REWILDING OUR CITIES

ZSL

Cover image © Matthew Maran

Since 2000 Matthew Maran has travelled the world winning awards for his landscape and wildlife photography in the Wildlife Photographer of the Year, European Wildlife Photographer of the Year, and the British Wildlife Photography Awards.

Matt works with commercial and non-profit organisations to showcase conservation efforts taking place on their land in the form of books and video. Running private and group workshops, Matt helps people to engage with nature through photography, encouraging them to explore ideas and themes with an end product, such as a book or archival print.

Matt's images have been published in The Guardian, Daily Telegraph, BBC Wildlife and National Geographic Magazines. He has also published three books under his own imprint, Hemisphere Publishing. His images are represented by Nature Picture Library and his current work tells the story of urban foxes close to his home in north London.

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CONSERVATION STARTS AT HOME

by Dr Nathalie Pettorelli, Lead Author

A Senior Scientist at the ZSL Institute of Zoology, Nathalie's main research focus is on assessing, predicting and mitigating the impacts of global environmental change on wildlife. A climate change ecologist and rewilding expert, her scientific achievements include demonstrating how satellite data can be used to support vulnerability assessments of species and ecosystems to climate change, to pioneering social media as a source of data for species on the move due to climate change. Nathalie has published several books and over 200 scientific contributions on the topics of biodiversity monitoring, conservation and wildlife management.

Bisons roaming endless prairies, wolves chasing elks across snowy landscapes, golden eagles preying on inattentive hares; these are the types of images of distant places devoid of human presence that generally pop into people's minds when talking about rewilding. Rarely do people associate the concept of rewilding with urban settings, despite the huge potential for urban rewilding to boost biodiversity and ecosystem services in our cities.

"...we all have a role to play to help address the environmental crises we are facing."

In this report, we argue that this perception bias needs to be addressed, and explore how rewilding could work for urban ecosystems, looking at potential benefits, opportunities, challenges and ways forward. Crucially, we make the point that urban nature is in dire need of visibility, support and respect, given its critical role in supporting the health and wellbeing of more than half of the human population in the world.

Admittedly, urban rewilding is unlikely to help recover the giraffe and lion populations of this world, but rewilding our cities isn't just about what it can do for improving species conservation statuses. It's also about what it can do for human-wildlife coexistence, and how it could help many of us to re-learn to live with, value and make place for nature, recognising that we all have a role to play to help address the environmental crises we are facing. A well-known adage says that "charity starts at home"; one could argue that conservation starts at home too. And home, for the majority of us, is a city or a town.

Snouted seahorse in the River Thames. © ZSL

High rise buildings around Lumphini park, Bangkok, Thailand. © Niradj, Shutterstock.

Roe deer in the Netherlands. © Rudmer Zwerver, Shutterstock.

FOREWORD
CREATING A WORLD WHERE WILDLIFE THRIVES

by Dr Andrew Terry, ZSL Director of Conservation and Policy

Andrew Terry works with pioneering scientists from ZSL's Institute of Zoology and animal management experts from ZSL's two world-class Zoos to shape its cutting-edge approach to the delivery of conservation impact. He leads the delivery of ZSL's new conservation plan across major ecosystem programmes in Europe, Africa and Asia. Before this he led Field Programme delivery for 11 years at the Durrell Wildlife Conservation Trust, where he was also responsible for co-developing Durrell's new global strategy. Prior to this Andrew served as a scientific advisor at IUCN's European Programme in Brussels.

At ZSL, our vision is for a world where wildlife once again thrives within rich and diverse ecosystems that are resilient and able to sustain human populations. Sadly, our current reality is instead one of emptying land and seascapes.

Everywhere we look, we see the impacts of the mass commodification of natural ecosystems and the reduction in the numbers of living creatures. The implication for humanity is disastrous – the combination of these threats increases pressures on food systems, human health and wellbeing. The recovery of healthy ecosystems and the wildlife they host, is not simply a nice-to-have, but a vital survival strategy for the future.

"For so many people, these areas will be their primary engagement with nature."

As this publication sets out, rewilding is an approach to the recovery of dynamic and diverse ecosystems that places a focus on how ecosystems function. Once seen as anarchic and challenging, it is also inspiring and empowering, and has fast become mainstream. Rewilding contains a strong social dynamic. At ZSL, we believe that to 'bend the curve' of biodiversity loss, we must first achieve a more balanced coexistence with wildlife. This balance will differ in time and space depending on the specific challenges people face and their beliefs and attitudes.

Rewilding calls for strong connections with wildlife to be rebuilt and become central to decision-making around future restoration. As a global conservation charity with two Zoos, this philosophy is at the heart of our approach. We want to see strong connections to nature to help support the next generation push for the mass recovery of wildlife.

In this report we show that there need not be a line drawn between rural and urban areas. In fact, our urban areas must be embedded within their wider landscapes. We want to see the edges blurred and rich habitats coexist alongside our typical urban settings. For so many people, these areas will be their primary engagement with nature. The growing set of global examples shows that 'wild' urban areas can moderate local temperatures, improve health and wellbeing and provide important habitats for wildlife to thrive; thus providing an important part of the response to the global climate and biodiversity crises.

REWILDING OUR CITIES – EXECUTIVE SUMMARY

Biodiversity is declining globally at unprecedented rates, eroding the very foundations of our economies, livelihoods, food security, health and quality of life. At the same time, humanity is facing a climate emergency, with anthropogenic greenhouse gas emissions altering climatic conditions, sea levels and the pH of surface ocean waters.

The biodiversity loss and climate change crises are interdependent issues: rapidly changing climatic conditions are threatening the long-term survival of many species and the integrity of many ecosystems across the globe, while the loss of biodiversity is reducing our planet's ability to store carbon and nature's and people's ability to adapt to and/or cope with changing climatic conditions. In addition, both climate change and biodiversity loss underpin the public health crises created by zoonotic disease emergence and spread. Given these linkages, there is increasing scientific and political recognition of the need to tackle the climate and biodiversity crises in unison.

Large-scale nature recovery as a solution to jointly address the biodiversity, climate change and public health crises has gained significant traction in scientific and political circles in recent years. However, attention on recovery tends to be focused towards more natural ecosystems, with relatively little focus on the contribution of significantly more anthropogenically disturbed environments, like cities, where 68% of the global population are projected to live by 2050.

"Rewilding is a flexible, low-cost, hands-off management approach to biodiversity conservation that can be deployed across a wide range of situations in urban settings."

Within this context, this report discusses the potential contribution of urban rewilding approaches to enhancing biodiversity and climate mitigation and adaptation opportunities in cities.


Pembrokeshire kelp. © Chris Yesson, ZSL

Rewilding is a flexible, low-cost, hands-off management approach to biodiversity conservation that can be deployed across a wide range of situations in urban settings. Rewilding seeks to reinstate natural processes, as opposed to restoring given former ecological states (invariably challenging in urban environments), and hence promotes reorganisation and redevelopment of ecological systems under changing environmental conditions, which increases ecological resilience. As such, it may provide a more successful approach to managing a variety of urban sites to enhance wildlife within cities, particularly those experiencing rapid climatic changes.

Rewilding of our cities could provide several benefits, including improved climate change mitigation and adaptation opportunities; air pollution reduction; slowing down of biodiversity loss; reduced environmental management costs; and improved human health and wellbeing. Integrating rewilding with other nature conservation initiatives at the landscape scale could bolster ecosystem services from our open spaces and make cities more resilient to global environmental change, including the most extreme effects of climate change. Crucially, rewilding also offers a tremendous opportunity to engage an often disconnected public with nature.

Chequered skipper feeding on nectar. © Dave Jones, Butterfly Conservation.

However, the adoption of rewilding approaches for environmental management in urban settings comes with a number of challenges, which, if not properly assessed and addressed, could ultimately lead to further biodiversity loss and increased threats to public health. This potentially includes the facilitation of the spread of invasive species; risks of disease transmission; increased human-wildlife conflicts; divestment from existing conservation sites; and reinforcement of existing social injustices in the distribution of benefits and risks arising from nature recovery.

"Over the next decades, urban spaces will become ever increasingly populated and more at risk of the impacts of climate change, such as intense heat and flooding."

If well implemented, urban rewilding projects are likely to generate substantial biodiversity, health and wellbeing benefits alongside significant opportunities for economic and social development. Opportunities for urban rewilding that could be considered practical, sustainable and likely contributing to the conservation and enhancement of nature and biodiversity are diverse and include private spaces such as home gardens and cemeteries; public gardens and parks; railways; and urban waterways such as rivers, wetlands and estuaries.

Key steps to support the successful implementation of urban rewilding projects include adopting a landscape conservation approach; factoring in the local policy context and developing a sustainable financing strategy; engaging local communities with urban rewilding efforts broadly and regularly; anchoring environmental management decisions in science; learning from existing projects; investing resources into monitoring; and building partnerships, especially between cities.

