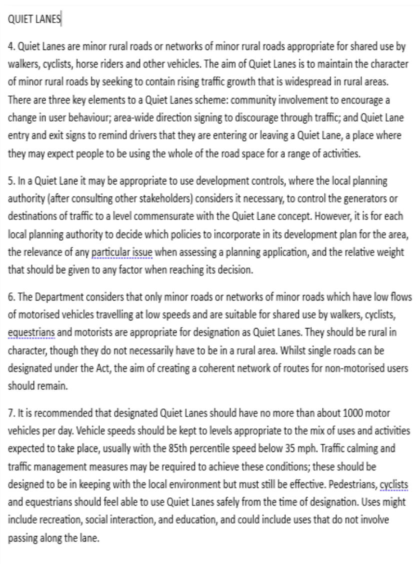
Should damage occur it should be reported to Norfolk County Council Highways department and the Parish Council. Repairs to the damaged verge should be sensitive to the status of the verge and re seeded accouringly.

Additional Quiet Lanes

There have been expressions of interest to extend the Quiet Lane initiative to include additional roads off Langmere Road that link Common Lane or Rectory Road to Langmere Road / Harvey Lane. There may be other roads within the parish that could justifiably be designated as Quiet Lanes, Semere Green Lane could qualify given the width of the road and concerns over speeding.

Relevant Publications





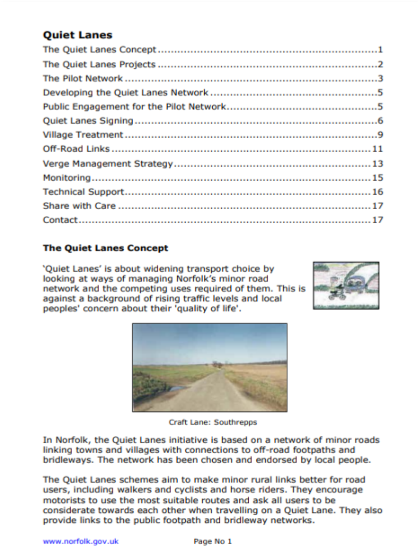
QUIET LANES

4. Quiet Lanes are minor rural roads or networks of minor rural roads appropriate for shared use by walkers, cyclists, horse riders and other vehicles. The aim of Quiet Lanes is to maintain the character of minor rural roads by seeking to contain rising traffic growth that is widespread in rural areas. There are three key elements to a Quiet Lanes scheme: community involvement to encourage a change in user behaviour; area-wide direction signing to discourage through traffic; and Quiet Lane entry and exit signs to remind drivers that they are entering or leaving a Quiet Lane, a place where they may expect people to be using the whole of the road space for a range of activities.

5. In a Quiet Lane it may be appropriate to use development controls, where the local planning authority (after consulting other stakeholders) considers it necessary, to control the generators or destinations of traffic to a level commensurate with the Quiet Lane concept. However, it is for each local planning authority to decide which policies to incorporate in its development plan for the area, the relevance of any particular issue when assessing a planning application, and the relative weight that should be given to any factor when reaching its decision.

6. The Department considers that only minor roads or networks of minor roads which have low flows of motorised vehicles travelling at low speeds and are suitable for shared use by walkers, cyclists, equestrians and motorists are appropriate for designation as Quiet Lanes. They should be rural in character, though they do not necessarily have to be in a rural area. Whilst single roads can be designated under the Act, the aim of creating a coherent network of routes for non-motorised users should remain.

7. It is recommended that designated Quiet Lanes should have no more than about 1000 motor vehicles per day. Vehicle speeds should be kept to levels appropriate to the mix of uses and activities expected to take place, usually with the 85th percentile speed below 35 mph. Traffic calming and traffic management measures may be required to achieve these conditions; these should be designed to be in keeping with the local environment but must still be effective. Pedestrians, cyclists and equestrians should feel able to use Quiet Lanes safely from the time of designation. Uses might include recreation, social interaction, and education, and could include uses that do not involve passing along the lane.



Quiet Lanes

The Quiet Lanes Concept

'Quiet Lanes' is about widening transport choice by looking at ways of managing Norfolk's minor road network and the competing uses required of them. This is against a background of rising traffic levels and local peoples' concern about their 'quality of life'.

Craft Lane: Southrepps

In Norfolk, the Quiet Lanes initiative is based on a network of minor roads linking towns and villages with connections to off-road footpaths and bridleways. The network has been chosen and endorsed by local people.

The Quiet Lanes schemes aim to make minor rural links better for road users, including walkers and cyclists and horse riders. They encourage motorists to use the most suitable routes and ask all users to be considerate towards each other when travelling on a Quiet Lane. They also provide links to the public footpath and bridleway networks.

www.norfolk.gov.uk Page No 1

Documents:
1 CPRE guide to Quiet Lanes
2 Extract from: Explanatory memorandum to the Quiet Lanes and home zones (England) regulations 2006 2006 no. 2082
3 Norfolk County Council Quiet Lanes

Tree Planting & Air Quality Paper from University of Lancaster, Xi'an University & Oxford University

Environmental Science & Technology

Article

Cite This: Environ. Sci. Technol. XXXX, XXX, XXX−XXX

pubs.acs.org/est

Efficient Removal of Ultrafine Particles from Diesel Exhaust by Selected Tree Species: Implications for Roadside Planting for Improving the Quality of Urban Air

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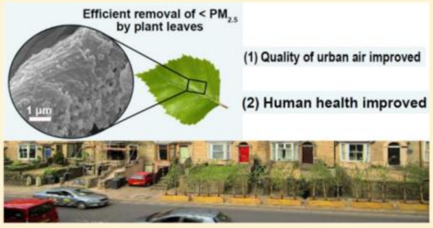
Supporting Information



ABSTRACT: Human exposure to airborne ultrafine (≪1 μm) particulate pollution may pose substantial hazards to human health, particularly in urban roadside environments where very large numbers of people are frequently exposed to vehicle-derived ultrafine particles (UFPs). For mitigation purposes, it is timely and important to quantify the deposition of traffic-derived UFPs onto leaves of selected plant species, with particularly efficient particle capture (high deposition velocity), which can be installed curbside, proximal to the emitting vehicular sources. Here, we quantify the size-resolved capture efficiency of UFPs from diesel vehicle exhaust by nine temperate-zone plant species, in wind tunnel experiments. The results show that silver birch (79% UFP removal), yew (71%), and elder (70.5%) have very high capabilities for capture of airborne UFPs. Metal concentrations and metal enrichment ratios in leaf leachates were also highest for the postexposure silver birch leaves; scanning electron microscopy showed that UFPs were concentrated along the hairs of these leaves. For all but two species, magnetic measurements demonstrated substantial increases in the concentration of magnetic particles deposited on the leaves after exposure to the exhaust particulates. Together, these new data show that leaf-deposition of UFPs is chiefly responsible for the substantial reductions in particle numbers measured downwind of the vegetation. It is critical to recognize that the deposition velocity of airborne particulate matter (PM) to leaves is species-specific and often substantially higher (~10 to 50 times higher) than the "standard" V_d values (e.g., 0.1−0.64 cm s^{-1} for $PM_{2.5}$) used in most modeling studies. The use of such low V_d values in models results in a major under-estimation of PM removal by roadside vegetation and thus misrepresents the efficacy of selected vegetation species in the substantial (≫20%) removal of PM. Given the potential hazard to health posed by UFPs and the removal efficiencies shown here (and by previous roadside measurements), roadside planting (maintained at or below head height) of selected species at PM "hotspots" can contribute substantially and quickly to improve in urban air quality and reductions in human exposure. These findings can contribute to the development and implementation of mitigation policies of traffic-derived PM on an international scale.

