GREEN DESIGN

FROM THEORY TO PRACTICE

EDITED BY
KEN YEANG AND ARTHUR SPECTOR

BEATRICE ROSENBERG DE ROTHSCHILD
ARTHUR SPECTOR
KEN YEANG
MIKE WELLS
FLEUR TIMMER
ALISTAIR CARR
MICHAEL PAWLYN
BERT GREGORY
STEFAN BEHNISCH
DAVID LLOYD JONES
THOMAS HERZOG
JOSEPH CORY
KHEE POH LAM
NADAV MALIN
STEVEN J STRONG
SIMON WOODS
ELMA DURMISEVIC
SIMOS YANNAS
MICHAEL MCDONOUGH
DOMINIC MUREN

black dog publishing

UNDERSTANDING DRIVERS AND SETTING TARGETS FOR BIODIVERSITY IN URBAN GREEN DESIGN

MIKE WELLS, FLEUR TIMMER, ALISTAIR CARR

INTRODUCTION

Anthropogenic environmental changes are now threatening societal stability and the very fabric of civilisation around the world. They are also threatening the survival of possibly half of the species on earth and the lives of millions of people. With our increasing urbanisation as a species, it is essential that we directly address these threats through the application of effective Green Design within the urban realm. A key component of this is the creation of appropriate green infrastructure. But for green infrastructure not to be a 'greenwash', lacking significant functionality, all disciplines involved in urban design need a deeper understanding and recognition of the functional performance and values of green infrastructure and how to realise them in practice. This would help to make Green Design the mainstream approach in urbanism. Within this context, it is important to increase our awareness of the role of biodiversity in the functionality of green infrastructure in urban areas and the role of urban green infrastructure in preserving biodiversity.

Slow adoption of green infrastructure-led design in mainstream urban planning has been partly due to the difficulty of quantifying the very real benefits it brings. Various sustainability rating systems exist for urban design around the world, identifying some of the important measurements and targets. New systems are constantly emerging. However, even the very latest and best systems do not fully represent and give credit to all green infrastructure functionalities.

A key goal of 'eco-urbanism' is to achieve sustainable modern urban living despite burgeoning urban populations. Success will depend on ever-increasing sophistication of approaches to the design of green infrastructure and the development of quantitative, measurable targets for such design, linked to economic valuations. Central to this is the setting of quantitative or semi-quantitative targets for urban biodiversity within green infrastructure, relating not only to the preservation and enhancement of biodiversity itself, but specifically to the goods and services that biodiversity provides.

The combined pressures of global urban population growth, unsustainable use and degradation of natural resources and climate change are compelling mankind towards innovative Green Design in the places where most of us now live and work and recreate – *our urban areas*[a].

POPULATION

Urban areas already contain more than 50% of the global human population, and are anticipated to absorb all global population growth over the next four decades (an estimated 2.9 billion people[1]) whilst also accommodating further migrants from rural areas. The number of cities of over 10 million inhabitants is expected to increase to account for over 10% of the world population by 2025[2]. Most of this growth will be in the less-developed countries. If the majority of growth were to occur in well-planned, high-density (not sprawling) cities, the associated increase in utilisation of energy and other resources and the associated increase in pollution might be greatly reduced[3-6]. In the developed world high-income city dwellers typically use less energy than equivalent suburban citizens, largely due to lower transport-related emissions[7]. Unfortunately, the majority of cities in developing countries are expanding by sprawl. However, even if this densification *were* to become the rule rather than the exception, urban life could well remain far from sustainable. Sustainability requires that the human environment be more than *tolerable*; it needs to be *favourable*, enabling people to *thrive* rather than merely exist[8-11], including the socially disadvantaged in society[12]. These facts pose key challenges for Green Design.

NATURAL RESOURCES – PRODUCTIVE LAND

A key component of the ecological footprints[b] of cities is the production and transport of food. Carbon release from ploughing of soils in intensive arable farming[13] and the general carbon footprint of modern 'industrial' agriculture are significant concerns, as are food imports. For example, 81% of the food

For bibliographical references, see page 142.

[a] The distinction between urban and rural areas is complicated and multifaceted, and varies between and even within countries. The reader is referred to the latest guidance available from the United Nations Statistics Section on this matter.

[b] Ecological Footprint of an urban area; the area of land needed to provide all the resources and services consumed and absorb all the waste produced.

Well-designed biodiverse food growing areas can have multiple functions, including notable biodiversity and social value.

consumed in London originates[c] from outside the UK with the associated carbon costs of transport, packaging[14] and 'virtual water' (which has been described as 'exporting drought'[15]).

Occasionally foreign imports can have lower carbon footprints than similar home-produced goods, but many of these cases relate to home-country production of crops out of season at high energy cost. Additionally, loss of productive land from growing city footprints is a concern at a time of such urban population growth[16]. Accordingly, many are now suggesting that we need to grow more of our food much closer to, and within, our urban areas on a sufficient scale to start creating real 'closed-loop' urban metabolisms[17, 18]. The emphasis here should ideally be on use of large-scale permaculture techniques that conserve rather than release carbon from soils and make use of the vast quantities of organic waste produced in urban areas. Examples such as Havana, Cuba where through necessity some 90% of the city's fresh fruit and vegetables are grown in local farms and gardens have been recently much-vaunted[19, 20].

There is still debate and uncertainty, however, as to what such enhanced urban and peri-urban food production could look like in decades to come and just how significantly it might contribute to the overall quantum of food consumed by urban citizens. Architectural magazines have recently been displaying many futuristic images of vertical and rooftop urban hydroponic farms[21, 22], though it is not yet clear how such installations could ever be a viable alternative to traditional agriculture, even if the high carbon releases from the latter were factored in. In Canada at least one company, Omega Garden Int., is claiming commercially viable hydroponic food production with a carbon footprint lower per unit of productivity

[c] The ecological footprint of London, for example, a city which covers 0.6% of UK land area but which is home to 12% of the population is estimated to be an area equivalent to all of the productive land in the UK, though the footprint is globally dispersed.

than normal commercial rural agriculture. Additional advantages claimed are water economy and much reduced incidence of pests and disease. It still remains difficult, however, to see how any significant quantity of grains and pulses – staples of our diet for millennia – could ever be produced in, or even near, our cities and towns.

Nevertheless, even if a given urban food production technology or installation only makes a relatively small contribution to reducing the carbon footprint of our food, it may still be worth pursuing. This is not only to develop the technologies involved, but also as part of a multiple-strand approach to reducing the total carbon embodied in all the food consumed in urban areas, which should include reduction in demand. In the west, where problems of obesity are rife, a key strand needs to be education to reduce food intake and promote quality over quantity.

Moreover, whether or not a compelling direct economic/carbon case can be made for urban and peri-urban food production, there are other compelling arguments to pursue it in Green Design. These include the very great benefits in terms of social cohesion, individual health and reconnection with nature that such installations have been shown repeatedly to bring, with various associated economic benefits[23, 24]. We need more quantitative or semi-quantitative measurements of these benefits. We should also more frequently be asking "what can an approach that seeks to maximise native biodiversity bring to such food growing systems and their associated benefits?"

NATURAL RESOURCES – BIODIVERSITY

In the current 'Anthropocene' period, man-induced losses, degradation, fragmentation, islandisation and pollution of habitats – contributing to and exacerbating climate change – are causing a mass extinction of species at a rate 1,000 to 10,000 times the estimated background rate. This is largely due to losses of rainforest and coral reef, but losses continue from all habitats[d]. Whilst some have suggested that evidence for this loss threatening mankind's very existence is not strong[25], other evidence suggests that we may pay a high price given the inherently greater instability of degraded ecosystems[26]. A well-publicised example is the loss of pollinators, especially bees[27, 28], due largely to the loss of biodiverse habitats to make way for intensively farmed monocultures, where the cultivation techniques used are having adverse effects on habitats well beyond field boundaries. Apart from the enormous economic cost[29-31], this could in some cases trigger a cascade of local extinctions amongst associated species[32]. According to one estimate, the ecosystem goods and services of different natural or semi-natural habitats could have an economic value between 14% and 75% (depending on the habitat) greater than that of the simpler systems that have replaced them[33]. In light of the above, there has been a steady increase in policy aimed at reversing the trend of biodiversity loss since the Earth Summit in Rio de Janeiro in 1992, and the establishment of the Convention on Biological Diversity[34]. Green Design and habitat creation in the *urban realm* have a significant role to play in this reversal.

CLIMATE CHANGE

Carbon footprint reductions from closed-loop metabolism in cities and high-density living will be focal to any serious efforts to minimise the effects of climate change. Green Design can and must include effective measures that will help us adapt to the already inevitable changes. Examples of this include reducing urban heat island effects (and hence carbon costs of cooling[35]) and reducing flood risk and damage to rivers in the context of more extreme and regular storm events[36]. Once again, biodiversity has a significant enhancing role to play in this regard and also stands to benefit as climate change is itself threatening urban biodiversity through overheating and promotion of disease and invasive species[37].

In summary, in addressing all the key pressing environmental issues of our time, Green Design in

[d] The result is predicted to be a 'mass extinction' comparable with the five other natural mass extinctions since the origins of life on earth some 3.5 billions years ago, and a loss of around half of global biodiversity. Recovery in species numbers from previous mass extinctions has taken hundreds of millions of years.

and around our urban areas has a *focal* role to play as a key component of 'Eco-urbanism'[e, 38].

SUSTAINABLE URBAN LANDSCAPE DESIGN AND THE GREEN INFRASTRUCTURE CONCEPT

Until recently, proponents of urban densification have generally spoken little of the potential contributions to sustainability of green space or wildlife habitats in urban areas, and some still discount them. Reasons for this have included:

- traditional conceptual schisms between what is 'town' and 'country' or indeed 'landscape' and 'urban realm'[39]
- the idea that towns were places where nature was controlled or suppressed[40]
- lack of appreciation of the full potential value of green space in urban areas
- commercial short-termism for capital gain
- high urban land values 'squeezing out' green spaces in our cities and towns.

Many landscape architects are only just realising the importance of ensuring sustainable design[41], and in the USA only in 2009 were assessment and benchmarking tools produced for sustainable urban landscape design to '*enable built landscapes to support natural ecological functions by protecting existing ecosystems and regenerating ecological capacity where it has been lost*'[42].