Over the next decades, urban spaces will become ever increasingly populated and more at risk of the impacts of climate change, such as intense heat and flooding. As such, urban design that supports biodiversity can be an effective accelerator of public health and wellbeing, and a cost-saving measure in the long term as the effects of climate change become an increasing economic burden. Urban rewilding projects can provide new ways to engage city residents with nature, including through monitoring and stewardship processes. This, in turn, could provide inspiration for further conservation initiatives, while helping to revitalise and rebalance relationships between people and nature.

The Thames European Eel Project © ZSL

1. UNDERSTANDING REWILDING AND URBAN REWILDING

1.1 What is rewilding?

Rewilding is a novel and rapidly developing concept in ecosystem management, representing a transformative approach to conserving biodiversity. Originally defined as a conservation method based on "cores, corridors, and carnivores" (Soulé and Noss 1998, Figure 1), the term is now broadly understood as a conservation approach that supports the reinstatement of natural processes in functionally degraded ecosystems, putting these ecosystems on a trajectory to being more ecologically complex and less controlled by humans (Pettorelli *et al.* 2019a, Svenning 2020).

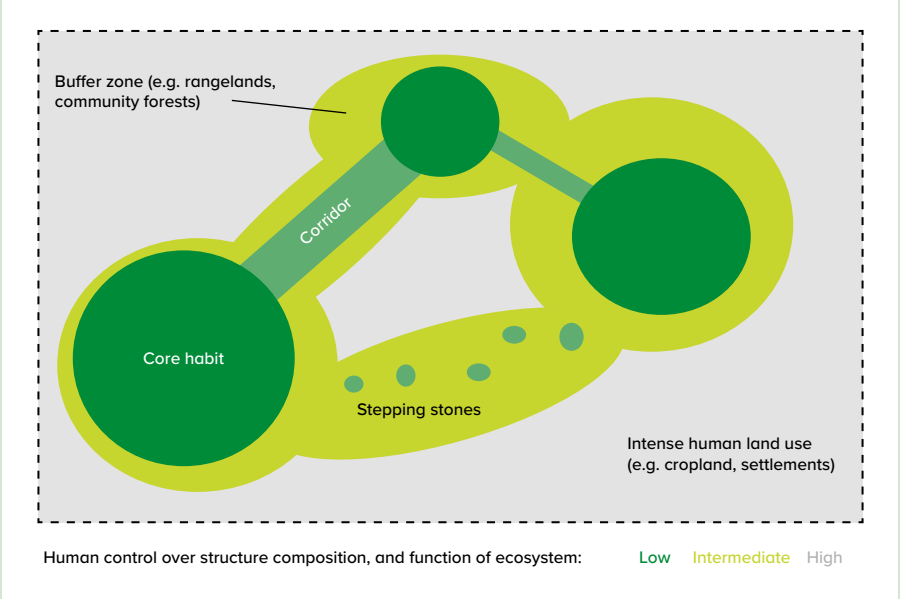


Figure 1: In its earliest form (Soulé and Noss 1998), rewilding was conceived as a way to restore wildness to large tracts of land by creating a network of large habitat cores, connected by corridors or through stepping stones, that can support a complete suite of species, including apex predators.

Rewilding is often conflated with restoration, because both might involve similar management actions (such as species translocations) and people can mistakenly assume that both approaches have similar aims. However, rewilding differs from traditional restoration approaches in several ways: (i) rewilding aims for minimal to no ongoing management in the long term; (ii) it focuses on present and future ecosystem functioning and resilience, as opposed to historical benchmark conditions; and (iii) it has lower fidelity to taxonomic precedent (i.e., what species were there pre-disturbance) which enables taxonomic substitutions for extinct native species that once underpinned the delivery of key ecological functions (du Toit and Pettorelli 2019).

1.2 What does rewilding entail?

Rewilding can be achieved in several ways, such as land abandonment, species translocation, civil engineering, or combinations thereof. It is based on the principle of minimal to no management intervention in the long-term, but interventions may be needed in the early phase of a rewilding project to facilitate the emergence of ecological and ecosystem processes that cannot be recovered without intervention (for example, when natural colonisation by species with key functional roles is limited or impossible). A famous example of a rewilding project that necessitated major civil engineering is Oostvaardersplassen in the Netherlands, 20km from Amsterdam, which involved the use of dykes, polders and pumps to reclaim an area of former seabed originally for industry but that was allowed to be colonised by terrestrial species, some of which were introduced and some of which continue to arrive unassisted (Marris 2009).

1.3 Can rewilding be implemented in cities?

Rewilding has long been associated with large herbivores and carnivores, as well as trophic cascades and landscape-scale nature recovery (Soulé and Noss 1998, Carver *et al.* 2021). As such, there has been hesitation and reluctance to use the concept of rewilding in the context of cities, given the fragmented, highly modified and mostly megafauna-free status of urban ecosystems.

That said, it has been increasingly recognised that urban ecosystems are ecosystems of concern for biodiversity conservation (being for example listed in the recent International Union for Conservation of Nature (IUCN) typology as part of the ecosystems found in the intensive land-use biome; Keith *et al.* 2020), with many cities being richer in plant species, including in native species, than rural areas, and sometimes harbouring self-sustaining populations of rare and threatened native species (Kowarik 2011, Ives *et al.* 2015).

Urban ecosystems are fundamentally different from many other ecosystems. They are structurally complex and highly heterogeneous fine-scale spatial mosaics of diverse patch types that include elements such as buildings, paved surfaces, transport infrastructure, areas with trees, patches of grass, waterbodies, gardens and allotments, mines or quarries, bare ground and refuse areas, usually with high and near-continuous levels of pedestrian and vehicular movements along numerous thoroughfares. These patch mosaics are dynamic over decadal time scales and driven by socio-ecological feedbacks and interactions among patch types. Patches may be small in size, but urban ecosystems as a whole can cover very large areas.

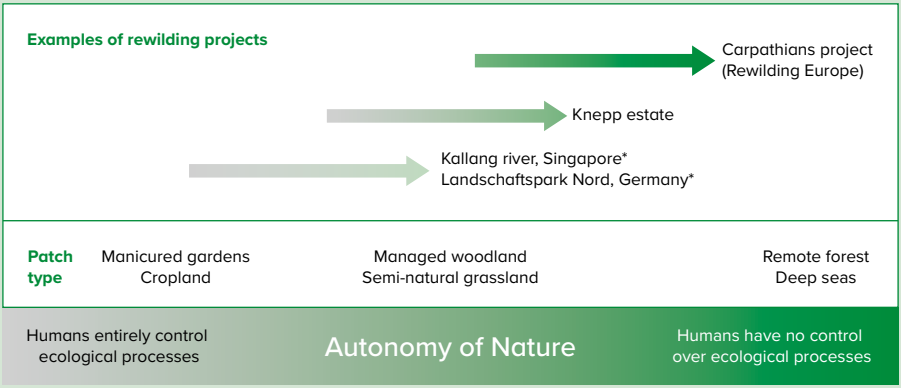


Figure 2: Rewilding can be thought of as moving an area – ranging in scale from a single garden to an entire landscape with multiple ecosystems – from a less "wild" to a "wilder" state, i.e., increasing the autonomy of nature. The starting points of rewilding projects differ significantly, as does the increase in autonomy that is achieved by any given project. It is the increase in the autonomy of nature that characterises rewilding efforts, rather than arriving at a particular endpoint. Note that human control is not only the result of active management of natural ecosystems, but more often an unintentional side effect of other human activities (for instance, fragmentation of habitat due to cropland expansion increases human control of species composition and water flows in a landscape). *Projects referenced throughout the report.

The notion that rewilding approaches aim to move ecosystems on a continuum of human modifications (Carver *et al.* 2021, Figure 2), transitioning them towards a state of increased ecological complexity and reduced human control supports the idea that rewilding ambitions are relevant to discussions pertaining to the management of urban ecosystems. Admittedly, urban rewilding efforts are unlikely to transition urban ecosystems to "functioning native ecosystems containing the full range of species at all trophic levels while reducing human control and pressures" (Carver *et al.* 2021). However, the strategic deployment of rewilding initiatives across the urban landscape can help urban ecosystems recover multiple ecological processes and interactions, including trophic interactions; boost a number of ecosystem functions; and increase overall ecosystem resilience (Box 1).