■ INTRODUCTION

1.1. Airborne Particulate Matter and Ultrafine Particles. Airborne particulate matter (PM) is a health hazard on a global scale. Ultrafine particles (UFPs, aerodynamic diameter <100 nm), with lifetimes in the atmosphere ranging from a few seconds to several days, may pose particular risk to the health of the very large populations living, commuting, and working in polluted urban environments, especially near major roadways.[1] UFPs have been shown to penetrate the respiratory system, enter the blood circulation, transfer to extra-pulmonary organs,[2,3] and also enter the brain directly via the olfactory bulb.[4,5] UFPs may be more toxic than microscale particles with the same chemical composition and at the same mass concentration owing to their very large surface area, increased chemical reactivity, and ease of cell penetration.[6−9]

Airborne UFPs can be derived both from anthropogenic and natural sources (e.g., biomass burning), but in many urban centers, motor vehicles are the primary emission sources of UFPs to the atmosphere, particularly in the morning and afternoon/evening rush hours.[10−12] Primary, vehicle-derived UFPs are produced directly from fuel combustion,[13,14] engine

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wear,[15] and frictional processes, especially brake, tire and road wear.[16,17] Resuspension of road dust provides multiple opportunities for postemission supply of airborne UFPs.[18] Primary, solid, vehicle-derived UFPs are often enriched in highly bioreactive transition metal species, especially Fe (both Fe^{2+} and Fe^{3+}), Cu, Mn, and Cr,[12,19] and other metals including Zn, Ni, V, and Pb.[12,20] Secondary UFPs are formed in the atmosphere through photochemical reactions involving gaseous precursors and postemission nucleation and condensation processes.[10,21]

Currently, policies for regulation of airborne PM are based on mass concentrations of PM_{10} and/or $PM_{2.5}$ (of aerodynamic diameter <10 μm or <2.5 μm, respectively). The contribution of UFPs to such mass-based metrics is minimal (<10%), whereas they make up ~80% or more of the PM number.[14,21,22]

Most of the PM emitted from vehicle exhausts lies within the $PM_{1.0}$ size range, with median mass diameter between ~100 and 200 nm and a median number diameter of ~20 nm.[23,24] Emissions control strategies, based on engine design and after-treatment devices, have reduced the average mass of particle emissions but are limited in their success in reducing UFP numbers. Indeed, some studies have reported increased UFP numbers[25] and increased UFP toxicity[26,27] with the introduction of after-treatment devices. Hence, it is timely and important to identify feasible and efficient technologies that can capture airborne UFPs, thus reducing human exposure and damage to health.

1.2. Effects of Roadside Vegetation on Airborne PM: Modeling and Measurements. Roadside vegetation has the potential to decrease airborne PM concentrations, through PM deposition on leaves, but also to increase PM concentrations by impeding airflow and reducing the dispersion of PM. As noted by recent reports[28] and reviews,[29] many modeling-based studies (using computational fluid dynamics, CFD, to simulate PM emission, dispersion, and deposition) have indicated rather small reductions, i.e., a few percent, in PM_{10} or $PM_{2.5}$ concentrations by deposition onto roadside vegetation.[30−33] If robust, such model-derived outcomes indicate that roadside planting schemes are unlikely to produce any large reductions (> 20%) in PM_{10} or $PM_{2.5}$ concentrations. Indeed, AQEG[28] warns against "campaigning zeal" in "popular publications" in communicating the likely improvements in air quality achievable with roadside vegetation.

In a recent review[34] of some measurement-based (roadside and wind tunnel) studies, the reported removal efficiencies of PM concentrations by roadside vegetation vary enormously, from enhancement of $PM_{2.5}$ (by up to 95%) to reductions (in, variably, PM, total suspended particulates, UFPs, PM_1, $PM_{2.5}$, PM_{10}) of ~2 to 90%.

A fundamental factor appears to be the key to both the parsimony of the model estimates and diversity of the measured PM removal rates. That factor is the (mis)treatment of particle deposition velocity (V_d) to leaf surfaces. Notwithstanding that particle deposition rates depend on a range of factors, including particle diameter, PM concentration, and wind speed, the critical influence of *species-specific* leaf surface properties on controlling particle deposition rates, capture, and agglomeration appears to have been under-recognized in measurement-based studies and substantially under-parametrized (i.e., typically by 5 to 50 times) in the majority of CFD models.[12,35]

Leaf number, size, surface structures and the thickness, structure, and composition of epicuticular wax play critical roles in the determination of V_d and particle retention.[36−40] For example, using magnetic particle loadings as a proxy for PM_{10}, Mitchell et al.[39] reported (magnetic) V_d values varying for different plant species as a function of leaf micro-topography, especially hairiness and rugosity. Lowest V_d values ranged from 0.5 to 0.9 cm s^{-1} for sweet chestnut, elder, elm, and willow; intermediate values ranged from from 1.3 to 1.9 cm s^{-1} for sycamore, horse chestnut, ash, and maple; higher V_d values ranged from 2.4 to 4.6 cm s^{-1} for lime, beech, and silver birch. Deposition velocities of 10 cm s^{-1} have been reported for grassland[41] and Douglas fir for PM_{10},[42] while Freer-Smith et al.[43] have reported V_d values exceeding 30 cm s^{-1} for maple, pine, and cypress for $PM_{1.0}$.

In contrast, and critically, many modeling-based studies choose to use "standard" deposition velocity values as low as 0.64 cm s^{-1} or 0.1 cm s^{-1} for $PM_{2.5}$[30,44,45] or 0.2 cm s^{-1} for PM_{10}.[33] Such values seem both low and indiscriminate, despite available data showing the species-specific nature of this key term. It is therefore unsurprising (and indeed self-fulfilling) that such modeling studies typically identify dominance of the aerodynamic (reduced ventilation) over the depositional effects of roadside vegetation.

On the basis of the *measured* deposition velocities, the installation (close to the emitting vehicle sources) of selected species, with optimal V_d values and controlled heights and permeabilities, can substantially reduce concentrations of traffic-derived PM (Figure S1), whether at the roadside[46] or in adjacent indoor environments.

For example, for a V_d of 4.6 cm s^{-1} (e.g., silver birch) and a leaf surface area of 125 m^2/tree (canopy diameter 8m), 8 trees/100 m street length would remove 50% of the traffic-derived PM_{10} (Figure S1). Such removal rates tally with published studies. In a street canyon setting, the leaf capture of PM by young, roadside silver birch trees was associated with major reductions (60−80%) in adjacent indoor concentrations of $PM_{1.0}$, $PM_{2.5}$, and PM_{10}.[12]

The orientation of roads in relation to predominant wind directions must also, of course, be taken into account, to ensure effective design of any newly installed vegetation whether at the roadside or within the roadway (e.g., as central lines, or lane separators).

