Overarching Topic

Integrating Ecosystem Services into Ecological Restoration

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Rebuilding nature

Good practice guidance for ecological restoration

CIEEM

This document is part of a series written by experts in ecological restoration from the UK and Ireland, led by members of CIEEM's Ecological Restoration Special Interest Group. The series is prefaced by ten good practice principles for ecological restoration, set out in *Rebuilding nature: Good practice guidance for ecological restoration*, and includes five Overarching Topics that apply to any ecological restoration project in the terrestrial, freshwater and marine environments of the UK and Ireland:

- **Integrating Ecosystem Services into Ecological Restoration**
- **Project Planning and Implementation**
- **Physical Environment**
- **Large Scale Nature Recovery and Restoration**
- **Monitoring**

Accompanying the five Overarching Topics are the habitat specific documents applicable to ecological restoration projects in terrestrial, freshwater and marine environments.

What are ecosystem services?

Ecosystem services are the direct and indirect contributions that living and non-living components of ecosystems (labelled as 'natural capital') provide for human wellbeing and quality of life. Natural capital includes stocks of the elements of nature that have value for society, like forests, fisheries, rivers, biodiversity, soils, minerals and land (CIEEM, 2022[1]). Ecosystem services encompass the tangible and intangible benefits that humans obtain from ecosystems. They are sometimes separated into 'goods' and 'services' (UK National Ecosystem Assessment, 2023[2]).

Ecosystem services are generally grouped as follows to reflect their roles and values:

- Supporting services including nutrient cycling, primary production, soil formation and habitat provision, all of which underpin other ecosystem services.
- Provisioning services are products or goods like food, fibre, ornamental and genetic resources.
- Regulating or maintenance services provide the key benefits of ecosystem processes such as climate regulation, flood management and clean air.
- Cultural services principally relate to the non-material world and benefit different aspects of life through recreation, aesthetic, cognitive and spiritual activities. Human health and wellbeing (mental and physical) is a separate service, but is also derived from the other activities. Heritage and archaeological values should be embraced here too although they are rarely incorporated into cultural services. However, a sense of place **(Figure 1)** could be derived from cultural heritage features. The cultural services are usually the most difficult to ascribe a monetary value.

The definitions in the list above are taken from the Millennium Ecosystem Assessment (2000[3]) and developed further by NatureScot[4] from which **Figures 1** and **2** are derived, showing the full range of ecosystem services for both terrestrial and marine systems.

1 https://cieem.net/wp-content/uploads/2022/11/Natural-Capital-and-Ecosystem-Service-information-and-guidance-v2-1.pdf

2 http://uknea.unep-wcmc.org/EcosystemAssessmentConcepts/EcosystemServices/tabid/103/Default.aspx

3 https://www.millenniumassessment.org/en/index.html

4 https://www.nature.scot/scotlands-biodiversity/scottish-biodiversity-strategy-and-cop15/ecosystem-approach/ecosystem-services-natures-benefits

Figure 1

Terrestrial Ecosystem Services

(NatureScot).

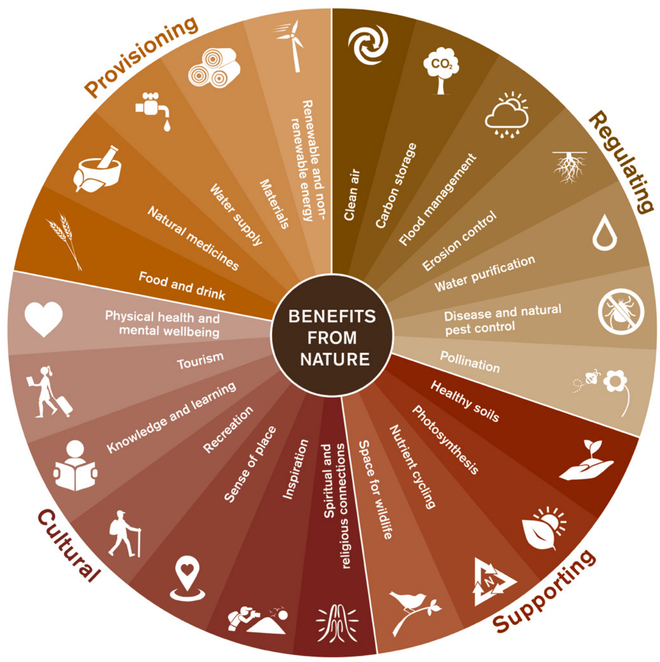
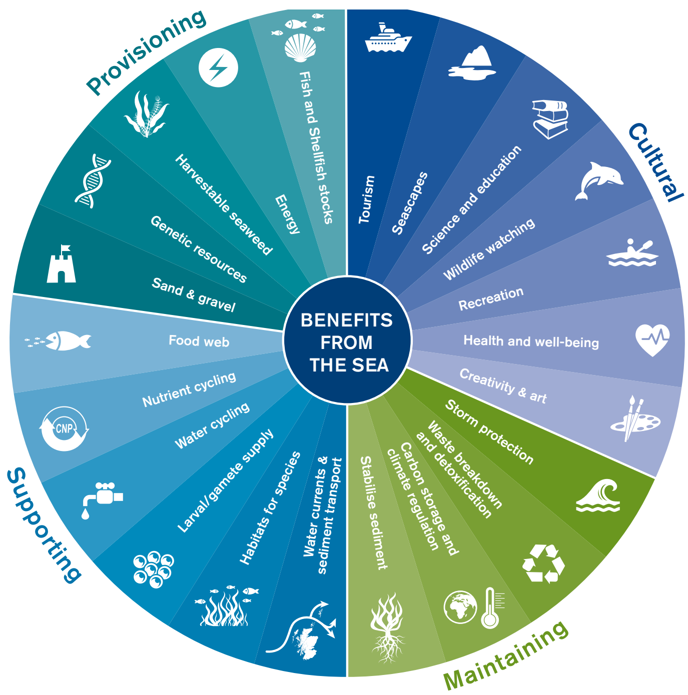


Figure 2

Marine Ecosystem Services

(NatureScot).



Importance

Until recently, ecosystem services have generally been taken for granted but research has shown that over half the world's ecosystem services are degraded or used unsustainably (Millennium Ecosystem Assessment, 2005) and this is closely tied to the inexorable loss of nature and degradation of ecosystems leading to the current biodiversity crisis. The coincidental degradation of so many ecosystem services also leads to reduced resilience to climate change. These multiple changes and losses strengthen arguments for considering and incorporating the concepts of natural capital and ecosystem service thinking into all restoration projects.

What to consider/ general principles

It is important to consider the range of ecosystem services that can be provided or enhanced when designing ecological restoration projects. Refer to **Figures 1** and **2** for the scope of these but it is important to take a system thinking approach (see Overarching Principles – Physical Environment for a definition of this) in order to optimise interrelationships between the ecosystem being restored and different services that can be enhanced, preferably on a large, such as catchment, scale (see Overarching Principles – Large-Scale Nature Recovery and Restoration).

Taking each ecosystem services group in turn, most projects will focus on the **supporting** ecological services (the restoration of biodiversity to support nutrient cycling, photosynthesis and healthy soils). However, to support some of the regulating and provisioning ecosystem services, ecological restoration plans need to focus more on development of healthy soils, soil organisms, microbes and organic layers to ensure optimum functioning and processes that can support other ecosystem services (see Overarching Principles - Physical Environment).

Provisioning services will be linked to project objectives and advice on these is outside the scope of this guidance. In contrast, incorporating measures to enhance **regulating** or maintenance services has the greatest potential to add project value and, as many are not yet mainstream, further guidance is incorporated here on increasing climate change resilience, managing water quantity and quality and on pollination. It should be noted that these all interact with and support other services simultaneously.

Many projects support **cultural** services but they need to be better integrated with other ecosystem services within ecological restoration projects. This topic is also explored further as it is relevant to most of the Habitat Sections although emphasis will be on human physical health and mental wellbeing, there are many links to recreation, sense of place, inspiration, knowledge and learning (as shown in **Figures 1** and **2**).

Ecosystem services do not generally operate in isolation. For example, a diverse flood meadow is a wildlife resource in its own right whilst also providing for stock grazing, capturing and storing carbon (plus reducing embedded carbon in agrochemicals) and providing an attractive amenity/recreational resource with bird song, colourful insects and plentiful flowers that collectively promote human health and wellbeing, whilst simultaneously contributing to flood mitigation and improved water quality when appropriately located (Lawson *et al*., 2018). The flowers may also support pollinating insects and predators to support nearby crops thus also enhancing their productivity and reducing pesticide use.

Many experimental studies show that biodiversity increases the magnitude and or stability of ecosystem functioning but there is concern that some services tend to be provided by a relatively limited number of common rather than rare or threatened species. This might apply to some crop pollinators for example. It is important therefore for ecosystem service requirements and benefits to provide additionality rather than be project drivers where increased biodiversity is the prime objective. This also suggests that the delivery of ecosystem services may be insufficient as a general argument for biodiversity restoration or creation (Kleijn *et al*., 2015).

There is alarm at the effect of biodiversity loss and fragmentation on the full functioning of some ecosystem services. There is often a lack of good understanding of long-term and large-scale changes in functional diversity (many analyses of biodiversity focus on taxonomic diversity rather than system functioning) except in particular circumstances such as cumulative impacts of agricultural intensification in river catchments. This limits full understanding of the vulnerability of key ecosystem services in the face of ongoing biodiversity change (Greenop *et al*., 2021).

Why should ecosystem services be integrated into projects?

1. They add significant dimensions to any project that can be key selling points to stakeholders and wider audiences.
2. They provide greater value than just biodiversity drivers due to the ability to deliver multiple benefits.
3. Effective ecological restoration can provide nature-based solutions (NbS) instead of an 'end of pipe' fix, usually at a reduced cost and with many added benefits for wildlife and people.
4. An appreciation of the wider environmental net gains can engender more support for a project.
5. Projects can simultaneously support or contribute to policies and programmes focusing, for example, on the

climate emergency, flood control, reaching net zero, biodiversity restoration, health and wellbeing, air quality, soil protection and water quality.

6. The benefits could feed into project Key Performance Indicators or support the development of a company's Environmental Social Governance-based investment.

7. These benefits are mostly qualitative although some can be quantified to some extent or by using proxies (see CIEEM, 2022[5] which includes information, tools and case studies).

Two issues of CIEEM's In Practice magazine provide several case studies and ideas on different approaches to applying and valuing ecosystem services (In Practice 68, 2010 and 92, 2016[6]).

Adopt the Ecosystem Approach

Using an Ecosystem Approach assists in integrating ecosystem services into ecological restoration projects. This method integrates people and their natural resources into decision making to promote conservation and sustainable use in an equitable way. The approach seeks to value the benefits that emanate from the environment to secure a greater range of ecosystem services for society and greater reward for those managing land and water appropriately. The concept is applied by the Convention on Biological Diversity to encompass social, cultural and economic factors (Postnote 377, 2011[7]) but can be relevant to any project where stakeholder and wider audiences are involved. Ecosystem services are part of this wider integrated ecosystem approach that also includes key elements of involving people and valuing the natural environment in decision making.

The ecosystem approach can:

- Resolve conflicts between competing priorities.
- Make those services without a market value more visible.
- Save money by letting nature work for people.
- Promote collaboration and efficiency.
- Encourage thinking about implications of decisions for future generations and those beyond the project's area (NatureScot[8]).

See Clarke (2010) in In Practice for a good review of its development and application.

Individual Ecosystem Services

Further guidance on the three regulating (climate change resilience, managing water quantity and quality, and pollination) and one cultural (health and wellbeing) ecosystem services highlighted as particularly relevant assists in their integration into ecological restoration projects. Note that other services might be relevant and there may be many mutually beneficial outcomes between different ecosystem services in any project as well.

