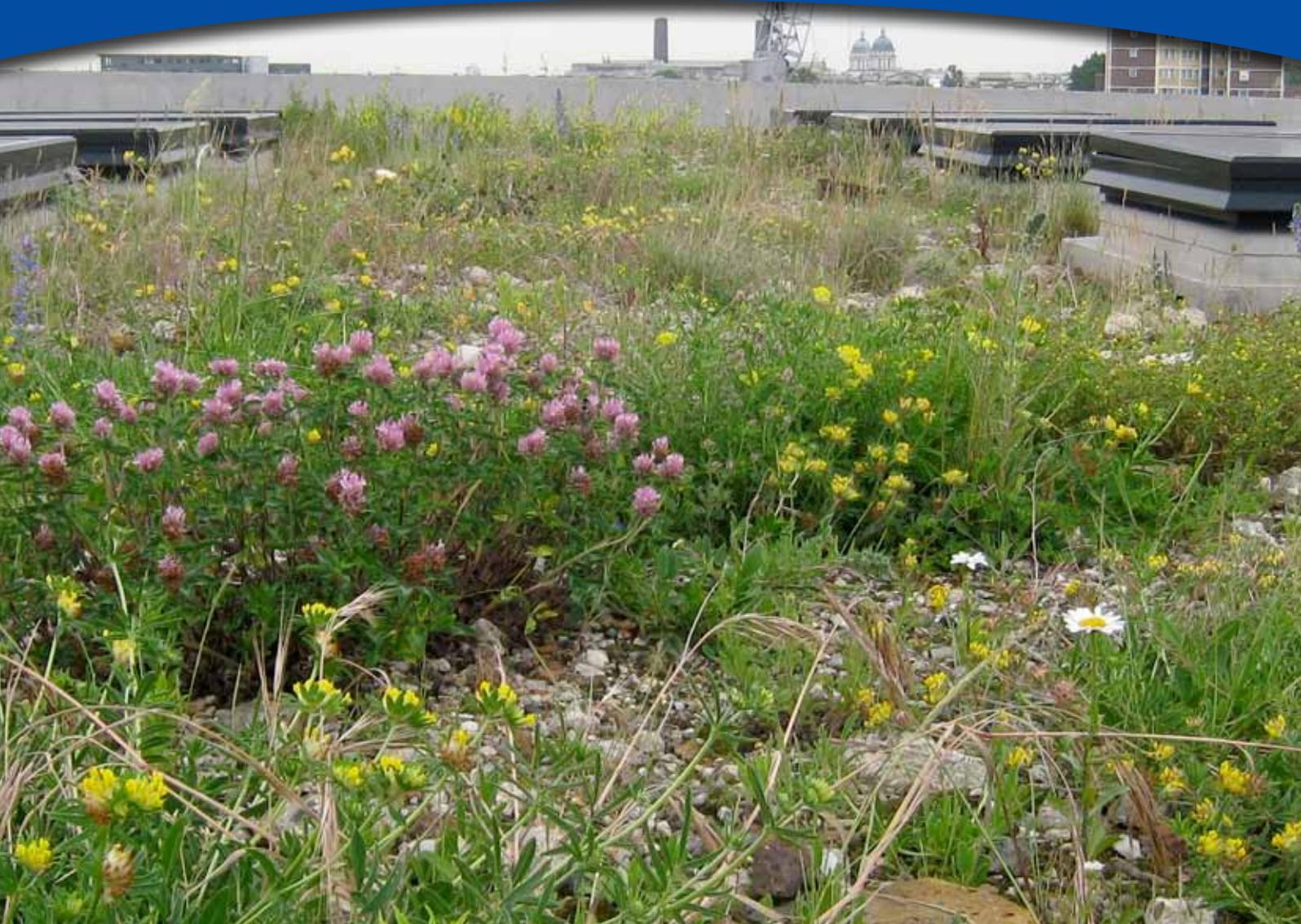




CREATING GREEN ROOFS FOR INVERTEBRATES

A BEST PRACTICE GUIDE



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FOREWORD

Space is a precious commodity in Britain, and this is especially so in towns and cities where every square metre is used and valued by local communities. What if we could make more use of that space to create additional value and greater functionality without displacing any other uses of that space? Well, we can. Putting a biodiverse green roof on top of a building turns a dull, grey, flat elevated landscape into a vibrant, buzzing, flower-rich wildlife habitat.

Most flat roofed buildings are sturdy enough to carry a skin of nature and biodiverse green roofs can be easily designed into new buildings. Techniques for building such roofs are now well established and routine. A well constructed roof improves building performance, protecting the waterproofing from frost, high temperatures, UV radiation and mechanical damage that cause leaks; and reduces both heating and air conditioning costs.

This guide contains the knowledge developed during a decade of practical experience of

establishing and monitoring biodiverse green roofs. Any business or organisation that wants to reduce its carbon footprint, energy costs and maintenance bills, while also bringing wildlife back into towns and cities should consider installing biodiverse green roofs. Local authorities can encourage green roofs through their planning policies, as in parts of mainland Europe where they have been required features of new developments for some time. Such policies will enrich people's lives now and create a healthier environment for future generations.

A building without a biodiverse green roof is wasting space.



Matt Shardlow
Director
Buglife – The Invertebrate Conservation Trust

SECTION 1

CREATING BIODIVERSE GREEN ROOFS FOR INVERTEBRATES



Above: A biodiverse roof in Islington, London

INTRODUCTION

Green roofs offer a wide range of sustainability benefits, from water attenuation to climate change adaptation. Standard 'off the shelf' products, which tend to be sedum based green roofs, can provide some benefit for invertebrates and other wildlife. However, key research in the UK and Switzerland

has shown that, by designing a green roof specifically with invertebrates in mind, it is possible to increase the overall ecological value of a roof. Furthermore it can also provide benefits associated with green infrastructure, improved building performance and amenity.



Above: Wildflower-rich biodiverse roof, London

CREATING BIODIVERSE GREEN ROOFS FOR INVERTEBRATES

BACKGROUND

Over the last ten years in the UK there has been an increasing interest in the use of green roofs to support conservation targets such as Local, Regional and National Biodiversity Action Plan (BAP) targets, and mitigate for habitat loss due to development. Much of this interest has been stimulated by work in London, especially in relation to Black redstart (*Phoenicurus ochruros*) conservation¹, but also with respect to the possibility of addressing the loss of populations of rare invertebrates associated with wildlife-rich brownfield sites. Other major cities in the UK such as Birmingham, Manchester, Sheffield and Edinburgh have also begun to consider the use of green roofs for similar purposes.

Although there are examples of green roofs that date from much earlier times, the modern phenomenon of green roofs as we have come to know them today began in Germany in the 1970s. The German Landscape Research, Development and Construction Society (FLL)² began to publish standards for green roofs in the 1980s and the green roof industry on the European continent now has more than three decades of experience.

The most recent version of the FLL 'Guideline for the Planning, Execution and Upkeep of Green Roof Sites' is a very useful resource on which to establish a minimum recommendation for green roof specification, installation and maintenance. In a similar vein in the UK, the Green Roof Organisation (GRO) produced the Green Roof Code of Best Practice 2011³, which also includes information on designing roofs for biodiversity.

A major study of green roofs and invertebrate biodiversity carried out in London between 2002 and 2006, along with partner research in Switzerland, forms the basis of this guidance and furthermore the basis of all the policy guidelines on green roofs and biodiversity in the UK. [See Section 2 'Review of Key Research' for further details.](#)



Above: Jakob Burkhardt roof in Basel, Switzerland



Above: Biodiverse roof at Eversheds, central London

In order to maximise the potential value of a roof for invertebrates, and to create a range of conditions to suit particular species, an informed approach must be taken when deciding on which plants and substrates to use. It is therefore imperative to engage suitably qualified specialists when designing biodiverse roofs.

SCOPE

This guidance is aimed at anyone who is considering installing or planning to install a biodiverse green roof. It specifically outlines how green roofs can support invertebrates, particularly those associated with wildlife-rich brownfield sites.

It is also hoped that the guidance will influence developers, planners, architects, engineers and landscape architects at the design stage to consider the creation of biodiverse roofs as opposed to low diversity sedum based systems.