The selection of species is vital but also important is the management of the trees since tall trees (>rooftop height) and high canopy density[47] can increase airborne PM mass concentrations, especially in street canyons, by obstructing airflow and reducing PM dispersion, effectively trapping the pollutants.[33] Additionally, some plant species can act as sources of biogenic volatile organic compounds (VOCs) to the urban atmosphere. For example, oxidation of isoprene, monotrepenes, and sesquiterpenes can enhance secondary formation of $PM_{2.5}$ and of ground level ozone.[48−50] Albeit less hazardous than UFPs, the pollen of some species can trigger allergic rhinitis (hay fever).

For humid areas like Lancaster, the PM capture capability of birch leaves is renewed through PM wash-off by abundant rainfall.[39,51] In drier areas, watering schemes might enable optimized PM removal by vegetation. The potential for contamination of the roadside soil[52] might require management, depending on the number of years of planned exposure time.

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Depending on climate (especially humidity, rainfall), some species are likely to offer the permanent take-up of PM via particle entry through the leaf stomata, especially in the case of waxy, evergreen leaves. Hence, a combination of tested, efficient deciduous and evergreen species might optimize PM removal through the entire year.

In terms of management, the selected roadside vegetation barrier, comprising selected, high-deposition-velocity, PM-tolerant mixed evergreen and deciduous species, should be kept well below roof height[35] and pruned to prevent development of a dense canopy crown in order to facilitate atmospheric dispersion of PM. Selected species of trees, managed as hedges ("tredges"), may thus provide the best option for the immediate improvement of air quality, especially in PM "hotspots", wherever the greatest number of people and the most vulnerable people (e.g., young children) receive the greatest PM exposure.

1.3. Vegetation Impacts on UFPs. Despite their abundance in the urban atmosphere and their potential toxicity, UFP removal by plants has so far received relatively little attention. Field measurements to quantify the influence of urban plants on UFPs and particle number concentrations (PNCs) are few. In Raleigh, Carolina, Baldauf et al.[53] found PNC reductions of 15−50% at distances up to 10s of meters behind a (discontinuous) noise barrier; combined noise and vegetation barriers consistently reduced the PNCs more efficiently than noise barriers alone.

For a major road in Guildford, U.K., Al-Dabbous and Kumar[54] reported a ∼37% reduction in PNCs by a coniferous vegetation barrier, during intervals with cross-road wind directions. Lin et al.[55] reported 38 to 64% reduction in UFP (14 to 102 nm) concentrations behind a deciduous roadside vegetation barrier when in leaf but no reduction in winter without foliage.

Fewer studies have examined the effects of different types of vegetation on the reduction of UFP numbers. Using pine and juniper branches in a wind tunnel, Lin and Khlystov[56] found UFP removal efficiency to be directly proportional to the vegetation packing density and inversely proportional to particle size and wind speed. Freer-Smith et al.[43] found that V_d values were dependent on plant species, particle size, and ambient PM concentrations. For some coniferous species, they reported V_d values for UFPs as high as 25 to 36 cm s^{-1} at a busy road and 12 to 30 cm s^{-1} at a parkland site. Hwang et al.[57] studied five different vegetation types in a deposition chamber. They reported higher V_d values for UFPs for needle leaf trees compared with those for broadleaf trees; the leaf surface roughness also influenced the deposition efficiency.

In summary, a limited number of studies has examined the removal efficiency of traffic-produced UFPs by different plant species. Given the limited space in urban areas, it is important to select the most effective plant species for UFP removal in terms of urban greening. Here, we examine, in a wind tunnel, the size-resolved removal of UFPs by nine plant species: silver birch (*Betula pendula*), yew (*Taxus baccata*), nettle (*Urtica dioica*), beech (*Fagus sylvatica*), cherry (*Prunus avium*), elder (*Sambucus nigra*), maple (*Acer campestre*), hawthorn (*Crataegus monogyna*), and ash (*Fraxinus excelsior*). Our new data indicate that selected plant species can remove, by surface deposition, substantial amounts (>50%) of ultrafine exhaust-derived PM and of the heavy metals contained within the high particle number concentrations of this PM fraction. Fast, nondestructive magnetic measurements provide effective indicators of leaf particle deposition. Scanning electron microscopy can identify the major leaf microsites associated with the greatest particle accumulation. Hence, roadside planting of carefully selected and managed plant species can effectively mitigate the exposure of road users and adjacent residents (especially vulnerable groups like school children) to UFP pollution near major roads. Careful testing and selection of the most efficient species can readily improve air quality.

2. EXPERIMENTAL METHODS

2.1. Plant Species. UFP removal efficiency was measured in a rectangular wind tunnel (200 cm long, 75 cm wide, 75 cm high, Figure S2). Nine plant species with different leaf surface characteristics and particle deposition velocities were selected based on our previous study,[39] including silver birch, yew, nettle, beech, cherry, elder, maple, hawthorn, and ash. These species are widespread in temperate regions, have different leaf retention behavior (i.e., deciduous vs evergreen species), and different leaf morphologies (i.e., broad leaves vs needles) and microtopographies, which are expected to have an influence on UFP deposition and accumulation (Table S1, Supporting Information).

To obtain "clean" leaves, plant species were collected after rainfall from the Lancaster University campus (maple, ash, hawthorn, beech, cherry, elder) and Williamson Park, Lancaster (yew, silver birch, nettle), as far as possible from roads. The branches (∼60 cm in length) of each species, freshly cut on the day of the measurements, were supported vertically and uniformly as a vegetation block (i.e., with very similar leaf area index, LAI, values, Table S1) to ensure that most of the air stream passes through them (Figure S2, Supporting Information). Particles were emitted from the exhaust of an idling diesel engine (2.1 L, with catalytic converter; BS EN590 standard diesel fuel) and injected via smooth plastic tubing into the wind tunnel. A fan positioned at the center of the front sidewall was used to produce a steady airflow of 1.0 m s^{-1} (typical for the Lancaster area in the summer)[58] and mix the exhaust stream with the airflow.

2.2. Particle Number Concentrations and Size Distributions. A GRIMM model 5.400 scanning mobility particle sizer (SMPS), comprising a long differential mobility analyzer (DMA, model 5.5-900), was used to measure particles in 44 size categories, between 9.8 and 874.8 nm, to obtain the size distribution and count of PNCs over consecutive 7 min intervals. Particle sampling was carried out via plastic tubing (∼60 cm), connected first to a sampling port located upwind (∼20 cm) and then downwind (∼20 cm) of the vegetation, to sample continuous PNCs and particle size distributions. PNCs and size distribution measurements were first made in the absence of any vegetation for four separate 7 min intervals. Measurements were then made first upwind and then downwind of the different vegetation species over successive sampling durations, 5 × 7 min for each plant species. For each of the plant species, the collection efficiency was measured at a wind speed of 1.0 m s^{-1}, typical in the summer in the study area (Lancaster, U.K.).

