TECTICOLOUS INVERTEBRATES

A preliminary investigation of the invertebrate fauna on green roofs in urban London

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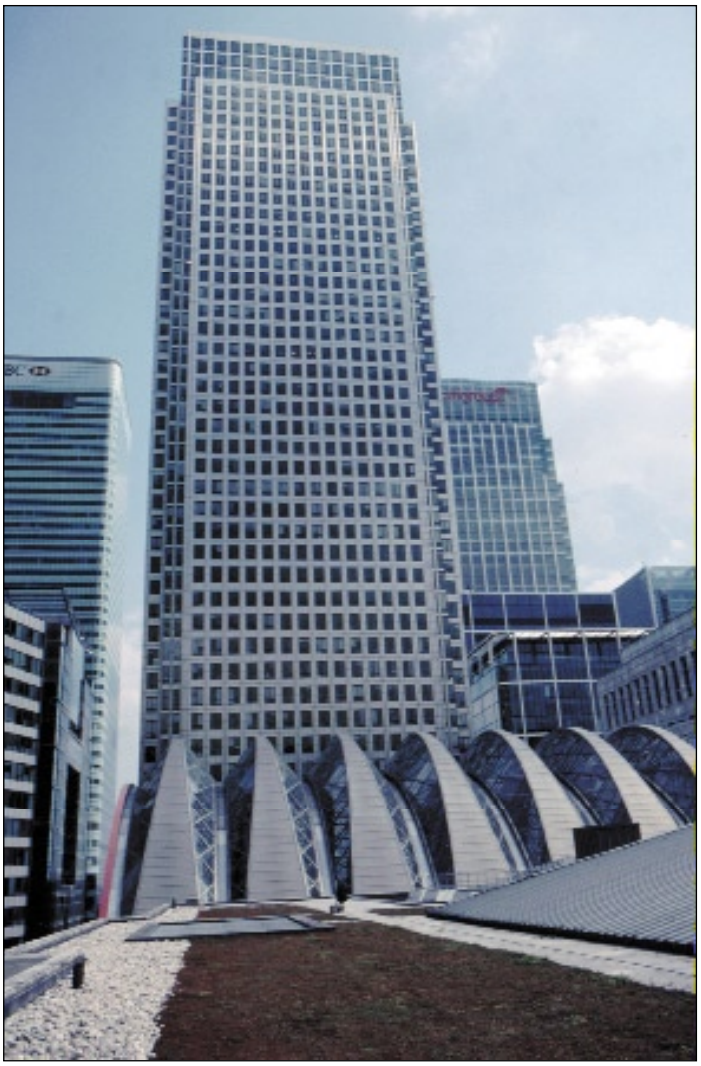

Roof of Canary Wharf Retail Building, looking towards the tower block of 1 Canada Square, showing some of the *Sedum* matting that covers one of the most extensive ecoroofs in London.

In an interesting booklet on the roof plants of East Anglia, botanist Ron Payne coined the term ***tecticolous*** (from the Latin *tectum*—a roof) analogous to the similar terms rupestral for plants growing on rocks and viatical for plants growing on roads.

CONTENTS

SUMMARY

— An invertebrate survey of eight green roofs in urban London was commissioned by English Nature.

— Two site visits were made to each ecoroof during 2002, in May and September.

— 136 invertebrate species were recorded, a relatively low species number.

— Uniformity of substrate, low plant diversity and virtually no variety in plant architecture contributed to the low number of invertebrate species recorded.

— However, many of these invertebrates are species adapted to harsh dry conditions and which are obviously benefiting from the peculiar habitat afforded by the roofs.

— Several very unusual and uncommon species were found that have not otherwise been recorded in the London area and which, it would seem, have taken advantage of a new type of habitat in the capital. These included:

Anthicus angustatus, a nationally scarce 'ant' beetle normally found on sandy shores or in salt marshes

Tachys parvulus, a nationally scarce ground beetle normally found in gravel pits or on exposed shingle

Olibrus flavicornis, a nationally rare flower beetle which feeds on autumnal hawkbit, a flower of urban brownfield sites

Oxypoda lurida, a nationally scarce rove beetle normally found in gravel pits or on exposed coastal shingle

Chlamydatus evanescens, a nationally rare plant bug which feeds on stonecrops and previously only known from the North Wales coast, and Staffordshire

Erigone aletris, a very local money spider, a recent colonizer of the UK and previously only known from East Lothian, Fife and Lincolnshire.

Pardosa agrestis, a nationally scarce wolf spider usually found in chalkpits, claypits and undercliff.

— Green roofs in urban London are providing a very useful and extremely interesting habitat for invertebrates and the environment benefits from their presence.

INTRODUCTION

Parks, gardens and open spaces have been an important part of urban planning for centuries. The grandeur of the architecture that characterizes our cities is softened and enhanced by these green spaces. Depending on the history of the land and the fashions of the day, these green spaces may be the large formal ornamental gardens of palaces or royal parks or the small varied plots attached to individual private dwellings. They may be remnant pockets of countryside enveloped by urban expansion or newly created nature parks on derelict land. Whatever their history, these green places echo, for urban dwellers, the nature in which humans have long found solace.

In an era of Earth summits, biodiversity action plans and fears of global warming, there is a growing environmental awareness. These urban open spaces are now being recognized, not just for their aesthetic form and setting, but for their potential as valuable wildlife habitat. With increasing pressure on land for housing, it has become official government policy that brownfield sites should be targeted for development. And yet also increasing is an awareness that many designated brownfield sites are rich in wildlife too, and worth preserving. This conflict, between the need to develop what many regard as merely derelict land and the need to provide urban wildlife habitat, is governed by many factors—financial pressures being not the least. But as new buildings are erected some pressure is now being brought to bear on developers to act at least sympathetically with regards to the environment.

Green roofs, also sometimes called ecoroofs, have been heralded as important and innovative design features likely to have great benefit in urban areas (Grant *et al*., 2002). They are proclaimed to alleviate problems with rain water run-off, absorb air pollutants, dust and noise, reduce heat loss from the buildings, and provide new wildlife habitat.

Sixteen percent of Greater London, 24 000 hectares, is covered with buildings (Anon, 2002) and therefore roofs. This is an area 28 times the size of Richmond Park. At present an insignificant proportion of London's roofs are 'green'. On the Continent, roof greening is being led by countries such as Germany where, for example, 10–11 million m^2 of green roofs were installed in 1997 (Hammerle, 1998, quoted by Grant *et al.,* 2002).

Intuitively, any 'green' roof can be reckoned to provide wildlife habitat, on the grounds that at least some soil and plant cover on a roof is better than what would otherwise be sterile bare concrete, tarmac or tiles. However, the quality of that habitat is still poorly understood. By the same premise, a small private garden provides some wildlife habitat whereas a tarmac car-port, concrete patio or block-paved driveway does not. But many urban gardens actually have rather mundane wildlife habitats, with close-mown lawn and bland herbaceous borders planted with non-native flowers. It is perhaps ironic that at a time when wildlife gardening (and gardening in general) is so popular, it is poorly tended gardens, derelict land and rubble-strewn post-industrial sites that provide some of the the best wildlife habitat in our towns and cities.

This invertebrate survey was commissioned by English Nature to add to the body of knowledge on green roofs, and to assess exactly what ecological interest they might possess.

METHODS

Site descriptions and visits

Seven roof sites were initially selected as suitable for study. Each was visited once in spring and once in late summer. An additional site was visited only once, in late summer.

11 Shaws Cottages, Perry Rise, Forest Hill

The private house of Jon Broome, the architect of the building, this single-storey house has both flat and pitched roofs, totalling about 250 m^2. It was constructed in 1993.