A series of basic principles are provided that need to be considered when designing a biodiverse roof. It must be stressed that it is not an exhaustive list of treatments. Thorough consideration should be given to relevant policy, conservation targets, and environmental and ecological factors that relate to the area where the roof is to be installed.

CREATING BIODIVERSE GREEN ROOFS FOR INVERTEBRATES

BENEFITS OF GREEN ROOFS

Green roofs of any description were not originally conceived for the purposes of conservation. Green roofs have been used in Scandinavia for centuries to secure the waterproof layer, improve thermal performance and provide forage for livestock. Modern uses of green roofs can provide a wide range of environmental benefits including:

Biodiversity

- Providing habitat at roof level, especially within urban areas, can have significant benefits for wildlife, notably invertebrates and birds;
- Appropriately designed biodiverse roofs can support Local, Regional and National BAP objectives, and contribute to mitigation plans.

Sustainable drainage

- Retention of water in the substrate reduces and slows run off;
- Improving water quality through filtration.

Improved building performance

- Increasing the life span of the roof by protecting it from frost, high temperatures, UV and mechanical damage;
- Reducing energy consumption by reducing the need for heating and cooling;
- Sound attenuation.

Climate change

- Vegetation on a roof removes carbon from the atmosphere as part of photosynthesis and releases oxygen;
- Evapo-transpiration can reduce the urban heat island effect (caused by the absorption and re-radiation of heat from dense and dark building materials).

Amenity

- Roofs can provide areas for recreation and relaxation;
- Roofs can be aesthetically pleasing.



Above: *Sedum plug planted extensive green roof* © Landmark Living Roofs



Above: *Sedum mat extensive green roof*
© Landmark Living Roofs

Types of Green Roof Terminology

This guidance focuses on biodiverse roofs, which are based on an extensive green roof system.

Extensive

Extensive green roofs are comprised of shallow, low nutrient substrates which require little or no maintenance and irrigation. The resulting environmental conditions are particularly suited to the growth of low growing hardy species of Sedum, wind and drought tolerant wildflowers, mosses and grasses.

They are generally split into three types:

- Sedum blanket/mat systems that can vary in depth from 40 – 80mm;
- Sedum plug planted roofs generally at a depth of 80mm;
- Biodiverse green roofs are based on shallow, low nutrient substrates (an average depth of 130mm) and have low maintenance requirements. By varying substrate depth, the roof can support a greater diversity of plants and therefore biodiversity. Mosses, succulents, herbaceous plants and grasses can be supported on a biodiverse roof.

CREATING BIODIVERSE GREEN ROOFS FOR INVERTEBRATES



Above: Brownfield land at an active industrial site, Teesside

OPEN MOSAIC HABITATS, BROWNFIELDS AND BIODIVERSE ROOFS

In 2007 the UK Biodiversity Action Plan (UKBAP) listed 'Open Mosaic Habitats on Previously Developed Land' ⁴ as a priority habitat for conservation action. This habitat is commonly found on abandoned industrial sites, old mineral workings such as quarries, gravel pits, brick pits, and railways. 'Open Mosaic Habitats' describe a patchwork of habitats which are extremely varied due to the wide range of ground conditions (substrate, topography, water availability, aspect), vegetation height and varying levels of neglect.



Above: Brownfield land on the outskirts of Scunthorpe

Biodiverse roofs can replicate habitats similar to those found on wildlife-rich, low nutrient, free draining sites such as brownfields.

Key features of brownfield sites

- **Nutrient poor soil conditions** support pioneer plant communities for extended periods of time. ⁵ Pioneer habitats are rare in the UK, which makes these sites all the more important for conserving wildlife;
- **Mosaics of habitats** including open fine-leaved grassland, wildflower-rich grassland, heathland and open bare areas boost overall invertebrate diversity;
- **Wildflower-rich habitats** provide a refuge for species of bees, butterflies, moths, beetles and many other invertebrates. Such habitats have suffered drastic losses in the wider countryside due to agricultural intensification - it is estimated that 97% of wildflower meadows have been lost in the UK since 1930; ⁶



Above: Brownfield land at Forge Dam, Scotland

- **Presence of bare, loose substrate** is an important feature of brownfield sites. Between 12% and 15% of all nationally rare and nationally scarce insects have been recorded from brownfield sites. ⁷ Bare areas in particular have been shown to support rare invertebrates including burrowing bees and wasps as well as many species of spiders, beetles and flies. ⁸ Bare ground and sparsely vegetated areas warm up quickly and are therefore particularly important for warmth-loving invertebrates to bask. They are used by burrowing and ground nesting species and are good foraging areas for visual predators such as spiders and ground beetles.

DESIGN CONSIDERATIONS

Structure and support

An important factor to consider when designing any green roof is the dead load capacity (or weight) that the roof exerts onto a building. New buildings can be designed to ensure that they can withstand the weight of a green roof. When retro-fitting onto an existing building it must be assessed by a structural engineer prior to installation. Table 1 gives the various saturated weights of the layers found within a typical biodiverse green roof system (based on figures provided by German green roof suppliers). The roof components used will dictate the required dead load capacity of a building or structure.

Please note that these figures are based on **average weights**, and buildings should always be assessed on an individual basis prior to roof installation by a suitably qualified structural engineer.

TABLE 1: TYPICAL WEIGHTS OF ROOF COMPONENTS

Layer	Saturated weight
Moisture/protection layer	4 kg/m ²
Drainage/reservoir layer	5 kg/m ²
Sedum substrate (10% organic content)	11 kg/10mm depth/m ²
Wildflower substrate (20% organic content)	13.5 kg/10mm depth/m ²
Plants	5 kg/m ²

As mentioned previously, biodiversity potential can be increased by varying the roof topography - ideally substrate depth should vary from 80mm to 150mm. Table 2 demonstrates the differences in the dead load capacity required within a roof structure when comparing minimum and maximum substrate depths.

TABLE 2: ROOF LOADINGS FOR TWO BIODIVERSE ROOF TYPES

Extensive roof type	Dead load
150mm Wildflower	216.7 kg/m ²
80mm Wildflower/sedums	122 kg/m ²

Drainage

Drainage outlets are an important component of a roof system, particularly on flat or shallow angled roofs, to allow excess water to escape, and should be



Above: Drainage outlet installation

kept free of any substrate or vegetation. To reduce the likelihood of blockages, a layer of pebbles should be laid around the outlets or an inspection chamber installed. Pebbles can also be used to line the perimeter of the roof to prevent vegetation establishing.

CREATING BIODIVERSE GREEN ROOFS FOR INVERTEBRATES



Above: Biodiverse roof installation showing the root barrier, drainage board and filter fabric

Waterproofing and root barriers

It is current practice to use a number of engineered layers in the establishment of biodiverse roofs. One of the most important factors to consider prior to installation is waterproofing. It is essential that the integrity of the waterproof membrane is confirmed in order to prevent possible damage to the building due to water ingress. When retrofitting onto an existing roof, it is essential that any faults that the roof may have such as leaks and damage are rectified. It is advisable to carry out an electronic leak test on the existing roof prior to installation.

A root barrier membrane, which lies on top of the waterproofing layer (or can be incorporated into the waterproofing itself), acts as a protective layer preventing any damage which may be caused to the waterproofing by roots. A drainage/reservoir board allows free lateral movement of excess water and in the case of some products may provide a source of water for the plants above. A protective fleece is usually laid below the drainage/reservoir board. The drainage/reservoir board allows free egress of water to the drainage layer.



Above: Roots and Shoots biodiverse roof, London

SUBSTRATE (GROWING MEDIUM)

Substrate **type** and substrate **depth** are the most important design elements when considering biodiverse roofs.

SUBSTRATE TYPE

Commercial substrates

Over the last ten years a number of commercial substrates have become available in the UK. Most of these are fire-clay based, have a pH of between 6 and 8, contain a high level of porous material and are nutrient poor, providing suitable conditions for the establishment of flower rich meadows. They are also designed to absorb water, are lightweight and should be used as the primary growing medium in establishing biodiverse roofs.

