Sheffield Local Biodiversity Action Partnership

in conjunction with the Green Roof Centre

The Green Roof Centre

Habitat Action Plan

Green Roofs

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Introduction

The aim of this Habitat Action Plan (HAP) is to increase the biodiversity value of all new green roofs in Sheffield through specific targets, actions and guidance, with an emphasis on optimising conditions on green roofs for local priority habitats and species. The HAP forms part of the Sheffield Local Biodiversity Action Plan (LBAP) and can help target future green roof research. It supports and provides detail for existing policies, guidance and other documents that are listed within this HAP. The HAP also includes a practical **Scoring System** to be used as a guide for developers, planners, architects and BREEAM (BRE Group Environmental Assessment Method) ecologists when considering the potential biodiversity value of green roofs – ideally in the design stage.

Although each section contains a main recommendation to achieve biodiverse green roofs in Sheffield, this document does not provide detailed guidance on how to design individual green roofs for biodiversity. In most cases a specialist ecologist will provide the detailed bespoke design needed to meet the objectives (including biodiversity objectives) and will refer to this HAP and other guidance, including the forthcoming Green Roof Code, which will include a Biodiversity section. However the HAP and Scoring System can be used to inform and guide site-specific designs.

Habitat description

A **'green roof'** (or **'living roof'**) is a roof with the majority of its surface covered by vegetation and/or growing medium. Green roofs may be publicly accessible, but access on the vegetated areas is likely to be limited to avoid damage, and typically the green roof will be installed to meet wider environmental objectives.

A **'roof garden'** will typically have a greater proportion of its surface unvegetated, growing medium is likely to be deeper (usually >150mm), often in containers or raised beds, and typically the main purpose of the roof will be for regular public access. The roof may also be designed more for aesthetic reasons and may require a higher level of maintenance. The biodiversity that this type of roof could support will depend on the design and variability of the roof and species used. Roof gardens are likely to contain non-native species of plants, including border plants, shrubs and even trees.
This document is aimed to support the design of green roofs rather than roof gardens fitting the description above, but it should be noted that all types of green roof/roof garden have the potential to provide biodiversity value and elements of this document could well be incorporated into roof gardens or hybrid green roofs/roof gardens.

Green roofs provide more opportunities for wildlife than traditional roofs, but many green roofs are constructed without considering the full potential for biodiversity. However, some green roofs are designed specifically with biodiversity in mind and are sometimes called 'biodiverse roofs' 'wildlife roofs' or 'meadow roofs'. For simplicity, we will use the term green roof for all levels of biodiversity throughout this document.

Green roof vegetation types

☼ **Main recommendation to achieve biodiverse green roofs in Sheffield: substrate-based green roofs offer more potential than pre-grown mats**

The type of vegetation supported by a green roof depends largely on the depth of the growing medium or substrate (which is again determined by the amount of weight or loading that the building can support). The lightest types of green roof may have little or no substrate present.

Non-substrate green roofs typically consist of pre-grown mats of sedum placed over a drainage board, or very thin layer of substrate. This type of roof offers the least value to biodiversity, but may be one of the only feasible options where the roof will support minimal additional loading. Sedum mat roofs are very common as they provide a lightweight instant year-round coverage, and other environmental benefits[1], but will be limited in meeting the biodiversity objectives for green roofs in Sheffield.

Substrate-based green roofs consist of layers of growing medium supporting plant growth. The types of plants and vegetation supported on green roofs varies greatly. The most common green roofs are composed of different sedum species[2], but green roofs can support a wide range of grasses and herbs from dry habitats, mosses, lichens, heathland and alpine species, species typical of sandy, stony and shingle surfaces, and many other habitats. It is possible to have wetland areas and open water. Bare ground and unvegetated areas may be equally important for some invertebrate or bird species (see next section). The conditions on the green roof, and therefore the types of vegetation that can be supported, can be manipulated by altering both the depth of the substrate, but also the substrate materials (for example by using materials with differing Ph) – see 'Maximising biodiversity opportunities' section.

Characteristic species - what biodiversity can Sheffield green roofs support?

Green roofs are highly artificial in their construction – not only are they created on buildings, but they differ from many habitats on the ground in that their substrates (soils) are generally very thin, and they sit on a solid impervious surface, with no connection to underlying soils or bedrock. Temperature variations may be more extreme, and vegetation and soils are more prone to desiccation and wind damage. Such stressful conditions can be very useful in promoting species-rich and diverse vegetation types. Green roofs can also develop into unique dry habitats, which may throw up new combinations of species.

In designing green roofs for biodiversity, it is important to differentiate between two different and complementary approaches:

1) Recreating priority vegetation types and habitats that may be threatened in the local region, and where rooftops could provide a valuable resource in providing new space for such threatened habitats. Importance has to be placed not only in encouraging appropriate plant communities, but also in ensuring that soil or substrate qualities are appropriate to support such vegetation.

2) Supporting target species or groups of species (for example threatened bird or animal species, or particular species of moss or flowering plant). In this instance it may not be so important to recreate a complete semi-natural habitat or plant community, but instead to create a set of conditions that will encourage populations of the target species to establish.

1) Habitats

☼ **Main recommendation to achieve biodiverse green roofs in Sheffield: if targeting habitats, concentrate on the local priority habitats (below)**

Priority habitats in the Sheffield LBAP that could potentially be created on Sheffield green roofs are:

- **Lowland dry acid grassland** (in Unimproved Grassland HAP)
- **Lowland dry neutral grassland** (in Unimproved Grassland HAP)
- **Lowland heathland**
- **Open mosaic habitats on previously developed land** (also known as brownfield land, urban common or urban wasteland)

These are also all **UKBAP** and **Regional Priority Habitats**.
It may be desirable for a roof to have a mixture of habitat types depending on the size, location and aims of the roof. However, for a small roof, larger areas of fewer habitat types are better for wildlife than tiny areas of many habitats.

Wet grassland types are more difficult to create on green roofs, although variation in landform may provide damp or wet areas. Planned wet areas can work on green roofs, for example the green roof on Unicorn Grocery store in Manchester supports a pond[3] (primarily for black redstarts). Wetland habitats on roofs are assuming increasing importance if viable breeding populations of birds or invertebrates are being encouraged – some form of water source may be vital.

