The Agile Initiative at the Oxford Martin School

Sprint 3: Scaling up Nature-based Solutions in the UK

GROUND-TRUTHING THE NATURE-BASED SOLUTIONS OPPORTUNITY MAPS

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Introduction

This document provides guidance on how to ground-truth the opportunity mapping tools developed as part of the Agile Initiative Sprint "Scaling up Nature-based Solutions in the UK". The Agile opportunity maps provide information on habitat type, the ecosystem service value of existing habitat, and opportunities for Nature-based Solutions (NbS) or nature recovery projects (habitat creation or management opportunities). The maps can be used in conjunction with Natural England's Environmental Benefits from Nature Tool to explore the anticipated change in natural capital value arising from potential interventions that alter habitat type or condition. For more information on how to obtain and use the mapping tools see here.

The maps are based on OS Mastermap merged with habitat and other data from multiple sources. The main source of habitat data can be either Natural England's Priority Habitat Inventory (PHI) or, if available, local data such as Phase 1 or UKHab mapping provided by Local Environmental Records Centres or other groups. In both cases, the habitat classification often comprises a mixture of on-the-ground surveys and less reliable data gathered from examination of aerial photos, and the data may not be up-to-date and accurate. When the maps are used to make decisions that will influence land-use or management, it is therefore **very important that a ground-truthing exercise is carried out** to ensure that the proposed changes are appropriate and will have positive impacts on biodiversity, ecosystem service delivery and local communities, and that unintended negative consequences are avoided.

Key considerations when using the maps are:

- **Ground-truthing is crucial** in areas where land-use change or altered management is likely.
- Any proposed **land-use change** requires input from an ecologist.
- Any proposed **land management change** on land already managed for nature or in a high nature value habitat (UK priority habitats/habitat of principal importance) requires input from an ecologist.

When ground-truthing the habitat maps, a combination of habitat type and condition will influence the recommended interventions at a site (Table 1). Existing high-quality habitats should be protected and changes in management will only be necessary if there are indicators of poor condition. For habitats that are of lower quality, a land-use change might be recommended; however, the recommended interventions will be determined by the underlying condition.

Habitat surveys require ecological expertise, a knowledge of relevant habitat classification schemes, and the ability to identify the indicator species that are used to define different habitat types. Ecological surveys must be carried out during late spring or summer (optimum timing will vary depending on habitat location and type), which is the best time of year for identifying the plants used to distinguish between habitat types.

Table 1. The decision-making matrix, highlighting the interaction between habitat type and condition, which determines the recommended interventions at a site and the trajectory following these interventions.

		Habitat type	
		High quality	**Low quality**
Habitat condition	**Good condition**	• High value habitat that must be protected. • Change in land-use or management risks damage to the habitat and must not occur without on-the-ground advice from an ecologist.	• Habitat type is not of high value for biodiversity. • There are no indicators of poor condition (e.g. species associated with a high nutrient burden), suggesting that habitat creation or restoration has a high potential for success.
	Poor condition	• The underlying habitat type suggests a high potential for restoration. • However, there are indicators of poor condition (e.g. species associated with a high nutrient burden or invasive species), which could be rectified by improved management.	• Habitat type is not of high value for biodiversity. • However, there are indicators of poor condition (e.g. species associated with a high nutrient burden), suggesting that remedial interventions may be needed prior to habitat restoration or creation to ensure restoration/creation success.

Does the habitat type align with the map?

The UK Habitats Classification (UKHab) defines habitat types using a hierarchical approach, based on vegetation structure and indicator species (UKHab Ltd 2023). There are five levels, going from Level 1 (Woodland and forest, Grassland, etc) to the very detailed Level 5, some of which include National Vegetation Classification (NVC) codes (e.g. Dry grasslands and scrub on chalk or limestone; upland (H6210)). For example:

- Broadleaved & mixed woodland (Level 3): Vegetation dominated by trees >5 m high when mature, forming a distinct canopy with cover >25%. It includes stands of both native and non-native broadleaved tree species and Yew where the percentage cover of these trees in the stand is >20% of the total cover of the trees present.
- Lowland calcareous grassland (Level 4): Meets two of these three criteria: 1) >15 species per m^2, 2) >30% cover of broadleaved herbs & sedges, 3) <10% cover of rye grasses and White Clover. Additionally, a list of indicator species is given and ≥2 indicators must be "frequent" on the DAFOR scale and ≥3 indicators "occasional".

It is particularly important to note whether there are any 'Priority habitats' in the area, as these should be protected or restored, and not converted to other habitat types. The UK Biodiversity Action Plan defined 65 priority habitats; these have been updated to 'habitats of principal importance' (see Useful Resources, p. 18) but are still commonly referred to as priority habitats. Priority habitats are also included within the UKHab classification, sometimes with several of the Level 5 UKHab classifications falling under the umbrella of one priority habitat. For example, the priority habitat 'Wet woodland' (Level 4) includes two Level 5 categories: Alder woodland on floodplains (H91E0), and Bog woodland (H91D0).

Finer habitat details

It is useful to note additional details of habitat condition and structure, as described below.

HABITAT CONDITION

The Biodiversity Metric 4.0 defines criteria for assessing habitat condition. The Biodiversity Metric habitat definitions mostly link to UKHab categories and correspondence between the two schemes is highlighted (Natural England 2023). For example, high distinctiveness grassland is assessed for condition based on: indicator species (as defined by UKHab), sward height, bare ground cover, bracken and scrub cover, sub-optimal species (as defined by the Biodiversity Metric condition criteria) and physical damage cover.