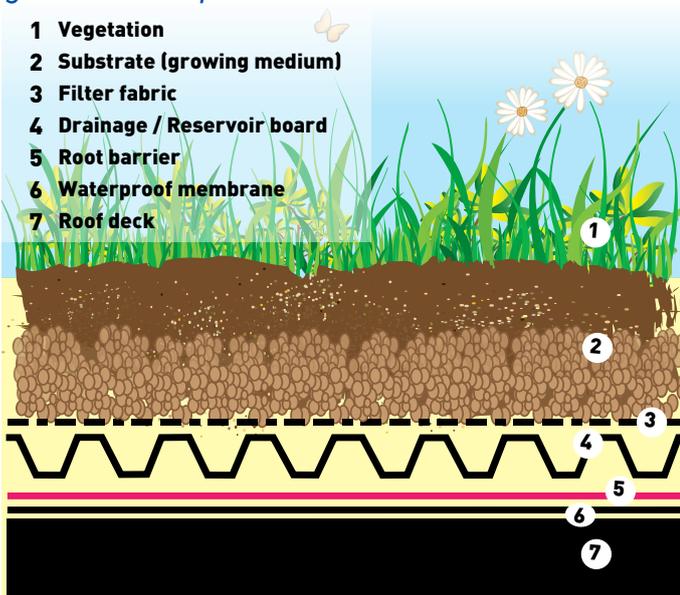
It is recommended that substrates used meet the minimum standards recognised by the green roofing industry in terms of drainage characteristics, weight and longevity, and are compatible with the other essential components of a green roof system. The Green Roof Directory ⁹, produced by Livingroofs.org, provides a comprehensive online directory of green roof professionals, suppliers and installers.

Where possible, substrate composition should take into consideration factors such as location, climate and the plants intended to be planted/seeded or which may colonise. For example, lime-rich substrates could be used to create calcareous grassland close to existing sites.

Natural substrates and site spoil

Natural substrates and site spoil (demolition waste such as crushed brick and concrete) can be used as a means of replicating local ground conditions up at roof level. The use of local substrate has been shown to have a positive influence on the diversity of beetles and spiders which colonise roofs.¹⁰ Other substrates such as sand and shingle can be added to a roof to enhance the range of habitats available for invertebrates. However, great care is required when using site spoil - it is essential that the material is appropriately screened and the additional load implications taken into account.

Below: Figure 1 Section showing typical extensive green roof components



CREATING BIODIVERSE GREEN ROOFS FOR INVERTEBRATES

The use of unscreened materials can lead to problems:

- Inappropriate materials placed on to roofs can cause damage to the waterproofing membrane and other layers of the roof;
- Excessive amounts of crushed concrete within the spoil can negatively affect thermal performance, evapo-transpiration rates and storm water retention capacity;
- There is the possibility that spoil may be nutrient rich and that unwanted seeds of invasive species (which can out-compete wildflowers particularly in fertile substrates), may also be present;
- Crushed concrete is an ideal substrate for *Buddleia* (*Buddleja davidii*) to colonise. This plant is unsuitable for roofs as it can damage the building fabric. It can also dominate other vegetation and be difficult to remove.

When adding further materials to a roof the additional saturated load implications must be taken into consideration.



Above: Using a variety of materials in addition to substrate such as sand and shingle can be of benefit and influence the flora and invertebrates that colonise.

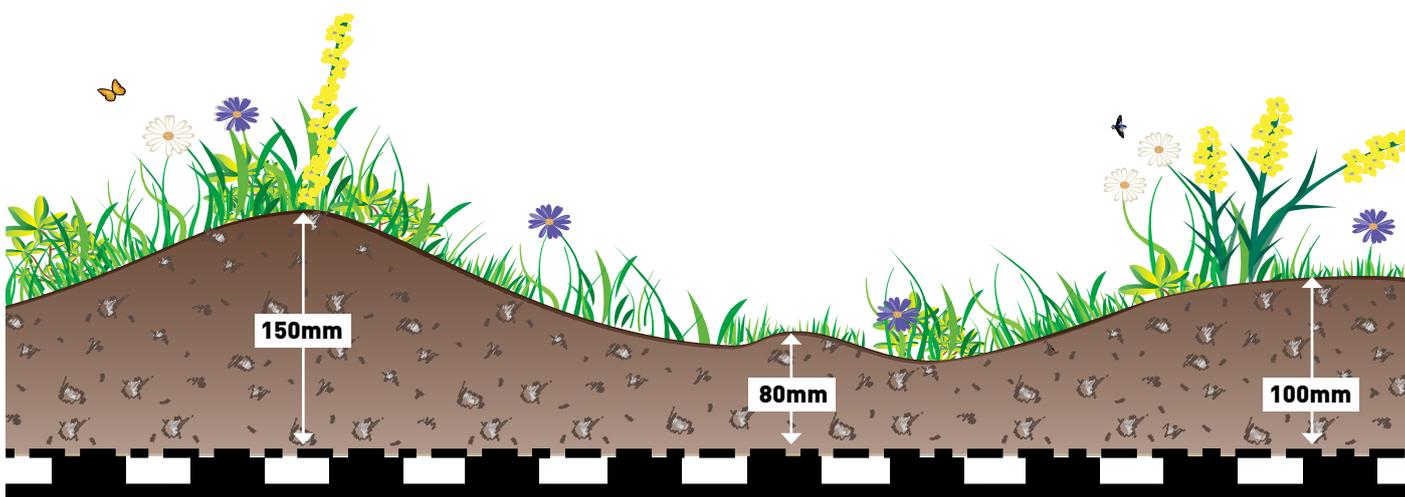
Substrate depth and structural diversity of the vegetation

Research has shown that variation in substrate depth¹⁰ is desirable on a biodiverse roof. Thin areas of substrate will be less vegetated, providing the bare areas favoured by warmth-loving invertebrates. Creating deeper areas of substrate and undulations will create small localised changes to the micro-climate due to varying exposure to sun, wind and rain. It will also produce hydrological variation ranging from very

dry substrate (shallow areas) to those that hold moisture or even ephemeral water-bodies (deeper areas).

This in turn will encourage the development of structurally diverse vegetation which will provide habitat for a wide variety of invertebrates. Deeper soils can also be important locations for some invertebrates to over-winter or find refuge during drought.

Below: Figure 2 Section of biodiverse green roof with varying substrate depth



CREATING BIODIVERSE GREEN ROOFS FOR INVERTEBRATES

PLANTS

Wildflowers and grasses local to an area will readily colonise a roof. Natural colonisation can provide habitat of high ecological value, and that which is most appropriate and suited to the site. However, relying on natural colonisation alone does come with some issues:

- Isolated roofs may not be exposed to an adequate seed source to produce a diverse plant community;
- Colonisation by unwanted invasive plant species, particularly Fleabanes (*Conyza*) and Buddleia could lead to problems. Buddleia is particularly unwelcome at roof level as it can cause structural damage to buildings; however, unwanted species can be removed as part of a management scheme.



Above: Plug planting of wildflowers on a roof in London

It is recommended that biodiverse roofs be seeded and/or plug planted with locally appropriate (and locally sourced) native seeds/plants that are matched to the substrate type, pH and the desired habitat in mind. Seeds and plants should be sourced from the Flora Locale approved Supplier's List found at www.floralocale.org. An alternative to purchasing seed or plug plants would be to collect the seed of desired species from local wildflower meadows or brownfield sites. Contact your local Wildlife Trust for advice.

When designing biodiverse roofs it is recommended to use suitable native species that are:

- Easy to establish;
- Appropriate to the locality (including common species);
- Suited to the substrate;
- Able to persist in the harsh roof environment (e.g., drought tolerant, shallow substrate, able to seed easily);
- Able to form resilient and permanent cover;
- Low growing – generally up to 60cm.

Below: White dead nettle (*Lamium album*) and Bladder campion (*Silene vulgaris*)



Above: Wildflowers on a biodiverse roof in Lewisham, London

Seeding and planting

Other than through natural colonisation, wildflowers are established on roofs using two main methods – seeding and/or plug planting. Seeding is the most cost effective option; however, plug planting of wildflowers in conjunction with sowing seeds can be beneficial as this provides a resource for invertebrates during the first few years whilst the seeded plants become fully established. Plug planting also gives greater control over initial plant coverage.