Calcareous grasslands are not naturally found in the Sheffield district, because of the underlying geology, but pockets can be found on areas of deposited limestone. Calcareous habitats are found in the wider South Yorkshire sub-region and neighbouring Derbyshire so would not be totally inappropriate for the Sheffield area. Calcareous grasslands are relatively straightforward to create on a green roof, can be extremely species-rich, and contain many plant species that are ideally suited to green roof conditions. Moreover, many of the flowering plants in calcareous grasslands are important insect food plants. It may therefore be desirable to consider calcareous grasslands on roofs in the Sheffield region, particularly to encourage wider faunal diversity.

Turf or predominantly grassed-roofs have been a fairly common choice in the past, although they have been less frequently used in recent years[4, 5] and the value to biodiversity will depend on the origin and diversity of the species used. Over time, turf roofs can develop into highly diverse grassland communities. Substrate depth will again have an influence. Some management may be needed to maintain a diverse sward[4].

2a) Target species or groups of species: Higher plants

☼ **Main recommendation: for higher plants consider the habitat you are targeting and include species listed below, but specialist input may well be required**

Dunnett has summarised the native and naturalised UK (higher) **plant species suitable for use on green roofs**[6]. Specialist advice should be sought when considering which habitats/species to target, but **UKBAP Priority Species** that have

been recorded in the Sheffield area that are also on Dunnett's list as being suitable for green roofs are:
Tall Thrift (*Armeria maritima subsp. elgongata)* – habitat cliffs and rocks
Basil Thyme (*Clinopodium acinos*) – habitat calcareous grassland
Pasqueflower (*Pulsatilla vulgaris*) - habitat calcareous grassland

Other species from Dunnett's audit that are also found in the Sheffield **Unimproved Grassland HAP** include: Heath Bedstraw (*Galium saxatile*) and Tormentil (*Potentilla erecta*), and some other grassland habitat species mentioned in this HAP and/or found in Sheffield area also likely to be suitable for green roofs.

Unlike natural meadows, green roof meadows on relatively thin substrate depths will not follow succession into scrub and then woodland; the limitations of the system will result in a natural self-sustaining grassland community[1]. Research has shown that naturalistic dry grassland roofs are the most productive for bees and associated species as they provide rich foraging habitat through the year. Although sedums also provide a good source of nectar for bees, the flowering period can be more limited[1].

Some of The Green Roof Centre **Case Study Roofs have been surveyed** for their biodiversity and The Centre can be contacted for further information about individual sites[7].

Heathland species can be targeted for Sheffield green roofs, in line with the Lowland Heathland HAP. Heathland species may be particularly suitable as they can tolerate nutrient poor (sandy, acidic) soils. Thin soils will result in relatively stressed plants that will only grow to dwarf height (with heather species such as *Calluna vulgaris* and *Erica cinerea* dominating). Hawkweed species (*Hieracium sp.)* that feature on Dunnett's list have been found on Sheffield heathland sites. The green roof habitats could be a mosaic of heathland and acid grassland, which can also support bryophyes and lichens. The species richness of such habitats will vary but in this case the type of species present (e.g. LBAP priorities) would be important and not just the number.

There is also great potential for plants found on **Open Mosaic Habitat on Previously Developed Land** (OMHPDL, also known as brownfield sites) – for example, a study by Sorby Natural History Society found 372 plant species across 50 such sites in South Yorkshire[8]. At ground level, OMHPDL sites consist of open semi-natural habitats on nutrient-poor, post-industrial derelict land. The South Yorkshire study found that the best sites (mostly for invertebrate diversity) were undisturbed and consisted of sand, crushed limestone/concrete/brick or pulverised fuel ash or steel slag[8]. The suitability of these materials for green roofs will vary (see 'Local and natural materials' section).

Because of their highly urban and disturbed nature, OMHPDL habitats have no clear equivalent in rural semi-natural plant communities or habitat types. They are characterised by being composed of both native plants but also many plant species that have escaped from parks and gardens and become naturalised in these urban spaces. For roofs, seed mixtures can be used but many mobile and wind-dispersed plant species will blow in and establish naturally if the conditions are designed to be suitable on the roof. Typical and widespread naturalised non-native species include Michaelmas Daisies (*Aster novi-belgii*) and Canadian Golden Rod (*Solidago canadensis*). Species such as this, flowering in late summer and autumn, can provide valuable food sources for late-flying insects. For example, a botanical survey of

Sharrow School Green Roof revealed a typical urban brownfield mixture of *Asteraceae* species including Yarrow, Ox-eye daisy, Mugwort, Common ragwort, thistle, Michalemas Daisy, Oxford Ragwort, Coltsfoot and hawkbit species, together with Mullein (*Verbascum thapsus*), Red Valerian, Purple Toadflax and Teasel.

To encourage a biodiverse fauna on this type of green roof, the structural diversity of the vegetation will be probably the most important factor along with the materials and additional features used (see 'Maximising biodiversity opportunities' section). Such habitats on roofs can support similar suites of invertebrate species to those found on ground level brownfield sites, but research in London showed that invertebrate species diversity was lower on the roofs, meaning they should not viewed as like-for-like mitigation for ground level brownfield sites lost to development. Post-implementation monitoring should be employed to assess the differences.

2b) Target species or groups of species: Lower plants and fungi

☼ **Main recommendation: for lower plants do consider the potential for mosses, liverworts and lichens as well as the more obvious sedums**

Green roofs can be particularly important for lower plants. **Mosses and liverworts (bryophytes)** will often colonise sedum roofs and can even be considered in place of sedum, and there is potential to design nutrient-poor systems to encourage scarce and uncommon species. Limited research has been carried out in the UK to see which moss species may be most suitable, although scarce species have been found on green roofs in London[1]. The bryophyte flora of urban Sheffield is poorly studied but could be very rich, although many are likely to be woodland species[9].

Three UKBAP Priority Bryophyte Species have been recorded in Sheffield[10]:
- *Didymodon tomaculosus* (Sausage Beard-moss). This tiny moss grows as scattered stems amongst other bryophytes on bare, slightly acid to neutral, clayey soils. Most records are from arable fields, but it has also been recorded from trampled ground in pasture so green roofs could potentially be suitable. However natural establishment is likely to be difficult as this species is very rare.
- *Pohlia scotia* (Scottish Pohlia) is unlikely to be found on roofs as it required regular inundation with water and is usually found on the gravel shores of river and lochs.
- *Eurhynchium pulchellum* (Elegant Feather-moss) is also unlikely to be found on green roofs as it is usually found on dry mountain rocks, but has been found on open calcareous soils so it is not out of the question.