Part of the roof, pitched at about 35º north-facing (Figure 1), was covered with turf cut from the garden of the existing plot when the building was constructed. The turf was laid grass-side down to give a sod covering of about 50 mm, but was later seeded with a proprietary grass seed mix. Other areas were variously covered with a gravel/soil mix and chalk rubble/soil mix (Figures 2–4). This was part of a conscious decision to give the roof varying habitats for plants and wildlife. A proprietary wildflower seed mix was also added to the roof and a few plants of biting stonecrop

Figure 1. Rear pitched roof of 11 Shaws Cottages, showing the relatively lush growth of long grass and herbs.

Figure 2. Some of the flat areas of roof at 11 Shaws Cottages.

Figure 3. Shallow pitched roof area at 11 Shaws Cottages. There are areas of bare gravel and soil.

Figure 4. Flat area of roof at 11 Shaws Cottages showing the proximity of garden trees.

Sedum acre and reflexed stonecrop *Sedum reflexum* from the existing garden were planted in various places on the roof. Since it was constructed very little 'gardening' maintenance has been done to the roof which has been allowed to develop more of less naturally (J. Broome, personal communication).

The steeply pitched roof is covered by relatively lush grass growth. Flat areas with gravel/soil mix are dominated by moss *Tortula muralis,* reflexed stonecrop *Sedum reflexum* and fat-hen *Chenopodium album.* A slightly pitched roof with chalk/soil mix is dominated by dove's-foot crane's-bill *Geranium molle,* moss *Tortula muralis,* fat-hen *Chenopodium album* with small patches of stonecrop *Sedum* species and with some extensive bare areas.

11 Shaws Cottages is situated at grid reference TQ362723, in vice-county 16, West Kent. Visits were made on 22 May and 16 September 2002.

London Wildlife Garden Centre, Marsden Road, East Dulwich

The London Wildlife Trust runs the centre as a garden shop, education centre and community garden. The single storey building has two pitched roofs: a narrow veranda-style roof over the front walkway pitched at about 20º south-facing and the main roof (Figure 5) pitched at about 20º north-facing. The total roof area is about 100 m^2.

The building was constructed in 1992 and was originally covered with garden-style turf. The turf failed, probably because the soil substrate was too shallow and drainage too great. It shrivelled, browned and started to die. Constant watering was regarded as unsatisfactory and contrary to the original ethos of a sustainable building design. In 1993, the turf was broken up and left *in situ.* Some compost was added and the whole roof was planted with plugs of reflexed stonecrop *Sedum*

Figure 5. Gently pitched main roof of the London Wildlife Garden Centre showing the more or less uniform *Sedum* growth.

Figure 6. Close-up photograph of the dense *Sedum* growth on the roof of the London Wildlife Garden Centre.

Figure 7. Front verandah-style roof running along over the entrance walkway of the London Wildlife Garden Centre.

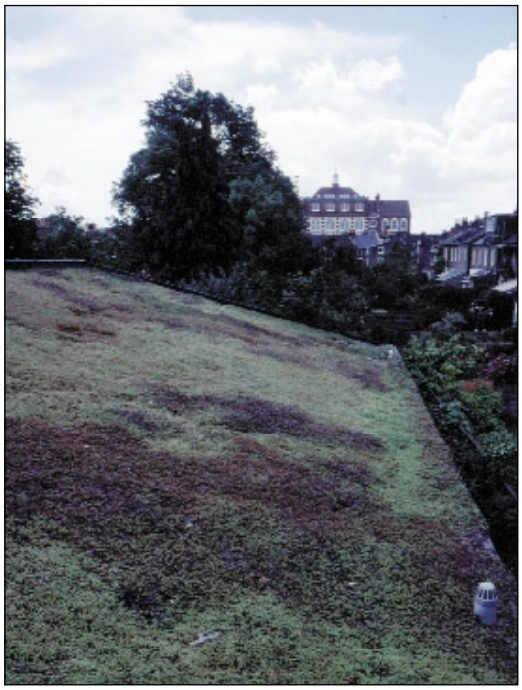

Figure 8. Rear roof of the London Wildlife Garden Centre. This is very similar to the view of the Centre from neighbouring houses.

reflexum and biting stonecrop *Sedum acre* at a density of about 2 plants per m^2. Some of the plants came from the Centre's own stock, some were bought at other garden centres in the area.

Both roofs are now dominated by an almost 100% mat-like cover of the stonecrops (Figures 6–8). House-leek *Sempervivum tectorum* and thyme *Thymus* species did not survive. Occasionally sycamore seedlings are cleared from the roof and there has been some dead-heading of *Sedum* plants if the entrance to the building was thought to be looking a bit untidy. At the time of the visit in September 2002, one corner of the roof was in danger of being invaded by Virginia creeper *Parthenocissus* species, but this was due for cutting back clear of the roof in the near future. In very hot summers the roof would sometimes be watered a little, but this was not necessary in 2002 (H. Firminger, personal communication).

The London Wildlife Garden Centre is situated at grid reference TQ338755, in vice-county 17, Surrey. Visits were made on 22 May and 16 September 2002.

The Calthorpe Centre, Grays Inn Road, King's Cross

The Calthorpe Centre is a community centre and community garden. The single-storey building was erected in 1991 and the flat roof of about 120 m^2 was laid out with a gravel/soil mix about 80 mm deep into which were planted cores of stonecrop, *Sedum* species.

Since construction no 'gardening' has been carried out and the roof has been allowed to develop naturally (L. Gates, personal communication). Various grasses and herbs have since become

Figure 9. General view of the Calthorpe Centre, Grays Inn Road, looking north.

Figure 10. View of the Calthorpe Centre looking south down Grays Inn Road.

established, including chives *Allium schoenoprasum* and viper's bugloss *Echium vulgare.* There are still extensive bare areas (Figures 9 & 10).

The Calthorpe Centre is situated at grid reference TQ307826, in vice-county 21, Middlesex. Visits were made on 27 May and 18 September 2002.

The Soanes Centre, Tower Hamlets Cemetery Park, Mile End

The Soanes Centre is a visitor centre and information point for people visiting the Tower Hamlets Cemetery Park. The single-storey building was constructed in 1993 when its flat roof of about 150 m^2 was covered with a substrate mix of crushed brick and concrete, minimal (about 10% composted bark provided by Erisco-Bauder Limited (R. Everitt, personal communication), but no soil, about 85 mm deep. At first it was seeded with a proprietary mix of various herbs and grasses. For the first 3 or 4 years, additional seeding was carried out on an experimental basis, using plants of chalk downland. At the same time, small cores were planted of house-leek *Sempervivum*

Figure 11. General view of the Soanes Centre, Tower Hamlets Cemetery Park, looking north.

Figure 12. Salad burnet, *Sanguisorba minor,* on the roof of the Soanes Centre.

Figure 13. Roof of the Soanes Centre, looking south, showing the large areas of bare gravel and sparse vegetation

Figure 14. A garden pink, *Dianthus* species on the roof of the Soanes Centre.

Figure 15. A garden pink, *Dianthus* species on the roof of the Soanes Centre.

Figure 16. Roof of the Soanes Centre, looking north-east, over the tombs and gravestones of the Tower Hamlets Cemetery Park.

tectorum, biting stonecrop *Sedum acre* and white stonecrop *Sedum album,* taken from the local area where they grow on graves and tombs in the cemetery (T. Lyle, personal communication).

Since construction little 'gardening' has been done, but occasionally sycamore seedlings have been removed (T. Lyle, personal communication). There are still extensive bare areas (Figures 13–16) and herbs include kidney vetch *Anthyllis vulneraria,* salad burnet *Sanguisorba minor,* maiden pink *Dianthus deltoides,* Deptford Pink *Diantus armeria,* campion *Silene* species, viper's bugloss *Echium vulgare,* small scabious *Scabiosa columbaria* and the stonecrops *Sedum* species.