Red-humped agoutis. © Miroslav Hlavko, Shutterstock

Box 1: Using animal reintroductions for rewiring ecological networks in an urban Atlantic Forest reserve in Brazil

Species translocations are used in both restoration and rewilding projects alike. In rewilding projects, the ultimate aim of species translocations is to establish or reinforce a missing ecological process, such as herbivory, trampling, seed dispersal, or predation, whereas restoration generally aims to achieve a particular species composition, or to conserve a particular species (although this can have beneficial side effects on ecosystem functioning). This means that choosing species for translocation in rewilding projects applies different criteria than choosing species for restoration or species conservation projects.

An example for this is the refaunation project in Tijuca National Park, a secondary Atlantic forest in the middle of Rio de Janeiro, Brazil. Used as agricultural land after European colonisation, it underwent reforestation in the second half of the 19th century (Matos 2002). However, the faunal community remains impoverished, and given the urban surroundings of the park which cut off natural recolonisation opportunities, it is unlikely that many species will disperse into the park without assistance. As a result, active translocation has been used to restore key animal-mediated ecological processes, especially seed dispersal.

The project identified a small group of animals which would likely be effective in dispersing seeds, helping to rewire the trophic network from the ground up. In 2010, red-humped agoutis were introduced, and a small group of brown howler monkeys followed in 2015 (Fernandez *et al.* 2017). While the howler monkey population has remained small, experiments using artificial seeds and observations of feeding behaviour of the released animals indicate that they could restore seed dispersal processes that usually involve large animals, which deposit seeds in their faeces (with evidence suggesting that this benefits seeds germination), and small dung beetles, which transport these seeds to germination-friendly microsites, benefiting the regeneration of trees (Genes *et al.* 2019). However, it is unlikely that a full suite of Atlantic forest mammals can be restored in the park. For instance, the top predator in these ecosystems, jaguars, have an average range size that exceeds the entire size of the park; in addition, their presence near densely populated areas might lead to unacceptable risks to nearby residents. Under these constraints, animal translocations in Tijuca National Park have been selected in order to restore some key ecological functions to this urban rainforest, making it wilder but not fully restored (Mongabay 2022).

2. BENEFITS OF URBAN REWILDING

As discussed in section 1, urban rewilding can be defined as any low to no management initiative that seeks to improve the biodiversity of urban environments. There are several potential benefits associated with the deployment of rewilding approaches in urban settings. These include improved climate change mitigation and adaptation opportunities as well as disaster risk reduction; reduced pollution levels; slowing down of, and potentially even supporting the reversal of, biodiversity loss; reduced environmental management costs; and improved human health and wellbeing. These benefits are individually detailed below.

2.1 Climate change mitigation and adaptation

Policy makers worldwide now recognise that urban green spaces have a key role in 'future proofing' cities against climate change (Demuzere *et al.* 2014, Quaranta *et al*. 2021). The rewilding of heavily degraded spaces (and the subsequent increase in vegetated cover) as well as drastic reductions in the management practices used to maintain monocultures and manicured green spaces could reduce carbon emissions while also boosting carbon sequestration capacity in cities. This is also likely to improve the resilience of carbon storage capacity in the face of climate change, as there are early indications that wild species and self-regulated ecological communities are more drought-resistant and sequester more CO_2 than ornamental and/or exotic plants (Lehmann 2021, Figure 3). This is likely to be the case especially in situations where rewilding would lead to an increase in shrubs and trees, and to increased retention of carbon in the soil (for instance through reduced erosion and increased organic matter content).

Giving nature freer reins in an increased number of situations across cities could moreover help to buffer them against extreme climatic events such as storms, floods and heat waves, which are expected to intensify and become more frequent with climate change (IPCC 2021). Creating new wetlands could, for example, attenuate spate flows caused by extreme rain events while increased vegetation cover in parks and gardens, as well as greening infrastructure such as roofs and walls, can help cool cities during heat waves. The recovery of coastal habitats adjacent to cities could help reduce the risk of flooding from storm surges. In addition, identifying ecosystem engineers of various body sizes in target habitats, and prioritising their inclusion in rewilding programs, could help protect biodiversity via microhabitat creation and maintenance, which in turn is protective against extreme climatic events such as droughts and heatwaves (Thakur *et al.* 2020).

Figure 3: The common primrose is a wild, spring flowering perennial across Europe. It has been extensively bred to provide new cultivars that improve the uniformity and seasonality of flowering, in addition to enhancing the flower size and colour. As a consequence, the majority of cultivars now in existence are similar in overall size to the wild species but generally offer more substantial floral displays in an extensive range of colours. In 2019, Lewis and colleagues evaluated the cultivated forms of the common primrose, and tested whether these were less resilient to the effects of droughts than their wild progenitor species. Their results demonstrated that cultivated taxa were more susceptible to the hydrological stresses imposed than the common primrose, which has implications for the design of future gardens and ornamental landscapes (Lewis *et al.* 2019). *Picture source: Primrose. © Fabrizio Conte, Shutterstock.*

2.2 Reduced pollution

In 2019, air pollution was the 4th leading risk factor for early death worldwide, surpassed only by high blood pressure, tobacco use, and poor diet (Health Effects Institute 2020). Specifically, the recent "*Global Burden of Disease*" study estimated that, in 2019, 4.5 million people died prematurely from outdoor air pollution (from particulate matter and ground-level ozone), while 2.3 million died from indoor air pollution. The burning of fossil fuels – (especially coal, petrol, and diesel) is a major source of airborne fine particulate matter, and it was recently estimated that air pollution from burning fossil fuels was responsible for about 1 in 5 deaths worldwide (Vohra *et al.* 2021).

Urban rewilding is expected to lead to increased vegetation cover and structural complexity of vegetated areas that can help reduce air pollution levels, which tend to be worse in cities. Some plants are markedly more effective at filtering pollutants from the air than others, with, for example, conifers offering highly effective particulate matter reduction. Canopy size, leaf size, and leaf structure are all factors shaping the potential of green patches for air pollution reduction. Aquatic and riparian vegetation may also process pollutants, helping to improve water quality. It is, however, important to acknowledge that increases in vegetation cover are far less effective at lowering pollution levels than are measures to reduce emissions at source, and hence the use of plants should not be the primary pollution reduction measure but should be combined with other pollution reduction strategies (Nemitz *et al.* 2020).

2.3 Contribution to wildlife recovery

Urban rewilding initiatives are expected to help slow species loss and support wildlife recovery by increasing habitat availability and connectivity. In turn, this could facilitate the return of certain species, support the natural or facilitated colonisation of urban areas by new species, and improve the viability of existing populations of species. Improved connectivity, for example, could benefit species such as West European hedgehogs, a species of conservation concern in the United Kingdom where populations have declined markedly since the 1950s (Figure 4).

Figure 4: Hedgehogs are important components of urban ecosystems, helping, among other things, to regulate insect populations in cities. In the UK, hedgehogs have experienced a dramatic decline over the last 20 years, with estimates suggesting that numbers have fallen from 1.5 million in 1995 to under 1 million in 2015. Multiple factors may be interacting to produce this effect, including habitat loss and fragmentation, use of pesticides and agricultural chemicals and road traffic. London HogWatch, a project supported by the Zoological Society of London (ZSL), was established in 2016 to identify the locations of some of the main hedgehog populations in greater London in order to protect these populations and encourage their growth, while ZSL's Garden Wildlife Health project investigates possible infectious and non-infectious disease threats to hedgehog conservation.

Despite declines being reported both in urban and rural areas, the West European hedgehog seems to be persisting in cities and towns, highlighting the importance of urban environments for the conservation of this species. Increased habitat availability and connectivity could further support this species and facilitate the return of other animals such as the Eurasian beaver, a keystone species known to promote local biodiversity through the impact it has on its habitats. The rewilding of our cities may also facilitate species movements at larger scales, as wildlife adapts to rapidly changing environmental conditions. Nature-led areas are likely to be more dynamic in terms of changes in composition, structure and function, adapting more rapidly, for example, to changes in climatic conditions. This could favour the creation of a greater diversity of habitats, which would support a greater number of species as they move through landscapes. Many cities around the world are home to a large number of non-native species, many of which can have ecologically benign impacts but are often the subject of costly removal programmes. The open-ended, passive management approach of rewilding is more open to the emergence of novel urban ecosystems that may develop as a result of the integration of exotic species and species redistribution in response to climate change.

2.4 Reduced environmental management costs

Rewilding is about establishing patches of nature that are self-regulating, self-reorganising, with minimal to no management interventions. As such, urban rewilding could reduce the need for, and the carbon emissions and financial costs associated with, active management. For example, in urban green spaces, procedures such as mowing lawns, watering, and weeding could be hugely reduced or eliminated (Box 2). Furthermore, increased ecological complexity in rewilded sites could increase the diversity of natural pathogens and predators, aiding pest control and leading to diminished needs for harmful (and costly) chemicals and pesticides.