INDICATOR SPECIES & POTENTIAL FOR RESTORATION

In some cases, lower quality habitats may have indicator species in lower abundances that highlight the possibility of restoration to a higher quality habitat. For example, modified grassland habitat may have a low abundance of some of the indicator species for neutral grassland.

Indicator species lists associated with different habitat types are given in the UKHab handbook (UKHab Ltd 2023).

HABITAT MOSAICS

Habitats are usually recorded at fairly large scales (400 m^2 or larger), meaning that smaller areas of higher quality habitat may be missed from maps.

On-the-ground surveys can identify areas of higher quality habitat within a mosaic of lower quality habitat, indicating higher potential for restoration.

Dealing with nutrient enrichment

Nutrient enrichment can limit the potential for restoration as characteristic species are outcompeted by species that are advantaged by high levels of nutrients. Key points to consider during ground-truthing are listed below.

- Nutrient enrichment can be recognised by an abundance of fast-growing species such as such as nettles, docks, and thistles.
- Habitat restoration is more likely to be successful if nutrients are lowered before habitat restoration interventions begin.
- Nutrient enrichment is most likely to be a problem in land that was previously used for agriculture.
- If semi-natural habitats are established on arable land, cultivation and harvest of a crop such as barley can reduce the nutrient-load prior to habitat restoration.
- Topsoil stripping is another method of removing high nutrient burdens in the soil.
- In grassland sites, nutrient enrichment can be reduced by hay harvests over successive years. This management technique can also be used in preparation for woodland creation on modified grassland sites.

Prioritising habitat transitions

In many locations it will be possible to restore multiple habitat types on an area of land. For example, woodland or grassland restoration can occur on arable land. There are multiple factors that will influence which habitat transition to prioritise.

- **Amount of habitat in the area:** is one of the habitat options a particularly rare and valuable habitat in the local area?
- **Connectivity to existing habitat**: will one of the habitat options contribute to an existing network of that habitat type? Higher connectivity will facilitate movement of associated species and nearby existing habitat will provide a source of colonists. The Agile opportunity maps identify potential restoration opportunities within 200 m, 500 m, or 1000 m of core habitat patches, but ground truthing can help to refine the selection of potential links by identifying additional factors such as potential connections along hedgerows or field margins, or barriers such as roads.
- **Habitats of local importance:** is it possible to restore a locally important habitat? For example, Wild Oxfordshire has defined Conservation Target Areas (CTAs) across the county, with each CTA having targets for the creation of key habitats (https://www.wildoxfordshire.org.uk/oxfordshires-nature/conservation-target-areas).
- **Wider benefits for nature and people:** could particular habitats offer additional benefits, such as flower-rich grassland supporting pollination in nearby fields, or woodland helping to reduce erosion risk on steep slopes? The Agile opportunity maps identify steep slopes and erodible soils, and areas where the soil is thought to have impeded drainage (where tree-planting can help to improve infiltration and thus reduce downstream flooding), but ground truthing can help to validate these opportunities – especially as national-scale soil maps are not perfect.

Do the proposed habitat transitions make sense?

- Are there any ecological risks (e.g. loss of rare or priority habitats, damage to sensitive habitat features, loss of a rare or protected species)?
- Are the baseline habitats appropriate for the proposed habitat transition and are there indicators that suggest a high potential for successful restoration?
- Will the surrounding landscape support the proposed habitat transition (e.g. seed sources, connectivity to established habitat)?
- Are there impacts on local hydrology to consider? This is particularly relevant for habitat restoration targeting flood mitigation, or for interventions adjacent to wetlands. For example:
    - Floodplain reconnection schemes could pose risks to nearby property and infrastructure if not carefully designed. Detailed hydrological modelling will be required here, coupled with ground truthing.
    - Planting trees adjacent to important wetland areas could have adverse impacts by drying out the wetland.
- Will the habitat transitions have positive effects on ecosystem service delivery for the local area? (see Prioritising habitat transitions, above).
- What is the human context – is the habitat transition in an area that is locally important for recreation, culture, or education?

Key considerations in each habitat type

ARABLE LAND

Arable land generally has a high potential for restoration and low risk of negative consequences.

Key considerations prior to restoration:

- Check whether there is a high nutrient load (soil testing can confirm this or it can be indicated by growth of species such as nettles/thistles).
- Methods of soil nutrient stripping can be found here: http://www.magnificentmeadows.org.uk/assets/pdfs/Soil_Nutrient_Stripping.pdf
- Is there a risk of competition between the target plant community and agricultural weeds?

Consider impacts on rare or desirable features of arable land:

- Rare arable weeds such as Upright Goosefoot (*Chenopodium urbicum*), Broad-fruited Cornsalad (*Valerianella rimosa*), Corn Buttercup (*Ranunculus arvensis*) can be present on arable land or supported by margins/fallow plots.
- Arable field margins are a habitat of principal importance in England, Wales & Scotland and have been noted for their benefits for wildlife in farmed landscapes – e.g. habitat for annual arable plants/animals, seed for wild birds, nectar/pollen resources for invertebrates.
- Some arable land can support breeding populations of birds with a restricted distribution in hedges or margins, e.g. grey partridge, tree sparrows, turtle doves.

GRASSLAND

The UKHab classification can be used to identify grassland types and distinguish between modified, acid, calcareous and neutral grassland, based on the following parameters (UKHab Ltd 2023):

- Indicator species lists for each grassland habitat.
- Number of species per m^2 (different thresholds of richness classify neutral, acid, and calcareous grassland).
- % cover of broadleaved herbs and sedges.
- % cover of species associated with modified grassland (rye grass and white clover).

The presence of indicator species in lower numbers, particularly in areas classified as modified grassland, indicates the potential for restoration to acid, calcareous, or neutral grassland.