The Soanes Centre is situated at grid reference TQ367824, in vice-county 21, Middlesex. Visits were made on 27 May and 18 September 2002.

Canary Wharf, Docklands

Three different roofs were examined at the Canary Wharf complex of buildings. The large modern buildings of Canary Wharf are offices and a shopping centre. The roofs are all flat and covered with a proprietary rubber matting impregnated with *Sedum* plants. The rubber matting, which has a depth of only about 20 mm, is delivered to the site in rolls and laid out much like a fitted carpet. Walkways are of concrete paving slabs and some roofs are decorated with large pebbles and stones around the edges (Figures 17–19).

Figure 17. *Sedum* matting on Canary Wharf 1, with decorative stones around the edge.

Figure 18. Roof of Canary Wharf Retail building, looking towards the tower block of 1 Canada

Figure 19. Typical section of the *Sedum* matting on Canary Wharf 1, with concrete paving slab pathways, pebble edging and air vent.

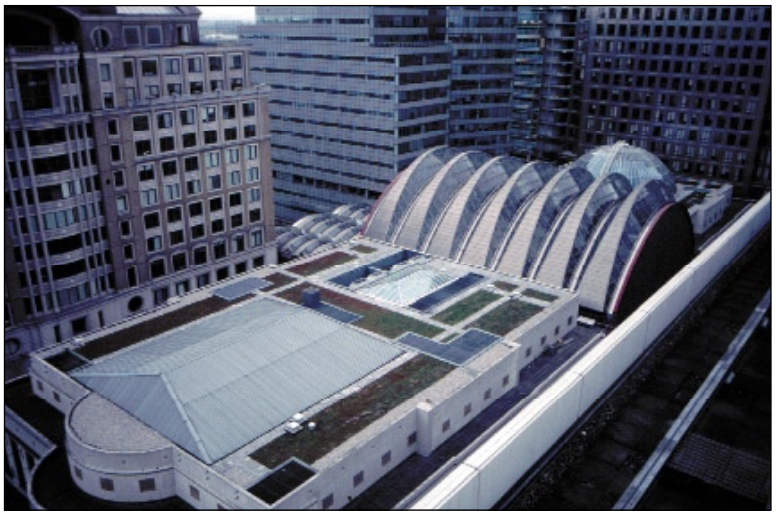

Figure 20. General view of the Canary Wharf Retail building, as seen from Canary Wharf 1.

Figure 21. Close up of the *Sedum* matting used throughout the Canary Wharf roofs.

Figure 22. *Sedum* matting on Canary Wharf Retail building looking west toward The City.

Canary Wharf 1, also called 20 Cabot Square or building number FC4, is about 800 m^2 in extent and the *Sedum* matting was laid in June and July 2000. The roof is at a height of about 50 m, on top of a 14-storey office block (Figures 17 & 18).

Canary Wharf Retail, also called Cabot Place, is about 250 m^2 in extent and the Sedum matting was laid in June and July 2001. The roof is at a height of about 25 m and covers the Canary Wharf shopping centre close to Canary Wharf 1 (Figure 20).

Figure 23. Roof of Canary Wharf LUL building looking approximately south.

Figure 24. Roof of Canary Wharf 1 showing particulate desposits on the *Sedum* near one the fume vents.

Canary Wharf LUL (London Underground Limited) is about 650 m^2 in extent and the *Sedum* matting was laid in June and July 1999. The roof is at a height of about 50 m, on top of the 14-storey offices of London Underground Limited. It is almost exactly adjacent to Canary Wharf 1 (Figure 23).

The *Sedum* matting was supplied by a commercial firm, Erisco-Bauder Limited. The matting for Canary Wharf Retail was imported from Poland. The other two roofs had matting grown at the firm's farm in East Anglia, but were grown on or near substrate (a light-weight soil) imported from Germany. Seeds come from all over the world and change every year (D. Wheals, personal communication). *Sedum* species used for the Canary Wharf roofs included: *S. album, S. acre, S. reflexum, S. spurium, S. pulchellum, S. sexangulare, S. hispanicum* and *S. kamtschaticum* together with *Saxifraga granulata.*

The roofs of Canary Wharf are dominated by a mixture of the *Sedum* species giving a more or less uniform (100 %) carpet-like (Figure 20) appearance when viewed from nearby buildings.

Figure 25. Close-up photograph of *Sedum* matting on Canary Wharf Retail building showing some bare areas.

Figure 26. *Sedum* plant growing out from between the paving stones on Canary Wharf roof, indicating that the *Sedum* is self-seeding itself on the roofs.

Part of the rationale for the roofs' design was aesthetic, since the buildings are overlooked by the neighbouring skyscraper, 1 Canada Square (Figure 18), and others now under construction. Consequently, the roofs are fairly intensively managed. Any areas where the *Sedum* becomes patchy are repaired with new sheets of impregnated matting. Different rolls of matting have slightly different characteristics and the 'joins' can sometimes be seen (Figure 27). The *Sedum* is flourishing in most places (Figures 22–25) and a few self-seeded plants are already sprouting through the paving stones (Figure 26).

Even though the Canary Wharf buildings are very high and surrounded by intense building development, the ability of plants to colonize these habitats is clearly demonstrated by the variety of other plants becoming established there. Some self-seeding plants such as chives *Allium schoenoprasum* and garden pink *Dianthus* species, are tolerated but grasses, groundsel *Senecio vulgaris* and *Buddleja* and the occasional willow are vigorously weeded out (A. Butcher, personal

Figure 27. *Sedum* matting on Canary Wharf Retail showing clear boundary between different rolls, probably as a result of subtle differences in drainage.

Figure 28. Sow thistle plant growing out from the decorative pebbles on a Canary Wharf roof.

Figure 29. Bellflower, *Campanula* species, growing between paving stones on the Canary Wharf LUL building.

Figure 30. Chickweed growing in the *Sedum* matting on a Canary Wharf roof.

communication). Other obviously self-seeded plants included yarrow *Achillea millefolium,* shepherd's purse *Capsella bursa-pastoris,* sow-thistle *Sonchus* species (Figure 28) and a single bellflower, *Campanula* species, growing out from between the cracks of the paving stone pathway (Figure 29).

Although all three Canary Wharf roofs are on separate buildings, they are so close together that they have more or less the same grid reference TQ374804, in vice-county 21, Middlesex. Visits were made on 28 June and 4 September 2002.

90 Grove Park, Camberwell

This two-storey private house was built in 2001 and the flat roof of about 80 m^2 has a covering of about 50% Erisco-Bauder matting containing *Sedum* species and other low plants (Figures 31–33). No 'gardening' has been carried out and the roof left to develop naturally. It is still dominated by *Sedum, Saxifraga* and *Allium* species.

The house is situated at grid reference TQ334762, in vice-country 17, Surrey. A single visit was made on 6 September 2002.

Figure 31. General view of the roof of 90 Grove Park, Camberwell.

Figure 32. General view of the roof of 90 Grove Park, Camberwell.

Figure 33. Close-up of the *Sedum* matting used on the roof of 90 Grove Park, Camberwell.

Location and collection of specimens

It was realized well in advance of the site visits that standard use of a sweep net would be inappropriate because the plant layer on most roofs was only a few centimetres high and impossible to sweep. Therefore a 'suction sampler' was used on all roofs (Figures 34 & 35).

A suction sampler is an adapted domestic garden 'blowervac'. Powered by a small two-stroke engine, these machines are used to first blow fallen autumn leaves into a heap and then to suck them up and mulch them into a soft compost. Their use for studying insects was first given serious thought to study leafhoppers in grassy places (Stewart & Wright, 1995). They have subsequently been used to study small insects in the short grazed sward of chalk downland and elsewhere.

