Barking Riverside Green Roof Ecomimicry Experiment

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Identity of the organisation

Organisation: University of East London Sustainability Research Institute and Barking Riverside Ltd.

Website: www.turas-cities.eu/case_study/10

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Site identity

Site: Barking Riverside

Location: Barking Riverside, London Borough of Barking & Dagenham, UK

Specificities: Post-industrial brownfield site that supported important biodiversity now being redeveloped to provide 11,000 homes

Challenges: Conserving important brownfield invertebrate community of regional importance as part of strategic multifunctional green infrastructure. Target species included the brown-banded carder bee (*Bombus humilis*) (UK Biodiversity Action Plan Priority Species) and *Gymnosoma nitens* (RDB1) but also a wider set of species.

Status: Open Mosaic Habitat is a Habitat of Principal Importance for Biodiversity in England

Areas: Open area, Wet area, Urban area, Other artificial environment - post-industrial brownfield habitat mosaic.

Action type: Creation of ecosystems/areas, Reallocation (for another use).

Action framework: Climate change adaptation, Land planning, Biodiversity conservation, Stepping stone connectivity.

History and context

This project used an innovative ecomimicry approach to designing urban green infrastructure for the new development. Ecomimicry involves mimicking the characteristics of local ecosystems, in this case regionally important open mosaic habitat which had formed on the post-industrial brownfield site.

Designing green roofs using ecomimicry of key brownfield habitat niches provided a mechanism for conserving the biodiversity, habitat connectivity and ecosystem service provision of the brownfield site post-development. This approach also offered opportunities for local communities to reconnect with nature, and the industrial heritage of the site, promoting engagement, ownership and enjoyment.

Novel green roof designs were developed and tested on site and were successful in supporting the regionally important biodiversity associated with the site prior to development. The results are being fed into innovative green infrastructure design that will be rolled out more broadly across the site as wider redevelopment continues. Embedding regional context into green roof design enabled alleviation of location-specific issues caused by urbanisation of the site and allowed restoration of regionally typical and important habitat and ecosystems. It is hoped that such design will enable Barking Riverside site to act as stepping stone habitat (Saura et al., 2014), providing connectivity between key sites that are being conserved and protected in the region

Location of the ephemeral green roof experiment at Barking Riverside, London, UK. Image taken from Nash (2017). Plan of Barking Riverside development site in upper half of figure - ©Transport for London. Aerial image © Blom, Bing maps, 2016.

Presentation of the project

Issues and objective

Bordering the River Thames, historically the Barking Riverside site was tidal grazing marsh. The site was later drained and Barking Power Station was developed.

Following the closing down of the power station in the 1980s, the site was largely abandoned leaving the areas where pulverised fuel ash was widely deposited to develop the typical post-industrial characteristics of unmanaged and sparsely vegetated greenspace. In this state, the site supported a suite of ecosystems services and regionally important biodiversity. In 2007, outline planning permission was granted to build a new community on the site including approximately 11,000 homes, schools and transport infrastructure. The planning process recognised the value of the pre-development (pre-construction) brownfield site in terms of supporting biodiversity of significant value, in particular a regionally important invertebrate assemblage, as well as providing ecosystem services such as pluvial and fluvial stormwater management and greenspace for health and wellbeing. Such Open Mosaic Habitat is a habitat of principal importance for conservation under Section 41 of the Natural Environment and Rural Communities Act. It is habitat type that can be found on post-industrial sites following abandonment when recolonisation occurs on low-nutrient/contaminated substrates.

The slow recolonisation, combined with lack of regular management intervention, can enable nationally important assemblages to develop, particularly rare invertebrate assemblages. The mosaic can include a range of early successional habitat types (e.g. annuals, mosses/liverworts, lichens, ruderals, inundation species, open grassland, flower-rich grassland, heathland) alongside other more mature habitat types (e.g. scrub and secondary woodland with varied hydrology). This habitat has become a proxy habitat for many species associated with natural and semi-natural early successional habitat types that have been lost in the broader landscape to costal management, agricultural intensification, urbanisation, etc (e.g. heathland, wildflower-rich open grassland, soft rock cliffs, littoral zones). A range of conservation target species in the pre-development brownfield area are found like water vole (*Arvicola amphibius*), grass snake (*Natrix natrix*), black redstart (*Phoenicurus ochruros*) and marsh warbler (*Acrocephalus palustris*) along with a broad invertebrate assemblage of regional importance (including the brown-banded carder bee (*Bombus humilis*) (UK Biodiversity Action Plan Priority Species) and *Gymnosoma nitens* (RDB1) and a number of nationally rare and scarce species).