5 https://cieem.net/wp-content/uploads/2022/11/Natural-Capital-and-Ecosystem-Service-information-and-guidance-v2-1.pdf

6 https://cieem.net/i-am/resources-hub/

7 The Ecosystem Approach. Houses of Parliament, Parliamentary Office of Science and technology https://www.parliament.uk/globalassets/documents/post/postpn_377-ecosystem-approach.pdf

8 https://www.nature.scot/scotlands-biodiversity/scottish-biodiversity-strategy-and-cop15/ecosystem-approach/ecosystem-services-natures-benefits

Climate change resilience

Context and importance

Climate change is an existential threat to ecosystems and people across the world. Greenhouse gases (GHGs[9]) in the atmosphere and their continued emissions need to be reduced significantly if there is any hope of reducing severe effects of climate change. At the same time, adaptation within existing habitats to reduce vulnerabilities and increase resilience to climate change is essential. This means that the Ecology and Environmental Management profession needs to grasp any opportunities to support all ecological aspects of climate change resilience in our work. Ecological restoration has a vital role to play in this, which is mostly complementary to enhancing and restoring biodiversity as well as making major contributions to other ecosystem services like flood management and improvement of water quality.

Put into perspective, habitats across the UK sequester around 9.8 MtCO_2e[10] per year (Cornelius *et al*., 2020) but this is offset by damaged peatlands which are estimated to be losing 21.3 MtCO_2e per year, 80 % of which is estimated to be derived from lowland agriculture on peat (https://post.parliament.uk/research-briefings/post-pn-0668/).

Figure 3

Milled, drained, drying peat in lowland raised bog, Shannon, Ireland.

Photo credit: Penny Anderson.

With an estimated requirement to reduce GHGs by 15.5 MtCO_2e per year in the UK for the next 30 years, the Committee for Climate Change (CCC, 2020) has recommended five investment priorities of which one, focusing on the natural environment, seeks to increase tree cover to 17 % (currently 13 %) by 2050, increase peat restoration and the quality and quantity of urban greenspaces, including green roofs, tree planting, park restoration and sustainable drainage schemes. Even with saltmarsh restoration added to this suite of opportunities, Bradfer-Lawrence *et al*. (2021) estimate that the achievable GHG reductions through habitat restoration would be equivalent to only about three years' worth of the UK's total annual net emissions (estimated at 424.5 MtCO_2 in 2021, O'Sullivan, 2022), stressing the need for other significant actions to reduce GHGs.

Government strategies within the UK have applied the CCC's targets in different ways but with similar objectives. The Irish Climate Action Plan 2023[11] combines some additional emphases, with changing land use as one of six themes to include

9 GHGs – Greenhouse gases include methane and nitrous oxide as well as other more minor gases. Methane is around 28 and nitrous oxide around 298 times more potent GHGs than CO_2, but methane only lasts for about 12 years before breaking down.

10 Mt = Million tonnes, CO_2e = Carbon dioxide equivalent where other GHG effects are converted to CO_2.

11 https://www.gov.ie/pdf/?file=https://assets.gov.ie/244355/1c421172-2901-4f9e-baa5-6e4445b342f4.pdf#page=null

improved carbon sequestration of 450,000 ha of agricultural grassland and reduced intensity of management on 80,000 ha of drained organic soils.

Although the CCC focuses on expanding tree cover and green infrastructure, there are other options, some of which are incorporated into the Irish Climate Action Plan and which are further expanded in the literature. The CCC's focus on tree planting and peatland restoration was derived from what they considered an inadequate research base for alternative approaches. However, more recent research is seeking to expand these. Key documents to consult are:

- An updated review of the capacity of ecosystems to store and capture carbon (Anderson, 2024[12]), prepared for CIEEM's 2030 group and summarised by Anderson and Morris (2021).
- Gregg *et al.*'s (2021[13]) review of carbon storage and sequestration by habitats for Natural England.
- Stafford *et al*. (2021[14]) focus on carbon sequestration through NbS produced by the British Ecological Society.
- Alonso *et al.'s* (2012[15]) earlier review of carbon storage by habitat for Natural England, but note that the basis of some of the carbon capture rates are whole carbon cycle based on English agri-environment schemes and are not always compatible with research figures.

Additionally, for guidance on adaptation management for habitats and species, see:

- Climate Change Adaptation Manual (Natural England and RSPB, 2019[16]), which is mostly equally applicable across the UK and Ireland.

The key messages below are extracted from these documents as well as recent research, but as this is an ever-expanding field, check the literature for more recent information.

Figure 4

Rye grass sward restored to flower-rich hay field with plenty of red clover which will help rebuild soil carbon.

Photo credit: Penny Anderson.

12 https://cieem.net/resource/carbon-and-ecosystems-restoration-and-creation-to-capture-carbon/

13 https://publications.naturalengland.org.uk/publication/5419124441481216

14 https://www.britishecologicalsociety.org/wp-content/uploads/2022/02/NbS-Report-Final-Updated-Feb-2022.pdf

15 https://publications.naturalengland.org.uk/publication/1412347

16 https://publications.naturalengland.org.uk/publication/5679197848862720

Key messages

1. The carbon stock (measured in tC ha^{-1}) in the ecosystem is largely in soils, (40-60 % in the top 20-30 cm, with more down to 1 m or below). Only woody plants – trees/shrubs, dwarf-shrub heathland - and saltmarsh hold significant amounts of organically derived carbon.

2. Carbon sequestration: the rate of carbon capture (expressed in tC or CO_2 ha^{-1} yr^{-1}), varies with habitat. Highest levels are found in woodlands, some grasslands, heathland, seagrass beds and saltmarshes, but many factors affect the rates. Other GHGs also need to be taken into consideration, especially methane.

3. Soil Organic Carbon (SOC) is critical for carbon capture, with microbes, fungi and soil fauna key components of the carbon cycle. Carbon stored within the soil's mineral component tends to be stable for hundreds of years and is facilitated by deep-rooted species, whilst carbon in the organic layer is more vulnerable to disturbance and loss. Drainage of peat/organic-rich soils results in rapid loss of carbon.

4. **Table 1** shows average carbon stocks under different habitats, emphasising the importance of organic-rich soils compared with ploughed arable land, which mostly loses carbon over its annual cycle.

Table 1

Carbon content in some Scottish soils (Lily and Baggaley, 2020)

Soils under different habitats	Carbon tC ha^{-1} to 1 m
Arable	115
Improved grasslands	138
Semi-natural grasslands	185
Woodland	267
Heathland/Moorland	290
Peat	528

5. Carbon continues to accumulate in the right conditions in organic-rich soils, ancient semi-natural woodlands, active floodplains and marine environments but is less likely in mineral soil-based habitats such as grasslands. It can take 100 years or more to reach any new equilibrium when starting from very degraded states.

6. Total carbon stocks in the UK relate to the overall extent of each habitat, thus, carbon-poor but extensive ecosystems like agricultural grassland could hold more carbon overall compared with woodland with a lower total cover.

7. There is adequate evidence to promote a mixture of new habitats for carbon capture (**Table 2**) rather than a dependency on planting trees, although research is insufficient to guide the optimum approach in all situations.

8. Climate change itself, especially drought, affects carbon stocks and sequestration so projects need to be climate change-proofed.

Table 2

Guidance on habitat restoration for carbon capture (taken from the key documents listed).

Habitat	Restoration for carbon	Comment
Peatlands	Re-wet, increase *Sphagnum* cover (the ecosystem engineer), revegetate bare peat	To reduce (or reverse if possible) carbon losses from drying peat - the most important measure to undertake
Existing semi-natural woodland	Minimise management in semi-natural woodlands but maintain good structural and age variation	These can continue to capture carbon over time with natural renewal and recycling
Plantations	Slow carbon capture when young that has to counterbalance losses in ground preparation. Rapid carbon capture as canopy forms, but slows subsequently	Carbon capture slows or stops on maturity, but most conifer crops are harvested before peak of carbon sequestration. Use of wood (short or long term) determines carbon benefits
New Woodland	Create using natural colonisation as far as possible on sites that are already disturbed. If planting, minimise soil disturbance	Can take 20-30 years+ for carbon stock to match that lost in site preparation and planting, takes time for canopy, fungi, soil microbes etc to establish
New Woodland	Do not plant on peatland or organic-rich soils	Peat is dried through planting and drainage and carbon lost
Hedges	Manage so they are tall and wide	Larger carbon stock and sequestration in larger hedges spreads out 2-3m into fields
Scrub, wood pasture, agro-forestry	More trees/shrubs will capture more carbon than arable land, but can compromise stocks in grasslands	Little research specifically available
Neutral grasslands	Low intensity grazing, low inputs, no artificial fertilisers, diverse with deep-rooted legumes like red clover sequestrate most carbon	High C sequestration rates found with added deep-rooted legumes. Length of period of increased sequestration not known but could be 100 years depending on condition of soils at start of enhancements, e.g. arable conversion
Flood plain grasslands	Diverse flora, with range of rooting depths, functioning as a flood plain	Can accumulate carbon over centuries through flooding and rebuilding of soils and remain productive for agriculture
Acid grasslands	Can hold high carbon stocks, restore diversity but check for specialist fungi (do not disturb soils if valuable for fungi), restore to heathland if no other interest	Twice the sequestration rate found in heathland than adjacent acid grasslands in one study
Heathland	Low grazing, diverse age structure, good cover of dwarf shrubs for best results	Highest sequestration rates for building age heather, but not all species researched. Lose carbon if extensive scrub/tree removed for heathland restoration
Ponds and lakes	Create small, well-vegetated ponds and small lakes	Can have high carbon capture rates, but methane emissions must be minimised. Water quality is important in reducing methane emissions
Rivers	Low gradients, high channel complexity, plenty of deadwood provide best potential	Probably low carbon sequestration rates. Insufficient research available
Marine and coastal	Large scale restoration of saltmarsh, seagrass beds and estuarine muds needed	Good sequestration levels, with added silt trapping holding carbon
Urban	Establish trees, green walls & roofs, flower-rich grasslands and gardens	Carbon content maybe quite low, but also important for reducing urban temperatures and insulating buildings

Case studies

Consult the key documents listed for accounts of multiple ecological restoration projects to increase carbon capture, most of which also benefit biodiversity and other ecosystem services. In addition, carbon codes have been developed for woodland[17] and peatland[18] and others are being developed including for soils and saltmarsh[19].

Some significant contributions are:

1. Gregg *et al*. (2021) on the effectiveness of measures to reduce carbon loss in blanket and agricultural peatlands. Swenson *et al*. (2019) show the effectiveness of peat restoration on cut-over bogs in Ireland and the overall sequestration potential.

2. Woodland Trust (Bavin, 2021) and RSPB (Crane, 2020) on woodland creation for carbon and Poulton *et al*.'s (2003) demonstration of carbon sequestration from different naturally colonised plots. Fletcher *et al.* (2021) model the potential carbon benefits of Scottish native woodland communities, matching their soil requirements, to give the best output for woodland wildlife and carbon to meet Scottish tree planting and carbon targets without relying on plantation forestry.

Figure 5

Recent woodland creation with minimal soil disturbance and avoiding plastic protection.

Photo credit: Penny Anderson.

3. See De Deyn *et al*. (2011) for grassland diversification and carbon research at Colt Park meadows, the similar German Jenna project (Steinbeiss *et al*., 2008) and some Dutch grassland experiments (Cong *et al*., 2014). There are few carbon studies for other types of grassland.

4. Few studies measure all the GHG inputs and outputs let alone for different communities, climates and soils to assess the balance of methane and nitrogen emissions with carbon sequestration. Anderson (2024) provides a brief review and Manning *et al*. (2022) demonstrate the impact of conservation grazing on GHG emissions and provide a carbon calculator for assessing stock emissions in different habitats.