More than 600 species of **lichens** have been recorded in the built environment and many of these grow on roofs[4]. Roofs allowed to naturally-colonise will attract lichens and mosses, and small steps can be taken to encourage colonisation[4]. The lichen flora of Sheffield is relatively well known, having been studied by experts for more than 30 years. An audit in 2001[9] highlighted that 156 species were known from the Sheffield district outside the National Park. None of these were in the Red Data Book of British Lichens; and none are UKBAP Priority Species. Two however are Data Deficient. *Micarea excipulata* and *Lecidea polycarpella* were both discovered new to Britain on the site of the now Meadowhall Shopping Centre in 1983/84. They are pioneer species so it is possible they could turn up on green roofs and post-implementation monitoring should include surveys for lower plants. The audit also stresses that the Urban Common habitats (now Open Mosaic Habitats on Previously Developed Land) in

Sheffield were found to be very rich in ruderal lichens during a 10 year study (1975-85), with up to 35 species per site[9]. However, some of the richness was accounted for by heavy metal residues in soils, which would not be found on Sheffield green roofs today.

There appears to be little research available on the **fungi** found on green roofs, although they have been seen on at least one green roof in Sheffield, but species lists have yet to be compiled. The Date-Coloured Waxcap (*Hygrocybe spadicea*) is the only UKBAP species of fungi to have been recorded in Sheffield and not for many years[10]. Fungi can be associated with the habitats on the roof itself, but also additional features such as logs. Fungi associated with the different habitats can be obtained from The Sheffield Biodiversity Partnership.

2c) Target species or groups of species: Invertebrates

☼ **Main recommendation: green roofs offer great potential for invertebrates, with undulating substrates, wildflowers, grasses, OMHPDL habitats and roof wildlife features being particularly important**

Any small wind-dispersed or flying arthropod could theoretically reach a green roof[4], but the habitat on the roof will determine which species are attracted. Scarce or notable invertebrates that might benefit from green roofs include various species associated with open, dry and sunny habitats containing sparsely vegetated and bare ground (mimicking OMHPDL habitats), or species associated with meadows. The height of the roof will be a limiting factor for some species; however, bees have been found at 23 stories high[4], butterflies at 20 storeys[11]. Connectivity to other habitats may also be a limiting factor, however one study in London found that habitat quality was more important than connectivity[12]. Although weather conditions are more harsh on a roof, invertebrates and birds can benefit from reduced human and predator disturbance[11]. Research on invertebrates on green roofs in the UK has built on European research and confirmed the role of green roof in invertebrate conservation. Researchers in London, have recorded 136 species on eight green roofs in one study[13], high spider diversity, and relatively high proportions of scarce or rare species (10% of all species recorded in one study were classified as 'nationally scarce')[12]. One of the conclusions from these studies is that native wild flowers were particularly important attracting hymenopterans, reflecting European research that naturalistic dry grassland roofs are the most productive for bees. Johnson and Newton[11] suggest UK invertebrate species that are likely to be found on green roofs and suggest which groups of invertebrates may benefit from different plant species. The London studies also revealed sedum and biodiverse roofs both supported invertebrate populations; the biodiverse roof was slower to colonise but developed much more diverse communities. The researchers concluded that the substrate used was actually the most important factor[12] (see 'Maximising biodiversity opportunities' section).

For OMHPDL (brownfield) roofs, rare ground-loving invertebrates include: ground-nesting bees and wasps; bumblebees; robberflies; bee-flies; ground beetles; tiger beetles; spiders; butterflies and moths. Some of the UKBAP Priority Species utilising bare-ground are Dingy Skipper (*Erynnis tages*), Grizzled Skipper (*Pyrgus malvae*), Small Blue (*Cupido minimus*), Grayling (*Hipparchia semele*), Silver-Studded Blue (*Plebejus argus*), Chalk Carpet-Moth (*Scotopteryx bipunctaria*). UKBAP butterflies and moth found on OMHPDL sites in acid and northern areas (i.e. like Sheffield) are Dingy Skipper, Green Hairstreak (*Callophrys rubi*) and Grayling. The Other UKBAP Priority

Species of butterfly that has been recorded in Sheffield and could be found on green roofs is the Wall Brown (*Lasiommata megera*). 49 UKBAP Priority moth species have been recorded in Sheffield – too many to list here – and one species is in the Sheffield Biodiversity Audit as needing particular attention – the Forester Moth (*Adscita statices*) which feeds on common sorrel. It would be interesting to undertake some studies of the moths found on Sheffield green roofs.

In Sheffield, a study of bumblebees and green roofs found six common bee species regularly visiting two green roofs, with more species visiting the wildflower roof than the sedum roof[14]. The species found were the Common Carder Bumblebee (*Bombus pascuorum*), the Red-Tailed Bumblebee (*Bombus lapidaries*), the Early Nesting Bumblebee (*Bombus pratorum*), the Buff-Tailed Bumblebee (*Bombus terrestris*), the White-Tailed Bumblebee (*Bombus lucorume*) and the Garden Bumblebee (*Bombus hortorum*).

Two OMHPDL hoverfly species could be attracted to green roofs in Sheffield. *Spaerophoria scripta* likes flowery waste ground in towns and is found in Sheffield and *Spaerophoria ruepelli* is scarce in local rural areas but did occur in 1988 on flower-rich, brick-rubble demolition sites in Hillsborough; it also occurs on vegetated pulverised fuel ash. The tephritid fly (*Urophora quadrifasciata*) is in the Sheffield Audit[9] as needing special attention. It is associated with Knapweed (*Centauria nigra*) and has been found at sites such as Holbrook, which could be mimicked on green roofs.

Only one UKBAP species of beetle has been recorded in Sheffield, the Violet Oil-beetle (*Meloe violaceus*). This is a grass-dwelling species and its larvae can be transported by bees – a possible route onto green roofs?