There are many makes and models on the market and for this study a McCulloch BVM 240 machine was used. To collect invertebrates, a muslin bag is firmly fitted over the air intake spout

with a large jubilee clip. Using the suction mode, the spout is then pushed into the plant layer and the vacuum is enough to lift invertebrates and trap, them by the pressure of the rushing air, in the bag. The machine is then turned off and the contents of the bag emptied out onto a large plastic sheet for examination.

Earlier ad-hoc experiments showed that a collection time of about 1 minute, lifting the spout up and pressing it down into the herbage about once a second, generated a good sample through which to search. This approximately uniform sample method was used on all occasions, the number of samples depending on the size of the roof and varying from three samples at 90 Grove Park to about 15 on the large Canary Wharf roofs.

If the opportunity arose specimens were noted by more conventional means, by sweeping with a sweep net, visual searching and finger searching in the plant layer. Voucher specimens of all but the most common and characteristic species have been kept.

Figure 34. Using the suction sampler on the roof of Canary Wharf.

Figure 35. Using the suction sampler on the roof of the Soanes Centre, Tower Hamlets Cemetery Park.

Taxonomic coverage

The survey concentrated on the following major groups: Coleoptera (beetles), Hemiptera (bugs, froghoppers etc) and Aranaea (spiders). A few examples of other groups were also noted.

Health and safety

Use of the suction sampler was not, in itself, regarded as compromising personal safety. The machine is manufactured, marketed and sold as a domestic garden leaf-blower and vacuum mulcher, for use in ordinary gardens by untrained personnel. The owner's handbook states obvious and straightforward safety requirements, particularly with regard to flammable fuel, sensible clothing, noise and vibration. All safety protocols were followed during use.

According to the manufacturer's instruction manual, the 50-cc machine conforms to EC and US standards regarding construction, power output, electromagnetic emissions, noise and vibration. The main safety issues are care when fuelling the machine, safety distance of about 10 m to other people or animals when starting up the machine (so as not to startle or offend), standard ear protection during use, correct storage and regular maintenance of the machine. A high-visibility reflective jacket was also worn, to reassure members of the public that what might be seen as the rather unorthodox behaviour of hoovering the ground was somehow 'official'.

None of the open roofs had specified health and safety risks. Access to all of them was either by built-in stairs and steps or by ladder. Most of the large high roofs of Canary Wharf have standard safety rails around them, but on the Retail building which lacked them, all work was carried out more than 2 m from any roof edge. Visits to pitched roofs were all during fine dry weather when there was no risk of slipping. All visits were arranged beforehand with the owners or managers. Special care was taken at all times to prevent damage to any of the roofs and to avoid any personal danger.

SURVEY RESULTS

General

A systematic list of 136 invertebrate species is given, together with various comments on their statuses, habits and distribution, at the end of this report. They represent:

Coleoptera (beetles)	51 species
Diptera (flies)	9
Hemiptera (bugs)	25
Hymenoptera (bees, wasps etc)	9
Lepidoptera (butterflies & moths)	1
Orthoptera (grasshoppers etc)	1
Collembola (springtails)	1
Aranaea (spiders)	31
Acari (mites)	1
Isopoda (woodlice)	3
Chilopoda (centipedes)	1
Mollusca (snails)	3
Total	136

For the level of recording activity, one hundred and thirty-six species is a rather poor list, but this is not really surprising given the strange nature of the sites and the harsh habitat they present. Plant diversity and plant architecture was extremely limited. Most of the species were common insects and spiders, known to occur widely throughout southern England, but the appearance of a number of unusual and uncommon species demonstrates that ecoroofs offer great potential as a new and interesting habitat.

In a very interesting booklet on roof plants in East Anglia, (Payne, 2000) the author struggled to find a suitable technical term to denote roof-dwelling plants. With the help of a colleague, P. Oswald, he coined the term 'tecticolous' (from the Latin *tectum* — a roof) analogous to the similar terms rupestral for rock-growing plants and viatical for road-growing species. I have adopted this term and its derivative 'tecticole' for invertebrates living on roofs.

Noteworthy species

The following species are picked out as being especially noteworthy. Most are uncommon nationally. Criteria for allocation of accepted 'nationally rare' (red data book) and 'nationally scarce' (notable) statuses are varied and complex (Hyman & Parsons, 1992, 1994 etc). However, a brief summary is given here.

Endangered (RDB-1). The rarest taxa. Taxa in danger of extinction in Great Britain; species with very few recorded localities or living in especially vulnerable habitats.

Vulnerable (RDB-2). Very rare species. Taxa likely to move into the RDB1 category; species declining in their range.

Rare (RDB-3). Rare species. Taxa with small populations and which are at risk; species estimated to occur in 15 or fewer of the 10-km squares in the national Ordnance Survey grid since 1970.

Rare, but insufficiently known (RDB-K). Species thought to be very rare in Britain, recorded from less than 15 of the 10-km squares of the national Ordnance Survey grid since 1970, and which warrant RDB classification of some sort, but for which there is a recognized lack of accurate information.

Nationally scarce (notable A). Very local species, thought to occur in 16 to 30 of the 10-km squares of the national Ordnance Survey grid since 1970.

Nationally scarce (notable B). Very local species, thought to occur in 31 to 100 of the 10-km squares of the national Ordnance Survey grid since 1970.

Nationally scarce status is sometimes not subdivided into categories A and B, (notable, occurring in 16 to 100 10-km squares).

The following is a list of some of the more interesting, unusual and noteworthy species taken during the survey.

Coleoptera — beetles

Anthicus angustatus Curtis, a small 'ant' beetle (family Anthicidae). Two specimens of this beetle were found on the roof of the Soanes Centre, Tower Hamlets Cemetery Park, on 27 May

2002. Status: nationally scarce (notable B, Hyman & Parsons, 1992). Named for their ant-like appearance of narrow thorax and broad triangular head, ant beetles are quick and active and live under the herb layer at ground level. *Anthicus angustatus* is recorded from a few localities spread across England, but is extremely scarce, usually occurring on sandy shores and probably also in saltmarshes. It is usually found in or on bare sand with little or no vegetation where it is thought to feed on decaying plant material. This is the first time the beetle has been recorded in the London area.

Helophorus nubilis (Fabricius), a 'crawling water beetle' (family Hydrophilidae). Three specimens of this beetle were found on the roof of the Canary Wharf Retail Building, on 28 May 2002. Status: very local. Most of the 20 British species of *Helophorus* are found at the edges of lakes, ponds and streams where they crawl in the mud and inundated vegetation. They are sometimes called 'crawling' water beetles to distinguish them from the true water beetles in the family Dytiscidae. *Helophorus nubilis* is one of three British species that are not aquatic, indeed this species is usually associated with sandy or clay soils, on open sunny or on cultivated land. It is found at the roots of plants, in decaying vegetable matter. Although widespread in Britain, it is rather scarce and this is the first time I have ever found the insect.

Olibrus flavicornis (Sturm), a flower beetle (family Phalacridae). One specimen of this beetle was found on the roof of the Soanes Centre, Tower Hamlets Cemetery Park, on 27 May 2002. Status: nationally rare but insufficiently known (red data book status K, Hyman & Parsons, 1992). This beetle is associated with autumn hawkbit *Leontodon autumnalis,* and possibly with other species in that and related genera. The larvae are thought to develop in the flower heads, while the adults feed on pollen. At the time of the national review of beetles (Hyman & Parsons, 1992), this species had not been seen since it was recorded in 1950 from Camber in East Sussex. However, it has recently been recorded fairly frequently in the London and Thames Valley region, particularly on the flowery brownfield post-industrial sites that now characterize the area (Jones, 1998, 2000). It remains, nevertheless, a very rare species in Britain.