5. Anderson (2024) reviews the benefits of urban habitats and carbon sequestration including ponds (with a cautionary study on reducing methane emissions); urban trees – total carbon stocks have been calculated for

17 https://www.woodlandcarboncode.org.uk/

18 https://www.iucn-uk-peatlandprogramme.org/peatland-code-0

19 https://www.ceh.ac.uk/our-science/projects/uk-saltmarsh-code?gad_source=1&gclid=EAIaIQobChMI8P-z7JTwiwMV5rlaBR3HNCvxEAAYASA-AEgIxOPD_BwE

several cities; green roofs; and gardens, which cover 433,000 ha and support 1/4 of the tree resource outside woodlands for which her blog[20] and Nex (2021) are useful references.

Figure 6

Green tram line, Manchester.

Photo credit: Penny Anderson.

6. The ground-breaking IGNITION project increases Greater Manchester's resilience to climate change extremes using NbS including rain gardens, street trees, green roofs and walls[21]. Their website includes a relevant research summary and their Green Roof Benefits Calculator provides a useful high level decision-making tool (https://ignitiongreenroofbenefitscalculator.greatermanchester-ca.gov.uk/).

7. Anderson (2024) and Gregg *et al*. (2021) both summarise the value of saltmarshes and seagrass beds for carbon capture owing to the vegetation trapping silt and sequestering carbon. Several long-established studies compare restored British and Northern European saltmarsh sites.

Water – quantity and quality

Context and importance

How much water, where it is (above or below ground), where it is moving to and at what rate are all important aspects of the natural environment. The availability of water, in the right quantity and at the right time, supports our ecosystems, whether these are terrestrial or aquatic, natural or heavily managed (for example for crop production). As such, understanding the water cycle, working with it and accounting for changes resulting from climate change are all critical in ecological restoration, both for the success of the project and to drive as wide a range of benefits as possible, locally and both upstream and downstream.

Flood management and water purification (as regulating services) and water supply (as a provisioning service) are very closely linked and critical services for life (Millennium Ecosystem Assessment, 2005[22]). Habitats have certain water requirements (see individual habitat guidance), which may comprise a wide or narrow tolerance range set by the characteristics of the physical environment within which the habitat is found (such as geology, soil texture and topography). Habitats will, depending on the health of the biological and physical components, also modulate how the water cycle

20 https://cieem.net/how-to-get-more-wildlife-into-your-garden-and-absorb-more-carbon-by-penny-anderson/

21 https://www.greatermanchester-ca.gov.uk/what-we-do/environment/natural-environment/ignition/

22 https://www.millenniumassessment.org/en/index.html

functions, for example how fast rainfall reaches watercourses, how much water is stored in soils and aquifers (and for how long), how groundwater is slowly released into surface water drainage systems and the quality of that water (Li et al., 2019).

The water cycle

The water cycle is demonstrated graphically in a Met Office infographic[23]. Precipitation delivers water to the earth's surface where its passage to the ground surface is first slowed, depending on the vegetation type and structure and the amount of rainfall which has previously fallen. Some rainfall infiltrates into the soil, filling soil pores and retained as soil moisture or moving deeper into the underlying sediment or rock to supply aquifers. As more water enters the soil and the pore spaces fill, water may no longer infiltrate and starts to form surface runoff.

All this water will eventually reach watercourses and flow out to the sea. How quickly it does so, how much water is held back to be released slowly over time and how much filtration and purification of the water occurs depends on the nature and health of the natural system (vegetation and soils) and the pressures on it.

Pressures on the water cycle and opportunities through Nature-based Solutions

There is clear evidence that land use change and land management along with climate change are putting pressure on the natural environment, affecting the water cycle and thus the services we receive.

Examples of pressures on the water cycle include:

- Soil compaction, reducing infiltration rates and increasing the risk of increased surface runoff from overgrazing, trafficking over soil surfaces during agricultural or construction activities, handling soils when they are too wet and reduced soil organic matter contents (reducing soil structural stability).
- Soil sealing - reducing the area of land available for infiltration and increasing the passage of rainfall to watercourses.
- Poorly planned drainage increasing the speed with which surface water is routed to watercourses; past river engineering increasing the speed of flow (and therefore bed erosion) in straightened channels.
- Abstractions from surface and groundwater bodies which exceed the recharge rate.
- Vegetation change - reducing the structure of the vegetative canopy and thus the potential for interception and direct evaporation before rainfall reaches the ground surface.
- Climate change - affecting the quantity and intensity of rainfall patterns and the duration and frequency of drought events.

Climate change will be exacerbating the effects of land management and land use change (The Earth Observatory, 2010). Where the system is less able to slow and store water (for example due to soil compaction), increased amounts and intensity of rainfall are likely to result in increased flood risk, faster routing of rainfall to watercourses (and thus less storage within soils and aquifers).

For example:

- At a global scale, the Global Commission on the Economics of Water (2023) highlights the issues faced, stating that more than two billion people still lack access to safely managed water and that one child under five dies every 80 seconds from diseases caused by polluted water.
- In the UK, flooding in 2015/16 was estimated to cost the economy £1.6 billion, whilst that between November 2019 and March 2020 was about £333 million (GOV.UK. 2021).

23 https://www.metoffice.gov.uk/weather/learn-about/weather/how-weather-works/water-cycle

- The International Panel on Climate Change[24] warns that a warming world will lead to more extreme rainfall, with the UK likely to receive about 10 % more rainfall on average per year by 2100 compared to 1986-2005 (most likely as an increase in intensity of rainfall events leading to more risk of overloading of the system).

However, a major opportunity lies with the role better land management practices and more informed land use change decisions can play in strengthening the resilience of the natural system and thus of the water cycle. Ecological restoration plays a clear part in this and understanding the water cycle, planning for climate change and incorporating wider benefits should be critical parts of these projects.

Figure 7

Natural Flood Management on the River Heddon, Exmoor, utilising trees felled as part of ash dieback management.

Photo credit: Bruce Lascelles.

Significant benefits (Staford *et al.*, 2021) and monetary value can be achieved through this focus on better water management across the whole water cycle (Natural England, 2012).

What to consider/general principles

1. Two key overarching questions should be:
    a. *How much water does the habitat(s) require? (further detail in the Habitats Sections)*
    b. *What role could the habitat(s) play in the water cycle to bring wider benefits (upstream and downstream)?*
2. Assess what data are available or would be needed. This could be more critical in relation to wet habitats and where there may be a need to assess/model the water supply from the catchment, groundwater levels and fluctuations, etc.
3. Understand the nature of the physical environment associated with the area under consideration (see Overarching Topic – Physical Environment) and how it functions. Understand the links and interrelationships with the system upstream and downstream (surface and groundwater).
4. Ensure the water requirements of the habitat(s) are understood and deliverable, working with the natural environment, for example soil type and geomorphology.
5. Ensure any changes to the water cycle are assessed in relation to potential effects on adjacent land (e.g. making land wetter or drier).

24 https://www.ipcc.ch/report/ar5/wg1/summary-for-policymakers/

6. Soil health, in terms of infiltration capacity (i.e. lack of compaction), soil organic matter content and soil structural strength are important considerations to ensure optimal function for any given soil type/landscape position. The baseline health of soils should be assessed and any activities which could compromise soil health should be managed in accordance with published guidance (Defra, 2009).

7. Engage with as wide a range of stakeholders as possible to identify opportunities to deliver multiple benefits for the environment and communities. Think local (to the site) and catchment-scale – what benefits could the project bring in combination with other projects in the catchment?

There are numerous NbS for flood management and water control (**Table 3),** but their overall efficacy will depend on the scale of the issues concerned and the landscape in which they occur. Multiple solutions will be needed in an integrated programme for many situations, but the scope for enhancing biodiversity simultaneously should be designed into every scheme (see Habitat Sections).

Table 3

Commonly applied Nature based Solutions for flood management and water quality enhancement.

Approach	Some solutions in different habitats	Examples of habitats where solutions may be applicable
Slowing the flow on land	Blocking drains, grips and gullies	Peatlands, wetlands, wet grassland
	Blocking ditches	All
	Blocking field drains	Restoring marshy grassland, peatlands, other wet habitats
	Increasing surface roughness e.g. reducing grazing, adding trees/shrubs	All
	Creating buffer zones from stock/ploughing adjacent to water courses	All
	Improved soil health (likely to result in improved infiltration and soil water storage)	All
Slowing the flow in water courses	Restoring longer stream/river courses (where there has been historical canalisation or straightening)	Streams, ditches and rivers
	Large woody material on one bank or across the full channel width	Streams, ditches and rivers
Floodplains	Reinstating functional flood plains	Floodplains
	Reinstating flood plain grasslands, woodlands and trees	Floodplains
	Offline ponds for some flood water	Floodplains
Agricultural practices	Increasing soil organic matter	Arable, pasture
	Contour ploughing	Arable, or ground disturbance for e.g. leys or other activity
	Undersowing with legumes	Arable
	Hedges, scrub and wooded belts across contours	Arable, grassland
	Diverting polluted runoff (nutrients or soil) away from water-courses and through natural filters	All

Other	Ensure new woodlands/scrub have structured ground cover to slow surface water flows	All where relevant
	Remove/reduce soil compaction	All where relevant
	Swales, non-impervious surfaces, water gardens, green roofs, trees and other habitats	Urban/suburban areas
	Constructed wetlands	All
	Introduction of beavers to hold back and filter water in streams	Appropriate river systems currently under licence

Constraints and limitations

1. Understanding how the physical environment functions will require expertise and data that may be lacking or expensive. **Expert judgement should always be sought** where water source, quantity and quality may be material to the success of the project.

2. Possible conflicts may arise. For example, blocking drains to raise the water table across a site could result in elevated water tables in adjacent land and reduced levels downstream. Increasing the diversity of form and function in a watercourse may conflict with riparian owners wanting stability in channel planform. Engagement with all stakeholders will be key to manage expectations and promote the wider benefits that will be derived.

Case Studies

1. The Stroud Valleys Natural Flood Management (NFM) Project[25] has clearly reduced flood risk and provided community benefits. So far achievements include:

   - Over 1000 interventions implemented throughout the wider Frome Catchment.
   - 25 % of the catchment now draining through NFM features.
   - 1 m reduction in peak river levels (between the two most closely comparable recent heavy rainfall events) on Slad Brook.
   - Over 1000 people from local and national groups have come together to learn more about NFM.
   - Fifty local land managers and contractors worked together to implement NFM actions.
   - Strong partnership working and networking locally and regionally.
   - Establishment of a monitoring network for NFM in Stroud Valleys.
   - Positive community feedback and engagement.
   - Contribution to achieving conservation objectives for the woodlands through greater amounts of deadwood on the woodland floor encouraging fungi, lower plants and invertebrates and helping maintain moisture levels in the valley for the benefit of the snail populations.
   - Keeping water off trackways by diverting it onto the woodland floor reducing flows significantly, resulting in less erosion and therefore reducing silt-laden runoff (whilst also reducing track maintenance costs for the landowner) and protecting surface water quality.

25 https://www.stroud.gov.uk/environment/projects/stroud-valleys-natural-flood-management-project/

- Reduction of water flows, allowing more sediment to drop out of the water column locally, reducing silt-laden runoff events and protecting surface water quality.
- Allowing more infiltration, supporting soil moisture balances and thus improving water availability to plants during dry periods.
- Enabling the natural creation of habitat diversity in terms of pools, riffles, sediment features etc. which all support greater biodiversity.

Figure 8

Flood Management in the Slad Valley (Gloucestershire) with felled trees secured across a gully to slow overland flow and encourage infiltration.

Photo credit: Bruce Lascelles.