2d) Target species or groups of species: Birds

☼ **Main recommendation: certain bird species will use green roofs if the habitat and invertebrate life are designed with birds in mind; additional features can be added to attract birds and provide breeding opportunities**

Of the bird species recorded in Sheffield City Centre (between 1989-2008)[10] the following have been found to use green roofs in the UK[4,15]. Those marked with a * are Sheffield LBAP species and those marked ~ are a UKBAP species.

Black redstart (*Phoenicurus ochruros*)
Goldfinch (*Carduelis carduelis*)
House martin (*Delichon urbica*)
*~House sparrow (*Passer domesticus*)
Kestrel (*Falco tinnunculus*)
*Pied wagtail (M*otacilla alba*)
*~Song thrush (*Turdus philomelos*)
*~Starling (*Sturnus volgaris*)
*Swallow (*Hirundo rustica*)

Of the Sheffield LBAP species, all except the Swallow have been found on green roofs. Lapwing (a Sheffield BAP Priority Species) and plover species have been found on very large green roofs in Sussex[15] but these species are unlikely to be found in the most built up areas of Sheffield where green roofs are likely to be developed. This is

because the have complex requirements of short grass/bare ground (for nesting) alongside wet and grassy areas (providing food supplies, especially for chicks).

Green roofs can provide nesting opportunities for the nationally rare black redstart. The black redstart is an urban-dwelling bird that used to be resident in Sheffield; recent sightings have suggested the species may be making a return to the city, and green roofs could be designed to mimic their preferred brownfield habitat, as has been done in other cities[16,3], however it could be insect levels rather than nesting sites prove to be the limiting factor.

In addition, green roofs in Sheffield may provide may provide habitat for peregrine falcon, partly because some attract pigeons. Peregrines have been actively prospecting the city and a nesting platform is to be erected on a church tower and this could be repeated on a suitable green roof.

Studies in Switzerland suggest that green roofs in urban areas are used by birds more than green roofs in suburban and rural areas[1], suggesting it would be worth targeting the green roofs suitable for birds in the most built up areas of Sheffield where there may a shortage of natural habitats for birds. Height and aspect of roofs in this study had no effect on the type of species using the roof or the frequency of use.

The available evidence suggests that there is great potential for green roofs to provide benefits for bird species, particularly the roofs will encourage insect life (bird food) in urban areas. Ground-nesting birds can benefit, as long as suitable feeding habitat for the chicks (who are not fed by adults) is considered in the roof design. Generic systems are more likely to provide habitat for more common species. Dry grassland habitats can provide seeds for seed-eating birds such as finches[1]. More be-spoke roofs can be designed to target specific species such the black redstart [3,16.] Specific features can be incorporated onto roofs to encourage birds to use green roofs, from bird boxes, to bird feeding stations, to pipes to provide protection for the chicks of ground nesting birds. (For more information on how to incorporate such features *into* roofs and buildings, see the forthcoming architects guide 'Biodiversity by Design'[17]).

2e) Target species or groups of species: Bats

☼ **Main recommendation: bats will be attracted by good invertebrate levels but also bat boxes and water features**

Bat populations have declined in the UK, mainly due to loss of roosting and foraging habitat. However, some species have adapted to live in towns and cities, roosting in trees and buildings and feeding on insects over greenspaces and water. A biodiverse green roof can therefore support the invertebrate populations that bats can feed on. The roof can also be made more attractive to bats by incorporating water and roosting opportunities such as bat boxes (see 'Features to benefit wildlife' section).

Bat species likely to benefit from green roofs in Sheffield are:
*Common pipistrelle bat (*Pipistrellus pipistrellus*)
*~Soprano pipistrelle bat (*Pipitrellus pygmeaus*)
*~Noctule bat (*Nyctalus noctula*)
*Leislers (*Nyctalus leisleri*)
(* = Sheffield LBAP species ~ = UKBAP species)

Maximising biodiversity opportunities

Research shows that green roofs designed to benefit biodiversity do support greater biodiversity than those that are not designed with biodiversity in mind. For example when the differences in biodiversity between a sedum extensive green roof and a roof designed for biodiversity were measured in one study, the number of species of invertebrates plateaued on the sedum roof after three years, but continued to increase on the biodiversity roof[18].

As mentioned in the introduction, this local document is designed to be used in conjunction with national guidance documents, including the forthcoming Green Roof Code (being produced for the UK by Groundwork Sheffield and the Green Roof Centre[7]) and the (German) FLL Standards[19]. However the HAP and Scoring System can be used to inform and guide site-specific designs. Research (much of it in Europe) has identified a number of design features that have a big influence on the biodiversity that can be supported by green roofs. These are summarised here.

Substrate

☼ **Main recommendation: deeper substrates offer more potential for biodiversity**

Using thin substrate exacerbates the already challenging conditions for plants and animals on green roofs; therefore there are limitations of green roofs to support drought-intolerant and less mobile species. For example, substrate type and depth had the biggest influence on invertebrate populations in London studies[12] and both substrate depth and structural diversity were important in influencing the number of spiders found in a Swiss study.

By using deeper substrates:

- A greater diversity of plants can be supported (see diagram)
- Plants are less likely to be affected by drought conditions, as deeper substrates may provide greater volume for water storage capacity.
- Ground dwelling animals will be better able to deal with drought conditions, as they will be able to retreat to lower-lying, damper areas (particularly if structural diversity is considered alongside depth).
- Temperature becomes less of a limiting factor for certain invertebrates- if the soil becomes very warm at the surface, these invertebrates are able to burrow into cooler soils.
- Strong winds will have less of an impact on substrates.

Guidance should be sought over the type of substrate to use for different situations, but the London studies suggest that nutrient poor, well-drained growing media should be used as a basic principle for green roofs[12].