In the late 1990s the Millennium Ecosystem Assessment[43] provided a classification which assigned the benefits that people derive from ecosystems into the following categories:

- 'supporting' (primary production and soils)
- 'provision' (e.g., food, water, fibre, fuel, medicines)
- 'regulating' (e.g., relating to climate, water, disease)
- 'cultural' (e.g., spiritual, aesthetic, recreational and educational).

The value of these services to man was estimated at close to twice the Global Gross National Product[44]. Over the same period, the concept of 'green infrastructure' – urban landscapes performing multiple functions for mankind – has rapidly attained a high profile[45, 46]. Green infrastructure has now been heralded, for example by the UK Town and Country Planning Association, as having an 'essential role' in the development of sustainable urban settlements[47]. Yeang[48] has recently strengthened the status of green infrastructure by placing it in an equal categorisation of the following 'infrastructures': 'green' (vegetation/natural and designed soft estate), 'blue' (surface water systems), 'red' (social – e.g., built forms, pedestrian networks) and 'grey' (hard engineering utilities).

The multiple benefits of urban green infrastructure have been progressively characterised[49-53]. Perhaps one of the greatest benefits, and until recently least acknowledged, in terms of the sustainability of high-density urban populations, is the promotion of human health and psychological well-being with all associated economic benefits[54-63].

'BIODIVERSITY PROVISION' VERSUS 'GREENING'

In practice, it is still often the case that green infrastructure is equated with general 'greening' with limited focus on biodiversity. The results of an increasing number of studies, however, are showing that (comparing between similar habitat types) biodiverse urban areas provide significantly enhanced ecosystem services compared with comparable species-poor areas.

Of particular interest in this regard is a recent study[64] that has shown clear links in a UK context between the biodiversity content of comparable urban landscapes and the well-being of the observer, even when the observer has little learned knowledge of, or particular interest in, biodiversity. Attitudes towards 'wildscapes' in towns, already fairly positive in some northern mainland European countries like Germany (witness Emscher Park, Duisburg[65]) may also be changing in countries such as the UK, where the traditional preference has been for highly manicured greenspace[66].

[e] The development of multi-dimensional sustainable communities within harmonious and balanced built environments' Ruano, M. Ecourbanism (1999).

The history of living roofs, from eclectic roof gardens to biodiverse roofs based on construction rubble, is a fascinating journey through Green Design. Control over substrate composition and isolation from polluted surfaces and groundwater flows increase the chances of good natural/semi-natural habitat analogues being created on roofs, given time and patience. The authors are currently developing schemes for creating excellent heathland, neutral and calcareous grasslands on roofs for schemes throughout the UK. The conviction that these will succeed comes from examples such as the two illustrated here in Switzerland.

The first is on the Moos Lake water filtration plant in Wollishofen (Zurich, Switzerland). These living roofs were created in 1914 by transfer of displaced meadow soils onto some 2 hectares of concrete slab roofs, as it was thought that this would help stabilise temperatures in the stored water. The cross-sectional make-up is beautifully simple – some 15-20cm of soil placed on a 5cm sand and gravel drainage layer over a bitumen waterproofing – the whole roof draining naturally via a slight slope to an edging of 'Roman' tiles. The bitumen has only weathered close to the edges of the roofs, elsewhere being in perfect condition after 90 years. The vegetation, developed from the natural soil seedbank of the emplaced soils, is stunningly biodiverse (175 plant species including 9 orchid species; there are over 6000 Green-winged Orchids Orchis morio – illustrated.) Moreover the roof habitats are an excellent analogue of the former ground-level meadow habitats, so good in fact that – as the original meadows of similar quality in the Canton have long been lost to agricultural 'improvement' – they are being considered for gazetting as a protected park.

Another example, on the Rossetti Building of the Cantonal Hospital in Basel next to the River Rhine, is an analogue of a river gravels habitat. This stony grassland with an undulating depth of local alluvial/gravel soils (mitigation for loss of these riverine habitats to industry) is again an excellent habitat for wildlife despite its limited size (1,500m²). It supports various uncommon invertebrates including several species of river edge habitats. It even partially floods in winter rains, further improving the niche diversity and similarities to flooded river edge gravels. As air conditioning is restricted in this part of Basel and the attractive architecture is achieved by glazing, the roof has a significant function in cooling the upper floor in summer.

A further example is of a rooftop meadow that has been monitored over a period in which its organic biomass has built up naturally and water features have been added until successful breeding by Lapwings Vanellus vanellus has occurred. The investigation forms part of a research project on roof-nesting by wading birds in Switzerland that is led by the leading Swiss living roof expert, Dr Stephan Brenneisen.

Nevertheless, attention must still be paid to the factors behind individual landscape preferences and dislikes so that design responses can 'broaden the constituency' for biodiversity.

Other examples are emerging. Better water-treatment performance may be achieved from more biodiverse wetlands compared with swards dominated by one or two tall emergent plant species[67-69]. Improved resilience in urban habitats to disease and environmental change and more sustainable productivity may result from greater complexity in comparable ecosystems[70, 71]. Livestock grazed on biodiverse grasslands may produce dairy and other products of a superior quality to those produced on agriculturally improved swards[72].

Opinions differ as to whether urban Green Design can significantly assist in reversing some of the biodiversity losses described above. Earlier treatises on urban ecology[73] stated that rarities did not tend to occur in urban areas. More recent work has shown that urban biodiversity can indeed include a very valuable and often rare biota[74, 75] that to a large extent has been rendered extinct in the countryside by modern 'industrial' agriculture.

Even quite recently created living roofs can accommodate many rare species[76-78]. One might be tempted to dismiss living roof habitats as contrivances that are not 'fully functional ecosystems'. However, excellent analogues of valued natural habitats (or in the UK for example semi-natural habitats, virtually all truly wild habitat having been lost to man's activities) *can* be established in the heart of the urban realm on buildings given time[79-82]. These can be stable and support not only large populations of pollinators but also many other valued species (see examples from Switzerland on page 18).

In the UK, the change in awareness of the importance of biodiversity in green infrastructure is reflected in the recent guidance for *net biodiversity gain* (after full mitigation) in 'Ecotowns', which provides *biodiversity-led* design principles for green infrastructure for the first time in the UK[83].

ECLECTIC URBANSCAPES OR SEMI-NATURAL HABITAT ANALOGUES?

Having established that biodiversity in urban 'soft estate' is highly valuable; its incorporation can be approached in a number of ways. Typically the decision is an eclectic choice of species and substrates to create new urban 'ecologies'. Examples include the combination of new techniques for production of urban food with the sciences of permaculture and ecology to create new productive landscapes, the use of 'supernormal stimuli'[f, 84] to create particularly successful habitat features (such as certain artificial wildlife refuges) and the melding of habitat creation with artistry (such as on some living roofs). Using natural colonisation as a design tool often results in the commingling of native and non-native species as 'urban wildscapes'[85] in what have been termed 'recombinant' ecologies[86] both of which have new 'culturo-biological' values. It is also true that urban habitats composed completely of alien species in urban areas can sometimes revive interest in the environment in social groups of foreign ethnic extraction, when the species have particular cultural resonance for the people involved[87].

Native flora and fauna can and do thrive in a wide variety of such man-made habitats, occasionally preferring them to semi-natural habitats. However, analogues of fully functioning native semi-natural or wild ecosystems are likely, on the whole, to provide the best overall habitats for many native species simply because of the longer period of co-adaptation. Moreover, creating natural/semi-natural habitat analogues in cities can increase citizen awareness of bio-regional context, bringing sometimes significant benefits to people in terms of their performance at work, through their gaining a 'sense of place' or at least increased acceptance of wilder urban landscapes[88, 89].

The idea, however, that we might be able to create functional copies of valued *semi-natural habitats* in urban areas has had generally less attention until relatively recently. The great number of non-native species present in urban areas together with the

[f] Supernormal stimuli are those which magnify the characteristics of a signal or releaser occurring in nature, such that a given animal responds to it in preference to the natural stimulus. One example is the preference shown by a Herring Gull chick to peck at a red football rather than the red spot at the base of its parent's beak when both are offered (pecking at the red spot in the natural situation elicits the regurgitation reflex of the parent, supplying food to the chick).

Large expanses of glass reflecting vegetation can cause significant avian mortality. This should be a specific 'negative target' in Green Design.

frequently challenging conditions of, for example, limited land availability, soil contamination, air pollution, water shortage, elevated temperatures, management difficulties and varied perceptions about what urban landscapes should look like, might suggest that efforts to create significant areas of good semi-natural/natural habitat analogues are unlikely to succeed [90]. Moreover, habitat creation in general, wherever it is undertaken, has been viewed with great caution by many nature conservationists who fear that an overstated ability to create valuable habitats could be used as an argument to destroy or move them for the purposes of development [91,92].

Nevertheless, certain semi-natural habitats such as wetlands *can* be created, with a very good approximation to many semi-natural ecosystem functions, in relatively short timescales (less than a decade). An excellent example of this is the London Wetland Centre [93].

Some grasslands of very high nature conservation value can be created in urban areas within several decades and do not necessarily support many non-native species [94]. The science of habitat creation has advanced steadily from the late 1980s, as the attached literature progression relating mainly to the UK attests [95-117], supplemented by a burgeoning global literature on restoration ecology [118-122]. In some countries, the database on the composition and autecology of plant communities is astonishingly detailed. Such references are not manuals for habitat design, but do give the green designer many cues as to how very good semi-natural habitat analogues might be created [123]. We predict that the functional differences between created and established semi-natural habitats in urban areas should continue to decrease as research progresses; and so the rationale for creating functional analogues in urban areas should strengthen over time.

PRESERVING THE BEST OF WHAT IS THERE NOW

It is now an established maxim that we must start our planning of green infrastructure by preserving, incorporating and buffering the best existing examples of habitats found in urban areas. This is not only because they can be surprisingly rich in species, but because they form clear source sites for colonisation of new green infrastructure. One of the best examples of this is the network of graded wildlife sites set up across the city by the London Ecology Unit [124]. This said, this piece is concerned more with the creation of new green infrastructure and habitats in urban areas.