2. Eddleston Water, UNESCO Ecohydrology Demonstration site (the only one in the UK), drains into the River Tweed at Peebles. After 200 years of changes to catchment land use and runoff plus shortening, draining and embankments to the river, floodplain connections were lost, with increased risk of flooding downstream and effects on river species such as Atlantic salmon *Salmo salar* and brown trout *S. trutta*. The Flood Risk Management (Scotland) Act 2009 required a total catchment approach to flood risk management and the use of NFM along with, not versus, flood defences. The project was established in 2010 to reduce flood risk downstream and enhance riparian habitats, whilst maintaining viable farm businesses in the valley. After much survey, modelling, consultation and working with local interests, the measures implemented were:

    a. *210 ha of native (grown in Scotland) trees planted to increase infiltration, evapotranspiration and surface roughness.*

    b. *116 leaky dams and high-flow log restrictors.*

    c. *38 ponds as runoff attenuation features and new wildlife habitats.*

    d. *Restoration of 3.1 km of natural meandering in the river– increasing river length, reducing slope and speed of flow, providing more space for floodwaters and better habitats.*

    The project[26] was thoroughly monitored (Spray, 2023) and successful. A £950,000 net cost-benefit has been calculated at net present value, which could be much higher applying the same measures on a larger scale with more funding and landowner involvement. The co-benefits identified were for amenity, biodiversity, carbon sequestration, education, watercourse flows, water quality and pollution thus supporting multiple ecosystem services.

3. Blanket bog peat restoration in the Peak District was shown to reduce flood risk downstream. A Defra-funded

26 www.tweedforum.org/eddleston-project-database

project (one of several Making Space for Water projects) on Kinder Scout (around 600 m altitude) in the River Ashop catchment (which drains into the River Derwent and contributes to flooding downstream in Derby) involving re-vegetation of bare, eroding peat and gully blocking. Monitoring showed a reduction in storm flow, reduced lag times and a 5 % reduction in peak discharge from restoring only 12 % of the poor quality catchment (Pilkington *et al*., 2015).

4. The habitat creation and natural flood management at the Steart Marshes is detailed in Stafford *et al*. (2021).

Figure 9

Meander on the River Culm showing diversity of channel form as a result of erosion and deposition.

Photo credit: Bruce Lascelles.

Monitoring

There are multiple appropriate monitoring methods, each geared to the action taken or the totality of the system. Research will be needed for each action adopted to define the most appropriate and cost-effective monitoring method. Options include dipwells to test water table levels; stage measurements in rivers to detect changes in the hydrograph; water quality measures of sediment and nutrients to test runoff measures; soil organic matter and compaction measures (although these may change only slowly); and habitat/species responses.

Pollination

Context and background

Pollination, as a regulating ecosystem service, underpins food production and its contribution to gene flows and restoration of ecosystems. Invertebrates are the primary pollinators of flowering plants but the importance of UK native species as pollinators (bumblebees, solitary bees, hoverflies and moths), has largely been underestimated and understudied compared with the domesticated honeybee (Buxton *et al*., 2022, Ollerton *et al*., 2011). Nocturnal pollinators, such as moths, may be equally important in delivering pollination services for crops and plant species in the wider landscape (Buxton *et al*., 2022; Walton *et al*., 2020).

Figure 10

Common snout hoverfly *Rhingia campestris* on lady's smock *Cardamine pratensis*. These have long snouts to feed deep into flowers that other flies cannot reach.

Photo credit: Penny Anderson.

There is growing evidence that a diversity of wild pollinators enhances pollination services and ecosystem function (Buxton *et al.,* 2022; Walton *et al*., 2020). Wild pollinators have been found to be more efficient pollinators compared to the domesticated honeybee (Garibaldi *et al*., 2013; Solis-Montero *et al*., 2023) and there is evidence suggesting that domesticated honeybees may negatively impact native wild pollinator populations, such as through increased competition for resources, and may negatively affect plant reproductive success (Henry & Rodet, 2018; Magrach *et al*., 2017). Further study is required to measure the long-term population effects of managed bees to better understand their impact upon wild bees.

Studies of the overall economic benefit of pollinators in the UK are limited but Breeze *et al*., (2011) suggest £430 million. Some 20 % of UK cropland depends on pollination from which is derived about 19 % of farm-gate crop value (Breeze *et al*., 2011), while 10 % of the total economic value of food production in Europe depends on insect pollination (Perennes *et al.,* 2021). The key crops needing pollination in the UK and Ireland are oilseed rape, orchard and soft fruit and field beans plus different horticultural crops and those grown in gardens and allotments. Flower seed production (garden or wild) also depends on pollinating insects for many species.

The area of crops needing or benefiting from pollination has expanded significantly (>300 %) since the 1960s, thus increasing pollination demands. This is set against a background of honeybee losses (reduction in beekeepers and the effect of the *Veroa* virus) and significant reductions in wild pollinators over the last 50 years (Breeze *et al*. 2011) due to pesticide use and landscape simplification (Bartholomée & Lavorel, 2019).

In addition to pollination services, insects such as hoverflies and dung beetles provide important natural pest control (Beynon *et al*., 2015; Rodriguez-Gasol *et al*., 2020). This is an important element of integrated pest management, thus enhancing another ecosystem service by increasing the complexity of the landscape to provide habitats for these species and reduce the need for chemical use.

Insect pollinators are also essential in non-market benefits for wider landscape aesthetics (flowers, fruits and the attraction of the pollinators themselves) and for biodiversity as integral parts of any ecosystem. Approximately 78 % of plants in temperate zones require pollinators and declining pollinators can lead to a parallel decline in wild plant species resulting in a community cascade effect, with the loss of species dependent on both the plants and the insects involved. This loss would also affect other ecosystem services such as wild food, fibre and medicine supplies and the cultural and aesthetic values of a landscape (Perennes *et al*., 2021). The value of pollinators is thus economic for crop productivity and to an extent for wild foods and as an essential part of the wider ecosystem with benefits for biodiversity and health and wellbeing (Defra, 2013).

What to consider/general principles

1. Research habitat requirements, foraging range and distribution of species that might benefit from actions. Consider nesting and hibernation sites as well as floral resources. For example, most solitary bees require bare ground for nesting.

2. If biodiversity is a main driver, ensure all species appropriate to the habitat are considered, not just key pollinators for commercial crops. Consider flight distances and ability to colonise a site as some solitary bees, for example, have very short flight ranges. Consult relevant societies - BWARS and hoverflies (https://hoverfly.uk/hrs/node/284), or local record centres for known species in your area.

3. Conduct an Ecosystem Approach study with stakeholders if necessary (see outline in the introductory section).

4. If you need to model likely occurrence or success of species, consult *Perennes et al*. (2021) who developed a model for *Andrena* species (mining bees are especially important for oilseed rape and apple pollination in Europe) combining distribution, habitat, foraging, bioclimatic and land use data. Although there are limitations to the use of the model, it is an improvement on earlier ones and assists in making land use decisions and identifying conservation measures and areas to prioritise for conservation planning.

Constraints and limitations

1. The value of nocturnal pollination is near-impossible to quantify and potentially adversely affected by light and air pollution and climate change (Macgregor & Scott-Brown, 2020). Design habitats for these pollinators that minimise effects of such pollution.

2. Plan for a diverse range of pollinators to support ecosystem function and pollination.

3. Many bee species, even generalists, have distinct preferences for host plants, so not all will forage in agricultural crops and many of the declining species do not visit crops. Long-tongued bumblebees for example are good bean pollinators whilst solitary bees can be effective pollinators of oilseed rape.

4. Crop flower production is highly seasonal and the pollinators will need a wider range of plants and good quality breeding and overwintering habitat to sustain them for the rest of their annual cycle.

5. Pollination as an ecosystem service for crops seems to depend on a limited range of species, one study finding that 80 % of crop pollination was provided by only 2 % of species and that these were generally widespread and common and survived within an intensive agricultural environment (Kleijn *et al.,* 2015). Consideration of pollination as an ecosystem service might not coincide with conservation or restoration of threatened insects that are also pollinators, which will usually need to be considered separately.

6. The conservation of pollinator habitat can also enhance overall biodiversity and other ecosystem services such as natural crop pest predators, protection of soil and water and landscape enhancement, but there are difficulties in measuring these benefits in a way that persuades land managers to advocate for them (Wratton *et al*., 2012).

7. The lack of empirical data on the effect of any single pollinator to a particular crop yield means pollination efficiency cannot be assessed. A broad range of factors are involved such as pollinator morphology and behaviour, flower visitation rates, pollen deposition and plant health (Perennes *et al*., 2021).

Case studies

The following research and guidance sets out the best approach to cater for pollinators:

1. Follow or fit into the guidance set out in the country pollination strategies (for England, Wales, All-

Ireland and Scotland - all downloadable on the Bumblebee Conservation Trust website https://www.bumblebeeconservation.org/).

2. Frequency of flower visits by pollinating insects and crop yield are greater close to semi-natural habitats and in less fragmented landscapes where pollination can be achieved by natural insect visitors without honeybees. The highest impact comes from creating pollinator habitat within intensively managed farmland, but this will serve commoner rather than threatened species, which are unlikely to have persisted (Keijn *et al*., 2015). Create networks of semi-natural areas at small spatial scales within agricultural settings for the best results as pollination services decline exponentially with distance from habitat patches (Albrecht *et al*., 2020)

3. Include ponds– their greater floristic resources also increase bee, hoverfly and butterfly pollinator complexity (Walton *et al*., 2021).

4. Perennial and older flower strips that are diverse are more effective (Albrecht *et al*., 2020).

5. Good quality hedges that are continuous, diverse and include trees are best at providing flowers, structure and habitat for overwintering and breeding. These simultaneously support more crop pest predators, but they also need more floral resources beyond the hedge (Garratt *et al*., 2017).

6. Target threatened bee species with specific habitat restoration or creation where the species still persist.

7. Recommendations from Pyewell *et al.'s* (2011) research for flower-rich grassland aimed at increasing pollinators for agri-environment schemes are:

   a. Plant in wildflower strips.

   b. Seed mixes should avoid competitive grasses.

   c. Use the best performing species for mid and late-season forage resources e.g. *Trifolium, Lotus corniculatus* and *Centaurea nigra* (but this may need to be moderated to meet other objectives related to establishing more diverse grasslands – see Habitat Section – Grasslands.

   d. Apply a cutting programme that treats half of each patch in May or early June (timing will depend on geographical locality, altitude etc) with removal of cut material to extend the flowering season and minimise damage to other breeding invertebrates like butterflies. This may conflict with other objectives as, for example, diverse grassland with a long flowering season is better for a wider range of invertebrates which might also better support biological crop protection. Priorities will need to be identified (see Habitat Section – Grasslands).

   e. Cut all patches in autumn and remove cut material.

   f. Add species-rich hedges that are allowed to flower and seed (see Habitat Section - Hedges).

Monitoring the effectiveness of actions

(see Overarching Topic - Monitoring)

The Flower-Insect Timed Counts (FIT Counts) is a simple monitoring method specific to pollinators, which can involve specialists or citizen science together with the benefits this brings (https://ukpoms.org.uk/). Breeze *et al*. (2020) evaluate the cost of different pollinator monitoring schemes using different approaches based on professional or citizen science input and emphasise the importance of scheme design and data quality.

In contrast, O'Connor *et al*. (2019) compared pan traps and transects for monitoring pollinators in a 1 km square of flowering crop and semi-natural habitat along with the differing expertise levels of the surveyors. Transects tended to count more individual bumblebees but fewer species, whilst pan traps sampled more solitary bees and hoverflies. More expert recorders could record almost commensurate detail in both methods. Bartholomée & Lavorel (2019) describe some of the issues and alternative approaches based on measuring pollinator activity, landscape resources for pollinators or fruit/seed output and also provide guidance on best approaches.