The Natural England Biodiversity Metric condition assessment sheets can be used to assess grassland condition, providing targets for enhancement by improved management (Natural England 2023). Indicators of good condition include:

- **Species richness:** higher vascular plant species richness is associated with good condition grassland.
- **Vegetation structure**: variation in sward height provides habitat for a wider range of invertebrates and vertebrates.
- **Physical damage**: evidence of bare ground caused by machinery and grazing animals is minimal.
- **Bare ground**: cover of bare ground is between 1-10% of the total area.
- **Cover of bracken & scrub**: bracken & scrub invasion is minimal, covering <20% of the site.
- **Non-native plants:** invasive non-native plant species are minimal.

Reduction of nutrient enrichment is key to grassland restoration; this can be achieved through successive hay cuts and aftermath grazing. Management to reduce nutrient enrichment will enhance the success of subsequent restoration

interventions such as the introduction of native seed sources (by spreading locally sourced green hay or locally sourced seed/plug plants).

HEATHLAND

Heathland habitats are characterised by dwarf shrub species such as heathers and *Vaccinium* species (UKHab Ltd 2023).

The UK Common Standards Monitoring Guidance for upland habitats and lowland heathland identify key variables for assessing good condition (JNCC 2009b, 2009a):

- **Vegetation composition**: indicator species are defined for different heathland habitats (see Common Standards Monitoring Guidance). Diversity of species and cover thresholds are also defined. Species associated with nectar and fruit production are beneficial to biodiversity.
- **Lack of tree and shrub encroachment:** a limited presence of trees and scrub can contribute to structural diversity but should be <20% of vegetation cover.
- **Lack of bracken encroachment**: similarly, bracken cover should be limited.
- **Lack of undesirable species**: species such as thistles, docks and nettles should be limited; high levels can indicate nutrient enrichment. Other species are noted as "negative" indicators in the heathland context.
- **Overgrazing**: overgrazing can lead to a reduction in desirable species and dominance of grazing-tolerant species.
- **Vegetation structural diversity**: heathlands should have species representative of different life-forms (bryophytes/lichens, herbs, tussocky graminoids, dwarf-shrubs, shrubs). Grazing and fire should be managed to maintain vegetation height and structural diversity of heathlands.
- **Disturbance & drainage**: soil disturbance and erosion (bare ground), often caused by grazing herbivores, and drainage should be avoided.
- **Habitat heterogeneity**: in the upland context heathlands are often found in association with other important upland habitats such as grassland, woodland, montane scrub, and freshwater habitat (flushes, streams, mires). These habitat mosaics, which can sometimes occur at small scales, are beneficial for biodiversity.

HEDGEROWS

Hedgerows can enhance connectivity in agricultural landscapes and provide habitat, shelter and resources for many species (Staley et al. 2023). High diversity hedgerows can also be an important source of seeds for woodland restoration and creation.

A set of indicators of favourable hedgerow condition were defined by DEFRA (DEFRA 2007) and additional criteria were recommended in a Natural England report in 2020 (Staley et al. 2020):

- **Size**: >1 m height, >1.5 m width, >3 m^2 cross-sectional area.
- **Gaps**: gaps along <10% of length, no gaps >5 m width, and gap between ground and base of canopy <0.5 m.
- **Undisturbed ground**: covering >2 m from centre of hedgerow.
- **Perennial herbaceous vegetation**: covering >1 m from centre of hedgerow.
- **Non-native species**: woody species <10% non-native, herbaceous species <10% non-native.
- **Lack of nutrient enrichment**: <20% combined cover of nettles, cleavers and docks.
- **Structural complexity within hedgerow**: at least 3 out of 5 of: shrub layer, standard trees, basal flora, marginal flora, ditch.
- **Structural diversity across hedgerow network**: 50% of hedgerows thick and bushy, 20% growing up without trimming prior to laying/coppicing, 5% just laid/coppiced, 5% in early stages of re-growth, 5% as lines of trees, 15% managed for safe access/screening.

- **Connectivity across hedgerow network**: aiming for connectivity to other hedgerows or semi-natural habitats.
- **Plant species richness**: minimum 3.7 woody species per 30 m stretch on average, herbaceous species richness restored to 1978 levels.
- **Standard hedgerow tree numbers, diversity & age:** an average of one mature tree every 20-50 m, high tree species richness, 45% young trees to maintain population.
- **Flower & fruit availability**: significant flowers, berries, nuts etc available in 2 out of every 3 years.
- **Lack of pesticides**: application below level that will cause lethal effects on non-target organisms.
- **Lack of water stress**: no hedgerow trees dying through water stress.
- **Invasive pests & diseases**: low level of pests and diseases throughout hedgerow network.
- **Dead & decaying wood**: at least one tree developing veteran features every 50 m, rotting stumps, stools and deadwood retained within hedgerows.

WOODLAND & SCRUB

The UK Habitats classification can be used to distinguish between woodland and scrub habitat types, based on the following parameters (UKHab Ltd 2023):

- Tree/shrub species composition.
- Soil type.
- Landscape context (upland/lowland).