SETTING SMART TARGETS FOR NEW GREEN INFRASTRUCTURE

Targets for design of new green infrastructure have been set in various ways over the years, examples including the UK Accessible Natural Greenspace Targets (ANGST) system [125]. Another example is the UK Town and Country Planning Association's recommended ratio of green infrastructure to built form in Ecotowns [126]. But to consider *biodiversity* targets in Green Design is to go to the *next level of detail* and involves comprehensive consideration of individual 'ecological features'.

The term 'ecological feature' was coined by the UK Institute of Ecology and Environmental Management [127] as a catch-all term for definable ecological units such as species, assemblages, habitats and whole ecosystems. Each feature will have certain key requirements and as part of a wider matrix, be able to deliver a wide variety of ecosystem services. The frequent absence of clear, specific and well-explained functional targets for all intended ecological features at the outset of projects often results in many ecosystem services not being secured. Even in one of the more advanced fields of habitat creation and restoration – wetland creation and restoration – the setting of goals and metrics that define functional success and then monitoring them adequately have long been seen as major shortcomings in most design projects [128,129].

Using the language of business planning, biodiversity targets should be 'SMART' – Specific, Measurable, Achievable, Realistic and Time-scaled. Targets should specifically include the *absence*, or low occurrence, of undesired phenomena. Examples include the exclusion of invasive alien species [130], dangerous supernormal stimuli [131], mirror effects of glazing leading to death by collision [132], disruptions and entrapment by lighting [133], and adverse effects relating to roads [134].

TARGETING RELEVANT ECOLOGICAL FEATURES – CONSIDERING ALL CURRENCIES OF VALUE

The obvious starting point for selecting biodiversity targets in Green Design is the Biodiversity Action Planning (BAP) system, where it exists [135]. Such plans list priority habitats and species which merit particular conservation effort. In the UK, for example, plans have or are being prepared for 65 habitats and 1,150 species [136]. Sometimes strategic BAP objectives are quantified, e.g., the restoration or creation of a certain number of hectares of habitat in a given area.

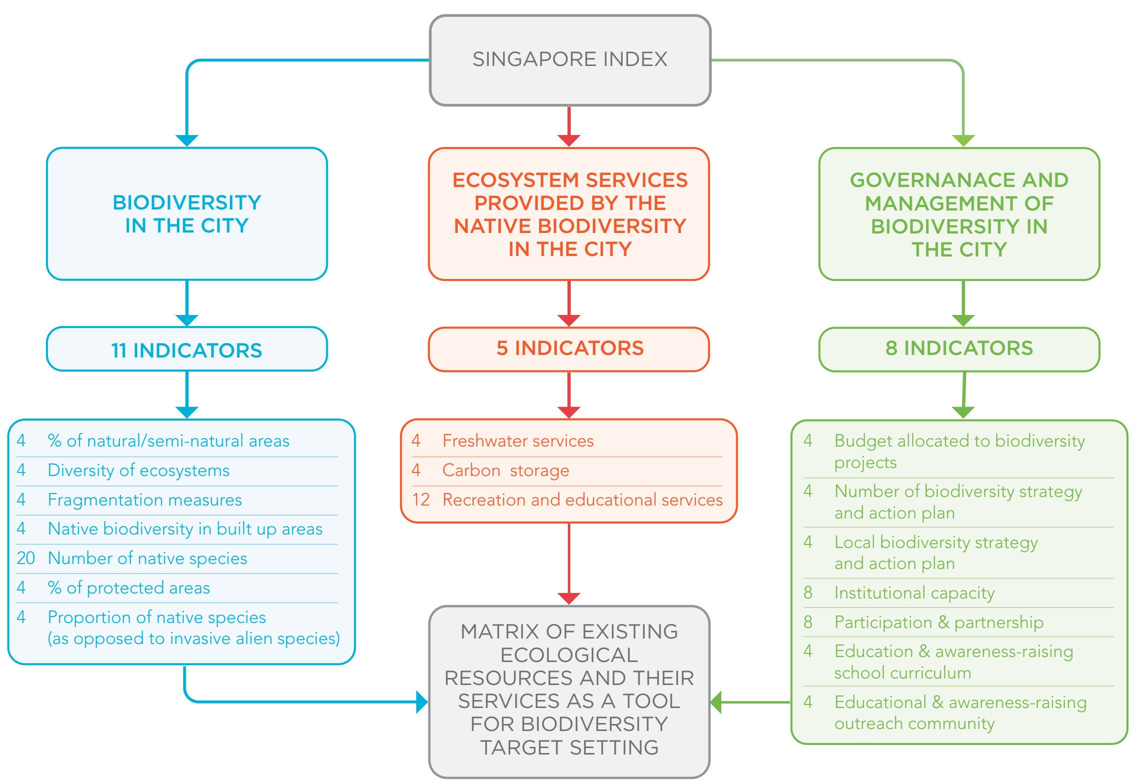

Figure 1
Summary diagram showing key components of the draft Singapore Index on Cities' Biodiversity

Other strategic objectives may relate to maintaining or restoring strategic connectivity and green networks in fragmented landscapes [137], which is often being defined by 'biodiversity opportunity mapping' [138]. Many such plans also consider ecological buffering values [139]. Where such plans do not exist, it can be time-consuming to list species and habitats relevant to the Green Design of a given urban area. It is essential, however, to make every effort to obtain the information, including by contextual field survey if necessary.

But biodiversity/genetic resource conservation value *per se* is not the only selection criterion in Green Design. Clear distinction should be made between intrinsic biodiversity value, social value and direct economic values of ecological features. Consideration should also be given to social equity in habitat provision as the quantum of urban biodiversity can be inversely proportional to the socioeconomic status of neighbourhoods [140]. In other words, poorer areas of town often have less soft estate, smaller gardens and generally less biodiversity than more affluent areas. This further widens social and health divides and disadvantages in society. Moreover, controlling for socioeconomic factors, crime rates have been shown to be higher in areas where there is less green infrastructure [141].

Within each categorisation of value, as much sub-categorisation as possible should be attempted. In relation to species, for example, values may include the following:

Biodiversity 'Innate' and 'Ecosystem Support' Values

- 'Priority'– due to its innate biodiversity value which may be assessed, for example, on the basis of rarity or its value as a particularly high-quality example of its kind
- 'Flagship' – species that champion the biodiversity of the wider landscape in which they are found, often because of their conspicuousness, appealing appearance/behaviour or cultural iconography
- 'Keystone'– having a disproportionate effect in the functioning of the local environment
- 'Umbrella' – useful in making conservation-related decisions, typically because protecting these species indirectly protects a wide variety of other species and habitats

Provision' Values

- 'Edible' e.g., for a fish species that is part of an exploited fishery whether near to or far from the site (many of the most important cities in the world border the estuarine reaches of major rivers)
- 'Energy' e.g., a species that can also be used as a biomass fuel crop

Regulating and Supporting Values

- 'Temperature regulating' and 'air quality improvement' effects of species which form significant parts of urban vegetation (all plant species contribute to this to some extent, but some species are better than others, and some are potentially harmful) [142]
- 'Water cleansing' species in wetlands, especially microbes and oxygenating plants
- Soil creation and stabilising species including a great diversity of invertebrates, fungi (such as mycorrhizae), microbes and other meio – and micro-fauna and flora of healthy soils

Social/Amenity/Cultural/Educational Values

- 'Early warning' – species that may give an early warning of threats to our own health rather like a Canary in a coal mine. Classic examples include the Peregrine Falcon and DDT, lichen assemblages and sulphur dioxide and invertebrate populations in rivers and water pollution
- 'Healing/health-inducing' – for example, a species of bird with particularly melodious song or perhaps a plant with particularly appealing perfume; or species contributing to a valued whole ecosystem aesthetic such as 'lushness' or 'multicoloured beauty' to which we respond positively

Sources of potential strategic objectives for promotion of ecological features for social/amenity/cultural values may include some of the better Biodiversity Action Plans (such as that for London [143]), but also other publications of government or charitable organisations. Objectives may include promoting species strongly associated with place and place names or with religious traditions.

Recently, an international panel of biodiversity experts under the auspices of the Convention on Biological Diversity has devised the Singapore Index on Cities' Biodiversity – essentially a measure of the value of a city for and through biodiversity (Fig. 1) [144].

Greenwich Peninsula Tidal River Wall, London, England

In 1998, renewal of the river wall along the Greenwich Peninsula was a requirement of urban regeneration works. Rather than merely being renewed, the old river wall was cut back and an inter-tidal terrace was created and filled with substrate similar to that of the foreshore before being planted with native species. The majority of the river edge, where space was limited to around 7m, was reformed as stepped terraces, but at the tip of the peninsula a 'folded edge' was created, incorporating a continuous slope 'jack-knifed' over a wider 10m terrace. The terraces have since formed into an excellent analogue of a semi-natural vegetated river edge, and have become an important Sea Bass nursery. It is now an exemplar in London for the progressive greening of the edges of the tidal River Thames, 60% of which is still sheet piled and only 1% natural. Continued efforts of this kind may help to restore fish populations in the North Sea.