Health and Wellbeing

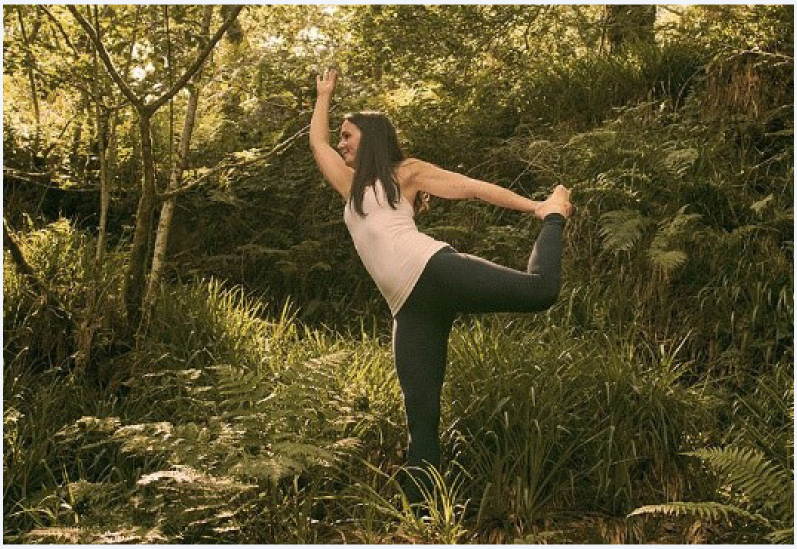
Context and Importance

There is an increasing body of evidence for positive effects of nature on people's health and wellbeing. Connection to nature (an individual's feelings and attachment to the nature around them) is correlated with selected wellbeing and educational attributes and tends to be stronger and more recuperative. Contact with nature (spending time in nature) at a population level is linked to lower all-cause mortality, lower rates of type 2 diabetes, cardiovascular and respiratory disease, more positive perinatal outcomes, and a better state of mental health, stress, mood disorders and pyscho-social wellbeing. Causal linkages between nature and most of these conditions is not always clear. The research is summarised for physical contact, mental health benefits and connecting with nature in three Natural England reports (see Seers *et al*., 2022a, b, c)

Figure 11

Spending time in nature enhances our wellbeing, including the likelihood of experiencing flow states.

Photo credit: Cabilla Cornwall.



Health and wellbeing is most relevant in ecological restoration projects where people see/access sites in residential and urban areas. International and national best practice approaches emphasise links to wellbeing to restore our relationship with nature and provide health benefits. But access to nature is unequal socio-economically, culturally and across some age groups. Improving environmental justice requires that the health and wellbeing benefits are distributed equally or targeted to reduce inequality.

General Principles

An integrated approach is needed to combine planning and design, site condition potential and early engagement with stakeholders in relevant projects to optimise benefits.

Engagement

To understand people's needs and avoid any potential negative impacts on wellbeing, three principles are proposed, combined with the components of a relatively simple model (PERMA) to focus attention on opportunities to promote health and wellbeing positively.

Projects should:

1. engage people early and frequently to understand their needs,
2. set health and wellbeing success criteria, and

3. monitor and adaptively manage health and wellbeing outcomes,

whilst at the same time

4. proactively seek to promote greater access to nature, and

5. understand and address existing inequality of access to nature.

The three principles of engagement are explored below.

First principle of engagement: Engage people early and frequently to understand their needs

The principle of engaging with stakeholders is advocated at international (Gann *et al.,* 2019, Nelson *et al.,* 2024), and national level. It is one of the principles in CIEEM's Good Practice Guidance for Ecological Restoration (Hicks, 2024) and included in the BNG Good Practice Principles for Development (CIRIA, CIEEM and IEMA 2016) as well as one of the principles in the JNCC's Nature-based Solutions Triple Win Toolkit (JNCC, 2021).

Freely available tools and techniques to support effective stakeholder engagement and empower communities include WildTeam's (2022) best practice guidance and accompanying templates and Pound *et al.*'s (2016) methods and resources.

Second principle of engagement: Set health and wellbeing success criteria

CIEEM has compared the similarities and differences between the many definitions of wellbeing[27]. Whilst multiple definitions can create confusion and perhaps be a barrier to applying wellbeing in a development context (CIEEM, 2021), simple compartment models can encourage practitioners to consider and measure impacts of ecological restoration on specific elements of wellbeing. For example, the PERMA model (Seligman 2011; **Figure 12**) suggests five components of wellbeing: Positive Emotion (P), Engagement (E), Relationships (R), Meaning (M), and Accomplishment (A).

Figure 12

The PERMA Model of Wellbeing (Seligman 2011) provides a simple lens through which to consider elements of human wellbeing and is more useful than top-level definitions when planning and implementing ecological restoration projects to achieve wellbeing objectives.

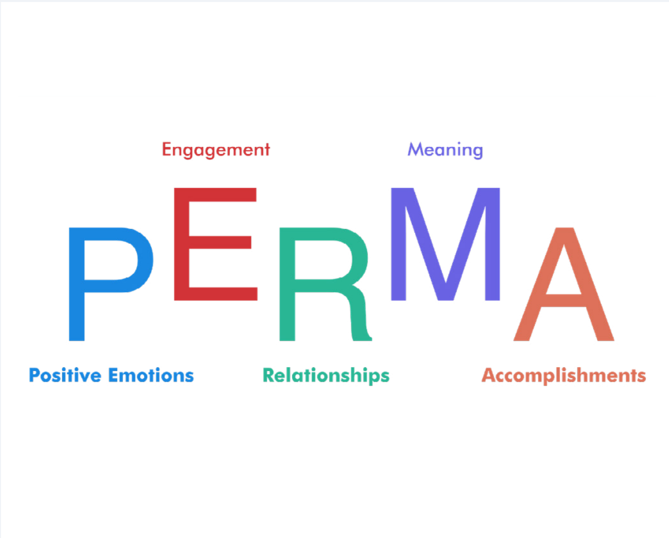


Table 4 amplifies the PERMA model elements which can be developed for considering health and wellbeing in ecological restoration projects.

27 https://cieem.net/wp-content/uploads/2021/10/Government-Definitions-FINAL-Oct2021-1.pdf

Table 4 Using PERMA model elements to explore the benefits of greater nature connectedness gained through involvement in ecological restoration.

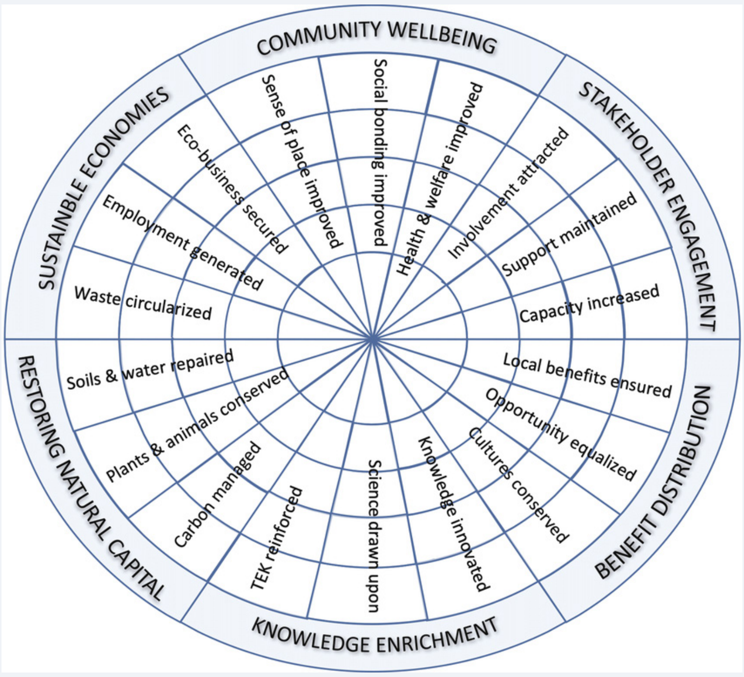
PERMA element	Benefits
Positive Emotions	*Nature contact or connection* enhances work performance, physical health, strengthens relationships, & creates optimism and hope for the future (Kun *et al*., 2017). *Nature contact or connection* increases happiness, hope, joy and satisfaction (Nisbet *et al.,* 2011, Kovich *et al*., 2022), reduces stress, negative emotions and levels of anger (Bowler *et al*., 2010, McMahan & Estes 2015. Nisbet *et al*., 2011, Hartig *et al*., 1991). *Nature views* assist recovery from illness in hospital (Ulrich, 1984) and n*ature smells* (not just sight and sounds) are associated with multiple wellbeing domains, positively and negatively (Bentley *et al.,* 2023).
Engagement	*Spending time in nature* enhances the likelihood of experiencing flow states (Pretty *et al.,* 2005) and reduces mental fatigue, making it easier to achieve and sustain flow (Berman *et al.,* 2008). *Complexity and variety of natural settings* can engage people more deeply than artificial environments (Nakamura and Csikszentmihalyi, 2002).
Relationships	*Involvement in community and group activities in nature* enhances social capital, strengthens relationships & social cohesion, leading to greater wellbeing (Putnam, 2001, Jenkinson *et al.* 2013; Peters, *et al.,* 2010). *Collaborative projects involving multiple stakeholders* strengthen social relationships by encouraging co-operative problem solving and collective action (Berkes, 2004). *Projects involving different age-groups in environmental activities* facilitate intergenerational learning & relationships, strengthen community ties by connecting diverse groups (Chawla, 2009) & can help to reinforce Local and Traditional Ecological Knowledge (LEK and TEK). *Group-based activities involving natural elements* cultivate connectedness & belonging, reducing loneliness (Sachs *et al.,* 2024).
Meaning	Through deeper connections to the natural world, *involvement in ecological restoration* provides a greater sense of meaning. Empowered stakeholders feel greater agency and purpose, & derive spiritual and emotional benefits, deepening a sense of connection to something larger (Bennett *et al.,* 2018, Amel *et al.,* 2009). *Particularly long-term projects* foster a strong sense of purpose and fulfilment, and participants find meaning by contributing to legacy (Clewell & Aronson, 2006).
Accomplishment	*Involvement in restoration projects* fosters a sense of agency and allows acquisition of new skills and personal growth leading to a sense of accomplishment, reinforcing social validation when recognised by others (Bennett *et al*., 2021). *Setting clear objectives* allows participants to track their progress and helps forward planning for celebrating milestones and achievements. *Involvement in projects* leads to a sense of accomplishment, not just through achievement of project objectives but by developing wider transferable / employability skills (Esmene, 2021).

Third principle of engagement

Monitor and adaptively manage health and wellbeing outcomes

There is less experience of setting explicit success criteria for wellbeing despite the strong link between nature and wellbeing combined with concerns around deteriorating mental health in the UK (ONS 2022; NHS Digital 2020; Mind 2020). The Social Benefits Wheel (**Figure 13**) assists in tracking the degree to which an ecological restoration programme attains its social development targets, recognising that ecological recovery cannot occur without robust community engagement. The Wheel is a powerful visual tool to encourage incorporation of multiple components of a restoration project.

Figure 13



The Social Benefits Wheel (Gann *et al.*, 2019) for evaluating restoration projects. TEK = Traditional Ecological Knowledge. Templates, guidance and datasheets to accompany this tool are available from https://www.ser.org/page/Standards-Tools

Placemaking, (the process of consultation and engagement with communities in establishing what good design means to them, UK Government, 2023) can be furthered through the UK Government's Levelling Up and Regeneration Bill (2023), which requires English Local Planning Authorities to produce a local Design Code based on a National Model to promote wellbeing as a key theme (Ministry of Housing, Communities and Local Government, 2021).

Direct application of models of wellbeing such as PERMA to placemaking design and implementation of ecological restoration projects should be used to identify opportunities to enhance wellbeing, optimise environmental justice and promote community engagement. Questionnaires structured around PERMA or psychological domains can also provide a tool that can be used pre- and post to monitor wellbeing success criteria.

Ecological restoration with empowered communities is more likely to be successful in the long-term. Individuals and groups benefit emotionally from spending time, being active, building relationships in nature and from the opportunity to give back to nature, establishing reciprocity and legacy to promote meaning and a sense of accomplishment.

What to consider in site design

Alongside engagement, the potential for a site is determined by its environmental opportunities and constraints (like soils or soil-forming materials and hydrology), its ecological quality and location in terms of connectedness to other sites and any other limiting factors or opportunities. By combining good design for human health and biodiversity, other ecosystem services can also produce multiple benefits.