Wildflower seeds can take some time to germinate and become established at roof level due to the extra stresses placed on the habitat such as drought and wind. The inclusion of fast germinating annual species will provide an important resource for insects in the first year of establishment.

CREATING BIODIVERSE GREEN ROOFS FOR INVERTEBRATES



Left to right: Autumn hawkbit (*Leontodon autumnalis*); Marmalade hoverfly (*Episyrphus balteatus*) on a Mayweed; Red-tailed bumble bee (*Bombus lapidarius*) on a Cornflower

Choosing wildflowers for your roof

When considering wildflower mixes, in terms of pollen and nectar sources for invertebrates, a variety of species should be considered. Composites such as Ox-eye daisy (*Leucanthemum vulgare*), Yarrow (*Achillea millefolium*) and Hawkbits (*Leontodon spp.*) provide good nectar sources that are easily accessible for more generalist species such as flies, short-tongued bees, butterflies and some beetles.

However, some species such as bumblebees have more specific requirements. The Garden bumblebee (*Bombus hortorum*) has a very long tongue and therefore requires long-tubed flowers such as Viper's bugloss (*Echium vulgare*) and White dead nettle (*Lamium album*). The Brown-banded carder bee (*Bombus humilis*) has a medium length tongue and species such as Red clover (*Trifolium pratense*) and vetches are favoured. Leguminous species such as trefoils and vetches benefit a variety of invertebrates, with Bird's foot trefoil (*Lotus corniculatus*) being a favourite of the Red-tailed bumblebee (*Bombus lapidarius*). This wildflower is also a food plant for many butterflies.

In common with long-tongued bees, moths often obtain nectar from long-tubed plants. Wildflowers from the campion family such as Bladder campion (*Silene vulgaris*), White campion (*S. latifolia*) and Night flowering catch-fly (*S. noctiflora*) along with many others, are known to provide good nectar sources for moths.

It is also important to include species which flower

in early spring and autumn as this will provide an extended pollen and nectar source for invertebrates throughout the year.

The wildflowers mentioned in this section do not provide a suggested species list, but simply an example of the types of plants which could be included on a biodiverse roof to attract a variety of invertebrates.

Sedum

A common approach to establishing an extensive green roof is to specify an 'off the shelf' standard green roof system. In most cases, these will consist of a uniform, low diversity sward, usually dominated by plants of the Sedum genus. The resulting lack of plant diversity and habitat diversity means that these systems do not constitute a biodiverse roof.

The inclusion of Sedum plants on a biodiverse roof can be useful – but should normally comprise no more than 30% of the species composition. There is some anecdotal evidence that drought tolerant Sedum species and other succulents can aid the establishment of wildflowers. Sedums also provide an important nectar and pollen resource in June and July. *Sedum acre* is a commonly used native species, which naturally occurs in the UK on dry grassland, dunes, beaches and walls.



Left to right: Bird's foot trefoil (*Lotus corniculatus*); Viper's bugloss (*Echium vulgare*); Honey bee (*Apis mellifera*) on Sedum © Landmark Living Roofs

CREATING BIODIVERSE GREEN ROOFS FOR INVERTEBRATES

MAXIMISING BIODIVERSITY

The creation of habitats, the addition of habitat features and management can maximise the potential of biodiverse roofs to support invertebrates and other wildlife such as birds. Many other factors, including the roof angle, aspect, size and height, will also have an influence and should be taken into consideration.



Above: Over-wintering vegetation for invertebrates at Sharrow Primary School © Sheffield City Council

- **Over-wintering habitat** such as wildflower meadows/vegetation left uncut during winter will provide additional habitat resources such as over-wintering opportunities for a variety of invertebrates in seed heads, hollows stalks and stems;

- **Provide areas of open bare ground and areas of stone, brick, rocks or gravel.** These dry areas can warm up quickly and will benefit a wide variety of species such as butterflies (e.g. Dingy skipper (*Erynnis tages*) and Grayling (*Hipparchia semele*) bees and wasps (e.g. Mining bees and Solitary wasps), beetles and spiders;



Above: Grayling (*Hipparchia semele*).

- **Log piles/deadwood piles** can provide areas for shelter and nesting sites for invertebrates such as bees and wasps that burrow into dead wood.



Right: Sharrow Primary School © Sheffield City Council

Deadwood is particularly important for beetles and flies and can support a wide variety of species.

- **Bee banks** are particularly beneficial for Solitary bees and wasps to dig nest burrows in. The size of bee banks will vary greatly depending on the size of the roof and should not be higher than the parapet wall (the barrier at the edge of a roof). Bee banks can be easily created by using sand and shaping it into a mound. They should ideally be south facing in order to receive the most sunshine throughout the day;



Above: Pond on Unicorn Grocery Green Roof, Manchester © Graham Jones

- **Water-bodies and wet areas** are an essential requirement for many species and can be provided for at rooftop level in the form of a pond, undulations or simply by placing a shallow plastic container on the roof which will retain rain water;
- **Bug hotels and habitat walls** can be purchased or made using items such as pallets, bamboo canes, logs and recycled building materials to create areas for invertebrates to shelter, over-winter or nest in.

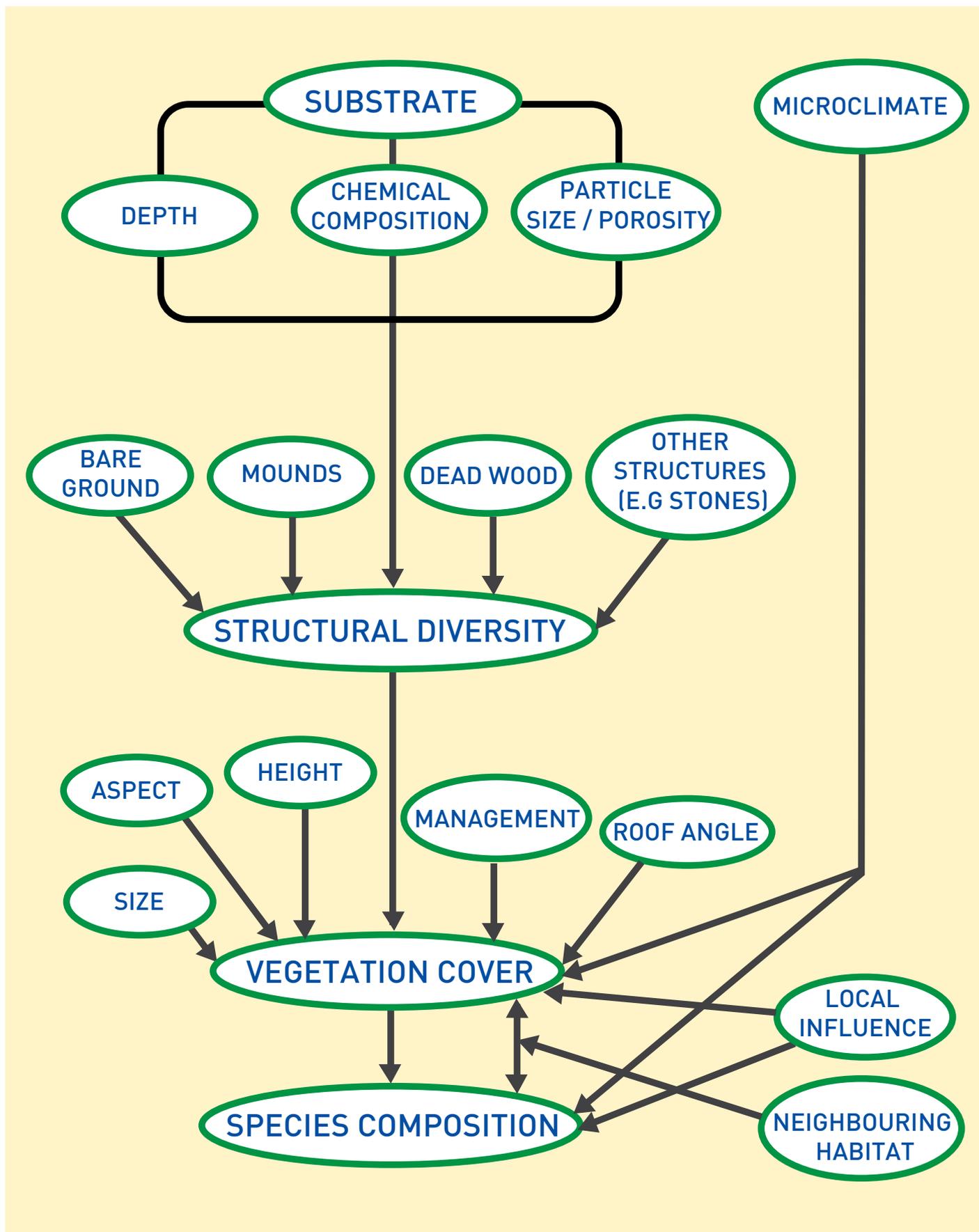
When adding habitat features to a roof always consider the additional loading implications.