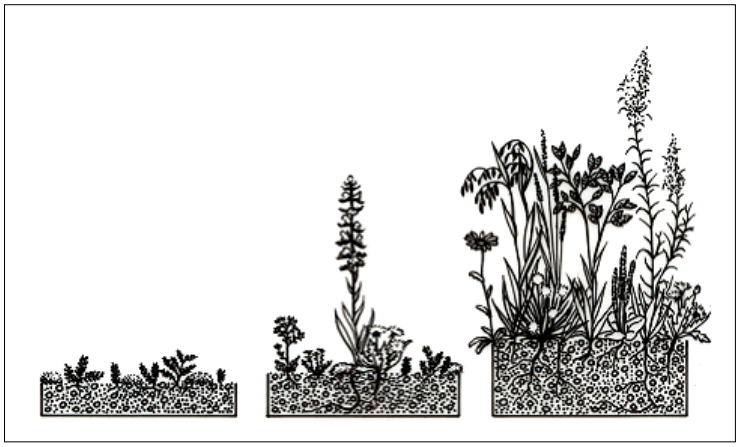

Illustration showing the diversity of plants supported with substrate depths of 6, 12 and 20cm (taken from Brenneisen, 2006[18])

Structural diversity

☼ **Main recommendation: variation in landform is easy and very important**

Adding some variation in landform and microhabitats (including unvegetated areas, hollows, clifflets etc) can highly increase the potential for biodiversity by:

- Creating wet areas in undulations
- Providing deeper growing medium for plants with more substantial rooting systems in higher areas.
- Providing a mosaic of microhabitats on and below the soil surface that can facilitate colonisation by a more diverse flora and fauna[18]
- Allowing the use of a variety of plant structures from low to high density.
- Creating shelter from winds reducing seed loss
- Allowing bare ground which can heat up more quickly – important for warmth-loving invertebrates

Creating structural diversity can help to provide the basics that wildlife need – food, shelter, water and somewhere to breed. For example, a study in Switzerland showed that the ability of the roof to retain water was a key factor in attracting beetles[4]. Additional features can then be added to boost the provision of these basic requirements. It is important to remember that one species can have a number of habitat requirements for whole life-cycle. For example, general requirements for butterflies and moths are: bare ground for basking; warm, sheltered spots with scrambling plants over bare ground for caterpillars; tall and short vegetation; and nectar-rich wildflowers. An advantage of green roofs is that the roof can be designed to provide all these features in close proximity.

Features to benefit wildlife

☼ **Main recommendation: adding simple, cheap features makes a big difference**

Simple features can be added to a green roof to maximise the suitability for wildlife. Log piles and other deadwood, scattered and piled rocks and rubble will compliment a diverse vegetation cover. Boulders and logs create microhabitats for invertebrates and fungi and even small logs can provide shelter and nesting sites for insects such as

wasps[1]. Artificial nesting sites can be provided for burrowing invertebrate, such as bees, as substrates are likely to be too thin shallow for burrowing. 'Bug hotels' can be readily bought or easily made from bamboo, bricks and other materials. If shade is not provided by vegetation, the building, or roof furniture (such as solar panels, chimneys or vents), then it may be important to erect simple structures to provide shade.

Pipes can be provided for ground nesting birds and vertical cracks can be provided for black redstarts. CIRIA (Construction Industry Research and Information Service) and forthcoming architectural guidance from Greenspec[17] provide detail on the various types of bird and bat boxes that can be incorporated into buildings and roofs[1] – these will complement the other features of a green roof. From the Sheffield priority species identified earlier, specialist boxes can be provided for house martins, house sparrows, swallow, pied wagtail, black redstarts and even peregrine falcons and kestrels[1]. A variety of perches can also be provided, to benefit birds with specific hunting strategies. Bat boxes can also be erected on or near green roofs and again different boxes are available to benefit the Sheffield priority species already identified.

If undulations do not already provide wet areas, then containers of any kind can be used to hold water – a key requirement for many species.

Making wildlife-friendly features such as bird boxes, bird tables, bat boxes and bug hotels can be an excellent way of engaging the community or users of the building with the green roof. For example, HSBC provided funding and volunteers to make wildlife features on the green roof at Sharrow School, Sheffield for the pupils and staff.

Local and natural materials

☼ **Main recommendation: screened local materials can be of increased value**

The pros and cons of native and non-native plant species are discussed below. Commercially available green roof substrates have been developed to promote healthy plant growth, and to be lightweight and practical. The objectives for green roofs that support biodiversity maybe somewhat different from those that are intended to maintain complete plant cover.

Research suggests that natural and local substrates are likely to be more suitable for local priority species. A study in Switzerland, for example, contributed the success of colonisation by spiders and beetles to the use of sand and gravel substrates from local riverbanks[18]. In Basel, the green roof policy requires that new development sites must conserve the local topsoil/substrate for subsequent use on the green roofs[18]. Great care and consideration must be taken, however, when re-cycling local aggregates from building or brownfield sites. Many UK aggregates are sufficiently porous to be used on roofs. Broken bricks and tiles can be used, as can lightweight concrete, but even these can have limited porosity. However, demolition waste can also be pose problems of dust, contamination, leaching and reactive mortar. Regulations therefore state that materials cannot be put onto a roof (where they could affect a watercourse) without knowing exactly what is in the material. It is possible to screen the demolition waste and mix it with organic matter (about 20%) but the screening process can be difficult. Using small amounts of screened material to provide specific areas of habitat may be a compromise. The Green Roof Centre are currently carrying out further research by adding different quantities of organic matter, sorting and grading demolition waste or using a higher proportion of aggregate waste.

Native vs non-native species

☼ **Main recommendation: native species will reflect local habitats the best, but non-native species are useful, especially for attracting invertebrates**

Ideally, the habitat created on the roof should reflect the surroundings and provide what is missing from the current habitats. Where the objective of green roof design is to promote or create priority habitats then clearly the species included must be representative of that habitat. In most instances this will require the use of native plant species (and where possible, using material of local origin). However, in urban areas the use of non-native species can be appropriate, for example to attract certain species and/or to provide a longer flowering season. As previously noted, green roofs which reflect the Sheffield OMHPDL priority habitat will contain a range of species such as Oxford ragwort, Canadian goldenrod, honesty, michaelmas-daisies, red valerian, mignonette and black horehound, which will be used for foraging by rare invertebrates[20]. Johnson and Newton's guide provides another list of suitable plant species for green roofs, containing both native and non-native species[11].

Where green roofs are being designed to promote or encourage target faunal species, then other factors may also be important. The key factors that promote faunal diversity tend to be the floral diversity of the vegetation, and the structural diversity of the vegetation, together with the characteristics of the substrate and the nature of the ground surface. Recreating a particular semi-natural plant community may not be of prime importance, although the provision of key food and egg-laying plants will be key to the success of supporting populations of certain invertebrates. But in general, many invertebrates are generalists in terms of food source and nectar supply.