Oxypoda lurida Wollaston, a rove beetle (family Staphylinidae). One specimen was found on the roof of the Calthorpe Centre, Grays Inn Road, on 27 May 2002. Status: nationally scarce (notable, Hyman & Parsons, 1994). Since it was first recognized as a British species in 1937, this scarce beetle has been found in only a few localities in the southern England (Hodge & Jones, 1995). It is usually associated with areas of open ground and is mainly recorded from grassland, coastal shingle, sand and gravel pits. Its precise life history is unknown but it is usually found in decaying organic material, on which it probably feeds. Small rove beetles are a sorely under-recorded group, but it is thought to be the first time that this species has been recorded in the London area.

Tachys parvulus Dejean, a small ground beetle (family Carabidae). This ground beetle was found on the roofs of The Calthorpe Centre, Grays Inn Road on 27 May 2002 (1 specimen), Canary Wharf 1 on 28 May 2002 (1 specimen) and the Soanes Centre, Tower Hamlets Park Cemetery on 27 May 2002 (4 specimens) and 18 September 2002 (many specimens seen, 4 collected). Status: nationally scarce (notable B, Hyman & Parsons, 1992). This very small beetle is recorded from only a few widely scattered localities in England and Wales. Like other

species in the genus, *Tachys parvulus* is a predator of other small invertebrates and is associated with river shingle, the margins of lakes and gravel pits where there are areas of bare ground and only sparse vegetation. It is mainly known from coastal sites, but does occur inland. This is the first time the beetle has been recorded in the London area. Ten years ago it was recorded from a garden path in Northamptonshire and a paved area in a garden in Bedfordshire (Welch, 1992). The implication was that it might be regarded as a patio species. Its appearance on three widely separated urban London roofs and in considerable numbers on one of them demonstrates that this species has found a very suitable niche on ecoroofs (Jones, 2002a).

Hemiptera — true bugs

Chlamydatus evanescens (Boheman), a leaf bug (family Miridae). This species was recorded from both Canary Wharf 1 (1 specimen) and Canary Wharf Retail (3 specimens) on 4 September 2002. Status: nationally rare (red data book category 3, Kirby, 1992). This very rare species has previously only been recorded from three localities in Britain: Colwyn Bay, Denbighshire (in 1890), a few miles away near Conway, Caernarvonshire (in 1924) and Dovedale, Staffordshire (in 1930 and 1936). The Colwyn Bay site was destroyed by development at the beginning of the 20th century, and the bug has not been rediscovered at the other sites (although no extensive search for the bug has been carried out). *Chlamydatus evanescens* feeds on stonecrops and although, in Britain, it has only been found on *Sedum acre* growing on limestone, on the Continent it is known from other *Sedum* species growing on sandy soils. Given the Polish and German source of *Sedum* matting and substrate for the Canary Wharf roofs, it is quite possible that specimens of this species have been imported from the Continent. But whatever its origin, it has a yearly life-cycle so the specimens found during this survey are part of a home-grown population indicating that the roof habitat here is suitable for its survival.

Chlamydatus saltitans (Fallen), a leaf bug (family Miridae). Single specimens of this bug were found on each of the three Canary Wharf roofs: Canary Wharf 1 on 28 May 2002, Canary Wharf Retail on 4 September 2002 and Canary Wharf LUL on 28 May 2002. Status: local. This is a fairly widespread species, known throughout Britain. Its precise life history and foodplants are unknown, but it is usually found in areas of bare ground and sparse vegetation. Likely foodplants are reported as knotgrass *Polygonum aviculare,* stork's-bills *Erodium* species and clovers *Trifolium* species (Wagner & Weber, 1964). The bug has two body forms — macropterous (long-winged) and brachypterous (short-winged). Until now, only brachypterous specimens have been recorded in Britain. The specimen from Canary Wharf 1 is macropterous, the first time this form has been found in the UK. As with *Chlamydatus evanecens* above, given the Polish and German source of *Sedum* matting and substrate for the Canary Wharf roofs, it is quite possible that specimens of the long-winged form of the bug has been imported from the Continent. Whatever its origin, like *C. evanescens,* it has a yearly life-cycle so the specimen found during this survey is from a home-grown population indicating that the roof habitat here is suitable for its survival.

Aranaea — spiders

Erigone aletris Crosby & Bishop, a money spider (family Linyphiidae). Three specimens were found on the Canary Wharf roofs on 28 May 2002. Status: naturalized, very local (Harvey *et al.,* 2002). This spider, thought to be a native of the North American coast, was first recorded in Britain in 1976, from East Lothian. Since then it has spread around the Edinburgh area, on the north and south coasts of the Firth of Forth. In 2001 it was found near the town of Whitton in North Lincolnshire. The discovery of specimens on Canary Wharf represents a significant extension to the animal's known range. It has been suggested that the spider arrived in Scotland through the docks at Leith on ships from the USA. Whitton lies on the River Humber just a few

miles inland from Hull and the spider could also have arrived here by ship. To date the species has not been found on Continental Europe so it seems likely that it arrived by ship to London and has made its own way onto the Canary Wharf roofs, rather than being imported with the *Sedum* matting from Poland. Many specimens of this spider were also found on the Canary Wharf roofs by Kadas (2002) who also recorded it from the ecoroof of Greenwich Ecology Park and from post-industrial brownfield sites at Crown Wharf and Greenwich Reach on either bank of Deptford Creek where it flows into the Thames. This spider is likely to spread and may even become cosmopolitan, however, its frequency on several ecoroofs suggests that it will be one of the species to benefit from this new niche.

Pardosa agrestis Westring, a wolf spider (family Lycosidae). One specimen of this spider was found on the Canary Wharf roofs, on 4 September 2002. Status: nationally scarce (notable B, Harvey *et al.,* 2002). This very local spider is more or less restricted to the southern half of Britain, where it seems to prefer sparsely vegetated sites such as clay pits, chalk pits, undercliff and dry banks above saltmarsh. The closely related *Pardosa purbeckensis* Pickard-Cambridge (of which *P. agrestis* was previously considered a variety) is a saltmarsh species.

Philodromus albidus Kulczyñski, a crab spider (family Thomiscidae). A single specimen of this spider was found on the roof of the Soanes Centre, Tower Hamlets Park Cemetery, on 18 September 2002. Status: nationally scarce (notable B, Harvey *et al.,* 2002). This very local spider is restricted to the southern half of England where it is sporadically found on trees or bushes at the edge of broad-leaved woodland clearings or in hedgerows. It seems an unlikely species to find a niche on ecoroofs, but there are many trees and bushes in the Cemetery and this specimen is likely to be a straggler from a nearby population. It is unusual, though, to find the species so late in the season; previously, it has only been recorded from April to August, with a peak in June.

DISCUSSION

The purpose of this survey was to examine what, if any, invertebrates were utilizing green roofs in urban London. In particular it was to address whether the species found were ubiquitous/ opportunistic species that are likely to be encountered throughout an urban environment or whether they were present because of the particular habitat and features provided by the green roof. For the latter group, the survey was to try and assess whether the green roof is likely to be a significant feature with regard to the species' breeding and foraging requirements or is simply an additional feature that complements other nearby habitat.

General

One-hundred and thirty-six invertebrate species were found on the eight ecoroofs. A simple breakdown of how many invertebrates were recorded from each particular invertebrate order, is immediately revealing.

The largest number of species (51) were beetles (Coleoptera). Beetles are arguably the most successful animals on the planet representing one-third of all known animal species. There are about 4000 species in Britain. Key to their success is the possession of hard wing-cases which protect the delicate flight wings that are folded underneath. This mechanism especially allows beetles to burrow and push under logs and stones, in grass sward and at the roots of plants. At the same time, most beetle species can (and do) fly readily to colonize new sites. Although many feed on the leaves of tall herbs, shrubs and trees, they are still very much a group of the ground layer.