Left: Bug hotels on a biodiverse roof at Wat Tyler Country Park, Basildon



CREATING BIODIVERSE GREEN ROOFS FOR INVERTEBRATES

Below: Figure 3 *Hierarchy of factors influencing biodiversity of green roofs*



MANAGEMENT

Biodiverse roofs require little management, largely due to the exposed, stressed, low nutrient, shallow substrates (as on typical brownfield sites) and root barriers that also slow the processes of ecological succession. Ideally an extensive roof should receive two maintenance visits per year by a suitably qualified contractor.

Some management considerations:

- Artificial irrigation is not usually required, however, the roof should be thoroughly watered after installation;
- Inspection of roof drainage outlets to ensure that they are not obstructed or blocked;
- Removal of unwanted plants which may colonise the roof (e.g. Buddleia);
- Removal of vegetation from unwanted areas on the roof e.g. the roof perimeter;
- Habitat management may include wildflower meadow management such as cutting, re-creation of bare ground areas where vegetation has encroached or providing additional habitat features such as woodpiles or bug houses. Habitat management will, of course, depend on the type of habitat that you are intending to maintain. See Maximising Biodiversity on page 12 for further details;
- Invertebrate monitoring would be useful in order to determine which species are using the roof. The information gathered can be used to inform future management, and to study how roof design influences biodiversity.



Above: Invertebrate surveys being carried out on a biodiverse roof in London. Left: Using a variety of materials in addition to substrate such as sand and shingle can be of benefit and influence the flora and invertebrates that colonise.



Above: © Landmark Living Roofs

CREATING BIODIVERSE GREEN ROOFS FOR INVERTEBRATES



Above: Sedum roof on new build © Falkirk Council, Kinnaird Primary School roof

POLICY AND GUIDANCE

Although there are no national policies on green roofs in the UK, there are a number of regional and local policies that are in place or are in preparation.

The Living Roof and Wall technical report¹² was produced in support of the London Plan¹³, this identifies enhancing biodiversity as an important objective in the implementation of green roofs in the capital. Furthermore, the policy articulates many of the guiding principles within this guidance.

The Environment Agency (EA) in the London area has played an active role in ensuring that green roofs are used in new developments along the Thames and its tributaries. In 2008, the organisation launched its online pre-application Green Roof toolkit.¹⁴ This provides a guide to the construction industry when considering green roofs as part of a new development, and a checklist of factors to consider during the design stage.

Sheffield City Council makes specific reference to green roofs in its supplementary planning guidance,¹⁵ which is complemented by the Sheffield Local Biodiversity Action Partnership's Green Roof Habitat Action Plan.¹⁶ This aims to increase the biodiversity value of new roofs with an emphasis on providing suitable conditions for locally important species and habitats. The Green Roof Centre,¹⁷ also based in Sheffield, operates with partners nationally to demonstrate the potential of green roof uptake in the UK.

The Scottish Green Roof Forum¹⁸ was developed in 2009 and is a voluntary partnership involving business, industry, commerce and Government, and works towards developing a holistic approach to addressing climate change, water management and generating benefits such as improved opportunities for biodiversity.

Right: Biodiverse roofs on storage sheds

BIODIVERSE ROOFS AND MITIGATION

The retention of existing habitats or the restoration/creation of habitats on the ground must always be the priority of a mitigation scheme when compensating for loss of habitat.

However, biodiverse roofs are an innovative way of providing additional habitat where brownfield land (and other similar low nutrient, free draining habitats) is to be lost.

Sedum green roofs do have some value for biodiversity and are preferable to traditional non-greened roofs. Considerable benefit can, however, be achieved by designing bespoke biodiverse roofs that aim to replicate specific habitats.

Adding biodiverse roofs to existing buildings (retro-fitting) can have great benefits for invertebrates especially within an urban context by providing forage, areas to bask and shelter, breed and over-winter - where these opportunities previously didn't exist.

Roof top habitats can also serve as 'stepping stones' for invertebrates by linking urban greenspace and the wider landscape, aiding species movement and dispersal.

Biodiverse roofs can form an important part of a wider mitigation strategy, but should not be the sole means for compensating loss of habitat for the following reasons:

- Biodiverse roofs (and green roofs in general) cannot exactly replace ground based habitats in terms of soil composition and hydrology etc. (although they can be closely replicated);
- Conditions at roof level are different to those on the ground particularly in terms of being more open, exposed and subject to greater variations in temperature. This directly influences the flora that develops and therefore the invertebrate assemblages that can be supported. The nature of the roof can also have limitations for certain species such as those with limited mobility.



CONCLUSION

- Biodiverse roofs can be designed to mimic wildlife-rich habitats and can support a wide range of invertebrates, including many of conservation concern. Furthermore, they are recognised as important tools for delivering nature conservation and local BAP targets in urban areas;
- Well designed biodiverse roofs provide considerably greater benefits in terms of biodiversity, green infrastructure and amenity when compared to sedum roofs, and are still relatively lightweight structures;
- Biodiverse roofs can be retro-fitted onto existing buildings or incorporated into new builds; considering wildlife during the design stage of a development can maximise biodiversity potential;
- The creation of open bare areas, variation in substrate depth and wildflower meadows, coupled with the addition of features such as logs/dead wood and sandy bee banks, can greatly increase a roofs potential to support invertebrates;
- By following the design guidance presented in this report, those involved with the design and specification of biodiverse roofs can greatly increase their value for biodiversity, particularly for invertebrates;
- Biodiverse roofs can provide benefits to a building such as increasing the life of the original roof and reductions in heating and cooling costs, plus wider environmental benefits such as water attenuation, improved water quality and can help reduce the urban heat island effect.

Biodiverse roof at Wearside, London



CASE STUDIES

The following case studies provide an overview of the changes in understanding and approach to the design of biodiverse roofs that have occurred over the past decade. Initially in the UK studies of biodiverse roofs

were largely focussed in the London area; however, the principles that emerged began to influence the use of green roofs in other cities such as Birmingham, Manchester, Sheffield and Edinburgh.

Eversheds, 1 Wood St, City of London

- Originally specified as a simple Sedum system, consisting of a 20mm drainage layer, 20mm substrate and 20mm blanket, Eversheds commissioned the Green Roof Consultancy to make improvements to the roof for biodiversity. This was done within six months of the original installation;
- A number of features were applied to the existing green roof including 20 mounds of extensive wildflower substrate planted and seeded and the addition of a series of log piles;
- These elements, in keeping with the principles outlined in the studies, are intended to increase the invertebrate biodiversity and provide a template for retrofitting features to existing Sedum roofs to increase invertebrate diversity.



Laban Dance Centre, Deptford, London

- The original 'rubble' roof installed in 2000 was designed in accordance with the London Biodiversity Partnership's black redstart action plan;
- The roof consisted of a protection fleece with between 50 and 200mm of crushed site waste (70:20:10 concrete/brick/fines). The roof was initially left to self-colonise but was later seeded with locally collected wildflower seeds and a commercial seed mix;
- Habitat features such as logs and sand boxes were also added, the latter as part of a study on nesting bees;
- Due to the type of substrate used the roof suffers from severe water stress in periods of drought, and the vegetation is therefore very slow to establish;
- The roof has been monitored since 2002 and numerous rare invertebrates have been recorded.