The National Forest Inventory identifies key indicators of woodland condition. These also form the basis for the Biodiversity Metric woodland condition assessment, and similar indicators are used in the Common Standards Monitoring Guidance for woodlands (Ditchburn et al. 2020; JNCC 2004b; Natural England 2023). Indicators of good condition include:

- **Age distribution of trees**: diverse representation across age categories (seedlings, saplings, and maturing, mature and senescent trees).
- **Herbivore damage**: low evidence of browsing, fraying and bark stripping.
- **Invasive plant species**: low presence/cover of non-native plant species.
- **Number of native tree species**: high richness of native tree and shrub species.
- **Occupancy of native trees**: high percentage area of native tree species.
- **Open space**: some open space allowing light penetration to the woodland floor.
- **Proportion of favourable land cover around woodland**: high proportion of favourable land cover (e.g. other woodland; acid, calcareous & neutral grassland) in the surrounding area.
- **Woodland regeneration**: seedlings, saplings and young trees present, indicating the woodland's potential to persist.
- **Tree health**: few signs of tree mortality, e.g. crown dieback, tree pests & diseases.
- **Vegetation and ground flora**: high % cover of desirable ground flora (see woodland NVC classifications for characteristic species (Hall et al. 2004)).
- **Woodland vertical structure**: high level of vertical complexity.
- **Veteran trees**: high number of veteran trees per unit area.
- **Volume of deadwood**: high volume of deadwood.

Generally, indicators of poor condition are: a lack of diversity, both in terms of vegetation structure, and tree, shrub and ground flora species; and a lack a of representation across all tree age classes. High levels of browsing and grazing can

have a negative impact on woodland, preventing tree regeneration, altering tree species diversity, and disturbing the ground flora.

When restoring woodland on previous agricultural land, reducing the nutrient burden in advance will increase the likelihood of achieving high quality woodland with a diverse ground flora in the future. Existing woodland can also receive an undesirable level of nutrient enrichment, which is indicated by dominance of fast-growing species (e.g. nettles) in the ground vegetation.

PEATLAND

The UK Habitats classification can be used to identify peatland types and distinguish between categories of bog (including degraded bog) and fen habitats, based on the following parameters (UKHab Ltd 2023):

- **Indicator species lists**, including peat-forming species, e.g. *Sphagnum* spp.
- **Landscape context:** upland or lowland.
- **Peat depth:** minimum 30 cm across >75% of site (National Trust for Scotland 2023).
- **Evidence of degradation:** e.g. peat extraction, drainage, burning, loss of peat-forming species (peat soils can be retained despite loss of surface vegetation).

The main threats to peatland habitats are (MoorLIFE 2017):

- **Drainage:** lowering of the water table inhibits peat formation and can alter vegetation composition.
- **Overgrazing**: high levels of grazing can alter vegetation composition and lead to erosion.
- **Loss of peatland-associated vegetation**: dominance of woody/scrub vegetation, dwarf shrub vegetation or grassland vegetation is undesirable.

Bog condition can be assessed using the field survey protocol for the Peatland Code (National Trust for Scotland 2023). Degraded habitats can be rewetted and revegetated to create rewetted modified bogs.

- **Actively eroding haggs and gullies**: bare peat with steep peat cliffs or bare gully bottoms, artificial drains that have begun to erode.
- **Actively eroding flat pea**t: bare peat, e.g. peat pan or former extraction site.
- **Drainage**: presence of drainage system within the peatland.
- **Modification:** no/little *Sphagnum*, presence of non-bog vegetation (e.g. *Calluna vulgaris*, *Molinia caerulea*); small patches of bare peat.

Fen condition can also be assessed using the field survey protocol for the Peatland Code (National Trust for Scotland 2023). Degraded habitats can be rewetted and revegetated to create rewetted fens.

- **Cropland on drained peat**: crops replaced the peatland vegetation and drainage may be present.
- **Grassland on drained peat**: grassland vegetation replaced peatland vegetation and drainage may be present.
- **Modified fen**: overgrazing or other disturbance to surface vegetation; possible drainage or eutrophication.

Peatlands can often be found with a mosaic of other habitats, e.g. heathland, but dominance of heathland-associated vegetation on deep peats is a sign of degradation.

WETLAND (FRESHWATER, NON-PEAT)

The UK Habitats classification can be used to identify wetland types based on the following parameters (UKHab Ltd 2023):

- Soil type (non-peat).

- Associated species.
- Source of water.

For freshwater wetland creation on non-peat soils, assessment of the whole catchment should be used to identify the best opportunities for wetland creation and locations where wetland creation will best mitigate issues such as pollution (Wake et al. 2022; Mainstone et al. 2016). This may require Environment Agency approval and on-the-ground input from a hydrologist.

- **Topography, geology & soils:** the Agile maps identify opportunities on the flood plain, where wetland creation is likely to be feasible. We can also generate maps of topographical wetness where there is high overland flow accumulation, to identify opportunities beyond the floodplain, though this is not yet integrated into the standard maps. Contact us if you are interested in testing this new feature. Wetland creation should also be targeted at areas with low soil permeability. As topography and soil type can vary at fine scale locally, it is very important to ground-truth the maps by identifying areas that remain wet after heavy rain.
- **Catchment hydrology**: for larger-scale wetland creation projects, hydrological modelling and on-the-ground input from a hydrologist will help to target wetland creation. Water transport pathways in the landscape will influence water quality in created wetlands and wetland contribution to flood and pollution mitigation.
- **Connectivity**: wetland creation should ideally be targeted at areas with connectivity to existing semi-natural habitats. The Agile maps identify areas close to existing wetlands, but ground-truthing can help to verify potential connectivity on the ground and identify any barriers that need to be addressed.
- **Existing wetland biodiversity**: good local knowledge of existing wetland biodiversity will maximise the benefits of new wetland creation and avoid negative impacts on rare or endangered species. This should consider biodiversity associated with wetlands, standing water, and running water.
- **Flood risk**: reconnection of rivers to their floodplains and associated wetlands can reduce downstream flooding, and wetland creation can be targeted to areas in Flood Zones. However, changes within the Flood Zone can potentially reduce flood storage capacity or increase flood risk for some properties and infrastructure, and in many cases will require an Environment Agency permit.
- **Optimising water quality improvements**: what are the sources and pathways of pollution in the catchment? Are there sensitive habitats that can be protected by wetland creation to reduce pollution inputs? Note that wetlands used for pollution mitigation offer lower biodiversity benefits than wetland creation with conservation objectives due to the lower water quality, however they will still support aquatic species and provide feeding opportunities for birds, bats and other species (Wake et al. 2022).