FEATURE OR SERVICE	TARGET	RESULT AFTER 10 YEARS
BIODIVERSITY/ ECOSYSTEM SUPPORT		
PRIORITY HABITAT INTERTIDAL BRACKISH MARSH	Creation of ca. 0.7ha of stable analogue tidal marsh along just over 1 km of river edge with over 90% plant coverage.	Habitat established. Stability excellent. Plant coverage achieved except in one short section where substrate settled below the required optimum level.
INTERTIDAL PLANT COMMUNITIES	Survival of over 50% of planted species and colonisation by others.	Achieved. But over-expansion of Common Reed *Phragmites australis* due to lack of rhizome barriers and management. Excellent natural colonisation by Sea Aster *Aster tripolium*, occasional Sea Club-rush *Bolboschoenus maritimus* and Grey Club-rush *Schoenoplectus tabernaemontani*. Nine other species at rare occurrence (two naturally colonised). Nine other species planted did not persist (these were more characteristic of other river reaches).
INVERTEBRATE COMMUNITIES	Assemblage comparable to those at similar tidal levels in more semi-natural stretches of the river.	Achieved. Colonisation by 24 macrofaunal and 11 meiofaunal species in only 6 months as compared with 3 taxa on the former sheet piles.
FISH COMMUNITIES	Regular use of new habitat by all the key fish species in the adjacent riverine reach.	Terraces a major nursery for Sea Bass *Dicentrarchus labrax*. Also used by the European-endangered Smelt *Osmerus eperlanus*. Stepped terrace areas used by all except demersal fish – Flounder *Platichthys flesus* and adult Common Gobies *Pomatoschistus microps* – due to their unwillingness to rise up submerged step. This finding informed new national design guidance – favouring continuous slopes in a folded sequence (as at the peninsula tip) over stepped terraces.
PRIORITY VERTEBRATE SPECIES Smelt *Osmerus Eperlanus* (EUROPEAN ENDANGERED)	Regular use of new habitats.	Present on the terraces at certain times.
PRIORITY VERTEBRATE SPECIES – Reed Bunting *Emberiza Schoeniclus*	Regular breeding presence of 1 or 2 pairs.	Breeding pair on terraces in most years (with two pairs of Reed Warbler *Acrocephalus scirpaceus*).
REGULATING/SUPPORTING		
FLOATING DEBRIS	Functional trap.	Achieved by accumulation at back edge of terrace behind Common Reeds where readily removable by maintenance.
WILDLIFE DISPERSAL	Corridor aiding colonisation of wider peninsula by invertebrates.	Achieved. Dragonflies disperse peninsula-wide in summer; shelter provided by reeds etc.
PROVISION		
SEA BASS AND COARSE FISHERIES	Significant feeding/nursery function.	The terraces are now an important Sea Bass nursery in the context of the southern North Sea. The terraces permit fish to feed and reduce energy use in holding their position against the ebb and flow of the tides.
SOCIAL/AMENITY/CULTURAL/ EDUCATIONAL		
AMENITY	Highly positive reaction by public to landscape aesthetic.	Survey showed theoretical willingness of even those members of the public passing occasionally to contribute financially (actually over £40 per year) from their own resources to retain the feature if it (hypothetically) had to be maintained by public donation.
EDUCATIONAL	Permanent education of public on river system and biodiversity.	High-quality signage conveys key messages of the tidal nature of the Thames and its high water quality and abundant fauna to the public immediately adjacent to the feature. Much visited by schools.

Intertidal terraces and environmental signage at the Greenwich Peninsula, London

Millennium Village Park, Greenwich Peninsula, London, England

Ralph Erskine's Greenwich Millennium Village Park created on former derelict land included an ecology park, designed as a 'wetland within a 'wetland' (the inner wetland being accessible only when wardens are present). Given the upmarket urban context there was considerable focus on maintaining the highest possible water quality. Elements of this included low phosphorus top-up water from chalk borehole, water circulation, water aeration, water filtration through a constructed reedbed and phosphorous scavenging pit, and occasional water treatment with bacterial phosphorus scavengers. The wetland was also occasionally electrofished to maintain balance. Targets were either attained or exceeded in nearly all instances. The site is now close to being nationally important in terms of its dragonfly fauna and supports an impressive assemblage of other wildlife. It is now an important educational and amenity feature in a Borough context. One of the authors (MW) was the ecological designer of the park.

ECOLOGICAL FEATURE	TARGET	RESULT AFTER 10 YEARS
BIODIVERSITY/ ECOSYSTEM SUPPORT		
2.3 HA WETLAND MOSAIC *INCLUDING: Open Water With Floating And Submerged Aquatics, Temporary Ponds, Lake Edge Reedbed, Treatment Reedbed, Biodiverse Marsh, Wet And Dry Grassland, Wet Woodland, Ruderal Sward, Vertical Deadwood Habitat, Artificial Refuges For Invertebrates, Birds And Bats.*	Stable communities with healthy plants and balanced faunal assemblage.	Habitat established and stable.
INVASIVE ALIEN SPECIES	Absent or readily controllable.	Colonisation by *Typha* has been controlled – and invasive alien aquatics so far excluded. Breeding Canada Goose *Branta canadensis* controlled. Brown-tailed moth *Euproctis chrysorrhoea* outbreaks controlled manually.
PLANT SPECIES	No net loss of species-richness from over 70 species planted.	More than 70 species present, some new species replacing some of the planted species.
TROPHIC STATUS BASED ON DIFFERENT INDICATORS	Mesotrophic (*based on measurements of Total P, Oxidation/Reduction Potential, DO. Secchi disc readings etc.)	Occasional algal blooms readily addressed. Water quality generally high on most parameters. Temporary colonisation for one season by Stoneworts *Chara* spp. (probably brought in by birds). These are indicators of very high water quality, so even their temporary presence is considered a success.
LEPIDOPTERA (Butterflies)	Good assemblage for London for a site of c. 2 ha.	Achieved.
ODONATA (Dragonflies And Damselflies)	Good assemblage for London for a site of c. 2 ha.	Achieved fairly quickly. After 7 years – 14 species. An outstanding assemblage in southeast England is 15 species.
Fish	Largely absent	Control of fish introduced by the public and as eggs on the feet of birds achieved by electrofishing and natural predation by e.g., Grey Herons, Common Terns and Cormorants.
Little Grebe *Tachybaptus ruficollis*	1-2 breeding pairs	1 pair
Mute Swan *Cygnus olor*	1 breeding pair	1-2 breeding pairs
Mallard *Anas platyrhynchos*	2-3 breeding pairs	2-3 breeding pairs
Moorhen *Gallinago chloropus*	3-4 breeding pairs	4 breeding pairs
Coot *Fulica atra*	2 breeding pairs	3-4 breeding pairs
Blackbird *Turdus merula*	2-3 breeding pairs	3 breeding pairs
Wren *Troglodytes troglodytes*	1 breeding pair	1 breeding pair
Dunnock *Prunella modularis*	1 breeding pair	1 breeding pair
Common Tern *Sterna hirundo*	1-2 breeding pairs on two rafts	3 pairs – increased further in subsequent years with further addition/modification of rafts
Woodpigeon *Columba palumbus*	2 breeding pairs	2 breeding pairs
Sedge Warbler *Acrocephalus schoenobaenus*	1 breeding pair	2-3 breeding pairs
Reed Warbler *Acrocephalus scirpaceus*	3 breeding pairs	4-5 breeding pairs
Reed Bunting *Emberiza schoeniclus*	1 breeding pair	1 breeding pair
Great Tit *Parus major*	Breeding (numbers not predicted)	2 breeding pairs
Blue Tit *Cyanistes caeruleus*	Breeding (numbers not predicted)	3-4 breeding pairs
Carrion Crow *Corvus corone*	1 breeding pair	1 breeding pair
Pied Wagtail *Motacilla alba*	1-2 pairs	0 pairs – too few open areas
Song Thrush *Turdus philomelos*	1 pair	0 pairs – in keeping with a national decline
Blackcap *Sylvia atricapilla*	1 breeding pair	0 pairs – inadequate quantity of thorny shrub?
Chiffchaff *Phylloscopus collybita*	1 breeding pair	0 pairs – woodland quantum possibly too small, edge to interior ratio perhaps too great and lack of nearby mature woodlands.

ECOLOGICAL FEATURE	TARGET	RESULT AFTER 10 YEARS
REGULATING		
WATER QUALITY	Wetland system to maintain high water quality for public amenity.	Achieved (see above).
URBAN TEMPERATURE	Temperature below that of areas of comparable urban density.	To be assessed. Anecdotal accounts suggest this to be the case.
PROVISION		
REED AND WILLOW	Harvested for use in other urban reserves.	Significant annual production is harvested and some of this is used elsewhere in London reserves.
SOCIAL/AMENITY/CULTURAL/EDUCATIONAL		
AMENITY	Amenity feature to become of at least Borough Value.	Possibly Metropolitan Value. Over 10,000 visitors per year. Visitor books almost completely lack negative comments and are full of praise.
SOCIAL	Positive interaction from nearby residents and involvement of volunteer groups on long-term basis.	Trust for Urban Ecology (TRUE) charity moved headquarters to park lodge and facilitates events and social involvement. Park now the social focus of the village. Large parties of volunteers assist with management works year-round.
EDUCATIONAL	Significant use by schools and colleges.	Extensive use by schools. Many hundreds of school visits per year. TRUE's expert educational skills sustain this. Several urban ecological studies by university students and amateur natural historians have been undertaken.

This is due to be finalised in November 2010. It aims to combine ecological summary metrics of ecosystem health and biodiversity content with scores relating to ecosystem services which include carbon storage, educational and recreational services and measures of community involvement and activism.

For each currency of value, a further important quantification involves estimation of the geographical scale at which the newly created viable ecological feature is likely to be significant, either on its own or in combination with other existing or proposed ecological features. That might just be within the context of the development site itself, or the context of the wider neighbourhood, region or of the whole nation. Some designed features of sufficient scale might even be able to accrue international value in time.

To do this requires a prediction of the value of different sizes and compositions of habitats and/or species populations that might colonise or utilise the designed site. Two examples which demonstrate the value of quantitative targets and monitoring, one involving tidal river wall habitats and the other an ecology park in an urban village in London [145,146,] are presented on pages 24-27 [g].

Crucial to this assessment is the place of the new ecological features within a wider network. Here the concept of the Urban Biosphere Reserve is key, where the best urban and peri-urban habitats can be linked into functional reserves that show complementary provision of nature conservation, environmental education, research and monitoring in the context of sustainable urban development [147].

The Green Designer should then try as far as possible to quantify the functional performance of the designed ecosystems in terms of possible provision of ecosystem goods and services in the urban realm [148]. Full data on the functional performance of ecological features are never available. Nonetheless, qualitative or semi-quantitative assessments of some functions can generally be made.

DEFINING CONDITIONS FOR LONG-TERM VIABILITY OF DESIGNED ECOLOGICAL FEATURES

Having listed the relevant targeted ecological features and described them as fully as possible, including predicted/desired areas/population sizes, etc., the conditions and parameters that would be associated with the viable long-term presence of the feature should be defined. This means defining the conditions or properties that are likely to be associated with the existence of a species population or habitat at a '*favourable conservation status*' [h] or with a proposed ecosystem that has '*integrity*' [i]. In essence this means ecological features that are healthy and likely to survive long-term in a variable environment as recognisable and functional entities [149]. A recent review draws the following key conclusions on the assessment of ecosystem health: [150]

- several metrics are needed at each ecosystem level and at different ecosystem levels
- both physico-chemical and biotic metrics are needed.