With little in the way of plant architecture on the roofs, the 51 species recorded are predominantly tough ground-dwelling species, predators after other small insects and detritivores feeding on decaying organic material.

Despite the fact that flies (Diptera) represent one of the largest orders of insects in Britain, with about 6700 recorded species, only nine fly species were found during this survey. As might be guessed from their English name, flies are aerial insects. And although many breed in plant roots, in the soil, or in decaying organic matter they are very much a group of dense vegetation where the adults visit flowers or rest in the herbage, and of rich humus soils where their relatively delicate maggots are less subject to desiccation. Most of the flies recorded are likely to be merely vagrants, sitting on herbage or visiting flowers, but not really well-adapted to green roof habitats.

Many of the true bugs (Hemiptera–Heteroptera) are, like beetles, adapted to a life at the ground layer. Their delicate flight wings are also folded under protective sheath cases, but not so tough or strong as in beetles. With about 570 species in Britain, they are a relatively small group and the 20 species found during the survey indicate that many of them are at home in the green roof habitat, including some predators.

Three species of leaf bug (*Chlamydatus* species) are likely to be feeding on *Sedum* and are obviously well-adapted to green roof habitats. Five species of their sister group, the aphids and plant hoppers (Hemiptera–Homoptera) were also found, but this group are entirely plant-dependent and are mainly species of lush dense vegetation. On the visits that I made to the roofs, I was particularly struck by the apparent absence of aphids, especially since the Canary Wharf roofs had abundant 7-spot ladybirds *Coccinella septempunctata,* which are voracious aphid predators. It appears that aphids are common at some times of the year (G. Kadas, personal communication) and that my visits missed these peak periods.

The Hymenoptera (bees, wasps, ants and their relatives) is the largest order of insects in Britain, with nearly 7000 species recorded and the fact that a mere nine species were found during this survey is quite startling. However, bees foraging at the *Sedum* flowers were reported anecdotally by several of the roof owners and managers and the three bee species recorded during this survey is likely to be an underestimate. Kadas (2002) lists five bee species seen during her survey. Most noticeable for their absence were ants. A very few (less than 15 specimens in total) were found of two extremely common species. In another survey (Jones, 2002b), use of the suction sampler to assess the invertebrates of the closely mown grass of playing fields showed that although there were also very few species, ants were abundant nevertheless. Like green roofs, mown lawns and playing fields present a relatively mundane environment with low plant diversity and little variety in plant architecture, but in grassy situations ants were a much more prominent part of the invertebrate community.

Butterflies and moths (Lepidoptera) are also a large order of insects, with about 2500 species in Britain, and with their bright colours and relatively large size they are an obvious and well-known group. All British species are plant-feeders and their diversity at a site is often a direct result of the diversity of the plant species growing there. Only one moth species was recorded during the survey, likely to be merely a vagrant sheltering during the day in whatever herb growth it could find. *Sedum*, the dominant plant of so many of the roofs, is not a foodplant utilized by many moth caterpillars. In the extensive life history tables of British Lepidoptera prepared by Emmet (1991), only four moths are recorded as feeding on *Sedum* species, and one of these only on *Sedum telephium*, the garden orpine, which is not one of the species suited to green roofs.

Grasshoppers and their relatives (Orthoptera) are also a usually obvious part of any invertebrate fauna even though there are only about 30 British species. They are mainly creatures of long-

grass and deep herb growth. Only one species of grasshopper was recorded showing that they are not really at home in the unusual conditions of the green roof. The common field grasshopper *Chorhippus brunneus* was only recorded from Shaws Cottages, where long grass grows on a pitched roof about 2.5 metres above the rest of the garden.

Springtails (Collembola) are a poorly studied and difficult group with about 350 recorded British species, but they are hugely abundant in some habitats. Estimates of their numbers vary, but many hundreds of thousands per square metre are recorded. The use of a suction sampler on close-mown garden lawns and playing fields found large numbers even when plant diversity and plant architecture was low (Jones, 2002b). Very small numbers of springtails were found on two of the roofs showing that this normally common group of insects are not well adapted to the unusual conditions of the green roof.

Spiders (Aranaea) are amongst the most important invertebrate predators in any habitat. Over 600 species are known from the British Isles. Although they cannot fly, spiders are able to disperse long distances by 'ballooning'. Letting out a long strand of silk into the wind, spiderlings are often wafted hundreds of kilometres. Thirty-one species were recorded during this survey, including several uncommon and unusual species indicating that many are able to utilize the unusual habitat provided by green roofs.

Mites are usually ubiquitous in any habitat. They have a huge range of habits and include plant-feeders, gall-makers, predators and parasitoids. Only one species was found during the survey. A single medium-sized plant of yarrow *Achillea millefolium* growing on the Canary Wharf LUL roof yielded countless hundreds of thousands of a minute oribatid (beetle) mite.

About 35 species of woodlouse (Isopoda) are recorded from Britain. They represent the only truly terrestrial crustaceans, a predominantly marine and freshwater group of animals. It is generally accepted that they are constrained by mechanisms of water loss to moist habitats such as those found under logs and in leaf litter. Small numbers of only three common species probably shows that they are surviving, rather than flourishing on green roofs. Since they are all flightless, the one species more associated with drier places (the pill woodlouse *Armadilidium vulgare*) is likely to have been brought to the Canary Wharf roofs in the *Sedum* matting. The two other species were found on Shaws Cottages where they are likely to have crawled up the walls from the garden 2.5 metres below to find the relatively safe haven of long grass on the sloping roofs of the house.

A single centipede (Chilopoda) was recorded during the survey. About 40 species are recorded in Britain, mostly soil-dwelling and probably not well-adapted to life on ecoroofs. Since it was recorded from the Canary Wharf roofs, it is likely to have been brought into the site on the *Sedum* matting, however it is recognized as a species of drier habitats than many other centipedes, and a species which is regularly found in houses.

Three species of snail (Mollusca) were recorded, of about 90 terrestrial snail species known from Britain. The garden snail *Helix aspersa* was found on Shaws Cottages, where it is likely to have crawled up the wall from the garden below and found a suitable habitat in the long grass of the sloped roof. Two species found on the Canary Wharf roofs are most likely to have been brought in with the matting and are surviving in low numbers.

Invertebrate diversity on ecoroofs

Previous studies on invertebrates on green roofs (Brenneisen, 2001; Kadas, 2002) tried to

Table 1. Species numbers recorded from each roof location.

Site	Age (years)	Size (m^2)	No of species
Shaws Cottages	9	250	54
Canary Wharf (combined)	1–3	1700	48
Calthorpe Centre	11	120	35
Soanes Centre	9	150	28
London Wildlife Centre	10	100	19
Grove Park	1	40	8

determine what factors of a roof's habitat would influence the fauna. Using elaborate statistical techniques they concluded that species diversity was related to roof age, substrate depth and substrate structure. It is clear that the roofs studied in this survey (many of which are the same as those studied by Kadas) broadly follow that previous analysis.

Species numbers from each roof are shown in Table 1. The roofs which clearly fall outside of this analysis are those of Canary Wharf. Because the spider records from Canary Wharf were combined, it is not possible to determine species numbers from each individual roof, but it is obvious that the roofs of the Canary Wharf complex are huge when compared to the other buildings. Given the location of ecoroofs in an urban environment, it is likely that some understanding of their ecology could be gained using the techniques of island biogeography. One of the basic tenets of such studies is that larger islands have larger numbers of species. Added to this, since the substrate for the Canary Wharf roofs was 'cultured' elsewhere then delivered whole to the roof it is not surprising that many species would have had extended opportunity to colonize the matting before it was put onto the roofs.