Therefore, creating a roof with a diversity of substrate depths and some topography, with areas of open and unvegetated surfaces, and with a diversity of vegetation types (including good nectar sources and seed producers) will promote wider faunal diversity. The precise nature of the plant component may not be of crucial importance.

In Sheffield, a 'Pictorial Meadow Green Roof seed mix' has been developed by Pictorial Meadows Ltd[21] (a collaboration between local social enterprise Green Estate and Sheffield University). The mix contains a range of native calcareous grassland species, but also includes a number of reliable and attractive green roof plants such as Chives, *Anthemis*, *Dianthus carthusianorum* and Blue Flax, and some native sedums. The mix has been designed to attract birds and beneficial insects including bees and butterflies, as well as creating visually attractive meadow-like vegetation and has been used on a wide range of roofs in the city.

It is worth remembering that although green roofs are a man-made habitat, the degree of design and intervention by humans can vary from using ready-made mats, to planting, to allowing natural colonisation[1]. Whichever method is used to begin with, local plant species (which may be a mixture of native and non-native depending on the location) will find their way onto the roof. Whether they establish will depend on the conditions on the roof and the maintenance regime.

Compromises and design

Green roofs created for biodiversity objectives will also deliver other benefits of green roofs: stormwater management, noise insulation, summer cooling. Stormwater

management can be maintained in biodiverse systems using deeper substrates and other types of plant species such as mosses[1].

Sometimes biodiverse roofs are not preferred for aesthetic reasons[1] – in cases such as these, a compromise may be needed where certain areas are more diverse for biodiversity or small features are incorporated rather than no features at all. Where a complete vegetation cover is required from the outset, pre-grown mats with a diverse flora (e.g. Green Roof Centre mix) are available, or sedum mats could be over-sown with a wildflower seed mix to provide instant cover and longer term diversity. Allowing a bare substrate to colonise naturally will provide a plant community that is in sympathy with its local environment. This is likely to be the cheapest and possibly the most ecologically beneficial way of vegetating a roof but the aesthetic properties of the roof are less immediate and predictable[1]. There may be other reasons why native habitats are not always desired – for example, areas may be set-aside for children to undertake gardening projects.

Typically, roof gardens are constructed on slopes of up to 5° and green roofs on slopes of up to 30-45°. Flatter roofs tend to support a greater plant, and therefore invertebrate, diversity[4]. The weight of different substrate depths and vegetation types can be a limiting factor for some buildings and should be considered early on in the design process. Typical substrate depths and weights for different vegetation types are available[22, 1 (tables 9.4-9.6)] although case-by-case guidance should be sought.

Green roofs in the wider biodiversity context

Green roofs are not the panacea to halting the loss of biodiversity, even the urban environment; they provide opportunities for certain species only and are usually not direct replacements for natural habitats (esp. UKBAP priority habitats). A study in Germany that directly compared green roofs to areas of conservation importance on the ground clearly showed the limitations of the roof for supporting certain species including some with restricted mobility and some unable to colonise the conditions found on the roof (e.g. web spiders are less able to survive on green roofs and earthworms require deep soils)[18]. For those species able to reach the roofs, the climatic conditions can also be limiting, or just different. For example, on a 6th storey green roof in London, plants flower and leaf three weeks earlier than the ground flora[4]. The size of green roofs can also be a limiting factor; they may not replace the size of habitat lost[11,4] and will be more limited than larger areas of natural or semi-natural habitats.

If planning mitigation, it should be considered that lost habitats may not be able to be replaced quickly enough to ensure continued provision of habitat and it may be impossible to re-create or maintain the correct soil, hydrological and micro-climatic conditions on a roof[4]. Although green roofs can act as green stepping stones between other patches of habitat, there are limitations of the habitat not being contiguous with that found at ground level[4,11]. Research has shown that green roofs adjacent to other types of vegetation support more biodiversity due to shade provided by trees and the natural distribution of local seeds.

However, when used in conjunction with urban trees, parks, nature reserves, waterways and other greenspaces within a green infrastructure network, green roofs can help to maximise available habitats and biodiversity, link surrounding green space and help to mitigate against lost habitat.

Status and current action

Green roofs are a man-made habitat, therefore they are a not a UKBAP Priority Habitat. They have been selected as a local priority habitat in Sheffield for the following reasons;

- The Sheffield district covered by this LBAP is very urban, therefore green roofs have a role to play in the biodiversity action across the city;
- Sheffield is one of the UK's centres of excellence for green roofs (it is home to the Green Roof Centre[7]);
- Around 35% of the space in Sheffield City centre currently belongs to roofs and there are thought to be about 120 green roofs in Sheffield at the time of writing– ranging from large developments to DIY green roofs on garden sheds.
- Sheffield and Rotherham host quality case study green roofs: for example Moorgate Crofts Business Park (Rotherham), The Cube (mixed business and residential) and Sharrow Primary School. Further details from The Green Roof Centre[7]
- Sharrow School Green Roof has been designated (September 2009) the first Green Roof Local Nature Reserve in the UK
- There is support for the production of this document to better link the biodiversity and green roof research with the policies and guidance - to lead to an increased biodiversity value of green roofs in Sheffield.

Current factors causing loss or decline

As green roofs are a man-made habitat this does not apply and the aim of this HAP is to maximise the biodiversity opportunities of green roofs.

Legislation, guidance and opportunities

The aim of this Action Plan is to provide a linking document between the existing relevant legislation, policies, guidance and standards (see below) and to provide local targets and actions to increase the biodiversity value of green roofs in Sheffield.

Sheffield Development Framework
The Sheffield (Local) Development Framework is in the process of being produced. Relevant adopted and draft policies can be found on the Sheffield City Council webpages. This HAP can be used to help support and implement the following policies

Core Strategy – adopted March 09
Policy CS73 'The Strategic Green Network' refers to maintaining and enhancing a green network along the river valleys and other strategic corridors (for details refer to the policy and the SDF proposals map).

Green roofs can play a part in such networks where appropriate and the more biodiversity the roof supports, the greater contribution it will make to the network.

City Policies – draft July 09
Draft policy GI 'Safeguarding and Enhancing Biodiversity' includes the statement "New development will be required to (c) provide new areas of habitat…or features to encourage wildlife…as appropriate to the location".