There is a need for the practitioner to draw on the fast-growing literature on urban ecosystem functionality to maximise the chances of design success [151].

Any degree of quantification reduces the risk associated with qualitative assessment and overlooking a potentially very important ecosystem service. It hence increases the likelihood that informed professional judgement will make sustainable design choices. The examples on pages 24-27 illustrate some of these principles. A further good example of frequently used but sometimes ill-conceived interventions of Green Design is the 'wildlife corridor'. The Green Designer should:

[g] Two of the authors (MW and AC) provided ecological design input to these habitats.

[h] IEEM (2006) provides definitions as follows: For habitats, conservation status is determined by the sum of the influences acting on the habitat and its typical species that may affect its long-term distribution, structure and functions as well as the long-term survival of its typical species within a given geographical area.
For species, conservation status is determined by the sum of influences acting on the species concerned that may affect the long-term distribution and abundance of its populations within a given geographical area.

[i] IEEM (2006). quoting other guidance provides a definition for site ecology integrity as follows: The integrity of a site is the coherence of its ecological structure and function, across its whole area, that enables it to sustain the habitat, complex of habitats and/or the levels of populations of the species for which it was classified.

TABLE 1

A review of the ecological components of some selected urban sustainability accreditation systems: N.B. Because categorisations used are sometimes quite different between systems a degree of simplification and division/grouping of weightings has been necessary to give some measure of comparison between approaches.

Countries have been placed in order of the overall weighting given to ecology in the overall sustainability score.

COUNTRY AND ASSESSMENT TOOL

PERCENTAGE OF THE TOTAL CREDITS AVAILABLE IN RELATION TO ECOLOGY, NATURAL SYSTEMS PROTECTION, HABITATS, VEGETATION AND SPECIES

	SINGAPORE GREEN MARK: INFRASTRUCTURE 2008	**NETHERLANDS** BREEAM: NEW BUILDINGS 2010	**UK** CODE FOR SUSTAINABLE HOMES 2009	**CANADA** LEED: NEW BUILDINGS 2009	**UK** BREEAM: OFFICES 2008	**CANADA** GREEN GLOBES: NEW BUILDINGS 2004	**ABU DHABI** ESTIDAMA PEARL RATING SYSTEM 2010	**MALAYSIA** GREEN BUILDING INDEX	**GULF STATES**[3] BREEAM GULF: NEW BUILDINGS 2008	**SOUTH AFRICA** GREEN STAR 2010	**NEW ZEALAND** GREEN STAR 2009
OVERALL WEIGHTING GIVEN TO ECOLOGY (%)	12.3	12	12	11	10	9.5	8.8	8	7	7	5.5
AVOID SITES WITH HIGH ECOLOGICAL VALUE	10-19.9%	30-39.9%	20-29.9%	0-9.9%	10-19.9%	0-9.9%	M (50-59.9%)[2]	10-19.9%	20-29.9%	M (50-59.9%)	M (50-59.9%)
USE PREVIOUSLY DEVELOPED LAND	0-9.9%			30-39.9%	10-19.9%	0-9.9%	10-19.9%	10-19.9%		20-29.9%	0-9.9%
USE CONTAMINATED LAND	0-9.9%	10-19.9%		0-9.9%	10-19.9%	0-9.9%	10-19.9%	10-19.9%		20-29.9%	20-29.9%
PROTECT VALUED FEATURES ON-SITE	20-29.9%	0-9.9%	30-39.9%	0-9.9%	20-29.9%	30-39.9%	M (50-59.9%)	0-9.9%	40-49.9%	40-49.9%	30-39.9%
MINIMISE BUILT FOOTPRINT	20-29.9%		20-29.9%	0-9.9%	30-39.9%			10-19.9%			
AFTERCARE AND MANAGEMENT		10-19.9%			20-29.9%		M (50-59.9%)		10-19.9%		
PROTECT OFF-SITE FEATURES						0-9.9%	M (50-59.9%)				
HABITAT RESTORATION AND CREATION	20-29.9%	10-19.9%	30-39.9%	0-9.9%	30-39.9%	0-9.9%	40-49.9%	0-9.9%	20-29.9%	10-19.9%	30-39.9%
ALLEVIATE HEAT ISLAND EFFECT	★			10-19.9%		0-9.9%	★	10-19.9%			
INSTALL FOOD SYSTEMS							10-19.9%				
INNOVATION[1]	30-39.9%						30-39.9%	30-39.9%			30-39.9%

Key

0-9.9% | 10-19.9% | 20-29.9% | 30-39.9% | 40-49.9% | M 50-59.9%

★ Allocated elsewhere

Absent from credits assigned to ecology (empty cells)

[1] Additional credits obtainable for innovation provide further incentives for imaginative design of green infrastructure.

[2] The indication of Mandatory in this row and later rows is caveated in that these metrics permit onsite mitigation or offsite compensation where habitat protection is impractical.

[3] Gulf States covers: United Arab Emirates (except Abu Dhabi), Oman, Qatar, Bahrain, Saudi Arabia and Kuwait.

TABLE 2

Existing shortcomings of ecological aspects of ecology assessment in urban design project sustainability accreditation systems and some selected possible improvements/elaborations

DESIGN ELEMENT	POSSIBLE ENHANCED DESIGN OF TARGETS: ASSIGN TARGETS AND CREDITS FOR...
VALUED FEATURES OUTSIDE THE DEVELOPMENT SITE	...developments with least collateral adverse effects on nearby sites of value from development-related influences such as disturbance from residents, pets, movement, light, noise, runoff, etc. This consideration should extend to avoidance of effects on mobile species from special sites at a distance (e.g., birds, bats, etc.).
CREATION OF SEMI-NATURAL HABITATS	....habitat creation based on the area of habitat created, its viability and similarity to semi-natural habitats valued in relation to local, regional and national priorities. Include concepts of habitat integrity. Accreditation systems should reward creation of full suites of ecosystem features, e.g., all functional stands in woodland, all trophic levels, crucial deadwood habitat, soils etc. – all part of developing ecosystem authenticity and resilience. Estidama is by far the most advanced system available in this regard.
USE BY FAUNA	...realistically predicted colonisation by faunal species including predicted numbers and status (e.g., rarity, breeder or non-breeder, migrant, etc.) and include the concept of favourable conservation status of populations.
CONNECTIVITY AND DEFRAGMENTATION	...contributions to improved connectivity and defragmentation in the wider landscape, especially for larger projects. Additional credits should be assigned when significant contributions are made to the coherence of Urban Biosphere Reserves.
GREEN INFRASTRUCTURE GOODS AND SERVICES	...the full range of functions of green infrastructure, e.g., heat island reduction, water treatment, air quality improvement and flood risk alleviation, psychological health and wellbeing and environmental education and (for larger projects perhaps) carbon sequestration and propose appropriate metrics and provision for biodiversity, reflected in the recent guidance for net biodiversity gain (after full mitigation) in 'Ecotowns,' which provides biodiversity-led design principles for green infrastructure for the first time in the UK [clix]. Additional credits should apply where enhanced ecosystem services are provided by biodiverse systems. Tree plantings should be differentially scored in relation to the ecosystem services provided (the simple difference between large and small trees in this regard is not recognised in all existing systems) and adverse influences avoided (e.g., mass plantings of trees that produce high concentrations of Volatile Organic Compounds or particularly potent allergens).
VEGETATED ARCHITECTURE	...habitat creation on buildings, beyond mere greening, for the particular value this has in creating relatively undisturbed habitats and countering the effects of high urban densities. The level of sophistication of targets should extend, e.g., to favouring deep substrates for living roofs for their contribution to hydrological balance, cooling and habitat resilience. Living roofs and walls should universally be officially recognised as part of Sustainable Drainage Systems by specific accreditation.
AFTERCARE, MANAGEMENT AND ENVIRONMENTAL EDUCATION AND AWARENESS	..different levels of involvement of existing organisations, communities in sustainable stewardship of created and existing ecological features. They should also significantly reward higher levels of commitment to horticulturally and ecologically sophisticated management the provision for quality and security of long-term funding and environmental education and awareness.
MONITORING	...proper and scientifically controlled monitoring should attract specific credits. Monitoring should relate to a variety of taxa both at a given trophic level and between levels.

- investigate the precise requirements of size and composition of the corridor so that it is actually used by the target species [152-154]
- realise that some corridors may actually *increase* vulnerability of valued ecological features by facilitating the movement of undesirable organisms
- understand that many species disperse very well across large areas of inimical habitat without corridors [155]
- refer to the very latest research findings [156].

There will always be gaps in our knowledge of the behaviour of species that militate against success, but a scientific and professional extrapolative approach should always be applied to maximise the chance that any created wildlife corridor is truly functional.

One crucial element in long-term viability will be appropriate management. In many cases far greater management resources for biodiversity are available in metropolitan areas than in the countryside. In some cases, this has permitted urban semi-natural habitats to be managed as biodiversity 'arks' for species in recovery programmes [157].

DEFINE SHORT-TERM/INTERIM TARGETS AND PREDICT MATURITY PATTERNS

Habitat creation generally involves elements of a 'scattergun' approach. More species of plant are generally seeded or planted than will be likely to survive in the long term. For wetlands and wetland treatment systems simplification of the species lists to a half or quarter of the number originally planted is quite common and often such a poor result is accepted as the best that can be achieved. Initial failures of species may be due to inappropriate initial conditions in terms of vegetation context, and hence continued planting, seeding and substrate modification over time may be required. Careful design and planning, however, including greater attention to species autecologies, hydroperiods, competition dynamics and successional changes can greatly reduce loss of originally planned diversity.

It is also important to consider whether each created ecological feature is likely to change in the long term through changes in other factors, such as climate. In landscape and ecological design in urban areas, the long-term view needs to be taken, and the likely effects of both climate and social structure change on ecological features need to be considered. Approaches to habitat creation that allow for natural dynamism and later direct modification are likely to be ever more relevant to urban Green Design in a changing climate [158]. Finally, how the ecological features created might be moved to a new location at decommissioning, or compensatory habitat created, should be considered early in project development.