Box 2: London Zoo's car park

London Zoo's car park consists of grass and trees, and the area used to be regularly mown. About 17 years ago, the Zoological Society of London (ZSL) changed its management regime by putting an end to the mowing, apart from removing docks and thistles before seed setting, cutting around the edges and creating a pathway through the middle of the park. One practical advantage of this management approach was, and remains, the lower impact on management resources. Early on, ZSL carried out additional whip planting, which was discontinued a few years later in favour of letting self-seeded trees establish, many of which were coppiced to feed as browse for the Zoo's animals. For the last three years or so, ZSL has also managed the bramble thickets in the car park on a rotational regime to provide suitable nest site cover for hedgehogs. Local wildlife surveys over the past eight years have shown that ZSL's car park is a hedgehog hotspot within Regent's Park, being home to a higher density of hedgehogs than other parts of the park. Butterfly surveys of the Zoo grounds (14.8ha) and car park (2.7ha) moreover regularly record almost the same number of species in both areas, but a higher density of individuals in the car park.

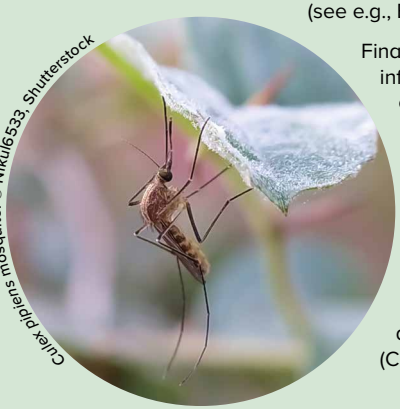
2.5 Improved human health and wellbeing

Contact with nature is beneficial for human existence, physical and mental wellbeing, and a good quality of life (Aerts *et al.* 2018). Green and blue spaces provide access or pathways to increased physical activities, reduced stress and more social interactions. Rewilding our cities is likely to benefit residents through four major mechanisms.

First, increased vegetation cover can improve urban microclimates, notably through its reduction of the urban heat island effect, which leads to significantly warmer urban areas compared to surrounding suburban or rural areas, particularly at night. Urban greenery and tree canopy cover help reduce this heat gain, cool homes and lessen the negative impacts of heatwaves on human health (Lehmann 2015).

Second, increased access to nature (such as trees, woodlands, parks, gardens) is likely to improve human health and wellbeing, including improved mental health and a reduction in disease, including reduced long-term risks of diabetes and heart disease. For example, access to green spaces is associated with lower mortality rates and there are increasing calls for green space prescriptions as a core approach to the treatment of some long-term medical conditions (Twohig-Bennett and Jones 2018). As urban populations continue to rise, nature focused urban design is likely to be increasingly needed to deliver health and social benefits and to play an effective role in creating sustainable, healthy urban spaces. Rewilding activities themselves offer important learning and enrichment opportunities with the general public and specifically schoolchildren that are key to ensure that future generations are aware of the importance of nature to human health and wellbeing. Increased access to natural ecological communities with higher biodiversity provides opportunities for children and adults to immerse themselves in nature and to learn how best to foster biodiversity in their local environments, including engaging in citizen science approaches to nature stewardship in urban communities and exploring their emotional connections to nature.

Third, an increased richness in wildlife species has been shown to provide a protective mechanism against human infection with certain zoonotic diseases. For example, the risk of West Nile virus infection in people decreases with increased avian diversity, while increased biodiversity can also protect against human infection with Lyme disease (see e.g., Ezenwa *et al.* 2005, Dobson *et al.* 2006).



Culex pipiens mosquito. © Nikul6533, Shutterstock

Finally, in addition to reducing direct damage to infrastructure, biodiversity and public health caused by climate change, rewilding helps to reduce the severity of extreme weather events (e.g., flooding, heat waves), thus mitigating the facilitating effect these events have on infectious disease threats to public health (Mora *et al.* 2022). Climate change has been demonstrated to increase the risk of cross-species viral transmission including zoonotic disease spill-over, so mitigation activities, such as urban rewilding, provide an additional mechanism for the protection of biodiversity and people from the emergence of novel diseases (Carlson *et al.* 2022).

2.6 Increased economic activity and wealth

Rewilded areas can potentially make significant economic contributions to urban areas. This includes attracting visitors to view wildlife and enjoy nature, with associated increases in economic activity for facilities including accommodation and restaurants. As urban areas improve their amenity values and reduce their disaster risks, property prices may increase, adding to the local tax revenues for cities and councils. For these reasons, rewilding could play a significant role in the regeneration of economically deprived areas, turning their often marginal locations into an asset rather than a liability.

Harbour seals in the Greater Thames Estuary. © ZSL

3. CHALLENGES ASSOCIATED WITH URBAN REWILDING

Adopting rewilding as a management approach for environmental management in urban settings is not free of challenges. Potential issues include rewilding sites providing safe havens for invasive alien species, potentially facilitated through increased levels of species introductions by the public; increased levels of human-wildlife conflict; green gentrification; negative perceptions of rewilded sites by residents; funds diversion from existing, traditional conservation sites; lowered monitoring standards; and complex legal and financing structures. These issues are discussed in detail below.

3.1 Problematic invasive alien species

Invasive alien species are species whose introduction is followed by a rapid spread causing, or contributing to, economic or environmental harm, or harm to human, animal, or plant health. These species are known to be a major driver of biodiversity loss worldwide, as they can dramatically impact the viability of native or indigenous species by reshaping the strength and type of ecological interactions found in the introduced environment, such as competition, predation, hybridisation, introduction of diseases and parasites. Because rewilding sites are expected to experience low to no management, rewilding sites may provide safe havens for invasive alien species, which tend to be quite frequent in urban settings. This may mean rewilded areas could become sources of problematic species for adjacent, more classically managed, spaces (Figure 5).

Figure 5: Examples of invasive species that could benefit from urban rewilding projects. Tree of heaven (left) is a tree that reaches heights of up to 30m, native to China and introduced to a wide range of other regions of the world. The species was first introduced to the UK in 1751 (Kowarik and Säumel 2007). It has been extensively planted as an ornamental tree in Southeast England, especially in London, where it is now naturalised. Tree of heaven grows on a wide range of soils and does particularly well in disturbed urban environments, such as derelict sites and railway lines; the species thrives in warmer temperatures and copes well with water stress. While introduced trees of heavens contribute to the provision of ecosystem services and their environmental tolerance indicates resilience to climate change, the species also has highly invasive traits. Being a pioneer species that reproduces vegetatively from suckers and by air-borne seeds, tree of heaven outcompetes other plants by forming dense stands and being strongly allelopathic. Once established, plants are extremely difficult to control through a combination of cutting and herbicide use. *Picture by L. F. García, published under a Creative Commons Attribution-Share Alike 2.1 (Spain) license.* Japanese knotweed (right), a highly invasive species, was introduced to the UK in the 1850s, and has since spread over all British Isles; the species is known to negatively impact native flora, as well as human infrastructure (Cheok *et al.* 2020). In the UK, home sellers are legally required to state whether Japanese knotweed is present on their property, and property owners are required to prevent it spreading to other sites. Invasive species such as Japanese knotweed could lead to significant damage to neighbouring areas if they established on rewilded sites, showing how important ongoing monitoring of rewilded sites will be. *Picture by W. Carter, published under a Creative Commons CC0 1.0 Universal Public Domain Dedication license.*

3.2 Species introductions by the public

Economic crises, changes in personal situations and misinformation around animal care and welfare requirements are all factors that can lead to individuals releasing native and exotic species into unsuitable urban settings. For example, evidence from Australia shows escapes of pet birds were reported more frequently within, or around, large Australian capital cities (Vall-llosera and Cassey 2017). As authorities increase communication about the importance of enhancing urban biodiversity to mitigate and adapt to the climate crisis, and economic conditions worsen, there is a risk that cities around the world could see an increase in the number and diversity of exotic and native species released in the environment. A sensitisation campaign around this issue should be conducted in parallel with any rewilding activities.

3.3 Disease

Rewilding may involve the deliberate movement of species for the purpose of population reinforcement, reintroduction, assisted colonisation or ecological replacement. Any translocation of animals during rewilding, whether intentional or unsolicited, involves the movement of not only animal hosts but an accompanying biological 'package' of parasites (bacteria, viruses, fungi, macro and microparasites) that have the potential to induce disease (see e.g., Figure 6). The risk of an outbreak of infectious disease is particularly high when these parasites are novel to the destination site (Cunningham 1996, Shadbolt *et al.* 2021). The consequences of infectious disease include compromised health and welfare of individual animals, reduced population numbers and potentially disease-induced extinction of rare species. For example, the international spread of amphibian chytridiomycosis caused by the fungus *Batrachochytrium dendrobatidis*, facilitated by human introduction, has been associated with the decline of many hundreds of amphibian species and the global extinction of more than 90 amphibian species worldwide (Scheele *et al.* 2019). In rare cases wildlife pathogens may evolve the capacity to 'jump' host species or to cause zoonotic disease in humans. Rewilding might also increase the abundance of wildlife species, such as rodents and mosquitoes, that carry and transmit pathogens that are harmful to other wild animals (e.g., avian malaria parasites), to domesticated animals (e.g., lungworm in dogs), or to people (e.g., *Leptospira* bacteria). Such risks may be particularly pertinent to rewilding within urban landscapes as the successful implementation of rewilding projects may lead to increased frequency of direct and indirect interactions between wildlife, domestic animals and people, with these being likely to increase over time. These risks can be avoided or mitigated, but to do this, disease threats need to be considered during the planning, implementation and adaptive management of the rewilding projects.