At the end of the experiment, ∼5% of the total leaves from each vegetation block was weighed (Oertling KC22 micro-balance) and scanned, and the leaf area was measured through the counting of image pixels. Total foliage area was determined by the mass proportion of the scanned leaf weight to the total weight and leaf area; the total leaf area was divided by the crown area to determine the LAI to ensure comparability

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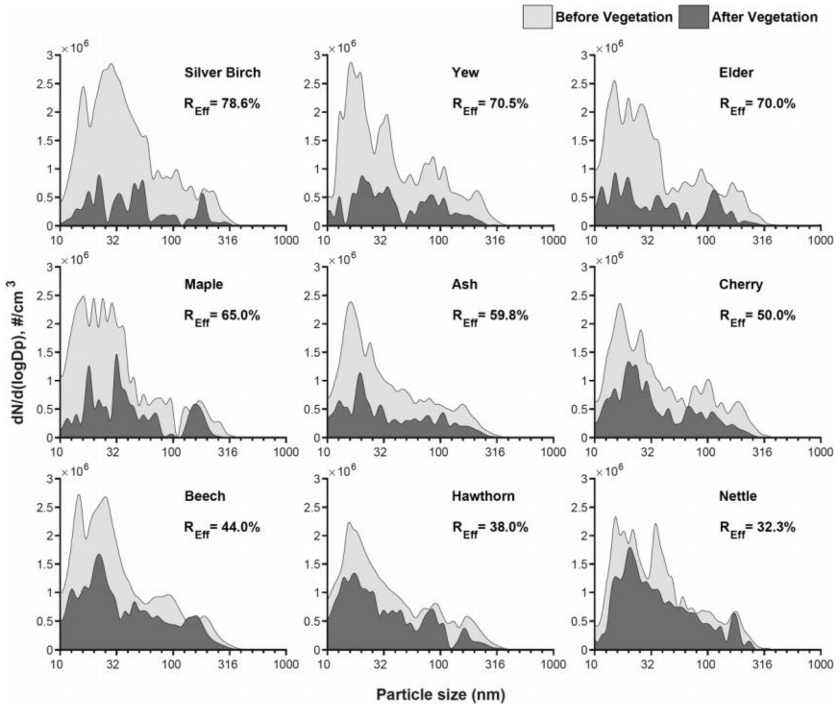

Figure 1. Mean particle number distribution pre- and postexposure (35 min) of each vegetation species to the diesel exhaust ("Before Vegetation" = upwind of vegetation block; "After Vegetation" = downwind of vegetation block). R_{Eff} (%) indicates the removal efficiency of UFPs by each species.

between the species removal efficiencies (the LAI values varied very little from 7.2 to 8.8, Table S1).

Leaf samples of each species were collected before exposure to the diesel exhaust (here, labeled as 0 min) and then after successive exposure intervals (i.e., after 2, 5, 10, 20, 30, and 35 min), using gloves to avoid contamination. The leaves were stored (upper surface to upper surface) in ziplock bags at 4 °C, prior to scanning (5–6 leaves per individual species sample) and packing into 10 cm^3 plastic pots for magnetic measurements (at the Centre for Environmental Magnetism and Palaeomagnetism, Lancaster University).

2.3. Magnetic Measurements. Measurements were made of anhysteretic remanent magnetization (ARM) and the saturation remanence (SIRM) of the leaves pre- and postexposure (see Supporting Information). ARM is sensitive to the presence of ferrimagnetic particles with a mean particle size of ~25 nm.[59] The SIRM indicates the total concentration of magnetic particles on the pre- and postexposure leaves. ARM was induced using a Molspin A. F. demagnetiser, with ARM attachment, generating a dc biasing field (0.08 mT) in the presence of an alternating field (100 milliTesla (mT) peak field). The ARM was measured using a spinner magnetometer (JR-6A, AGICO). The susceptibility of ARM (χ_{ARM}) was calculated by normalizing the ARM by the dc biasing field.

Room temperature remanent magnetization (IRM) was then incrementally acquired (in dc fields of 100 and 300 mT) by using a Molspin pulse magnetizer. Calibration of the magnetometer was performed, on a regular basis, using a cross-calibrated rock sample (56.05×10^{-8} Am^2). All samples were measured in triplicate; the average value of each magnetic parameter was normalized for the leaf surface area (in m^2).

2.4. Metals Analysis. The leaf-deposited PM was also evaluated by an acid wash procedure and an analysis of metal concentrations using inductively coupled plasma-mass spectrometry (ICP-MS). Two leaves from each species, pre- and postexposure, were washed thoroughly using purified 2% HNO_3 into acid-cleaned centrifuge tubes. The resultant, replicate leachates were then analyzed for Mn, Fe, Co, Ni, Cu, Zn, Ti, V, Cr, As, Zr, Mo, Se, Cd, Sn, Sb, Pt, and Pb using a PerkinElmer quadrupole NexION 350D ICP-MS instrument. The metal concentrations reported here represent the average concentrations. The elements Se, Cd, Sn, Sb, Pt, and Pb were measured under nonpressurized conditions (standard mode) whereas the remaining elements were measured in a collision

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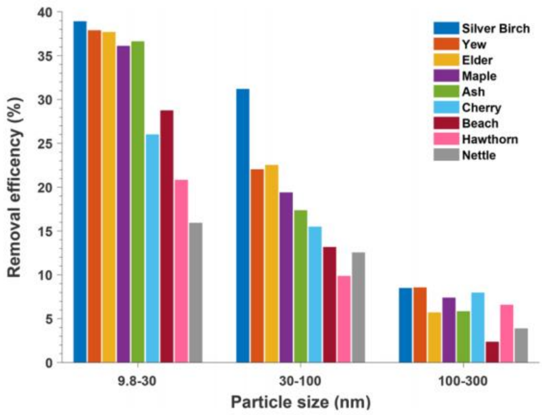

Figure 2. UFP removal efficiency of different plant species for different particle size bins.

cell with kinetic energy discrimination (collision mode) using helium gas. Metal compositions in the stock acid wash solution were well below 25 ng L^{-1}, except for Ti (<65 ng L^{-1}) and Zn (<201 ng L^{-1}), most likely a contribution from tubing used during the ICP-MS analysis.

2.5. Electron Microscopy. To identify UFP capture sites, the leaves of the most effective species (silver birch) were examined by using scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDAX). Three leaf discs (10 mm diameter) of the pre- and postexposure silver birch leaves were cut with a clean ceramic blade and coated with a thin layer (<5 nm) of gold using an ion sputter. Each leaf disc was degassed (for 3 h at 0.7 bar) and mounted on an aluminum stub over double-sided sticky tape, and their microstructure was examined with an SEM (FEI Quanta 650, FEI, Hillsboro, Oregon, U.S.A.) operating at an accelerating voltage of 10 or 20 kV. Elemental mapping was performed with an Oxford energy-dispersive X-ray spectrometer (EDAX). To reduce detection levels below the typical limit (~1000 ppm by weight), spectra were collected after acquisition times of up to 5 min. At least 5 spots from each leaf (before and after exposure) were analyzed by EDAX.

2.6. Statistical Analysis. Removal efficiencies were calculated using the following equation

$$R_{\text{eff}(i)}\ (\%) = \frac{\text{PNC}_{\text{upwind}(i)} - \text{PNC}_{\text{downwind}(i)}}{\text{PNC}_{\text{upwind}(i)}} \times 100 \quad (1)$$

where R_{eff} (%) is the removal efficiency, $\text{PNC}_{\text{upwind}}$ is the particle number concentration upwind in the wind tunnel experiment (#/cm^3), $\text{PNC}_{\text{downwind}}$ is the PNC downwind (#/cm^3), and i represents the different particle size bins (i.e., 9.8–874.8, 9.8–30, 30–100, 100–300, and 300–874.8 nm).