Davern *et al.* (2017) summarises features to consider for designing or enhancing green spaces in urban areas and shows the multiple ecosystem services on offer (**Table 5**).

Table 5

Summary of synergies and benefits of different attributes for designing green space. POS = Public Open Space. Adapted from Davern *et al*. 2017.

Attributes	Physical health	Mental health & wellbeing	Social & cultural	Ecosystem services	Biodiversity
Size & area	*Physical activity* Large POS + more amenities lead to greater recreational use. *Quality of design* – grassed areas, amenities, trees, dog-related facilities (off leash areas), gardens, paths, water features & wildlife	*Perceptions of safety* –natural surveillance important *Wellbeing* – better quality parks needed	*Sense of community* – access encourages greater sense of community – places to meet *Heritage* – larger POS may preserve landscape level cultural features e.g. sightlines to surrounding hills, smaller reserves possible to protect specific artefacts/ sites	*Cooling, storm protection, noise reduction* – Larger vegetated areas provide greater effects *Pollination* – native insect species more likely in larger, less managed sites	*Diversity* – larger POS more likely to provide for greater variety of resources for plants and animals, also smaller edge effects, more sustainable populations. Alternative high-quality POS can reduce pressure on nature reserves
Accessibility & distance to POS	*Physical activity* – local (<500 m) encourages activity, plus size of site for levels of walking. Adding informal activity amenities increases activity for children e.g. large logs *Health Protection* – access increases microbe biodiversity on skin, increases immunity. Increases healing in hospitals with access to nature	*Perceptions of safety* – Safe road crossings to access important. Wellbeing – access to attractive POS includes presence of street trees & views of POS *Childhood development-* Access & use of POS supports cognitive development and enhances motor abilities in children. Forest school facilities important	*Sense of community* – access & use of POS encourages sense of community. *Access to heritage* can be important culturally and spiritually	*Cooling* – decreases with distance from green space *Noise reduction* – greatest when plantings close to sources	*Conservation* – ensure accessibility good and does not exclude people, although may be warranted in special cases to protect rare species - involve community in this
Trees	Trees provide shade, create more attractive POS	Manage safety issues of potential for falling branches. Trees associated with wellbeing benefits of POS	Street trees encourage sense of community. Trees can form important part of cultural heritage features	Tree canopy good predictor of cooling effects of urban green space. Can protect infrastructure in storms. Can filter particulates. Captures more carbon	Old trees with hollows etc offer more habitat diversity for animals. Native trees provide better habitat for native birds
Lawns	Grassed areas provide for activity e.g. sports, dog walking & passive use	Scattered trees in grass preferred	Lawns more important in UK & USA, less so in many other cultures	If managed using pesticides and fertilisers can cause high levels of carbon emissions	Mown grass provides little habitat for wildlife. Less managed flower-rich grassland can provide important habitat

Social infrastructure	Range of facilities encourages physical activity e.g. lighting round sports areas, skate parks etc	Vegetation that obscures visibility of houses, roads, paths can reduce perception of safety	Views of green areas from houses, public art, connected paths, seating, absence of graffiti & litter all increase connection	Habitat & vegetation complexity benefits diverse pollinators. Structurally complex vegetation helps reduce stormwater runoff & attenuate wider frequency of noise	Complex habitats benefit more animal species, especially associated with leaf litter, logs, long grass, old trees & native species
Heterogeneity	Greater variation in greenery decreases hospital admissions for cardio-vascular disease & stroke & increases adolescents' physical activity	Different kinds of people respond to different kinds of landscapes. Have a range for wider benefits	Wider range of POS gives more opportunities for wider range of social activities	Greater variation in urban greenery can increase resilience to extreme climatic events e.g. high temperatures or storms	Heterogeneity critical to support high biodiversity

Figure 14

Simple pleasures of getting muddy and playing 'Pooh sticks' connects children with nature.

Photo credit: Penny Anderson.

In addition: (Taken and extended from Davern *et al.*'s (2017) review)

- Wilder green space appeals more to those who are more environmentally focused, whilst those with more human-centred values prefer more managed landscapes. Both are needed.
- Fewer, better quality larger spaces can be more valuable than more, poorer quality spaces.
- Good habitat structure is critical for animal diversity, driven by habitat and niche complexity.
- Diverse bird song is very important to people so good quality habitats need to support multiple species.
- Diverse plants are an important determinant of biodiversity and colour and scent are also important to people.
- Vegetation can filter nitrogen dioxide, sulphur dioxide and particulate matter thus enhancing the environment.
- Wooded belts 1.5-3.0 m wide can significantly reduce perceived and actual noise through absorption and reduce wind effects creating a more pleasant environment.
- Green spaces can reduce nearby city temperatures by 1-4 ^{o}C, slow and filter runoff and improve water quality.

- Native plant species are better than exotic ones although the latter can contribute.
- It is important to consider any disbenefits - e.g. tree root damage to paths, mess from falling fruits etc.
- Sites must be perceived as safe, especially for women, avoiding features that might engender feelings of isolation or threat such as dense scrub or woodland planting too close to paths.
- Wilder sites can be made more attractive through selective management such as mowing edges and paths (where not surfaced) to show positive care (otherwise possibly perceived as neglect), ensuring spaces have neat boundaries like walls or fences. Vegetation (such as spring woodland flowers, wildflower meadow, etc) are less threatening and more attractive than unmanaged masses of tall competitive (weedy) species.

Figure 15

Landlife established wildflowers in Merseyside in the 1980s/90s for harvesting seeds on various areas of often temporary wasteland, but which were also splendid visually and used extensively for art and environmental activities with local people.

Photo credit: Richard Scott.

Recent research suggests an association between a larger range of natural features and greater wellbeing (Hammoud *et al.,* 2024) meaning (with the caveat that access to nature is of paramount importance), that a projects' biodiversity objectives should align naturally with wellbeing goals.

Case studies

1. Use tools such as **Tree Equity Score** UK, a map-based application created to help address disparities in urban tree distribution and identify areas in greatest need of people-focused investment in trees; https://uk.treeequityscore.org/).
2. CIEEM award-winning case studies summarising best practice in stakeholder engagement include the **Every Step Counts** project (https://www.iucn.org/news/commission-education-and-communication/201809/how-best-practice-stakeholder-participation-results-best-outcomes-nature).
3. The Your Shore Beach Rangers project coordinated by the Cornwall Wildlife Trust and The Cornwall College Group (2016 – 2021) allowed young people to gain new employability skills. The National Lottery funded project engaged 5,000 participants under the age of 11 and 16,000 aged between 11 and 24 in activities to improve their connection to the coast and their communities, such as silent disco beach cleans and snorkel safaris. The project established five new community groups and supported participants to complete accredited training, for example First Aid at Work. A key learning point was to assign specific roles and job titles for young adult volunteers - encouraging them to become community group members from a skills and career development perspective (Esmene, 2021).

4. The **Adur River Recovery** project, https://www.adur-river-recovery.org/, a land manager-led project to restore the River Adur in West Sussex, has 'strengthen community' as an explicit objective and a strong focus on open learning and public engagement through citizen science, river user surveys, recreation and competitions. The Adur Elders initiative is also considering historical knowledge, as recommended in SER's Principle 2 underpinning ecological restoration.

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References

Albrecht, M., Kleijn, D., Williams, N. M., Tschumi, M., Blaauw, B. R., Bommarco, R., Campbell, A. J., Dainese, M., Drummond, F. A., Entling, M. H., Ganser, D., Arjen De Groot, G., Goulson, D., Grab, H., Hamilton, H., Herzog, F., Isaacs, R., Jacot, K., Jeanneret, P., … Sutter, L. (2020). The effectiveness of flower strips and hedgerows on pest control, pollination services and crop yield: A quantitative synthesis. *Ecology Letters,* 23(10), 1488–1498. https://doi.org/10.1111/ele.13576

All-Ireland Pollinator Plan. (2021). *All-Ireland Pollinator Plan* 2021–2025. National Biodiversity Data Centre. https://pollinators.ie/aipp-2021-2025/

Alonso, I., Weston, K., Gregg, R., & Morecroft, M. (2012). *Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources.* Natural England Research Report (NERR) 043. https://publications.naturalengland.org.uk/file/1438141

Amel, E. L., Manning, C. M., & Scott, B. A. (2009). Mindfulness and sustainable behavior: Pondering attention and awareness as means for increasing green behavior. *Ecopsychology*, 1(1), 14–25. https://doi.org/10.1089/eco.2008.0005

Anderson, P., & Morris, T. (2021). Carbon and ecosystems. *In Practice,* 111, 50–54. https://cieem.net/wp-content/uploads/2024/05/CIEEM-Carbon-and-Habitats-May-2024-1.pdf

Anderson, P. (2024). *Carbon in ecosystems: Management, restoration, and creation for carbon capture*. Chartered Institute of Ecology and Environmental Management. https://cieem.net/resource/carbon-and-ecosystems-restoration-and-creation-to-capture-carbon/

Bartholomée, O., & Lavorel, S. (2019). Disentangling the diversity of definitions for the pollination ecosystem service and associated estimation methods. *Ecological Indicators,* 107, Article 105576. https://doi.org/10.1016/j.ecolind.2019.105576

Bavin, S. (2021). *How do soil properties influence carbon storage and sequestration in newly established woodland across the UK?* Woodland Trust. https://api.cabi.org/abstract/reader/pdf?id=eyJBbGciOiJIUzI1NiIsIlR5cCI6IkpXVCJ9.eyJVc2VyIjoie1wiUGFuXCI6MjAyMTA0MDM0NzAsXCJVc2VyXCI6e1wiU3Vic2NyaXB0aW9uQ29kZXNcIjpbXCJFU1wiXSxcIkF1dGhlbnRpY2F0aW9uVmFsdWVcIjpudWxsLFwiVmFsaWRpdHlSZW1haW5pbmdcIjpcIjAwOjAwOjAwXCIsXCJJcEFkZHJlc3NcIjpudWxsLFwiT3BlbkFjY2Vzc1wiOmZhbHNlLFwiTm9uRXhwaXJpbmdQZGZDb2Rlc1wiOltcIkVTXCJdLFwiUHJpb3JpdGlzZUZ1bGxUZXh0T3ZlclVybHNcIjp0cnVlfX0iLCJFeHBpcmVzIjoiOTk5OS0xMi0zMVQyMzo1OTo1OS45OTk5OTk5In0%3D.Kz09ziR4V7NKiExrzUCuf3r2Ap%2BJdPdOaKk7mGKHMig%3D

Bennett, N. J., Whitty, T. S., Finkbeiner, E., Pittman, J., Bassett, H., Gelcich, S., & Allison, E. H. (2018). Environmental stewardship: A conceptual review and analytical framework. *Environmental Management*, 61(4), 597–614. https://doi.org/10.1007/s00267-017-09 93-2

Bentley, P. R., Fisher, J. C., Dallimer, M., Fish, R. D., Austen, G. E., Irvine, K. N., & Davies, Z. G. (2023). Nature, smells, and human wellbeing. *Ambio,* 52(1), 1-14. https://doi.org/10.1007/s13280-022-01760-w

Berkes, F. (2004). Rethinking community-based conservation. *Conservation Biology,* 18(3), 621–630. https://doi.org/10.1111/j.1523-1739.2004.00077.x

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological Science*, 19(12), 1207–1212. https://doi.org/10.1111/j.1467-9280.2008.02225.x

Beynon, S., Wainwright, W. A., & Christie, M. (2015). The application of an ecosystem services framework to estimate the economic value of dung beetles to the U.K. cattle industry. *Ecological Entomology,* 40(S1), 124-135. https://doi.org/10.1111/een.12240

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health*, 10(1), Article 456. https://doi.org/10.1186/1471-2458-10-456