Wooden frames constructed as a base for the ephemeral wetland green roof experiment - Barking Riverside, London, UK. (©UEL SRI)

Planning consent included a requirement to conserve this biodiversity and ecosystem service value on the site post-development as part of the vision for a sustainable new community. Included in the planning conditions was the requirement for 40% of properties to have green roofs to ensure the site could continue to support key species assemblages and provide multifunctional ecosystem services. This 40% target was determined by the Local Authority during the outline planning permission application process, building on the Mayor of London guidance recommending green roofs on major developments. A key step in relation to this condition was to ensure that the designs for the green roofs on the development were multifunctional and based on regional context, both in terms of being climate-resilient and relevant to regional biodiversity of national and international conservation importance. A Knowledge Transfer Partnership was set up between the developer, local authority and local university to investigate best practice for green roof design to achieve these aims. This partnership later became part of the EU FP7 programme TURAS (Transitioning towards Urban Resilience and Sustainability) within which an experiment was established to investigate the potential for incorporating ecomimicry of locally typical and important habitats associated with the pre-development brownfield habitat mosaics present on the site into the design of the green roofs. During a scoping process, it was identified that ephemeral wetland habitats were a key microhabitat associated with the brownfield mosaic that were not being incorporated into typical green roof design in the region. As a result of this, an experiment was established to investigate whether ephemeral wetland habitat could be recreated as part of green roof design and whether this would add to the habitat heterogeneity of the roofs providing a greater diversity of niches to support biodiversity. The overall aim being to maximise the value of the green roofs in terms of providing compensatory habitat for the loss of high environmental value brownfield land.

Freight containers with ephemeral wetland green roofs on top in place for experimental monitoring - Barking Riverside, London, UK. (©UEL SRI)

The roof design took inspiration from the Open Mosaic Habitat found on the Barking Riverside site prior to development. Part of the project involved analysing invertebrate assemblages associated with post-industrial sites like the one at Barking Riverside. Key assemblages and their habitat associations were identified at these sites. An analysis was then carried out to identify which of those assemblages were already being supported by standard extensive biodiverse green roof designs. Those assemblages that were not typically recorded on green roofs were then assessed to identify which could potentially be supported by green roofs if the roof design were manipulated to provide a greater range of habitats. It was these habitat associations that were targeted for mitigation (re-creation).

Human and material resources

Nine used 20 foot freight containers were purchased as the base for the experiment. The frames for the green roof test beds were constructed out of timber. Freight containers were used as a practical solution in the absence of suitable built structures. Whilst these provided only a single storey level, their position on site, close to the river corridor, meant that they were very exposed and, thus, environmental conditions on the roof would have been similar to those experienced at higher roof levels in other locations. As such, habitat development would be expected to be typical of building roof conditions. Previous studies have demonstrated that height of roof may lead to limitation for accessibility for some groups/species. However, this is a gradated response in relation to height and species/groups, so further experimentation would be required to investigate any effect in relation to colonisation of ephemeral wetland roofs.

In terms of thermal insulation, most modern buildings have such efficient insulation that it would not be expected to impact on a green roof above. Due to the wooden construction of the green roofs, which left a space between the container and the green roof, a similar lack of direct influence would have been expected in terms of the thermal dynamics of the freight container impacting roof development. Nevertheless, roof trials would be the only way to confirm the replicability of results in other situations.

Each green roof platform was approximately 6 x 3 m and also included a waterproof membrane, geotextile filter fabric, substrate and seeds/plug plants. Edge protection was also needed because the experiment was on a live construction site and was to be regularly monitored. All materials used were standard green roof construction materials. All plant plugs and seeds were obtained by a local supplier with local provenance.

Freight containers with ephemeral wetlands green roofs with substrate installed. Barking Riverside, London, UK. (©UEL SRI)

Construction of the experiment involved:

— 2 construction workers from the Barking Riverside site 2 days to prep the ground for the experiment (levelling) and moving the freight containers into position,

— Approximately 4 days training from 2 specialist green roof construction workers from the Grass Roof company, followed by 4 workers (staff members and PhD student from UEL) working for approximately 14 days to build the green roof platforms and install the waterproofing, substrate and plants.