The policy refers to green roofs as being one of the possible 'features to encourage wildlife'.

Supplementary Planning Document (SPD)
The City Council intends to produce a supplementary planning document which will provide more detailed information about green roofs and which will encourage their use for biodiversity improvement.

BREEAM (Building Research Establishment Group Environmental Assessment Method) www.breeam.org
The current 'Guidance for relating ecology reports to BREEAM' within the 'Land Use & Ecology' sections of the assessor manuals includes reference to local biodiversity and biodiversity action plans in the following questions (which are to be completed by the consultant ecologist).

"Does it [the management plan] include the following: management of any protection features on site; management of any new, existing or enhanced habitats; a reference to the current or future site level Biodiversity Action Plan"
and
"Do your responsibilities to the client/developer include providing advice on the creation of a new ecologically valuable habitat, which is appropriate to the local area and is either nationally, regionally, or locally important, or supports nationally, regionally, or locally important biodiversity?"
Credits (points) are awarded for "demonstrating a positive increase in the ecological value of the site" (criterion ID no. LE05). There are two categories of credits – one for up to 5 species, and one for 6 or more species. For other BREEAM credits potentially available for green roofs, contact the Green Roof Centre.

For some developments in Sheffield, particularly in the most urban areas, there may be no open space associated with the development. In these cases, a green roof may be the best or only opportunity to provide biodiverse habitat using appropriate plant species and opportunities for animal species. This Habitat Action Plan will guide ecologists advising on green roofs in Sheffield to which BAP priority habitats and species they should target through their design and management recommendations. This will also help compliance with the SDF requirements.

Wildlife Trusts Biodiversity Benchmark
The 'Biodiversity Benchmark for Green Roofs' is a new standard offered by the Wildlife Trusts. Award of the standard will be based on meeting a set of design and implementation requirements that include: an assessment of the local biodiversity and ability of the roof to meet BAP targets, and a design that will include the creation of appropriate wildlife habitats and enhancements. Full details have not yet been finalised but will be available from Biodiversity Benchmark[23].

Sheffield's Great Outdoors - Sheffield Green and Open Spaces Strategy (GOSS)
Draft July 09
The draft GOSS contains the following policy statement ENV S3 "Adopt standards for the regeneration and new development of green and open spaces so that they are able to contribute to the improvement of the city's environmental quality" and the actions associated with the policy statement are a) Set a sustainable 'quality standard' and use

in projects to guide developers, managers and communities alike to ensure their long-term viability and b) Promote multi-functioning spaces that support environmental management alongside social benefits (through SUDS, Green roofs etc)."

Information in this HAP can be used to increase the quality of green roofs for biodiversity and the 'Biodiversity Benchmark for Green Roofs' could be used as one of the quality standards. Designation of nature conservation sites can also be used as an indication of quality. The GOSS already refers to the declaration of Sharrow School Green Roof as a Local Nature Reserve to be an 'early action'.

Green Roof Code

The Green Roof Centre and Groundwork Sheffield are leading on a project to prepare a UK Code of best practice for the design and installation of green roofs, including a chapter on 'Designing for wildlife on green roofs'. The focus of the section is to aid landscape architects, architects, ecologists and other relevant professionals to know the key specific design criteria for achieving roof-level, sustainable biodiversity. Ecological concepts, theories and practical techniques will all be explored and set out. More details from Groundwork Sheffield[24] or the Green Roof Centre[7].

Other policies, duties and guidance

For Public Bodies increasing the biodiversity value of green roofs in Sheffield contributes to fulfilling their Biodiversity Duty (s40 of the NERC Act). *"Every public body must, in exercising its functions, have regard, so far as is consistent with the proper exercise of those functions, to the purpose of conserving biodiversity".*

Increasing the biodiversity value of Green Roofs is in line with policy statements within National Planning Policy Statement (PPS)1[1], PPS9 and The Yorkshire & Humber Regional Spatial Strategy (ENV8). In particular, green roofs can support policies and strategies that encourage networks of habitats and biodiversity within developments.

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ideas from Landscape Architecture students at The University of Sheffield.

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Objectives, Targets and Actions

	Objective 1 **To increase the biodiversity value of new green roofs in Sheffield**				
Ref	**Target**	**Target Measure**	**Action**	**Action Measure**	**Lead & Partners**
1.1.1	**To produce a Green Roof SPD as part of the Sheffield LDF**	Green Roof SDP included in adopted Sheffield LDF	Produce SPD	SPD accepted by SCC as part of LDF	SCC planning (Environmental, Forward & Area Planning)
1.2.1	**Biodiversity and green roof guidance to be available to all developers and architects from 2010**	Proportion of new green roofs whose designs will benefit local biodiversity	All developers, architects and planners made aware of Green Roof HAP	Number of signpostings	SCC planning (Urban Design & Conservation, Environmental Planning, Developmental Management), Green Roof Centre
1.2.2			Publication of biodiversity section of the UK 'Green Roof Code' by 2013	Code published	Groundwork Sheffield, Green Roof Centre
1.3.1	**For all new green roofs in Sheffield to have specialist ecological input from 2010**	Proportion of new green roofs designed to attract biodiversity	Ecology Service, Landscape Architects and Green Roof Centre to make planners aware of target	Proportion of planners aware of target	Green Roof Centre, SCC Ecology Service and Landscape Architects
1.3.2			SCC planners to signpost developers to Green Roof Centre for advice	Proportion of developers that are aware of HAP and seek further input	SCC Planning (Urban Design & Conservation, Environmental Planning) and Architects
1.4.1	**For 10 green roofs taken up as part of the ecology section of the BREEAM accreditation by 2011**	Number of green roofs considered in BREEAM assessment	Signpost ecologists to Green Roof HAP and specialist advice from the green roof centre	Number of signpostings	Green Roof Centre, SCC Planning (Urban Design & Conservation, Environmental Planning) & Architects
1.5.1	**For 80% of new green roofs to score as 'good' or 'excellent' using the HAP scoring system**	% of green roofs to be scored as 'excellent'	Promote the use of the scoring system and score the roofs accordingly	Number of green roofs taking up the scoring system	Green Roof Centre, SCC Planning (as above)
1.5.2		% of green roofs scored as 'good'	Promote the use of the scoring system and score the roofs accordingly	Number of green roofs taking up the scoring system	Green Roof Centre, SCC Planning (as above)