Bradfer-Lawrence, T., Finch, T., Bradbury, R. B., Buchanan, G. M., Butler, S. J., Jerram, T., & Stone, D. (2021). The potential contribution of terrestrial nature-based solutions to a national 'net zero' climate target. *Journal of Applied Ecology,* 58(11), 2349–2360. https://doi.org/10.1111/1365-2664.14003

Breeze, T. D., Bailey, A. P., Balcombe, K. G., & Potts, S. G. (2011). Pollination services in the UK: How important are honeybees? *Agriculture, Ecosystems & Environment*, 142(3–4), 137–143. https://doi.org/10.1016/j.agee.2011.03.020

Buxton, M., Graham, L. L. B., Stout, J. C., & Memmott, J. (2022). A global review demonstrating the importance of nocturnal pollinators for crop plants. *Journal of Applied Ecology*, 59(12), 2890-2901. https://doi.org/10.1111/1365-2664.14284

Climate Change Committee (CCC). (2020). *The Sixth Carbon Budget: The UK's path to net zero*. https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf

Chawla, L. (2009). Growing up green: Becoming an agent of care for the natural world. *The Journal of Developmental Processes*, 4(1), 6–23. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=9ee4ec4516096769b1fee7e-00a0792f8a9e4f7d4

Chartered Institute of Ecology and Environmental Management (CIEEM). (2021). *How do governments and organisations define wellbeing?* Chartered Institute of Ecology and Environmental Management. https://cieem.net/wp-content/uploads/2021/10/Government-Definitions-FINAL-Oct2021-1.pdf

CIEEM. (2022). *Natural capital and ecosystem services information and guidance*. Chartered Institute of Ecology and Environmental Management. https://cieem.net/wp-content/uploads/2022/11/Natural-Capital-and-Ecosystem-Service-information-and-guidance-v2-1.pdf

CIRIA, CIEEM, & IEMA. (2016). *Biodiversity net gain: Good practice principles for development*. https://cieem.net/wp-content/uploads/2019/02/Biodiversity-Net-Gain-Principles.pdf

Clarke, S. (2010). Ecosystem services: From theory to application. *In Practice,* 68, 4–7. https://cieem.net/resource/in-practice-issue-68-ecosystem-services-june-2010/

Clewell, A. F., & Aronson, J. (2006). Motivations for the restoration of ecosystems. *Conservation Biology,* 20(2), 420–428. https://doi.org/10.1111/j.1523-1739.2006.00340.x

Cong, W.-F., van Ruijven, J., Mommer, L., De Deyn, G. B., Berendse, F., & Hoffland, E. (2014). Plant species richness promotes soil carbon and nitrogen stocks in grasslands without legumes. *Journal of Ecology,* 102, 1163–1170. https://doi.org/10.1111/1365-2745.12280

Cornelius, S., Matheson, S., Coath, M., Luraschi, B, & Smith, P. (2020). The role of nature in a UK NDC. *WWF and RSPB*. https://www.naturebasedsolutionsinitiative.org/news/the-role-of-nature-in-the-uk-ndc/

Crane, E. (2020). Woodlands for climate and nature: A review of woodland planting and management approaches in the UK for climate change mitigation and biodiversity conservation. *Report to the RSPB*. https://community.rspb.org.uk/ourwork/b/martinharper/posts/woodlands-for-climate-and-nature-new-rspb-report-published-to-help-navigate-the-evidence-maze

Davern, M., Farrar, A., Kendal, D., & Giles-Corti, B. (2017). Quality green space supporting health, wellbeing, & biodiversity: *A literature review*. https://parksleisure.com.au/wp-content/uploads/parc-library/722-0-Green_Spaces_Evidence_Review_-_FINAL_website.pdf

De Deyn, G. B., Shiel, R.S., Ostle, N.J., McNamara, N.P., Oakley, S., Young, I., Freeman, C., Fenner, N., Quirk, H., & Bardgett, R. D. (2011). Additional carbon sequestration benefits of grassland diversity restoration. *Journal of Applied Ecology*, 48(3), 600–608. https://doi.org/10.1111/j.1365-2664.2010.01925.x

Department for Environment, Food & Rural Affairs (DEFRA). (2009). *Construction code of practice for the sustainable use of soil on construction sites*. UK Government. https://assets.publishing.service.gov.uk/media/5b2264ff40f0b634cfb50650/pb13298-code-of-practice-090910.pdf

Department for Environment, Food & Rural Affairs (DEFRA). (2013). Bees and other pollinators: *Their value and health in England*. https://www.gov.uk/government/publications/bees-and-other-pollinators-their-health-and-value

Esmene, S., Rogers, M., & Leyshon, M. (2021). *Your Shore Beach Rangers Evaluation*. SIG Reports and Policy Paper Series, Centre for Geography and Environmental Science, University of Exeter, UK. https://repository.falmouth.ac.uk/5567/

Fletcher, T., Hulme, P. E., & MacLean, I. M. D. (2021). The carbon sequestration potential of Scottish native woodland. *Environmental Research Communications*, 3. https://doi.org/10.1088/2515-7620/abf467

Gann, G. D., McDonald, T., Walder, B., Aronson, J., Nelson, C. R., Jonson, J., Hallett, J. G., Eisenberg, C., Guariguata, M. R., Liu, J., Hua, F., Echeverría, C., Gonzales, E., Shaw, N., Decleer, K., & Dixon, K. W. (2019). International principles and standards for the practice of ecological restoration. *Restoration Ecology*, 27(S1). https://doi.org/10.1111/rec.13035

Garibaldi, L. A., Steffan-Dewenter, I., Winfree, R., Aizen, M. A., Bommarco, R., Cunningham, S. A., Kremen, C., Carvalheiro, L. G., Harder, L. D., Afik, O., Bartomeus, I., Benjamin, F., Boreux, V., Cariveau, D., Chacoff, N. P., Dudenhöffer, J.-H., Freitas, B. M., Ghazoul, J., Greenleaf, S. S., … Klein, A.-M. (2013). Wild pollinators enhance fruit set of crops regardless of honey bee abundance. *Science,* 339(6127), 1608–1611. https://doi.org/10.1126/science.1230200

Garratt, M. P. D., Breeze, T. D., Boreux, V., Fountain, M. T., McKerchar, M., Webber, S. M., & Potts, S. G. (2017). The benefits of hedgerows for pollinators and natural enemies depends on hedge quality and landscape context. *Agriculture, Ecosystems & Environment*, 247, 363–370. https://doi.org/10.1016/j.agee.2017.06.048

GOV.UK. (2021). *Counting the cost of flooding*. https://www.gov.uk/government/news/counting-the-costs-of-flooding

Greenop, A., Woodcock, B. A., Wilby, A., Outhwaite, C.L., Carvell, C., Pywell, R. F., Mancini, F., Edwards, K.F., Johnson, A.C., & Isaac, N.J.B. (2021). Patterns of invertebrate functional diversity highlight the vulnerability of ecosystem services over a 45-year period. *Current Biology*, 31(20), 4627-4634. https://doi.org/10.1016/j.cub.2021.07.080

Gregg, R., Alonso, I., Crosher, I., & Morecroft, M. (2021). Carbon storage and sequestration by habitat: *A review of the evidence* (second edition). Natural England, NERR094. https://publications.naturalengland.org.uk/publication/5419124441481216

Hammoud, R., Tognin, S., Smythe, M., Gibbons, J., Davidson, N., Bakolis, I., & Mechelli, A. (2024). Smartphone-based ecological momentary assessment reveals an incremental association between natural diversity and mental wellbeing. *Scientific Reports*, 14(1), 7051. https://doi.org/10.1038/s41598-024-55940-7

Hartig, T., Mang, M., & Evans, G. W. (1991). Restorative effects of natural environment experiences. *Environment and Behavior,* 23(1), 3–26. https://doi.org/10.1177/0013916591231001

Henry, M., & Rodet, G. (2018). Controlling the impact of the managed honeybee on wild bees in protected areas. *Scientific Reports*, 8, Article 9308. https://doi.org/10.1038/s41598-018-27591-y

Hicks, J. (Ed.). (2023). *Rebuilding nature: Good practice guidance for ecological restoration.* Chartered Institute of Ecology and Environmental Management, Romsey. https://cieem.net/wp-content/uploads/2024/01/Good-Practice-Principles-V4.pdf

Intergovernmental Panel on Climate Change (IPCC). (2013). Fifth assessment report: *Summary for policymakers.* https://www.ipcc.ch/report/ar5/wg1/

Jenkinson, C. E., Dickens, A. P., Jones, K., Thompson-Coon, J., Taylor, R. S., Rogers, M., Bambra, C. L., Lang, I., & Richards, S. H. (2013). Is volunteering a public health intervention? A systematic review and meta-analysis of the health and survival of volunteers. *BMC Public Health,* 13(1). https://doi.org/10.1186/1471-2458-13-773

Joint Nature Conservation Committee (JNCC). (2021). *Nature-based solutions triple win toolkit – International climate finance evidence project.* JNCC, Peterborough. https://hub.jncc.gov.uk/assets/376d989f-0563-4e7f-b034-c79108f63758

Kleijn, D., Winfree, R., Bartomeus, I., Cariveau, D., Henry, M., Isaacs, R., Klein, A.-M., Kremen, C., M'Gonigle, L. K., Rader, R., Ricketts, T. H., Rundlöf, M., Williams, N. M., & Woyciechowski, M. (2015). Delivery of crop pollination services is an insufficient argument for wild pollinator conservation. *Nature Communications*, 6, Article 7414. https://doi.org/10.1038/ncomms8414

Kovich, M. K., Simpson, V. L., Foli, K. J., Hass, Z., & Phillips, R. G. (2022). Application of the PERMA model of well-being in undergraduate students. *International Journal of Community Well-Being*, 6(1), 1–20. https://doi.org/10.1007/s42413-022-00184-4

Kun, A., Balogh, P., & Krasz, K.G. (2017). Development of the work-related well-being questionnaire based on Seligman's PERMA model. *Periodica Polytechnica Social and Management Sciences,* 21(1), 56-63. https://doi.org/10.3311/PPso.9326

Lawson, C., Rothero, E., Gowing, D., Nisbet, T., Barsoum N., Broadmeadow, S., Skinner, A. (2018). The natural capital of floodplains: management, protection and restoration to deliver greater benefits. Valuing Nature Natural Capital Synthesis Report VNP09. https://valuing-nature.net/FloodplainNC

Lilly, A. & Baggaley, N.J. (2020). *Scoping study to identify current soil organic carbon stocks and the potential for increasing carbon sequestration in Scottish soils*. James Hutton Institute for the Scottish Government. https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2021/12/scoping-study-identify-current-soil-organic-carbon-sequestration-scottish-soils/documents/scoping-study-identify-current-soil-organic-carbon-stocks-potential-increasing-carbon-sequestration-scottish-soils/scoping-study-identify-current-soil-organic-carbon-stocks-potential-increasing-carbon-sequestration-scottish-soils/govscot%3Adocument/scoping-study-identify-current-soil-organic-carbon-stocks-potential-increasing-carbon-sequestration-scottish-soils.pdf

Li, P., Sheng, M., Yang, D., & Tang, L. (2019). Evaluating flood regulation ecosystem services under climate, vegetation and reservoir influences. *Ecological Indicators*, 107, Article 105642. https://doi.org/10.1016/j.ecolind.2019.105642

Macgregor, C.J. & Scott-Brown, A.S. (2020). Nocturnal pollination: an overlooked ecosystem service vulnerable to environmental change. *Emerging Topics in Life Sciences*, 4(1), 19-32. https://doi.org/10.1042/ETLS20190134

Magrach, A., Gonzalez-Varo, J.P., Boiffier, M., Montserrat, V., and Bartomeus, I. (2017). Honeybee spillover reshuffles pollinator diets and affects plant reproductive success. *Nature Ecology and Evolution 1*, 1299-1307. https://doi.org/10.1038/s41559-017-0249-9