The Kolmogorov–Smirnov and Levene tests were used to verify the assumption of normality and the homogeneity of variances for the magnetic data (ARM, IRM_{100}, IRM_{300}, and SIRM) and metal concentrations. One way analysis of variances (ANOVA) was carried out to investigate the effects of the plant species and time intervals on the magnetic data. The significance of differences among the plant species was checked with Tukey's test ($p = 0.05$). The differences in metal concentrations among plant species were also tested by ANOVA and Tukey's test. Differences in metal concentrations between pre- and postexposure leaves were tested using student's t test for each species. The data were analyzed with SPSS software (ver. 20.0, IBM Corp, Armonk, NY).

3. RESULTS AND DISCUSSION

3.1. UFP Removal Efficiency of Different Plant Species. The measured mean PNC for the diesel exhaust (in the absence of vegetation) was $\sim 25 \times 10^5/cm^3$ (Figure 1). There is no obvious increase in PNC upwind of the tested vegetation species compared with the no-vegetation case (Figure S3, Supporting Information); occasionally, the upwind PNCs are slightly lower, perhaps indicating some upward deflection of UFPs away from the central CPC measurement point.

The average number size distributions of the UFPs, both in the absence of and upwind and downwind from the vegetation, displayed two major peaks at 16 and 26 nm (nucleation mode) and a subsidiary peak of accumulation mode (soot) particles at ~100 nm (Figures 1 and S3). This distribution showed little change upwind and downwind for most of the plant species investigated, indicating the permeability of each tested vegetation block to the air stream. In marked contrast, measurements of $PM_{2.5}$ (by TSI, U.S.A., SidePak AM520) upwind and downwind of a dense conifer species (juniper) identifies "blocking" of air flow and resultant upwind enhancement of PNCs (Figure S4). Some species induced slight increases in downwind mean particle size (see below).

Compared to the no-vegetation measurement, significant PNC reduction was measured downwind of most species tested, with much of the reduction occurring for the smaller particle sizes. Different plant species resulted in different removal efficiencies, reducing PNCs by up to ~79%. Silver birch is the most efficient species in removing UFPs, followed by yew > elder > maple > ash> cherry > beech > hawthorn > nettle (Figure 1).

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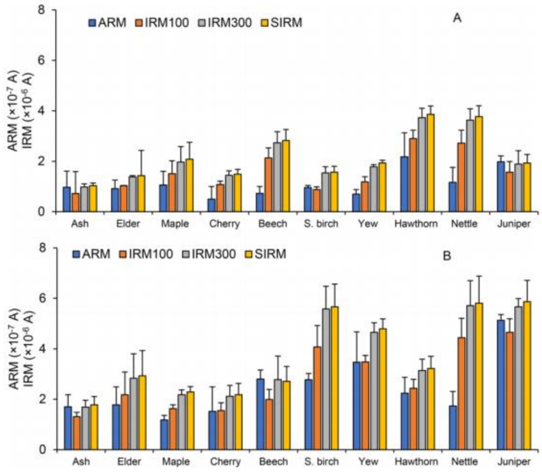

Figure 3. (A) Pre- and (B) postexposure leaves display differences in magnetic particle loadings, as measured by ARM, IRM_{100}, IRM_{300}, and IRM_{1000}.

When the diesel exhaust had passed through the vegetation, the geomean diameter showed small but measurable increases, except in the case of hawthorn, elder, and cherry (Table S2, Supporting Information). Silver birch and yew showed the largest mean increase in particle size, from 20.8 to 27.2 nm and 19.3 to 29.6 nm, respectively, followed by maple (from 18.5 to 23.8 nm).

When the PNC data were divided into four size bins, 9.8−30 nm ($N_{9.8-30}$; nucleation mode), 30−100 nm (N_{30-100}; Aitken mode), 100−300 nm ($N_{100-300}$; accumulation mode), and 300−874.8 nm ($N_{9.8-30}$; coarse mode), the plants displayed differences in their removal of different particle size ranges (Figure 2). For the nucleation mode (9.8−30 nm), silver birch removed the greatest particle numbers, followed by yew > elder > maple > cherry > ash > hawthorn > nettle. The nine different plant species followed this same order of removal efficiency for the PNCs in the accumulation and coarse modes.

3.2. Leaf Magnetic Values, Magnetic Mineralogy, and Grain Sizes. The pre- and postexposure leaves display differences in ARM, IRM_{100}, IRM_{300}, and SIRM (Figure 3A,B). The nettle and hawthorn displayed the highest pre-exposure magnetic content. For all but the hawthorn, the magnetic particle loadings on the leaves increased after their exposure to the diesel exhaust (Figure 3 and Figure S5, Supporting Information). The ARM, IRM_{100}, IRM_{300}, and SIRM of pre-exposure leaves ranged from ~5.0 to 22 × 10^{-8}, 0.7 to 3 × 10^{-6}, 1 to 4 × 10^{-6}, and 1 to 4 × 10^{-6}A, respectively. The ARM, IRM_{100}, IRM_{300}, and SIRM values of the exposed leaves ranged from ~13 to 35 × 10^{-8} , 1 to 4.5 × 10^{-6}, 2 to 6 × 10^{-6}, and 2 to 6 × 10^{-6}A, respectively.

For each species, the leaf magnetic particle loadings, as measured by ARM, IRM_{100}, IRM_{300}, and SIRM, vary through the successive periods of exhaust exposure. The silver birch leaves showed both the highest rate and most continuous accumulation of magnetic particles through the whole exposure period, followed by yew and elder and then maple and nettle (Figure S5, Supporting Information). Hawthorn showed little magnetic difference between pre-experiment and postexposure leaves (Figure S5). Elder, maple, ash, cherry, beech, and nettle all appear to reach a dynamic equilibrium (i.e., particle deposition balanced by particle resuspension) in magnetic particle loadings within the timespan of the experimental exposure.

All leaves acquired most magnetic remanence at low applied fields: ~ 70% by 100 mT and 95% by 300 mT (Table S3, Supporting Information). This indicates the presence of magnetically "soft" material (i.e., easily magnetized and demagnetized), such as magnetite (Fe_3O_4). Between 8% and 30% of the SIRM was acquired at higher applied fields (100 to 300 mT), indicating the presence of some maghemite and/or some nanoparticulate hematite.[60] The acquisition of some additional remanence (mostly ~1 to 2%, max 8%) at highest dc fields (>300 mT) shows that magnetically "hard" hematite also contributes to the leaf magnetic mineralogy. Given that hematite is much more weakly magnetic than magnetite, up to ~40 times more hematite than magnetite may have deposited on the leaves during exposure to the diesel exhaust stream.

The different plant species also showed different leaf χ_{ARM}/SIRM values after exposure to the exhaust. Silver birch leaves had the highest χ_{ARM}/SIRM values, ranging from 62 to 138 × $10^{-5}A^{-1}$, with successive increases with exposure time. Because ARM is particularly sensitive to the presence of ultrafine magnetite particles, around 25 nm in size,[59] χ_{ARM}/IRM_{300} values can be used as a rough estimate of magnetite grain size.