1.6.1	**For 100% new Sheffield green roofs to support at least one local priority habitat**	% of new green roofs supporting at least 1 priority habitat	Signposting developers etc to HAP and providing specialist ecological input	Number of roofs targeting local priority habitats	Green Roof Centre, SCC Planning (as above)
1.6.2		How many of each habitat type present on green roofs and its area	Record what is actually put in place/established and enter into BARS	Area of habitat created for each habitat type	Sheffield Uni, SCC – Ecology Unit, Green Estate, SWT
1.7.1	**For 100% of new Sheffield green roofs to support at least one local priority species**	% of new green roofs supporting at least 1 priority species	Signposting developers etc to HAP and providing specialist ecological input	Number of green roofs targeting local priority species	Sheffield Uni, SCC – Ecology Unit, Green Estate, SWT
1.7.2		Which priority species are present on the roofs and how many different species	Record what is actually present on the roofs	How many of each priority species are present on the roofs	Sheffield Uni, SCC – Ecology Unit, Green Estate, SWT
1.8.1	**For one pair of black redstarts or peregine falcons to be breeding on a green roof by 2011**	Number of pairs of black redstarts or peregrins	Encouragement of 10 specialist green roofs designed for these species	Number of roofs designed for black redstart or peregrines	Green Roof Centre, RSPB, Sheffield Bird Study Group
1.8.2			Survey for black redstarts on green roofs		Sheffield Bird Study Group
	Objective 2 **To maintain the biodiversity value of green roofs**				
Ref	**Target**	**Target Measure**	**Action**	**Action Measure**	**Lead & Partners**
2.1.1	**Management regime to be in place for all green roofs for a minimum of 5 years after construction**	Proportion of green roofs with management regimes	Management regime for 5 years to be planning condition	Proportion of planning permissions for green roofs containing 5 year management conditions	SCC planning (Developmental Management)
2.1.2			Signpost developers to Green Roof Centre, who can recommend local organisations to carry out management	Number of management contracts awarded to local organisations	SCC planning (Developmental Management, Environmental Planning) and Ecology Service
2.1.3			Green roof management plan examples to be made available for other roofs		Green Roof Centre and Sheffield University
2.1.4			Monitoring of whether management is taking place	Proportion of roofs owners fulfilling their management requirements	SCC planning (Developmental Management) and Ecology Unit

2.2.1	**For 100% of management plans and schedules to have appropriate ecological input**	Proportion of green roofs managed in line with the biodiversity recommendations	Promotion of existing successful management arrangements		The Green Roof Centre, Green Estate
2.2.2			Training of more people to be able to carry out green roof management	Number of trained people	Green Roof Centre, Green Estate
2.2.3			Training of green roof managers in the relevant ecology	Number of people attended ecology training sessions	SWT, Green Roof Centre
	Objective 3 **To monitor the biodiversity of new roofs in Sheffield**				
Ref	**Target**	**Target Measure**	**Action**	**Action Measure**	**Lead & Partners**
3.1.1	**That at least 2 examples each of 'adequate', 'good' and 'excellent' green roofs in Sheffield are in a monitoring programme by 2012**	Proportion of green roofs in monitoring programme	Continue existing monitoring/research programmes	Proportion of existing green roofs in monitoring programme	University of Sheffield – Landscape dept/ The Green Roof Centre/
3.1.2			Develop further monitoring programmes on new roofs	Proportion of new roofs in monitoring programme	University of Sheffield – Landscape dept/ The Green Roof Centre
3.1.3			Volunteers signposted to the Green Roof Centre if surveys cannot be covered by students	Number of volunteers engaged in rooftop monitoring	Sheffield Wildlife Trust/Green Estate/ Groundwork
3.1.4			All ecological records from surveys to be submitted to the Local Records Centre	Proportion of surveys results that have been submitted to the LRC	Sheffield Wildlife Trust/Green Estate/ Groundwork/ University of Sheffield
3.2.1	**All green roofs to be mapped and classified for their importance to biodiversity by 2012**	Proportion of roofs which have had ecological surveys and mapping	For the partners to agree how map and classify the sites e.g. use scoring system		University of Sheffield/Green Roof Centre/ SWT/SCC/ Groundwork
3.3.1	**2 research papers to be published on biodiversity of green roofs in Sheffield by 2011**	Number of papers published			University of Sheffield

	Objective 4 **To recognise green roofs of high quality and publicise good practice**				
Ref	**Target**	**Target Measure**	**Action**	**Action Measure**	**Lead & Partners**
4.1.1	**To designate one green roof as an LNR by 2010 – the first green roof LNR in the UK**	*New LNR designation*	Natural England to recommend Sharrow School be designated as an LNR and SCC to designate	Report from Natural England to SCC and Designation taken place	SCC – Parks & Countryside, Natural England, Sharrow School
4.1.2			To celebrate LNR designation through launch event	Number of attendees at event	SCC – Parks & Countryside, NE, SWT, GE, Sharrow School
4.1.3			To publicise LNR designation through press release	Number of press articles	NE, SCC – Parks & Countryside
4.2.1	**For 10 green roofs to have been awarded the Green Roof Biodiversity Benchmark by 2015**	*Number of green roofs with award*	Biodiversity Benchmark to complete and publish guideline	Biodiversity Benchmark guidelines published	Wildlife Trusts
4.2.2			Partners to raise the awareness of the BB when in place and encourage developers to apply	Proportion of green roofs applying for BB status	Green Roof Centre, SCC – Planning and Ecology Service, Sheffield Wildlife Trust, Green Estate
4.2.3			Local partners to work with BB to train local assessors	Number of local assessors	Green Roof Centre, Sheffield Wildlife Trust, Green Estate
4.3.1	**For Sheffield to be the lead for biodiverse green roofs**		For all partners to work together to deliver these objectives		Sheffield Green Roof Forum
4.3.2			Issue press releases about successes	Number of press releases	The Green Roof Centre
4.3.3			Talk at conferences and events	Number of events attended	The Green Roof Centre/ Sheffield University
4.3.4			Lead of demonstration tours	Number of tours lead	The Green Roof Centre
4.3.5			Promote the Sheffield Green Roof HAP	Number of other Green Roof HAPs	All partners