PONDS (FRESHWATER)

Before undertaking restoration of existing ponds, it is crucial to establish that interventions won't damage any valuable features (Sayer et al. 2023).

- Restoration of existing ponds should not occur without expert advice in the following contexts:
    - Pond is in semi-natural habitat (woodland, unimproved grassland, heathland, wetland).
    - Pond is on pond priority habitat map.
    - Pond has abundant wetland plants.
    - Pond is known to contain rare or protected species.
    - Pond is in a nature reserve or Site of Special Scientific Interest.
    - Pond is a scheduled monument.
    - Pond is a listed structure or within the curtilage of a listed structure.
- For the types of ponds listed above, lighter touch management may be more appropriate.

- If ponds are on intensive agricultural or urban land and are dark, dry and with few plants, restoration is likely to provide benefits.
- The historic integrity of old ponds should be maintained, and the original size, shape and profile of the original pond should be restored.

The Freshwater Habitat Trust gives guidance on identifying priority ponds (https://freshwaterhabitats.org.uk/advice-resources/survey-methods-hub/identify-a-priority-pond/), based on five criteria that consider species present and habitat type. Due to the high level of expertise needed to identify priority ponds based on these criteria, the Freshwater Habitats Trust defined two additional methods for identifying priority ponds: the presence of clean water, defined as nitrate levels <0.5 mg/l and phosphate levels <0.05 mg/l, and the Priority Pond Assessment system, based on physical pond characteristics (Biggs & Williams 2023).

The Priority Pond Assessment system (Biggs & Williams 2023) uses the following criteria to assess pond condition:

- **Shade**: the proportion of the pond overhung by trees and shrubs. Open/less-shaded ponds are rarer in the landscape than shaded ponds (Sayer et al. 2023). Overall, maintaining a diversity of pond types is important; if all ponds within a project site (for small projects also consider wider landscape) are tree/scrub dominated, scrub/sediment removal from a proportion of the ponds can be beneficial.
- **Inflow:** presence of streams, ditches, springs, wet seepage or inflow pipes. Ponds without inflow are more likely to maintain clean water status.
- **Isolation:** the distance of the pond from waterbodies (ponds, lakes, rivers, streams, ditches) and waterlogged habitats (marsh, fen, bog, wet heath, wet woodland). Ponds close to other freshwater habitat facilitate movement of aquatic plants/animals in the landscape.
- **Plant cover:** percentage of the pond area covered by wetland vegetation (submerged, emergent or floating plants).
- **Grazing:** the intensity of grazing and trampling in the area surrounding the pond.
- **Surrounding land-use**: areas of habitat types, used to calculate the total area of semi-natural habitat surrounding the pond. Ponds with a large buffer of semi-natural vegetation are protected from pollution, and good-quality terrestrial habitat benefits pond wildlife.

UCL & The Freshwater Habitat Trust's Guide on the Restoration, Creation & Management of Ponds (Sayer et al. 2023) offers guidance on the wider context to consider when considering pond creation:

- Within semi-natural habitat, pond creation is simpler and likely to be beneficial, provided that loss of rare or important habitat or species is avoided.
- High quality habitat and rare features (e.g. springs, damp depressions, flushes) should be avoided for pond creation.
- In agricultural/urban landscapes, pond location is more challenging. The aim should be to avoid pollution (e.g. from agricultural run-off or from roads and car-parks) entering the pond, and maximise surrounding semi-natural vegetation, to support wildlife and also to filter pollution and sediment out of surface run-off before it enters the pond.
- The underlying geology will influence the source of water. Surface-water ponds (usually on clay) should have a clean catchment; ground-water ponds (e.g. on sands and gravels) usually have good water quality.
- Stream-fed ponds should be avoided if the stream is polluted.
- Moderate grazing can manage scrub and trees at pond edges. Without grazing, tree/scrub management may be needed to prevent excessive shading or encroachment into the pond.
- Creation of multiple ponds with a diversity of sizes, shapes and depths is more valuable than a single large pond, benefiting a wider range of species.
- Aim to locate ponds in places where there will be minimal disturbance from dogs or duck-feeding.

- The Environment Agency should be consulted if the pond site is close to a main river or on a major floodplain.

Ponds created as NbS often have a purpose beyond preservation of biodiversity. However, ponds with multiple purposes (e.g. pollution interception or flood management) usually offer limited wildlife benefits, particularly where nutrient levels become raised (Sayer et al. 2023).

SALTMARSH

The UK Habitats classification defines Coastal Saltmarsh based on tidal limits and characteristic salt-tolerant vegetation (UKHab Ltd 2023).

Indicators of saltmarsh habitat condition are given in the Common Standards Monitoring Guidance for saltmarsh (JNCC 2004a):

- **Habitat extent:** consider pressures from sea level rise, patterns of erosion, and possibilities for managed realignment.
- **Physical structure (creeks/pans)**: creeks absorb tidal energy and influence sediment delivery, but increased internal dissection and enlargement of the drainage network can lead to the creation of mud basins and is a sign of erosion.
- **Vegetation zonation:** presence of the characteristic saltmarsh zones (pioneer, low-mid marsh, mid-upper marsh, transition to terrestrial habitat).
- **Sward structure**: determined by grazing. With light or no grazing, good structural diversity is usually retained. Heavy grazing can negatively influence sensitive species; however, close cropped vegetation is also associated with characteristic bird communities.
- **Vegetation composition**: characteristic species for each saltmarsh zone and negative indicator species are listed.
- **Other negative indicators**: signs of disturbance, pollution, turf cutting, vehicle damage or tramping.