EXISTING AND EMERGING SYSTEMS FOR ORGANISING, RECORDING AND MONITORING PROJECT-LEVEL TARGETS FOR BIODIVERSITY IN URBAN DESIGN

Various systems for prescription of targets for ecology/biodiversity in urban design exist around the world as part of wider sustainability rating systems, several of which are reviewed in Table 1. The following key points are suggested by the data presented:

1. The weighting given to ecology in the overall sustainability scores of these systems varies between 5% and 12%. This may to some extent reflect different national priorities for development over protection of wilderness, though for some countries with the lowest weightings for ecology in the overall scoring system, the requirement to protect the most valued habitats is mandatory.
2. The other variations reflect differences in the historical, geographical and other conditions prevailing in the different countries, but also differences in levels of sophistication of thinking about green infrastructure and habitats.
3. The variation in emphasis given to habitat creation/positive ecological change is significant. The suggestion is that to some extent countries with the largest areas of remaining natural habitat perhaps place lower emphasis on habitat creation in the urban setting. The systems also vary notably in the level of sophistication of their approach to assigning credits for ecological enhancement. Estidama is outstanding in this regard, and invokes numerous metrics of ecosystem functionality and monitoring that require deep ecological understanding to apply.

4. Long-term management and monitoring are in general poorly covered in these appraisal systems with the notable exception of Estidama.

5. Targets tying in the provision of green infrastructure/urban habitats to sustainable goods and services other than provision for biodiversity are far less well addressed overall (Estidama usefully introduces credits for food production systems). Design to ensure water treatment or air purification or general and psychological health and wellbeing may be covered indirectly elsewhere in some systems but is rarely linked directly to development of green infrastructure.

The last point may seem wishful with the many constraints on urban development budgets. Target setting, however, is pointless without an effective regime for monitoring the success of incorporated/created ecological features. This should be as simple and automated as possible. Baseline data collection should be undertaken in keeping with the planned future monitoring protocol. Data gathered should be widely disseminated, including both positive and negative results. New targets can always be introduced as long as we have not too readily abandoned efforts to achieve our original goals. Biodiversity targets are, therefore, to be regarded as clear ambitions, but ones that may be reviewed in the light of habitat development, succession and social responses.

CONCLUSION

Biodiversity is an important element of green infrastructure, which must be appropriately, sensitively and holistically designed if we are to address some of the key threats caused by our own environmental degradation of planet Earth. Advanced Green Design should set and monitor detailed targets associated with the maintenance or creation of robust ecological features that will combine to form new green infrastructure to greatly enhance the sustainability of urban areas for all life. The resultant biodiverse urban realm can potentially bring real economic, social and environmental benefits and contribute significantly to reversing biodiversity loss.

To achieve success in this endeavour requires the different urban design disciplines to develop a deeper shared understanding of the functional characteristics of urban green infrastructure and to work together in more synergistic collaborations than is often currently the case.

The various systems in use for sustainability accreditation around the world vary in their quality and sophistication as regards the setting of ecological design targets, the most recent and in most ways the best being the United Arab Emirates' Estidama system. However, notable improvements can be envisaged for all systems in use to enhance results both in terms of biodiversity *per se* and the urban goods and services it provides.

ACKNOWLEDGEMENTS

The authors wish to thank Professor David Goode, Dr Lincoln Garland (Biodiversity by Design), Ben Dewhurst (TRUE) and Oliver Prudden (Biodiversity by Design) for comments on earlier drafts. Thanks are also extended to the Environment Agency and Trust for Urban Ecology for use of material.

BIBLIOGRAPHIES

CHAPTER 4

[1] United Nations. (2010). World Urbanization Prospects. The 2009 Revision. Highlights. UN, New York.

[2] United Nations. (2010). Ibid.

[3] Giradet, H. (1999). Creating Sustainable Cities (Schumacher Briefing). Green Books, London.

[4] Rogers, R. (2005). Cities for a Small Planet. Faber and Faber, London.

[5] Goode, D. (2000). **Cities as Key to Sustainability**. In D. Poore (Ed.) Where Next? Reflections on the Human Future. The Board of Trustees. Royal Botanic Gardens, Kew.

[6] Register, R. (2006). Ecocities. Rebuilding Cities in Balance with Nature. New Society Publishers, Canada.

[7] Glaeser, E.L. (2009.) **Green Cities, Brown Suburbs**. *City Journal*, 19(1): 1-5.

[8] Hall, P. (1999). Sustainable Cities or Town Cramming? Town and Country Planning Association, London.

[9] Farr, D. (2007). Sustainable Urbanism. Urban Design with Nature. John Wiley & Sons, London. (p.103).

[10] Goodacre, R. (2006). RECEP Urban Environments Desk Study: The Benefits of Urban Living. Report to the Royal Commission on Environmental Pollution. HMSO London.

[11] Nicholson-Lord, D. (2003). Green Cities and Why We Need Them. New Economics Foundation, London.

[12] Frith, M & Harrison, M. Decent Homes, Decent Spaces. (Undated). Report as Part of the Neighbourhoods Green. Improving Green Spaces for Social Housing Project. Peabody Trust, London.

[13] Montgomery, D.R. (2001). **Soil Erosion and Agricultural Sustainability**. *Proc. Nat. Acad. Sci.* 104(33): 13268-13272.

[14] Best Foot Forward Ltd. (2002). City Limits. A Resource Flow and Ecological Footprint Analysis of Greater London. City Limits Project Partnership, London.

[15] Porritt, J. (2010). **Do the Maths**. In E. Yarrow (Ed.) The Global Environment. Edition 2. Circle Publishing, Richmond.

[16] Hofman, N. (2001). **Urban Consumption of Agricultural Land**. *Rural and Small Town Canada Analysis Bulletin*, 3 (2): 1-13.

[17] Giradet, H. (1999). Creating Sustainable Cities (Schumacher Briefing). Green Books, London.

[18] Newman, P. & Jennings, I. (2008). Cities as Sustainable Ecosystems. Island Press, Washington.

[19] Vilgoen, A. (2007). Continuous Productive Urban Landscapes. Designing Urban Agriculture for Sustainable Cities. Architectural Press, London.

[20] Knowd, I, Mason, D. & Docking, A. (2006). **Urban Agriculture: The New Frontier**. *Changing City Structures*, 23:1-23.

[21] Despommier, D. (2009). **The Rise of Vertical Farms**. *Scientific American*, 301, 80-87.

[22] Nelkin, J. & Caplow, T. (2008). **Sustainable Controlled Environment Agriculture for Urban Areas**. *Acta Hort*. (ISHS) 801:449-456.

[23] Hassel, M.V. (2005). **Community Gardens in New York City: Place, Community and Individuality**. In: P.F. Barlett (Ed.). Urban Place. Reconnecting with the Natural World. pp 91-116. MIT Press, London.

[24] Stuart, S.M. (2005). **Lifting Spirits. Creating Gardens in California Domestic Violence Shelters**. In: P.F. Barlett (Ed.). Urban Place. Reconnecting with the Natural World. pp 61-88. MIT Press, London.

[25] Jenkins, M. (2003). **Prospects for Biodiversity**. *Science*, 302:1175-1177.

[26] De Leo, G.A. & Levin, S. (1997). **The Multifaceted Aspects of Ecosystem Integrity**. *Conservation Ecology*, 1(1):1-23.

[27] Goulson, D. Lye, G.C. & Darvill B. (2008). **Decline and Conservation of Bumble Bees**. *Annu. Rev. Entomol.* 53:191–208.

[28] De la Rua, P., Jaffe R., Dall'Olio, R., Munoz, I. & Serrano, J. (2009). **Biodiversity, Conservation and Current Threats to European Honeybee**. *Apidologie*, 40 (3): 263-284.

[29] Southwick, E. E. & Southwick Jr., L. (1992). **Estimating the Economic Value of Honey Bees (Hymenoptera: Apidae) as Agricultural Pollinators in the United States**. *Journal of Economic Entomology*, 85 (3): 621-633.

[30] Kevan, P. G. & Phillips., T. P. (2001). **The Economic Impacts of Pollinator Declines: an Approach to Assessing the Consequences**. *Conservation Ecology* 5(1): 8. [online] URL: http://www.consecol.org/vol5/iss1/art8/

[31] Pretty, J. N., Brett, C., Gee, D., Hine, R. E., Mason, C. F., Morison, J. I. L., Raven, H., Rayment M. D., & van der Bijl, G. (2000). **An Assessment of the Total External Costs of UK Agriculture**. *Agricultural Systems*, 65 (2):113-136.

[32] Pimentel D., Wilson, C., McCullum, C., Huang, R., Dwen, P., Flack, J., Tran, Q., Saltman, T. & Cliff, B. (1997). **Economic and Environmental Benefits of Biodiversity**. *BioScience*, (47) 11: 747-757.

[33] Balmford, A., Brunder, A., Cooper, P., Costanza, R., Farber, S., Green, R.E., Jenkins, M., Jefferis, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S., Paavola, J., Rayment, M., Rosnedo, S., Roughgarden, J., Trumper, K & Turner, R.K. (2002). **Economic Reasons for Conserving Wild Nature**. *Science*, 297:950-953.

[34] Goode, D. (2000).

[35] Mayor of London. (2006). London's Urban Heat Island: A Summary for Decision Makers. Greater London Authority.

[36] Gill, S.E., Handley J.F., Ennos, A.R & Pauleit. F. (2007). **Adapting Cities for Climate Change: The Role of the Green Infrastructure**. *Built Environment*, 33(1):115-133.

[37] Yukihiro, M. (2009). **Biodiversity and Ecosystem Services in Urban Areas for Smart Adaptation to Climate Change**. In: Proceedings of the Second International Conference on Urban Biodiversity and Design. URBIO(2010). J. Imanishi and J. Hon (Eds.) Nagoya, Japan, May 18-22, 2010. URBIO2010 Organising Committee. http://www.jilac.jp/URBIO2010/doku.php

[38] Ruano. M. (1999). Ecourbanism. Sustainable Human Settlements. 60 Case Studies. Gustavo Gilli, Barcelona.