Living Roofs for London's Wildlife

In 2009 Buglife -The Invertebrate Conservation Trust embarked on a project in partnership with Livingroofs.org, which successfully installed and monitored biodiverse green roofs in London and raised awareness as to the importance of these rooftop habitats within an urban environment. The 'Living Roofs for London's Wildlife' project, funded by the SITA Trust¹⁹, is now in its final year and will have successfully installed six biodiverse roofs by the end of 2011.



Above: Bombardier beetle (*Brachinus crepitans*)
© Roger Key

The invertebrate fauna of these roofs are being monitored as part of a wider recording scheme being carried out on green roofs across London. It is intended that information gathered from this study will serve to further identify the key factors associated with green roof design

specifically for the purpose of biodiversity, thereby allowing future living roofs to be designed to provide maximum benefits for rare invertebrates associated with brownfield sites and other valuable habitats.

Data from the studies has shown that the roofs support common species of bumblebee, spider and beetle including the Common carder bee (*Bombus pascuorum*), the Zebra spider (*Salticus scenicus*) and the Common sun beetle (*Amara aenea*), respectively; as well as UK BAP species such as the Brown-banded carder bee (*Bombus humilis*) and nationally scarce species such as the Bombardier beetle (*Brachinus crepitans*).



Right: Brown-banded carder bee (*Bombus humilis*) © Sam Ashfield

Abbey Hive – Camden, London

- In July 2011 a biodiverse roof was installed on the Abbey Hive community building in the London Borough of Camden;
- Specifically designed for the purpose of enhancing biodiversity, the roof, which covers 200m² and is split over three levels, included features such as the use of a low nutrient, free draining substrate of varying depths (typically between 80mm – 150mm), areas of exposed bare ground, and was seeded and plug planted using a variety of species beneficial to invertebrates such as Bird's foot trefoil (*Lotus corniculatus*), Lady's bedstraw (*Galium verum*) and Selfheal (*Prunella vulgaris*). Locally collected wild flower seeds such as Viper's bugloss (*Echium vulgare*) were also added;
- To add further diversity to the habitat, features such as log piles and sandy banks were included within the design which provide areas for invertebrates to bask, burrow and hunt for prey.



Sharrow Primary School - Sheffield

- The green roof at Sharrow Primary School created in 2007 covers an area of 2000m² split over three levels and includes intensive, extensive and biodiverse areas, some of which were planted while others were left to colonise naturally;
- The roof was designed to represent habitats found in the local area including wildflower meadows, urban brownfield sites and wetland (in the form of a pond). The range of locally sourced and screened substrates (crushed brick, organic waste and limestone), of varying depths (100 – 500mm) help to support these diverse habitats;
- Additional features such as mounds of local soils, gravel, sand and pebbles, log piles and dead wood were also added;
- In 2009 the roof was designated as a Local Nature Reserve by Natural England²⁰ for its ecological value and is the first in the country to attain this status. A management plan is in place which aims to maintain the distinctive nature of the different habitat areas, to prevent dominance by aggressive species and to undertake regular botanical and faunal surveys.

Below: *Sharrow School Green Roof* © Sheffield City Council



West Midlands Fire and Rescue Authority's (WMFRA) Regional Head-Quarters, Birmingham

- The green roof was incorporated into the design element of the new WMFRA development with sustainable construction practices in mind. The roof aimed to replicate brownfield land typical of the local area, and as such elements of extensive roof design were incorporated;
- The biodiverse element of the roof was designed with invertebrates and black redstarts in mind and the roof is being monitored on an on-going basis by Birmingham University;
- The roof which was installed in 2008 covers an area of 300m² and utilised layers of calcareous screened demolition waste laid in varying depths (75mm - 150mm), providing ideal conditions for wildflower meadows to flourish;
- The roof was seeded with nectar and pollen rich species such as Common knapweed (*Centaurea nigra*) Yarrow (*Achillea millefolium*) and Kidney vetch (*Anthyllis vulneraria*); some areas were deliberately left bare to encourage colonisation by local species;
- Although management requirements for the roof are low, removal of unwanted colonising vegetation is necessary.



Above: *Biodiverse element of WMFRA Green Roof, Birmingham* © Moore Environmental

SECTION 2

REVIEW OF KEY RESEARCH

INTRODUCTION

This section provides an overview of research into green roofs and invertebrate biodiversity carried out in Switzerland and the UK (primarily London). The Swiss research was the inspiration for much of the

work on green roofs and biodiversity in the UK and elsewhere in the world. The research carried out in London followed the same protocols and research methods as studies in Switzerland and is on-going.



Above: Jakob Burkhardt roof in Basel, Switzerland

Switzerland

During the 1990s there was growing concern in Switzerland over the loss of Rhineland alluvial grassland habitat. The invertebrate fauna associated with such grassland appeared to be finding refuge on brownfield sites in the city of Basel.

Green roofs were already a statutory requirement in new developments in Switzerland at that time, so a study was undertaken to investigate how green roofs could be modified or designed to provide suitable habitat for invertebrates.²¹ The study sought to ascertain whether green roofs could provide appropriate and meaningful mitigation for the loss of brownfield sites through development. Surveys of beetles and spiders on sixteen green roofs in Basel, were conducted. A total of 172 species of beetles were recorded, 10% of which were listed in the national Red Data Book. The study on spiders revealed that 40% of the collected species were

of 'faunistic interest' (a term used in the German speaking countries to indicate rarity).

The study concluded that there were a number of factors that influenced the composition of invertebrate assemblages on green roofs, the most important of which was variation in substrate depth. Areas of thin substrate, which tend to be bare or sparsely vegetated, were found to provide habitat for a number of drought tolerant invertebrates. Deeper areas of substrate, however, retained more moisture and supported more vegetation, which had the effect of creating habitats that were able to support quite different invertebrate assemblages. The results of this research have led to changes in Cantonal Law in Basel, which requires extensive green roofs to be topographically varied. Also, in accordance with local regulations on sustainability, locally obtained substrates should be used.

REVIEW OF KEY RESEARCH

London

Research undertaken during 2002 concentrated primarily on spiders (Arachnids).²² Spiders occupy the mid-trophic level of the food chain, and therefore provide a useful indication of the overall complexity of the invertebrate assemblages present. Samples were collected each summer from six green roofs in London. These were mainly sedum mat systems, which were the predominant type of green roof in London at the time.



Above: Ground crab spider (Thomisidae)

Over 3,000 individual spiders representing 59 species were collected – 9% of the total UK and 26% of the Greater London spider faunas.²³ There were six new records for Greater London – namely *Pardosa agrestis* (Nb* status) *Steatoda phalerata* (Theridiidae), *Bianor aurocintus* (Salticidae) (Na status), *Silometopus reussi* and *Erigone aletris* (Linyphiidae). *E. aletris* had not been recorded in southern England prior to this study. The list included ubiquitous species as well as nationally rare and scarce and locally and nationally uncommon species.



Above: House jumping spider (*Euophrys lanigera*)
© Gr. Ide

Further research into the invertebrate fauna of green roofs was undertaken between 2003 and 2006.²⁴ The study sampled invertebrates on four sedum roofs and three biodiverse roofs in the London area (Table 1).²⁵ The purpose of the study was to quantify invertebrate diversity and abundance and to correlate these with habitat features. By doing this, it was hoped that the research would help practitioners to maximise invertebrate diversity on green roofs.