Monitoring was undertaken by a PhD student at UEL for two growing seasons.

Creation, restoration methods

The test platforms were built according to small green roof construction best practice and following principles for biodiverse green roof design (e.g. using varied substrate types and depths and planting with native species). The roofs were seeded with a combination of three 100% wildflower seed mixes supplied by Emorsgate Seeds (www.wildseed.co.uk) as follows: EM8F wildflowers for wetlands; EN1F special pollen and nectar wildflowers; ER1F wildflowers for green roofs. This mix was then broadcast at a rate of 2 g/m2.

Toits verts à zone humide éphémère une fois les plantes installées, Barking Riverside, London, UK. (©UEL SRI)

Seeded species comprised: *Achillea millefolium*, *Agrimonia eupatoria*, *Anthyllis vulneraria*, *Betonica officinalis*, *Centaurea nigra*, *Centaurea scabiosa*, *Clinopodium vulgare*, *Daucus carota*, *Echium vulgare*, *Eupatorium cannabinum*, *Filipendula ulmaria*, *Galium verum*, *Hypericum perforatum*, *Iberis amara*, *Knautia* *arvensis, Leontodon hispidus, Leucanthemum vulgare, Linaria vulgaris, Lotus corniculatus, Lotus pedunculatus, Malva moschata, Onobrychis viciifolia, Origanum vulgare, Plantago lanceolata, Plantago media, Poterium sanguisorba, Primula veris, Prunella vulgaris, Ranunculus acris, Reseda lutea, Rhinanthus minor, Rumex acetosa, Salvia verbenaca, Sanguisorba officinalis, Scabiosa columbaria, Silaum silaus, Silene dioica, Silene flos-cuculi, Silene vulgaris, Trifolium pratense, Verbascum nigrum, Vicia cracca.*

Wetland species plugs were planted at a density of 5 plugs per square metre. These species comprised: Achillea ptarmica, Carex dioica, Juncus effusus, Lythrum salicaria, Ranunculus flammula, Myosotis scorpioides.

The ecomimicry approach involved designing novel drainage treatments for the roofs to recreate an ephemeral wetland habitat niche - a specialised habitat of value to rare and scarce invertebrates that inhabit regionally important brownfield sites. The ecomimicry design involved the use of two substrates:

— A standard recycled brick extensive green roof substrate from Shire Green Roof Substrates Ltd (http://www.greenroofsubstrates.co.uk/).

— A novel aggregate made from recycled pulverized fuel ash (PFA) called Lytag (http://www.lytag.com/), mixed with 10% by volume green waste compost (PFA was present on the brownfield site and had contributed to its biodiversity value, therefore this substrate was designed to mimic the ground level substrate found on site pre-development).

The roof design should impose no additional constraints for the architect. The roof held no more water than a standard green roof, it merely held the water within the substrate and pools rather than within a standard drainage layer. As such, the roof would be expected to be heavier for longer periods of time than a standard extensive green roof, but the maximum loading (for which structural loading is calculated for a green roof) should be no different.

Similarly, construction costs would be similar to a standard extensive biodiverse green roof. As there was no cost associated with a drainage layer (often the most expensive part of green roof design), the cost may actually be less.

The only technical issue for architects would be related to having standing water sitting directly on the waterproofing membrane for sustained periods of time. This could, however, be avoided by manipulating the design so that water was pooled in a separate layer above a drainage layer/waterproofing membrane. Thus, if the pooling layer failed, the roof would then perform as a standard free draining green roof system. Planting was based on native species of known value on brownfield sites in the region and included a range from dry to wetland species.

Two plant species on the green roofs.. Barking Riverside, London, UK. (©UEL SRI)

Monitoring and evaluation methods

The experimental roofs were monitored for two growing seasons in 2014 and 2015. Monitoring comprised botanical surveys using a 50 x 50 cm quadrat to record species frequency and abundance and line transects to monitor plant structural development, as well as invertebrate surveys using a standard pitfall trap methodology. Each method was repeated across key habitat features on each roof, and surveys were conducted 4 times throughout each survey period to coincide with early, mid and late summer. Surveys recorded plant development (diversity and structure) and invertebrate community composition in relation to key design features (novel drainage treatment, and substrate depth and type).