For coastal saltmarsh, indicators of suitable locations for creation and restoration include (Hudson et al. 2023):

- **Existing habitats & species:** presence of species associated with saltmarshes can be an indicator of success, conversely saltmarsh should not be created in areas with existing rare/protected species or habitats.
- **Known pressures:** avoid locations with pressures such as poor water quality, presence of pollutants or risk of high levels of erosion and sea level rise. Although saltmarsh can help to mitigate coastal erosion, in some cases high erosion will disrupt saltmarsh restoration or additional mitigating protection will be needed.
- **Coastal processes & geomorphology**: a supply of fine sediment and space to accommodate high wave exposure are needed. Saltmarsh usually occurs between Mean High Water Neaps and Mean High Water Springs.
- **Environmental designations & heritage protection**: ensure no negative impacts on adjacent freshwater habitats/species and designated sites.
- **Existing management regimes**: check that existing management plans won't be compromised by the restoration.
- **Infrastructure constraints**: major roads, utilities and public rights of way may constrain restoration and creation.
- **Historical use of land:** ensure no risk of contamination from historical landfill or hazardous material.
- **Habitat connectivity**: aim to distribute newly created or restored habitat to maximise connectivity within an estuary.

Case study: Charlbury parish, Oxfordshire

We visited Charlbury parish in Oxfordshire on 4th May 2023 to assess the accuracy of the maps on the ground and consider the implications of potential land-use change scenarios. Charlbury was chosen due to its active participation in the Oxfordshire Treescapes project, through which the parish is developing a Nature Recovery Plan in collaboration with four adjacent parishes. Two members of Charlbury Town Council Land and Nature Group led us on a walk through some areas of interest to the north-west of Charlbury. Interesting issues that add complexity to land-management decisions and show the importance of ground-based information and local knowledge to support the mapping tools are outlined below (see Fig. 1 for locations).

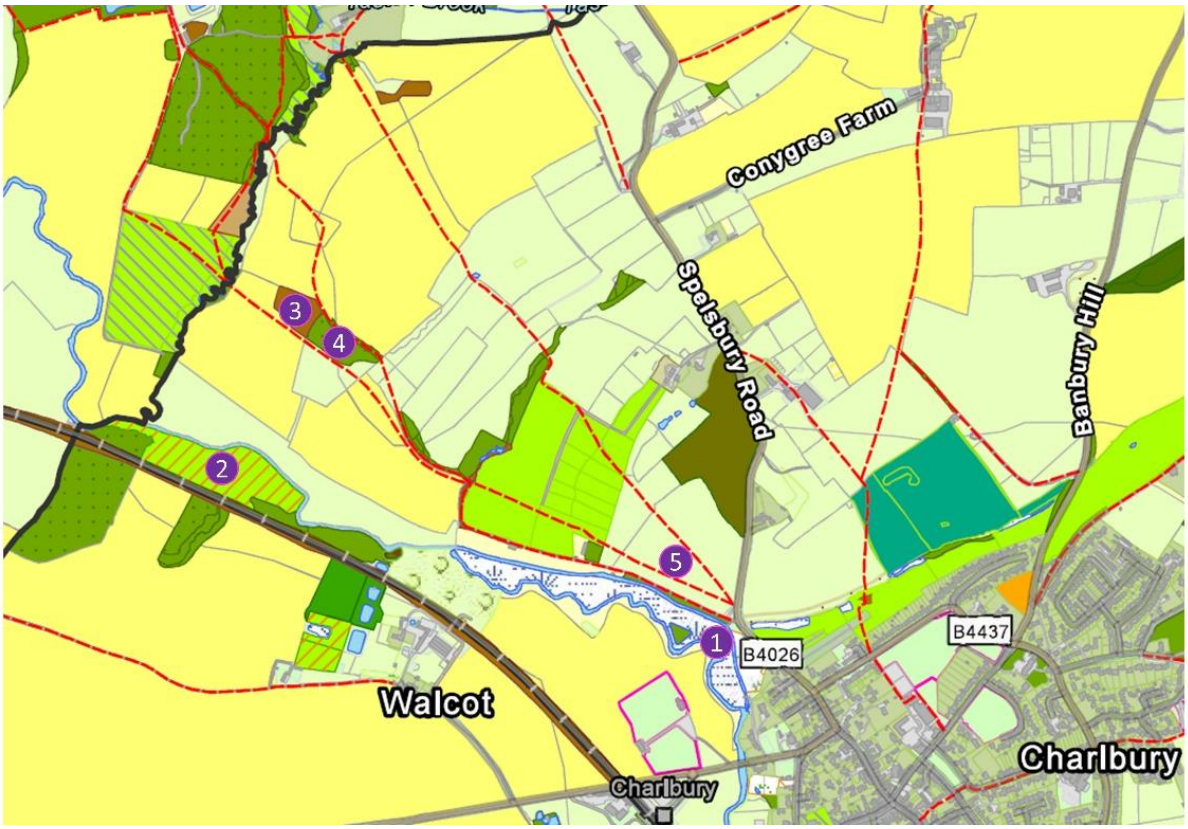

Figure 1. Numbered locations show where on-the-ground information adds complexity to land-use or management decisions in Charlbury parish, highlighting the need for ground-truthing & local information to support the use of the mapping tools.