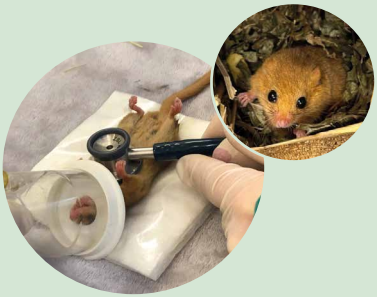


Figure 6: The disease risk analysis and health surveillance (DRAHS) team at the Zoological Society of London (ZSL) quarantines captive-bred hazel dormice each year prior to release into the wild as part of a collaborative initiative with conservation partners. In 2000, parasitology screening of hazel dormice faeces during quarantine detected ova of a *Rodentolepis*-like cestode species, unreported in free-living hazel dormice and considered capable of causing infectious disease in both rodents and humans. Dormice were treated to eliminate the endoparasite prior to release and to mitigate the risk of a translocation-associated disease outbreak in free-living animals. DRAHS continues to conduct rigorous veterinary health examinations on hazel dormice each year during quarantine as part of managing disease risks during translocations and to ensure the health and viability of released and recipient populations.

3.4 Divesting resources from existing, traditional conservation sites

As the popularity of rewilding continues to increase, rewilding approaches could be perceived by various audiences as a replacement to traditional conservation approaches, which could lead to resources being diverted from existing important conservation sites. This problem may further be exacerbated as cities continue to expand and encroach on nearby protected or conserved areas.

3.5 Human wildlife conflict

Human-wildlife conflict is a term that broadly captures situations when encounters between humans and wildlife lead to negative impacts on people, such as damage to property, livelihoods, domestic animals and even human life. Increased wildlife in cities through rewilding may lead to increased human-wildlife conflicts through, for example, increased wildlife-vehicle collisions, risk of zoonotic disease transmission, allergies, property damage, tree roots as trip hazards, falling branches that can kill or injure, and physical attacks to people or their pets. Such conflicts can increase hostility to wildlife and may lead to public retaliation, including attempts to eradicate species deemed to be problematic. Thus, increases in human wildlife conflict could have negative consequences for both people and wildlife that will need to be mitigated and balanced against potential benefits.

3.6 Green gentrification

City residents represent a very diverse community, with, for example, large differences in average income and political power among people living in urban settings. New urban greening projects, including rewilding ones, can magnify disparities and lead to the exclusion of more marginalised communities from the areas where these projects are implemented. Increased enthusiasm for rewilding projects within cities could indeed impact neighbourhoods' character, attracting private investment and increasing property prices. This could lead to the exclusion and displacement of politically disenfranchised residents, a process known as green gentrification. Left unchecked, this could exacerbate inequity and compromise any contribution that urban rewilding can make to health and social benefits (Maller *et al.* 2019).

3.7 Attitude to urban green spaces

Urban green spaces such as parks are public amenities that are often managed for their visual impact. This tendency to treat these spaces as 'gardens to be manicured' or conversely to see unmanaged areas as unkept, grubby, or literally waste ground, will be a challenge to enabling the reduction in management attention. Areas left free from weeding, mowing or intense management are likely to host more wildlife and a greater diversity of species; but these may also be targeted either as areas for regeneration or as areas where anti-social activities take place, such as refuse dumping. Finding a balance of enabling areas to be wild but equally making them safe and accessible to all will be key in future efforts.

3.8 Lack of monitoring

Rewilding is, in many respects, defined as an open-ended approach to biodiversity restoration, whereby a high level of unpredictability in ecological outcomes is expected. Moreover, it may be seen as a hands-off approach to biodiversity management. This may result in pressure from some stakeholders to reduce stewardship of rewilded sites and to regard ecological monitoring as an unnecessary task. However, rewilding will continue to require stewardship, even if at lower levels than other approaches to biodiversity conservation; a lack of monitoring would lead to (i) an inability to assess the effectiveness of rewilding interventions and (ii) hamper opportunities for adaptive management. This would ultimately prevent the detection and mitigation of potential socio-ecological risks, which could place projects and their ecological outcomes in jeopardy.

3.9 Challenging policy contexts, and complex legal and financing structures

The current environmental and biodiversity policy landscape of most countries worldwide takes an historical view that emphasises the preservation of past environmental and ecological conditions. This traditional thinking is mirrored in the style and substance of environmental, biodiversity and conservation legislation that has limited flexibility in adapting to new approaches like rewilding. However, global environmental change is driving some species far beyond their traditional ranges and some ecosystems far beyond their limits: in such situations, restoring historical conditions, particularly when looking at urban landscapes, may not be a realistic objective and the facilitation of the emergence of novel ecosystems through rewilding may prove a more sensible and cost-effective alternative to address declining biodiversity and ecosystem services delivery (Pettorelli *et al.* 2018).

Without supportive and enabling policy and legislative environments, urban rewilding projects will yet remain limited in scope and spread. The broader adoption of rewilding as an approach to boosting nature recovery in cities will require policy landscape changes around the world, from legislative frameworks currently in place for biodiversity, land use and agricultural policy that focus on historical benchmarks and species and habitat composition, towards more comprehensive regulatory environments that also make space for nature-led projects and recognise the importance of enhancing ecosystem functionality (Pettorelli *et al.* 2018).

In addition to facing challenging policy contexts, rewilding projects may also be complex to design from a financing perspective. They may typically require diverse revenue streams that will need to be stacked together to cover the cost of up-front investments. Embedding these projects in markets that are emerging or incomplete, such as nutrient trading, biodiversity credits or insurance premium reductions, could make such enterprises challenging. Revenues from the ecosystem services provided to outcome payers such as utilities and local governments will indeed need to be captured through bespoke legal structures. This is done to assign rights (such as carbon rights), to provide assurance of permanence (such as conservation covenants) and to gain investments and sales (such as offtake agreements). Quantifying future benefits of an ecosystem that, by definition, is not directed, adds further challenges. Financing solutions that “work” from a commercial perspective may be difficult to identify, meaning that public and/or philanthropic funding will be required.

4. IDENTIFYING OPPORTUNITIES FOR URBAN REWILDING

The Covid-19 pandemic has brought about a seismic shift in the way we think about space in cities. It became obvious during successive lockdowns that a lot of our urban environment is not green or accessible enough, directly impacting our health and wellbeing, particularly in more deprived areas of our cities. Sections 2 and 3 of this report have explored the potential benefits and challenges associated with the rewilding of our cities, but, practically speaking, where could we, or should we, retrofit our existing towns and cities to accommodate rewilded spaces? In this section, we explore opportunities for urban rewilding that could be considered practical, sustainable and likely contributing to the conservation and enhancement of nature and biodiversity.

4.1 Improving the proportion of vegetated private spaces

Often overlooked in comparison to parks and larger green spaces, private spaces such as domestic gardens are key components of urban ecology, providing multiple ecosystem services and refuge for urban wildlife. For example, the Greater London Area in the United Kingdom covers an area of 1,569 km^2, with private gardens making up approximately 24% of this area. Only 57% of existing private gardens is vegetated cover however, meaning that approximately merely 14% of Greater London is made up of private green space. This percentage is declining, negatively impacting biodiversity (Webb and Moxon 2021).

Similarly, the major faiths are important landowners and public facing bodies in many countries around the world. Cemeteries, places of worship and associated gardens are quiet spaces for reflection, but also important urban green spaces that could be partially or wholly rewilded (Figure 7). Being relatively undisturbed, they could represent significant opportunities for wildlife recovery, while still accommodating the needs of their users. Promoting a change in behaviour of private landowners, to convert part or all of their green spaces to attract more wildlife could increase cities' biodiversity and resilience to climate change, while also improving health and wellbeing.