The importance of green roof habitat in the urban environment

To get a measure of how important an ecoroof habitat is likely to have been to the presence of an individual invertebrate species, it is helpful to know the 'normal' habitat requirements of each species. It can then be deduced how much the unusual conditions of ecoroofs have contributed to the invertebrate's ability to adapt to this particular ecological niche.

In the systematic list at the end of this report each species has been assigned a 'tecticole' status. The word tecticole is derived from tecticolous coined (as described above) by R.M. Payne (2000) when considering plants on roofs. Fundamental to the survival of plants on roofs is the moisture-retaining properties of the substrate. Although no moisture measurements are given, it is clear from Payne's booklet that the plants found were those that can suffer prolonged drought, or annuals which sprout from seed during the wet spring weather and which have flowered and set seed before they dry out and die in the hot summer. Payne was not, after all, studying ecoroofs, but ordinary domestic or commercial structures that had been neglected to some extent.

An assumption has therefore been made that, although roofs can be wet and spongy at some times of year, a defining factor of a roof's flora and fauna is the ability of a plant or animal to survive through prolonged dry periods. The tecticole statuses have been calculated as follows.

1. Vagrant species. Species not at all associated with harsh or dry environments. Species highly unlikely to be breeding on site. Likely to be merely a lone passing individual.

2. Species not really associated with harsh or dry environments. Species likely to be a more or less chance visitor, but which might take some advantage of the roof habitat.

3. Species not especially associated with harsh environments, but which are established on site, and are so common in a wide variety of habitats that their appearance is not unexpected.

4. Mainly ground-dwelling species of grassy places in general, but which are obviously established on site, and probably rather suited to the harsh roof environment.

5. Xerophilous (drought-tolerating) ground-dwelling species of harsh environments, bare ground, sparse vegetation, hot and dry habitats, obviously well-established on site and seeming to benefit greatly from the ecoroof habitat. Some species in this category are further assigned statuses:

5*. Anticipated 'key' roof species.

5**. Especially uncommon 'key' roof species.

A cursory look at the species list confirms general comments, made above, regarding the orders of invertebrates found on roofs (Table 2). Groups found most often on roofs (beetles, bugs and spiders) have high proportions of species from grassy places in general (status 4) and xerophiles from harsh dry environments (status 5, 5* and 5**).

To take this analysis further and to give some measure of each roof's make-up of vagrant, neutral or xerophilous species, scores have then been allocated to each status:

Tecticole status	Tecticole score
1	1
2	2
3	3
4	4
5	5
5*	7

Table 2. Numbers of species of each order analysed according to the degree by which they are adapted to living in harsh dry environments

Order of insects	Total spp	Status:	1 Vagrant	2	3 Neutral	4	5, 5*, 5** Xerophilous
Coleoptera (beetles)	51		1(2%)	7(14%)	9(18%)	23(45%)	11(22%)
Diptera (flies)	9		5(56%)	4(44%)	—	—	—
Hemiptera (bugs)	25		2(8%)	2(8%)	5(20%)	6(24%)	10(40%)
Hymenoptera (bees,wasps)	9		1(11%)	—	6(67%)	1(11%)	1(11%)
Lepidoptera (moths)	1		1(100%)	—	—	—	—
Orthoptera (grasshoppers)	1		—	—	—	1(100%)	—
Collembola (springtails)	1		—	—	1(100%)	—	—
Aranaea (spiders)	31		1(3%)	2(6%)	5(16%)	9(29%)	15(48%)
Acari (mites)	1		—	—	—	—	1(100%)
Isopoda (woodlice)	3		—	—	2(67%)	1(33%)	—
Chilopoda (centipedes)	1		—	—	—	—	1(100%)
Mollusca (snails)	3		—	—	1(33%)	—	2(67%)

Table 3. Total tecticole score for each roof locality, and tecticole index (total tecticole score divided by the number of species found.

Site	No of species	Total tecticole score	Tecticole index
Canary Wharf (combined)	48	225	4.69
Soanes Centre	28	123	4.39
Calthorpe Centre	35	143	4.09
London Wildlife Centre	19	74	3.89
Grove Park	8	31	3.88
Shaws Cottages	54	188	3.48
All roofs combined	136	561	4.13

5** 10

For each of the roofs, a total tecticole score can be calculated together with a tecticole index (total tecticole score divided by the number of species present). An index of 3 or below should indicate that the roof carries species not associated with harsh dry environments. The higher the score above 3, the greater proportion of xerophilous species used to harsh and dry environments. The lower the score, the greater proportion of common species of varied habitats and vagrants. Scores for each site are given in Table 3.

At present, based upon a limited amount of data, this is a rather crude analysis, but it does confirm some basic observations.

Even though Shaws Cottages has greater invertebrate diversity in terms of the number of species, its fauna contains many common and widespread garden species that occur in a wide variety of habitat types. This is probably because some of the roof on Shaws Cottage has long grass growth much as any overgrown garden in the neighbourhood.

The roof at Grove Park had a very low index, but it is very new and very small. A single visit produced only 8 species, likely to skew any comparison with other sites.

The roofs of Canary Wharf have a very high tecticole index, probably because their height makes vagrants less likely to arrive and the extremely harsh environment favours only species adapted to this rather extreme habitat. The Canary Wharf roofs are also very large, probably allowing a greater number of species to form the invertebrate community there.

It is interesting to note that both the Soanes Centre at Tower Hamlets Park Cemetery and the Calthorpe Centre on Grays Inn Road both have a mainly gravel substrate and even after a decade or so they still have extensive areas of bare ground. This may account for their higher tecticole indexes compared to the London Wildlife Garden Centre which has an adapted soil/sod substrate with very few bare areas.

Brownfield comparisons

Throughout the study of ecoroofs there has run a tacit assumption that they might take on some of the interesting fauna at present being discovered on brownfield sites. The sparsely vegetated areas of usually post-industrial ground do not necessarily fit the popular vision of a natural idyll; they are not very green and not very rural. Nevertheless, they are becoming more widely recognized

as having wildlife importance (Jones, 2002c). Currently, 12–15% of all nationally rare (red data book) and nationally scarce (notable) invertebrates in Britain are recorded from brownfield sites, more than the proportion recorded from ancient broad-leaved woodland or calcareous grassland (Gibson, 1998). Key to the importance of brownfield sites is the sparse vegetation and extensive areas of bare ground. In this broken habitat, a well-drained substrate and lack of plant shade produce areas of very warm and dry microhabitat in which many scarce and unusual invertebrates thrive. Often these are species with more Mediterranean preferences, right on the northern or western edge of their European distributions.

In some areas, brownfield sites have replaced in importance what were previously unimproved grazing meadows or chalk downland. In the Warwickshire subregion, for example, some of the richest butterfly sites are on brownfield land (Falk, 2000). Here, the small blue *Cupido minimus* is only known from brownfield sites, the only places where its limestone-loving foodplant kidney vetch is abundant. Likewise the declining dingy skipper *Erynnis tages* is no longer found in Warwickshire greenfield sites and the green hairstreak *Callophrys rubi* only on one, but both are stable or expanding on the derelict limestone pit workings (S.J. Falk, personal communication).

The Essex and Kent coasts of the Thames Estuary have been the subject of a fairly intense study of their invertebrates (e.g. Plant & Harvey, 1997) and are now recognized for their important fauna of spiders, bees, wasps and ants (Harvey, 2000). The brownfields of urban London are uniquely sited at the focus of the funnel-shaped corridor of the Thames Estuary. As brownfield sites are developed in the London area, it has been mooted that green roofs might offer opportunities for mitigation against the loss of this important habitat by encouraging a brownfield flora and fauna to develop when the building development is complete.