1. MARSHY GRASSLAND NEXT TO THE RIVER EVENLODE

- This area of grassland next to the River Evenlode is currently managed by regular mowing with the cuttings not removed.
- The ratio of grasses to forbs and presence of docks and nettles suggests nutrient enrichment.
- The grassland condition could be enhanced by introducing a hay meadow cutting regime.
- However, this area is of high value to the local community: it is a popular dog-walking area and hosts an annual Riverside Festival in the summer. Therefore, long grass during the summer would potentially conflict with some valued current uses of the land.
- A compromise in this area could include introducing collection of the cuttings after mowing to reduce the nutrient load in the site, allowing some areas to grow long, and introducing locally sourced wildflower seed.

2. TREES PLANTED ON LAND MAPPED AS UNIMPROVED NEUTRAL GRASSLAND

- This area is marked as unimproved neutral grassland on the map: a rare habitat type that can contain high plant diversity. Neutral grassland is a UK BAP priority habitat. It wasn't possible to verify this classification as the land wasn't publicly accessible.
- If the grassland was unimproved, even in poor condition, simple changes to land management, such as introduction of a late summer hay cut and removal of the cuttings, could enhance the grassland condition.
- However, trees had recently been planted in this area of grassland. If the habitat classification on the map is correct, then this goes against the terms of England Woodland Creation Offer and damages an important habitat that should be kept open.
- This example also highlighted challenges of making informed management decisions on privately owned land. This field was not accessible by public footpath and the landowner is unknown.

3. SMALL HABITAT FRAGMENTS & SCRUB VS HEATH

- This area was recorded as dense scrub on the map and was dominated by gorse. Confirmation of whether this is classified as heathland or scrub would depend on determination of the gorse species (UKHab Ltd 2023).
- Scattered trees were present in the north of this habitat block, and bluebells (an Ancient Woodland Indicator species) were present throughout, suggesting a lack of historical disturbance.
- As a small area of habitat not found elsewhere in the wider area, its preservation and management are important.
- Future management and habitat creation decisions should consider the balance between scrub and woodland, facilitation of woodland regeneration, and interventions to maintain and enhance the ground flora community.

4. ON THE GROUND ASSESSMENT OF HABITAT CONDITION

- This area of woodland was continuous with improved grassland to the south (i.e. no fence present) and grazed by sheep.
- Bluebells were present throughout, suggesting a history of woodland in this location and lack of soil disturbance. There was also some fallen deadwood, which can provide important habitat for specialist species.
- However, there were clear impacts from the grazing animals: signs of nutrient enrichment (nettles and docks) and a lack of structural heterogeneity and tree regeneration.
- A reduction in grazing intensity or exclusion of the grazing animals could improve the woodland structural diversity, ground flora species richness, and increase the capacity for woodland regeneration, enabling the expansion of this woodland patch.

5. HETEROGENEOUS INDICATORS OF POTENTIAL

- Returning through fields variously categorised as improved and semi-natural grassland, we noticed indicators of higher quality grassland.
- Desirable forb species (e.g. birds-foot trefoil, meadow vetchling, red clover) and fine grasses were present in the improved grassland, suggesting potential for restoration and enhancement.
- We also noted that the timing of our visit (early May) was not ideal for assessing grassland type and condition. Assessments are most easily made from mid-May to late-June, when plant communities are fully visible and before cutting takes place.

GENERAL TAKE-HOME MESSAGES

- Mapping must be complemented by on-the-ground ecological knowledge, to pick up finer details, e.g. species indicating the potential for restoration, indicators of poor habitat condition, and opportunities for improvement.

- Local community knowledge should inform land-use and management changes, e.g. grassland adjacent to the River Evenlode is currently highly valued for recreational use.
- Land ownership limits the potential to ground-truth the maps, e.g. tree planting on possible unimproved grassland.
- Land ownership also influences control over land management and use decisions: if the local community propose recommendations for land-use or management changes, uptake of the recommendations will depend on the landowner.

Useful resources

HABITAT & CONDITION SURVEYS

UK Habitats Classification
https://ukhab.org/

Phase 1 Habitat Survey
https://hub.jncc.gov.uk/assets/9578d07b-e018-4c66-9c1b-47110f14df2a

The Biodiversity Metric 4.0 – Natural England
https://publications.naturalengland.org.uk/publication/6049804846366720

Habitats & species of principal importance – England
https://www.gov.uk/government/publications/habitats-and-species-of-principal-importance-in-england

Habitats of principal importance – Northern Ireland
https://www.daera-ni.gov.uk/articles/northern-ireland-priority-habitat-guides

Habitats of principal importance – Scotland
https://www.nature.scot/scotlands-biodiversity/scottish-biodiversity-strategy-and-cop15/scottish-biodiversity-list

Habitats of principal importance – Wales
https://www.biodiversitywales.org.uk/environment-wales-act

Common Standards Monitoring Guidance (Coastal, Freshwater, Lowland grassland, Lowland heathland, Lowland wetland, Marine, Upland, Woodland) – JNCC
https://jncc.gov.uk/our-work/common-standards-monitoring-guidance/

GRASSLAND

Managing grassland road verges – A best practice guide – Plantlife
https://www.plantlife.org.uk/wp-content/uploads/2023/03/Managing-grassland-road-verges_2020.pdf

The good meadow guide – Plantlife
https://meadows.plantlife.org.uk/wp-content/uploads/2021/11/Plantlife-The-Good-meadow-guide-English_WEB.pdf

Natural England Technical Information Notes:
TIN 038 – Seed sources for grassland restoration and re-creation in Environmental Stewardship
TIN 066 – Arable reversion to species-rich grassland: site selection and choice of methods
TIN 067 – Arable reversion to species-rich grassland: establishing a sown sward
TIN 068 – Arable reversion to species-rich grassland: early management of the new sward

HEATHLAND

Impact of heathland restoration and re-creation techniques on soil characteristics and the historical environment – Natural England
https://publications.naturalengland.org.uk/file/63031