[39] Ipsen, D. (1998). **Ecology as Urban Culture.** In: J. Breuste, H. Fledmann & Uhlmann, O. (Eds.). Urban Ecology. Springer, Berlin.

[40] Sukopp, H. (1998). **Urban Ecology – Scientific and Practical Aspects**. In: J. Breuste, H. Fledmann & Uhlmann, O. (Eds.). Urban Ecology. Springer, Berlin.

[41] Thompson, I. (2006). Ecology, Community and Delight. An Inquiry into Values in Landscape Architecture. Routledge, London.

[42] American Society of Landscape Architects (2009). The Case for Sustainable Landscapes. ASLA, Washington DC.

[43] Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-Being: Synthesis 1 available at http://www.millenniumassessment.org/documents/document.

[44] Costanza,R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. & van den Belt, M. (1997). **The Value of the World's Ecosystem Services and Natural Capital**. *Nature* 387: 253 – 260.

[45] Goode, D. (2006). RECEP Urban Environments Desk Study: Green Infrastructure. Royal Commission
on Environmental Pollution, London.

[46] The Royal Commission on Environmental Pollution. (2007). **26th Report. The Urban Environment**. Chtr. 4: The Natural Urban Environment. HMSO, Norwich.

[47] Town and Country Planning Association. (2008). The Essential Role of Green Infrastructure: Ecotowns Green Infrastructure Worksheet. Advice to Promoters and Planners. TCPA, London.

[48] Yeang, K. (2009). Ecomasterplanning. John Wiley and Sons, London.

[49] Town and Country Planning Association. (2008).

[50] CABE Space (2003). Does Money Grow on Trees? CABE, London.

[51] Lancaster University & Centre for Ecology and Hydrology (2004). Trees and Sustainable Air Quality. Lancaster University, UK.

[52] Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R.R., Doshi, H., Dunnett, N.., Gaffin, S., Køhler, M., Liu, K.K.Y. & Roe, B. (2007). **Green Roofs as Urban Ecosystems: Ecological Structures, Functions and Services**. *Bioscience*, 57(10): 823-833.

[53] Mentens, J.H., Raes, D. & Hermy, M. (2006). **Green Roofs as a Tool for Solving the Rainwater Runoff Problem in the Urbanized 21st Century?** *Landscape and Urban Planning*, 77: 217-226.

[54] Rhode, C.L.E. & Kendle A.D. (1994). Human Well-Being, Natural Landscapes and Wildlife in Urban Areas – A Review. English Nature, Peterborough. ISBN 1-857 161556.

[55] Ulrich R.S., Simons, R., Losito, B.d., Fiorito, E., Miles, M. & Zelson, M. (1991). **Stress Recovery During Exposure to Natural and Urban Environments**. *J. Exp. Psychology*: 11, 201-230.

[56] Ulrich, R.S. (1999). **Effects of Gardens on Health Outcomes: Theory and Research.** In: C.C. Marcus and Barnes, M. (Ed.) (1999). Healing Gardens: 27-86. Wiley, New York.

[57] Royal Commission on Environmental Pollution. (2004). Desk Study: Urban Nature. RCEP, London Nicholson-Lord, D. (2003). Green Cities and Why We Need Them. New Economics Foundation, London.

[58] Nicholson-Lord, D. (2003). Green Cities and Why We Need Them. New Economics

Foundation, London.Burls, A. & Caan W. (2005). Human Health and Nature Conservation. *BMJ*, 331: 1221 – 1222.

[59] Burls, A. & Caan W. (2005). Human Health and Nature Conservation. *BMJ*, 331: 1221 – 1222.

[60] Sullivan, W.C. (2005). Forest, Savanna, City: Evolutionary Landscapes and Human Functioning. In: P.F. Barlett (Ed.). Urban Place. Reconnecting with the Natural World. pp 237-252. MIT Press, London.

[61] Douglas, I. (2005). Urban Greenspace and Mental Health. Discussion Paper for the UK Man and the Biosphere Urban Forum. UKMAB, London.

[62] Kaplan, R. & Kaplan, S. (2005). Preference, Restoration, and Meaningful Action in the Context of Nearby Nature. In: P.F. Barlett (Ed.). Urban Place. Reconnecting with the Natural World. pp 273-298. MIT Press, London.

[63] Stone, D. (2006). Health and Nature: Critical Elements for Sustainable Developments. In: E. Williams (Ed.) Proceedings of the 22nd Conference of the Institute of Ecology and Environmental Management 2005. Sustainable New Housing and Major Developments – Rising to the Ecological Challenges. pp. 61-66. IEEM, Winchester.

[64] Fuller, R.A. Irvine, K.N., Devine-Wright, P., Warren, P.H. & Gaston, K.J. (2007). Psychological Benefits of Greenspace Increase with Biodiversity. *Biological Letters* 5: 352-355.

[65] URBED (2004). Biodiversity by Design. A Guide for Sustainable Communities. Town and Country Planning Association, London.

[66] Harrison, C. & Davies, G. (2002). Conserving Biodiversity that Matters: Practitioner's Perspectives on Brownfield Development and Urban Nature Conservation in London. *Journal of Environmental Management*. 65, 95-108.

[67] Mitsch, W.J., Wang, N., Zhang, L., Deal, R., Wu, X., & Zuwerink, A. (2005). Using Ecological Indicators in a Whole-Ecosystem Wetland Experiment. In: S.E. Jørgensen, R. Costanza & X. Fu-Liu (Eds.). Handbook of Ecological Indicators of Ecosystem Health. Taylor and Francis, London.

[68] Millet, M. (1997). Demonstration Reedbed Filtration Systems. WWT, Slimbridge

[69] Biologic Design. See http://www.biologicdesign.co.uk/page.php

[70] Nicholls, C. (2004). Biodiversity and Pest Management in Agroecosystems. CRC Press, Oxford.

[71] Loreau, M. (2000). Biodiversity and Ecosystem Functioning. Recent Theoretical Advantages. *Oikos*, 91:3-17.

[72] Rural Economy and Landuse Programme. (2008). Eating Biodiversity: an Investigation of the Links Between Quality Food Production and Biodiversity Protection. Relu, Newcastle-upon-Tyne.

[73] Kendle, T. & Forbes. S. (1997). Urban Nature Conservation. E & FN Spon, London.

[74] Plant, C. W & Harvey, P. (1997). Biodiversity Action Plan. Invertebrates of the South Essex Thames Terrace Gravels – Phase 1: Characterisation of the Existing Resource (3 volumes). Unpublished report number BS/055/96. English Nature, Colchester.

[75] Harvey, P. (2000). The East Thames Corridor: a nationally important invertebrate fauna under threat. *British Wildlife*, 12 (2): 91-98.

[76] Kadas, G. (2004). Rare Invertebrates Colonizing Green Roofs in London. *Urban Habitats*, 4(1): 66-86.

[77] Wells, M.J.(2001). Rarity on the Roof? Finding Partial Solutions to Challenges of Brownfield Redevelopment. *Ecology and Environmental Management In Practice*: 33:14-15.

[78] Ecoschemes Ltd & Studio Engleback. (2003). Green Roofs: Their Existing Status and Potential for Conserving Biodiversity in Urban Areas. English Nature Research Reports. No. 498. English Nature, Peterborough.

[79] Burga, C.A., Klötzli, F. & Gloor, M. (2001). Orchiden-Wiesen in Wollishofen (Zürich) – ein Erstaunliches Relikt aus dem Anfang des 20. Jahrhundrets. *Vierteljahrsschrift der Natureforschenden Fesellschaft in Zürich*. 146(2-3): 39-52.

[80] Gedge, D. & Kadas, G. (2005). Green Roofs and Biodiversity. *Biologist*: 52(3):161-169.

[81] Hochschule Wädenswil & Living Roofs (2005). Green Roofs and Urban Biodiversity. Science and Technology Transfer. Hochschule Wädenswil, Wädenswil.

82 Wells, M.J. & Grant, G. (2006). Biodiverse Vegetated Architecture Worldwide: Status, Research and Advances. In: E. Williams (Ed.) Proceedings of the 22nd Conference of the Institute of Ecology and Environmental Management 2005. Sustainable New Housing and Major Developments – Rising to the Ecological Challenges. pp. 61-66. IEEM, Winchester.

[83] Town and Country Planning Association. (2009). Biodiversity Positive: Ecotowns Biodiversity Worksheet. TCPA, London.

[84] Staddon, J.E.R. (1975). A Note on the Evolutionary Significance of Supernormal Stimuli. The *American Naturalist*. 109 (969): 541-545.

[85] Jorgensen, A. (Ed.). (2007). Urban Wildscapes. Sheffield University, UK.

[86] Barker, G. (Ed.). (2000). Ecological Recombination in Urban Areas: Implications for Nature Conservation. English Nature, Peterborough.

[87] Lynch, B.D. & Brusi, R. (2005). Nature, Memory and Nation: New York's Latino Gardens and Casitas. In: P.F. Barlett (Ed.). Urban Place. Reconnecting with the Natural World. pp 191-211. MIT Press, London.

[88] Newman, P. & Jennings, I. (2008).

[89] Pretty, J. & Barlett, P.F. (2005). Concluding Remarks: Nature and Health in the Urban Environment. In: P.F. Barlett (Ed.). Urban Place. Reconnecting with the Natural World. pp 273-298. MIT Press, London.

[90] Sukopp, H. (1998).

[91] Morris, R.K.A., Alonso, I., Jefferson R.G. & Kirby K.J. (2006). The Creation of Compensatory Habitat— can it Secure Sustainable Development? Journal for Nature Conservation 14 (2): 106-116.

[92] Treweek, J. (1999). Ecological Impact Assessment. Blackwell Science, Oxford.

[93] Goode, D. (1998). Integration of Nature in Urban Development. In: J. Breuste, H. Feldmann &Uhlmann, O. (Eds.). Urban Ecology. Springer Verlag, Berlin.

[94] Morris *et al*. (2006). Ibid.

[95] Bradshaw, A.D., Goode, D.A. & Thorp, E.H.P. (Eds.) (1983). Ecology and Design in Landscape. Blackwell Scientific Publications, Oxford.