4.2 Public gardens and parks, partly or wholly

Public gardens and parks represent major green spaces in many cities and the partial rewilding of some or all of these areas could significantly boost urban wildlife recovery. In a number of situations, local authorities already have initiatives to actively increase nature within their areas, with, for example, one in five county councils having embraced rewilding on public land in Great Britain, with a growing number setting aside former golf courses, post-industrial scrubland and recovering waterways for nature (The Guardian 2022). Many local authorities may thus be interested in supporting a rewilding agenda for their city, potentially being willing to act as centres of rewilding effort, demonstration and wildlife recovery. The rewilding of public gardens and parks, taking into account current primary uses, could include passive approaches such as the removal of any form of management on parts of the land; but it could also include active replanting and targeted species recovery efforts, including potential translocations of wildlife into gardens and parks that are sufficiently large and well connected to sustain their populations.

Figure 7: Green spaces can spontaneously rewild during periods of neglect. This creates new opportunities for wildlife, but often requires careful balancing of the needs of nature with economic, social and cultural functions of such spaces. Highgate Cemetery, one of the 'Magnificent Seven' cemeteries in London, is one such site. During a period of neglect and economic problems in the 20th century, vegetation was able to grow unchecked, creating its characteristic overgrown appearance. In the eastern part, a secondary woodland formed. Today, the cemetery is a Site of Metropolitan Importance for Nature Conservation, and while management of the vegetation is more proactive to preserve the gravestones and historical monuments, biodiversity conservation remains an explicit aim of the management of the entire site (Highgate Cemetery 2019). *Picture source: East cemetery of Highgate Cemetery © GaryPerkin, Shutterstock.*

4.3 Railways

Cities' railway networks often comprise extensive green space, including railway verges, unused tracks and other lineside landholdings, which, if rewilded, could help boost urban biodiversity in multiple ways. In the United Kingdom, for example, the primary rail infrastructure manager (Network Rail) is also one of the nation's largest public landowners, with a total estate of 51,700 hectares, with the densest concentrations of this land in urban areas where rail lines converge. These landholdings represent and traverse diverse habitats (Figure 8), in theory providing refugia for rare and threatened species and enabling functional connectivity between habitat patches, as seen e.g., on French railways (Vandevelde and Penone 2017). Habitat availability and movement potential are critical for species persistence under pressure from human-induced threats, such as land use change and climate change (Morelli *et al.* 2017) and can be a particular challenge in complex urban environments. Yet green spaces surrounding railways are frequently subjected to intensive vegetation management and are sometimes disconnected from adjoining landscapes.

While some management is necessary for the safe and efficient operation of railways, there are significant opportunities to rewild the railway green spaces, particularly in cities, with benefits for urban biodiversity and people. In the UK, Network Rail recently made ambitious commitments to enhance biodiversity throughout its lineside estate and to maximise the value and connectivity of its landholdings as ecological corridors, including transforming its approach to vegetation management. Rewilding could represent a cost-effective way to deliver on this mission, from passive removal of management and amelioration of barriers to enable regeneration of habitats, enhance connectivity, and build ecological resilience, to active rewilding to restore processes like natural vegetation management and carbon sequestration.

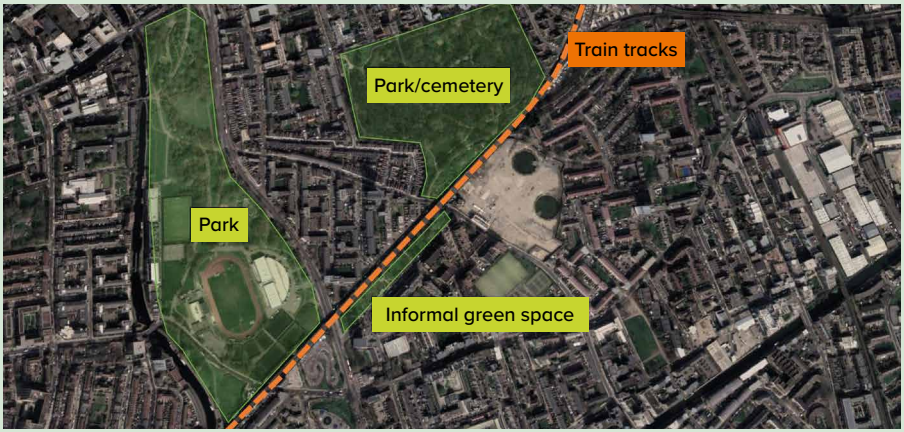


Figure 8: A train track running through East London, potentially connecting diverse green spaces. Used and unused train tracks, and adjacent vegetation, can create linear corridors through densely settled urban environments. These could connect urban green spaces (such as private gardens and public parks), as well as urban habitats with the surrounding rural landscape. *Picture from Google Earth and Maxar technologies 2022.*

4.4 Rivers, wetlands and estuaries

Many cities around the world have been built near and around rivers, wetlands and estuaries. Urban waterbodies can play a critical role in supporting urban biodiversity and ecosystem services in a rapidly changing world (see e.g., Belaire *et al.* 2022) with, for example, urban streams and vegetated riparian areas often providing vital connectivity across developed landscapes and often being important hotspots for both biodiversity and local provisioning of ecosystem services (Butler *et al.* 2022). However, in many places, sections of rivers are disconnected from their riparian zone or worse, buried in culverts (i.e., artificial structure to channel a subterranean waterway, such as a pipe or reinforced concrete), while wetlands are being drained or hidden under our feet, and intertidal habitats built on (Box 3).

Rewilding provides an opportunity to reimagine how we manage urban surface water drainage and to daylight rivers and streams used as surface water sewers. The creation of wetlands will filter and improve water quality, replenish ground water and build resilience to extreme weather events and climate change. In many cities established on estuaries, there may be opportunities to create new intertidal habitats such as saltmarshes, mangroves or mudflats, which are important for supporting wildlife, including economically important fish species, as well as providing buffering from floods and storm surges. Rivers often forming natural blue corridors through urban centres. Deculverting rivers in cities and the removal of the numerous barriers that restrict fish movement could achieve a great deal for restoring ecosystem services and making space for wildlife, while allowing natural vegetation to cover the banks of urban rivers and streams could provide further resilience against extreme weather and contribute to increased functional connectivity.

Box 3: Rewilding an urban river

Kallang River in Bishan-Ang Mo Kio Park. © Danny Ye, Shutterstock

Historically, rivers in urban centres have been polluted by sewage and other by-products of people and their activities; their channels have been straightened to facilitate transportation (or diverted underground); they have been disconnected from their floodplains; and their water has been (over-) abstracted. Taken together, urban rivers are often severely degraded, having for example very little normal flooding behaviour, low water quality and reduced biodiversity (Everard and Moggridge 2012). Rewilding can be a useful tool to restore river functionality, with benefits for people and wildlife alike. One example for this is the Kallang River in Bishan-Ang Mo Kio Park in Singapore, whose channel had been straightened and reinforced with concrete in the 1970s as part of a series of hard infrastructure projects aimed at alleviating water management problems across Singapore. In 2006, this river was restored as part of Singapore's Active, Beautiful and Clean (ABC) Waters Programme, which focuses on re-naturalising waterways to aid flood management and create new communal spaces. The channel was un-straightened and widened, slowing down the waterflow and creating habitats for freshwater species. Hard and soft engineering techniques, including the use of riverbank vegetation, were used to stabilise the new riverbanks. The river was also reconnected to a floodplain (the surrounding park), allowing excess surface water during rainstorms to drain away from the residential areas, thus restoring a key function of the river. In addition, accessibility to the park for the surrounding residents was improved, so that people could benefit from the revitalised river (An *et al.* 2020).

5. KEY STEPS TO SUPPORT URBAN REWILDING PROJECT IMPLEMENTATION

As discussed in section 1, rewilding is a journey with no fixed end point, where the goal is to help nature help itself so it can thrive in the future. How this goal will be achieved in specific urban settings will depend on a number of factors, including ambition, finances, the size and level of connectivity of the area(s) to be rewilded as well as their current level of ecological degradation. That said, there are some principles that should underpin all urban rewilding projects, such as the consideration of the wider landscape context in which the proposed rewilding project will sit; a good understanding of the local policy context and the setting up of sustainable financing arrangements; broad, inclusive and sustained engagement with the local communities likely to be impacted by the rewilding project; the use of scientific evidence to underpin environmental management decisions; the drawing of inspiration and wisdom from existing rewilding projects; the development of a well-funded, long-term, comprehensive, monitoring strategy; and the building of strong partnerships. These principles are detailed below.

5.1 Adopting a landscape view

Any new urban rewilding project will want to add value to the work already being undertaken to help conserve and enhance nature in the city considered. As such, it will be important to consider the wider landscape context in which individual conservation sites, including rewilded ones, sit. This includes accounting for the relationships between 1) different rewilding sites in the same city, 2) rewilding sites and other sites nearby that are primarily managed for nature (such as traditionally managed parks or nature reserves), 3) rewilding sites and other urban land uses (such as settlements or industrial plants), and 4) urban rewilding sites and nature in the surrounding rural areas.