The design was successful in producing a novel ephemeral wetland habitat on the green roofs and the overall design enabled a habitat mosaic of tall and short herbs, bare ground and seasonally wet areas to develop. In total 114 plant species were recorded during 2014 and 2015, comprising 36 of the planted species, and 78 species which had spontaneously colonised the roofs. Many colonising plant species were characteristic of high quality brownfield sites. Plant development was significantly different on the two substrates and cover and richness was higher on mounds.

The invertebrate community recorded on the roofs demonstrated that many of the species characteristic of the pre-development brownfield site had colonised the roofs, including a relatively high number of nationally rare and scarce species. A total of 53 species were identified from pitfall trap samples across all roofs for the target Orders Araneae, Coleoptera and Hymenoptera. This included *Scybalicus oblongiusculus* (RDB1+extinct), *Bombus humilis* (UKBAP species) and *Lasioglossum*

SRI researcher, Dr Caroline Nash, carrying out vegetation quadrat surveys on the experimental ephemeral wetland green roofs - Barking Riverside, London, UK. (©UEL SRI)

pauperatum (RDB3). In terms of enhancing the mitigation value of biodiverse green roofs, results of the monitoring indicated that adopting an ecomimicry design principle was an effective way to provide more locally-attuned green infrastructure solutions.

Description

Facilitation

For the developer, impetus for involvement in this project came from planning conditions in relation to biodiversity and SuDS combined with an overarching aim to create a sustainable development pushed by the public-private partnership of the Greater London Authority working with a private housing developer.

Funding and technical expertise/knowledge exchange to realise the project was provided to the developer via the TURAS EU FP7 project which included a research and innovation work package investigating state-of-the-art technology and processes to maximise the biodiversity and economic value of urban green infrastructure. Reporting was delivered at two levels. Firstly to the developer in terms of implications for the design of the development as a whole. Secondly to the European Commission that funded the research.

Partners

— Technical: Grass roof company (GI specialists - delivery), Green Infrastructure Consultancy (GI specialists -design), Hertalan UK (roof membrane expertise), Shire Aggregates Ltd (green roof substrate manufacturers).

— Scientific: University of East London Sustainability Research Institute

— Financial: Barking Riverside Ltd, the European Commission's DG Research and Innovation, University of East London.

Costs and financing

The approximate cost for establishing the experimental units (9 shipping containers, each with a 6 x 3 m green roof on top) was approximately €45,000. Cost for the PhD studentship was approximately €70,000 for the three year period.

Timetable

ACTION TIMETABLE

April 2014	May to October 2014	May to October 2015	Dec 2015	Nov 2017
Green roof construction completed	Green roof monitoring	Green roof monitoring	Green roof design guidance document produced	Ecomimicry PhD completion

Construction was completed in April 2014, and a two year biodiversity monitoring programme finished in October 2015.

Overall assessment

— It was possible to read the landscape and embed this into the design of green infrastructure at the site to make it locally contextualised and valuable to target biodiversity.

— Adding habitat variability created more niches for biodiversity and habitat suitable for local conservation priority biodiversity.

— Habitat provision was suitable for supporting at least some of the lifecycle requirements for a range of target conservation priority invertebrate species.

— Lots of interesting results in terms of niche partitioning, flora, invertebrate species and assemblages (including a high proportion of rare and scarce species), and birds - many of which were also associated with the pre-development brownfield state of the site

- Additional structural loading requirements for the green roof from such an approach were avoided.
- Industry standardisation of green infrastructure (e.g. green roofs) can be avoided through collaborative processes that bring local context, ecological expertise and design expertise together in projects.
- It is possible to expand the range of habitats provided by standard urban landscape design by incorporating expert ecological understanding into the design.
- Academic-industry case studies are an excellent tool for streamlining and maximising the benefits of the green infrastructure design processes.
- Green roof aggregates can be designed to mimic substrates found on the ground in the pre-development state of post-industrial sites.
- Whilst the case study was locally targeted, the principles of what were done were globally applicable.
- The broader ecosystem service functions of green roofs should not be impacted by the change in design (e.g. no obvious trade-off).
- There is often more potential for creating ecologically functioning systems and incorporating habitat heterogeneity at roof level than at ground level in cities (due to less pressure for aesthetics at roof level).
- Co-creational approaches enable better understanding between partners and better pathways to impact for academics.

The project was mitigation for what was being lost at the time of the development. The invertebrate assemblages associated with this open mosaic habitat were a key factor in the importance of the site for biodiversity and need for mitigation.