However, none of the green roofs studied in this survey showed much similarity to flowery species-rich urban brownfield sites. Of the 84 named insects (i.e. excluding unidentified species), I have previously recorded 37 from London brownfield sites. These 37 were all common and widespread species of fields, parks, gardens and woodlands, with the exception of the flower beetle *Olibrus flavicornis,* a nationally rare species which has occurred in several post-industrial sites (Jones, 1998, 2000). Likewise, Kadas (2002) found little similarity between the spider faunas of ecoroofs and neighbouring brownfield sites.

The substrates of the roofs examined in this survey fell into three broad types: soil/sod (parts of Shaws Cottages, LWT Garden Centre), various gravel mixes (Soanes and Calthorpe Centres) and *Sedum* matting (Canary Wharf). Of these, the gravel roofs probably more closely resemble brownfield habitat, however, there are some important differences. Brownfield habitats are usually characterized by areas of broken concrete and brick rubble mixed, with soil, and bulldozed into undulating heaps. Despite presenting a harsh environment for plants and animals, drainage is probably not so great as in the uniformly flat and shallow (2–10 cm) substrate on an ecoroof.

Possible parallels between greenroofs and brownfield sites are based, to some extent, on the early successional state of the habitat. Brownfield sites are usually not very old and habitats have developed from large areas of disturbed ground. A flush of adventitious species—grasses and annual herbs—appear quickly, but for some years there are often large areas of bare earth. However, *Buddleja* soon invades and it does not take long for the site to become dense scrub. Ecoroofs, on the other hand, appear to retard the successional process by preventing plants becoming established. Payne (2000) comments on the evanescent nature of some roof floras. He noted that many plants grew from seed at the beginning of the season, but then died because of lack of moisture later in the year, setting back the successional state of the roof.

The construction and specifications for green roofs continue to evolve in rather an experimental

fashion and while this survey was being carried out, two ecoroofs were being constructed more specifically to mimic brownfield habitat. Roofs on the Laban Dance Centre and the Creekside Educational Trust, both in Deptford, have been covered with deeper layers of crushed brick and concrete in a conscious attempt to more closely resemble the substrate of the brownfield land that occurs there. It will be a year or two before these roofs can be studied in any detail.

Ecological benefit from urban green roofs, now and in the future

In a general study of green roofs and their potential for conserving wildlife (Grant *et al*., 2002), a list is given of 16 invertebrate species which might benefit from ecoroofs. None of these species was found during this survey of ecoroofs, nor in the parallel survey by Kadas (2002). To some extent, that list was compiled from various biodiversity action plans that had identified brownfield habitats as being important. However, as discussed above, the green roofs studied in this survey were not very like brownfields.

Nevertheless, several unusual and uncommon invertebrates are shown to benefit from existing green roofs. These are are listed in Table 4.

It also seems likely that in the future green roofs will benefit other invertebrates in the environment in almost any situation, be it high-rise commercial blocks such as Canary Wharf or small low units such as the Soanes Centre. This bodes well for the arguement that existing flat roofs, and those proposed in future developments, should be 'greened'.

Judging from this initial survey, recommendations for future green roof construction could include: using a variety of substrates (including mixtures incorporating added soil, S. Brenneisen, personal communication); varying the substrate depth across a roof and incorporating mounds and irregular undulations. Innoculating the roof surfaces with soil or spoil from the immediate vicinity containing seeds and other plant material is also likely to maintain any key local plant biodiversity and regional distinctiveness. Where green roofs are constructed to mitigate against brownfield loss, the substrate should mimic existing brownfields of crushed brick and concrete mixed with soil.

One of the hidden benefits of green roofs is that although they are often overlooked by neighbouring buildings, access to them is usually limited. Thus, although they may have bare patches and rough ruderal growth, they are seen close-up by only interested parties and are less likely to be unjustly decried as looking dirty and untidy. On the contrary, from afar they often resemble the type of gardening landscape created in rockeries and alpine gardens. Equally, they are less likely to be disturbed by trampling, unnecessary 'gardening', or defaced by litter.

It is difficult to estimate how a given green roof will evolve or change ecologically over time or how the 'brown' roofs, now under construction, will develop new floras and faunas. Future monitoring will have to be carried out to analyse these changes.

With the exception of the Canary Wharf roofs, which were regularly weeded and manicured, all the roofs in this study were allowed to develop naturally. When green roofs are more extensively used on buildings in the future (as I am sure they must), it will probably be necessary to create management plans for future owners and maintenance companies. The most important aspect of such plans is likely to be the instruction not to interfere too much; to accept the natural succession of plants (with the exception of invasive shrubs and trees such as buddleja and sycamore) and to recognize the ecological value of sparse vegetation and patches of bare ground.

Any opportunities for erecting interpretation panels and display boards should be vigorously taken

Table 4. Key species seemingly benefiting from current green roofs in urban London.

Species	Habitat preferences	Found
Beetles (Coleoptera)		
Anthicus angustatus	A nationally scarce ground beetle found on sandy shores and in salt marshes	Soanes Centre
Bembidion lampros	A ground beetle of sandy places, especially where there are areas of bare ground	Canary Wharf
Helophorus nubilis	A rather local beetle of open dry sand or clay ground	Canary Wharf
Metabletus foveatus	A ground beetle of dry sandy places, with sparse vegetation	Shaws Cottages, LWT garden Centre and Soanes Centre
Olibrus flavicornis	A nationally rare flower beetle which feeds on autumnal hawkbit	Soanes Centre
Oxypoda lurida	A nationally scarce rove beetle found on coastal shingle and in gravel pits	Calthorpe Centre
Tachys parvulus	A nationally scarce ground beetle found on gravel, shingle, patios and paths	Calthorpe, Soanes and Canary Wharf
Bugs (Hemiptera)		
Chlamydatus evanescens	A nationally rare leaf bug that feeds on Sedum in dry places with patches of bare earth	Canary Wharf
Chlamydatus pullus	A leaf bug associated with dry grassy places, with areas of bare ground	LWT Garden Centre and Canary Wharf
Chlamydatus saltitans	A local bug of dry grassy places, with areas of bare ground	LWT Garden Centre and Canary Wharf
Dictyonota tricornis	A local lace-bug of dry chalk or sand districts	Soanes Centre
Scolopostethus decoratus	A local ground bug of open sandy heaths, often under heather.	Shaws Cottages and LWT Garden Centre
Spiders (Aranaea)		
Erigone agrestis	A very local spider, a recent arrival in Britain with uncertain requirements	Canary Wharf
Meioneta rurestris	A local spider of disturbed, sparsely vegetated ground	Calthorpe Centre and Canary Wharf
Ostearius melanopygius	A local spider found on buildings, in gardens and rubbish tips	Canary Wharf
Pardosa agrestis	A nationally scarce spider of sparsely vegetated clay or chalk areas	Canary Wharf
Pseudeuophrys erratica	A local spider usually found on walls, under stones, mainly nothern	Shaws Cottages
Pseudeuophrys lanigera	A local spider usually found near houses and on roofs and walls	LWT Garden Centre
Troxochrus scabriculus	A local spider found in various dry habitats, sand dunes etc	Grove Park
Xysticus kochi	A local crab spider found in sparsely vegetated dry places	Soanes Centre

up; they will further educate the local residents, commuting office workers and the passing public in general, of the ecological value of the green roofs and brown fields in our cities.

CONCLUSION

Green roofs in urban London are providing useful and interesting habitats for invertebrates and other wildlife. Many of these invertebrates are species adapted to harsh dry or well-drained conditions and which are obviously benefiting from the peculiar habitat afforded by the roofs. Several very unusual and uncommon species have been found that have not otherwise been recorded in the London area and which, it would seem, have taken advantage of a new type of niche not available elsewhere in the capital.

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