The magnetic particles present on the pre-exposure silver birch leaves were in the size range of ≤30 nm (Figure S6, Supporting Information). After a 20 min exposure to the diesel exhaust, the magnetic grain size of the particles deposited on the silver birch leaves decreased to ~ 20 nm in size. When the exposure time increased from 20 to 35 min, the magnetic

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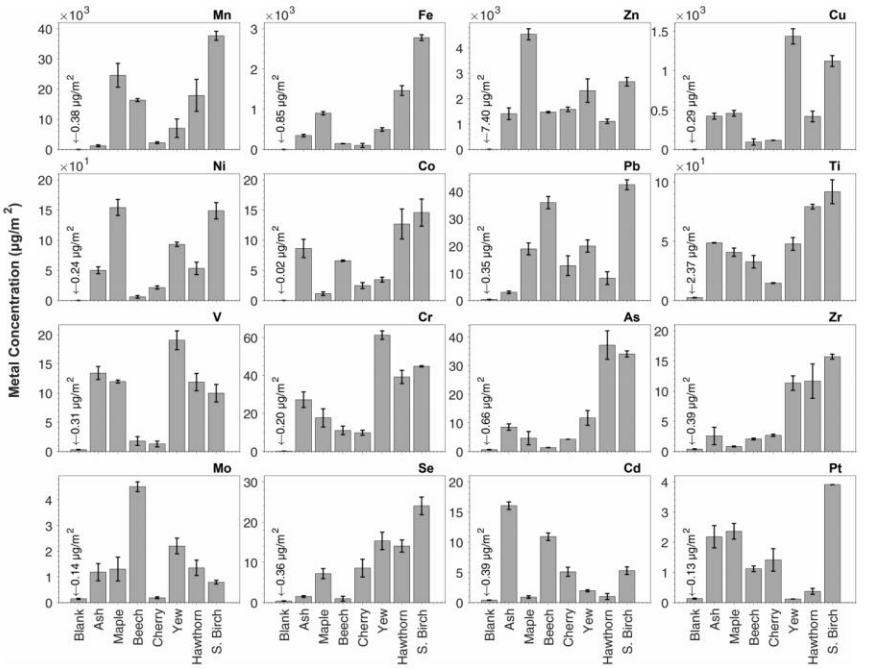

Figure 4. Metal concentrations of leaf leachates postexposure (i.e., metal $concentrations_{postexposure}$ − metal $concentrations_{pre\text{-}exposure}$). ICP-MS data expressed as μg metal per m^2 of leaf surface area.

particle size increased to ~70 nm. In contrast, the size of the magnetic particles on nettle leaves was in the range of ~200−600 nm (Figure S6, Supporting Information).

3.3. Metal Concentrations of Leaf-Deposited PM. The concentrations of Mn, Fe, Cu, and Zn on the postexposure leaves were much higher than those of the other metals analyzed (Figure 4). The metal contributions, postexposure, are as follows: Mn > Zn > Fe > Cu > Ni > Ti > Cr > Pb > As > Se > Cd > V > Co > Zr > Mo > Pt. The very high Mn concentrations probably arise from the use of the diesel fuel additive, methylcyclopentadienyl manganese tricarbonyl (MMT) and/or from engine, especially cylinder, wear. The latter source, together with lubricating oil, is also likely to contribute the observed concentrations of Zn, Fe, Cu, and Cr.[13] The postexposure metal concentrations from the leaf-deposited PM differed significantly between plant species (Figure 4 and Table S4, Supporting Information). The highest metal concentrations were found in the leaf leachates from the silver birch, followed by yew and maple.

3.4. SEM-EDAX. Scanning electron micrographs (Figures 5 and 6) show the typical rough, hairy morphology of the adaxial leaf surfaces of the most efficient species, silver birch, which is hypostomatic, i.e., stomata occur only on the underside of the leaves. SEM-EDAX analysis of the silver birch leaf surfaces shows a very low content of transition metal-bearing PM on the pre-exposure leaves (Figure 5). In contrast, postexposure, the silver birch surface displays an abundance of particles within the $PM_{2.5}$ range (Figure 6), displaying a range of particle sizes and morphologies, including aggregated rounded chains of particles (Figure 5C and Figure S7) and discrete geometric particles (Figure 6G). The postexposure accumulation of UFPs within the microindentations of the rough leaf surface and along and around the leaf hairs is noteworthy. These locations appear to be "hot spots" for capturing UFPs and may also act as gateways for UFP access to the leaf interior structure.

Prior to exposure, the major PM elemental contributions comprise C, O, Mg, K, and Ca (Figure 5B). In contrast, the postexposure birch leaves display higher concentrations of UFPs containing a much broader elemental range: specifically, the presence of Ni, Fe, Ti, V, Ce, Al, Pd, Cu, and Co (Figure 6H).

4. DISCUSSION

These wind-tunnel experiments show that some plant species (silver birch, yew, elder, maple, and ash) display UFP removal efficiencies as high as ~60 to 80%, demonstrating that selected plant species can act as effective UFP "sinks" in the urban environment. Similar magnitudes of PM removal have been reported in real-world contexts for silver birch (for PM_1, Maher

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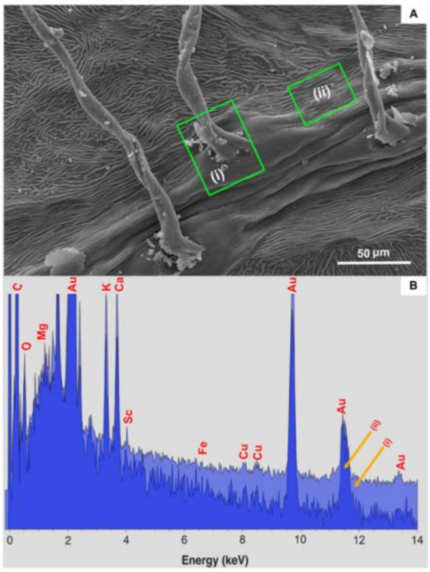

Figure 5. (A) Scanning electron micrograph of the adaxial surface of the pre-exposure silver birch leaf and (B) EDAX spectra for the leaf-deposited PM in subareas (i) and (ii) of image A (note that the sample was gold-coated).

et al.[12]) and mixed woodland in Birmingham, U.K. (for PM estimated at 0.7 μm, Fowler et al.[52]).

Silver birch displayed both peak UFP removal values (~80%) and peak removal of particles <30 nm. It continued to accumulate the finest magnetic particles (<~20 nm) for 20 min of exposure and then accumulated slightly larger and/or agglomerated PM (~70 nm) through to the end of the experiment. It is thus the most efficient of our sampled species in removing diesel exhaust UFPs, followed by yew and elder. Some of the sampled species (e.g., ash, cherry) display magnetic evidence of both particle deposition and resuspension through the time sequence of exposure.

Although nettle and hawthorn appear to be the least efficient plant species, their pre-exposure magnetic particle loading was higher than the other sampled species. This suggests they may have been "preloaded" with airborne PM and were effectively at or close to a dynamic equilibrium between the rates of particle deposition and particle loss by resuspension. In the real world, leaves can continue to accumulate particles (rather than attain equilibrium with ambient PM concentrations) through rainfall wash-off[39] and entry of PM into the leaf structure via stomata and/or wax cuticle overgrowth.[61]

Leaf surface characteristics and size appear critical regarding PM deposition. Particles are more readily deposited on smaller leaves, with shorter petioles, surface roughness, especially in the form of leaf trichomes, and/or mucilage.[12,36,38,39,62−64] Phoretic effects in response to gradients in turbulence[65] and chemical and/or electric potential[66] may enhance UFP deposition along leaf hairs.