Manning, F, Wynn, S, Webb, E. & Green, L. (2022). *The Impact of Conservation Grazing on GHG emissions.* NECR489. Natural England. https://publications.naturalengland.org.uk/file/5970371506077696

McMahan, E. A., & Estes, D. (2015). The effect of contact with natural environments on positive and negative affect: A meta-analysis. *The Journal of Positive Psychology*, 10(6), 507-519. https://doi.org/10.1080/17439760.2014.994224

Mind. (2020). *Mental health in crisis: How COVID-19 is affecting mental health*. https://www.mind.org.uk/about-us/our-policy-work/coronavirus-research/#:~:text=58%25%20of%20people%20receiving%20benefits,their%20problem%20was%20serious%20enough

Ministry of Housing, Communities and Local Government. (2021). *National model design code.* UK Government, London. https://www.gov.uk/government/publications/national-model-design-code

Nakamura, J., & Csikszentmihalyi, M. (2002). The concept of flow. In C. R. Snyder & S. J. Lopez (Eds.), *Handbook of positive psychology* (pp. 89-105). Oxford University Press. https://psycnet.apa.org/record/2002-02382-007

Natural England & RSPB. (2019). Climate Change Adaptation Manual. Evidence to support nature conservation in a changing climate, 2nd edition. Natural England, York, UK. NE751 https://publications.naturalengland.org.uk/publication/5679197848862720

Natural England Commissioned Report NECR101. (2012). Valuing Ecosystem Services: Case Studies from Lowland England. https://publications.naturalengland.org.uk/publication/2319433

Nelson, C.R., Hallett, J.G., Romero Montoya, A.E., Andrade, A., Besacier, C., Boerger, V., Bouazza, K., Chazdon, R., Cohen-Shacham, E., Danano, D., Diederichsen, A., Fernandez, Y., Gann, G.D., Gonzales, E.K., Gruca, M., Guariguata, M.R., Gutierrez, V., Hancock, B., Innecken, P., Katz, S.M., McCormick, R., Moraes, L.F.D., Murcia, C., Nagabhatla, N., Pouaty Nzembialela, D., Rosado-May, F.J., Shaw, K., Swiderska, K., Vasseur, L., Venkataraman, R., Walder, B., Wang, Z., & Weidlich, E.W.A. (2024). *Standards of practice to guide ecosystem restoration – A contribution to the United Nations Decade on Ecosystem Restoration 2021-2030.* Rome, FAO, Washington, DC, SER & Gland, Switzerland, IUCN CEM. https://doi.org/10.4060/cc9106en

Nex, S. (2021). *How to garden the Low Carbon Way: the steps you can take to help combat climate change*. Royal Horticultural Society.

NHS Digital. (2020). *Mental Health of Children and Young People in England, 2020: Wave 1 follow up to the 2017 survey*. https://digital.nhs.uk/data-and-information/publications/statistical/mental-health-of-children-and-young-people-in-england/2020-wave-1-follow-up

Nisbet, E. K., Zelenski, J. M., & Murphy, S. A. (2011). Happiness is in our nature: Exploring nature relatedness as a contributor to subjective well-being. *Journal of Happiness Studies*, 12(2), 303-322. https://doi.org/10.1007/s10902-010-9197-7

O'Connor, R.S., Kunin, W.E., Garratt, M.P.D., Potts, S.G., Roy, H.E., Andrews, C., Jones, C.M., Peyton, J.M., Savage, J., Harvey, M.C., Morris, R.K.A., Roberts, S.P.M., Wright, I., Vanbergen, A.J., & Carvell, C. (2019). Monitoring insect pollinators and flower visitation: the effectiveness and feasibility of different survey methods. *Methods in Ecology and Evolution,* 10(12). 2129-2140. https://doi.org/10.1111/2041-210X.13292

O'Sullivan, C. (2022). *2021 UK Greenhouse gas emissions, provisional figures*. Department for Business, Energy and Industrial Strategy. https://assets.publishing.service.gov.uk/media/62447a158fa8f527729bfab2/2021-provisional-emissions-statistics-report.pdf

Office for National Statistics. (2022). *Coronavirus and the social impacts on Great Britain*. https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandwellbeing/bulletins/coronavirusandthesocialimpactsongreatbritain/previousReleases

Ollerton, J., Winfree, R., & Tarrant, S. (2011). How many flowering plants are pollinated by animals? *Oikos,* 120(3), 321-326. https://doi.org/10.1111/j.1600-0706.2010.18644.x

Ollerton, J. (2017). Pollinator diversity: distribution, ecological function, and conservation. *Annual review of ecology, evolution, and systematics,* 48(1), 353-376. https://doi.org/10.1146/annurev-ecolsys-110316-022919

Perennes, M., Diekötter, T., GroB, J., Burkhard, B. (2021). A hierarchical framework for mapping pollination ecosystem service potential at the local scale. *Ecological Modelling*, 444(5), Article 109484. http://dx.doi.org/10.1016/j.ecolmodel.2021.109484

Peters, K., Elands, B. and Buijs, A. (2010). Social interactions in urban parks: Stimulating social cohesion? Urban Forestry & *Urban Greening,* 9(2), 93–100. https://doi.org/10.1016/j.ufug.2009.11.003

Pilkington, M., Walker, J., Maskill, R., Allott, T. & Evans, M. (2015). *Restoration of Blanket bogs; flood risk reduction and other ecosystem benefits*. Final Report for the Making Space for Water Project: Moors for the Future Partnership, Edale. https://www.moorsforthefuture.org.uk/__data/assets/pdf_file/0032/80789/Making-Space-for-Water-Annex-5.Flood-Risk_0.pdf

Poulton, P.R., Pye, E., Hargreaves, P.R., & Jenkinson, D.S. (2003). Accumulation of carbon and nitrogen by old arable land reverting to woodland. *Global Change Biology*, 9, 942-955. https://doi.org/10.1046/j.1365-2486.2003.00633.x

Pound, D., Reed, M., Armitage, L., & Pound, J. (2016). Engaging and empowering communities and stakeholders in rural land use and land management in Scotland. Scottish Government. https://www.gov.scot/publications/engaging-empowering-communities-stakeholders-rural-land-use-land-management-scotland/

Pretty, J., Peacock, J., Sellens, M., & Griffin, M. (2005). The mental and physical health outcomes of green exercise. *International Journal of Environmental Health Research,* 15(5), 319-337. https://doi.org/10.1080/09603120500155963

Putnam, R.D. (2001). *Bowling alone: the collapse and revival of American community.* Simon and Schuster, New York. https://www.jstor.org/stable/24562625

Pywell, R. F., Meek, W.R., Hulmes, L., Hulmes, S., James, K.L., Nowakowski, M., & Carvell, C., (2011). Management to enhance pollen and nectar resources for bumblebees and butterflies within intensively farmed landscapes. *Journal of Insect Conservation* 15, 853-864. https://doi.org/10.1007/s10841-011-9383-x

Rodriguez-Gasol, N., Alins, G., Veronesi, E.R., & Wratten, S. (2020). The ecology of predatory hoverflies as ecosystem-service providers in agricultural sy stems. *Biological Control*, 151, Article 104405. https://doi.org/10.1016/j.biocontrol.2020.104405

Sachs, A.L., Kolster, A., Wrigley, J., Papon, V., Opacin, N., Hill, N., Howarth, M., Rochau, U., Hidalgo, L., Casajuana, C., Siebert, U., Gerhard, J., Daher, C. and Litt, J. (2024). Connecting through nature: A systematic review of the effectiveness of nature-based social prescribing practices to combat loneliness. *Landscape and urban planning*, 248, Article 105071. https://doi.org/10.1016/j.landurbplan.2024.105071

Seers, H., Mughal, R. & Chatterjee. (2022a). Links between natural environments and mental health. Natural England Evidence note EIN065. https://publications.naturalengland.org.uk/publication/4973580642418688

Seers, H., Mughal, R. & Chatterjee. (2022b). Links between natural environments and physical health. Natural England Evidence note EIN066. https://publications.naturalengland.org.uk/publication/6416203718590464

Seers, H., Mughal, R. & Chatterjee. (2022c). Connection to Nature, Natural England Evidence note EIN068. https://publications.naturalengland.org.uk/publication/5777215462834176

Seligman, M. (2011). *Flourish: A visionary new understanding of happiness and well-being*. https://psycnet.apa.org/record/2010-25554-000.

Solís-Montero, L., Landaverde-González, P., Zamora-Gutierrez, V., & He, X. (2023). The forgotten pollinators: the importance and conservation of wild pollinators. *Frontiers in Sustainable Food Systems, 7,* Article 1323557. https://doi.org/10.3389/fsufs.2023.1323557

Spray, C. J. (2023). Learning by doing- Eddleston Water and Natural Flood Management. *Conservation Land Management*, 21(4), 3-11. https://www.riveredenfife.org/wp-content/uploads/2024/03/CLM21-4-02-Eddleston-Water-Project.pdf

Stafford, R., Chamberlain, B., Clavey, L., Gillingham, P.K., McKain, S., Morecroft, M.D., Morrison-Bell, C. and Watts, O. (Eds.) (2021). *Nature-based Solutions for Climate Change in the UK: A Report by the British Ecological Society*. London, UK. www.britishecologicalsociety.org/nature-basedsolutions

Steinbeiss, S., BeBler, H., Engels, C., Temperton, V.M., Buchmann, N., Roscher, C., Kreutziger, Y., Baade, J., Habekost, M., & Gleixner, G. (2008). Plant diversity positively affects short-term soil carbon storage in experimental grasslands. *Global Change Biology*, 14(12), 2937-2949. https://doi.org/10.1111/j.1365-2486.2008.01697.x

Stroud Valleys Natural Flood Management Project (2025). https://www.stroud.gov.uk/environment/projects/stroud-valleys-natural-flood-management-project/#:~:text=Explore%20the%20Stroud%20Valleys%20Natural%20Flood

Swenson, M.M., Regan, S., Bremmers, D.T.H., Lawless, J., Saunders, M., & Gill, L.W. (2019). Carbon balance of a restored and cutover raised bog: comparison of global trends. *Biogeosciences*, 16(3), 713-731. https://doi.org/10.5194/bg-16-713-2019

The Earth Observatory. (2010). The Water Cycle. https://earthobservatory.nasa.gov/features/Water/page1.php#:~:text=The%20water,%20or%20hydrologic,%20cycle

The Global Commission on the Economics of Water. (2023). Turning the Tide. https://turningthetide.watercommission.org/

The Meteorological Office. (2025). The Water Cycle. https://www.metoffice.gov.uk/weather/learn-about/weather/how-weather-works/water-cycle

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science,* 224(4647), 420-421. https://doi.org/10.1126/science.6143402

Ulrich, R.S., Simons, R.F., Losito, B.D., Fiorito, E., Miles, M.A. and Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, 11(3), 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7

Walton, R. E., Sayer, C. D., Bennion, H., & Axmacher, J. C. (2020). Nocturnal pollinators strongly contribute to pollen transport of wild flowers in an agricultural landscape. *Biology Letters,* 16(5), Article 20190877. https://doi.org/10.1098/rsbl.2019.0877

Walton, R.E., Sayer, C.D., Bennion, H., & Axmacher, J.C. (2021). Improving the pollinator pantry: Restoration and management of open farmland ponds enhances the complexity of plant-pollinator networks. *Agriculture, Ecosystems and Environment,* 320, 107611 https://doi.org/10.1016/j.agee.2021.107611

WildTeam. (2022). *Stakeholder Engagement for Wildlife Conservation v1*. Wildlife Conservation Professional Series. WildTeam, Cornwall, UK. https://www.wildteam.org.uk/conservation-best-practice-stakeholder-engagement

Wratton, S., Gillespie, M., Mader, E., & Desneux, N. (2012). Pollinator habitat enhancement: Benefits to other ecosystem services. *Agriculture, Ecosystems and Environment*, 159, 112-122. https://doi.org/10.1016/j.agee.2012.06.020

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