Ephemeral wetland green roof experiment after a summer rain event. Image shows the effect of manipulating the hydrological dynamics of the roofs with water pooling on the green roof in the foreground and no pooling present in the roof in the background - Barking Riverside, London, UK. (©UEL SRI)

STRONG POINTS	WEAK POINTS
— Successful partnership between research organisation and private companies — Consideration of local context — Use of local wild plant species (genetic diversity, adaptability to local conditions…) — The ephemeral wet areas amongst open flower-rich habitat that was trialed at roof level represented many of the habitat features that are typically associated with marshland areas of brownfield sites (e.g. wetland plant species, pollen and nectar sources, ephemeral wet areas)	— Short term assessment (two growing seasons) of the biodiversity transfer on green roofs (sustainability over long term?) — No specific assessment of transferability to real green roof — ...There may be a reluctance for architects to put standing water on roofs. However, it is possible to adapt design so that pooling is never directly on the water proofing membrane. — There may be concern regarding the trade-off in terms of increased risk of mosquitos. However, the roofs are designed to be ephemerally wet, rather than permanently. During the summer (the time with greatest risk of mosquito development) the roofs typically only pooled water for 24 hours following a rain event. This is generally not long enough for mosquitos to complete their development cycle. The roofs would be expected to pool for longer periods during the winter months, but this is not currently an issue for mosquitos due to the cold climate in the UK during the winter months.

IMPROVEMENTS - ADVISES

— Allow more cost and time than you would envisage at the start of the project.

— Creating sufficient replication to enable large-scale controlled experimentation.is one of the biggest challenges for urban ecology.

— Co-creational process require buy-in from all partners and independent facilitation can help all partners understand each other's aims and objectives for involvement.

— Reading the landscape is the critical first step in such ecomimicry design. Both in terms of understanding the natural features and ecosystems and in terms of understanding the ecosystem service needs of a location.

Perspectives

Continuation

The project has been relocated to the university campus where it will continue to be monitored for its biodiversity value. The university's Docklands Campus is in close proximity to the development. As such, open mosaic habitat is a key habitat in the new location also.

Monitoring will be used to create an inventory of species and change over time. The ephemeral wetland green roof and ecomimicry green roof concepts are already being embedded within London and more broadly. This included embedding design and process guidance (Connop and Nash 2016) into the Phase 2 green infrastructure masterplan for the new development at Barking Riverside.

Transposability

The exact designs used in this case study were locally contextualised and therefore are not appropriate for all locations. However, the process of feeding ecomimicry into the design of urban green infrastructure to make it locally contextualised and adapted for locally important biodiversity is universally applicable. All too often, biodiversity is an assumed benefit of urban green infrastructure with a singular or narrow purpose (e.g. SuDS, amenity space, grass verges or allotments).

However, if urban areas are to fulfil their potential in terms of providing habitats for biodiversity and opportunities for urban communities to experience nature on their doorsteps, design for biodiversity needs to be a key consideration in the development process. This project shows how academia-industry partnerships and learning-by-doing processes can help to support such targeted biodiversity-driven design.

Ephemeral wetland green roof during summer rain event - University of East London Docklands Campus, London, UK. (©UEL SRI)

Publications

— Nash, C. (2017) Brownfield-inspired green infrastructure: a new approach to urban biodiversity conservation. PhD thesis submitted to the University of East London, UK.

— Connop, S. and Nash, C. (2016) Ecomimicry for Barking Riverside: Achieving locally contextualised biodiversity-led multifunctional urban green infrastructure. TURAS report: University of East London.

— Connop, S., Vandergert, P., Eisenberg, B., Collier, M., Nash, C., Clough, J. and Newport, D. (2016) Renaturing cities using a regionally-focused biodiversity-led multifunctional benefits approach to urban green infrastructure. Environmental Science & Policy 62, Pages 99–111.

— Connop, S. and Nash, C. (2014) TURAS Milestone 8 - Barking Riverside Green Roof Experiment: Phase 2. London. Report produced for the EU FP7 project TURAS (Transitioning towards Urban Resilience and Sustainability) project by the University of East London, London, UK.

Other text references:

— Saura, S., Bodin, Ö., & Fortin, M.J. (2014). Stepping stones are crucial for species' long-distance dispersal and range expansion through habitat networks. Journal of Applied Ecology 51, 171-182.

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