Here, we also found that when the diesel exhaust passed through some of the sampled species, the geomean diameter increased downwind of the vegetation showing that these plants (silver birch, yew, maple) removed more of the smallest UFPs, possibly of greatest potential hazard to human health.

For our most efficient species, silver birch, many of the UFPs deposited on the postexposure leaves were rich in transition metals, including Mn, Ni, Fe, Al, Cr, V, Ti, and Cu, together with the antiknock and catalytic converter metals, Ce and Pd. Most of the magnetic remanence-capable particles deposited on the postexposure silver birch leaves were <30 nm. Nanoparticles of this size can penetrate the body very efficiently,[2] even bypassing the blood−brain barrier via the olfactory bulb.[4,5] Similarly, Maher et al.[5,12] found that many particles deposited on the leaves of silver birches that were installed at a busy roadside (Lancaster, U.K.) were <200 nm, exhibited spherical or semispherical morphologies, and Fe-rich. Such Fe-rich particles, abundant and typical of condensation droplets released from high-temperature combustion and frictional (brakewear) processes, are likely to contribute to much of the measured magnetic remanence of the plant leaves. Particles rich in transition metals might cause oxidative stress by direct generation of reactive oxygen species not only in lung and cardiovascular cells but also in the brain.[5] Oxidative brain damage is a characteristic of most types of neurodegenerative disease, including Alzheimer's and Parkinson's diseases.

All of the data reported here are consistent with the efficient interception and capture of vehicle-derived UFPs by plant leaves, rather than airflow impedance or perturbation, or physical screening effects and "fumigation" of the upwind zone. (In marked contrast, similar experiments on juniper indicate "blocking" of airflow and resultant enhancement of upwind PNCs, Figure S4.)

Given the health impacts of exposure to traffic-derived PM, it is essential to understand and optimize the mitigation potential of roadside vegetation in order to guide policy appropriately. In the U.K. for instance, even a reduction of only 1 $\mu g/m^3$ in the annual average concentration of $PM_{2.5}$ would result in a saving of ~3.6 million life years, equivalent to an increase in life expectancy of 20 days in people born in 2008.[67] It is thus timely to improve and update the available data and information regarding PM removal rates by leaf deposition to optimize selection and design of new roadside planting.

An under-estimation by most CFD modeling studies of the potential for substantial PM removal by designed vegetation has negative impacts on policy and potential mitigation. The adoption of realistic, species-specific particle deposition velocities (i.e., up to ~50 times higher than the values of 0.1, 0.2, and 0.64 cm s^{-1} commonly employed for $PM_{2.5}$) and an appropriate microscale approach at road user-relevant heights[35] are both essential.

In summary, these data indicate that selected plant species can remove, by surface deposition, substantial amounts (>50%) of ultrafine exhaust-derived PM and the heavy metals contained within the high particle number concentrations of this PM fraction. Fast, nondestructive magnetic measurements provide effective indicators of leaf particle deposition. Scanning electron microscopy can identify the major microsites associated with the greatest particle accumulation. Hence, the roadside planting of carefully selected and managed plant species can effectively mitigate the exposure of road users and

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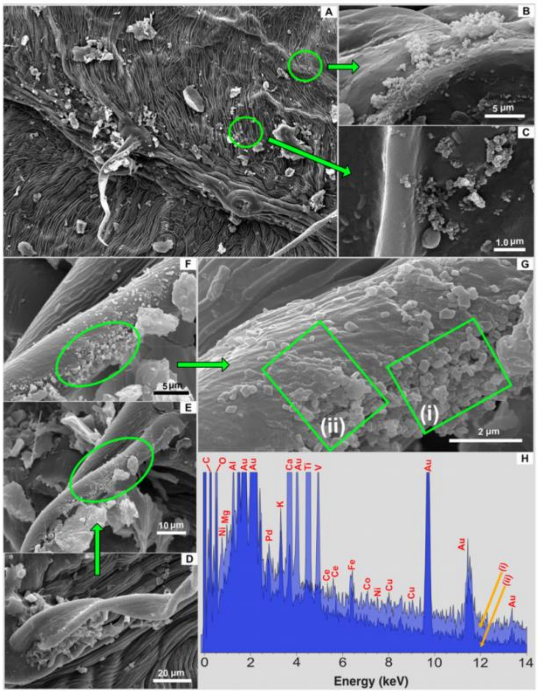

Figure 6. (A−G) Scanning electron micrographs of the postexposure silver birch leaves and (H) EDAX spectra of the deposited particles shown in areas (i) and (ii) in micrograph G.

adjacent residents (especially vulnerable groups like school children) to UFP pollution near major roads. Careful testing and selection of the most efficient species can readily improve air quality.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.est.8b06629.

> Ratio of vegetation deposition flux to traffic emission flux, schematic diagram showing the configuration of the wind tunnel experiments, particle number concentration and size distribution experiments, magnetic particle loadings experiments, summary of the vegetation attributes in the wind tunnel studies, magnetic time series of leaf samples, leaf leachate metal enrichment ratios, plant species, determination of leaf area index, magnetic measurements, metals analysis, (PDF)

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Notes

The authors declare no competing financial interest.

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NB an aditional academic research report was also studied, 'Impact of Roadside Tree Lines on Indoor Concentrations of TrafficDerived Particulate Matter' by Barbara A. Maher, Imad A. M. Ahmed, Brian Davison, Vassil Karloukovski, and Robert Clarke.

Miscellaneous

Dark Skies

Various articles and papers relating to health and light pollution:

Exposure to Artificial Light at Night Can Harm Your Health

https://www.darksky.org/light-pollution/human-health/

Too Much Light? Cancer, Among the Adverse Effects Caused By Light Pollution
https://www.medicaldaily.com/too-much-light-cancer-among-adverse-effects-caused-light-pollution-284354

Can Light Pollution Really Cause Breast Cancer?
https://earthtalk.org/light-pollution-breast-cancer/

Outdoor Light at Night and Breast Cancer Incidence
https://ehp.niehs.nih.gov/doi/10.1289/ehp935

What rising light pollution means for our health

https://www.bbc.com/future/article/20160617-what-rising-light-pollution-means-for-our-health

Various articles and papers relating to light pollution and its effects on wildlife:

Light Pollution:The Effects of Light Pollution on Wildlife

https://biofriendlyplanet.com/environment-issues/pollution/light-pollution-the-effects-of-artificial-light-on-wildlife/

Garden Lighting: The Effects on Wildlife

https://www.rhs.org.uk/advice/profile?pid=513

NB *This is not an exhaustive list of publications but a selection of some of the reading materials studied*

Trees
Tree Preservation Orders for South Norfolk County Council spreadsheet July 2017 is held and has been reviewed.

This features:
TPO reference SN403

For 'land at Harleston Road, Rushall' and described as

‘The Norfolk (South Norfolk District Council) Dickleburgh and Rushall Tree Preservation Order 2008 No.1’
Involving 3 x Oak Trees

Additional TPO submissions have been submitted throughout 2019/2020

Wildlife Surveys
Also held in the archive is a survey of wildlife recorded in and from Pensby Lodge IP21 4PS

Footpaths
Note that local ecology groups are working to support South Norfolk Claylands Conservation Volunteers to develop a walking trail that takes a circular route around Dickleburgh Moor, Langmere Green & St Clements Common in Dickleburgh & Rushall with Brockdish Common. This will include at least a partial audit of the footpaths.