Considering the relationship between rewilding sites across the whole city is useful for ensuring that species can freely move between sites, to encourage higher species diversity and more diverse ecological processes, and to enhance the delivery of ecosystem services. Taking into account the proximity and connectivity with other wildlife sites, particularly those primarily used for nature conservation, is necessary to ensure that sensitive sites (e.g., key populations of endangered species) can be safeguarded from any risks of harmful spill-over effects of rewilding projects. Considering the urban landscape in which a potentially new rewilding project is situated is needed to make the site accessible and safe for potential visitors, especially for groups of people otherwise excluded from urban nature.

Taking the regional view, ensuring that urban rewilding networks are themselves connected to natural spaces beyond the city could create migration corridors for species for which urban areas are normally difficult to traverse, helping them to shift their ranges and adapt to climate change, thus benefiting biodiversity at a much larger spatial scale. However, some species could potentially be lured into poorer quality, urban habitats inside the city, creating a population sink, with potential negative impacts on the growth rate of the wider population (Figure 9). Considering urban sites in the context of the wider landscape will help identify which spaces might benefit most from connectivity within and beyond the urban rewilding network.

Figure 9: Raptors are often important apex predators and scavengers in urban ecosystems, taking advantage of suitable nesting sites in tall buildings, and hunting small mammals, birds and insects in urban green spaces such as public parks (Mak *et al.* 2021). However, urban areas can also be an ecological trap – an area that appears like high quality habitat, but cannot in fact sustain wildlife, for instance because of a lack of food or breeding sites. This then requires active decisions by people (such as building managers) about whether to support the wildlife attracted by these traps by providing the missing resources, or whether to discourage them from settling. For example, when a pair of peregrines initially nested on the roof of London's Charing Cross Hospital, their attempts were unsuccessful, as the nest was vulnerable to rain. Only after a nesting box was installed were offspring raised successfully, but this required the hospital to make significant concessions to the peregrines (e.g. giving up parts of their rights to the property under the Wildlife and Countryside Act 1981, Mak *et al.* 2021). *Picture © Harry Collins Photography, Shutterstock.*

5.2 Understanding the local policy context and setting up sustainable financing arrangements

Although urban rewilding projects may share the same vision, they will inevitably be implemented within different ecological, socio-economic and legislative contexts, which need to be accounted for. In particular, what can and cannot be done will be shaped by the local policy context, with environmental, biodiversity, land use and agricultural policy varying, often significantly, between countries and regions.

Moreover, there are costs associated with initiating rewilding projects. These will vary in magnitude depending on the size of the project and its current ecological conditions, but may include costs for actions to kick-start the ecological rewiring process (including animal species introductions, seeding of wildflowers or planting of trees, or infrastructure work like naturalising riverbeds) and, very importantly, public engagement activities. Examples of such public engagement activities include working with local communities and other stakeholders to develop an understanding of the benefits and potential risks associated with the project or creating governance frameworks for active stakeholder input into rewilding projects. Such actions are necessary to create support for urban rewilding projects, without which sustained project success is unlikely. Sufficient funding needs to be secured over an appropriate timeframe, with low level of long-term finance likely to be more desirable than higher levels of short-term funding. This will vary depending on the socio-ecological context and the size and scope of the rewilding project, but funding is likely to be required over many years for many rewilding projects. For rewilding projects with identified income streams, a strong enabling environment will be required for up-front investors, whether it is land tenure and zonation or legal framework and regulation of markets, such as carbon credits, biodiversity credits and nutrient net gain.

5.3 Ensuring that residents are onboard

For urban rewilding to deliver on its potential, it will be imperative to engage residents with the approach, so that (i) they are prepared and ready to share their city with an increased abundance and diversity of wildlife, and (ii) they are equipped with the knowledge needed to sustainably increase natural processes on their properties.

As discussed in sections 2 and 3, rewilding projects can bring both benefits and disadvantages to local communities, highlighting the importance of communicating a nuanced picture of rewilding into which health and social benefits can be positioned (Maller *et al.* 2019). Awareness and education campaigns that reach audiences beyond the usual communities that engage in conservation are thus important activities to secure support ahead of, and throughout, the implementation of rewilding projects in urban settings. In that respect, initiatives such as Rewild My Street (Rewild My Street 2022) provide an interesting example of grass roots engagement and how knowledge can be shared.

Citizen science initiatives also hold potential for the public to contribute to monitoring of the impacts of urban rewilding, while providing opportunities for residents to learn about local biodiversity. This can enhance the positive effects of nature on human health and well-being (Cox and Gaston 2015, Figure 10) while boosting support for rewilding projects by local communities. Technology-enabled, online citizen science platforms, such as ZSL's Instant Wild (Instant Wild 2022), may also provide a means to enable residents to participate directly in rewilding efforts, and to engage groups traditionally excluded from enjoyment and conservation of wild spaces, including individuals who, for physical or mental health reasons, are unable to easily spend time in nature.

Figure 10: Remote monitoring images of grey and harbour seals in the Greater Thames Estuary, identified by members of the public using an online citizen science platform called Instant Wild. Seals can be found throughout the Thames, including central London, and are important top predators, helping maintain complex estuarine communities and their ecosystem functions and services. Monitoring is vital to ensure conservation efforts are successful in the face of threats like habitat loss. Instant Wild, a project from the Zoological Society of London, enables the public to participate directly in seal monitoring. Citizen science platforms could also provide a means to engage city residents in monitoring of urban rewilding projects, and in so doing to build support for and knowledge of the approach.

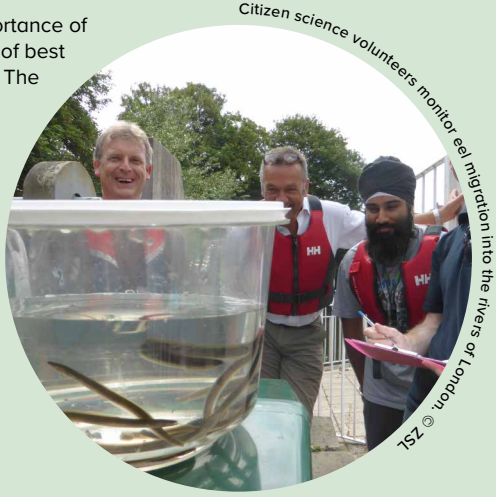
Community 'buy-in' will be central to not only the establishment, but also the longevity of rewilded spaces. Public education, engagement and perceived 'ownership' of these spaces will be needed for them to be accepted and in turn protected by local communities. For such acceptance to take place there will be a need for education on how these spaces can benefit communities in the short and long term. The benefits need to be spelled out clearly, along with how rewilding differs from how people may traditionally think of and relate to green spaces. Local engagement and education will also need to sit alongside national education campaigns and awareness raising to create both a local and national sense of understanding, ownership and pride of these new rewilded spaces. Political leadership at all levels of government will be needed to ensure the relevant policy is both put in place and implemented to support local communities in the transition to living alongside rewilded spaces.

5.4 Following the science

The science of rewilding has progressed tremendously over the past decade (Pettorelli *et al.* 2019a), with institutions such as the IUCN firmly engaged in providing evidence-based recommendations to guide the implementation of rewilding projects (see e.g. IUCN Rewilding Working Group 2022).

For example, animal translocation and introduction projects are expected to implement best practice IUCN guidelines. The IUCN Species Survival Commission (SSC) guidelines pertaining to the movement of species for conservation purposes, stress the importance of protecting the health of translocated individuals and the recipient ecosystem (IUCN SSC 2013). A disease risk analysis should be conducted as part of planning any rewilding strategy that includes species translocations, to identify the potential for pathogens to cause disease in either the target or sympatric species (OIE/IUCN 2014), including human beings. Disease risk management, based on the outcomes of disease risk analyses, should involve the development of a comprehensive protocol for health screening animals prior to translocation and maintaining biosecurity during translocation (Cunningham 1996, Shadbolt *et al.* 2021).

Furthermore, IUCN guidance recognises the importance of post-release health surveillance as a component of best practice following translocation (IUCN SSC 2013). The intensity and duration of this surveillance, which may include active and passive components, needs careful consideration for rewilding projects and is likely best tailored according to the recommendations of disease risk analyses, outcomes of disease risk management and long-term vision for the programme. Involvement of social and natural scientists, including wildlife health experts, as well as investment in risk management throughout the duration of rewilding initiatives should be considered vital to their success.