Heathland creation for wildlife – Natural England
https://publications.naturalengland.org.uk/file/146001

Common Standards Monitoring Guidance for Lowland Heathland – JNCC
https://hub.jncc.gov.uk/assets/cea45297-15af-46b7-8bf4-935d88b0a30a

Common Standards Monitoring Guidance for Upland Habitats – JNCC
https://hub.jncc.gov.uk/assets/78aaef0b-00ef-461d-ba71-cf81a8c28fe3

HEDGEROWS

Hedgerow Survey Handbook – Hedgelink
https://www.hedgelink.org.uk/cms/cms_content/files/89_hedgerow-survey-handbook.pdf

Hedgerow Management Advice – Hedgelink
https://hedgelink.org.uk/guidance/hedgerow-management-advice/

Other resources are available on the UK website Hedgelink:
https://hedgelink.org.uk/guidance/hedgelink-documents/

The Great British Hedgerow Survey – People's Trust for Endangered Species
https://hedgerowsurvey.ptes.org/survey-guidelines

Definition of Favourable Conservation Status for Hedgerows – Natural England
https://publications.naturalengland.org.uk/publication/5656675205820416?category=5415044475256832

PEATLAND

Peatland Code Field Protocol – IUCN UK Peatland Programme
https://www.iucn-uk-peatlandprogramme.org/sites/default/files/2023-03/FieldProtocol_%20v2_clean.pdf

Blanket Bog Land Management Guidance – Moors for the Future
https://www.moorsforthefuture.org.uk/__data/assets/pdf_file/0024/87441/Blanket-bog-land-manager-guidance-FAQs-Report.pdf

A wide range of guidance documents are available from Moors for the Future
https://www.moorsforthefuture.org.uk/our-resources

PONDS (FRESHWATER)

Guide to the restoration, creation and management of ponds – Freshwater Habitats Trust
https://freshwaterhabitats.org.uk/advice-resources/pond-creation-hub/

Priority Pond Assessment Manual – Freshwater Habitats Trust
https://freshwaterhabitats.org.uk/advice-resources/survey-methods-hub/identify-a-priority-pond/

A guide to the methods of the National Pond Survey – Freshwater Habitats Trust
https://freshwaterhabitats.org.uk/advice-resources/survey-methods-hub/national-pond-survey-method/

SALTMARSH

Saltmarsh Restoration Handbook for UK & Ireland – Environment Agency
https://catchmentbasedapproach.org/learn/saltmarsh-restoration-handbook/

Common Standards Monitoring Guidance for Saltmarsh Habitats – JNCC
https://hub.jncc.gov.uk/assets/7607ac0b-f3d9-4660-9dda-0e538334ed86

Saltmarsh Management Manual – DEFRA & Environment Agency
https://assets.publishing.service.gov.uk/media/602bf8d8e90e070556671435/Saltmarsh_management_manual_Technical_report.pdf

WETLAND (FRESHWATER, NON-PEAT)

Introduction to Freshwater Wetlands for Improving Water Quality – Natural England
https://publications.naturalengland.org.uk/publication/4866931000868864

A narrative for conserving freshwater and wetland habitats in England – Natural England
https://publications.naturalengland.org.uk/publication/6524433387749376

WOODLAND

NFI woodland ecological condition in Great Britain: Methodology – National Forest Inventory
https://www.forestresearch.gov.uk/tools-and-resources/national-forest-inventory/what-our-woodlands-and-tree-cover-outside-woodlands-are-like-today-nfi-inventory-reports-and-woodland-map-reports/nfi-woodland-ecological-condition/

National Vegetation Classification field guide to woodland
https://hub.jncc.gov.uk/assets/673dc337-e58f-4f6b-ac7b-717001983c2e

Woodland Creation Guide – Woodland Trust
https://www.woodlandtrust.org.uk/publications/2022/02/woodland-creation-guide/

Site assessment handbook – Woodland Trust
https://www.woodlandtrust.org.uk/publications/2023/04/site-assessment-handbook/

Restoring your ancient woodland – Woodland Trust
https://www.woodlandtrust.org.uk/publications/2021/10/practical-guidance-on-restoring-your-ancient-woodland/

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Hall JE, Kirby KJ, Whitbread AM (2004) National Vegetation Classification: Field guide to woodland. Peterborough

Hudson R, Kenworthy J, Best M (2023) Saltmarsh Restoration Handbook: UK & Ireland. Bristol, UK

JNCC (2009a) Common Standards Monitoring Guidance for Lowland Heathland. Peterborough

JNCC (2004a) Common Standards Monitoring Guidance for Saltmarsh Habitats. Peterborough

JNCC (2009b) Common Standards Monitoring Guidance for Upland habitats. Peterborough

JNCC (2004b) Common Standards Monitoring Guidance for Woodland. Peterborough

Mainstone C, Hall R, Diack I (2016) A narrative for conserving freshwater and wetland habitats in England.

MoorLIFE (2017) Blanket Bog Land Management Guidance: Frequently Asked Questions.

National Trust for Scotland (2023) Peatland Code Field Protocol.

Natural England (2023) The Biodiversity Metric 4.0 - User Guide.

Sayer CD et al. (2023) Guide to the restoration, creation and management of ponds. London

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Staley JT, Wolton R, Norton LR (2023) Improving and expanding hedgerows — Recommendations for a semi-natural habitat in agricultural landscapes. Ecological Solutions and Evidence 4:1–7

UKHab Ltd (2023) UK Habitat Classification Version 2.0.

Wake H et al. (2022) Introduction to Freshwater Wetlands for Improving Water Quality.

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https://www.agile-initiative.ox.ac.uk/