Above: Cabot square, Canary Wharf



Above: FC4, Canary Wharf

TABLE 1: LONDON SAMPLING SITES²⁵

SEDUM ROOFS	Date established	Height (m)	Area (m ²)	Sampling period	Description
FC4, Canary Wharf:	1998	67	800	2004-2006	Lightweight <i>Sedum</i> (20mm blanket, 20mm Rockwool) showing sign of water stress.
Retail (DLR station), Canary Wharf:	2000	18	300	2004-2006	Light weight <i>Sedum</i> (20mm blanket, 20mm Rockwool), in shade for much of the day, therefore quite moist, even in the height of summer.
Waitrose, Canary Wharf:	2000	20	600	2004-2005	<i>Sedum</i> mat on 70mm of crushed brick based substrate.
Barclays HQ <i>Sedum</i> section, Canary Wharf:	2005	160	150	2005-2006	<i>Sedum</i> mat on 90 mm crushed brick based substrate and 10mm pine bark mulch.
BIODIVERSE ROOFS					
Laban, Deptford:	2003	25	200	2004-2006	200mm of crushed concrete and brick (recycled from site). In the first year, 2003, the roof was not seeded, but subsequently seeded with native wildflower mix in 2005 and locally collected wildflower seeds.
Barclays HQ, Canary Wharf (Rubble section), Canary Wharf:	2005	160	300	2005-2006	100mm of crushed concrete and brick substrate and pebbles covered with organic green waste compost. Seeded with native wildflower mix.
Grays Inn:	2006	18	150	2006	Varied substrate (70-100mm), including sand, fired clay pellets and crushed brick and concrete. Seeded with native wildflower mix.

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Above: Waitrose, Canary Wharf



Above: Barclays HQ, Canary Wharf



Above: Laban Dance Centre in Deptford, London

In summary, the highest numbers of spider species were recorded from the Laban biodiverse and Waitrose sedum roofs. The greatest numbers of different spider families were, however, recorded from the Laban and Barclays rubble roofs.

Spider species diversity was higher on biodiverse roofs compared to sedum roofs. On the sedum roofs, almost 10% of all the collected spiders were locally or nationally important, whereas this figure was closer to 20% on the biodiverse roofs.

The study was also able to demonstrate how species diversity fluctuated on the various roofs from year to year, increasing in the case of recently established roofs and decreasing in the case of some of the longer established sedum roofs.

The study confirmed the value of green roofs as invertebrate habitat and that invertebrates readily colonised these artificial habitats where they are provided. Whilst the colonisation of biodiverse roofs was found to be initially slower in comparison with sedum roofs, diverse invertebrate assemblages were recorded on all the biodiverse roofs studied. The established invertebrate community does, however, vary greatly depending on the characteristics of each roof.

In 2004, the FC4 roof at Canary Wharf supported hunting spiders from the Lycosidae and Thomisidae families which require open habitat, and do not need tall vegetation on which to build webs.²⁶ By 2005, species from the family Salticidae were present. Salticid spiders are typically found in warm sunny dry and open habitats. The presence

of Salticidae may be indicative of the drying out of the sedum roof. By 2006, the sedum was even drier, with numbers of individual Thomisidae and Salticidae spiders higher.

Spider species from the Linyphiidae, Lycosidae, Thomisidae and Salticidae families were found on the Retail roof in 2004, but there were also Theridiidae (comb footed spiders), which require taller vegetation to support three dimensional criss-cross webs. In 2004, this taller vegetation was provided by a lush sedum sward. However, by 2005 the sedum started to dry out, causing a reduction in the number of species in the Theridiidae family.

Spider family assemblages were also shown to change on the biodiverse roofs over the years. The Laban and Barclays rubble roofs had only Linyphiid and Lycosid spiders to begin with. Both of these families are known to be early colonisers of new and disturbed habitats.²⁷ By the second year on both Laban and Barclays other spider families, which require different conditions began to appear. On Laban, Thomisidae and species from other spider families colonised. By the third year of sampling, spider diversity increased again on the Laban roof as it developed a more complex habitat structure with the establishment of more plants. On the Barclays roof, Salticid spiders started to appear by the second year - this family is found on low vegetation and specifically favours warm sunny habitats (At 160m above ground, this site provides a very sunny, windswept and therefore arid habitat).

Species of interest

The most remarkable fact about green roofs is that they host a very high percentage of species of conservation concern. In all green roof categories combined (sedum and biodiverse) 15% of the spiders and 10% of beetles recorded had either a local or national importance, including Notable and Red Data Book species. Both green and biodiverse roofs host diverse spider faunas. Almost 10% of the whole UK fauna²⁸ and almost 20% of the Greater London spider fauna²⁹ was recorded from these few roof sites.



Above: Leaf bug (*Chlamydatus evanescens*) © Tristan Bantock

Initially sedum roofs generally supported a greater quantity, but less diverse invertebrate community than biodiverse roofs. On green roofs with sedum mats, invertebrate numbers were high from the start. On sedum roofs, where the substrate is shallow (less than 40mm) and drying occurs, initially high invertebrate populations were not sustained. Roofs with deeper substrates with better water retention, however, maintained a higher abundance of invertebrates and year on year are likely to continue to support more diverse invertebrate communities as the flora develops.

In contrast, colonisation of biodiverse roofs by invertebrates is slow at the beginning, as these sites represent a harsher environment, but, over time, invertebrate abundance as well as diversity increases with succession. These communities tend to be more diverse than those on simple light-weight sedum systems. Biodiverse roofs, as a result of their low nutrient well-drained substrates,



Above: Ladybird (*Hippodamia variegata*) © Ben Hamers

develop species-rich plant vegetation and structural diversity. Most invertebrates respond, not only to the presence of plant species, but also to the structural diversity of the vegetation.³⁰ Therefore invertebrate diversity is lower in the Sedum dominated roofs. This is demonstrated by the fact that on all the sedum roofs, spider species from 10 families were recorded, whilst on biodiverse roofs 13 families were represented, even though more sedum roofs were sampled and the biodiverse roofs were immature.



Above: Pin-stripe wolf-spider (*Pardosa monticola*) © Trigueirao

REVIEW OF KEY RESEARCH

Invertebrates that benefit from green roofs

Studies have demonstrated that green roofs provide habitats for invertebrates associated with Open Mosaic Habitats and arrested pioneer communities (which are often, but not exclusively, associated with brownfield sites). Both ubiquitous and specialist species can be found on well-

designed green roofs. Over 10% of the sampled species in the one study were locally or nationally scarce or rare. A few interesting species associated with salt marsh, shingle and even wetland habitats were also noted during the study. Table 2: Species of note on green roofs in London (Coleoptera, Aculeate Hymenoptera, Arachnids)

TABLE 2: SPECIES OF NOTE ON GREEN ROOFS IN LONDON (COLEOPTERA, ACULEATE HYMENOPTERA, ARACHNIDS)

Roof or roofs	Group	Family	Species	Status*
Barclays	Coleoptera	Carabidae, ground beetles	<i>Polistichus connexus</i>	RDB-2
Barclays rubble	Coleoptera	Coccinellidae, ladybirds	<i>Hippodamia variegata</i>	Notable/Nb
Biodiverse roof (Texaco)	Coleoptera	Curculionidae, weevils	<i>Stenopelmus rufinusus</i>	Notable/Nb
Biodiverse roof (Zoo lab)	Coleoptera		<i>Stenolophus teutonus</i>	Notable/Nb
Biodiverse roof (Grays inn)	Coleoptera	Melandryidae	<i>Phloiotrya vaudouri</i>	Notable/Nb
Biodiverse roof (Laban)	Coleoptera	Phalacridae, smut beetles	<i>Olibrus flavicornis (Sturm)</i>	RDB-K
Biodiverse roofs	Coleoptera	Staphylinidae, Rove beetles	<i>Staphylinus fuscatus</i>	Notable/Nb
Biodiverse roof (Texaco)	Coleoptera	Throscidae	<i>Trixagus elateroides</i>	RDB3
Biodiverse roof (Texaco)	Aculeate hymenoptera	Formicidae	<i>Ponera coarctata</i>	Notable/Nb
Biodiverse (Laban)	Aculeate	Apidae	<i>Lasioglossum lativentre</i>	Rare
Waitrose	Hymenoptera	Apidae	<i>Sphecodes niger</i>	RDB3
Biodiverse roof (Laban)	Aculeate	Apidae	<i>Andrena trimmerana</i>	Notable/Nb
Biodiverse (Laban)	Hymenoptera	Sphecinae	<i>Ectemnius sexcinctus</i>	Notable/Nb
Biodiverse (Laban)	Aculeate	Popmpilidae	<i>Dipogon bifasciatus</i>	RDB3
Biodiverse (Laban)	Arachnids	Salticidae	<i>Bianor aurocintus</i>	Notable/Na
Biodiverse roof (Laban)	Arachnids	Salticidae	<i>Pseudophrys lanigera</i>	Loc
Sedum and Biodiverse roofs	Arachnids	Linyphiidae	<i>Erigone aletris</i>	1st S. Eng
Sedum roof (Barclays), Biodiverse roofs	Arachnids	Linyphiidae	<i>Erigone arctica</i>	Local (1st since 1957)
Biodiverse roof (Laban)	Arachnids	Linyphiidae	<i>Ostearius melanopygius</i>	Nat
Biodiverse (Laban)	Arachnids	Theridiidae	<i>Neottiura bimaculata</i>	Local (1st London)
Biodiverse (Laban)	Arachnids	Lycosidae	<i>Pardosa agrestis</i>	Notable/Nb (1st Lon)
Biodiverse (Laban)	Arachnids	Lycosidae	<i>Pardosa agricola</i>	Loc (1st Lon)
Sedum roof (Waitrose)	Arachnids	Lycosidae	<i>Pardosa monticola</i>	Comm(1st s1957)
Biodiverse roofs (Barcays rubble, Texaco)	Arachnids	Zodariidae	<i>Zodarion italicum</i>	Notable/Na
Biodiverse roofs (Barcays rubble, Texaco)	Arachnids	Theridiidae	<i>Theridion melanurum</i>	Synanthropic
All green roofs	Hemiptera	Miridae, leaf bugs	<i>Chlamydatus evanescens</i>	RDB3