[96] Kusler, J.A. & Kentula, M.E. (1990). Executive Summary. In. J.A. Kentula & M.E. Kentula (Eds.). Wetland Creation and Restoration. The Status of the Science. Island Press, Washington.

[97] Emery, M. (1986). Promoting Nature in Cities and Towns. Croom Helm, London.

[98] Baines, C. & Smart, J. (1991), A Guide to Habitat Creation. London Ecology Unit, London.

[99] Merritt, A. (1994). Wetlands, Industry and Wildlife. A Manual of Principles and Practices. Wildfowl and Wetlands Trust, Slimbridge.

[100] Rodwell, J. & Patterson, G. (1994). Creating New Native Woodlands. Forestry Commission Bulletin 112. HMSO, London.

[101] Parker, D.M. (1995). Habitat Creation – a Critical Guide. English Nature Science Series No. 21. English Nature, Peterborough.

[102] Dryden, R. (1997). Habitat Restoration Project: Fact Sheets and Bibliographies. English Nature Research Report 260. English Nature, Peterborough.

[103] Helliwell, D.R. (1998). Case Studies in Vegetation Change, Habitat Transference and Habitat Creation. Reading Agricultural Consulant, Didcot.

[104] Kendle, T. & Forbes. S. (1997).

[105] Gilbert O.L. & Anderson, P. (1998). Habitat Creation and Repair. Oxford University Press, Oxford.

[106] Wells, M.J., Luszczak, M & Dunlop, B. (1998). Sustainable Habitat Creation on a Former Industrial Site. In: H.R. Fox, H.M. Moore and A.M. McIntosh (Eds.). Land Reclamation. Achieving Sustainable Benefits. AA Balkema, Rotterdam.

[107] Mitsch, W.J. & Gosselink, J.G. (2000). Wetlands. (3rd Edition). John Wiley and Sons, New York.

[108] Penny Anderson Associates (2002). Highways Agency Task C002. Chalk Grassland Habitat Creation. A Literature and Project Review. PAA, Buxton.

[109] White, G. & Gilbert, J. (2003). Habitat Creation Handbook for the Minerals Industry (RSPB Management Guides). RSPB, Sandy.

[110] Betts, C.J. (2003). British Wild Plants in Natural Associations. A Database for Landscaping, Habitat Creation and Local Planning. Christopher Betts, Worcester.

[111] Dunnett, N. & Hitchmough, J. (2004). The Dynamic Landscape. Spon Press, London.

[112] Luscombe, G. & Scott, R. (2004). Wildflowers Work. A Guide to Creating and Managing New Wildflower Landscapes. Landlife, Liverpool.

[113] Hitchmough, J. & Fieldhouse, K. (2004). Plant User Handbook A Guide to Effective Specifying. Blackwell Science, Oxford.

[114] Nottage, A. & Robertson, P. (2005). The Saltmarsh Creation Handbook: A Project Manager's Guide to the Creation of Saltmarsh and Intertidal Mudflat. The RSPB, Sandy and CIWEM, London.

[115] Earth Pledge. (2005). Green Roofs. Ecological Design and Construction. Schiffer Books, Atglen.

[116] Newton, J., Gedge, D., Early, P., & Wilson, S. (2007). Building Greener: Guidance in the use of green Roofs, GreenWalls and Complementary Features on Buildings. CIRIA, London.

[117] Environment Agency (2009). Estuary Edges. Ecological Design Guidance. EA, London.

[118] Urbanska, K.M., Webb, N. & Edwards, P. (1997). Restoration Ecology and Sustainable Development. Cambridge University Press.

[119] Fox, H.R., Moore H.M. & McIntosh A.M. (Eds.). (1998). Land Reclamation. Achieving Sustainable Benefits. AA Balkema, Rotterdam.

[120] The River Restoration Centre (2002). River Restoration Manual of Techniques. RRC, Silsoe.

[121] Eades, P. Bardsley, L., Giles, N. & Crofts, A. (2003). The Wetland Restoration Manual. The Wildlife Trusts, Newark.

[122] Rooney, P., Nolan, P. & Hill, D. (2005). Restoration, Re-Introduction and Translocation. Proceeding of the 20th Conference of the Institute of Ecology and Environmental Management. IEEM, Winchester.

[123] Rodwell, J. 1991 to 2000). British Plant Communities. 5 volumes. Cambridge University Press.

[124] Goode, D. (2005). Connecting with Nature in a Capital City: The London Biodiversity Strategy. In: T. Tryzna (Ed.) The Urban Imperative. Urban Outreach for Protected Area Agencies. California Institute of Public Affairs, Sacramento.

[125] Harrison, C., Burgess, J., Millward, A. & Dawe, G. (1995). Accessible Natural Greenspace in Towns and Cities: A Review of Appropriate Size and Distance Criteria. English Nature, Peterborough.

[126] Town and Country Planning Association. (2008).

[127] Institute of Ecology and Environmental Management. (1996). Guidelines for Ecological Impact Assessment. IEEM, Winchester.

[128] Kusler, J.A. & Kentula, M.E. (1990).

[129] Box, J. (1998). Setting Objectives and Monitoring for Ecological Restoration and Habitat Creation. In: H.R. Fox, H.M. Moore and A.M. McIntosh (Eds.). Land Reclamation. Achieving Sustainable Benefits. AA Balkema, Rotterdam. pp 7-11.

[130] Global Invasive Species Database. See: http://www.issg.org/database/welcome/

[131] Robertson, B.A. & Hutto, R.L. (2006). A Framework for Understanding Ecological Traps and an Evaluation of Existing Evidence. *Ecology*, 87 (5): 1075-1085.

[132] Klem, D. (2006). Glass: A Deadly Conservation Issue for Birds. *Bird Observer*, 34(2): 73-81.

[133] Longcore, T. & Rich, C. (2004). Ecological Light Pollution. *Front Ecol Environ*, 2(4): 191-198.

[134] Sherwood, B., Cutler, D. & Burton, J. (2002). Wildlife and Roads. The Ecological Impact. Imperial College Press, London.

[135] English Nature (1994). Planning for Wildlife in Towns and Cities. English Nature, Peterborough.

[136] UK Biodiversity Action Plan. UKBAP Priority Species and Habitats. Accessed 2010 at http://www.ukbap.org.uk/newprioritylist.aspx

[137] Hill, D. (Ed.) (2007). Making the Connections: A Role for Ecological Networks in Nature Conservation. Proceedings of the 26th Conference of the Institute of Ecology and Environmental Management. IEEM, Winchester.

[138] Town and Country Planning Association (2009).

[139] Semlitsch, R.D & Bodie, R.J. (2003). Biological Criteria for Buffer Zones around Wetlands and Riparian Habitats for Amphibians and Reptiles. *Conservation Biology*, 17(5): 1219–1228.

[140] Melles, S.J. (2005). Urban Bird Diversity as an Economic Indicator of Human Social Diversity and Economic Inequality in Vancouver, British Columbia. *Urban Habitats* (3)1:1541-7115.

[141] Kuo, F. E. & Sullivan., W.C. (2001). Environment and Crime in the Inner City: Does Vegetation Reduce Crime? *Environment and Behavior*, 33, Number 3:343-367.

[142] Lancaster University and the Centre for Ecology and Hydrology. (2004). *Trees and Sustainable Urban Air Quality. Using Trees to Improve Air Quality in Cities*. University of Lancaster, Lancaster.

[143] Mayor of London. (2002). Connecting with London's Nature. The Mayor's Biodiversity Strategy. Greater London Authority, London.

[144] Singapore National Parks Board and Convention on Biological Diversity. (2009). User's Manual for the Singapore Index on Cities' Biodiversity. Final. CBD, Montreal.

145 Wells, M.J. & Engleback, L. (1997). Ecological Sustainability in Urban Design: Aspirations and Achievements. In: Environmental Policies in Europe: Towards Sustainability. Proceedings of the 1997 European Environment Conference. ERP Environment, Shipley.

[146] Wells, M.J. (2006). Ecologically-led Landscape Design in Brownfield Regeneration Projects. In: E. Williams (Ed). Designing Nature into Urban Development and Regeneration. Proceedings of the 16th National Conference of the Institute of Ecology and Environmental Management 2002. pp156-171. IEEM, Winchester.

[147] Douglass, I. & Box. J. (2000). The Changing Relationship between Cities and Biosphere Reserves. Report prepared by the Urban Forum and the UK Man and Biosphere Committee. http://ukmaburbanforum.org.uk/Publications/Cites

[148] Goode, D. (2006).

[149] de Leo, G.A. & Levin, S. (1997). The Multifaceted Aspects of Ecosystem Integrity. *Conservation Ecology* (online): 1(1):3.

[150] Jørgensen, S.E., Costanza, R.& Fu-Liu, X. (Eds.). (2005). Handbook of Ecological Indicators of Ecosystem Health. Taylor and Francis, London.

[151] Imanishi, J. & Hon, J. (Eds.) (2010). Proceedings of the Second International Conference on Urban Biodiversity and Design. URBIO(2010). URBIO2010 Organising Committee. http://www.jilac.jp/URBIO2010/doku.php

[152] Reynolds, P. (1998). Wildlife Corridors and the Mitigation of Habitat Fragmentation. European and North American Perspectives. Capreolus Wildlife Consultancy, Garvald, Scotland.

[153] Andrews, J. (1993). The Reality and Management of Wildlife Corridors. *British Wildlife*, 5(1):1-8.

[154] Kirby, K. (1995). Rebuilding the English Countryside: Habitat Fragmentation and Wildlife Corridors as Issues in Practical Conservation. English Nature Science Series, 10. English Nature, Peterborough.

[155] Dawson, D. (1994). Are Habitat Corridors Conduits For Animals and Plants in a Fragmented Landscape? English Nature Research Report, 94. English Nature Peterborough.

[156] Farr, D. (2007).

[157] Newman, P. & Jennings, I. (2008). Cities as Sustainable Ecosystems. Principles and Practice. Island Press, Washington.

[158] Dunnett, N. & Hitchmough, J. (2004).

[CLIX] Town and Country Planning Association. (2009). Biodiversity Positive: Ecotowns Biodiversity Worksheet. TCPA, London.