Citizen science volunteers monitor eel migration into the rivers of London © ZSL

5.5 Learning from existing projects

A number of cities around the world have now engaged with rewilding; together, they provide inspiration for what might be achieved in degraded urban settings (Box 4) and examples of how such activities can be replicated and scaled up. For example, Singapore has worked to rewild its spaces by introducing green walls and roofs (and incentivising people to install them); installing 18 'Supertrees', 50-meter-tall artificial trees that contain over 150,000 diverse plants and act like trees by filtering rainwater, generating solar power and providing shade; and creating 150 kilometres of 'Nature Ways', which mimic the multi-layered structure of a rainforest habitat and act as green corridors to boost biodiversity.

In addition, abandoned spaces have become successfully rewilded in Germany, where abandoned lots in Frankfurt, Dessau and Hanover were transformed into wildflower meadows. The project, called *Städte wagen Wildnis* (Cities Dare Wilderness), has reported increases in the numbers of birds, hedgehogs, butterflies, and bees, and authorities say the meadows are more drought-tolerant than the short lawns they replaced, which in turn saves water.

Box 4: Abandoned and neglected, or wild and biodiverse? Two examples for rewilding to respond to socio-economic change in Germany

Rewilding is often suggested as an effective strategy for using abandoned land, such as permanently fallow agricultural fields or the outskirts of shrinking cities. Local communities may perceive this encroachment of wild(er) nature as a sign of neglect and decline, or as an enrichment of their existing surroundings, resulting in very different perceptions of the value of rewilding for a region.

The Landschaftszug Dessau-Roßlau in East Germany is an example of a rewilding project that was challenged by negative perceptions of the ecological changes rewilding brought about. Dessau-Roßlau is a small town that, like much of East Germany, is experiencing population decline, leading to buildings being abandoned and remaining empty. As part of the 'Städte wagen Wildnis' project (Städte wagen Wildnis 2022), the city redesigned its development strategy (Deutsche Welle 2016). Aiming to concentrate urban areas into smaller 'islands', surrounded by a partly rural, partly rewilded matrix with different management intensities, they aimed to capitalise on low competition for space between 'wild' nature and other land uses, while keeping the budget for nature management low. Empty buildings in Dessau were razed, and the basements filled in, before either being left completely to themselves, or reseeded with wildflowers and mowed annually. However, there was criticism from both local residents and conservation groups, who saw this approach as signifying abandonment, rather than revitalisation. In fact, rubbish was left in rewilded areas, which was interpreted as a sign that few people saw these as desirable spaces. However, by ensuring the rewilded areas remained

Landschaftspark Nord in Duisburg. © Alice-D. Shutterstock

accessible, and explaining ecological change to visitors, as well as by documenting the return of wildlife to these areas, perception of the rewilded sites has been improved.

The Landschaftspark Nord in Duisburg (Landschaftspark Duisburg-Nord), a landscape park situated on the site of a former iron works, is an example for how rewilding can be part of a wider revitalisation strategy. The region in West Germany where it is located has been historically dominated by heavy industries – especially coal mining, and iron and steel production – since the 19th century. With the decline of the coal industry, starting in the middle of the 20th century, many of the old industrial sites have been successively abandoned. The Landschaftspark Nord was designed to reflect its industrial past, with lots of the original buildings being maintained and made accessible to visitors, while other opportunities for recreation were created alongside it, such as hiking trails, a diving site in an old gasometer, climbing walls, and event spaces. While there are managed gardens within the park, there also are areas where nature is left to its own devices. This has resulted in spontaneous succession and the arrival of trees, and many insects, birds and bats. In fact, 700 of the 2000 plants species known to occur in the region can be found on this former industrial site, 50 of which are red listed (Keil 2019). Rather than becoming a symbol of the decline of major industry (a key source of local identity), the site is now a symbol of nature recovery and a popular space for humans and other species alike.

5.6 Getting the monitoring right

Rewilding is a low-cost management approach, but investment will still need to be made to systematically and robustly monitor rewilding projects so that we build understanding of the socio-ecological impacts of different interventions, detect and manage potential risks, and provide evidence of the benefits of the approach in the long term. An important part of this is monitoring species and habitats at landscape scales to detect signals of ecological change and rewilding benefits while keeping a careful record of management interventions: these changes and benefits will differ depending on the ecological context, but could for instance include increased vegetation cover, higher species diversity and more species interactions, or improved carbon storage and water cycling. Evaluating reinstatement or reinforcement of ecosystem functions can be methodologically challenging, not least because of the potential for relatively long time lags between the implementation of a rewilding project and the recovery of ecological and ecosystem processes (Torres *et al.* 2018), often necessitating repeated interventions and measurements over multiple years. Where appropriate, technology may offer opportunities to enable cost-effective, repeated monitoring of ecological outcomes at scale, including via satellite (Figure 11) and ground-based remote sensing, automated AI-enabled data analysis, and Internet of Things connectivity. In addition, actively engaging residents in the monitoring process, for example via participatory digital citizen science platforms (see e.g., Mac Aodha *et al.* 2018, Pettorelli *et al.* 2019b, Schulte to Buhne *et al.* 2022, Gallacher *et al.* 2021) can be beneficial to local understanding and acceptance of rewilding.

Figure 11: "Monte Scherbelino", a former landfill site situated in a city forest In Frankfurt am Main, Germany. This area has been allowed to regenerate autonomously since 2014, as part of the Städte wagen Wildnis project (see Box 4). The site is currently closed to the general public due to harmful emissions from the landfill: however, managed access is possible as part of guided tours (e.g., for photography, or for school visits). *Pictures from Google Earth, Maxar Technologies, 2022.*

To make sure resources spent on monitoring return relevant information, it is crucial to have a scientifically robust theory of change for a given rewilding project, which should be informed by expert opinion, including local ecological knowledge, as well as insights from ecological and social sciences. Monitoring provides important opportunities to involve local citizens in surveying nature and engage with the monitoring process, including developing local understandings around relationships between biodiversity, ecosystem functions and rewilding interventions. This, in turn, can inspire further rewilding efforts and build a nature stewardship community within our cities.

5.7 Building partnerships

Whether we are looking at urban greening, restoration or rewilding, bringing back nature in cities is a goal shared by many across the world. Much could be gained if stronger connection, collaboration and partnerships could be built among initiatives supporting nature recovery in cities. For example, cities could partner together as a way of starting a journey for urban rewilding across a given region, country or continent. This could boost engagement with rewilding initiatives in given cities, by e.g., engendering local interest and pride amongst citizens, opening opportunities for financial support for multi-city projects and initiatives, as well as facilitating knowledge and best practice sharing between decision makers and other stakeholders. Initiatives such as the IUCN urban alliance (IUCN Urban Alliance 2022) and the Urban Biodiversity Hub (Urban Biodiversity Hub 2022) can represent important platforms for promoting knowledge exchange and collaboration among urban rewilding projects, but also between urban rewilding projects and other approaches to nature recovery in cities.

REWILDING OUR CITIES: CONCLUSIONS

The next decades will see urban spaces expanding, becoming ever increasingly populated and more at risk to the impacts of climate change, such as intense heat and flooding. In this era of climate shifts, the long-term safety and sustainability of our cities will depend on their ability to adapt and mitigate climate shocks. Rewilding could be a key part of the urban design toolbox to improve public health and wellbeing and save costs in the long term as the effects of climate change become an increasing economic burden.

Every city is unique. Cities differ not only in their size and density and in the distribution of their population and green spaces but also in their climatic and cultural contexts, geography, and in the ways in which they are vulnerable to climate change. When it comes to enhancing urban resilience through applying nature-based solutions such as rewilding, what works in one city may not work in another. In particular, cities around the world are subject to very different policy landscapes, some of which potentially reducing opportunities for rewilding to deliver on its promises. To make rewilding work for cities, it will be essential to create enabling policy environments that can build an effective regulatory space for nature-led projects to thrive.

Nature recovery, whether in urban environments or other settings, requires funding, but it also requires a reduction in practices that are known to substantially and negatively impact biodiversity, such as the use of pesticides or the replacement of vegetated cover with artificial lawns. Artificial turfs, which are proliferating in many rich countries, pose several health and environmental risks, including urban habitat loss, increased urban temperatures, reduced carbon sequestration, reduced water and nutrient cycling and environmental pollution via contaminant release. We need stronger legislation to counteract the spread of artificial turfs and other activities that undermine efforts to restore nature in cities.

Urban rewilding offers exciting opportunities to (re)introduce new species in cities around the world, but our recommendation is that rewilding efforts will prioritise existing biodiversity action plan species for the areas considered. We also recommend that rewilding efforts will be geared towards improving connectivity within urban landscapes, thereby supporting natural recolonisation whenever possible.

By 2050, two out of every three people are likely to be living in cities or other urban environments (United Nations 2019). Rewilding provides new prospects to engage these residents with nature, including through monitoring and stewardship processes. This, in turn, provides inspiration for further rewilding initiatives, while helping to revitalise and rebalance relationships between people and nature.

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