Above: White tailed bumblebee (*Bombus lucorum*) © DenisG

Bee studies (Switzerland and UK)

Research was undertaken in Switzerland between 2004 and 2005 on how bees forage on green roofs and their plant preferences.³¹ The study compared different green roof categories, namely sedums, sedums with wildflowers, and species-rich meadows, to establish which green roof types provided the best foraging habitat and potential nesting habitat for bees.

The study recorded 77 different bee (Apoidea) species from 18 genera; ten of which were Red Data Book (RDB3) species. The most commonly found species on the roofs were the honey bee (*Apis mellifera*), followed by bumblebees (*Bombus* sp), (*Lasioglossum* sp) and (*Andrena* sp).

The study demonstrated that the green roofs provided foraging grounds for bees and were frequented by varying numbers of species according to the vegetation characteristics present. Typical sedum roofs supported half the number of bee species when compared with green roofs with species-rich vegetation. The roofs with sedum



Above: Common carder bee (*Bombus pascuorum*) © Mark Burnett



Above: Honey Bee (*Apis mellifera*)

bumblebees (*Bombus pascuorum*, *B. lapidarius*, *B. pratorum*, *B. terrestris*, *B. lucorum*, *B. hortorum*) on green roofs was carried out in Sheffield in 2007.³² This study has a similar conclusion to the Swiss study, i.e. the greatest bee activity is on flower-rich roofs, which attract more visits than roofs which are predominantly vegetated with Sedum.

Further observations in London in 2009 continued to back this principle of greater floral diversity as an important factor in how green roofs are used by bees; 21 species of bee were recorded during this study alone.³³ This is an interesting result as the bees were collected as by-catch in larger pitfall traps and were not the main focus of the study.



Above: Shrill carder bee (*Bombus sylvarum*) © MJ Clark

REFERENCES

- 1 HYPERLINK <http://www.blackredstarts.org.uk/>
- 2 HYPERLINK <http://www.fll.de/>
- 3 HYPERLINK <http://livingroofs.org/2010022857/about-livingroofs.org-living-roofs/gro-background.html>
- 4 HYPERLINK <http://www.ukbap.org.uk/PriorityHabitats.aspx>
- 5 M. Kattwinkel et al. *Biological Conservation* 144 (2011) 2235 – 2343
- 6 Fuller, R. M. (1987) *The changing extent and conservation interest of lowland grasslands in England and Wales: a review of grassland surveys 1930 to 1984. Biological Conservation* 40, 281-300
- 7 Jones, R. 2002. *Brown can be beautiful. Urbio*, 2, 12-13
- 8 Gibson, C.W.D. 1998. *Brownfield red data: the values artificial habitats have for uncommon invertebrates. English Nature Research Reports No 273. Peterborough: English Nature*
- 9 HYPERLINK <http://greenroofdirectory.com/>
- 10 Brenneisen, S., 2002. *Vogel, Kafer und Spinnen auf Dachbegrunungen - Nutzungsmoglichkeiten und Einrichtungsoptemeierungen. Geographisches Institut Basel Universitat Basel/Baudepartment des Kantons Basel-Stadt*
- 11 HYPERLINK <http://www.wildlifetrusts.org/>
- 12 HYPERLINK <http://static.london.gov.uk/mayor/strategies/sds/docs/living-roofs.pdf>
- 13 HYPERLINK <http://www.london.gov.uk/thelondonplan/thelondonplan.jsp>
- 14 HYPERLINK <http://www.environment-agency.gov.uk/business/sectors/91967.aspx>
- 15 HYPERLINK http://sheffield-consult.limehouse.co.uk/portal/spd/climate_change_and_design_spd?pointId=1303291785776#section-1303291785776
- 16 HYPERLINK http://www.thegreenroofcentre.co.uk/Library/Default/Documents/Sheffield%20Green%20Roof%20HAP%20Feb%202010_634159246532552600.pdf
- 17 HYPERLINK <http://www.thegreenroofcentre.co.uk/>
- 18 HYPERLINK <http://www.sgrf.org/>
- 19 HYPERLINK <http://www.sitatrust.org.uk/>
- 20 HYPERLINK http://www.lnr.naturalengland.org.uk/Special/lnr/lnr_details.asp?C=0&N=&ID=1627

Below: *Biodiverse roofs on out-buildings*



REFERENCES

- 21 Brenneisen, S., 2002. *Vogel, Kafer und Spinnen auf Dachbegrunungen - Nutzungsmoglichkeiten und Einrichtungsoptemeierungen*. Geographisches Institut Basel Universitat Basel/Baudepartment des Kantons Basel-Stadt
- 22 Kadas, G. 2002. *Study of invertebrates on green roofs – how roof design can maximize biodiversity in an urban environment*. UCL (unpublished)
- 23 Harvey P, Nellist D and Telfer M. 2002. *Provisional Atlas of British spiders. Vol. 1 2*. Huntingdon Biological Records Centre
- 24 Kadas, G. 2007. *Can green roofs provide habitat for invertebrates in an urban environment?* Royal Holloway College, University of London
- 25 Kadas, G. 2007. *Can green roofs provide habitat for invertebrates in an urban environment?* Royal Holloway College, University of London
- 26 Roberts, M. 1995. *The spiders of Great Britain and Ireland. Vol. 1-3*. Harley Books Colchester
- 27 Shochat, E., W.L. Stefanov, M.E. Whitehorse and S. Faeth. 2004. *Urbanization and spider diversity: Influences of human modification of habitat structure and productivity*. *Ecological Applications*. 14, 268-280
- 28 Harvey P, Nellist D and Telfer M. 2002. *Provisional Atlas of British Spiders. Vol. 1 & 2*. Huntingdon Biological Records Centre
- 29 Milner, E. 1989. *Spider records for London and Middlesex in 1998, damage to an important spider habitat, and revised species list*. *The London Naturalist*. 78, 135-145
- 30 Woodcock, B., Lawson, C., Mann, D. & McDonald, A. 2006. *Effects of grazing management on beetle and plant assemblages during the re-creation of a flood-plain meadow*. *Agriculture Ecosystems and Environment*. 116, 225–234
- 31 HYPERLINK <http://livingroofs.org/images/stories/pdfs/Bericht%20Wildbienen-compW.pdf>
- 32 Gong. 2007. *Green roofs and bumblebees: Observation of bumblebees on green roofs*. University of Sheffield (unpublished)
- 33 HYPERLINK <http://livingroofs.org/20100317201/about-livingroofs.org-living-roofs/bees-and-green-roofs.html>

Below: Biodiverse roof in Camden, London





Above: A biodiverse roof in Islington, London



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