Biodiversity Net Gain
Various publication have been studied and considered, for example, the Department for Environment Food & Rural Affairs, *Net Gain Consultation Proposals* from December 2018 and Section 40 of the *Natural Environment and Rural Communities Act 2006,*https://www.biodiversityinplanning.org/news/bd-net-gain/, http://publications.naturalengland.org.uk/publication/6020204538888192 , https://consult.defra.gov.uk/land-use/net-gain/ etc.

Miscelleneous Additional Research

Following a meeting with *Norfolk Wildlife Trust* on 21 August 2019 additional research was conducted at their suggestion on;

- ‘Nature Recovery Networks,’ now embedded in the Government’s 25 year Environment Plan and covered by various papers including the updated paper from November 2020, https://www.gov.uk/government/publications/nature-recovery-network/nature-recovery-network

- Natural Wildlife Solutions via *The WildlifeTrusts,* incorporating wild places and species protection, well-being etc., and arange of solution to climate change, https://www.wildlifetrusts.org/what-we-do/natural-solutions-climate-change

- *Campaign for the Protection of Rural England* resources, including Dark Skies, Hedgerows & Transport

- *Natural England* guidelines for Natural Green Space Standards, http://publications.naturalengland.org.uk/publication/35033 including Natural England’s Green Infrastructure Guidance document (ref NE176) and the document Green Infrastructure Strategies (ref NE139) and others.

Research: Insect Decline

Dickleburgh and Rushall NP Biodiversity – insect decline

The world is today experiencing the Anthropocene or Holocene epoch. Unlike all others this epoch is defined by human impact on the planet.[1] It is human activity which, uniquely amongst animals has contributed to the consumption of fossil fuels and the build-up of greenhouse gases, that in turn are significant contributors to global warming and rising sea levels.[2] It is estimated that 80 percent of all the different kinds of animals on this planet are insects. They maintain the world as we know it.[3] Therefore one can make the assumption that, if the insect world is affected during this epoch then human activity is likely to be the trigger of that effect. There is now incontrovertible evidence that direct human activity is having a direct impact on the quantity and variety of insects around us, both friend and foe.

Habitat loss and degradation of land almost inevitably causes the reduction of resources for insects over their life cycle, thus amplifying the opportunities to diminish the populations, be that loss of breeding sites, foraging sites, shelter from predators and weather. Studies have shown that insect populations have reduced by 50% over the last 50 years.[4] Between 1969 and 2016 moth populations have fluctuated up and down, there is however, an overall downward trajectory with the Moth population declining precipitously, by 31% overall.[5]

Insects are vital components in the production of food and maintaining human health. There is now clear evidence that insect numbers and varieties are declining. Currently there are estimated to be around 1 million insects per Acre of land.[6] Climate change is a factor in the reduced number of insects, contributing to the loss of habitat along with the reduced variety of plants and exposure to chemicals.[7] The insect world is without doubt a resilient world, some insects are adept at adapting to changing environments, others less so.

Creating hostile environments between fragmented semi natural habitats again makes it more difficult for insects to move successfully between locations. Urbanisation is clearly a significant factor in the creation of insect-dead land. Although it can be argued that building houses with gardens can stem the damage, evidence suggests gardens tend to be full of generalist species and although they may go some way in sustaining some species

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[1] https://www.digitalatlasofancientlife.org/learn/geological-time/geological-time-scale/#:~:text=Earth's%20history%20is%20characterized%20by,Archean%2C%20Proterozoic%2C%20and%20Phanerozoic.

[2] https://www.sciencedirect.com/topics/earth-and-planetary-sciences/holocene-epoch

[3] https://www.nationalgeographic.com/magazine/2020/05/where-have-all-the-insects-gone-feature/

[4] https://www.theguardian.com/environment/2020/apr/23/insect-numbers-down-25-since-1990-global-study-finds

[5] https://www.pnas.org/content/118/2/e2018499117

[6] http://www.bbc.co.uk/pressoffice/pressreleases/stories/2005/10_october/20/life_facts.shtml

[7] UK Parliament Post. Post note number 619 March 2020

of insect it requires management, more purposeful and systematic planning and planting to maintain diversity and animal routeways from on area to another.[8]

There are things that can be done to mitigate against the worst effects and may go some way to supporting and maintaining a healthy environment of insects which in turn maintains a healthy environment for us, including, the enabling of human wellbeing.

The Committee on Climate Change 2018, looking at the ways we could reduce our emissions by 2050, identified areas and activities that could be addressed that would reduce carbon emissions from Britain and support a more sustainable environment. Depending upon the strategies and practices adopted the committee-visioned a reduction of Carbon emissions from between 30 – 80% of $MtCO_2e$. From the perspective of the Parish of Dickleburgh and Rushall these include:

Restoring peatlands. Nationally this could contribute to a saving of 4 – 11 $MtCO_2e$.
Increase Woodland and Hedgerow planting. Nationally this could contribute to a saving of 8 -18 $MtCO_2e$[9]

There are relatively simple things that can be done by developers within the parish to protect the biodiversity and maintain healthy insect populations. These include:

- Planting wildflower meadows. Since the 1930's 97% of wildflower meadows have disappeared.[10] When considering planting a meadow, generally the higher the plant diversity in meadows the greater the chance of a higher diversity of animals. A variety of herbivores will be on hand to consume all the different plant species and they in turn will supply food for any number of carnivores from spiders to beetles and birds.[11] On average, five acres of grassland contain about one ton of insects. The number of predatory invertebrates such as beetles may exceed 2000 per cm^2 of ground. 1 acre of hay meadow may contain 2.25 million spiders.[12]

- Joining existing woodlands together by planting trees, shrubs to create woodland corridors this could include integrating roses. This not only improves habitats for wildlife, it will also help connect people with nature.[13]

- Expanding an existing woodland serves the existing wildlife better, rather than creating a standalone area of woodland.

[8] UK Parliament Post. Post note number 619 March 2020
[9] The Committee on Climate Change. Land Use: Reducing Emissions and preparing for Climate Change 2018. theccc.gsi.gov.uk
[10] Professor Dave Goulson: Reversing the Decline in Insects. The Wildlife trusts.
[11] http://www.countrysideinfo.co.uk/meadows/animals.htm

[12] http://www.countrysideinfo.co.uk/meadows/animals.htm
[13] https://forestrycommission.blog.gov.uk/2020/08/26/wonderful-woodlands-and-why-you-should-create-them/

- Where a road is created include a hedgerow and ideally include a ditch. Include taller shrubs like Woods' rose (rosa woodsii) and elderberry alternated with smaller plants, these environments will draw insects into the local environment and therefore encourage, pollination, fertilisation and food for birds and bats.

- Creation of brownfield sites or open spaces of land, ponds, verges, gardens allotments and green roofs can all support the insect population.

- Reduction in artificial light.[14] This will include light escaping from properties and flooding dark areas with light, as well as street lighting.

[14] https://www.theguardian.com/environment/2020/apr/23/insect-numbers-down-25-since-1990-global-study-finds